IMPACT ASSESSMENT OF PUBLIC SUPPORT FOR PHOTOVOLTAIC SELF-CONSUMPTION

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SUMMARY

Photovoltaic self-consumption installations (PVSC) have grown exponentially in the Spanish electricity system since 2021. These installations, along the storage systems coupled to them, have also benefited from significant public aid during the same period. Such aid may have affected both the development of the sector and the competitive dynamics in the energy field and in other markets. The study analyses the various public support schemes offered at the national, regional and local levels in the form of grants, tax reductions and tax deductions. It assesses their impact on the penetration of the PVSC and, from there, evaluates their effect on competition. To strengthen the effectiveness and pro-competitive effects of these support measures, as well as to minimise possible competitive distortions, the CNMC recommends, first, reinforcing the institutional framework and coordination among administrations. This includes ensuring that the combined aid intensity does not exceed a certain threshold, implementing one-stop-shop solutions, and grouping incentives. Second, it proposes defining aid in terms of fixed unit amounts and regularly reassessing priority areas eligible for public support. Third, it suggests speeding up access to aid by streamlining administrative procedures and granting aid automatically where possible, expanding advance payment systems for subsidies, concentrating tax reduction in the first year, and considering the use of financial instruments.

KEY WORDS: regulation; competition; public aid; electricity generation; photovoltaic self-consumption.

JEL CODES: H23; K23; L52; L9; Q42; Q48

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EXECUTIVE SUMMARY

Photovoltaic self-consumption (PVSC) has experienced unprecedented growth since 2021, becoming a key lever for achieving national and European environmental objectives, as well as other objectives of general interest, such as improving energy security.

To accelerate its deployment, a wide range of public support measures have been introduced over the last few years – including direct subsidies, local tax-reduction and income-tax and corporate-tax – managed by Spanish public administrations at national, regional and local levels. These measures may influence both the functioning and the intensity of effective competition in various markets. By consolidating self-consumption and strengthening related operators, these schemes can broaden and diversify the range of energy solutions available to consumers – whether businesses or households –. In addition, PVSC can also serve as an entry point for new electricity retailers. All this can increase competitive pressure across the energy sector. Likewise, since support measures can benefit companies in all types of sectors, such aid has the capacity to affect competitive dynamics in other non-energy markets. As with any aid scheme, however, public support may also generate distortions that undermine competition if not properly designed. It is therefore essential that such measures avoid unnecessary or disproportionate distortions in both the energy sector and other industries.

The Spanish National Markets and Competition Commission (CNMC) has prepared this study to assess how public support for the deployment of PVSC may have affected market competition. The report identifies potential areas for improvement and formulates recommendations to strengthen the pro-competitive orientation of support measures while minimising adverse effects on market performance.

The study begins by describing the recent evolution of PVSC and its current situation. Although large-scale or ground-mounted solar photovoltaic installations entered the Spanish electricity system strongly from 2007 onwards, the self-consumption modality has only started to gain relevance since 2021, from which point it has experienced exponential growth[1]. In June 2025, REE recorded nearly 696 thousand installations with a total installed capacity of 5.4 GW. In contrast, storage systems coupled to PVSC, despite having also accelerated their growth, still have a testimonial weight.

The current landscape is dominated by many small, individual residential installations and by installations of service and industrial SMEs of medium

[1] CNMC (2025b). In any case, this growth would still be far from the path necessary to meet the PNIEC objective of reaching 19 GW of self-consumption by 2030.

size. Only 10% of customers with self-consumption belong to collective self-consumption installations, despite Spain being the EU country with the highest proportion of the population living in flats or apartments (more than 65% live in multi-family buildings). Geographically, PVSC penetration is more intense in the southern half and eastern coast of the country, areas characterised by high solar irradiation. From a socio-economic perspective, self-consumption penetration is also generally higher in municipalities with a higher per-capita income and a greater presence of houses. It is also noteworthy that from 2021 to 2024, coinciding with the deployment of public support measures, there has been a significant increase in the surplus energy fed into the grid, mainly from household PVSC installations.

The study identifies that PVSC may be contributing to boosting competition in the retail electricity market, by becoming a gateway for small retailers. To examine this issue, a comparative analysis is carried out of the market structure and supplier-switching rates of self-consumers compared to the overall retail market. Indeed, compared with all retail customers, self-consumption clients tend to operate to a greater extent in the liberalised market and, within it, with smaller suppliers. In the household segment, customers with PVSC also show higher suppliers-switching rates (*switching rates*) than the average household in the retail market. Therefore, the PVSC can become a vector of competitive pressure and commercial innovation. At the same time, the stimulus to the entry of new operators may favour the uptake of PVSC, thus generating a virtuous circle. However, it is also observed that advantages may persist for traditional vertically integrated retailers linked to the distributor, since their market shares are relatively higher in those areas where they operate as distributors.

The analysis reveals an overlap in time of different PVSC support initiatives, without any coordination mechanism among public administrations. PVSC support has been channelled mainly through direct subsidies, local tax reductions, national and regional deductions in personal income tax (IRPF) and deductions in Corporate Income Tax in foral territories.

- Particularly noteworthy are the subsidies aimed at households, companies and public administrations from the Recovery, Transformation and Resilience Plan (PRTR), which initially had a budget of 660 million euros and were progressively extended to exceed 2 billion euros.
- Also relevant, although more fragmented, are the tax deductions introduced by a large part of the municipalities in local taxes such as the Property Tax (IBI), the Tax on Construction, Installations and Works (ICIO) or the Tax on Economic Activities (IAE), also aimed at households and/or businesses.

- In the case of households, notable as well are the deductions introduced since October 2021 in the national Personal Income Tax (IRPF) for homes renovation, where PVSC installations have been indirectly benefited. Several autonomous communities also have tax deductions in their IRPF tranche that introduce direct incentives to PVSC installations and storage or, more generally, energy efficiency improvements that can be achieved through these installations.
- Finally, regarding companies, the existing Corporate Income Tax deductions in the foral territories of the Basque Country and Navarra are also important.

The study describes and analyses the design of these aids. A sound design is essential both to ensure their effectiveness and to enhance the pro-competitive effects, as well as to prevent the introduction of elements that may unnecessarily harm or distort competition through, for example, unjustified barriers or aspects that violate competitive neutrality.

The study also explores the geographical and social distribution of some of these aids, finding, for example, that the IBI tax reduction associated with PVSC are strongly and positively correlated with municipal income levels, because this tax is based on cadastral properties value. This, in addition to having distributive implications and reducing the efficiency of public resources, can affect competitive dynamics by influencing the competitive position of companies – both energy-related and in other sectors – located in different municipalities.

It is also found that the administrative processing of subsidies has been complex and considerably delayed due to the large number of applications, which can create costs and access barriers that particularly harm potential applicants with fewer resources, thereby impacting competitive dynamics. Finally, it is shown that the accumulation of the different available aids may have led to situations of overcompensation, covering in some cases more than 90% of installation costs for a household.

The econometric analysis included in the study assesses the impact of public aid on PVSC penetration, using a panel of more than 700 municipalities in the period 2021-2024. This is of interest for analysing the extent to which aid is shaping the sector, given that higher PVSC penetration can influence the dynamics of competition in both energy and other markets.

The results show that the effectiveness of public aid varies depending on the type of economic actor and the specific design of each instrument. Among local tax reductions, the most effective appears to be the IBI tax reduction for households, but there is no clear evidence of effectiveness of other local tax reductions for households and firms. This diversity of effects, in the current framework of fragmented aids – by both instrument type and geographical scope – may affect competition among companies depending on which aids the can access. A positive step effect in PVSC uptake is also identified from 2022 onwards, once national PRTR subsidies and state deductions in personal income tax (IRPF) came into full force at the national level.

The econometric analysis also indicates that competitive conditions in the retail electricity market may exert a positive effect on PVSC deployment. Finally, structural municipal conditions – such as solar irradiation, income level, the share of single-family homes, or the share of rental housing – also appear to be determining factors in the adoption of these technologies. Moreover, expectations regarding the long-term electricity prices may have temporarily boosted the PVSC during the recent energy crisis. Overall, the findings point to the desirability of differentiated and tailored policies adapted to the different territorial profiles and actors involved.

The design of the PVSC aids faces several challenges from the perspective of effectiveness, efficiency and market competition. To the extent that the aid is designed to effectively promote the development of PVSC as a viable alternative for energy generation and consumption, it can generate pro-competitive effects within energy markets. However, inadequate design can also create risks of unnecessary distortions, linked, for example, to possible differences among companies in terms of access to public support. To avoid unnecessary distortions and promote a pro-competitive design, there is room to reduce administrative complexity and improve effective coordination among different levels of public administrations, both in the design and implementation phases.

To address these challenges, strengthening the effectiveness and efficiency of aid and its pro-competitive effects, while minimising possible distortions on competitive dynamics, the CNMC makes the following **recommendations**:

1. **Strengthen the institutional framework and coordination among administrations**.

   It is recommended to frame PVSC aid from all administrations within a coherent medium-term national strategy. This strategy should ensure that the intensity of the combined aid does not exceed a maximum threshold, thus ensuring proportionality and preserving energy-saving incentives for households and businesses. Stable medium-term planning would mitigate the expansion and contraction cycles of demand that can distort proper functioning and effective competition in the sector, reduce aid efficiency and jeopardise the viability of firms when aid is withdrawn.

   It is also recommended to create a one-stop shop system for accessing different aids, to consider the grouping of aids and incentives, enhance transparency and improve official statistics to facilitate *ex-post* evaluations.

Finally, in line with the recommendations set out at the 2024 Self-Consumption Dialogue Roundtable, measures should continue to be adopted to facilitate grid access for installations, as well as to improve the information available on self-consumption installations to enable better monitoring of their effective deployment in the grid and facilitate real-time generation scheduling.

2. **Reinforce the pro-competitive, efficient and effective orientation of support measures.**

   It is recommended to define public aid in terms of fixed-unit amounts linked to energy and environmental objectives, instead of basing them on incurred cost or on variables unrelated to those objectives, such as cadastral value. It is also recommended that future public aid programmes be designed on a clear exercise of strategic prioritisation of the use-cases to be incentivised, relying on regular evaluations to avoid supporting activities where aid is less necessary or justified, in order to minimise distortions to competition.

   As a preliminary step, and based on an analysis of necessity and proportionality, it may be useful to focus aid more on coupled-battery installations and collective self-consumption, as well as medium-to-large PVSC projects (especially in industrial and commercial sectors), where energy consumption is usually high and continuous, while fully respecting the State aid framework.

3. **Accelerate access to aid** to avoid competitive distortions stemming from differences in applicants' resources or financial capacity.

   It is recommended to streamline administrative procedures for aid to shorten processing time. To this end, measures such as the automation of administrative processes, automatic information exchange between administrations and automatic (*ex oficio*) granting could be explored.

   It would also be advisable to make advance-payment requirements for subsidies more flexible and concentrate tax reduction in a single year and a single local tax, thus easing the financial pressure on self-consumers due to the delays in receiving aid. Likewise, if collaborating entities are used to process aid applications, these systems should be voluntary and include neutral accreditation mechanisms that do not hinder the entry of new operators.

   Finally, it is recommended to complement the aid schemes with financial instruments such as concessional loans or public guarantees, in cooperation with the private sector.

1. INTRODUCTION

Photovoltaic self-consumption (hereinafter, PVSC) has acquired an important role in the EU's energy transition strategies, particularly since 2021. This technology is a key instrument for meeting the climate objectives set at European level for 2030.

In Spain, as of June 2025, the system operator had registered nearly 696 thousand installations with a total installed capacity of 5.4 GW. Thus, the forecasts included in the Self-Consumption Roadmap, approved in December 2021 as a milestone of the Recovery, Transformation and Resilience Plan (hereinafter, PRTR), have been exceeded.

Looking ahead, the National Integrated Energy and Climate Plan 2023-2030 (hereinafter, NIECP) establishes ambitious projections, according to which this technology will reach an installed capacity of 19 GW by 2030, which is expected to cover 11% of total electricity demand[2]. Measure 1.8. of the NIECP ("Development of self-consumption with renewables and distributed generation") summarises some of the main mechanisms for achieving the self-consumption penetration targets, in line with the objectives established in the Roadmap. Among these mechanisms, of particular relevance for this report are the subsidies granted under the PRTR and, looking to the future, the possible deployment of soft-financing mechanisms that could facilitate the mobilisation of private investment[3].

The massive entry of self-consumption could have significant implications for competition and the structure of the energy sector. As this option becomes a more attractive and accessible alternative for consumers – both households and businesses – self-consumption may intensify competitive pressure across market participants, thereby encouraging improvements in the offers of other energy alternatives. For instance, it could increase competitive pressure in electricity retail, particularly given that this market niche has enabled the entry of new suppliers in recent years, and even in traditional generation,

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2 In 2024, self-consumption as a whole – considering all existing technologies, such as photovoltaic, cogeneration, hydropower, wind, biomass, biofuel or waste – covered more than 5% of demand (CNMC, 2025b).

3 Also noteworthy is the reference in the PNIEC to promotion measures at the local and regional levels, in particular the simplification of administrative procedures and the proper integration of self-consumption into urban planning instruments (although it makes no reference to the local tax reduction examined in this study). The PNIEC likewise mentions the creation of a Self-Consumption Office by IDAE, "a space for information and advice aimed at supporting consumers (individuals, businesses and companies) who wish to adopt a self-consumption installation".

insofar as self-consumption represents a new, currently modest but growing alternative.

Most advanced countries have implemented public aid programmes to support PVSC, particularly since the COVID-19 pandemic and the war in Ukraine. The significant reduction in the costs of photovoltaic technology has made investment in PVSC economically viable for a wide range of uses – especially in a country like Spain, where solar irradiation conditions are favourable across much of the territory. Some short-term factors, such as the rise in energy prices following the outbreak of the war in Ukraine, have also increased the profitability of these installations. However, market failures persist which, in the absence of public intervention, could lead to suboptimal levels of investment regarding general interest goals such as combating climate change or improving energy security (through a distributed generation system less dependent on fossil fuel imports). In this context, many countries have opted to introduce public aid schemes as a means of addressing such market failures, thereby reducing potential barriers to investment and promoting faster technological diffusion.

Public aid represents a public intervention in market functioning and may therefore affect both efficiency and competition. Specifically, the aid examined in this report supports demand for PVSC, which can foster the development and consolidation of this activity and its associated operators, promote a relatively new mode of energy consumption, and thereby introduce competitive pressure by broadening and diversifying the range of energy options available to households and businesses. On the other hand, aid can also generate distortions in market functioning that undermine competitive dynamics. These effects may impact, on the one hand, on competition conditions in energy markets and, on the other hand, on the competitive position of energy-consuming firms in their respective industries (more than 40% of installed PVSC capacity corresponds to businesses). Therefore, to foster pro-competitive effects and minimise distortions – both within the energy sector and in other industries – it is essential to ensure sound aid design, including aspects related to procedures, eligibility criteria, and access conditions.

In Spain, public aid has been channelled at the national, regional and local levels through a variety of instruments, such as direct subsidies, tax reductions and deductions applicable to different sectors (residential, industrial, commercial or public administrations), each with specific conditions and procedures. Under the PRTR, more than € 2billion have been budgeted in grants for self-consumption and renewable thermal uses, most of which are allocated to photovoltaic installations. Numerous municipalities have also adopted tax reductions on local levies such as Property Tax (IBI), Constructions, Installation and Works Tax (ICIO), and the Economic-Activities Tax (IAE). Finally, national and regional personal income tax (IRPF) deductions have been introduced, often linked to the energy renovation works in housing.

Public aid must be properly designed to avoid distortions of competition and to ensure efficient use of public resources. Impact assessment is therefore essential to determine the effectiveness of these measures in removing barriers and promoting sustainable and competitive market growth[4]. The CNMC has, previously, assessed public aid schemes in other sectors, notably in its study on the impact of public aid for broadband deployment in Spain (EI/01/2022).[5]

The purpose of this study is to carry out a qualitative and quantitative analysis of public aid for photovoltaic self-consumption, with the aim of assessing its impact on effective competition and putting forward proposals to minimise distortions while enhancing its effectiveness and potential pro-competitive potential. Accordingly, Chapter 2 describes the penetration and current situation of the PVSC in Spain, as well as the structure of the retail market for customers with PVSC installations. Chapter 3 provides a brief reflection on the theoretical foundations of public aid for PVSC and outlines the main subsidies, tax reductions and deductions available in Spain. Chapter 4 presents an econometric assessment of the effectiveness of public aid in stimulating PSC installations across different groups and municipalities, as well as the effects of retail market structure. The annexes provide further methodological details of the study.

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4 The CNMC's Annual Report on Public Aid provides a detailed analysis of the public aid granted in Spain. In the most recent report published, aid related to environmental protection and energy efficiency accounted for 16% (nearly € 1 billion) of total aid in 2022.

With regard to the evaluation of aid schemes, it should be noted that the CNMC has published a Methodological Document for the Evaluation of State Aid (PRO/CNMC/001/16, 2016) and the CNMC Decalogue to Improve the Effectiveness of Public Aid (G-2021-01, 2021). In addition, as part of its advisory role to other public administrations in matters of public aid, the CNMC has prepared numerous reports – either on its own initiative or at the request of other authorities – analysing various public aid programmes (further information is available at the following link: link).

5 Given the impact of public aid on effective competition in the affected sectors and activities affected, Law 15/2007, of 3 July, on the Defence of Competition (LDC) and Law 3/2013, of 4 June, on the creation of the Spanish National Markets and Competition Commission (LCCNMC), assign to the CNMC the task of preparing, either *ex officio* or at the request of other public administrations, reports on public aid from a competition perspective, including recommendations to those administrations. In particular, the LDC highlights the "*system for monitoring and proposing measures in the field of public aid*" as one of the three pillars of competition policy.

More broadly, Article 5.1 of the LCCNMC establishes that, in order to guarantee, preserve and promote the proper functioning, transparency and existence of effective competition in all markets and productive sectors for the benefit of consumers and users, the CNMC shall promote and carry out studies and research work on competition, as well as general reports on economic sectors (5.1 h LCCNMC).

2. ANALYSIS OF PHOTOVOLTAIC SELF-CONSUMPTION IN SPAIN: EVOLUTION AND COMPETITION

In recent years, photovoltaic installations – both large-scale (ground-mounted) and distributed self-consumption systems, have become the leading renewable technology. Their share in the renewable energy mix is expected to continue increasing across most advanced and developing countries.

According to 2023 statistics from the International Renewable Energy Agency (IRENA), new photovoltaic installed capacity, including PVSC, accounted for approximately 80% of the total new renewable capacity across EU countries[6]. Its growth in the period 2016 – 2023 far outpaced that of wind energy (both onshore and offshore), which had been the dominant renewable technology during 2010-2016[7].

Traditionally, investment in photovoltaic generation was concentrated in large, ground-mounted plants, oriented towards centralized generation. However, in the last decade – especially the last five years – self-consumption has gained weight at an accelerated rate[8]. According to estimates by the International Energy Agency (IEA), PVSC will play a leading role in Europe in the coming years, becoming by 2026 the technology with the highest installed renewable capacity, surpassing hydro, onshore wind and ground-mounted solar (IEA, 2024b).

A common driver behind the international expansion of PVSC is the drastic reduction in its installation costs. Among all renewable technologies, photovoltaic installations have registered the largest drop in their costs, with a reduction of more than 80% between 2010 and 2023[9].

While international cost data is focused on large-scale and/or ground-mounted PV installations, smaller PV installations – such as those intended for residential, commercial or industrial self-consumption – also appear to have benefited from

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6 The share of new PV installations in total new renewable power increased from 26% in 2016 to 80% in 2023.

7 In the International Energy Agency's projections to 2030 (IEA, 2024b), distributed applications (covering residential, commercial, industrial, and off-grid projects) will account for nearly 40% of total PV expansion.

8 Under the definition of Royal Decree 244/2019, self-consumption is understood as the consumption, by one or several consumers, of electricity generation by installations located near the consumption sites and associated with them.

9 According to IRENA (2024), the weighted average cost of photovoltaic technology has dropped from €4,910/kW in 2010 to €701/kW in 2023 (all expressed in terms of 2023 euros). In terms of cost reduction, photovoltaics are followed by onshore and offshore wind, solar thermal and bioenergy. In contrast, the costs of geothermal and hydraulic installations have increased.

this downward trend. Falling prices of modules, inverters and batteries, together with the simplification of installation and permitting processes, have made photovoltaic self-consumption increasingly accessible and competitive across many markets, becoming a new attractive alternative for a growing number of homes and businesses.

In parallel with the drop in the costs of photovoltaic self-consumption, battery prices have also fallen considerably in recent years, further enhancing the competitiveness of PVSC systems with coupled storage. Between 2010 and 2023, the cost of battery equipment fell by 89% (from €2,322/kWh to €252/kWh).[10] This cost improvement has been driven by industrial-scale production, optimisation of manufacturing processes and more efficient use of materials.

Following this international overview, the analysis focuses on the specific evolution of PVSC in Spain. The following sections are based on information requested by the CNMC from the System Operator, Red Eléctrica de España (hereinafter, REE), relating to the PVSC installations registered in the Electricity Measurement Information System (SIMEL), including their technical characteristics and their monthly production of surplus generation. For the purposes of this study, REE provided structural data on installations registered as of 30 June 2025 and data on energy fed into the grid up to 31 May 2025.

It should be noted, however, that discrepancies exist between REE data and the figures published by Unión Española Fotovoltaica (UNEF) – the national photovoltaic industry association – as previously identified by the CNMC in its *Report on the Conclusions of the Self-Consumption Roundtable* (INF/DE/106/24).[11]

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10 IRENA (2024) reports data in USD/kW or USD/kWh. This data has been converted to €/kW or €/kWh using the 2023 annual exchange rate, the reference year in IRENA data.

11 According to the Photovoltaic self-consumption annual report of the APPA (2025), the installed capacity of PVSC amounted to 8.6 GW at the end of 2024. UNEF estimates slightly lower values in its annual report, around 8.1 GW. In contrast, the installations registered according to REE data amount to 5 GW on the same dates.

This discrepancy could be explained by methodological differences, as well as the nature of the sources used. While REE relies on installation data reported by electricity distributors (for installations whose readings are not managed by the System Operator), UNEF prepares its estimates based on surveys of companies in the sector, manufacturers, installers and distributors. It is possible that the installations not observed by REE correspond mainly to the modality of self-consumption without surpluses, since installations with surpluses (with or without compensation) participate in the market and must be registered to receive remuneration. Therefore, UNEF's data offer a more up-to-date view of the market, although less precise from an administrative standpoint, as they may also include certain self-consumption installations `without feed-in to the grid' modality that are not registered in the REE database.

As stated at the 2024 Self-Consumption Roundtable, the figures recorded by REE in SIMEL differ even more markedly from those currently registered in the Administrative Register of Self-Consumption Installations (RADNE), which has been in operation since 2014 and managed by the Directorate General for Energy Policy and Mines (DGPEM). The RADNE relies on information submitted by the competent bodies of the autonomous communities, which may also maintain their own self-consumption registers in their territorial area. However, there are many installations registered in the corresponding regional systems without being registered in RADNE, so this register includes a very limited part of the information contained in SIMEL. This reveals that, for the moment, RADNE does not fulfil the statistical and monitoring objectives envisaged under the Electricity Sector Law and the Royal Decree on Self-Consumption.

In some cases, REE information has been combined with other public data sources – from the CNMC, the National Statistics Institute (INE), other REE databases, local tax information from the Ministry of Finance and compilation of information about local reductions from Fundación Renovables – as well as with confidential data on subsidies obtained from the Institute for the Diversification and Saving of Energy (IDAE).

2.1. Recent trends

Solar photovoltaic technology has experienced two major phases of strong growth in Spain[12]: the first, between 2007 and 2012; and the second, from 2019 to the present. Within this second stage, self-consumption has registered exponential growth since 2021.

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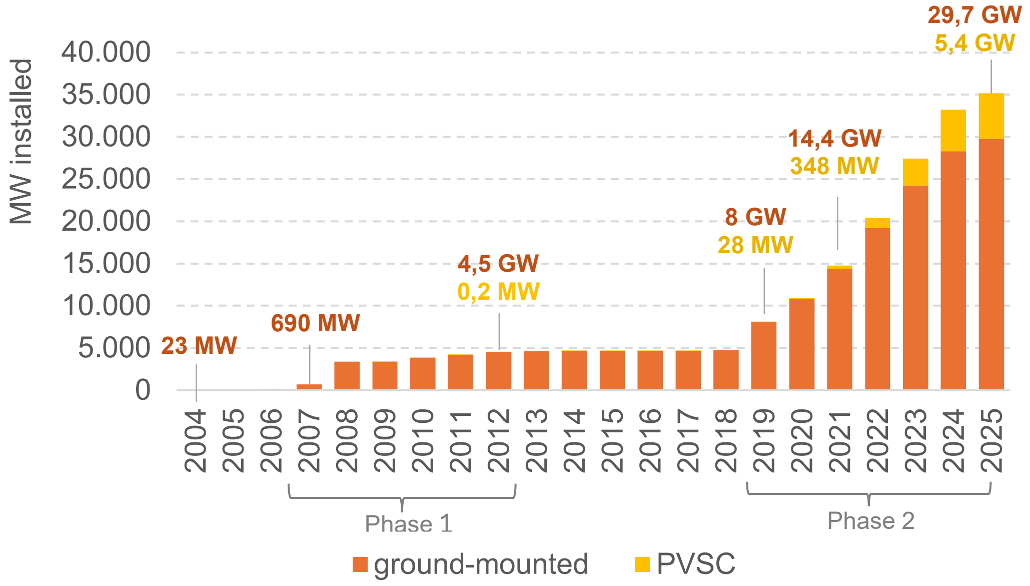
[12] Although a few small-scale solar installations were already present in Spain in the 1990s, the penetration of this technology remained minimal until 2007.

Figure 2-1 Cumulative installed solar photovoltaic capacity in Spain, by ground-mounted and self-consumption installations



Source: Own elaboration based on data from the CNMC and REE. *Note: Data for 2025 refer to installed capacity up to June. Aggregated data come from CNMC public statistics.

The first historical milestone in the development of large-scale solar photovoltaic technology occurred with the approval of Royal Decree 661/2007. This regulation introduced modifications to the remuneration scheme of the renewable generation regime established in 2004, providing strong economic incentives for the adoption of renewable energy. These measures sparked and initial phase of rapid expansion of solar power and renewables more broadly.

During this initial phase, photovoltaic self-consumption was minimal, as it was not economically viable and there were no specific support schemes for end users to install these systems. Nevertheless, installed ground-mounted photovoltaic capacity reached around 4.5 GW in 2012.

After this initial phase, concentrated in electricity generation plants, a slowdown occurred in 2013, followed by a prolonged stagnation from 2014 to 2018, mainly due to two reasons. Firstly, the impact of the financial crisis in Spain. Secondly, various regulatory changes that reduced the remuneration of renewables, based on a criterion of "*reasonable profitability*", aiming to restore financial stability in the electricity sector. Additionally, charges were imposed on self-consumed energy by grid-connected installations (popularly known as the "sun tax").[13]

[13] Law 24/2013, Royal Decree-Law 9/2013, and Royal Decree 900/2015.

The second phase of great renewable expansion, with a remarkable dynamism of solar energy, began in 2019 and continues to the present[14]. This second phase coincides not only with international costs reduction in photovoltaic technology, but also with the implementation of a new national regulatory framework. Specifically, Royal Decree-Law 15/2018 and Royal Decree 244/2019 introduced several changes favourable to self-consumption, eliminating charges on self-consumed energy, introducing compensation mechanisms for installations up to 100 kW under the surplus self-consumption modality, and simplifying several technical standards and administrative processes, among other changes. Installed capacity of solar technology (including self-consumption) has increased sixfold between the end of 2018 and mid-2025, reaching approximately 29 GW.[15]

However, the share of self-consumption in the electricity system remained at very low levels until 2020. Until that date, practically all photovoltaic power corresponded to large-scale photovoltaic plants (over 99% in 2020). **Only from 2021 onwards did PVSC gain significant relevance**, coinciding with the rollout of PRTR-funded subsidies and the sharp increase in energy prices recorded that year and the next.

By the end of the first half of 2025, REE had registered a total of 695,789 PVSC installations, with a total capacity of 5,444 MW. Compared to the level recorded at the end of 2018, the number of PVSC installations had increased by approximately 1,500 times, and the installed capacity by more than 500 times. **The growth of the PVSC has been driven primarily by the residential segment**[16]**, with plenty of small individual installations**. The services and industry sectors have also contributed significantly, with fewer installations, but larger in size.

The rapid entry of self-consumption capacity in recent years may be one of the elements contributing to the low growth in electricity demand in Spain since 2022[17]. In this sense, as self-consumption becomes more relevant, the reduced grid consumption by self-consumers, together with the surplus energy these installations can feed into the system, may displace or substitute part of the

14 Fabra (2023).

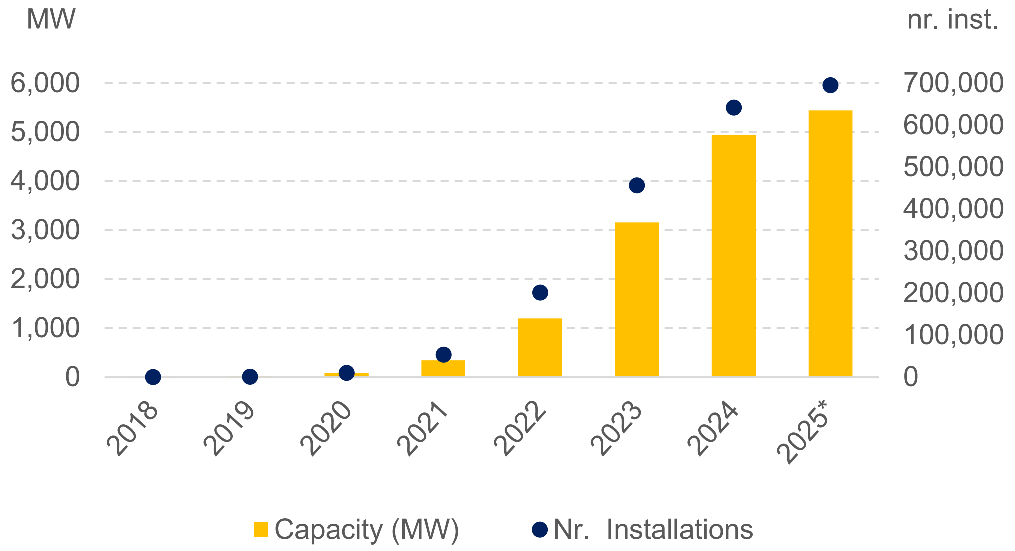
15 CNMC (2025c).

16 According to REE data, until the end of the first half of 2025, more than 86% of the registered PVSC installations were from households.

17 In addition to the impact of self-consumption, the evolution of electricity demand may also have been negatively affected by other factors, such as improvements in energy efficiency and the increase in electricity prices in 2022 and 2023. In 2024, despite the continued growth in self-consumption, national electricity demand rose again (by nearly 3%), a change that may be related to the general decline in prices (CNMC, 2025b).

generation from other technologies supplying the wholesale market. Its consolidation as an attractive alternative for households and businesses may also increase competitive pressure, particularly in the medium and long term, on other generation alternatives.

Figure 2-2 Capacity and number of PVSC installations in Spain, 2018-2025



Source: Own elaboration based on REE data. Note: (*) Cumulative data on installations until the end of each year, except in 2025 (information up to 30/06/2025).

PVSC installations with coupled storage still represent a very small share, but their presence is growing rapidly. The information currently available to REE on coupled batteries is partial, yet it shows a trend parallel to the growth of PVSC[18]. IDAE's subsidy files confirm that coupled storage systems have accelerated their penetration, with **more than 85,000 grant applications submitted for the addition of storage to PVSC installations** (new or existing) between the second half of 2021 and the end of 2023, of which almost 48,000 had been verified and/or resolved by mid-2025 (a total of 650 MW).

2.2. Current overview of the PVSC

This section presents a description of the status of the PVSC as of 30 June 2025, the last full month for which REE information is available.

18 The coupling of storage to new or existing PVSC installations seems to have taken place mainly in the residential segment, with limited activity from service and industrial companies.

When analysing the distribution of the PVSC facilities, the installations have been classified according to the main economic activity of their owner[19] and the installed power registered in the REE database. Specifically, the installations are classified into four groups[20]:

- **Group 1 (GR1): Residential PVSC installations.** It includes installations of private households, with an installed capacity equal to or less than 15 kW[21]. This group is characterized by a high geographical dispersion and a strong link to consumer-support policies.
- **Group 2 (GR2): Small and medium-sized PVSC installations in the service sector and other productive sectors**. It includes a wide variety of sectors (such as agriculture, manufacturing, construction, commerce or transport, among others), with an installed capacity equal to or less than 100 kW. This group includes plenty of SMEs, with energy production and consumption generally higher than in the residential sector, but with a still limited scale.
- **Group 3 (GR3): Large PVSC installations.** It includes installations similar to those of the GR2 in terms of economic activity, but with an installed capacity of more than 100 kW. This group consists of larger companies or companies with energy-intensive production processes, such as electro-intensive industries or large shopping centres, where self-consumption can play a relevant role from the point of view of their competitiveness.
- **Group 4 (GR4): public sector and others.** These are mainly public administration facilities, health centres, education centres and other activities not previously classified.

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19 The REE registry contains information on the economic activity of installation owners, according to the National Classification of Economic Activities (CNAE 2009). In households that own PVSC installation, the CNAE code assigned by REE corresponds to section T *"Activities of households as employers of domestic personnel; production of goods and services for own use*". For more details in Annex I.

20 For more details on the assignment of the CNAE 2009 categories, the grouping adopted and the correspondence to the incentive programmes, see Table I-1 in the ANNEX II.

21 Installations with a capacity greater than 15 kW represent 0.9% of the installations registered as owned by the residential sector according to REE data and account for 7% of the installed capacity within this group.

In this analysis, installations with a capacity above the 15kW threshold (a total of 5,243 installations with 211 MW) have been excluded, as they are considered to likely correspond to registry errors or outliers, which could distort the analysis given their lack of representativeness for households. It should also be noted that the 15 kW threshold marks important regulatory differences. Specifically, PVSC installations with surplus capacity up to 15 kW are exempt from grid access and connection procedures, unless they are located on non-urban land (RD 244/2019, art. 7.1 b-ii).

This segmentation, depending on the type of owner and the characteristics of the installation, helps to understand market dynamics and enables a deeper analysis of the impact of public aid, since incentives may differ between groups. Likewise, aid granted to business-type consumers has the particularity of potentially affecting competitive dynamics in those markets where these beneficiary companies operate, which reinforces the interest of carrying out a segmented analysis.

2.2.1. Number of Installations and installed power

Small-scale residential installations (GR1) are predominant within PVSC, both in number and in total installed capacity. As shown in Table 2-1, they represent 86% of the total installations and account for 53% of the total installed capacity, with an average power of 4.8 kW per installation.

The next most important group is that of small and medium-sized installations in services and other productive sectors (GR2): they represent 11% of the total installations but concentrate 25% of the total installed capacity.

For its part, the **group of large installations in these sectors (GR3),** although it barely represents 0.2% of total installations, concentrates 14% of the installed capacity, due to the high average capacity of its installations.

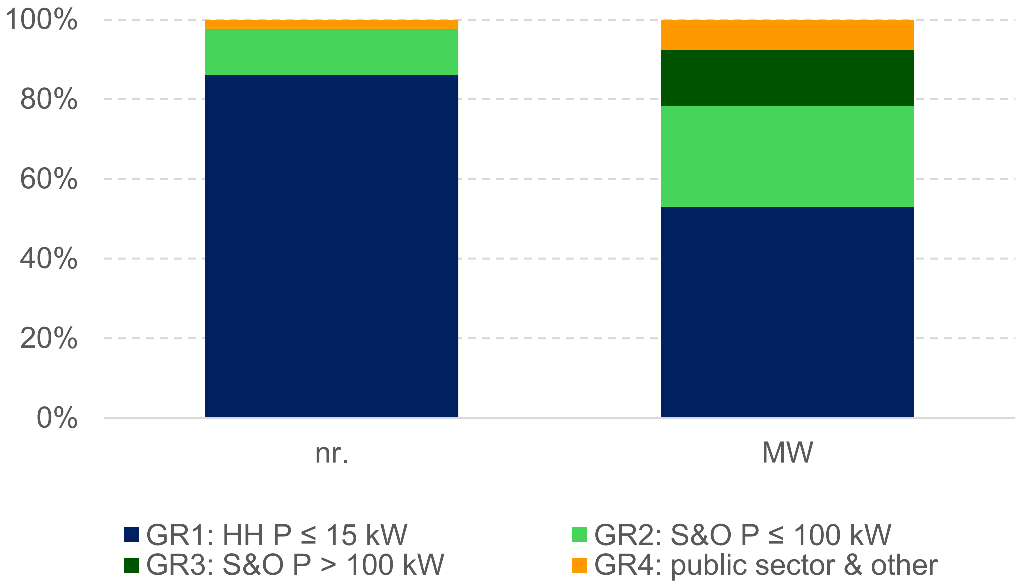
Finally, the public sector and others (GR4) have a low penetration, with only 2% of total installations and 8% of installed capacity.

Table 2-1 Number of PVSC installations and installed capacity, by group, as of 30/06/2025

	Instalations		Capacity		Average size
	Nr.	% total	MW	% total	kW/inst.
GR1: HH P ≤ 15 kW	599.313	86%	2.886	53%	5
GR2: S&O P ≤ 100 kW	79.456	11%	1.380	25%	17
GR3: S&O P > 100 kW	1.276	0%	764	14%	599
GR4: public sector & other	15.744	2%	415	8%	26
Total	695.789	100%	5.444	100%	8

Source: Own elaboration based on REE data.

Figure 2-3 Comparison of PVSC distribution by groups, as of 30/06/2025

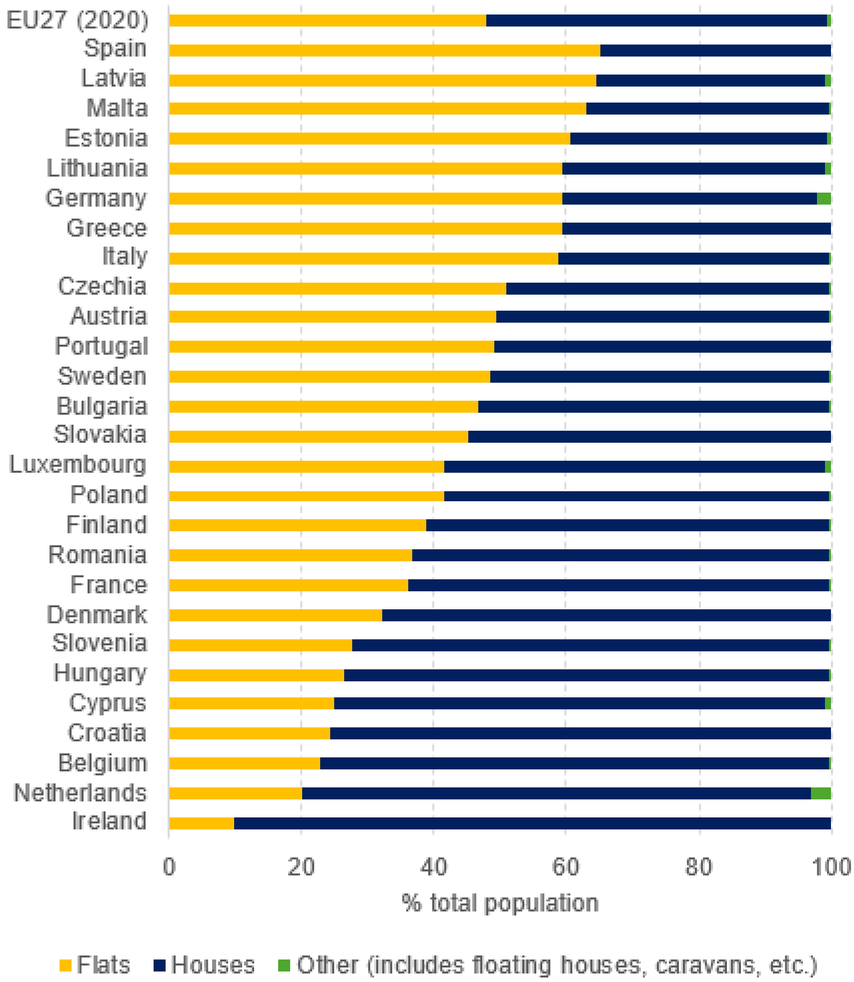


Source: Own elaboration based on REE data.

2.2.2. Individual and collective installations

According to Eurostat data, Spain is the European Union Member State with the highest percentage of the population living in buildings where several households live together: in 2024, 65.3% lived in flats or apartments. Therefore, Spain is one of the countries where collective self-consumption can offer greater opportunities and potential for households.

Figure 2-4 Distribution of housing types in the EU, 2023



Source: Eurostat Interactive Publication "Housing in Europe 2024".

Although a significant share of investments in PVSC are made by households and the type of housing in Spain should favour the collective self-consumption model, this continues to have a limited presence. As of June 2025, only **10% of consumers who had PVSC installations were part of collective self-consumption scheme**.

In this regard, it should be recalled that in recent years various measures have been adopted to promote collective self-consumption[22].

2.2.3. Surplus and self-consumed energy

The energy self-generated with photovoltaic panels is divided into self-consumed energy and surplus energy, which the self-consumer feeds into the electricity grid and may be remunerated for, depending on whether it is under an economic regime with or without compensation[23]. **At present, around three-quarters of PVSC installations are assigned to the modality of surplus with compensation**.

The proportion of surplus energy over total energy produced depends mainly on how well self-consumption pattern aligns with the hours of highest solar production. Since surplus energy cannot be managed in the absence of storage, it requires adjustments in grid operation, particularly in low and medium voltage networks[24].

The weight of surplus energy varies by segment, being higher in households and lower in services and other productive sectors (Figure 2-5), due to their different electricity consumption patterns. **In households, surplus energy has increased significantly between 2021 and 2024**, coinciding with the boom in these facilities, reaching 43% of the consumption of households with PVSC in 2024. In services and other productive sectors, this percentage for

22 Recent measure supporting collective self-consumption include, for example, the First call for innovative projects for collective self-consumption with storage (2024), with a budget of €78.7 million, extendable up to €133.7 million. Along the same lines, noteworthy initiatives include the Collective Self-Consumption Guide (IDAE, 2024) and the promotion of energy communities through PRTR grants (components 7 and 8). In addition, the Report of the Self-Consumption Roundtable (CNMC Report INF/DE/106/24) provides conclusions on the existing regulatory barriers that hinder the expansion of collective self-consumption.

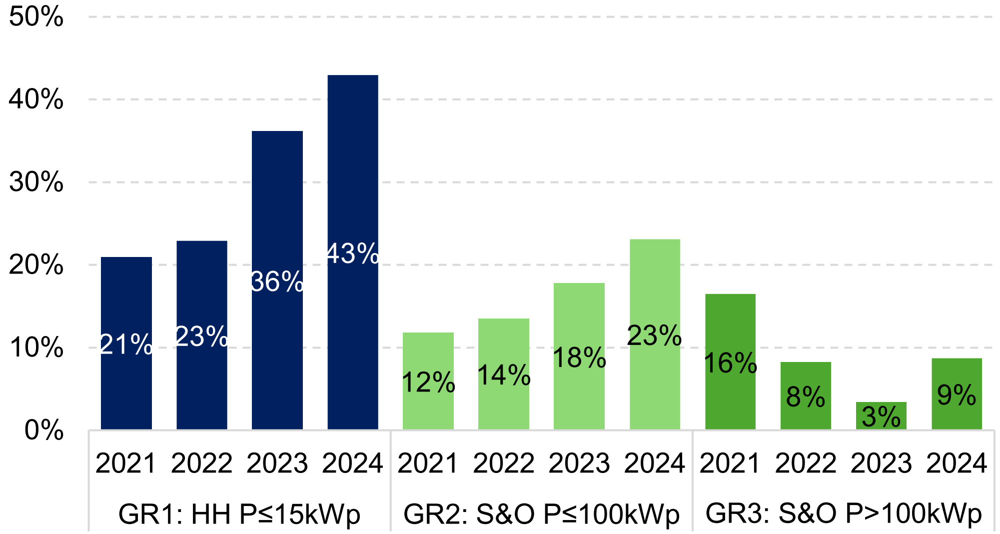
23 According to Royal Decree 244/2019, a self-consumption installation may take two basic modalities: without surplus or with surplus. In self-consumption without surplus, it is mandatory to have an anti-feed-in system to prevent energy from being injected into the distribution and transmission grids.

Self-consumption with surplus, in turn, is subdivided into: i) with surplus covered by compensation (≤ 100 kW, simplified compensation contract), and ii) with surpluses not covered by compensation (ordinary sale of energy). In the case of the simplified compensation mechanism, which covers most self-consumers, remuneration for surplus hourly energy is limited and its value cannot exceed that of the energy consumed during the billing period (Royal Decree 244/2019, art. 8.3.ii.b).

24 At certain times, these surpluses may also have positive effects, helping to meet nearby demands without using the grid – for example, during certain summer peak hours, when electricity consumption of air conditioners is typically high.

installations without coupled storage ranges between 5% and 23% and varies depending on the size and sector.

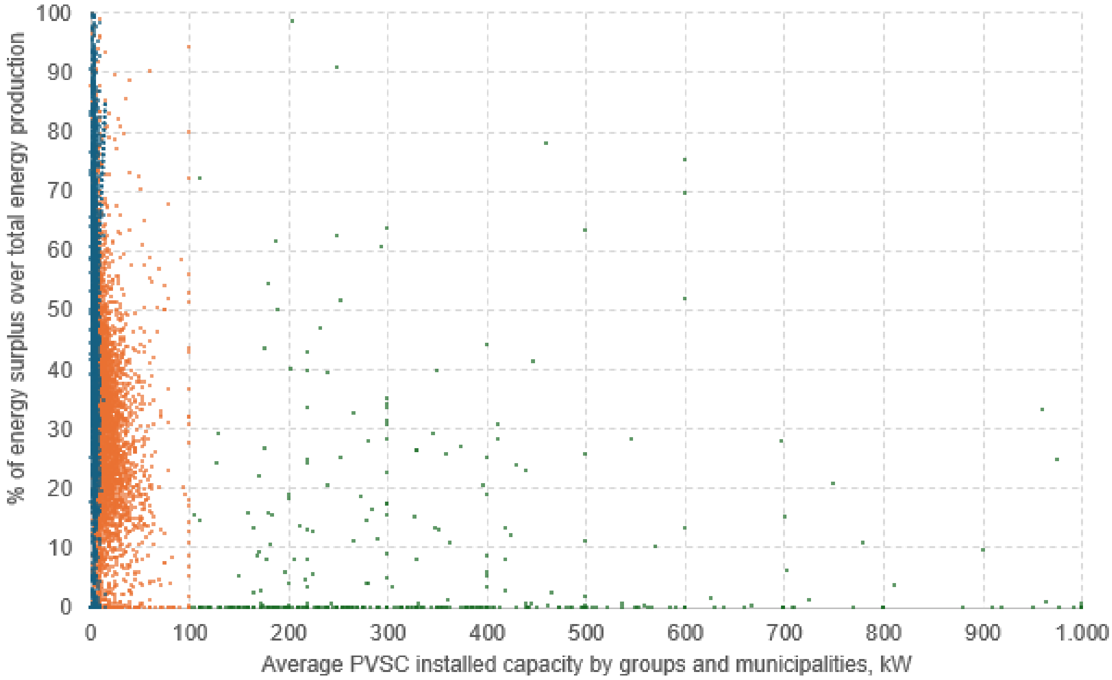
Figure 2-5 Percentage of surplus energy over total energy produced, by groups, 2021-2024



Source: Own elaboration based on REE and CNMC data. Notes: Energy data only includes individual installations without coupled storage. The estimate of surplus energy is a simplified approximation based on: i) the registered installed capacity of each PVSC facility, ii) the solar equivalent hours (published in the CNMC's energy statistics, here) by autonomous community (average for 2021-2024) and iii) the grid consumption of each self-consumer (according to REE).

The data suggest that larger facilities typically self-consume a higher percentage of self-produced energy and therefore feed relatively less energy into the grid – meaning that in general terms larger installations achieve greater local energy utilization. The smaller installations, especially those of households, show more heterogeneous but generally higher percentages of surplus energy, as shown in Figure 2-6. These high surpluses levels can reduce the economic profitability of installations (before aid), especially ifor those under simplified compensation, since remuneration for surplus energy is limited to the value of monthly grid consumed, as established by Royal Decree 244/2019.

Figure 2-6 Relationship between average installation size and surplus energy injected into the grid, by municipality and group, 2024



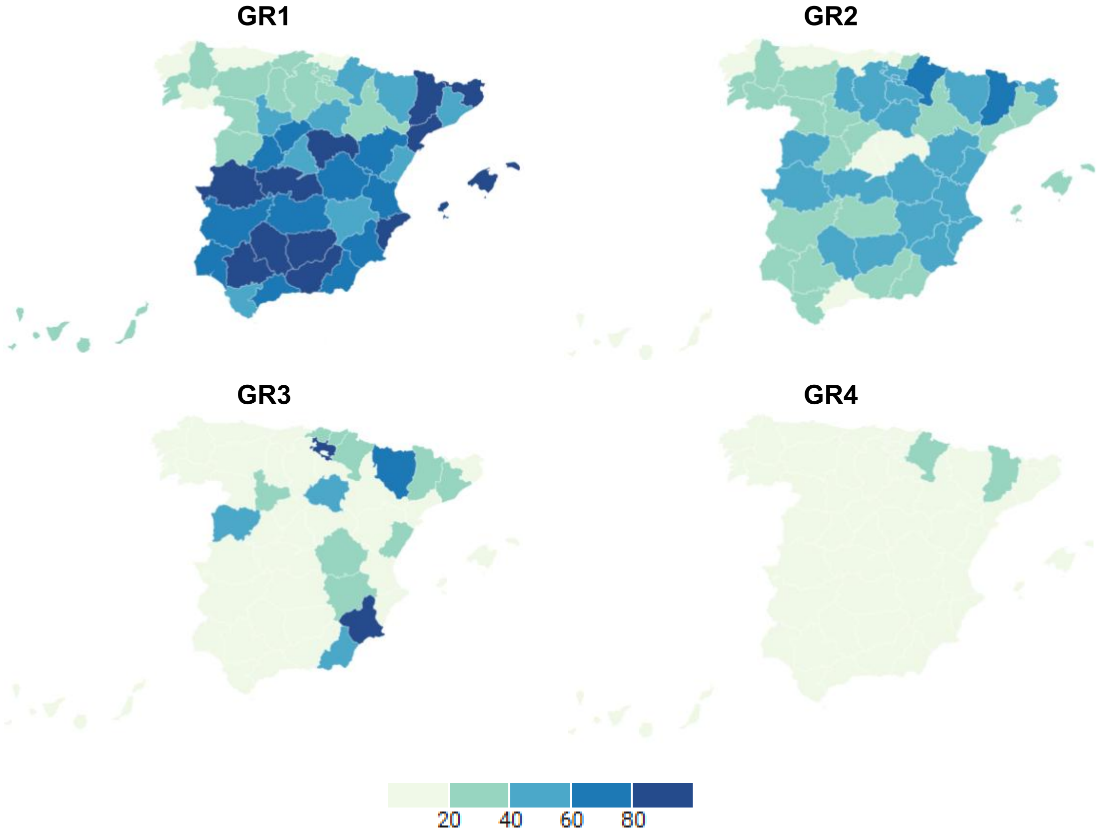
Source: Own elaboration based on REE data. Note: The figure shows the arithmetic mean of the percentage of self-consumed energy of all individual PVSC installations without storage in each municipality, by group.

2.2.4. Geographical distribution of PVSC

The analysis of geographical distribution can be of interest from a competition perspective, as it can provide insight into market conditions in different areas and the potential impact of the aid on companies in each region – both in the energy market and in other sectors – especially given differences in local aid programmes and other factors, such as varying levels of solar irradiation.

There is a markedly heterogeneous territorial distribution of PVSC, with significant variations between groups.

Figure 2-7 Installed capacity of PVSC by group and province as of 30/06/2025 (kW per 1,000 inhabitants)

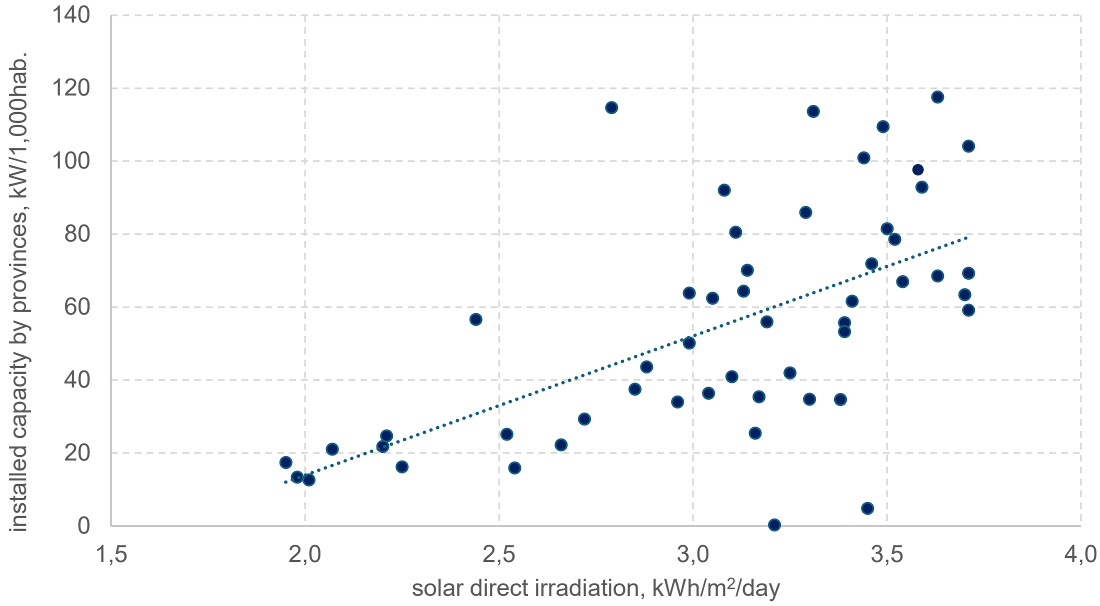


Source: Own elaboration based on REE and INE data.

In the residential sector (GR1), higher PVSC penetration is observed in the southern half and eastern coast of Spain, areas in general with higher solar irradiation. The provinces of Granada, Girona, Guadalajara, Toledo, Seville and Alicante show the highest figures of installed capacity per 1,000 inhabitants (above 100 kW/1,000 inhabitants). They are followed by the Andalusian provinces of Jaén and Córdoba, along with the Catalan provinces of Lleida and Tarragona, with values between 98 and 86 kW/1,000 inhabitants. In contrast, the PVSC penetration is still low on the Cantabrian coast (with less than 25 kW/1,000 inhabitants).

As shown in the following figure (for households, GR1), this pattern is linked, at least partly, to the level of solar irradiation in each province (correlation of 0.61).

Figure 2-8 Relationship between solar irradiation and installed capacity of GR1 by province, until 30/06/2025



Source: Own elaboration based on REE and AEMET data. Note: Direct solar irradiation data is available for each provincial capital in AEMET (2012) and is expressed as the monthly average value.

For PVSC installations in services and other productive sectors, the distribution varies considerably by size, no clear geographical pattern is observed[25]. In GR2 (small and medium-sized installations), Lleida, Navarra and Murcia lead with a penetration above 57 kW/1,000 inhabitants, while Asturias and Madrid are at the lower end, with less than 12 kW per 1,000 inhabitants. In GR3 (large industry), the highest PVSC concentration is found in Murcia and Álava, followed by Huesca, Soria and Almeria. In the western half of the country, the presence of this type of large installations is very low (below 12 kW/1,000 inhabitants), except in Salamanca, where it reaches more than 41 kW/1,000 inhabitants).

For the group of public administration and others (GR4), PVSC installation activity is highest in Navarra, followed by Lleida.

25 Solar irradiation shows a very weak correlation with installed capacity in non-residential sectors (correlation of 0.06 for GR2, 0.12 for GR3 and 0.05 for GR4). This suggests that, although irradiation could be a relevant factor, investment decisions in non-residential installations are likely influenced by many other factors, such as the industrial structure of each region or institutional factors.

Regarding storage, the territorial distribution is even more concentrated, with a prominent leadership of installations in Catalonia.

2.2.5. Cost of installations

For the purposes of this study, it is also useful to understand the cost associated with investments in PVSC and storage projects. These costs can be estimated from the information contained in the grant application files under the PRTR (Recovery, Transformation and Resilience Plan)[26].

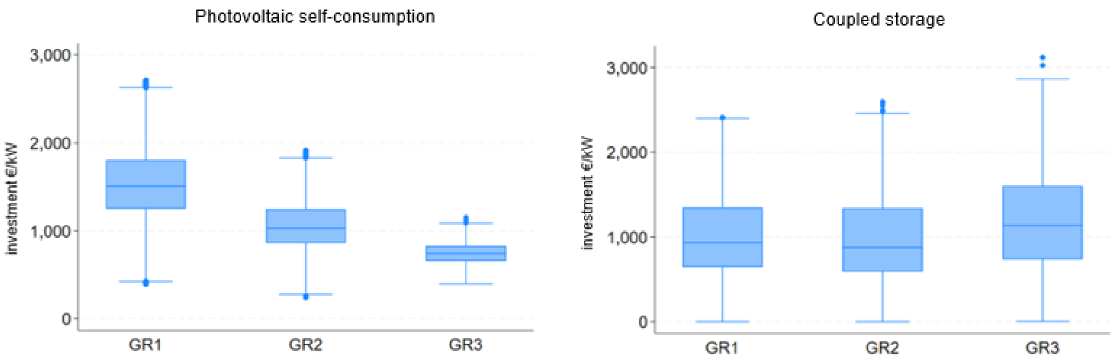
The Figure 2-9 **suggests the existence of economies of scale**, since the average cost per kW decreases as the installed capacity increases – both for PVSC and storage installations. Thus, households pay on average more per kW installed than the service and other productive sectors, whose installations are typically larger. Cost dispersion also appears to be lower among companies, especially for large PVSC installations, which may indicate greater bargaining power and capacity to seek competitive offers among these types of self-consumers.

[26] The microdata from grant application files provided by IDAE contain information on the investment value reported by grant applicants (see Section 3.2.1 for a detailed description of the data).

The analysis considers the total investment reported by applicants, encompassing both the costs associated with the renewable installation and with storage. Only information from files with a favourable resolution or those in the verification phase has been used.

Furthermore, to avoid distortions arising from errors and outliers, the database has been cleaned using the interquartile method; that is, data outside the lower and upper bounds were removed, with the lower bound defined as $lower\ band = p25 - 1{,}5 * (p75 - p25)$ and upper band as $upper\ band = p75 + 1{,}5 * (p75 - p25)$.

Figure 2-9 Distribution of average reported costs of PVSC and storage installations applying for aid in 2023



Source: Own elaboration based on IDAE data, updated on 01/07/2025. Note: The charts (left and right panels) are box-and-whisker plots, which allow for a quick visualization of data distribution. The box represents the central 50% of the data, where the middle line is the median (50th percentile), the bottom of the box is the first quartile (25th percentile), and the top is the third quartile (75th percentile). Thus, a longer box implies greater data dispersion. The "whiskers" show variability outside the upper and lower quartiles (usually representing normal or expected values). Individual points above or below the "whiskers" are outliers.

2.3. Retail market structure and competition

The rapid entry of self-consumption may have implications for the structure of the retail electricity market and, consequently, affect effective competition in the retail market.

The role of the retailers is key in ensuring the efficient and orderly development of self-consumption in an increasingly dynamic and competitive market. Except in the case of certain large consumers who choose to participate directly in the electricity market as direct consumers, self-consumers in general need a retailer to manage both the additional energy they require from the grid and the compensation or sale of the surpluses they may produce. This obligation is detailed in Royal Decree 244/2019, specifically in articles 8 and 9, which regulate access and supply contracts under the different self-consumption modalities. The intervention of a retailer ensures the correct settlement of energy flows and the contribution to system costs, in addition to providing value-added services such as surplus management or financing of installations. Retailers can also facilitate communication between the self-consumer and the distribution company (or, where applicable, the transmission company), for example, for the purpose of notifying changes in the installed capacity of the generation facility[27].

2.3.1. Market share of retailers'

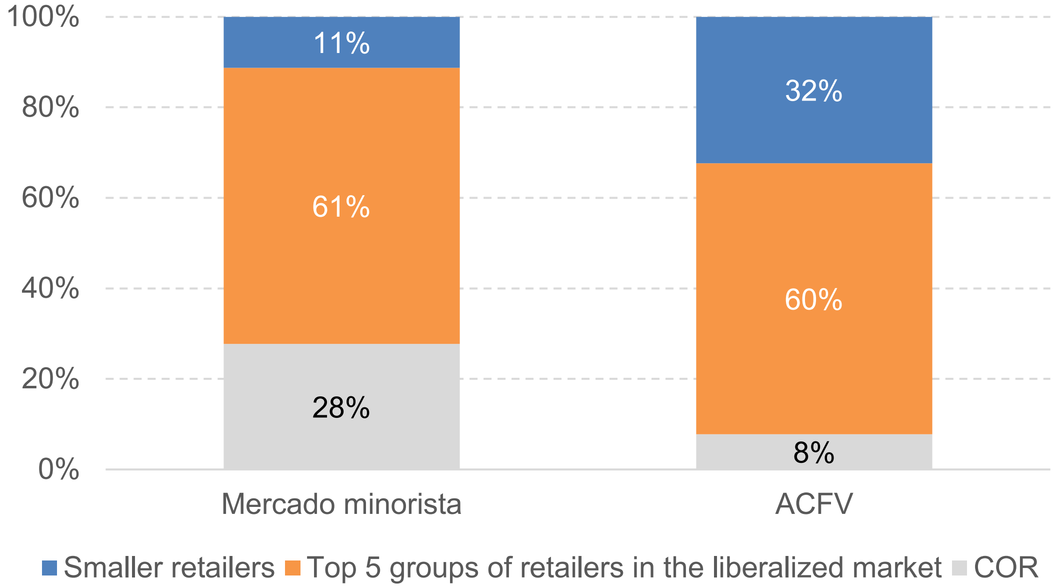
The following section compares the structure of electricity retailing for customers with and without PV self-consumption (PVSC). The data presented here refer to 2024, the most recent full year for which information is available.

First, it is worth noting that customers with PVSC installations are much more present in the liberalised market, and less in the regulated market, compared to the overall retail market customer base. Indeed, at the end of 2024, reference retailers (COR)[28] covered 28% of the retail market's supply points. In contrast, for the supply points corresponding to PVSC, the share of these suppliers only amounted to 8%. Most self-consumers were, therefore, on the liberalised market.

27 In this context, on 16 May 2024, the CNMC approved a Resolution (INF/DE/478/23) establishing new formats for data exchange between distributors and retailers with the aim of streamlining the processing of contracting, information, billing and claiming for electricity self-consumption, especially collective self-consumption.

28 According to the list of reference retailers published by the CNMC, these are: Base Comercializadora de Referencia, S.A. (TotalEnergies Group), Energia XXI Comercializadora de Referencia S.L.U. (Endesa Group), Teramelcor S.L. (Gaselec Group, only in Melilla), Comercializador de Referencia Energético, S.L.U. (CHC Group), Régsiti Comercializadora Regulada, S.L.U. (Repsol Group), Comercializadora Regulada, Gas & Power, S.A. (Naturgy Group), Curenergía Comercializador de Último Recurso S.A.U. (Iberdrola Group), Energía Ceuta XXI Comercializadora de Referencia S.A. (Endesa Group, only in Ceuta). It should be noted that Repsol acquired 50.01% of the CHC Group and the operation was authorized by the CNMC in July 2023.

Figure 2-10 Retailers' market share by type of retailer[29] (number of supply points), 2024



Source: Own elaboration based on REE and CNMC (2025b). Note: Market share calculations are based on CAU and CUPS codes.

Second, within the liberalized market, the distribution of retailers serving customers with PVSC was also markedly different from that of the overall

[29] The top five groups of retailers in the liberalised market by number of supplies are: **Iberdrola** (composed of Iberdrola Clientes, Iberdrola Servicios Energéticos and Iberdrola Energía España), **Endesa** (Endesa Energía and Empresa de Alumbrado Eléctrico de Ceuta Energía), **Naturgy** (made up of Naturgy Iberia, Gas Natural Comercializadora and Naturg Clientes), **TotalEnergies** (composed of TotalEnergies Electricity and Gas Spain, TotalEnergies Customers and TotalEnergies Market Spain) and **Repsol** (composed of Repsol Comercializadora de electricidad y gas, Gaolania Servicios, Ekiluz Energía Comercializadora and CIDE HCENERGÍA S.A.U).

It should be noted that TotalEnergies became the fourth largest gas and electricity supplier in Spain by customer volume following its acquisition, in May 2020, of EDP's portfolio of residential and SME customers in the liberalised market. In addition, EDP's regulated activity began to operate under the band Baser, which was also integrated into TotalEnergies. Since then, all these customers have been managed by TotalEnergies Spain, which consolidated the portfolio under its own brands.

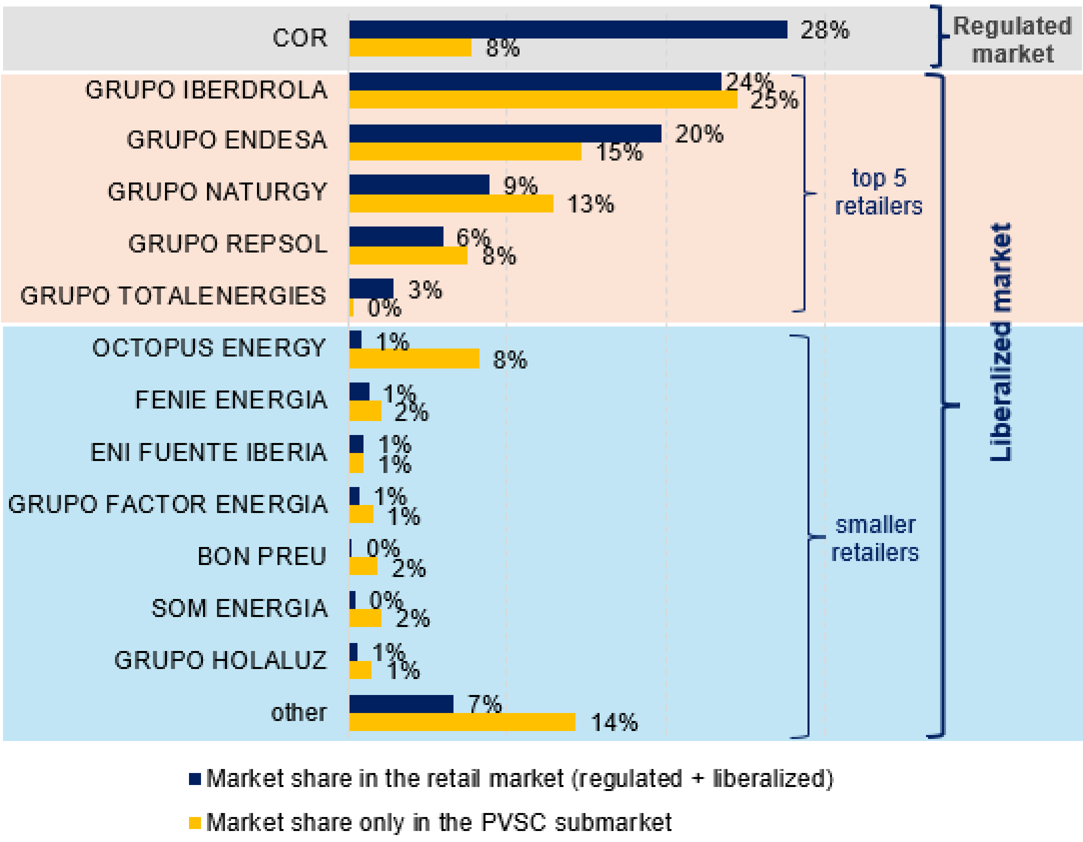
retail customer base. Among PVSC customers, smaller retailers[30], not belonging to the five largest groups, had a much more significant presence. These smaller retailers accounted for 32% of supply points with PVSC, compared to 11% in the general retail market at the end of 2024, as shown in Figure 2-10.

Concretely, as shown in Figure 2-11, **in 2024 there were seven smaller retailers with a market share exceeding 1% among PVSC customers.** Notably, among the latter, Octopus had an 8% share in the PVSC segment, higher than some traditional retailers, despite being a recently established company, which entered the Spanish market in the second half of 2021.

[30] The grouping of retailers follows the classification used in Report IS/DE/014/24 for the second quarter of 2024, published by the CNMC on 08/05/2025 (CNMC, 2025a).

Accordingly, the smaller retailers not included in the five main groups, are: Fenie Energía, ENI Plenitude Iberia (Aldro Energía y Soluciones has belonged to the ENI Group since February 2021), CHC Group, Grupo Factor Energía (composed of Factor Energía and Factor Energía España), MásMóvil (composed of Energía Colectiva and PepeEnergy), Grupo Holaluz (composed of Holaluz-Clidom and Bulb Energía Ibérica until its deregistration in June 2022), Octopus Energy, Grupo Audax (composed of Audax Renovables, UniEléctrica Energía, ACSOL Energía Global, ADS Energy 8.0, Fox Energía, Iris Energía Eficiente, Nabalia Energía 2000, Vivo Energía Futura, Ahorreluz Servicios Online, Cima Energía Comercializadora, Masqluz 2020, By Energyc Energía Eficiente, Love Energy, Comercializadora Adi España, Pasión Energía, ADX Renovables and Energía Ecológica Económica), Som Energía, Gesternova, Bon Preu, Eleia, Comercializadroa Eléctrica de Cádiz and others.

Figure 2-11 Market shares of retailers serving customers with PVSC[31] (number of supplies), 2024

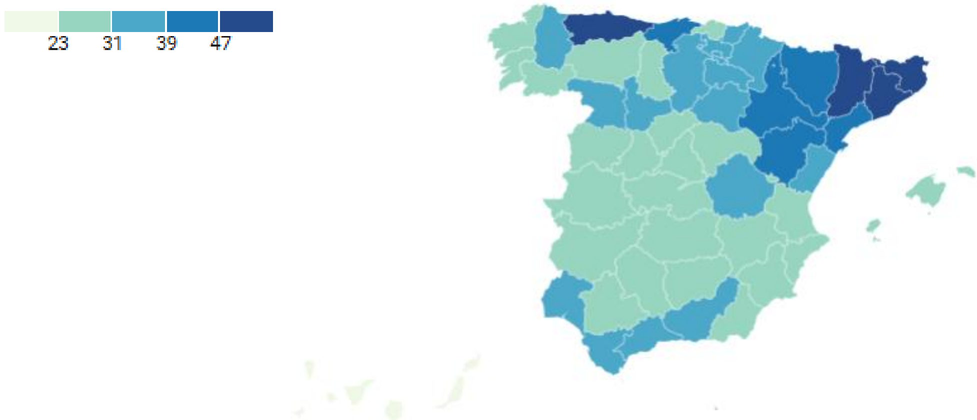


Source: Own elaboration based on REE and the CNMC (2025b) data.

From a geographical perspective, according to the latest REE data, **smaller retailers supplying PVSC installations held around 50% market share in terms of supply points in Asturias and the Catalan provinces.** In contrast, the provinces with the lowest penetration of these smaller retailers – below 25% – were the Canary Islands, Murcia, Jaén, Cáceres, and Ourense, where the market remains dominated by traditional actors.

31 Most of PVSC's customers are individual consumers (90% of supplies), with less than 10% of consumers belonging to collective installations (data for all retailers, as of mid-2025). retailers with markedly higher penetration of collective self-consumers include TotalEnergies (66% / 34%), CHC (34% / 66%), Gesternova (62% / 38%), Com. Ele. Cádiz (22% / 78%).

Figure 2-12 Market share of smaller retailers in terms of PV self-consumer supply points on 31/12/2024

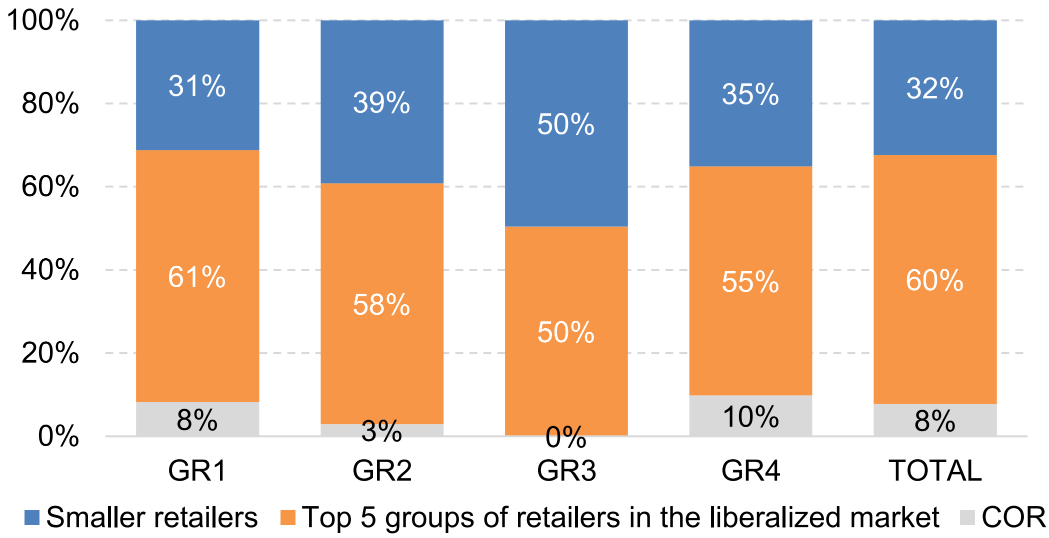


Source: own elaboration based on REE data.

Considering the type of self-consumers defined in section 2.2.1, the participation of smaller retailers is particularly notable among service companies and industrial users, reaching 43% for both installations under 100 kW (GR2) and larger installations (GR3). For households with PVSC, smaller retailers serve 33% of supply points[32].

[32] In the general retail market, small retailers have a greater presence in the SME and industrial sectors than in the household segment (SMEs 19% and industrial 16%, according to data from the CNMC's 2023 Retail Market Supervision Report). In the PVSC segment, the presence of smaller retailers in the SME and industrial segments is slightly higher.

Figure 2-13 Retailers' share in terms of PVSC supply points, 2024



Source: own elaboration based on REE data.

Overall, these data suggest that **PVSC represents a niche with high growth potential for smaller retailers**. The PVSC submarket is acting as a space for innovation and competition, where these retailers are finding opportunities to differentiate themselves, attract new customers – especially among businesses – and offer services better adapted to emerging energy demands. Therefore, PVSC could contribute to the consolidation of smaller retailers, thereby increasing their ability to exert competitive pressure on the traditional retail market.

2.3.2. Change of retailer in the PVSC segment

The **retailer switching rate**[33] (*switching* rate) is an indicator frequently used to approximate the level of competitive intensity in the retail electricity market, as it reflects the sensitivity of consumers to changes in prices or other conditions offered by retail companies. It is important that the switching process works properly within the competitive dynamics of retail markets. This facilitates informed decision-making by consumers, which helps prevent distortions in competition and the infringement of their rights.

In principle, self-consumers have the same rights as other traditional electricity consumers to change their retailer[34], but in practice, the dynamics are not necessarily the same[35] due to the different profiles of the users and companies involved and the complexity of the contracts.

In the entire retail electricity market in Spain, the retailer switching rate has reached high levels – 23.9% in 2024 – which corresponds to 7.2 million activated requests[36]. By segments, the highest switching rate was observed in the SME segment (31.9%), followed by the domestic-commercial segment (23.7%) and the industrial segment (22.8%).

In 2024, the switching rate among customers with photovoltaic self-consumption stood at 30.8%, which represents a difference of 7 percentage points compared to the rate observed in the retail market as a whole. The Figure 2-14 illustrates that the segment[37] with the greatest positive difference in the switching rate between self-consumers and consumers in the retail market as

[33] The retailer switching rate can be calculated as the ratio between the number of activated switches and the number of registered supply points at the beginning of the period in question.

For the purposes of this study, the switching rate for 2024 has been calculated considering only photovoltaic self-consumers. Thus, the numerator of the quotient includes the total number of switches throughout the year 2024 of self-consumers (both individual and collective taking into account their CUPS – Universal Supply Point Code –) that were active at the beginning of that year, on 01/01/2024. The denominator of the quotient includes all active photovoltaic self-consumer supply points as of 01/01/2024.

[34] Retailer switching is regulated in Articles 12 and 19 of EU Directive 2019/944.

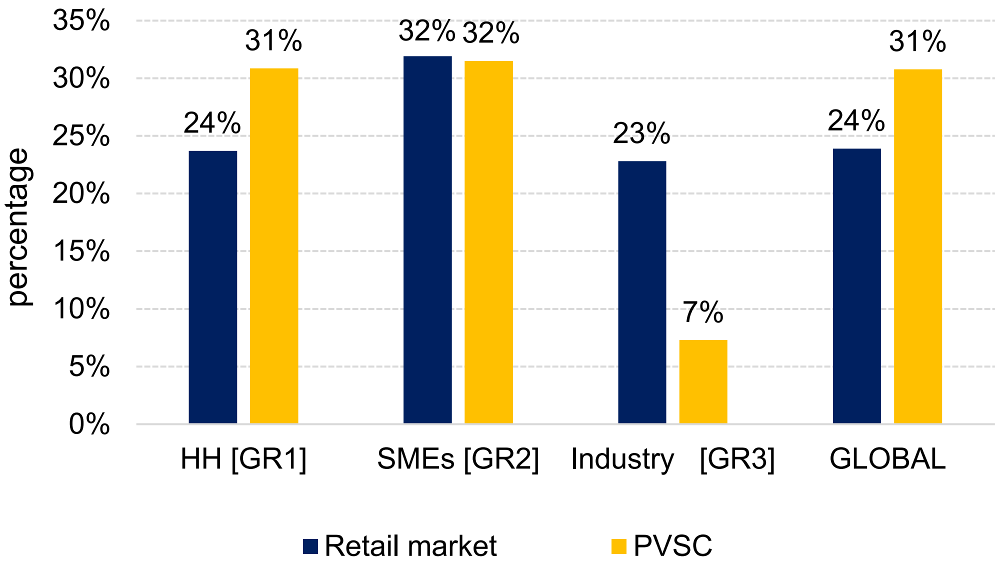
[35] The formats of the data exchange files between distributors and retailers, approved by the CNMC, which include the switching formats, are identical for customers with and without self-consumption. Nevertheless, the activation of new supply points (or new self-consumption installations) may follow a more complex dynamic due to the installation of self-consumption systems.

[36] Source: CNMC supervision report (2025b).

[37] To compare the retail switching rate among the different segments of self-consumers, the consumer classification reported in the CNMC's Retail Market Report (2025a) has been approximated using the groups GR1 (households), GR2 (SMEs) and GR3 (industry).

a whole was the most numerous one, **GR1** (domestic), with a rate of 30.8%. In the case of the **GR2 (SMEs),** self-consumers have a switching rate of 31.5%, very similar to that of their counterparts in the overall retail market. On the contrary, in **GR3 (industry),** a significantly lower rate of 7.3% is observed. However, this later result could be attributable to comparability problems, due to the different composition of PVSC industrial customers compared to the average industrial customers in the overall retail market. The greater complexity that may be involved in a supply contract for large consumers with PVSC could also contribute to greater stability in the relationship with the retailer.

Figure 2-14 Retailer switching rate in the retail electricity market and among photovoltaic self-consumers, 2024



Source: own elaboration based on data from CNMC (2025b) and REE.

In general terms, it can therefore be observed that PVSC customers tend to contract more often with small and independent retailers and display higher mobility. This occurs even though, in principle, they may have less economic incentive to compare offers once they have a PVSC installation, as their electricity consumption from the grid is lower and, consequently, the potential savings from switching are less relevant. Nonetheless, this segment exhibits greater competitive dynamism compared to the entire retail market.

2.3.3. Relationship between distributors and retailers

Finally, it is worth analysing the distribution of companies that manage grid access for PVSC installations. In this regard, the three main electricity

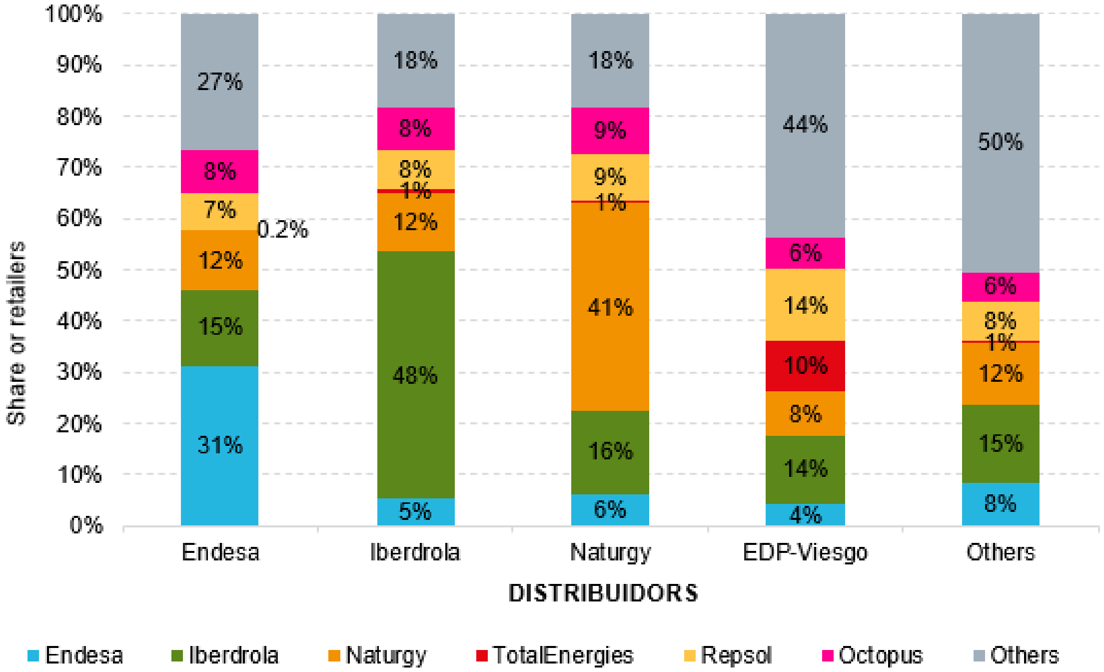
distribution groups – Endesa, Iberdrola and Naturgy – account for approximately 96% of the supply points associated with PVSC installations. This high level of concentration is explained by the natural monopoly characteristics of electricity distribution, as recognised under Spanish law (Law 24/2013, on the Electricity Sector). Unlike electricity supply, where consumers are free to choose their retailer, the distributor is determined by the geographical location of the connection point.

This reality has important implications for the development of self-consumption, since distributors are responsible for the technical processing of grid access and connection, as well as managing surplus electricity fed into the grid. In this sense, smooth and effective coordination between distribution companies and electricity retailers is crucial, both for the initial processing of PVSC installations[38] and for their ongoing management, including surplus billing, contract modifications, or incident resolution.

Indeed, PVSC customers contract with smaller and independent retail companies more frequently than other customers in the retail market (see Figure 2-10). Nevertheless, **a significant part of PVSC customers still have a distributor and a retailer vertically integrated within the same business group**.

[38] In this respect, the formats of the exchange files approved by the CNMC facilitate this coordination.

Figure 2-15 Market share of retailers by the distribution company of photovoltaic self-consumers, as of 31/12/2024



Source: own elaboration based on REE data.

As shown in the Figure 2-15, traditional retailers have a significantly higher market share among those self-consumers whose electricity distributor belongs to the same corporate group. For example, by the end of 2024, Endesa's retail company held a 31% market share among self-consumers whose distributor was Endesa. In contrast, its share ranged between 4% and 8% when the distributor belonged to another company. In the case of Iberdrola, its retail share among self-consumers whose distributor was Iberdrola reached 48%, while it dropped to between 14% and 16% among self-consumers supplied by other distributors. A similar pattern was observed for Naturgy (41% in its own distribution area and between 8%–12% in others). For smaller, non-vertically integrated retailers such as Octopus Energy, their share among self-consumers does not appear to depend on the distributor.

3. AID FOR PHOTOVOLTAIC SELF-CONSUMPTION

3.1. Theoretical foundations

This section presents general considerations on the factors that may influence individual investment decisions in PVSC, the reasons that could justify public support for these investments and the tools available to the public sector if it wishes to incentivise such installation.

3.1.1. The investment decision from a microeconomic perspective

To assess the impact that public aid may have on the PVSC, it is useful to analyse the rationale for investment decisions in this type of installation from a microeconomic perspective.

A household's or business's decision can be modelled using a discounted cash flow model, in which the net present value of investment (NPV) is calculated as the difference between the initial outlay on the installation (CAPEX) and the expected net savings or revenues stream over the installation’s useful life, taking into account the "time value" of money.

$$NPV = -CAPEX + \sum_{t=1}^{T} \frac{P_t^{retail} \cdot E_t^{selfcons} + P_t^{excess} \cdot E_t^{excess} - C_t^{O\&M}}{(1+i)^{t-0,5}}$$

Where,

- CAPEX is the **initial outlay** covering panels, inverter, structure, wiring, labour, permits, engineering, and applicable taxes[39].
- $P_t^{retail} \cdot E_t^{selfcons}$ are the **expected savings from self-consumption**, i.e. the monetary value of the energy that the household avoids purchasing from the grid, calculated as the average retail price avoided (P_t^{retail}) multiplied by the energy self-consumed ($E_t^{selfcons}$).
- $P_t^{excess} \cdot E_t^{excess}$ are the **expected revenues from surplus energy**, i.e. the economic compensation received for the energy exported to the grid (E_t^{excess}) at the price determined by a net-billing mechanism or another sales scheme (P_t^{excess}). Surplus energy, in turn, is the difference between the energy produced (which depends on factors such as solar irradiation, installation

[39] In this example, it is assumed that CAPEX is fully disbursed at the beginning of the period t=1 and that the remaining cash flows are generated uniformly throughout each year t (so that the flows are discounted in the middle of the period).

capacity and progressive degradation over time) and the energy self-consumed.

- $C_t^{O\&M}$ are the **costs of operation and maintenance**, i.e. recurring expenses for cleaning, insurance, monitoring and replacement of components throughout the installation's useful life.
- *T* is the **useful life** of the panels (usually between 25 and 30 years).
- *i* is the **discount interest rate** used to update future money flows.

In this theoretical model, for a rational household or company to decide to invest, it is a necessary condition that the expected NPV is positive. Furthermore, the greater the uncertainty surrounding future cash flows, the higher the NPV required by the household to undertake the investment. Since many of these variables are not known with certainty at the time of investment, the agent will make its decisions based on expectations, sometimes grounded in market elements such as the future prices of electricity.

Another way to approach this investment problem, perhaps closer to the usual reasoning of most households, is to calculate the time required to recover the initial investment ("payback period" approach). The greater the uncertainty or the higher the opportunity cost of the investment, the shorter the payback period required to undertake the investment.

A simplified example of a household's investment decision is presented, for illustrative purposes only. The Table 3-1 contains a series of **assumptions** on the characteristics and costs of a typical PVSC installation without storage, the household's consumption and the expected average price during the useful life of the installation.

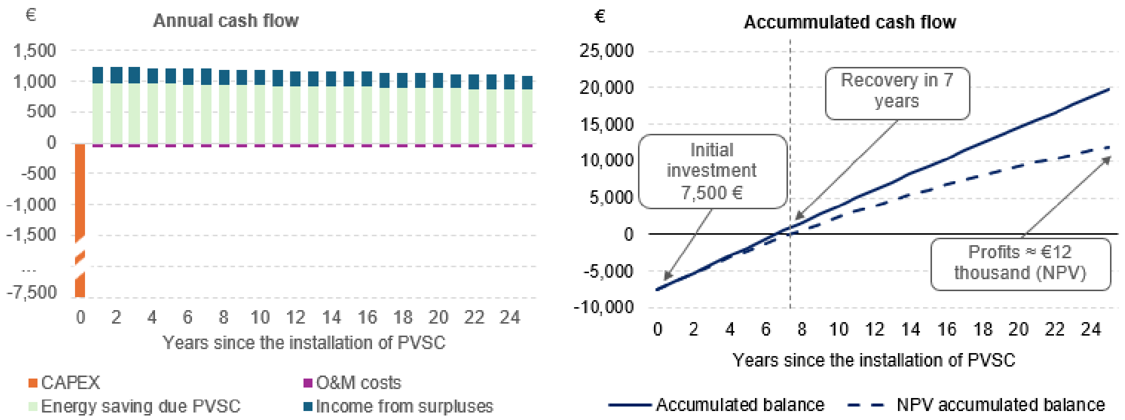
Table 3-1 Assumptions Used in the Simplified Household Investment Example

Concept	Magnitude	Unit
Installed capacity	5	kWp
Initial annual production	1.300	kWh/kWp
Annual efficiency los	-0,5%	Annual degradation of capacity, %
Percentage of self-consumption	60%	Energy consumed / self-produced
Installation cost (VAT included)	1.500	€/kWp
Average Price per kWh consumed from the grid	0,25	€/kWh
Average Price per kWh fed into the grid	0,10	€/kWh
O&M costs	1,5%	% of CAPEX
Discount rate	3%	%
Useful life	25	years

Source: own elaboration. Note: The assumptions are illustrative but based on rounded average values for households in terms of capacity, costs or percentage of surpluses/self-consumption, described in sections 2 and 3. The final electricity price assumptions are based on rounded figures from Eurostat for households (DC range) until the second half of 2024 and should not be interpreted as forecasts by the CNMC. A ratio of 2.5 between the price of the kWh consumed and that of exported energy is assumed, reflecting a household that consumes during expensive hours and exports during cheaper ones. For simplicity, prices and other variables, such as O&M costs and discount rates, are assumed constant over time.

As shown in Figure 3-1, the investment requires a significant initial outlay, recovered through positive cash flows in subsequent years. These cash flows, due to the stylized assumptions chosen (constant prices), are very stable, although decreasing, due to the progressive loss of efficiency of the installation. **Under these assumptions, the household could recover the investment in a period of 7 years**. In addition to recovering the initial investment, over the useful life, the installation would generate around 12 thousand euros of profits in net present value, which is equivalent to an internal rate of return (IRR) of 16%.

Figure 3-1 Cash flows of a PVSC Investment



Source: own elaboration. Note: The CAPEX bar has been truncated to make for better visualisation of the rest of the cash flows.

The above result is sensitive to the underlying assumptions. A sensitivity analysis is therefore conducted to assess the impact of deviations from the stylized base case. First, if the household consumed a smaller percentage of self-produced energy (30% instead of 60%), the payback period would extend to 9 years, and the IRR would fall to 11%. Second, if the retail price and surplus were half of that assumed in the base scenario, the payback period for investment would increase to 15 years and the IRR would decline to 5%. Finally, in an adverse scenario combining both previous assumptions, the payback period for investment would extend to 21 years and the IRR would drop below 2%.

In conclusion, this stylized example suggests that, under reasonable assumptions, PVSC investment can offer competitive levels of return in many cases, regardless of additional public support. The effective return on investment is subject to risk, as it depends on market variables that fluctuate over time, such as electricity prices. However, self-consumed energy may provide a hedge against market price volatility, especially when the proportion of self-produced energy (that is also consumed) is high.

In the stylized example above, the decision to complement the photovoltaic installation with energy storage systems (batteries) was ignored. This decision can also be modelled using a cash flow model. This decision can also be modelled using a cash flow approach. In this case, the final investment profitability will depend on additional factors that make the decision more complex. As explained in Ahmad et al. (2024), the economic viability of combined photovoltaic-battery systems (PV-BESS) depends critically on the degree of temporal coincidence between solar generation and the user's hourly consumption profile, as well as the desired level of self-consumption. Battery installations allow temporarily shifting photovoltaic production to periods with higher marginal energy value, thus increasing savings in grid acquisitions and minimising the opportunity cost of feeding poorly remunerated surpluses into the grid. However, storage integration also involves significant additional costs, particularly related to the initial acquisition of equipment, its operation and maintenance, and the technological degradation associated with charge-discharge cycles. In this context, investments in storage systems could be more sensitive to changes in market prices and the existence of specific public supports, such as storage subsidies, which can strongly influence the final investment decision (Ahmad et al., 2024).

Finally, it is important to note that the above cash flow models rely on some basic assumptions:

- First, they assume that there is **no financial friction,** which would allow households and companies to borrow for the desired term to undertake these investments. In practice, households – especially the most vulnerable – and companies – especially SMEs – may in some cases have financial constraints that hinder or delay investments that are economically viable, which can have implications for the design and management of aid.
- Second, a high level of **rationality and knowledge** is also presumed among self-consumers, which is not always realistic. Relaxing this assumption may have implications in terms of transparency and dissemination of the advantages of self-consumption, the available aid and the associated procedures.
- Third, the simplified cash flow model that has been presented ignores other types of advantages associated with investments in PVSC, such as the possibility of **capitalising the value of the investment** through its impact on property value, i.e. the appreciation of the homes or buildings where the installation is carried out or the usefulness or subjective satisfaction that these installations can bring to self-consumers with special environmental awareness.

Therefore, in a context in which these and other assumptions are not met, **public aid** could in some cases contribute to reducing initial barriers to investment and facilitate an accelerated return on investment, as well as disseminating the benefits of these investments to the general public, thus catalysing a higher level of private investment aimed at the adoption of renewable energies.

3.1.2. Reasons for public support for PVSC

The deployment of photovoltaic self-consumption can generate benefits for society that are not fully internalized by self-consumers, i.e., they are not (sufficiently) considered in their private investment decisions.

In this sense, the authorities have seen PVSC as an opportunity to address environmental challenges and achieve broader energy policy and public interest goals. Beyond private benefits, European and national policies deployed in recent years have promoted self-consumption to foster a decentralised model of energy production, with a greater impact on employment and the generation of savings at local level.

In this context, public support may be justified if it helps correct market failures – such as financial barriers, positive externalities, or imperfect information – thus, supporting energy and climate policy objectives or other public general goals.

- **Environmental externalities[40].** Each kWh generated *on-site* avoids the marginal emission of CO_2 and other pollutants associated from fossil-based electricity generation (gas, coal or fuel oil). These global benefits are not reflected in the price received by the self-producer and may justify policies that correct the gap between social and private costs.
- **Grid relief.** Distributed production close to consumption points reduces technical losses in transmission and distribution networks due to the circulation of energy. It can also mitigate demand at peak times, especially when combined with storage systems. Peak shaving can yield savings in the transport and distribution infrastructure, which are not internalized by the self-consumer.
- **Learning effects and economies of scale.** Support programmes stimulate technology diffusion, accelerate learning curves, and induce additional cost reductions for the benefit of future adopters.
- **Security of supply and resilience.** Diversifying the energy mix and distributed generation reduces dependence on imported fuels from third countries and enhances the resilience of the economy[41].
- **Distributional effects.** The NIECP and the Self-Consumption Roadmap consider support for collective PVSC installations as a tool to assist vulnerable populations of energy poverty, thus contributing to possible income distribution objectives.

[40] In addition, compared to traditional ground-mounted photovoltaic plants, photovoltaic self-consumption is usually installed on the building rooftops, thus minimising the environmental impact and allowing rural land to be dedicated to other uses (EEA, 2022).

[41] However, the high dependence on imports of photovoltaic panels from third countries, especially China, also raises concerns from the point of view of economic security. See, for example, references to the European Commission's critical products or essential inputs (minerals such as lithium, cobalt, etc.) of economic security (the European Economic Security Strategy was presented on 20 June 2023, here).

At the same time, support programmes are not without risks, which are also present in the promotion of other sources of distributed generation. Recent literature[42] is profuse and has identified various issues to be considered when promoting self-consumption. The following can be highlighted:

- **Distribution network impact**: although distributed generation can generate savings due to *peak shaving*, it may also require additional investments for the expansion of low-voltage networks, as well as adaptations in system operation to manage greater complexity. Thus, for the electricity system operator, the safe integration of small and dispersed generation installations requires certain adaptations and improvements in their prediction systems, to ensure safe operation[43]. In this context**, the promotion of self-consumption with storage integration could offer a balanced solution**.
- **Overinvestment risks and cross-incentives**: current subsidies and tariffs may encourage socially inefficient PVSC investments if retail prices do not reflect the true system costs. **Self-consumption can also amplify the effects of inefficient tariffs and generate a "vicious circle" of overinvestment and loss of system revenue**.
- **Equity issues:** Support could benefit those with means to install PVSC with their own resources (roofs owners), implicitly transferring the financing of these aids (via present or future taxes) to those who cannot (tenants, vulnerable households, etc.). In addition, the reduction in net consumption billed to self-consumers could erode the electricity system's toll revenues (intended to pay for transmission and distribution costs, as well as other regulated costs), leading to toll increases for the remaining users (captured consumers).

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42 Gallego-Castillo, C., M. Heleno, and M. Victoria (2021): "*Self-consumption for energy communities in Spain: a regional analysis under the new legal framework" (*here); T. D. Gararden (2023): *Demanding Innovation: The Impact of Consumer Subsidies on Solar Panel Production Costs* (here); Robinson, D. y I. del Guayo (2022): “Alignment of energy community incentives with electricity system benefits in Spain”, en*: Energy Communities – Customer-Centred, Market-driven Welfare-Enhancing?*, ed. S. Löbbe, F. Sioshanshi y D. Robinson, Chapter 5, p.73-94; Vargas-Salgado, C., I. Aparisi-Cerdá, D. Alfonso-Solar, T. Gómez-Navarro (2022): *“Can photovoltaic systems be profitable in urban areas? Analysis of regulation scenarios for four cases in Valencia city (Spain)*", en: Solar Energy, Volume 233, Pages 461-477 (here).

43 See Consolidated Financial Statements 2024 of Redeia (p. 111): "*The increase in generation facilities with installed capacity below the system operator's observation and controllability threshold, mainly self-consumption facilities, implies greater uncertainty associated with the lack of knowledge of their energy production, which represents a risk to the safe operation of the electricity system*.”

The Council of European Energy Regulators (CEER) published recommendations on self-consumption regulation at the end of 2024[44]. Among these recommendations, notably **advocating financial support via subsidies for PVSC projects with storage**, which would reduce congestion in the network and balance supply and demand.

3.1.3. Types of public sector intervention

In the analysis of public policies aimed at promoting renewable energies, some authors make a distinction between "support policies" and "promotion policies" (Lage et. al, 2022). Supportive policies would aim to boost the development of renewable technologies until they reach "grid parity", i.e. until they become economically viable without the need for public support[45]. Promotion policies, on the other hand, would seek to accelerate the penetration of mature technologies, through mechanisms that favour the increase of their installed capacity.

For PVSC, **the significant cost reduction of solar panels in recent years makes investment currently economically viable for many cases.** This explains why traditional support instruments have been shifting in most countries to other types of instruments more focused on accelerating the penetration of technology in different segments. Despite this general trend, large differences persist between countries, as each has opted for different strategies and combinations of instruments over time.

Regardless of the form these support schemes take, they must comply with EU State aid rules and other associated requirements. In this sense, the regulations have generally been made more flexible in recent years to facilitate support for self-consumption up to certain amounts. For example, the 2022 Guidelines on State Aid for Climate, Energy and Environment (CEEAG) provide exemptions from mandatory competitive tendering processes for granting aid for installations with a capacity of up to 1 MW.

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44 The CEER (2024) publication *Joint Recommendations on Self-Consumption Regulation* (here) has been developed within the framework of the EU4Energy Programme Phase II – *"Promoting the Clean Energy Transition in the Eastern Partnership Countries"*. The 7 recommendations mentioned are as follows: 1) Shift from net metering to net billing, 2) Implement cost-reflective tariffs for maintaining the network, 3) Simplify grid connection procedures for self-consumers; 4) Make self-consumers responsible for energy imbalances; 5) Promote energy storage solutions for grid stability; 6) Enable peer-to-peer energy trading for community resilience; and 7) Support vulnerable consumers in the energy transition.

45 Grid parity is achieved when the cost of producing electricity at the point of consumption is equal to or less than the cost of obtaining it from the electricity grid. This allows distributed generation technologies to compete directly with conventional generation.

Some of the most relevant instruments used in the recent past are highlighted below, with brief reference to the experience of Spain and other neighbouring countries.

3.1.3.1. Feed-in Tariff (FiT)

Feed-in Tariffs (FiT) are support mechanisms that guarantee a fixed remuneration for energy generated from renewable sources for a certain period[46].

In Spain, FiT has never been used to support self-consumption (only for large-scale renewable energy production), but there are precedents in other countries. Although it is becoming less frequent, there are still some countries that remunerate with FiT the electricity injected into the grid by PVSC installations.

A prominent example is **Germany**, which introduced FiT in 1991 to boost renewable energies and consolidated its model with the passage of the Renewable Energy Act (EEG) in 2000. This scheme, replicated internationally, was based on fixed rates, long-term contracts and collective financing. These fees varied depending on the technology, the size of the facility, and the year of commissioning. As technology costs declined, FiT payoff progressively declined.

Since 2009, the EEG has introduced specific incentives for self-consumption. Owners of photovoltaic installations could receive remuneration for self-consumed electricity, in addition to the tariff for surplus energy injected into the grid. In 2012, Germany reached grid parity, which made self-consumption more profitable, as the cost of generation became equal to retail price. Until then, FiT encouraged the full injection of generated energy into the grid, without promoting direct self-consumption. From that year onwards, successive reforms of the Renewable Energy Act introduced charges and requirements to promote self-consumption, requiring installations to consume a minimum percentage of the energy produced in order to qualify for FiT remuneration.

A second case to highlight is that of feed-in tariffs for photovoltaic energy in **France**, which are guaranteed for a period of twenty years. They were introduced in 2000, in the context of a strong European push for renewable energy. In the context of the European debt crisis, in March 2011, France adjusted its feed-in tariff system, reducing the hitherto high tariffs, to reduce the costs of the system.

More recently, the Finance Act of 2021 introduced further amendments, providing for a downward revision of feed-in tariffs to ensure that projects maintain reasonable profitability and avoid an undue burden on the state budget.

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46 A related modality is the feed-in premium, which – instead of guaranteeing a fixed price – grant a premium over the market price, thus maintaining a certain degree of exposure to price signals from the electricity market.

Currently, the FiT-based support framework is structured in a system of differentiated tariffs according to the size of the PV installation, adjusted quarterly by the Energy Regulatory Commission (CRE). The feed-in tariffs set by the CRE for February to June 2025 range from €0.0839/kWh to €0.1295/kWh, depending on the size of the system, from 3 kW PVSC installations to large 500 kW farms.

3.1.3.2. Electricity Compensation Mechanisms

In general, European countries are replacing FiT-based support systems with compensation mechanisms. Thus, in a growing number of electricity systems, the surplus energy injected into the grid by the self-consumption installation is economically compensated, with ***net metering*** and ***net billing*** being the most important modalities. According to these schemes, the self-consumer receives financial compensation for the surplus electricity, which is deduced from their electricity bill, thus reducing the cost of electricity consumed from the grid. The difference between the two schemes is that, in net metering, credits are granted at the retail price of electricity, while in net billing credits are granted at a lower price, generally close to the wholesale price.

In Spain, a simplified compensation mechanism based on a net billing scheme has been established by Royal Decree 244/2019. This scheme allows self-consumers with photovoltaic installations of up to 100 kW to compensate for surplus energy that they do not use. In exchange, they receive financial compensation for that energy, although its value is always lower than the retail price of electricity. The total value of the compensated energy can never exceed the value of the energy that the self-consumer consumes from the grid in the billing period[47].

With a few exceptions, net metering has disappeared in the European Union for being considered as an inefficient system. An example of a net-metering compensation scheme is that of the **Netherlands**, which allows owners of PVSC installations to fully offset the final price of the electricity they feed into the grid with the electricity they consume from it. However, parliament has approved the replacement of this system from January 2027 with a net billing scheme, due, among other reasons, to the reduction in the cost of photovoltaic technology in recent years, the incentive for households to directly consume their own electricity instead of feeding it into the grid and the decrease in tax revenues derived from this compensation mechanism[48].

Another example of a simplified compensation mechanism based on a net metering scheme is **Italy**, with the scheme known as *Scambio sul Posto*.

[47] RD 244/2019, art. 8.3.ii.b.

[48] See Web information of the Dutch Government on the transition to the new system.

However, Italian law provides that this mechanism will cease to apply throughout 2025[49]. Instead, self-consumption installations will be able to benefit from the *Ritiro Dedicato*, an existing mechanism that allows the remuneration of surplus energy fed into the grid, but without the direct compensation between produced and consumed energy that characterises net metering.

3.1.3.3. Grants (Subsidy programmes)

Grants or subsidy programmes are usually used to finance part of the initial cost of installing PVSC systems on a non-refundable basis. These programmes reduce the initial investment barrier, making the technology more accessible to households and businesses.

In this context, it is worth highlighting the grant programmes deployed by numerous Recovery and Resilience Plans in several countries, charged to funds from the **Next Generation EU programme**. In this regard, it should be recalled that Regulation 2021/241, which establishes the Recovery and Resilience Facility, requires national plans to include investments aimed at the ecological transition that represent at least 37% of the total allocation of the plan. For these purposes, the mentioned Regulation considers that the amounts allocated to investments in solar energy count at 100% for the purposes of this percentage of "green labelling". Some of these programmes included in the recovery and resilience plans have been key to boosting PVSC, providing funds for the installation of photovoltaic systems in residential and industrial sectors.

In **Spain**, these funds have been regulated through Royal Decree 477/2021, with more than 2,000 million euros having been allocated to promote self-consumption and energy storage, mainly through the installation of photovoltaic panels (for more details, see section 3.2.1). The first call for aid for innovative energy storage projects for an amount of 700 million euros, defined by Order TED/535/2025, of 28 May, has recently been approved[50].

In **Portugal**, the Recovery and Resilience Plan includes a programme to improve energy efficiency in buildings, allowing the installation of photovoltaic systems (with or without storage) with a reimbursement of 85% of the cost, up to a maximum of €2,500 per project. In addition to European funds, there are other direct aid programmes for the installation of solar panels in Portugal, such as the *Vale Eficiência programme*, which offers 1,300 euros plus VAT per beneficiary.

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49 Press release of the Energy Services Manager (GSE) of Italy.

50 The aid defined in the Ministerial Order and in the First call is aimed at independent energy storage projects (reversible pumping or thermal systems), hybrid storage initiatives with new or existing renewable sources. The management and coordination of the project is carried out by IDAE (here).

Italy's Recovery and Resilience Plan supports both new and existing installations of self-consumption up to 1 MW, which is in force until the end of 2025 or 2027, depending on the type of installation. The support consists of a *premium* tariff for 20 years for self-consumers and renewable energy communities, with a total budget of 3,500 million euros. In addition, the aid includes grants covering up to 40% of the costs, on the condition that the facilities must be operational by 30/06/2026 and located in towns with less than 5,000 inhabitants. The budget allocated for investments amounts to 2,200 million euros.

In **France,** the prime à l'autoconsommation stands out, which is an investment subsidy designed to encourage solar systems installations for self-consumption with surpluses sale. Its main goal is to reduce the initial cost of installation, making solar energy more accessible. It is calculated based on the installed capacity (kW) and is granted as a direct financial aid.

Moreover, it should be noted that in **Germany** some federal states make subsidies for photovoltaic self-consumption conditional on the installation of a storage system. This condition varies according to the state and specific aid programme in force[51].

For example, in **Bavaria**, the *10,000 Häuser-Programm* has for years incentivized the installation of batteries together with photovoltaic systems to promote energy self-sufficiency in single-family households. Although this programme has evolved, regional aid continues to prioritise installations with storage, with subsidies that can reach €500/kWh of installed battery capacity. In **Baden-Württemberg**, the *Netzdienliche PV-Speicher* programme, put in place by the Ministry of the Environment, promoted the installation of batteries as a condition for accessing aid. Although the specific programme has ended, the region continues to promote the use of storage as part of its energy transition strategy. Meanwhile, in **North Rhine-Westphalia** (NRW), the *progres.nrw* programme provides additional support if storage is installed alongside PV installations, especially as part of municipal initiatives such as *Klimafreundlich wohnen* in cities such as Freiburg, where up to €150/kWh of battery capacity is offered, with a maximum of €1,500 per installation.

3.1.3.4. Tax incentives

Along with subsidies, tax incentives are also common in many countries, which allow individuals or companies to deduct part or all of a tax payment. These deductions, when partial, are usually determined as a fixed amount, a proportion

[51] Weiser (2025), here, and the Ministry of Environment, Climate and Energy of Baden Würtenberg (2022), here.

of the total tax liability, a proportion of the PVSC investment cost, or a combination of these options.

As explained in more detail in section 3.2.2, in **Spain**, there are many municipalities that apply local tax reduction to encourage new photovoltaic installations, although there is a great variability between municipalities[52]. These credits can include reductions of up to 50% on the Property Tax (IBI), up to 95% on the Tax on Installations, Constructions and Works (ICIO), and up to 50% on the Tax on Economic Activities (IAE). There are also variable deductions in personal income tax (IRPF), both at the state and regional levels.

In **Portugal**, Decree Law 85/2022 was published at the end of 2022, which exempts natural or legal persons from paying VAT and taxes associated with the sale of surplus electricity from self-production units with an installed capacity equal to or less than 1 MW.

In **Italy**, two main schemes were established under the Next Generation EU programme. Scheme I, *Superbonus*[53], offered a 110% tax deduction for the first five years, although without the possibility of selling surplus energy to the grid[54]. On the other hand, Scheme II, *Ecobonus*, allows a 50% deduction for ten years and provides the option of commercializing the energy generated.

In **the Netherlands**, a 0% VAT rate was established in 2023 for solar panels installed in households, in addition to other measures such as *net metering*.

In **France**, the 2025 Finance Law has introduced significant tax incentives. Specifically, this law establishes that electricity consumption from collective self-consumption projects with a capacity of less than or equal to 1 MW is exempt from the special tax on electricity (*taxe d'accise*). This measure, which came into force retroactively on 1 January 2025 and will remain in place until 1 January 2027, was already applicable to individual self-consumption and seeks to make collective self-consumption projects more attractive and economically viable.

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52 This heterogeneity in the tax treatment of PVSC installations also extends to the regulatory sphere. Thus, for example, the requirement for a municipal building permit has been withdrawn in most of the autonomous communities because, generally, due to their technical simplicity, they do not affect structural elements of the building. This licence has been replaced in most cases by responsible declaration or prior communication procedures (see document already cited on Municipalities and Competition, p. 12, and Guide professional processing of self-consumption of IDAE, p. 119).

53 The *Superbonus* 110% was an extraordinary tax incentive introduced by the Italian government in 2020 to promote energy rehabilitation, including the installation of photovoltaic technology.

54 The financial impact of this programme on public accounts has been the subject of extensive debate in Italy. In 2023, the bonus was reduced from 110% to 90%, falling to 70% in 2024, with further reductions expected.

Similarly, in **Germany**, since 1 January 2023, the purchase and installation of photovoltaic systems (new or existing and without limitation of installed capacity) are exempt from VAT. This measure applies to installations in residential and public buildings and, in addition to providing tax incentives for this technology, it also reduces the associated red tape. Furthermore, in 2022, an income tax exemption was approved for income generated by PV systems of up to 30 kW in single-family homes and up to 15 kW in multi-family or commercial buildings (total maximum of 100 kW per taxpayer).

3.1.3.5. Financial instruments

In several European countries, repayable financing instruments under favourable conditions have been successfully deployed, often combined with public grants through “blending” schemes. These mechanisms are particularly effective when PVSC investments are economically viable, but liquidity constraints or limited access to credit hinder their implementation.

Instruments such as concessional loans or subsidised credit lines make it possible to adapt the financial burden to the income profile of the self-consumer, while also optimizing the use of public resources. In the case of the PVSC, where there is a large number of potential beneficiaries and individual investments are typically of small-scale, these mechanisms are often channelled through public-private schemes. Among these, public guarantees and other risk-sharing instruments stand out, as they encourage the participation of private financial institutions, leveraging their territorial presence and operational capacity.

Another relevant modality is energy leasing, through which an energy service company (ESCO) or a public entity finances the installation, and the user pays a periodic fee, which is offset by the energy savings generated ("*pay-as-you-save*"). This formula eliminates the need for upfront outlays by the end user. Although some installation companies and some marketers are starting to offer this type of financial solutions on their own, it is not yet a widespread practice in all countries, and the public sector may try to support these schemes in their initial phases.

There are consolidated precedents in several European countries. For example, the German public development bank, Kreditanstalt für Wiederaufbau (KfW), offers specific financing lines for PV installations with low interest rates and partial guarantees, in combination with federal aid. In France, leasing programmes for solar installations in social housing have been launched, with the involvement of local authorities and energy cooperatives.

3.1.4. Technical and regulatory barriers

Finally, it is important to remember that public administrations, such as regulators, while supporting the deployment of PVSC, may also be at the origin of some of the barriers that hinder its development.

In recent years, the CNMC has been very active in analysing the technical and regulatory barriers to investment in PVSC, both in its aspect of promoting competition and in its role as regulator and supervisor of the electricity market. Although carrying out an exhaustive analysis of these barriers is beyond the scope of this study, it is worth highlighting some recent documents from the CNMC on this subject.

In February 2023, a working paper was published as part of the **Municipalities and Competition** https://www.cnmc.es/sites/default/files/MyC_DT_RENOVABLES.pdf project analysing the local administrative obstacles that hinder the deployment of renewable energy in Spain, including self-consumption. The analysis identified problems such as duplication of procedures, lack of resources in local administrations, diversity of fees, delays resulting from poor digitalisation and discretion in technical criteria. To overcome these problems, the document proposed a set of actions focused on: i) reducing information asymmetries and search costs, ii) strengthening institutional structures to speed up processing, and iii) mitigating local externalities. Recommendations such as the creation of a single state information point, preferential zoning, the simplification of procedures through responsible declarations, regulatory coordination and the establishment of collaborative structures between municipalities should be highlighted.

In November 2023, the CNMC established **the Self-Consumption Roundtable**, a forum that brought together the main players in the electricity sector for several months to identify and address the barriers that hinder the development of self-consumption in Spain. Multiple public administrations, transmission and distribution network operators, retailers, installers and consumer associations participated. The **Report on the Conclusions of the Self-Consumption Roundtable** (**INF/DE/106/24**), published in July 2024, highlights that complex administrative procedures, the multiplicity of interlocutors and the lack of homogeneity in information constitute significant obstacles to the deployment of self-consumption, especially in its collective modalities.

The report includes a series of proposals put forward by the participating stakeholders to overcome these obstacles. These include, among others, guaranteeing greater access capacity to the distribution network and reducing the economic burdens associated with the access and connecting process for self-consumption installations, as well as standardizing the commissioning process of such facilities. The report also refers to a subsequent circular published by the

CNMC on access and connection for demand, which stipulates that online platforms will facilitate the full management of self-consumption applications[55]. It is also proposed to promote collective self-consumption through the figure of the manager; to improve transparency for consumers by providing access to energy data related to self-consumption installations or by expanding the information on electricity bills; to finalize regulatory developments that will enable new configurations for self-consumption; to encourage convergence in the monitoring data on self-consumption deployment in Spain; to develop new self-consumption models; and to ensure that the System Operator and distribution network operators have access to information on self-consumption installations connected to the system for real-time generation scheduling, demand forecasting, and determining reserve levels to compensate for imbalances between renewable generation and demand[56].

At the international level, there are also numerous bodies that have carried out analyses of possible regulatory and technical considerations to promote self-consumption and other sources of distributed generation[57].

3.2. Description of public aid in Spain

This subsection describes the main subsidies, tax reductions and tax deductions that have directly or indirectly incentivised PVSC installations in Spain in recent years.

3.2.1. Recovery, Transformation and Resilience Plan Grants

3.2.1.1. Legal basis of the subsidies analysed

In Spain, the main grants for the installation of photovoltaic self-consumption have been financed by funds from the Recovery,

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55 Circular 1/2024, of 27 September 2024, by the CNMC.

56 It should also be noted that the CNMC, as a regulator of the sector, has a key role in the resolution of conflicts related to third-party access to electricity transmission and distribution networks, one of the bottlenecks frequently pointed out by the actors involved in the installation of photovoltaic self-consumption. Likewise, in March 2019 the CNMC published a draft regulatory report on Royal Decree 244/2019, of 5 April, which regulates the administrative, technical and economic conditions for the self-consumption of electricity. In this document, the Commission suggested improvements to promote a regulatory framework that promotes self-consumption, including the simplification of administrative procedures and the elimination of charges for self-consumed energy.

57 For more details, see, for example, the March 2025 report of the Council of European Energy Regulators (CEER): "Regulatory and Consumer Considerations for Decentralised Energy Opportunities" (available here).

Transformation and Resilience Plan (PRTR). These grants form part of the investments aimed at developing innovative renewable energies, integrated into building and production processes of renewable energies (component 7 of the PRTR) and the deployment of energy storage (component 8 of the PRTR). The support has also been reinforced thanks to the REPowerEU Plan, which expanded PRTR investments to rapidly reduce dependence on fossil fuels from Russia after the start of the war in Ukraine (component 31 of the PRTR).

The main regulation governing the operation of these subsidies is Royal Decree 477/2021[58], which established six differentiated incentive programmes. **The subsidy programmes had an initial budget allocation of 660 million euros, but this amount has been progressively increased to reach 2,086 million euros** (after the last extension on 27/06/2024).

The aid regulated by this royal decree took the form of **non-repayable support (grants). The basic aid was defined as a percentage of the eligible cost** of the generation facility and, where appropriate, the storage facility, **or as a fixed value per unit of capacity/storage**, depending on the specific incentive programme[59]. By way of example, in programme 5 (P5), an individual PVSC installation in a household with a capacity of less than 10 kW had a unit subsidy of €600 for each kW of installed capacity. If this same installation had also coupled storage systems, it would have also been eligible to receive additional unit aid of €490/kWh under the same programme. This aid was also modulated according to various criteria (for example, whether the self-consumption was individual or collective, whether the company was an SME or large company, whether it was a new installation or the expansion of an existing one). There were

58 Royal Decree 477/2021, of 29 June, approves the direct granting to the autonomous communities and the cities of Ceuta and Melilla of aid for the implementation of various incentive programmes allocated to self-consumption and storage, with renewable energy sources, as well as for the deployment of renewable thermal systems in the residential sector, within the framework of the Recovery, Transformation and Resilience Plan.

59 In accordance with Annex III of the aforementioned Royal Decree, the PVSC installations in incentive programmes 1 and 2 (P1 and P2) with an installed capacity between 1,000 kW and 5,000 kW had a maximum eligible unit cost of €460/kW. The final amount was modulated between 15% and 35% of the eligible cost depending on the size of the company (the smaller the installation, the higher the applicable percentage).

In P3, aimed at installations incorporating storage, the eligible unit cost varied between €200 and €700/kW, with aid ranging from 45% to 65%, also depending on the size of the company.

In P4, for the residential segment, general government and third sectors, the aid for PVSC ranged between €300 and €600/kW for individual installations and between €355 and €710/kW for collective installations.

The incorporation of storage (P5) could receive aid between €140 and €490/kW.

also some additional grants for municipalities of up to 5,000 inhabitants or non-urban municipalities of up to 20,000 inhabitants.

Although Royal Decree 477/2021 established in great detail the conditions for granting subsidies (eligible actions, maximum unit costs, required documentation, deadlines, intensity of aid by type of company, etc.), **the application and management of incentive programmes was transferred to the autonomous communities**[60]. Thus, the autonomous communities had to make calls for application addressed to final beneficiaries within a maximum period of three months from the entry into force of the Royal Decree (until 1 October 2021).[61] The implementation system was therefore fully decentralised, although subject to common rules and with a leading role for the Institute for the Diversification and Saving of Energy (IDAE) in the coordination and monitoring of the funds at national level.

The deadline for interested parties to submit their applications for aid in the different regional calls ended, for all incentive programmes, on **December 31, 2023.** However, the resolution and verification of these application files have continued beyond that deadline, and some are still being processed at the time of preparing this report.

3.2.1.2. Distribution of the budget by programme and technology

The first five incentive programmes (P1 to P5) established by Royal Decree 477/2021 focused on promoting electricity self-consumption with renewable sources, as well as on the incorporation of storage systems linked to both new and existing facilities.

The P6 incentive programme was aimed at promoting thermal renewable energy installations in the residential sector (see Table 3-2 Related incentive programmes defined in RD 477/2021).

60 The distribution of NGEU grants among the autonomous communities was initially carried out using the criteria established in Annex V of the Royal Decree, which is similar to those applied in previous energy efficiency aids, without prejudice to the possibility of being extended for those autonomous communities that requested it, provided that there was budgetary headroom. Specifically, the criterion applied in Annex V is a weighting of the gross value added (GVA) of services, GVA of industry and GVA of agriculture, livestock, forestry and fishing, updated as of 01/01/2019 and the Total Primary Dwellings or Households according to the 2011 Census of the INE.

61 Nevertheless, most of the autonomous communities and autonomous cities were late in their calls for application. In particular, only 5 autonomous communities strictly met the deadline of 1 October 2021, another 6 made the calls with only a few days of delay during the month of October, another 5 called it between November and December of the same year and there were 3 that did so between January and April 2022.

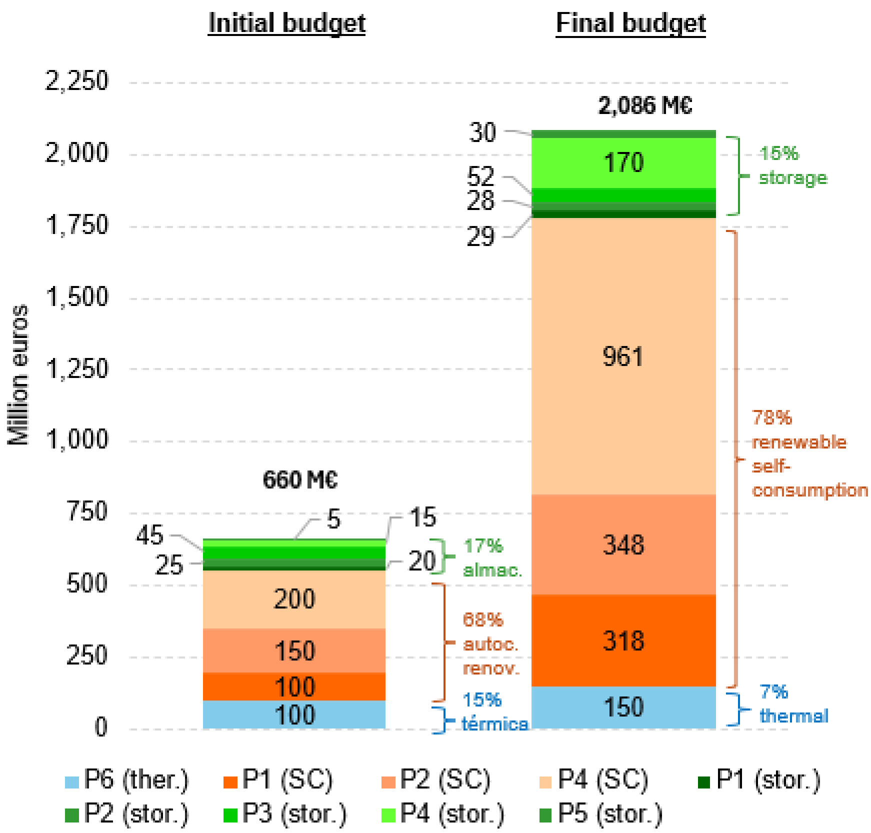
Table 3-2 Related incentive programmes defined in RD 477/2021

Incentive programmes		Sector	Type of installation
P1	Implementation of self-consumption installations using renewable energy sources, in the service sector, with or without storage.	Services	PVSC (with/without storage)
P2	Implementation of self-consumption installations using renewable energy sources, in other productive sectors of the economy, with or without storage.	Other productive sectors	PVSC (with/without storage)
P3	Incorporation of storage in existing self-consumption installations using renewable energy sources in the service sector and other productive sectors.	Services and other productive sectors	Storage
P4	Implementation of self-consumption installations using renewable energy sources, in the residential sector, public administrations and the third sector (NGO), with or without storage.	Residential, Public Administration and Third Sector	PVSC (with/without storage)
P5	Incorporation of storage in existing self-consumption facilities, using renewable energy sources, in the residential sector, public administrations and the third sector.	Residential, Public Administration and Third Sector	Storage
P6	Implementation of thermal renewable energy installations in the residential sector.	Residential	Thermal installations

Source: own elaboration based on RD 477/2021.

The initial budget allocation was established within the framework of RD 477/2021 at 660 million euros, distributed between self-consumption (450 million euros), storage (110 million euros) and thermal installations (100 million euros). **The final allocation of grants reached a total of 2,086 million euros**, after numerous budget extensions. The funding category that experienced the largest increase, both in absolute and relative terms, was the onw dedicated to the financing programmes supporting renewable self-consumption, which accounted for 78% of the total budget.

Figure 3-2 Distribution of the initial and final (extended) endowment under Royal Decree 477/2021



Source: own elaboration based on RD 477/2021 and IDAE information.

Most of the budget allocated within the framework of Royal Decree 477/2021 has been requested to carry out projects related to the PVSC, with a very small weight allocated to other generation technologies. Thus, in the case of incentive programmes 1, 2 and 4, which offered grants for new renewable self-consumption installations with or without storage, more than 99% of the new installations have been photovoltaic (the percentage is similar in terms of installed capacity or investment volume). The second most installed technology after photovoltaic is wind power, but its weight is testimonial (0.07%). In storage projects, which channel investments to existing renewable installations, practically all pre-existing installations are also photovoltaic technology.

Given that photovoltaic installations account for practically all the installations subsidised in the P1, P2, P3, P4 and P5 programmes, from now on this assessment will analyse in detail only the evolution of photovoltaic self-consumption (PVSC).

3.2.1.3. Status of grant application processing

The data used in this study reflect the status of the processing of the subsidies based on the information available as of 01/07/2025, when IDAE sent the latest update of the database to the CNMC[62].

Although the data received correspond to a period after the application deadline stipulated in Royal Decree 477/2021 (31/12/2023), a large part of the files had not completed their processing at the time the CNMC received the information. This is due to the evaluation and final award process for these grants taking several months after the application.

Based on the information provided by IDAE, this study has considered a total of 420,715 grant files[63] for the installation of PVSC systems and associated storage technologies (P1 to P5)[64].

The files provided by IDAE make it possible to distinguish the status of processing of the different cases on 1 July 2025. Specifically, there is information on the date of application submission by the interested party, the date of notification of the granting **resolution** (favourable or unfavourable) and the date of **verification** (or its potential cancellation at this stage), after which payment is ordered to the recipient[65].

For the purposes of this analysis, files with unfavourable resolutions or cancellations in the verification phase (a total of 38,153 files) have been omitted**.**

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62 Los datos de IDAE se apoyan en información remitida durante junio de 2025 por la mayoría de las CCAA, si bien algunas remitieron la última actualización en meses anteriores.

63 The figures reported here contain only the files for photovoltaic and related storage installations in the P1 to P5 programmes, after the database has been cleaned (e.g. by deleting observations with late or inconsistent dates, data without information on the installed capacity of self-generation or storage and the files resolved unfavourably).

64 Most of these files also corresponded to aid for PVSC installations without storage. Specifically, 335,530 files analysed (80%) were linked to PVSC without storage. There are also 73,674 files (18%) with PVSC and storage. The rest, 11,511 files (3%), correspond to storage coupled to existing facilities.

65 Royal Decree 477/2021 establishes that the autonomous communities must offer advance payments to anyone who requests it after a favourable resolution and before verification. The royal decree establishes some basic requirements (such as the need for a bank guarantee to collect the advance) but delegates the detailed regulation of these advances to the autonomous communities. However, these advances are only required for actions that have a total eligible cost greater than or equal to €50,000. In most autonomous communities, these advances have therefore been limited.

The **382,562 files that have been analysed** were in different stages of processing at the time the information from IDAE was received[66]:

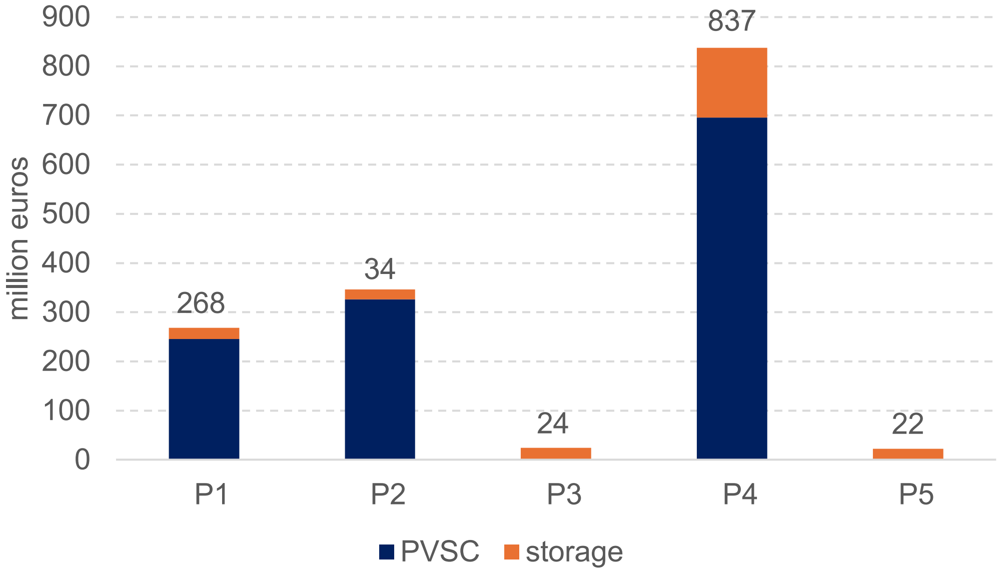
- **40 % were still in the application phase**, awaiting the grant decision from the regional authority (favourable or unfavourable).
- **43%** had already obtained a **favourable resolution**, pending verification.
- 17 **%** had already been **verified.**

Therefore, according to the data provided by IDAE, the files that had already obtained approval from the administration (favourable resolution phase, verified and pending verification) **already represented 60% of the total number of open files** and therefore totalled **almost 231,000 files** as of 1 July 2025. In monetary terms, the subsidies resolved and/or verified amounted to an amount of **1,498 million euros**.

As shown in Figure 3-3, the **P4** – aimed at PVSC installations in the residential, public government and third sectors, with the possibility of coupling storage – has absorbed **almost half of these grants**.

66 It should be noted, however, that the data notified by the autonomous communities to IDAE could contain errors and omissions. In particular, it should be noted that the database provided by IDAE does not contain any information on subsidy programmes aimed at companies (P1, P2, P3) and that in the case of Catalonia there is no information on the verifications of any programme (only applications and resolutions).

Figure 3-3 Grants awarded in resolved or verified files as of 01/07/2025, by incentive programme



Source: own elaboration based on IDAE data as of 01/07/2025.

It is noteworthy that the average grant awarded to PVSC projects with a favourable resolution or verified status represents approximately 22% of the investment declared at the time of application. In contrast, storage-related grants reached an average of 41% of the investment, reflecting a higher aid intensity for this technology.

The nearly 152,000 files still awaiting resolution correspond to applications amounting a total of 1,146 million euros in grants. These applications also correspond to installations with an eligible capacity far exceeding the total installed capacity in Spain. These figures reflect a high participation in the application calls and a strong interest on the part of potential self-consumers in accessing the aid. However, part of these applications will remain unsatisfied, since the total grant budget – after successive extensions – was around 2 billion euros, which is insufficient to cover all the applications once the amounts already resolved and/or verified are deducted.

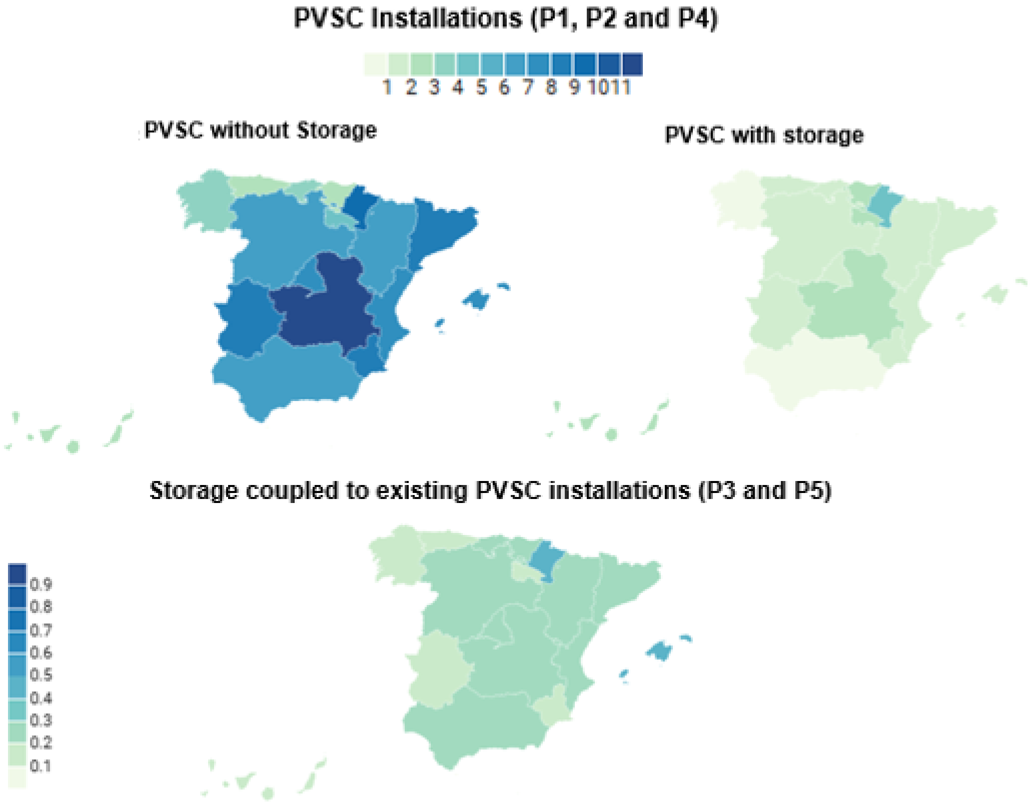
3.2.1.4. Territorial distribution of grants

As shown in Figure 3-4, **Castilla-La Mancha leads in the number of grant applications for PVSC installation without storage,** with an average of 12 applications per thousand inhabitants, followed by Navarra, Catalonia and Extremadura. In contrast, the Cantabrian coast – the Basque Country, Asturias, Cantabria and Galicia – has the lowest levels of applications per thousand inhabitants.

Regarding new installations with storage, Navarra leads the ranking of applications for subsidies, followed by the Canary Islands, La Rioja, Castilla-La Mancha and the Basque Country. The regions with the lowest requests to couple storage to new PVSC installations are Galicia and Andalusia.

As for the grant applications to couple storage to existing PVSC installations (P3 and P5 incentive programmes), the autonomous communities with the highest number of applications are Navarra and the Balearic Islands, although with a modest average of 0.4 applications per thousand inhabitants on average.

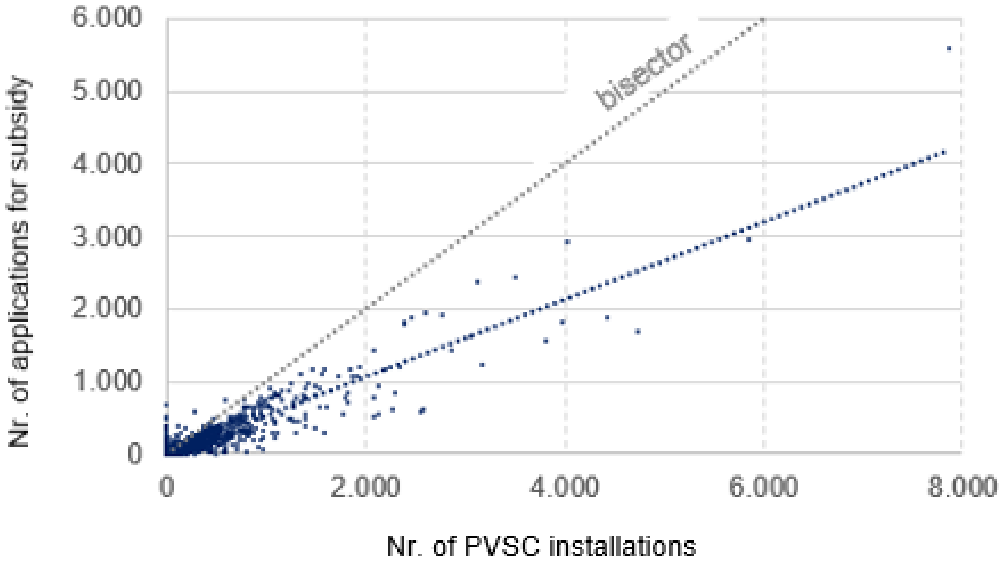
Figure 3-4 Regional average of grant applications for PVSC and storage installations (applications per thousand inhabitants)



Source: own elaboration based on IDAE data. Note: * The number of registered applications was calculated separately for P1, P2 and P4 (for PVSC) and for P3 and P5 (for storage), divided by each thousand inhabitants in each autonomous community. ** For clarity of visualisation, the maps for P1, P2, and P4 use a scale from 0 to 12, while the storage maps for P3 and P5 use a scale from 0 to 1.

While these differences in the level of applications are partly related to the different level of PVSC penetration in each region, they may also reflect different levels of knowledge or ease of access to grants, which may lead to no-application or "*no-take-up*" phenomena. Thus, it is possible that some households and companies, despite having the right to apply for the subsidy, did not do so due to the lack of awareness or difficulties in completing the application. In this regard, as illustrated in the following graph, although there is a very high correlation between the level of applications for subsidies and the number of PVSC installations registered during the period, there is also considerable heterogeneity across municipalities.

Figure 3-5 Relationship between the total number of grant applications and the number of PVSC installations in households (GR1), by municipality



Source: own elaboration based on REE and IDAE data. Note: The number of applications reflects the total applications registered since the grant programme came into effect (01/07/2021) until the deadline for applications (31/12/2023). The number of PVSC installations reflects the number of self-consumption points (CAUs) from 01/07/2021 to 01/07/2025 (latest available data).

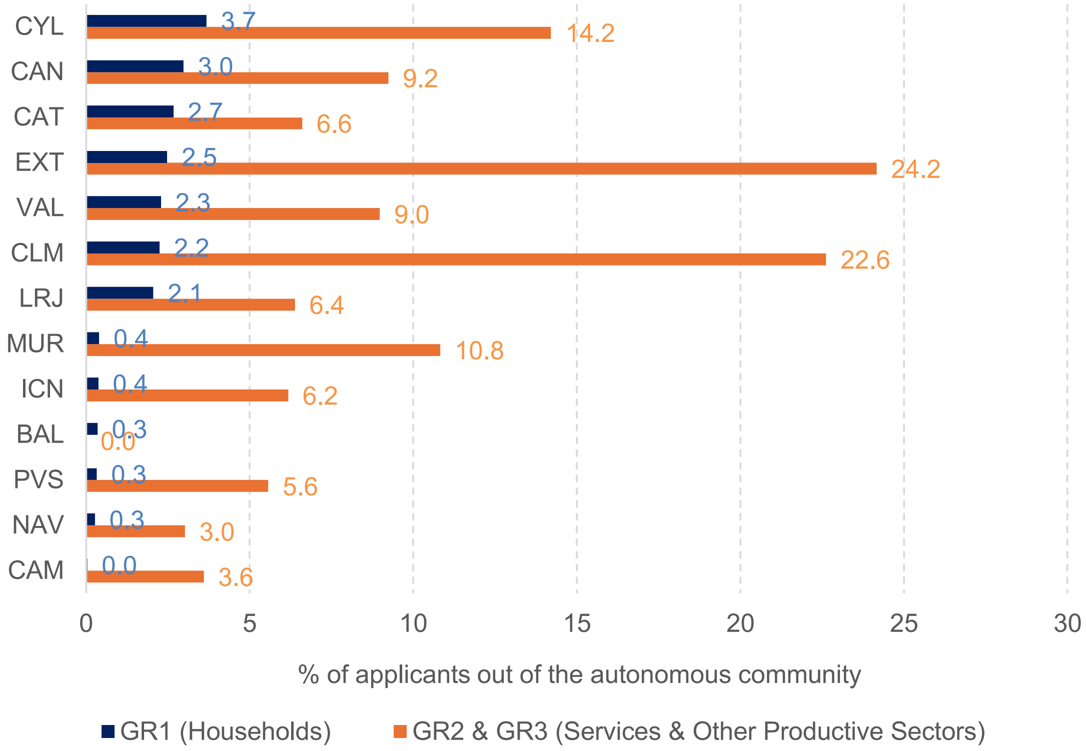
The grant database makes it possible to differentiate between the beneficiary's place of residence and the location of the subsidised project. On average, 3% of applicants have their residence outside the autonomous community where the project is executed.

In the case of households (GR1), part of these applications may be linked to second homes or holiday properties, where the beneficiary does not usually reside in the autonomous community where the installation is located. This percentage reaches its highest value in Castilla y León (3.7%) and is lower in communities such as Madrid (0.03%).

In the case of companies, the percentage of installations where the investor comes from an autonomous community other than the community where the installation is located varies widely: from 29% in Extremadura to around 4% in

Madrid. This may be due to the fact that the company's registered office may be located in a different place from the place where the investment is made and where the company carries out part of its economic activity, while, in the case of some communities with a greater tendency to have company headquarters, such as Madrid, this effect is less pronounced.

Figure 3-6 Percentage of applicants residing in a community other than that of the subsidised PVSC installation, by autonomous community where the grant is awarded and by group



Source: own elaboration based on IDAE data as of 01/07/2025. Note: The graph excludes Galicia, Ceuta and Melilla, since in these autonomous communities there were no applications from beneficiaries from other communities, or the number of observations was very low.

3.2.1.5. Processing time of grants

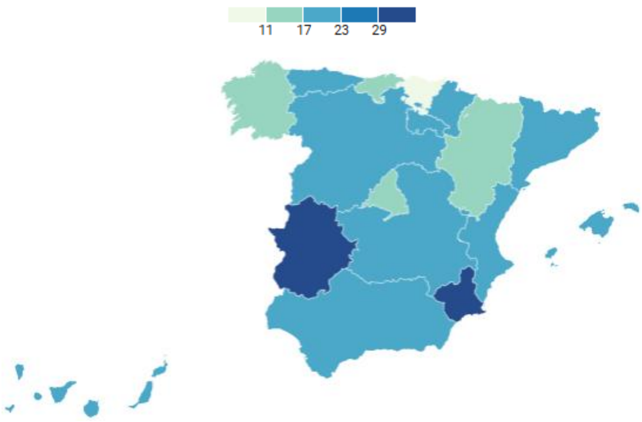
Processing times may be of interest from the perspective of competition, as they are a potentially relevant factor in the decision to apply for aid by potential beneficiaries. They can affect households and companies differently depending on their financing needs, as well as the conditions and timing of such financing.

The time required for the physical installation of PVSC panels is usually quite short, with an estimated average duration of about 3 months (CNMC, 2023). However, the processing of the grants to finance these installations has been considerably slower, due to the complexity involved in managing hundreds of thousands of applications by the public administration.

One indicator that helps assess the efficiency of grant management by the regional administrations is the time elapsed between the submission of the application and the issuance of the favourable resolution[67].

The data indicate that the Basque Country achieved the shortest processing times, with an average of 6.5 months between application and resolution, considering the different incentive programmes. In contrast, the average processing time in Spain extended to **18.5 months**, which may reflect management capacity constraints in some regions.

Figure 3-7 Number of months between the dates of the application and the resolution for grants under RD 477/2021, by autonomous community



Source: own elaboration based on IDAE data up to 01/07/2025. Note: only files that have reached at least the resolution phase (favourable or unfavourable) are considered in the calculation.

Since, after the resolution, applicants had up to eighteen additional months to provide documentary evidence of the execution of the required investment and the administration could delay in the verification processes of such documentation, **the total time elapsed between the application and the effective receipt of funds by the beneficiary far exceeded two years in most cases**.

On the other hand, as of July 2025, the autonomous communities have reported to IDAE very uneven levels of progress in the processing of grants. Some

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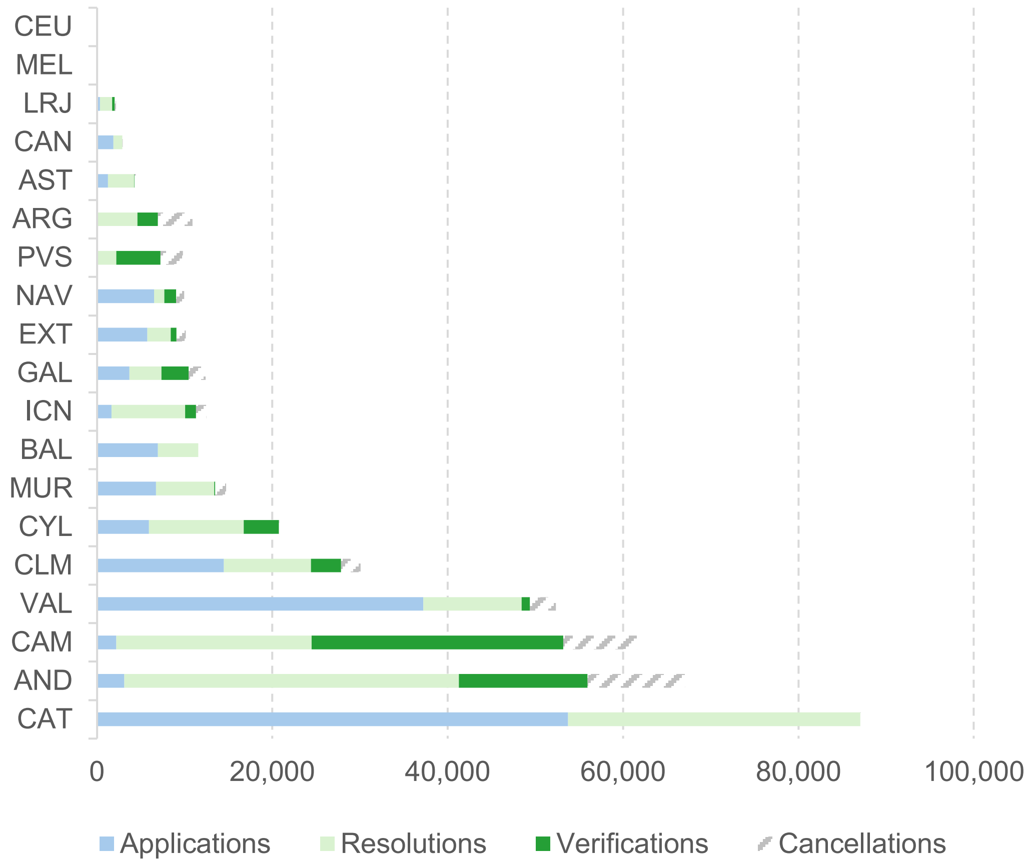
67 At the time of receipt of the subsidy data at the CNMC, most of the applications were still in the evaluation phase and only a small part had been verified. Therefore, for the territorial comparison, it has been decided to use the most complete data on the dates of resolution (favourable or unfavourable) and not those of verification.

autonomous communities have already resolved and/or verified a large part of the application files (for example, Aragon or the Basque Country) and others (such as Catalonia), which have resolved a low percentage and report practically no verifications. Some of these differences could be due to delays in reporting information to IDAE, but they could also reflect administrative delays.

Figure 3-8 Number and status of registered applications, as of 01/07/2025



Source: own elaboration based on IDAE data.

3.2.2. Local tax reductions

Tax credits are fiscal policy instruments designed to achieve specific economic and social objectives. These may include exemptions, reduced rates, reductions or exemption in tax payments, which generates incentives or improvements in the income of individuals and legal entities. In general, these tax reliefs result in lower tax collection but encourage desired economic and social activities[68].

In Spain, there are many municipalities that have decided to promote PVSC by introducing tax reductions in their main local taxes: the IBI (Property Tax), the ICIO (Tax on Constructions, Installations and Works) and the IAE (Tax on Economic Activities).[69]

Unlike the PRTR grants, which were deployed in all the autonomous communities under similar conditions, these taxes are local in scope, and the municipalities therefore have much greater discretion in deciding whether or not to establish such reliefs and, if so, determining their scope and specific requirements.

3.2.2.1. Legal basis of the local tax reductions analysed

In municipalities under the common regime, the main local taxes are regulated by **Royal Legislative Decree 2/2004, of 5 March**, which approves the revised text of the **Law Regulating Local Finances** (arts. 60 to 77 for the IBI, arts. 78 to 91 for the IAE and arts. 100 to 103 for the ICIO).

In the **foral territories** of Navarra and the Basque Country, these taxes are regulated by their own rules, in accordance with the first additional provision of the Spanish Constitution, Organic Law 13/1982, of 10 August, on the Reintegration and Improvement of the Foral Regime of Navarra, and the Statute of Autonomy of the Basque Country. Like this:

- In **Navarra**, the regulation is included in the **Foral Law 2/1995, of 10 March, on Local Treasuries**, and its subsequent amendments.
- In the **Basque Country**, the competence corresponds to the General Assemblies of each Historical Territory, which approve their respective **Provincial Regulations on Local Treasuries** (v.gr., Foral Law 9/2005, of 16 December, on Local Treasuries of Bizkaia; Provincial Law 11/1989, of 5 July, in Gipuzkoa; and Provincial Law 41/1989, of 19 July, in Álava).

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68 AIReF (2020): "In Spain, a significant part of spending policies is implemented through tax benefits. Taken together, they amount to close to 60,000 million euros (5 points of GDP) and cover a wide range of policies related to the promotion of employment, the provision of social services, the complement to pensions, housing policy, the promotion of research, health, education, culture, access to essential goods and services, and the protection of strategic sectors and the environment."

69 It should be noted that Royal Decree-Law 7/2025, published on 25 June 2025, introduced some modifications to the IAE, IBI and ICIO to favour industrial and air conditioning electrification. However, this RDL was repealed due to the non-validation of the rule in Congress.

The framework regulations on these taxes are in any case similar between territories, providing for similar reliefs and delegating similar regulatory powers to local entities.

The **IBI** is a direct tax levied on the value of real estate. It applies to the ownership of an administrative concession, a real right of surface, usufruct or property right of ownership over rural and urban real estate.

There are exemptions, mandatory reductions and optional reductions. Among the optional reductions, there are those that give tax incentives for systems installed for thermal or electrical use of energy from the sun, which can reach, at most, 50% of the full IBI tax amount.

Each municipality has the power to determine in its ordinances the specific conditions for accessing this fiscal incentive. Initially, this tax reduction was mainly applied to residential properties, but in recent years its application has extended to buildings in the tertiary or industrial sector.

It should be noted that neither national nor regional regulations establish a maximum duration for this IBI tax reduction. Although the most common is that the relief lasts between 1 and 5 years after installation in the property, there are cases in which it can be extended for more than a decade, reaching up to 30 years[70].

The **ICIO** is an indirect tax whose taxable event consist of the execution of any construction, installation or work that requires a building or urban planning license, responsible declaration, or prior notification from the municipality.

In the case of a PVSC installation, the tax base would be made up of the material execution cost of the work (mainly photovoltaic panels and labour). The tax rate can reach a maximum of 4% in common regime territories and up to 5% in foral territories.

Article 103 of RDL 2/2004 provides for a reduction of up to a maximum of 95% for constructions, installations or works incorporating systems for the thermal or electrical use of solar energy.

By its nature, and unlike the IBI or the IAE, the ICIO is paid on a single occasion, so the tax relief is applied only for a single year, when the installation is carried out. Moreover, the taxable event of the ICIO is directly related to the PVSC installation, it increases the initial cost of these investments (less so when the tax reduction is higher). This contrasts with IBI or IAE reductions, whose taxable event is not directly related to the PVSC, so only when there are specific tax reductions associated with the installation of PVSC are these taxes likely to alter

70 In the extreme case of Oñate (Guipúzcoa), the reduction can be applied for a period of 30 years.

the net costs of the PVSC investment and, therefore, to affect the incentives of self-consumers.

The **IAE** is a direct tax, whose taxable event consists of the exercise of economic activities of a business, professional or artistic nature (organization of means of production and/or human resources).

Article 88 of RDL 2/2004 sets out both the mandatory and optional tax reduction that are applied to the tax liability. Among the optional tax reductions, it specifies that taxpayers who use or produce energy from renewable energy installations or cogeneration systems may receive a reduction of up to **50%**, without specifying a duration. Each municipal ordinance establishes the application of the tax reduction, as well as the conditions and/or restrictions for its use. The IAE exists in all the autonomous communities except Navarra, where another regulation applies (Regional Law 2/1995 of 10 March) that does not contemplate tax reduction for photovoltaic self-consumption[71].

Quantifying local incentives for the PVSC through IAE tax reduction is complex due to the multiple factors that influence the calculation of the tax liability (different tax rates depending on the activity and characteristics, classification by category, geographical location, weighting coefficients, etc.). This would require an individualized analysis of each local tax ordinance and the situation of each company. For this reason, the analysis of the quantification of these incentives in the following subsections will be omitted.

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71 Fundación Renovables. Tax incentives in the IAE for photovoltaic self-consumption installations in municipalities with more than 10,000 inhabitants.

Table 3-3. Summary of local PVSC reductions

Local Tax	Type	Description	Maximum Reduction	Duration
IBI	Direct	Levied on the value of real estate	50%	Not specified (usually 1-3 years, but may reach up to 30 years)
ICIO	Indirect	Levied on constructions, installations or works	95%	1 year
IAE	Direct	Levied on the performance of economic activities	50%	Not specified

Source: own elaboration.

3.2.2.2. Strategy to approximate the value of tax reduction

At present, there are no official statistics on the revenue lost due to the local tax reduction associated with PVSC[72]. Therefore, an own estimation has been developed.

To approximate the level of tax reduction associated with the PVSC in each municipality, data from Fundación Renovables have been combined with information from the Ministry of Finance, IDAE and REE.

The database provided by Fundación Renovables to the CNMC has served as a starting point for the analysis. This database compiles information on PVSC tax reduction from the tax ordinances of all municipalities with more than 10,000 inhabitants (which together account for approximately 80% of the Spanish population). The information provided makes it possible to identify basic characteristics of the tax reliefs, such as the percentage of reduction, its duration (number of consecutive years in which the tax reduction can be applied), the economic sector of the PVSC installation benefitting from the tax reduction, and other requirements. It also includes an assessment of the Foundation itself regarding the conditions for accessing these reliefs (assumable, restrictive or very restrictive).

72 According to the Directive 2011/85/EU of the Council, Member States must provide detailed information on the impact of tax benefits on public revenue (Article 14). However, this information is not provided in practice with a sufficient level of granularity for the local tax reduction analysed in this study. It should be noted that AIReF analysed 13 state-wide tax reduction in its Tax Benefits Study (Phase II of the *Spending Review*), published in July 2020. In this document, AIReF underlines the importance of having detailed and homogeneous information to adequately assess tax benefits.

However, due to the design of the tax reduction, the information contained in the municipal fiscal ordinances is not sufficient to adequately assess the differences in the level of support provided by the different municipalities.

In the case of IBI, it is particularly important to also take into account other factors such as the IBI tax rates and its tax base. The information from Fundación Renovables has therefore been complemented with the cadastral statistics of the General Directorate of the Cadastre and the General Secretariat of Financing. The IBI tax reduction is configured as a percentage of the gross tax liability (instead of a percentage of the costs incurred by the installation or a unit cost per unit of capacity, as in the case of PRTR grants). Therefore, it is crucial to consider the information that allows the full tax amount to be approximated when comparing the tax reduction between municipalities.

The current design of the IBI tax reduction means that they depend very directly on the cadastral value of the properties. This can have distributional effects, since, on average, higher-income households tend to reside in homes with a higher cadastral value and, therefore, could have access to higher tax relief regardless of the size of the installation. Without prejudice to possible distributional and equity considerations, which are beyond the scope of this evaluation, **this design could reduce the efficiency of the aid.** Thus, two households that decide to install a PVSC system with identical characteristics within the same municipality (or in different municipalities, but with identical tax reduction rates), could end up receiving very different aid, depending on the cadastral value of their property.

In principle, the environmental contribution of both PVSC installations would be identical, as it can hardly be related to the cadastral value of the land on which they are installed. In this way, the design of the tax reduction could even create incentives for owners of properties with a high cadastral value to carry out installations, even if they are of small capacity, since the incentive focuses on said cadastral value and not on other aspects more linked to the reason of general interest that justifies the aid. This could undermine the efficiency and effectiveness of the measure in achieving its environmental goal. As a result, the mechanism may unjustifiably bias aid towards self-consumers residing in properties with a higher cadastral value (typically, with higher incomes), who are also usually those with fewer financial restrictions to undertake investments.

To illustrate the above with specific examples, two pairs of municipalities have been chosen with apparent similarities in terms of the elements expressly regulated by the city council in its fiscal ordinances (IBI tax rate, percentage of the tax reduction and duration of the reduction). As shown below, despite these similarities, the total tax reduction in euros that an average household in these municipalities could have access to can be very different.

Table 3-4 Examples of estimated average tax reduction for typical residential Installations in selected municipalities, 2024

			Comparativa 1		Comparativa 2	
			Barcelona	Cartagena	Madrid	Zaragoza
(1)=(2)/(3)	Average tax base (average cadastral value)	€	111.655	45.935	119.539	76.500
(2)	Total cadastral value (residential use)	million €	78.357	5.741	181.287	25.264
(3)	Nr. of properties (residential use)	units	701.774	124.981	1.516.556	330.254
(4)	IBI tax rate	%	0	0	0	0
(5)=(1)*(4)	Full IBI amount	€	737	274	528	306
(6)	Percentage of reduciton	%	1	1	1	1
(7)	Duration of reduction	years	3	3	5	5
(8)=(5)*(6)*(7)	**Total amount of reduction**	**€**	**1.105**	**412**	**1.321**	**765**
(9)=(8)/5	**Reduction for a typical installation***	**€/kW**	**221**	**82**	**264**	**153**

Source: own elaboration. *Note: For normalization purposes, it is assumed that the average residential is 5 kW.

In the first pair of comparisons, the IBI tax reduction available in **Barcelona and Cartagena** are compared.

- Both municipalities had a similar IBI tax rate for urban properties in 2024 (around 0.6%). Both also offered a very similar tax reductions in the IBI for investments in solar energy: 50% of the full tax amount applicable for a period of 5 years.
- The main difference for the purposes of our estimates lay in the average cadastral value of the properties (143% higher in Barcelona than in Cartagena).
- Consequently, based on these approximate calculations, residents of Barcelona could benefit, on average, from a total tax reduction of 1,105 euros during the three years of the reduction. On the other hand, in Cartagena, the same tax reduction percentage translated, on average, into 412 euros (694 euros less).

The second set of municipalities involves **Madrid and Zaragoza**.

- In both municipalities, the IBI tax rate was similar (around 0.4%), the tax reduction was 50% and the tax reduction were applied for a longer time than in the previous example (5 years).
- In this case, the cadastral value per property in Madrid was 56% higher than in Zaragoza.
- As a result, the average tax reduction for a residential PVSC installation in Madrid was €1,321, while in Zaragoza it was €765 (difference of €556). It is noteworthy that although the differences in the cadastral value between Madrid and Zaragoza are not as high as in the previous comparison, the fact that the duration of the tax reduction s is longer in this case contributes to amplifying the overall gap.

In the case of the ICIO, as the tax reduction is expressed as a percentage of the full amount, it is also important to consider the tax rates applied in each municipality and the costs of the PVSC installations (tax base). In this case, the differences between municipalities do not depend so sharply on the differences in the tax base, since the cost is not so directly related to local factors, but the applicable tax rate can vary substantially. In the case of the ICIO, the information from Fundación Renovables has therefore been complemented with data on the costs of the PVSC facilities from the information requests to IDAE, as well as information on the tax rates of the Ministry of Finance.

3.2.2.3. Distribution of IBI tax reduction

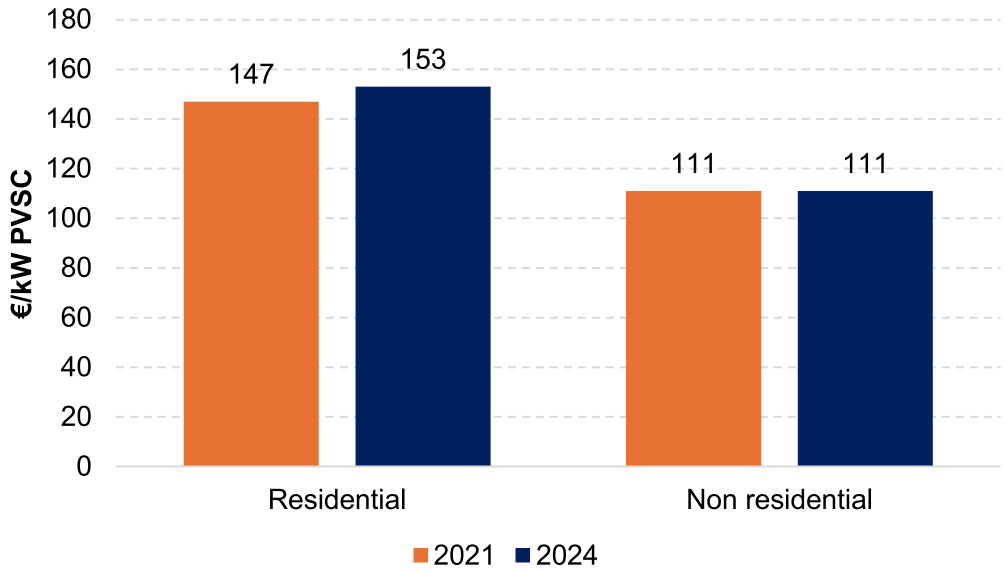
Between 2021 and 2024, the number of municipalities with more than 10,000 inhabitants offering IBI reduction for households or companies that install self-consumption systems has risen significantly. Thus, while in 2021 the municipalities that had this type of IBI reduction accounted for 48% of the total number of municipalities analysed, in 2024 this percentage rose to 64%. In practically all these municipalities, the IBI tax reduction were available for properties with residential use, although in some cases it was reserved only for first homes. Although less frequent, some of these discounts were also open to self-consumption installations in properties owned by service or industrial companies. Thus, in 2021 22% of municipalities offered tax reduction targeted at companies, while in 2024 this percentage had risen to 36%.

Among the municipalities offering tax reduction, the percentage for PVSC installations has remained on average around 40%-43% (slightly below the legal limit of 50%) and its average duration has also remained at around 4.6 years. Nevertheless, it should be noted that there is a high degree of heterogeneity, and some municipalities modulate the percentage of the tax reduction or the duration of the reduction according to various criteria, such as installed capacity, time elapsed since installation, household income, energy efficiency or age of the building, among others. Although relatively uncommon, some municipal tax ordinances cap the maximum cumulative tax reduction – either as an absolute amount or as a percentage of the installation cost[73]. Finally, it should also be noted that, in some cases, there is no express limitation in the tax ordinance on the number of years in which the tax reduction can be applied, or this limitation is very lax (for example, 30 years). As a result, in principle, the tax reduction could be applied throughout the useful life of the installation.

Although there are no official statistics on the financial aid granted through these tax reduction s, it has been estimated that, in 2024, the average IBI tax reduction for households amounted to a total of approximately €730 per household (equivalent to €147/kW for a typical 5 kW installation), which would be distributed over several years after installation. In the case of companies, it is estimated that this amount could be lower, mainly because the cadastral value of industrial and service land is on average lower than the value of residential land. Specifically, it is estimated that the average tax reduction for companies would amount to a total of approximately 555 euros per company (111 €/kW for a typical 5 kW installation).

73 For example, in Tacoronte (Santacruz de Tenerife), the maximum of the discount may not exceed 50% of the cost of the installation. Another notable example is Terrace (Barcelona), where the total amount of the tax reduction for the IBI, the ICIO and the IAE together may not exceed 25% of the subsidized costs of the installation (determined from standard unit costs).

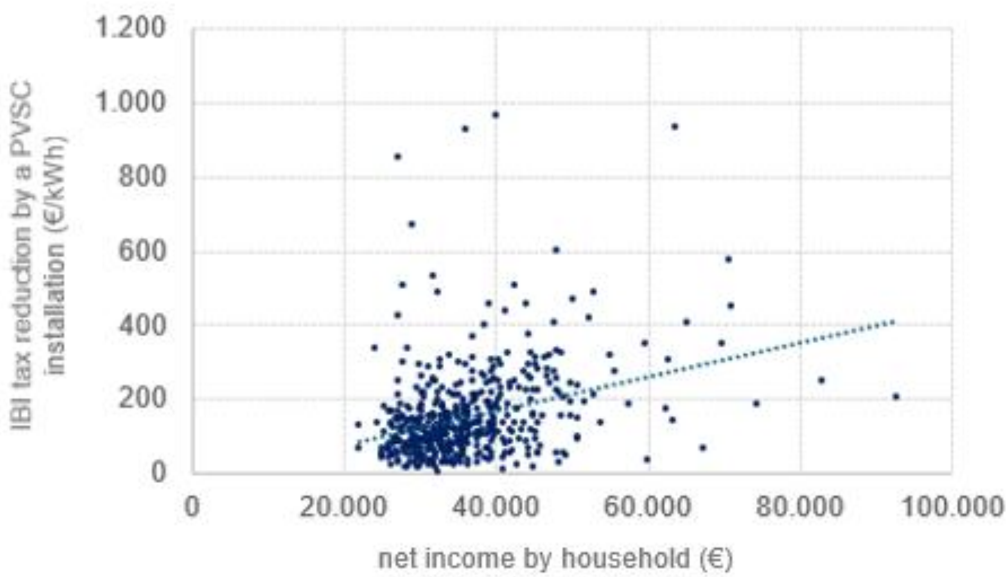
Figure 3-9 Average municipal IBI reduction available for a typical 5kW installation, estimates for 2021 and 2024



Source: own elaboration based on data from Fundación Renovables and the Ministry of Finance.
Note: average tax reduction in euros per kW for a typical 5 kW installation.

Finally, the Figure 3-10 confirms that **there is a strong positive correlation between the net income per household and the reduction of each municipality**. This correlation is derived from the fact that municipalities with higher incomes also tend to have properties with higher cadastral values. All things being equal, the municipalities with higher cadastral values will tend to offer, on average, higher monetary aid.

Figure 3-10 Relationship between net income per household and average available IBI tax reduction for the residential sector



Source: own elaboration. Note: the data on tax reductions are own estimates for the year 2024, while the data on net income per household correspond to 2022, the last year for which the INE offers data at the municipal level.

3.2.2.4. Distribution of ICIO tax reduction

The ICIO tax reduction for the PVSC installations were more widespread than the IBI in 2021 and have continued to be extended, albeit at a slower pace. Thus, while the percentage of municipalities with more than 10,000 inhabitants that offered this type of ICIO reduction stood at 57% in 2021, in 2024 this percentage had risen to 63% (a level similar to that of the IBI reduction).

It is also noteworthy that a significant share of municipalities simultaneously offers both ICIO and IBI reductions (47% of the municipalities analysed in 2024).

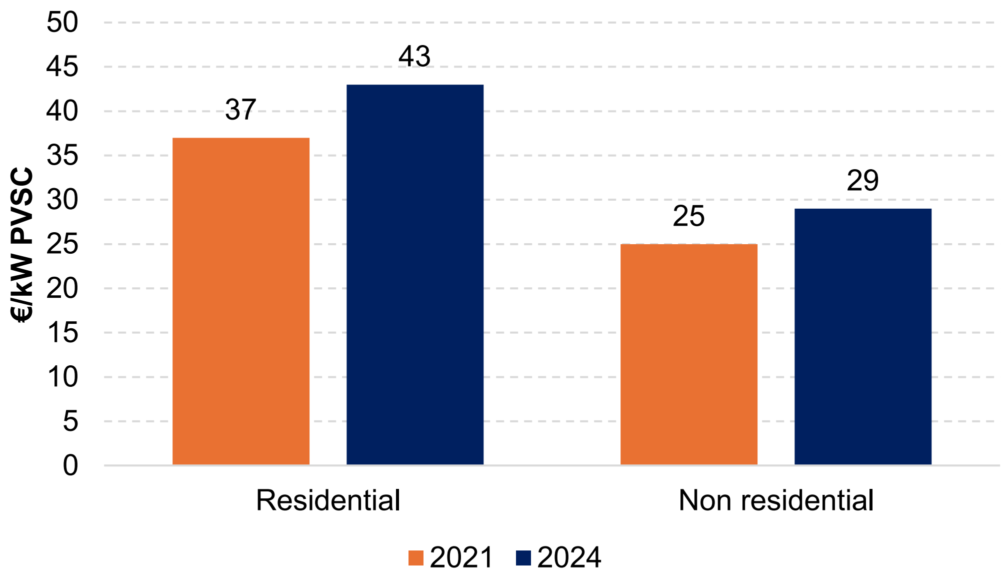
The average percentage subsidised in the ICIO reached 72% in 2021 and rose slightly to 76% in 2024[74], although plenty of municipalities chose to apply the maximum reduction of 95%.

In monetary terms per unit of installed capacity, it is estimated that the ICIO reduction is lower than the IBI reduction for a typical residential installation.

[74] The municipalities that apply discounts to ICIO tax do so in general for all groups (households, services and industry). The percentage of the discount and the criteria for application may, however, vary by group, being in most cases more generous in residential uses.

Thus, according to the estimates made for 2024, a household could benefit on average approximately €43/kW of ICIO reduction, which is less than a third of the estimated IBI reduction. In the case of companies, something similar happens and it is estimated that the unit reduction of ICIO is lower than the same reductio for households (measured in €/kW), mainly because households report higher unit costs on average than companies[75].

Figure 3-11 Municipal average of the available ICIO reduction, estimates for 2021 and 2024



Source: own elaboration based on data from Fundación Renovables, IDAE and the Ministry of Finance. Note: average tax relief in euros per kW, based on the unit costs declared by grant applicants.

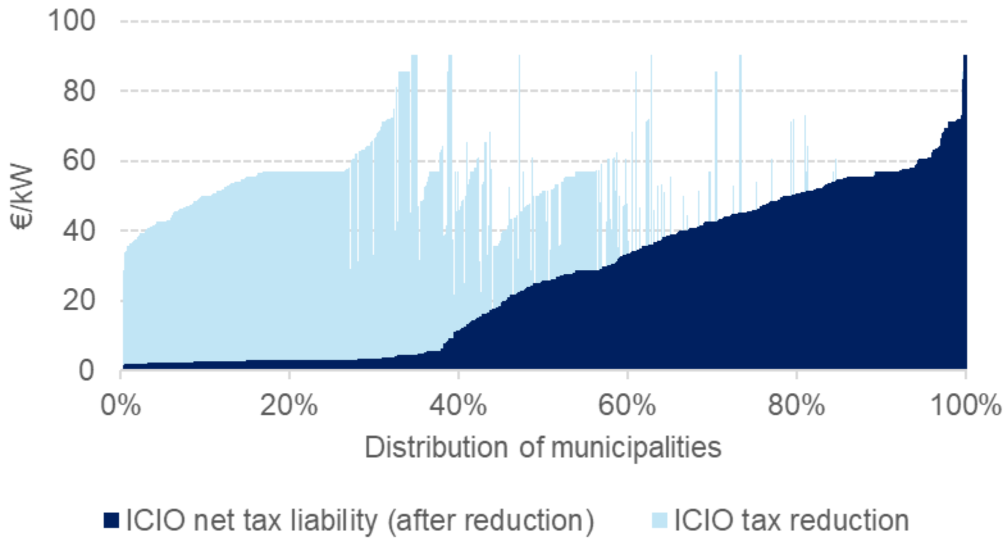
In the case of the ICIO, it is important to remember that the tax directly affects the initial costs of investment in PVSC, even in those municipalities where there are no tax reductions for this technology. For example, there are municipalities where, despite there being no tax relief expressly intended to promote the PVSC, the general ICIO tax rate may be very low (or even zero), so the incentive effect may be similar to that of a tax reduction[76]. The following graph illustrates that the

[75] The taxable base of the ICIO tax is the real and effective cost of the works, understood as the cost of material execution (excluding taxes, fees, business profit, etc.). In the case of PVSC installations, this cost can be approximated by the investments declared when applying for the grants established by RD 477/2021.

[76] For example, according to the tax ordinance of the municipality of Hernani, the ICIO tax rate is 0% for works with a cost of less than 12,000 euros.

ICIO's net tax liability can be very heterogeneous between municipalities, considering not only the tax reduction, but also the other key elements of the tax structure (tax rate and tax base).

Figure 3-12 Distribution of the ICIO net tax liability and tax reduction by municipalities, estimates for the year 2024



Source: own elaboration based on Fundación Renovables, IDAE and the Ministry of Finance. Note: each bar represents a municipality, and the distribution is ordered by the amount of ICIO paid after applying tax reduction for PVSC.

3.2.2.5. Distribution of IAE tax reduction

Finally, it should be noted that the IAE (Economic Activities Tax) tax reduction related to PVSC are the least frequent of the three local tax relieves analysed. Specifically, according to the information compiled by Fundación Renovables, only 27% of municipalities with more than 10,000 inhabitants offered a tax reduction type.

On average, municipalities that had this type of incentive in 2024 offered a tax reduction of 34% of the gross tax due. With regard to the duration, it is noteworthy that, in many cases, a maximum duration is not expressly set and, when it is, there are municipalities that reach up to 10 years.

3.2.3. Other state and regional incentives in Personal Income Tax (IRPF) and Corporate Income Tax (IS)

3.2.3.1. Personal Income Tax (IRPF) deductions related to energy savings

Households that invest in PVSC and energy storage facilities can also benefit from specific deductions in Personal Income Tax (IRPF), both at the state and regional levels. Some of these deductions are related to energy rehabilitation of homes, while others are more specifically linked to the installation of solar panels.

At the state level, as of October 2021, three deductions were introduced for the state portion of the Personal Income Tax on the amounts invested in renovation works of residential buildings that allowed savings in energy consumption, accredited through energy efficiency certificates. These tax incentives were part of the PRTR, specifically in Component 2 ("Implementation of the Spanish Urban Agenda: Urban Rehabilitation and Regeneration Plan"). Specifically, Royal Decree-Law 19/2021, of 5 October, introduced the following **three deductions**:

- Deduction of 20% for investments that reduce heating **and cooling demand by at least 7**%, with a maximum annual base of €5,000 (maximum deduction of €1,000).
- Deduction of 40% when the works reduce at least 30% of the consumption of non-renewable primary energy or **improve the energy rating of the home to levels A or B**. This deduction is especially relevant for self-consumption installations, allowing a maximum annual base of €7,500 (maximum deduction of €3,000).
- 60% deduction for **comprehensive energy rehabilitation works in complete residential buildings** that achieve a reduction equal to or greater than 30% in non-renewable energy consumption, with a maximum cumulative base of €15,000 (maximum deduction of €9,000) per taxpayer.

These three state deductions (incompatible with each other) therefore ranged between 20% and 60% of the net cost of the installation, depending on the action carried out. The first two deductions were applied to works carried out from October 6, 2021, to December 31, 2024[77], while the third has also been extended to 2025.

It should also be noted that, when applying these deductions, the Spanish Tax Agency (AEAT) specifies that "those amounts that, where appropriate, have been

[77] According to the Personal Income Tax Manual 2024, these deductions are made "in the tax period in which the energy performance certificate issued after the works have been carried out, regardless of the year in which the amounts were paid or the work was carried out". The certificate must in any case be issued before January 1, 2025.

subsidized through a public aid programme or were going to be subsidized by virtue of a final resolution of the granting of such aid"[78] must be discounted. This is, however, a source of complexity in the event that the subsidy is received later, in which case the AEAT indicates that "the tax situation must be regularized so that the amounts corresponding to said subsidy are not included in the basis of the deduction".

According to the latest data available from the AEAT[79], in the 2022 and 2023 financial years, deductions were applied for works to improve the energy efficiency of homes, worth 103 million euros and 200 million euros, respectively. The average amount per taxpayer remained at around 1,900 euros in both years. It is important to note, however, that these deductions were not exclusively aimed at PVSC installation works, but could have encompassed much broader actions to improve the energy efficiency of homes (including, in addition to the installation of renewable energies, the installation of double windows, installation of insulating panels on walls and ceilings, façade insulation, etc.).

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78 AEAT (2024). Personal Income Tax Practical Manual.

79 Statistics of Personal Income Tax filers, financial year 2022 (available here) and financial year 2023 (available here).

Table 3-5 Deductions for works improving the energy efficiency of households, 2022 and 2023

Deductions	2022			2023		
	No. of taxpayers	Amount (€)	Avg. (€)	No. of taxpayers	Amount (€)	Avg. (€)
Reduction in heating / cooling demand	12,351	10,387,292	841	26,888	23,188,668	862
Improvement in non-renewable primary energy consumption	30,543	65,627,180	2,149	48,834	106,078,744	2,172
Works on predominantly residential buildings	11,036	26,889,696	2,437	29,357	70,410,380	2,398
Total	52,803	103,012,870	1,951	103,161	200,031,543	1,939

Source: AEAT, Statistics of IRPF taxpayers, 2022 and 2023.

At the regional level, the autonomous communities present a great diversity in terms of specific deductions applied in the regional personal income tax bracket, with different amounts, requirements and approaches. As shown by the Table 3-6, the most significant deductions correspond to the Balearic Islands (50% up to €10,000 per year) and the Valencian Community (40% up to €8,800). However, in the Balearic Islands there are income limitations (individual taxable base of less than 33,000 euros or 52,800 euros in joint taxation), so the deduction is accessible to a more restricted number of taxpayers.

Table 3-6 Regional Personal Income Tax deductions related to PVSC (2021-2024)*

Region	% Deduction	Annual limit	Specific requirements	% Deduction for €7.500 installation**
Valencian Community	40% main home / 20% second home 20% 2ª residencia	8.800 €	Registration of renewable installation	40%
Murcia	10%	10.000 €	Investments in renewable energy installations	10%
Navarra	≥15%	no limit	Investments in renewable energy installations	15%
Guipúzcoa (since 2022)	15%	3.000 €	Solar energy supply in main home	6%
Álava (since 2022)	15%	3.000 €	Renewable energy and efficiency	6%
Castilla y León	15%	20.000 €	Solar panels for domestic hot water	15%
Baleares	50%	10.000 €	Main home, ≥1-letter energy rating improvement, income limits	50%
Canarias***	12% (10% until 2021)	€7,000 & 10% of regional tax	Main home	4%
Cantabria	15%	€1,000 (single) / €1,500 (joint)	Energy efficiency or renewable works	13%
Galicia	15% (efficiency) / 5% (renewable hot water) 5% ACS renov.	9.000 € efic. ener. 280 € ACS renov.	≥1-letter energy rating improvement, installation registration	15%

Source: own elaboration based on AEAT (Personal Income Tax Practical Manuals 2020-2024) and regional tax regulations. Notes: *The table includes deductions applicable in the years 2021-2024, unless otherwise indicated. **For ease of comparison, the last column includes an estimate of the maximum deduction percentage for an eligible PVSC type installation at a cost of €7,500, assuming it meets the deduction requirements. In the Canary Islands, the deduction is limited to 10% of the full regional contribution. According to personal income tax statistics from the AEAT, the full regional tax in the Canary Islands was 2,973 euros in 2023.

In summary, since 2021, state and regional tax deductions in personal income tax – linked in many cases to home renovation and energy efficiency and, in some cases, more directly to the installation of renewable energies – have been an additional source of public aid available to households interested in installing PVSC. They have therefore complemented local subsidies and tax reductions.

3.2.3.2. Corporate Income Tax Incentives for Provincial Territories

In the case of companies, the foral territories of the Basque Country and Navarra contemplate certain incentives in Corporate Income Tax (IS) aimed at favouring investments in PVSC installations and other clean energies.

In the Basque Country, since 2004 the three Provincial Councils (Álava, Bizkaia and Gipuzkoa) have recognised in their respective Provincial Corporate Income Tax Regulations[80] a deduction for investments in technologies included in the so-called "**Basque List of Clean Technologies**",[81] approved and updated by the Basque Government. This list expressly includes photovoltaic solar panels and associated storage systems, among other technologies. Until 2024, **the deduction reached 30% of the investment**, a percentage that has risen to 35% as of January 1, 2025. Although this incentive seeks to promote the ecological and energy transition, its objectives also include boosting business competitiveness through greater production efficiency, with a simple and harmonised processing system.

In the Autonomous Community of Navarra, there is also a similar deduction for investments in renewable energies, including photovoltaic self-consumption installations[82]. In the case of the PVSC, the deduction percentage **is 25% but can reach up to 30%** if the project has storage and/or if it is part of a shared self-consumption project or energy community. It is worth noting that the law stipulates that the deduction base must be reduced by the amount of the subsidies received for the same investment, in order to avoid a double tax benefit. It is also important to note that the deduction is only applicable to installations that are not mandatory according to the Technical Building Code.

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80 The deduction is regulated in Article 65 of the Foral Corporate Income Tax Regulations of the three historical territories (Norma Foral 11/2013, of 5 December, of the IS of Bizkaia; Norma Foral 37/2013, of 13 December, of the IS of Álava; and Norma Foral 2/2014, of 17 January, on the Corporate Income Tax of Gipuzkoa).

81 The 2024 list is accessible on the web of Ihobe, a public entity of the Basque Government that, together with the Basque Energy Agency and SPRI, promotes the processing of these incentives (for example, with the preparation of reasoned reports), in collaboration with the Basque Treasuries and the Tax Coordination Body of the Basque Country. The list is currently made up of 64 technologies, of which 16 are in the field of renewable energies, 19 in the circular economy and 29 in zero pollution.

82 See Article 64 of the Regional Law 26/2016, of 28 December, on Corporate Income Tax.

In the common regime, the Corporate Income Tax has not contemplated specific deductions for photovoltaic self-consumption in recent years. Extraordinarily, a small incentive was introduced to this technology allowing the freedom of amortization of these investments, which allows companies to advance tax-deductible expenses and improve the company's liquidity in the first years (equivalent to an interest-free loan from the Treasury). However, this flexibility was only applicable in common territory to facilities that came into operation during 2023 and 2024 and was also subject to a requirement to maintain the company's employment[83]. The regulations of the foral territories of the Basque Country and Navarra also provide flexibility in the depreciation of these investments for the purposes of Corporate Income Tax. These flexibilities remain in force and are furthermore compatible with the deductions described.

3.3. Overview of the aid programmes

This section illustrates the aggregate potential impact of the main public aid programmes described above.

For illustrative purposes only, and based on the same assumptions as in section 3.1.1, the aid available in 2023 for a taxpayer who has decided to install a 5 kW non-storage PVSC system in their main residence is analysed. The cases of the cities of Valencia and Madrid are presented.

[83] This incentive was articulated through the seventeenth additional provision of Law 27/2014, of 27 November, on Corporate Income Tax, introduced by the Royal Decree-Law 18/2022, of 18 October. Although the measure was extended to the 2025 financial year by means of Royal Decree-Law 9/2024, this extension was not validated by Congress in January 2025.

Table 3-7 Examples of aid available in 2024 for a typical residential PVSC installation in Valencia and Madrid

Concept	Valencia	Madrid
Instalation cost (1,500 €/kW)	7.500 €	7.500 €
Full ICIO tax amount (3% and 3,75% of cost)	225 €	281 €
Aid		
RD 477/2021 subsidy (P4: 600 €/kW)	-3.000 €	-3.000 €
National PIT deduction (40%)	-1.800 €	-1.800 €
Regional PIT deduction	-1.800 €	
Property tax (IBI) reduction (cumulated)	-141 €	-1.321 €
Construction tax (ICIO) reduction (95%)	-214 €	-267 €
Net cost after aid	770 €	1.393 €
% of aid over installation cost	90%	81%
Payback period (years)	2	2
IRR	49%	40%

Source: own elaboration. It is assumed that the application for subsidies under Royal Decree 477/2023 was submitted before the deadline of 31/12/2023.

This example illustrates that, due to the accumulation of aid from different administrations, the net cost of a PVSC installation could have exceeded 90% in some cases, significantly shortening the payback period of the investment – up to 2 years – and significantly increasing the expected return, even under conservative assumptions[84].

However, to access all these aids, beneficiaries must carry out up to five different procedures, with specific documentary requirements and different deadlines. In the case of personal income tax (PIT) deductions, it may even be necessary to file amended tax returns, since the Tax Agency requires the regularization of the tax return for the year in which a subsidy is received if it has been granted at a later date.

In addition, aid payments are usually made in stages, which forces the self-consumer to initially assume the entire cost of the investment. This administrative complexity could have limited the effectiveness of incentives, despite their high attractiveness from an economic and financial point of view.

[84] The return period could be affected by the processing times of the aid, which in this example are assumed to be less than two years in the case of grants.

4. IMPACT ASSESSMENT OF THE AID

4.1. Potential implications on competition dynamics

Aid to PVSC reconfigures competition on multiple levels. Among other aspects, they can displace demand from the grid previously satisfied with traditional generation sources, alter marketing strategies, modify incentives for the electrification of consumption of other energy sources and, also, grant competitive advantages to beneficiary companies that operate in non-energy markets.

The design of the aid determines the magnitude and direction of these effects on competition. Thus, aspects such as the complexity of procedures, fragmentation, collection deadlines and lack of technological neutrality can skew access, unjustifiably favour some operators and cause damage to competitive dynamics both in the energy field and in other markets. On the other hand, the impetus they provide to the development of the PVSC can foster competitive pressure on other traditional energy operators.

4.1.1. Effects of PVSC aid on competitive dynamics in different markets

State aid may impact on competition at different stages of the electricity supply chain, on competition with other energy products and on competition in other markets for goods and services in which the beneficiary companies operate.

The most direct effect of the PVSC aid is to alter the relative price between consuming electricity from the grid and generating and consuming it *on site.* This can boost investments in self-consumption by agents compared to a counterfactual scenario where their decisions would have been based mainly on costs and signals from the grid. The above incentive effect is precisely the main objective pursued by public aid, but this aid may also have implications for the competitive dynamics of several markets. Depending on the design of the aid, some of these effects may be pro-competitive, while others could lead to undesirable distortions that harm competition; for example, by unjustifiably granting higher benefits to certain companies compared to others.

Some of the areas where aid could have an impact on competition are detailed below:

- **Electricity generation.** The aid helps to consolidate an alternative for distributed electricity production that can be attractive to households and businesses. Increased distributed generation in solar hours can displace marginal generation from other traditional technologies (in particular, from generators that play a pivotal role, such as combined-cycle gas plants), reducing their revenues and altering their investment signals. This could, in turn, lead to a reduction in the production shares of traditional generators.

- **Electricity retailing**. PVSC has become a way of entry and growth for many small retailers, fostering competitive dynamics of the retail market. The PVSC segment can function as a way for new or smaller retailers to access the market and consolidate, also expanding their presence in the general retail market. Strengthening the presence and competitive position of these operators can help invigorate competition in this market. By making the option of leaving the traditional market more viable for consumers (an “outside option”), the aid may also increase medium-term demand elasticity and discipline the prices and margins offered by all retailers to the overall customer base. PVSC can also foster efficiency and innovation in retailers’ products and services (e.g. dynamic tariffs, turnkey solutions, storage and demand management, etc.).
- **Installation companies and other energy services**. The aid can influence companies more directly dedicated to the installation of solar panels and other associated services. The sudden concentration of aid at a moment in time can lead to peaks in activity that favour operators with financial muscle and execution capacity. Likewise, it can encourage rapid growth in the sector, oversizing it and leading to contraction once the aid is withdrawn, which can lead to adjustment costs and reallocation of resources, affecting efficiency and competitive dynamics. An additional risk is that the companies that survive these cycles are only those with sufficient diversification to withstand regulatory and public policy volatility, not necessarily the most cost-efficient ones.

  Another effect of this congestion and supply rigidity is potential increases in costs and margins among installers. Thus, the benefit of the aid would shift from the applicants to the suppliers and their production chain, reinforcing the competitive position of the indirectly beneficiary companies.
- **Interactions with other energy consumption**. By encouraging the use of a particular technology, PVSC support can also generate competition between energy sources, favouring electrification and thus displacing final demand for other types of energy.

The aid also has effects on competition in other non-energy markets. Approximately 40% of PVSC's installed capacity is owned by companies, where energy is a productive input for services and other goods. At the same time, companies in all sectors are eligible for a significant share of this aid. Therefore, beneficiary companies could obtain competitive advantages over those that do not receive aid:

- Firstly, through increased revenues or reduction in their costs, as a direct result of the aid.
- Secondly, through competitive improvements granted by PVSC's own technology, either due to a reduction in their energy costs, less dependence on energy prices and protection against their volatility or, even, due to the benefits for the image and marketing advantages of their products perceived as clean. These effects may be more pronounced in electro-intensive sectors with tight margins.

4.1.2. Factors that may favour a greater pro-competitive effect of aid

If not properly designed, **aid can lead to distortions that unnecessarily hinder proper functioning, transparency and competition of the markets**. These effects arise, on the one hand, from the direct influence that receiving aid has on the behaviour of consumers and suppliers in the markets analysed above. On the other hand, they stem from the barriers and distortions linked to the design and administration of the aid, since these can determine who accesses the aid and, consequently, the competitive position of some companies compared to others.

A neutral design of aid, which limits the complexity and costs of procedures, coordinated, transparent and avoids uncertainty and financial exclusion as much as possible, can enhance its efficiency and effectiveness, while helping to boost pro-competitive effects and minimise distortions, both in the energy market and in third markets.

The following aspects of aid design can be highlighted as relevant elements in determining their effect on competition:

- **Justification and proportionality in the overall aid.** In accordance with the principle of proportionality, aid must be applied in such a way that it achieves its purpose (in this case, the promotion of PVSC as part of energy transition) while introducing the least possible distortions. In this regard, aid linked to aspects not directly related to its purpose (for example, the cadastral value of the property where the installation is carried out) could introduce distortions to competitive dynamics, by bringing a higher level of benefits to certain consumers compared to others, without this being justified to fulfil the pretended goals. Likewise, the award criteria should not contain discriminatory elements that could affect the competitive dynamics of the markets where the recipients operate, unnecessarily harming, for example, certain economic activities compared to others.

- **Complexity in the administrative procedure**: administrative costs constitute an access barrier that may result in the non-application by potential interested parties, which may have effects on competition, both on the configuration of the demand for PVSC and by its influence on the competitive position of companies receiving and not receiving aid in their respective markets. Generally, barriers linked to administrative costs affect companies and households with fewer resources to bear them.

- **Fragmentation**: the diversity in the aid schemes translates into an increase in the difficulties and costs of accessing them. These obstacles can especially harm those who have worse information or fewer resources to deal with them, generally smaller companies or lower-income households. Among the drawbacks associated with fragmentation, the following can be highlighted:

  - **Information and transparency issues**: the existence of several types of aid increases costs and difficulties for potential applicants to be aware of them.

  - **Multiplicity of procedures and requirements**: interested parties must undertake similar procedures before different administrations, and often meet different requirements, which increases the costs of accessing the aid.

- **Collection deadlines and financial cost overruns.** Significant delays between execution and collection increase the cost of capital and *de facto* exclude applicants with less access to financing, generally households and companies with fewer resources. It also increases the final price for consumers who internalize the risk through higher margins for the installer.

  The delay in receiving aid can also encourage disinterest among potential beneficiaries, particularly those who suffer from the so-called present bias, or the preference for immediate rewards over future ones[85]. This bias can, on the one hand, reduce the effectiveness and efficiency of aid, requiring higher levels of expenditure to achieve similar objectives, and, on the other hand, it can introduce competitive distortions by disproportionately affecting certain agents – especially those with fewer resources or limited capacity to commit current costs (such as information, processing, etc.) in exchange for potential benefits perceived as distant in the future, as might be the case for SMEs.

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85 See the Study on Behavioural Economics for Efficient Regulation and Supervision (E/CNMC/002/23).

4.2. Econometric analysis

This section presents an econometric analysis aimed at estimating the impact of public aid on investment in PVSC installations. This may be of interest for assessing the extent to which such aid is transforming this sector, since greater effects on PVSC could have repercussions on the dynamics of competition both in energy and other markets.

The dependent variable used in the analysis is the new installed capacity each year per thousand inhabitants, distinguishing two differentiated segments: households with installations of up to 15 kW (Group 1) and service companies and other productive sectors with installations of up to 100 kW (Group 2).[86] This separation responds to important differences in the determinants of investment between the two groups.

Key explanatory variables include indicators related to available public aid[87], as well as variables that capture the structure of the retail electricity market and other relevant municipal characteristics (such as rent, solar irradiation, type of housing, electricity price expectations and average installation costs).

4.2.1. Model and choice of variables

A panel data model based on annual information from more than 700 Spanish municipalities with a population of more than 10,000 inhabitants is used, during the period 2021-2024. The information has been collected from REE, Fundación Renovables, IDAE, AEMET, INE and the Ministry of Finance, as described below.

The model specification is as follows:

$$kWpop_{i,t} = \beta_0 + \beta_1 IBI_{i,t} + \beta_2 ICIO_{i,t} \quad + \beta_4 PITr_{i,t} + \mathrm{d2021} + \Gamma X_{i,t} + \mu_i + \varepsilon_{it}$$

where:

- The subscripts refer to the municipality (i) and the year (t).

86 Industrial PVSC installations with more than 100 kW of installed capacity have been excluded from this empirical exercise due to the lack of sufficient observations at the municipal level during the years of the study.

87 It should be noted the analysis did not include, as an explanatory variable, the number of applications or resolutions/verifications of grants under RD 477/2021, due to an of endogeneity problem and the impossibility of identifying valid instruments for an instrumental-variable modelling approach. Subsidy applications may be influenced by unobservable factors that also affect the installation of PVSC, generating a bidirectional relationship between both variables. However, this approach has been approximated through a dummy variable that assesses whether there is a step effect from 2021 onward.

- **kWpop** (dependent variable) is the new installed capacity of PVSC each year in each municipality, measured in kW per thousand inhabitants. Source: REE and INE.
- **IBI**[88] is a variable that approximates the monetary value of the local property tax (IBI) reduction (measured in €/average taxpayer). It captures the intensity of the aid coming from these reductions in each municipality, based on a combination of the percentage subsidized, the number of years in which the reduction is applicable, the IBI tax rate and its taxable base (average cadastral value) in each municipality. When there is no reduction in a municipality, this variable is equal to zero. Source: own elaboration based on information from Fundación Renovables, the Ministry of Finance and municipal tax ordinances (for more details see ANNEX III. Methodological aspects of the econometric analysis).
- **ICIO** is a variable that approximates the monetary cost associated with the payment of the municipal construction tax (ICIO) for works related to PVSC installation (measured in €/kW), net of any applicable local tax reduction. The lower the value of this variable, the more favourable the municipal tax treatment of PVSC will be (either because there are reductions or because the ICIO tax rate is relatively low). Again, this variable has been estimated based on information from Fundación Renovables, the Ministry of Finance and municipal tax ordinances (for more details see ANNEX III. Methodological aspects of the econometric analysis).
- **PITr (Personal income tax, regional component)** represents the maximum effective deduction rate in the regional component of the Personal Income Tax (PITr), calculated for a representative PVSC installation at a cost of €7,500. The percentages applied are set out in the Table 3-6 in Section 3.2.3[89].
- **d2021** is a binary variable (*dummy)* that takes the value 1 when the observations correspond to the year 2021 and 0 otherwise. The variable tries to capture whether there is a structural difference in the PVSC entry level between 2021 and subsequent years, during which the state subsidies and deductions in Personal Income Tax introduced as part of the PRTR were already fully rolled-out.

88 The information available on IAE business tax reductions covers only for 2023 and 2024 and has therefore not been included in the econometric estimation.

89 On the other hand, on 6 October 2021, new state deductions in personal income tax (IRPF) potentially applicable to PVSC and storage came into force. Since the measure was implemented nationwide and was not in force for most of 2021, no specific municipality-level variable has been introduced for its analysis.

- **X** is a matrix that groups **other control variables**:
  - **Indicator of the retail electricity market:** market share, expressed as a percentage, of smaller retailers over the total number retailers supplying self-consumers who entered the municipality the previous year, by group. Source: REE.
  - **Electricity futures:** specifically, the annual average quotation of the SPEL Base Futures product in OMIP with 10-year physical delivery during the previous year (first lag) is used. This indicator reflects market expectations regarding the price of electricity in the medium to long term, a key determinant of PVSC investment profitability. Source: OMIP.
  - **Median cost of PVSC installations** by province, estimated from the information declared in the subsidy applications. Source: IDAE.
  - **Income:** is the annual net income per household. Source: INE.
  - **Solar irradiation:** average solar irradiation in the capital of the province where the municipality is located (kWh/m^2/day) in the period 1998-2002. Source: AEMET.
  - **Single-family housing:** percentage of single-family dwellings in each municipality. Source: INE, 2021 Census.
  - **Rental housing**: percentage of rental dwellings for rent over the total number of dwellings in a municipality and segment. Source: INE, 2021 Census.
- μ_i are fixed effects that reflect specific elements of each municipality not captured in the rest of the variables.
- ε_i is the random error term.

After applying a Hausman test (for details see ANNEX III. Methodological aspects of the econometric analysis), the use of a fixed-effects model was confirmed as appropriate. However, given the limitation of the fixed-effects model to capture the effects of variables that do not vary or hardly vary over time (such as structural features of each municipality – e.g. irradiation levels or net household income, among others), the Mundlak model (1978) will be applied. This model combines the benefits of fixed- and random-effects approaches, allowing the separation of temporal variability (within municipalities) and structural or cross-sectional variability (between municipalities). Specifically, the Mundlak method adds to the original specification the time mean of each explanatory variable at the municipal level. This enables decomposition of the total impact of each variable into two components:

- Intra-municipal component (temporal effects): captures how changes in a variable within a municipality *over time* affect the penetration of PVSC.
- Inter-municipal component (structural or cross-sectional effects): measures how permanent structural differences *between municipalities* in certain explanatory variables influence the different penetration of PVSC in municipalities.

See ANNEX III. Methodological aspects of the econometric analysis for more methodological details.

4.2.2. Results

The results of the estimates made separately for households with installations up to 15 kW (GR1) and for service companies and other productive sectors (S&P) with installations up to 100 kW (GR2) are analysed below.

Table 4-1 Results of the econometric estimates

	GR1 (households≤15 kW)		GR2 (services & industry ≤100 kW)	
	within-municipality effect	between-municipality effect	within-municipality effect	between-municipality effect
IBI: reducion (€ per average taxpayer)	0.00194**	0.00189	-0.000374	-0.000660
ICIO: amount paid (€ per kW)	-0.00161	0.0405	-0.0458	0.00493
Regional PIT deduction (%)		0.210***		
Average 10-year futures price from previous year (€/MWh)	0.973***		0.922***	
Median installation cost (€/kW)	0.0585***	-0.0778***	0.00658	-0.0509***
Direct irradiation (kWh/m^2/day)		11.15***		0.896
Net household income (€)		0.00112***		
Rental housing (% of total dwellings)		-0.235		
Single dwelling residential building (% of total dwelling)		0.450***		
Smaller retailers` share (%)	0.0989***	-0.0668	0.0191*	-0.0584***
Dummy 2021	-8.557***		-5.731***	
Constant	-80.94***		18.54***	
Number of observations	2,394		1,789	
Number of municipalities	732		702	
R^2	0,45		0,22	

Source: Own elaboration. Notes: 1) the stars indicate the level of significance of the coefficients as a function of the level of the p-value: * p<10%, ** p<5%, *** p<1%), 2) the empty spaces indicate that the variable in question has not been included in the model because it did not have temporal variability (for the effects within municipalities) or because it did not have variability between municipalities (for the effects between municipalities, specific case of futures prices).

With respect to local tax reductions, the effects are heterogeneous depending on the tax and the type of agents.

- **In the case of households, the results suggest that those applied to the IBI act as an effective incentive in the short term, while those applied to the ICIO do not seem to have significant effects on the PVSC**. Thus, the results suggest that an increase in the IBI reduction in a municipality would lead to a significant increase in the PVSC inflow. However, this effect could be transitory, as the effects between municipalities are not significant: that is, the municipalities with higher IBI reductions do not structurally show a higher inflow of PVSC. The ICIO does not seem significant, possibly due to the lower amount of this tax payment and its associated reductions (less than a third of the average IBI reduction for a typical installation, according to the estimates in Section 3.2.2.4).
- **For companies, the effects of the IBI and ICIO tax reductions are not significant**, either over time within municipalities or when comparing between municipalities.

Likewise, a "step effect" is observed following the full implementation of direct subsidies and deductions in the state component of the Personal Income Tax, provided under the PRTR. The estimated negative coefficient for the dichotomous variable "d2021" indicates that the entry of PVSC in 2021, when the state-level deductions and the subsidy programme of RD 477/2021 had not yet begun to be fully deployed[90], was structurally lower than in the following three years, once other model variables are controlled for. This suggests that the introduction of state subsidies and deductions in Personal Income Tax, as part of the PRTR measures, would have contributed to accelerating the diffusion of PVSC.

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[90] It should be noted that both measures began to operate from the last quarter of 2021 and, in some cases, at the beginning of 2022. Although RD 477/2021 came into force on 1 July, the autonomous communities were given three months to launch their grants calls, many of which were delayed. Similarly, the state-level personal income tax deductions introduced by Royal Decree-Law 19/2021, of 5 October, are only applicable to installations carried out from 6 October of that year and remained in force through 2024. Moreover, although no new subsidy applications could be submitted in 2024, it is highly likely that a significant share of those filed in 2023 resulted in ACFV installations recorded by REE during 2024.

For households, an additional control was introduced to assess the effect of **regional tax deductions on personal income tax**[91]. Results show that the municipalities where the regional deductions of Personal Income Tax are higher, also have significantly higher levels of installed capacity.

On the other hand, in relation to the structure **of the retail market**, results indicate that an increase over time in the percentage of **smaller retailers** can foster the entry of PVSC within a municipality, both in households and in companies. Conversely, municipalities with a structurally higher presence of small retailers tend to have – on average – lower penetration of PVSC. This apparent paradox could be explained by the fact that small retailers are more present in municipalities where the propensity to invest in self-consumption is lower due to other unobservable factors.

Among the **control variables**, the 10-year futures price of electricity **stands out**, used as a *proxy* for investors' price expectations. In line with what is expected from a microeconomic viewpoint, the results suggest that an increase in this indicator has a significant positive effect on investment in new installations, both in households and companies.

As for the installation costs, the effects on the penetration of the PVSC are mixed. On the one hand, as might be expected, it is observed that, in those municipalities with structurally lower costs, the PVSC entry of households and companies has generally been higher (statistically significant effects). However, the increase in costs over time within the same municipality is not significant in the case of companies and in the case of households it is associated with a positive coefficient (the opposite of what would be expected).[92] Overall, the above

[91] Over the four-year period of the panel (2021-2024), there has been no relevant variation in the PVSC and other technologies deductions under the Corporate Income Tax of the foral territories of the Basque Country and Navarra. As it is not possible to apply a "difference-in-difference" temporal comparison approach, this assessment does not specifically assess the impact of these deductions on companies' investment in PVSC. Including a dummy variable for these territories in the GR2 regression, as an approximation, yields a positive but not significant coefficient, which may reflect other characteristics specific to municipalities in these regions. Assessing the impact of the Basque Clean Energy List and other similar measures adopted in Navarra would require more detailed data covering longer periods, as well as a broader evaluation of the implications for the adoption of other clean technologies and for industrial competitiveness.

[92] This result is counterintuitive and difficult to interpret. These results could be reflecting the impact of the increase in PVSC installation costs after the COVID-19 pandemic, because of the interruptions in the supply chains of imported equipment, coinciding with a time of high penetration of the PVSC due to other factors. Another hypothesis is that the effect responds to a phenomenon of reverse causality: the increase in demand for PVSC installations by companies in some municipalities could have made their installation in these municipalities partly more expensive, due to the higher margins of the installation companies (see next section).

findings are in any case consistent with the thesis that greater competition among installation companies, which ensures reasonable prices and margins across municipalities, can contribute to accelerating PVSC for both households and the business segment. The elasticity of agents to gross installation costs is likely to be higher when access to aid programmes (which reduce the net cost received by the agent) is more limited or when the aid is less intense.

Solar **irradiation** also has a significant influence on the adoption of PVSC by households and businesses.

In the **sociodemographic characterisation of households**, three key variables stand out: net income per household, the percentage of single-family homes and the percentage of rental homes. The first two are positively associated and the latter negatively, although not statistically significant, with the deployment of the PVSC by households. Thus, municipalities with higher incomes have had greater investment in self-consumption, which seems to indicate that households with fewer financial constraints are better able to undertake such investments. At a structural level, municipalities with a higher proportion of single-family homes have more installations, probably due to the better technical conditions for the installation of these systems and the lower incidence of technical and regulatory barriers associated with collective self-consumption.

In summary, the results show that **public aid can play an important role in promoting photovoltaic self-consumption**. **However, its effectiveness varies depending on the type of economic actor and the specific design of each instrument**. Conditions of competition in the retail electricity market can also play a decisive role in the development of PVSC. The structural conditions of municipalities – such as income level, type of housing, installation costs – could also be determining factors in the adoption of these technologies. In addition, expectations about the future price of electricity seem to be a key factor that may have boosted PVSC in a cyclical manner, coinciding with the energy crisis. This variety of effects, within a context of fragmented aid – both in terms of instrument types and their geographical scope of application –, would indicate that the aid could be causing distortions to competition, depending on the aid to which the companies are eligible or that affects their competitors or customers.

4.3. Impact on installation companies

It is worth considering whether the acceleration experienced in the installation of PVSC has also occurred in the economic activities linked to the installation of photovoltaic panels. It is equally relevant to analyse whether this impact has resulted in the entry of new competitors, in increased activity among companies that were already operating, or in a combination of both.

The answer to these questions is complex because there is no specific definition or classification of the PVSC installation companies. Although there is an official list of energy service providers[93], they cover a very heterogeneous group of companies (and self-employed workers) dedicated to variety of different activities, including issues such as building renovation, among others.

Given these challenges, **a sample of companies whose activities are related to photovoltaic solar technology has been constructed. These firs belong to sectors such as the manufacturing of materials and components, construction, sales or leasing of the necessary machinery, as well as project consulting**. This sample was built using information from annual accounts filed in the Spanish Commercial Registry (*Registro Mercantil*), based on an automated keyword search combined with a filtering of CNAE codes – Spanish NACE classification –[94]. The results associated with this sample should be interpreted with caution and only qualitatively.

Although the sample of companies has been selected based on objective criteria, it is limited in scope. The results should thus be interpreted with caution and in no case should they be understood as accurate statistics, but as a simple tool to approximate major trends. It should be borne in mind that some of the companies selected in the sample carry out multiple activities, not all of them related to the PVSC, and companies for which financial information was not available (possibly, many SMEs and the self-employed) are not included.

Between 2020 and 2023, despite the boom in PVSC and ground-mounted PV, the information collected would suggest that there could have been a decrease in the number of companies linked to the installation of this technology. In 2020, before the subsidy programmes were established in Spain and the penetration of the PVSC was accelerated, the number of companies in the sample that were listed as active amounted to 588 companies. By 2023, the

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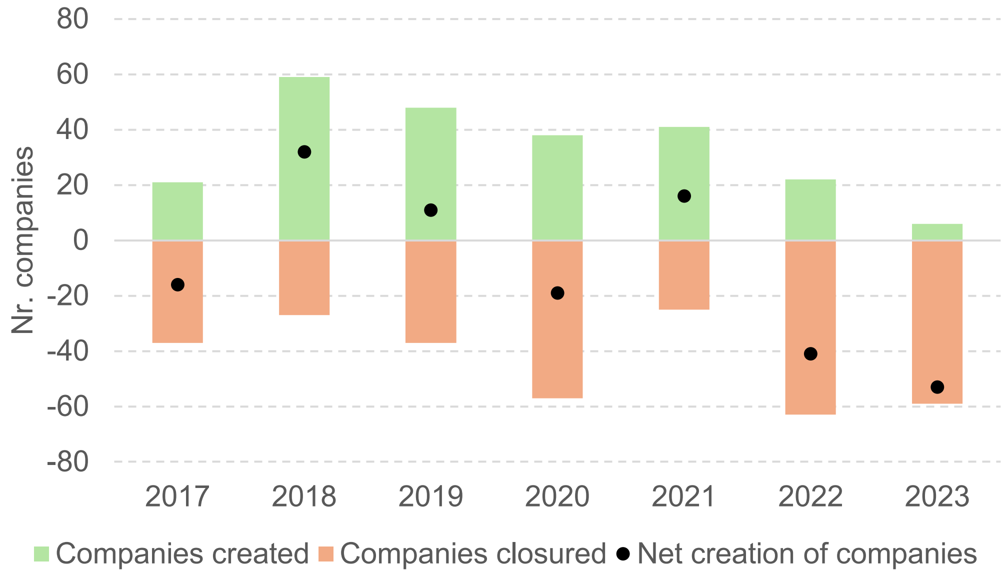
[93] List of energy service providers, available on the IDAE website (here).

[94] The selection of companies has been made based on a search in May 2025 in the "SABI Informa" database, which groups information from the Spanish Commercial Registry. Companies whose description of activity contained keywords such as "photovoltaic", "solar energy" or "solar panels" have been selected. On this first search, the data have been filtered with several criteria. Firstly, those companies with unknown status, without information on revenue or with revenues of less than 10,000 euros per year have been discarded. Secondly, the CNAE codes have been declared to the Commercial Registry. At this point, it should be borne in mind that companies can declare several CNAE codes, without knowing the exact moment when they start or cease their activity in the photovoltaic field. Finally, to determine when a company ceased activity, the last year in which it filed accounts was taken as its final year of operation, assuming normal business activity up to that date. This may have led to an underestimation of active firms in 2023 if there were delays in filing accounts with the Commercial Registry.

sample included a total of 510 active companies. There has therefore been a 13% reduction in the number of companies during the period.

Figure 4-1 Creation and closure of companies linked to the installation of PVSC projects



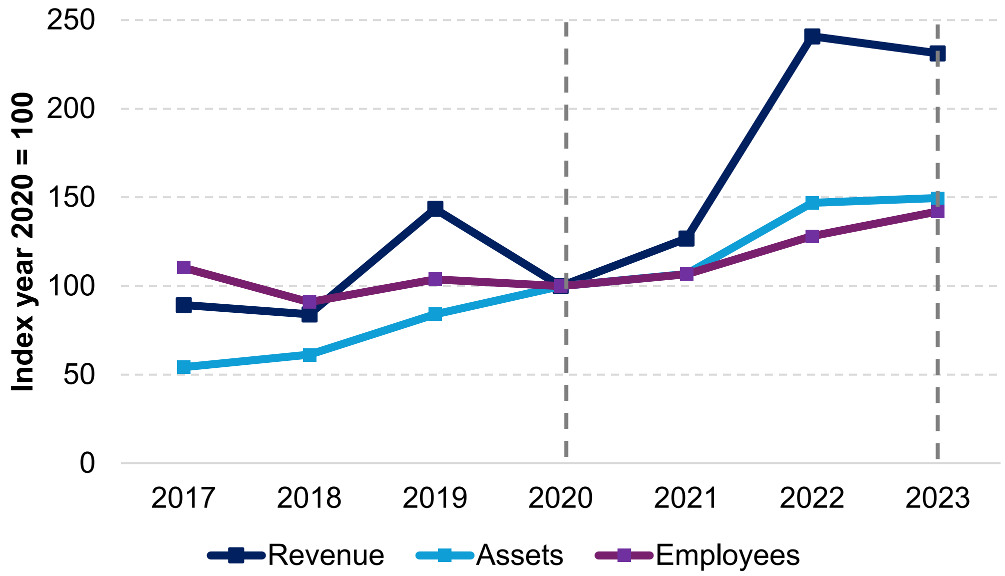
Source: own elaboration based on SABI Informa database (2025).

This may suggest, as an initial indication, that **the high demand for PVSC facilities in recent years has been met, primarily, through the growth and consolidation of companies already operating in the sector**[95].

Indeed, the data in the sample indicate that the revenues and asset size of companies whose activity is linked to the installation of photovoltaic panels grew significantly between 2020 and 2023 (+131% for revenues and +50% for assets). Likewise, the average number of workers per company also increased significantly in the same period (+42%, to 16 workers per company).

95 It has been preferred not to include the variable referring to profitability, as it could be conditioned by elements unrelated to business activity, such as financial conditions.

Figure 4-2 Evolution of average revenue and the average number of employees in companies linked to PVSC projects installation



Source: own elaboration based on data from SABI Informa (2025).

This consolidation process may partly reflect greater professionalization and maturation of the sector. Likewise, this change in the structure of the market could be driven by the existence of natural barriers to entry, related to the scarcity of human capital and the need for a minimum scale to meet the specific requirements of the activity.

In any case, a better definition of the design and implementation of the aid could have favoured the entry of new operators to a greater extent and boosted the competitive dynamics to a greater extent. In this regard, according to the provisions of Royal Decree 477/2021, the subsidy application by households or companies had to contain a budget from the installation company. This budget of the company had to be provided as part of the initial documentation for the application, even though installation work would take place, in many cases, more than one or two years later, once the decision to grant the subsidy by the regional administration was known. This implies that, after the favourable resolution of the concession, the applicants could no longer change their installation company, even though since then more competitive companies capable of offering better prices had entered the market. In other words, the subsidized facilities that were executed in each year had mostly been budgeted many months before. Given the limited time duration of the subsidy programme and the time required for the establishment of a specialised technical company, existing companies would probably have benefited from this requirement over new entrants, as they were the only ones able to provide budgets from the outset.

5. CONCLUSIONS AND RECOMMENDATIONS

Since 2021, the PVSC has experienced exponential growth and it is expected to continue gaining importance in the Spanish electricity system, thereby contributing to national and European energy and environmental objectives. On the other hand, storage coupled to PVSC installations still has a residual weight, but the growth observed in recent years indicates some acceleration.

The development of PVSC expands a new alternative for the energy consumption by companies and households, which can reinforce competitive pressure on other energy generation and retail modalities. It has facilitated the entry of new players into the retail electricity market: small retailers are finding opportunities to differentiate themselves, attract customers and offer innovative services. It is, therefore, a gateway to the retail market that can improve competitive dynamics in energy markets.

Private investment in PVSC can be profitable by itself in many cases. In addition, public administrations have decided to launch various aid programmes in recent years to speed up their deployment. This aid has taken the form of subsidies, tax reductions on various local taxes and state and regional tax deductions in the Personal Income Tax, as well as in the Corporate Income Tax of the foral territories of the Basque Country and Navarra.

Public aid schemes involve intervening in the functioning of markets which can affect efficiency levels and competition. In the specific case of the aid analysed in this report, on the one hand, it can encourage the development and consolidation of a previously residual alternative, increasing the competitive pressure on energy operators. There is also a risk that they will introduce distortions or unnecessary barriers to competition, which will affect competitive dynamics both in the energy field and in the markets where the beneficiary companies operate. All this highlights the importance of a good design of support schemes to boost their efficiency and effectiveness in achieving objectives of general interest, strengthen their pro-competitive potential and minimise possible unnecessary or disproportionate distortions to competition, both in the energy field and in other sectors.

Based on the information available, which is imperfect, the analysis carried out suggests that some aids, such as IBI property tax reductions for households, have been effective in accelerating investment in PVSC in the residential segment. On the other hand, in other cases, such as ICIO construction tax reductions, no significant effects are found. Subsidies financed by PRTR funds and Personal Income Tax deductions are also associated with a certain positive step effect on the penetration of the PVSC since 2022, but significant delays have been found in the processing of subsidies, which could reduce their effectiveness. In addition, the significant deployment of aid could have resulted in a significant increase in the turnover of companies specialising in activities related to the installation of PVSC, but it does not seem to have favoured the entry of new operators into the market.

These results suggest that there could be scope to improve the effectiveness and efficiency of public support schemes addressed at boosting PVSC, in order to strengthen their pro-competitive potential and minimise unnecessary harm to competition both in energy markets and in other activities affected by these schemes. Among other aspects, better coordination between administrations in the design and processing of these aids is needed. There may also be duplicated, unnecessary, or excessive administrative hurdles and costs for applicants that undermine effectiveness. Likewise, delays in receiving aid could reduce its attractiveness and effectiveness.

In light of the above, the following recommendations are proposed:

First. 1. Strengthen the institutional framework and coordination among administrations

Strengthening the institutional framework and coordination between administrations is desirable to minimise obstacles and costs that may unnecessarily limit access to aid for interested parties. In general, such obstacles may affect to a greater extent the companies and households with fewer resources, thereby limiting, in case of companies, their competitive position. Thus, a pro-competitive aid framework – coordinated among public administrations, transparent, avoiding financial exclusion, and respecting the principles of necessity, proportionality and competitive neutrality – can enhance positive effects on competitive dynamics and minimise damage and distortions, both in the energy market and in third markets.

I. Frame aid for photovoltaic self-consumption in a joint medium-term strategy

The Recovery, Transformation and Resilience Plan (PRTR) subsidies addressed to households and firms have been channelled through incentive programmes managed by the competent authorities of different autonomous communities, with application systems that can vary by region. At the same time, households could benefit from various tax deductions – both at the national level and, in some cases, at the regional level – with non-uniform conditions and requirements. In the case of foral territories, companies also had access to Corporate Income Tax deductions that were not available in other territories. At the local level, the fragmentation is even greater: municipal tax reductions show wide variability, with access criteria that vary substantially between municipalities and that apply to taxes of different kinds (property tax – IBI, construction tax – ICIO, business tax – IAE), with different rules depending on the target segment (households, SMEs and large industry).

This accumulation of aid can be inefficient or even lead to situations of overcompensation of certain PVSC installations. As a result, investment decisions may not align with consumers' real needs and lead to inefficient oversizing of installations. In addition, if aid is not distributed appropriately over time, there could be cycles of strong expansion followed by sharp declines in demand. Such fluctuation would concentrate activity within short periods of time, potentially leading to abrupt downturns and even the exit of a significant number of firms from the market when the aid programmes end. Moreover, since short-term demand tends to show a low-price elasticity, concentrating aid in a short timeframe may favour a significant portion of resources to end up being shifted toward upper segments of the value chain, potentially increasing profit margins and leading to an inflation of costs – thus limiting the effective benefit for the final consumer.

These situations of overcompensation could go unnoticed if a clear coordination and information-sharing system is not established[96]. As illustrated in this report, the sum of the various incentives could have covered, in some cases, more than 90% of the total cost of the installations. Disproportionate aid could lead to inefficient investment decisions at the aggregate level.

Furthermore, the lack of alignment in the timing and administrative requirements of the different aid programmes may have limited their effectiveness, due to red tape costs. Another consequence of this institutional and regulatory fragmentation is seen in communication to citizens and companies. This may result in limited awareness among self-consumers about the available aid. Information disadvantages and bureaucratic costs may lead some potential applicants – particularly those with more limited resources to deal with these obstacles – not to apply for or to access aid, affecting their competitive position in the market compared to other operators who manage to gain access.

It is therefore recommended that all aid for self-consumption be framed within a joint medium-term national strategy that allows for better coordination of all levels of the administration in the design, processing and communication of

[96] It should be noted that Article 8.1 of Law 38/2003 establishes that the bodies of public administrations and public entities responsible for managing subsidies must prepare, prior to the establishment of any line of aid, a Strategic Plan for Subsidies (PES). This plan should include: (i) the objectives and expected effects of the grants; (ii) the time required for its completion; (iii) the foreseeable costs; and (iv) sources of funding. However, beyond this individual responsibility, there is no obligation to prepare a joint plan to ensure effective coordination between the various public administrations or public entities that grant aid for similar purposes.

these aids, while respecting existing competences[97]. This strategy should ensure that the combined aid intensity does not exceed a maximum threshold, to safeguard proportionality and create appropriate incentives for investors. The strategy should be stable, subject to regular reviews based on predictable criteria, to reinforce the efficiency of public expenditure and the sustainability of the sector in the medium term. Likewise, to increase its effectiveness, information on incentives for installing PVSC systems should be coordinated among administrations and presented clearly, accessibly, and comprehensibly.

II. Establish a one-stop-shop system

The difficulties due to lack of knowledge of the different types of aid, red tape and the documentary complexity associated with the existence of different aid frameworks increase transaction costs and can significantly delay the entry into operation of the facilities. These difficulties can create competitive distortions if they affect certain groups of consumers, whether households or businesses, particularly those with fewer resources. For this reason, mechanisms such as a one-stop shop may be relevant, as they allow both information and procedures to be grouped together, providing transparency and streamlining processes.

Thus, to strengthen transparency and reduce red tape, **it is recommended to establish a one-stop-shop system**, the practical implementation of which could be defined as part of the joint national strategy. This would allow self-consumers to identify and apply for all available incentives – subsidies, tax reduction or deductions – in a single procedure. Ideally, this system would also offer digital access, to facilitate procedures online without physical presence. To this end, it

97 In accordance with art. 8.1 of Law 38/2003, of 17 November, General Subsidies, the public administrations must previously develop a "strategic subsidy plan".

In this sense, the PES of the Ministry for the Ecological Transition and the Demographic Challenge 2022-2024 includes several descriptive tables of the self-consumption aid programme (line 2.D.04). In addition, the Self-Consumption Roadmap (MITECO, 2021) incorporates some brief references to the possible role of public aid and describes the subsidies deployed by Royal Decree 477/2021. Likewise, the PRTR introduces planning elements referring to the aforementioned subsidies. Nevertheless, none of these documents provides a comprehensive overview of all aid schemes deployed —including those at the regional and local levels— that would allow for medium-term planning and coordination of their implementation in an efficient manner.

The development of a comprehensive strategy at the national level could be supported by existing coordination forums, such as the Commission for the Coordination of Climate Change Policies (CCPCC) or the National Climate Council.

It should also be noted that the CNMC has previously recommended the development of strategic planning in the field of public aid, for example, in the 'Recommendations to the public authorities for an intervention in favor of market competition and an inclusive economic recovery' (G-2021-01).

would be advisable to harmonize as much as possible the documentary requirements demanded by the different administrations, unifying formats and information criteria. As an alternative or complement, mutual recognition mechanisms could be established, whereby an administration unilaterally accepts as valid, the documentation or *on-site* verification processes carried out by other competent administrations.

Finally, it is essential to improve the clarity and quality of the information provided, avoiding unnecessary technicalities and making it easier for all citizens to understand the procedures, regardless of their level of technical knowledge.

III. Assess the grouping of incentives in the same instrument

The coexistence of multiple programmes and instruments aimed at promoting PVSC stems from the fact that different levels of Administration have simultaneously decided to prioritise this type of action, allocating their own budgetary resources within the scope of their competences. Although in some cases this overlapping of instruments may be unavoidable (and even reasonable and efficient, provided that it addresses diverse problems requiring differentiated interventions), it implies greater complexity for potential beneficiaries. It makes it difficult for them to identify and apply for all the available aid, which can harm the competitive position of those who finally do not access it. And, even when they succeed, it imposes procedures and costs on them that, in some cases, could have been avoided if the aid had been articulated through a smaller number of instruments.

Therefore, **it is recommended to assess, within each of the levels of the administration (state, regional and local), whether there is scope to group the incentives offered through various aid instruments**. Particularly, in those municipalities where IBI, ICIO and/or IAE reductions are offered simultaneously, it is recommended to consider merging some of the incentives into a single tax. Likewise, if a joint strategy between the different administrations were proposed, the concentration of aid through the fewest possible instruments could be assessed. In this regard, the analysis in this report points to the desirability of differentiated policies adapted to the different territorial profiles and actors involved, so that the existence of several instruments that adapt to different circumstances may be reasonable, although they must be designed in a pro-competitive way, justified and adequately coordinated, to avoid any distortion that may be unnecessary.

IV. Enhancing transparency and improving official statistics

This study has used data available in the registry of the Electricity Market Information System (SIMEL), managed by Red Eléctrica de España (REE), as a reference to evaluate the penetration of PVSC in Spain. However, the associations of photovoltaic installers handle figures higher than those registered in SIMEL. Likewise, relevant discrepancies are observed with respect to the data contained in the Administrative Register of Self-Consumption Facilities (RADNE), administered by the Directorate General of Energy Policy and Mines and nourished, in turn, by information from the autonomous communities.

In this context, the Self-Consumption Roundtable ("Mesa de Diálogo del Autoconsumo") has stressed the need to ensure the convergence of the data used to monitor the deployment of self-consumption in Spain between the different agents involved in the collection and processing of this information.

In addition to the information directly related to the electricity system, this study has also integrated data related to public aid. Specifically, the above information has been combined with the data provided by the IDAE, obtained from the autonomous communities within the framework of the PRTR, and estimates have been made on the level of local tax reductions based on public and private sources, in the absence of a consolidated official source.

In the particular case of subsidies regulated by Royal Decree 477/2021, although the documentation requested during the processing is very detailed and includes specific aspects such as the geolocation of the installations, it is not possible to establish a direct correspondence between the aid files and the microdata of installations collected by REE. This situation has forced data aggregations to be carried out at the municipal level in order to cross-reference information, which means a loss of precision for impact analyses.

These limitations in the availability and homogeneity of data constitute a considerable obstacle that complicates and makes ex-post evaluations of aid programmes more expensive.

It **is therefore recommended to enhance transparency and strengthen official statistics**. Specifically, it would be advisable to establish a minimum and homogeneous set of mandatory information on the installations, which must be systematically incorporated into the public aid files for this technology. In addition, common technical systems and formats could be established for the exchange of this information, in order to ensure interoperability and facilitate the creation and maintenance of integrated databases. These measures would facilitate the cross-referencing of information and would allow to carry out regular impact assessments of the aid, allowing progressive adjustment of their design according to market and technological developments, as well as other broader strategies on environmental taxation.

V. Continue to facilitate connection to the grid and improve the information available from the installations

This evaluation has focused on public aid to PVSC. It is important, however, to remember that the public sector can also complement this aid and decisively foster the penetration of this technology by adapting technical, regulatory and administrative requirements that unnecessarily or disproportionately restrict entry into the electricity market.

In the Report on the Conclusions of the Self-Consumption Roundtable (CNMC, 2024), it was noted that multiple procedures are required for self-consumption installations – especially collective ones – to connect to the grid. The CNMC, in dialogue with the main agents in the sector, identified various proposals to reduce and simplify some of these procedures, as well as to facilitate dialogue between the numerous agents involved in the authorisations – distributors, Red Eléctrica, the autonomous communities, consumer representatives, electricity suppliers and the Ministry for the Ecological Transition.

Progress in these measures can be key to promoting the penetration of PVSC and facilitating the entry of small electricity suppliers.

Within its scope of action, the CNMC has already taken steps to facilitate and streamline the processing of self-consumption installations and the activation of consumer bills. In October 2024, it published the Circular on access and connection of demand, which incorporates specific actions aimed at providing greater specificity, homogeneity and transparency to all the phases that make up the comprehensive management of self-consumption files, through the web platforms that distributors will implement.

Moreover, for administrations and the different relevant agents in the sector to be able to make more efficient decisions – whether in the design of public policies, in investment planning, in the management of networks or in the programming of electricity production, among other areas – it is essential to improve the information available on the actual deployment of these installations and on the generation they actually produce and self-consume.

In summary, **it is recommended to continue promoting measures to eliminate regulatory, technical and administrative barriers that hinder the connection of installations to the grid, especially collective ones.** Specifically, it is recommended to continue advancing in the adoption of the measures identified in the Self-Consumption Roundtable. In the conclusions of this Roundtable (**INF/DE/106/24**), in addition to the actions aimed at facilitating the connection of installations to the grid, measures were proposed to promote transparency for consumers through access to energy data related to self-consumption installations or the expansion of information on electricity bills. An attempt was also made to respond to other key aspects raised by the sector regarding self-consumption, such as finalising regulatory developments that allow new configurations of self-consumption; fostering the convergence of monitoring data on the deployment of self-consumption in Spain; developing new models of self-consumption; as well as the access of the System Operator (SO) and distribution network managers to self-consumption installation data for real-time generation scheduling, demand forecasting, and reserve sizing to address imbalances between renewable generation and demand.

Second. Strengthen the pro-competitive approach and improve the efficiency and effectiveness of public aid

VI. Define aid in fixed unit amounts linked to energy and environmental objectives

The intensity of the public aid analysed is sometimes linked to factors not directly related to the general-interest objective pursued (e.g. environmental objectives such as the reduction of CO2 emissions). This could mean the introduction of competitive advantages for certain companies over others, without this being justified by a higher contribution to the intended goals. Some examples are observed in:

- The IBI property tax reductions, where the cadastral value of the property plays a key role in determining the public aid, since the maximum reduction percentage is defined as a proportion of the full tax liability. This link with the cadastral value is not related to the ultimate objectives pursued, which would entail a risk of inefficient use of public resources, especially considering that municipalities with higher cadastral values (and higher income levels) already have higher levels of PVSC penetration. This may affect the efficiency and effectiveness of the aid, the competitive position of the beneficiary companies and, in addition, could also have distributional and equity implications, as it enables larger aid associated with higher cadastral values, which, however, is outside the scope of this assessment.
- The ICIO construction tax reductions and personal income tax deductions are based on the cost actually incurred (*ad valorem aid*).[98] In general, the literature indicates that subsidies per unit of energy savings (*per-unit*) would be more effective than cost-proportional subsidies (*ad valorem*) (Giraudet, 2025).

[98] In the case of subsidies under Royal Decree 477/2021, unit reference costs and maximum eligible costs are applied, depending on the programme.

Therefore, **it is recommended to establish a system of aid based on fixed unit amounts, linked to the objectives pursued**. These amounts can be differentiated according to objective criteria, reinforcing the justification and proportionality of the aid and minimising unjustified distortions. For example, unit aid could be defined as a specific amount per kW installed or the improvement in energy efficiency achieved. Likewise, it could be modulated according to aspects such as the hourly electricity consumption profile of the sector to which the applicant belongs, the condition of habitual residence of the property where the installation is to take place or the contracted capacity, among others, provided these criteria is connected to objectives of public interest such as the reduction of CO2 emissions.

VII. Regularly assess aid priorities and consider storage, large-scale self-consumption and collective self-consumption

Investment in PVSC has become economically viable for a large number of users without the need for public support, thanks in part to lower costs, which has facilitated its expansion. If this trend continues, it may be appropriate to periodically reassess the priority areas on which future public support programmes should focus, in order to target them to where they are most needed and effective in boosting still-emerging markets or where competitive dynamics can be improved, while reducing them in markets where they are less essential in order to limit competitive distortions.

For example, the installation of energy storage systems, such as batteries, can contribute significantly to the reduction of surplus energy, but it is still residual in the Spanish electricity system. The reduction of electricity fed into the grid contributes to its stability and can therefore be considered a positive externality for the system, one that could be suitable for receiving public support. Despite these potential system-level benefits in terms of reducing surpluses, storage technologies are still at a relatively early stage of development, meaning that without support, a significant part of stakeholders might prefer to wait for further reductions in their costs before investing in it.

Similarly, the development of collective self-consumption still seems to be scarce, in relation to the high potential that Spain presents due to its particular urban structure. In this regard, it is observed that the PVSC penetration is lower in those municipalities with fewer single-family homes and a higher proportion of residents in multi-storey buildings. It should be noted that this modality could face barriers and challenges related to coordinating self-consumption among a collective. In any case, it may be worth considering whether public aid[99] could be efficient and effective and play a transformative role, generating additional incentives for this type of installation and helping to facilitate coordination among the agents involved (mainly, neighbourhood communities).

Finally, the promotion of medium- and large-scale self-consumption installations, especially in industrial and commercial sectors, where energy consumption is high and continuous, can improve the stability of the grid. In general, this type of installation has a self-consumption more aligned with self-production, so they feed less surplus into the grid and demand less electricity from the grid. Therefore, it could also be considered to prioritise aid focused on these uses over other types of installations that exert greater pressure on the network.

All of the above is relevant from the perspective of competition policy, as it is desirable for the aid to be necessary and justified in order to avoid unnecessary distortions to competition. For this reason, the assessment of priorities can be useful to identify activities where there is a greater need for aid and where its adoption is proportionate – despite distortions – as well as to discard aid when it is dispensable or unjustified.

It **is therefore recommended that future public aid programmes be designed on the basis of a clear exercise of strategic prioritisation of the use cases to be incentivised**, in order to increase their effectiveness and limit their distorting effects on competition. This could begin with a regular assessment weighing advantages and disadvantages, taking into account developments in the sector and the costs of PVSC and storage technologies, as well as the overall benefits for the energy system. As a preliminary step, consideration could be given to increasing the share of aid allocated to coupled battery installations and collective self-consumption, as well as strengthening support for medium- to large-scale PVSC projects, particularly in industrial and commercial sectors, where surpluses are smaller due to high and continuous energy consumption[100] – while, in all cases, respecting the State aid framework[101].

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99 State-level deductions in personal income tax for energy efficiency works already offer a higher deduction in cases of comprehensive renovations of buildings. Likewise, some autonomous communities also offer greater deductions for collective installations.

100 An example in this regard is the recent call for aid for innovative energy storage projects for an amount of 700 million euros, defined by Order TED/535/2025, of 28 May (aid from ERDF funds 2021-2027).

101 According to the General Block Exemption Regulations (art. 43), aid for PVSC projects with an installed capacity of less than or equal to 1 MW is exempt from the obligation to notify the European Commission established in art. 108.3 TFEU, provided that they meet certain conditions (among which it should be noted that "*The aid will be limited to the minimum necessary to carry out the project or activity receiving the aid*"). The previous power limit has been relaxed from July 2023 (previously, the limit was 500 kW).

Third. Accelerating access to aid

VIII. Streamlining administrative procedures and promoting ex officio grant allocation

The lengthy processing of subsidies and the distribution of local tax reduction and deductions over several years create a time gap between the moment when investors must finance the installation and the moment when they actually receive public aid.

This delay can slow down or postpone investment decisions if investors do not have sufficient short-term liquidity or cannot access external financing. On many occasions, the aid is received by the final beneficiary precisely when the liquidity needs are lower, as the installation is already operational and generating energy savings for the self-consumer. In some cases, it is the installation companies themselves that advance all or part of the amount of the aid to the customer to facilitate the investment. However, when the administrative process of this aid is long and effective payments are delayed, the problem can end up being transferred to these companies, which may face cash-flow tensions, particularly in the case of SMEs as they generally have fewer resources. All of this can place those operators who lack the resources or financial capacity to face these obstacles at a competitive disadvantage, compared to those who can face them and receive the aid.

Moreover, it is important to bear in mind that the aid analysed in this report is of a requested nature. This means that they are not applied automatically (*ex officio*), but it is up to the household or business to expressly request them, providing the documentation that proves compliance with the requirements set out in the corresponding regulations (for example, the urban planning licence or declaration responsible for the installation, the invoices for the execution cost, the technical report or the final work certificate). Although at the state and regional level, as well as in most municipalities, electronic portals have been set up to speed up the telematic processing of these applications, households and companies frequently report problems in the operation of these electronic systems and duplication of procedures. These administrative barriers can give rise to "*non-take-up*" phenomena, meaning that citizens fail to apply for aid they are entitled to due to lack of information, difficulties in access or bureaucratic complexity[102]. In the case of local tax reductions for self-consumption and the rest

[102] In this regard, the Independent Authority for Fiscal Responsibility (AIReF) has documented such problems, for example, in its Spending Review on the Minimum Living Income, where significant rates of non-take-up were found despite beneficiaries being entitled to the benefit.

of the aid analysed, however, there is no data available to accurately quantify the magnitude of this phenomenon.

All of the above may reduce the attractiveness of aid and, therefore, its effectiveness as an incentive to invest in these systems. In addition, these effects can create competitive distortions, as they are usually more severe in SMEs, and can also particularly affect households with more limited income.

To shorten payment times, **it is recommended to streamline administrative procedures and explore the possibility of granting some aid automatically (*ex officio*).**

- Firstly, it would be advisable **to simplify and harmonise the documents required** by the different administrations in the processing of aid, in coordination with the requirements for access to the network and registration of installations, as well as **to promote the automatic exchange of relevant information** between administrations. To this end, the joint development of common technological solutions that automate the application, resolution and verification processes and establish a secure framework for the exchange of relevant information (e.g. municipal building permits, registered installation certificates, REE registration, etc.) could be considered.
- Secondly, the **feasibility of tax reductions and deductions being granted automatically** could also be explored, without the need for an express request from the household or company (for example, by cross-referencing data between the urban planning area and the area in charge of local tax collection of the municipalities).

IX. Broaden and make more flexible the subsidy advance payments

For subsidies, a more flexible system of advance payments would allow beneficiaries to cover the initial costs without having to wait for the final verification of the aid (which requires completion of the works). In this sense, Royal Decree 477/2021 establishes a voluntary system of advance payments, but the regional governments are only obliged to regulate it for subsidies of more than €50,000. As a result, most have not established these advance payments for subsidies of lower amounts. Furthermore, the advance payment is also linked to requirements such as providing a bank guarantee[103]. In practice, most households and SMEs applying for small subsidies have been excluded from the

[103] This is also the case of the new TED Order 535/2025 for storage, where the beneficiary must provide a guarantee covering 100% of the advanced payment amount to the General Deposit Fund, in the form of a bank guarantee, surety insurance or other legally accepted forms.

advance payments, as well as companies that planned to make larger investments but had difficulties in accessing bank guarantees. A relaxation of these criteria could increase the risks (contingent liabilities) borne by public administrations but would make it possible to alleviate the liquidity constraints that in some cases hinder investment in PVSC, and would facilitate more balanced access among market operators, reducing possible competitive distortions.

Accordingly, **it is recommended to consider expanding and making the advance payment system more flexible** as far as possible, in order to facilitate investments, particularly for those households and companies with fewer resources. An alternative observed in other grant programs involves partner entities managing subsidies on behalf of beneficiaries and applying discounts directly on purchase and installation invoices for solar panels. This approach allows beneficiaries to receive immediate financial relief while avoiding red tape. Should such systems be implemented in the future, it would be important that they remain optional (allowing beneficiaries to apply directly if they wish) and that the accreditation of partner entities be neutral and non-discriminatory, in order to avoid entry barriers for new market operators[104].

X. Concentrate tax reductions in the first year of the installation

Beyond liquidity constraints, distributing aid payments over a long period can have disincentivizing effects, as near-term benefits tend to be valued more highly by recipients. This behavioural effect – known in the behavioural economics literature as “present bias”[105] – suggests that smaller, earlier incentives can be more effective than larger, delayed ones. Concentrating aid in the initial years can therefore help reduce competitive distortions and increase effectiveness while maintaining or even reducing the fiscal cost.

Therefore, **it is recommended to limit and concentrate the tax reductions to a single year after installation.** In the case of the ICIO tax, the reduction can only be applied for one year; however, reductions for the IBI and IAE taxes are often granted indefinitely or over very long periods, so there is room to shorten their duration.

104 See, for example, similar recommendations of the CNMC in relation to Plan Moves III aid (PRO/CNMC/003/21).

105 The present bias refers to a preference marked by immediate gratifications over future ones. See the Study on Behavioural Economics for Efficient Regulation and Supervision (E/CNMC/002/23).

XI. Consider public financing instruments

In many countries, the public sector has deployed financial instruments to facilitate access to self-consumption, especially in households and SMEs. These instruments include subsidized loans, public guarantees and other products, deployed in many cases in collaboration with private sector entities. Such mechanisms allow committed public resources to be leveraged, minimizing the budgetary impact, while reaching a wider range of beneficiaries. Reducing barriers to access and increasing the number of beneficiaries can reduce potential distortions of competition between those who benefit from aid and those who do not.

To overcome the financial barriers to investment in PVSC, **it is recommended to consider the introduction of public financial instruments**. These could potentially be applied in collaboration with private financial institutions and target areas where financing needs and difficulties are greatest – such as households, particularly those with more limited income or neighbourhood associations, or SMEs.

ANNEX I. Grouping of economic activities for empirical analysis

The following table shows the correspondence between the groups of self-consumers used in this study, the CNAE classification – Spanish NACE classification – and the incentive programmes of Royal Decree 477/2021.

Table I-1 Assignment of economic activities to study **groups** and their corresponding Incentive Programme established in RD 477/2021

CNAE 2009		Group assignment		Incentive Programmes
A	Agriculture, forestry and fishing	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
B	Mining and quarrying	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
C	Manufacturing	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
D	Electricity, gas, steam and air conditioning supply	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
E	Water supply; sewerage, waste management and remediation activities	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
F	Construction	GR2 / GR3	SERVICES & INDUSTRY	P2 / P3
G	Wholesale and retail trade; repair of motor vehicles	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
H	Transportation and storage	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
I	Accommodation and food service activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
J	Information and communication	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
K	Financial and insurance activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
L	Real estate activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
M	Professional, scientific and technical activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
N	Administrative and support service activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
O	Public administration and defence; compulsory social security	GR4	OTHERS	P4 / P5
P	Education	GR4	OTHERS	P4 / P5
Q	Human health and social work activities	GR4	OTHERS	P4 / P5
R	Arts, entertainment and recreation	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
S	Other service activities	GR2 / GR3	SERVICES & INDUSTRY	P1 / P3
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	GR1	HOUSEHOLDS	P4 / P5
U	Activities of extraterritorial organizations and bodies	GR4	OTHERS	P4 / P5

Source: Own elaboration based on data from REE, incentive programmes of RD 477/2021 and the categories applied by municipalities for local tax reductions.

ANNEX II. APPROXIMATION OF THE AVERAGE AMOUNT OF LOCAL TAX REDUCTIONS

A) Processing of IBI tax reduction data

The tax reductions to the Property Tax (IBI) for solar installations are optional and can be applied by local entities to installations intended for thermal or electrical use of solar energy. These reductions can reach up to 50% of the taxable amount, and their maximum duration is not limited at the state level, remaining at the discretion of each municipality [106].

To estimate the IBI tax reduction in the different segments analysed by municipality – GR1 (households up to 15 kW), GR2 (services and other productive sectors up to 100 kW), GR3 (services and other productive sectors of more than 100 kW) – a database has been built from various sources:

- IBI tax rates[107] for urban plots and cadastral values and number of properties (by municipality and use), from the Ministry of Finance[108].
- IBI tax reduction percentages compiled by Fundación Renovables.

Firstly, the average taxable base per property in each municipality has been calculated, according to cadastral use, using data from the Ministry of Finance. To this end, the cadastral values and the number of properties per use in each locality have been compiled.

The 13 cadastral uses defined by Royal Decree 417/2006, of 7 April, have been grouped into the three groups mentioned[109] to facilitate the cross-referencing of data with the IBI (Fundación Renovables) reductions, the NGEU subsidies (IDAE)

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106 Royal Legislative Decree 2/2004.

107 Local taxation statistics of the General Secretariat for Regional and Local Financing.

108 Data by municipalities of provinces of common regime from the General Directorate of Cadastre. In the case of the municipalities belonging to the provinces (Álava, Guipúzcoa, Vizcaya and Navarra), the average cadastral value of each municipality has been approximated based on a regression that takes into account the income per household and population of each municipality according to the INE (only relevant for cases where the discount was different from 0).

109 The uses have been grouped as follows. For the GR1 (household segment), the cadastral value and number of receipts only intended for residential use have been taken into account. In the GR2 and GR3 (services and other productive sectors segment) the cadastral value and number of receipts of commercial uses have been grouped; leisure and hotel; sporty; of shows, of the warehouse and industrial. The use of land has not been used due to its very diverse use, the use of a unique building and the religious use. In addition, cultural, office and health uses, which could fall into a category of public administrations, have not been considered. This category has been discarded as forming too small a group of PVSC installations.

and the installations registered by REE. This mapping allows a coherent approach between the different sources of information.

Secondly, for each municipality and each year, the average taxable base has been multiplied by the applicable urban IBI tax rate to obtain the full amount.

Thirdly, the full tax liability has been multiplied by the percentage of the reduction and the number of years of application of the reduction. For simplicity, when there were several possible values depending on the characteristics of the installation or the taxpayer, the maximum percentage of reduction and years contemplated for each municipality in the database of Fundación Renovables has been assumed. Likewise, when the tax ordinances established a reduction indefinitely (i.e., they did not define an explicit duration), it is assumed that the duration is 25 years (the expected useful life of the facilities).

This analysis focused on municipalities with more than 10,000 inhabitants, as these are the only ones for which IBI reduction rate (Fundación Renovables) are available. The resulting reduced amount, expressed in euros per average taxpayer in the municipality, has in some cases been expressed in euros per kW, assuming a typical 5 kW installation (see, for example, section 3.2.2.3).

B) Processing of data related to the ICIO tax

The taxable base of the Tax on Constructions, Installations and Works (ICIO) is estimated from the cost of the installations. In this study, this cost has been approximated using the investments declared by the potential beneficiaries of the NGEU programme subsidies, managed by the IDAE.

To calculate the cost per installation (expressed in euros per kW), the unit investments declared for self-consumption and storage facilities during the period 2021–2023 have been used, without territorial disaggregation (i.e. without distinguishing between autonomous communities or provinces). The calculation has taken into account the size of the installations, the economic segment of the applicant and the corresponding incentive programme.

The total investment declared has been interpreted as an approximation of the real cost of the installation, and, therefore, as a *proxy* for the ICIO tax base.

Once these average values were obtained, they were cross-referenced with the database of all PVSC installations registered in Spain up to en of June 2025, according to data provided by REE. This has made it possible to estimate the total cost invested in PVSC and storage by municipality.

Finally, the average investment of the installations that applied for aid has been used as an estimate of the taxable base of the ICIO for the set of existing installations.

ANNEX III. METHODOLOGICAL ASPECTS OF THE ECONOMETRIC ANALYSIS

This section includes some additional methodological aspects related to the econometric analysis described in the Section 4.2.

(a) Fixed-effects and random-effects models

The estimate is made on a panel of data from more than 700 municipalities in four years (2021-2024). This structure allows controlling the unobservable heterogeneity of the agents studied – that is, intrinsic characteristics that do not vary over time but are relevant to explain the dependent variable – thereby improving the accuracy of the estimation.

Depending on the assumptions made about the nature of these unobservable effects, different estimation methods can be applied. Specifically, it is important to decide whether to apply a fixed-effects model or a random-effects model, depending on the assumptions between the correlation of the explanatory variables and the error term.

- **Fixed effects**: A fixed-effects model controls for omitted variables that do not vary over time and provides consistent estimators when specific effects are correlated with explanatory variables. Its main limitation is the loss of degrees of freedom, which can affect the efficiency of the estimators.
- **Random effects**: In contrast, random-effects models take advantage of both the variability between municipalities and the temporal variability within each municipality, which improves efficiency and preserves degrees of freedom. However, its validity depends on a restrictive assumption: that municipality-specific effects are not correlated with explanatory variables.

As explained in the next subsection, in the present analysis, the fixed-effects model appears to be more appropriate than the random-effects model. However, the fixed-effects model does not allow the inclusion of constant variables over time that are of interest for the present analysis (such as irradiation, income level, variables related to the 2021 Housing Census, etc.).

To overcome these limitations, the Mundlak model is applied[110]. Under this model, municipality-level means of the explanatory variables are included in the specification, allowing the analysis of variables with little temporal variation and clearly differentiating between cross-sectional (between municipalities) and temporal (within municipalities) effects.

(b) Results of econometric tests on fixed and random effects

The first test applied is the Breusch and Pagan test for random effects in a panel data model (also known as the Lagrange multiplier test). This test evaluates the null hypothesis (H_0) that the variance of the entity-specific effect is zero (implying no unobserved heterogeneity between municipalities, and that a simple Ordinary Least Squares – OLS model would be adequate). The alternative hypothesis (H_1) states that this variance is greater than zero, indicating significant individual effects by municipality and justifying the use of a random-effects (RE) model.

As shown below, the p-value is very low (< 0.05), so H_0 is rejected. Therefore, it is concluded that there is significant heterogeneity between municipalities, and a random-effects model (RE) is more appropriate than a simple OLS.

[110] The Mundlak model introduces the means of the variables for each municipality and allows implicitly testing whether the variables are correlated with the unobservable individual effects. In case the coefficient of the variable, which represents the mean per municipality, is statistically different from zero, it implies that there is a correlation between the variable and the unobservable effects included in the error term, $Cov(X_{i,t}; \varepsilon_i) \neq 0$. This therefore implies a violation of the key assumption of a random-effects model and points out that only fixed-effect or Mundlak models can deliver consistent results. On the other hand, the significantly different coefficients of zero of the mean variables mentioned do not directly imply that these variables are endogenous.

The Mundlak model is widely used in empirical studies (Baltagi, 2021) because it presents solid results as a compromise between the fixed-effect and random-effects models.

Table 0-1 Breusch-Pagan test for the GR1

```
Breusch and Pagan Lagrangian multiplier test for random effects

        kW_pob[id_muni,t] = Xb + u[id_muni] + e[id_muni,t]

        Estimated results:
                         |       Var     SD = sqrt(Var)
                ---------+-----------------------------
                  kW_pob |   510.3028       22.58988
                       e |    120.739       10.98813
                       u |   168.3221        12.9739

        Test: Var(u) = 0
                             chibar2(01) =   755.16
                          Prob > chibar2 =   0.0000
```

The second set of tests (Hausman test and robust Hausman test by bootstrap with *cluster-robust* errors), **allows to choose between two types of panel data models: 1) random effects model (RE), and 2) fixed effects model (FE).**

Hausman's test is based on the H_0 that there is no correlation between individual (municipal) effects and regressors and, therefore, the RE estimators are consistent and efficient. On the other hand, H_1 states that there is a correlation between individual effects and regressors, so the RE estimators are inconsistent.

The result is a very low p-value (< 0.05), so H_0 is rejected, and it is concluded that there is a significant correlation between the individual effects (of the municipalities) and the regressors. The fixed-effects (FE) model is preferable to the random-effects (RE) model.

Table 0-2 Hausman test for the GR1

	Coefficients (b) FE	(B) RE	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
IBI_cbonif	.001882	.0021152	-.0002332	.0003622
ICIO_cuota	-.0068293	.0148731	-.0217024	.0218532
FTB_YR	1.006756	.8136168	.1931393	.0210762
inv_gen_€k~n	.0622002	.0238349	.0383653	.0040015
rentaNET_p~r	.0021015	.0012097	.0008918	.0008107
IRPF_ccaa_pc	-.5760311	.1483451	-.7243762	.6143135
Lporcent_n~o	.105829	.0884224	.0174067	.0085925
d2021	-4.251481	-11.89788	7.6464	1.677393

```
                          b = Consistent under H0 and Ha; obtained from xtreg.
           B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

    chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            = 101.91
Prob > chi2 = 0.0000
```

The robust Hausman test by *bootstrap* strengthens and confirms the previous analysis. This test is a more robust version of the former one and allows heteroscedastic or correlated errors within clusters of municipalities.

The results show a p-value that is still very low (< 0.01), so H_0 is rejected again, even after robustly controlling for clustering and error structure.

Table 0-3 Hausman robust by Bootstrap for GR1

```
bootstrap in progress
──┼── 1 ──┼── 2 ──┼── 3 ──┼── 4 ──┼── 5
.................................................. 50
(This bootstrap will approximately take another 0h. 0min. 18sec.)
.................................................. 100
.................................................. 150
.................................................. 200
──────────────────────────────────────────────────────────────────────────

Cluster-Robust Hausman Test
(based on 200 bootstrap repetitions)

b1: obtained from xtreg kW_pob IBI_cbonif ICIO_cuota FTB_YR inv_gen_€kW_SOLICITUDin irradDIR_anual vivienda_enalquiler_pc vivienda_1resid_pc
b2: obtained from xtreg kW_pob IBI_cbonif ICIO_cuota FTB_YR inv_gen_€kW_SOLICITUDin irradDIR_anual vivienda_enalquiler_pc vivienda_1resid_pc
Excluded (not identified, or only identified in one model):  irradDIR_anual vivienda_enalquiler_pc vivienda_1resid_pc

    Test:  Ho:  difference in coefficients not systematic

                 chi2(9) = (b1-b2)' * [V_bootstrapped(b1-b2)]^(-1) * (b1-b2)
                         =        75.82
                Prob>chi2 =       0.0000
```

The tests applied indicate that a fixed-effects model by municipality is consistent, because 1) there is unobservable heterogeneity between municipalities

(Breusch-Pagan confirms this), and 2) this heterogeneity is correlated with regressors (classical Hausman and robust confirm this).

The results of the tests corresponding to the GR2 models are presented below, which point to the same conclusions.

Table 0-4 Breusch-Pagan test for the GR2

```
Breusch and Pagan Lagrangian multiplier test for random effects

        kW_pob[id_muni,t] = Xb + u[id_muni] + e[id_muni,t]

        Estimated results:
                        |       Var     SD = sqrt(Var)
                ---------+-----------------------------
                  kW_pob |    128.675       11.3435
                       e |   55.59078      7.455922
                       u |   46.64005      6.829352

        Test: Var(u) = 0
                             chibar2(01) =   252.17
                          Prob > chibar2 =   0.0000
```

Table 0-5 Hausman test for the GR2

	Coefficients (b) FE	(B) RE	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
IBI_cbonif	-.0001568	-.0005208	.000364	.0006072
ICIO_cuota	-.0429299	-.0365083	-.0064216	.0306077
FTB_YR	.9494474	.8919516	.0574957	.0180186
inv_gen_€k~n	.0045733	-.0146699	.0192433	.0040244
rentaNET_p~r	-.0003536	-.0000853	-.0002684	.0008214
IRPF_ccaa_pc	-2.835633	.1357134	-2.971346	.6501676
Lporcent_n~o	.0209266	.0102895	.010637	.0058623
d2021	-6.676308	-7.5613	.8849916	1.607554

```
                          b = Consistent under H0 and Ha; obtained from xtreg.
           B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

    chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =  54.12
Prob > chi2 = 0.0000
```

Table 0-6 Hausman robust by Bootstrap for GR2

```
bootstrap in progress
──┼── 1 ──┼── 2 ──┼── 3 ──┼── 4 ──┼── 5
.................................................. 50
(This bootstrap will approximately take another 0h. 0min. 18sec.)
.................................................. 100
.................................................. 150
.................................................. 200
________________________________________________________________________________

Cluster-Robust Hausman Test
(based on 200 bootstrap repetitions)

b1: obtained from xtreg kW_pob IBI_cbonif ICIO_cuota FTB_YR inv_gen_€kW_SOLICITUDin irradDIR_anual rentaNET_phogar IRPF_ccaa_pc
b2: obtained from xtreg kW_pob IBI_cbonif ICIO_cuota FTB_YR inv_gen_€kW_SOLICITUDin irradDIR_anual rentaNET_phogar IRPF_ccaa_pc
Excluded (not identified, or only identified in one model):  irradDIR_anual

    Test:  Ho:  difference in coefficients not systematic

                  chi2(8) = (b1-b2)' * [V_bootstrapped(b1-b2)]^(-1) * (b1-b2)
                          =       30.62
                Prob>chi2 =      0.0002
```

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ACRONYM INDEX

AIReF	Spain's Independent Authority for Fiscal Responsibility
CAU	Code for self-consumption installations
CNMC	Spanish National Markets and Competition Commission
EU	European Union
IAE	Municipal Tax on Economic Activities (*Impuesto sobre Actividades Económicas*)
IBI	Municipal Property Tax (*Impuestos sobre Bienes e Inmuebles*)
ICIO	Municipal Tax on Constructions, Installations and Works (*Impuesto sobre Construcciones, Instalaciones y Obras*)
IDAE	Spain's Institute for the Diversification and Saving of Energy
IEA	*International Energy Agency*
IRENA	*International Renewable Energy Agency*
PIT	Personal Income Tax (*Impuesto sobre la Renta de las Personas Físicas*, *IRPF*)
CIT	Corporate Income Tax (*Impuesto sobre Sociedades*)
OS	System Operator
NIECP	National Integrated Energy and Climate Plan (PNIEC)
PRTR	Spain's Recovery, Transformation and Resilience Plan
PVSC	Photovoltaic self-consumption installations
REE	Red Eléctrica de España
SIMEL	Electrical Measurement Information System