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Financial Resources for the Investments in Renewable Self-Consumption in a Circular Economy Framework

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Abstract: The availability of financial resources has been pointed out as one of the determining factors for the investment in renewable self-consumption solutions for the energy transition in the European Union. In economic terms, the barriers to investment are related to low levels of profitability and difficulties in accessing financing in some European regions. These barriers must be overcome to foster a sustainable energy transition. However, this topic of analysis is still underexplored in the literature to date. This study provides a characterisation of the financial resources applied to self-consumption from an economic–financial approach to the decision-making investors in a case study in Spain from a novel focus on the subject. The relevance of alternative financial resources as a mechanism to reduce existing barriers is revealed through the analysis of the active role that installers play in making investment decisions, facilitating the growth of self-consumption. The alternative financial channels and the bank intermediation for renewables are topics of interest to promote the energy transition towards a low-carbon economy.

Keywords: energy transition; circular economy; corporate finance; renewable self-consumption; energy research



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1. Introduction

Economies of the most developed countries are involved in an energy transition, and new models for energy supply based on renewables within a zero-emission economy can be expected in the coming decades in the framework of the sustainable paradigm. Since the beginning of this century, there is no doubt that the connection between renewables and sustainability is intimate [1,2]. This link has led to the search for energy solutions for on-site electricity generation using low-carbon sources, such as photovoltaics (PV) or other renewables, at a scale suitable for a single consumer who owns the installation [3,4].

Self-consumption provides an answer to the multiple environmental sustainability challenges posed for the first half of the 21st century, such as the goal of a low-carbon economy, the energy transition to a fully renewable scenario, a distributed energy model, and the implementation of the circular economy (CE). Furthermore, sustainable energy consumption nowadays is an essential step toward sustainability because of concerns about the effect of current energy production systems [5], facing the energy transition challenge. In addition, the active participation of consumers as producers and the decentralisation of the energy sector also align with the CE framework [6].

Despite the numerous advantages of self-consumption for small and medium enterprises (SMEs)—residential, commercial or industrial—and particular prosumers, small-scale renewable energy facilities entail scattered investments in the territory. Its penetration

varies in the different countries of the European Union (EU). This disparity is fundamentally due to the uneven difficulties associated with its financing, the installation costs that can reduce profitability, and the legislative and administrative barriers at the national level [7]. This analysis topic is still underexplored in the literature because profitability and payback are related to the selected technology and the existing local and national regulatory framework [8].

The dissemination of decentralised renewable energy generation with storage and smart metering devices leads to new consumption models in the energy sector [9]. In fact, the relevance of the availability of alternative financial channels (banking disintermediation through the financing of the retail energy company, cost savings in equipment, in addition to the financing provided by public subsidies) as a mechanism to reduce the possible barriers to renewable technologies is a line of inquiry under development. The definition of the compelling reasons for the investments and the impact of specific promotion plans is still being examined in the academic literature, particularly the drivers to mobilise the investments [7,10–14] in the framework of the Trade Credit Theories [15]. Likewise, the detailed study of the financing sources used to carry out these investments and their main characteristics contributes to enhancing the knowledge on the transitional change toward a CE [6,16].

Given these premises, this study investigates the financial resources associated with self-consumption facilities in the EU through a case study in Spain as an interdisciplinary analysis in order to bring sustainable energy consumption, zero-emission goals and renewables in a CE together in a single research framework. In summary, the main objective of this heuristic research is the characterisation of specific financial resources and the analysis of alternative financing channels for investments in self-consumption and the theoretical framework of the trade credit. A new approach is provided as it considers the perspective of installers and their role as drivers in investment decision-making. This work contributes to the collaborative business model operations area for sustainable energy consumption through the incorporation of non-energy services, such as alternative financing channels. The paper is structured as follows. The underlying background is summarised in the following section to introduce the research questions of this study. Subsequently, the applied methodology and the main results obtained are described. A final section summarises the main conclusions that are achieved through a brief discussion of the energy policy.

2. Background

The multidimensional nature of an energy transition towards sustainability triggers the need for new technologies, products, services, organisations, standards and practices of users who gradually replace the previous ones. Along with the complementarity of systems and technologies, deep social transformations are also necessary to achieve the proposed objective [17,18].

Self-consumption with renewable energies is considered one of the most feasible strategies in the short term. On the one hand, it responds to supplying reliable power at affordable prices and low carbon content. On the other hand, it relies on technologies with a high development level, such as photovoltaics, with a demonstrated success in microgeneration projects. The main contribution of self-consumption to the traditional distributed generation is the possibility of making transactions under specific rules with the electricity produced and not consumed.

Households and companies view renewable self-consumption as a solution to assure stable costs in the coming decades and avoid exposure to the volatility of energy prices in the future [19].

From a financial point of view, self-consumption allows consumers to actively participate in energy transition through a real option of revitalising the private capital of lower expectations regarding rates of return compared to conventional financial investors of the energy sector. In addition, the flexibility of self-consumption by supplying demand through storage solutions, smart devices and more flexible contracts for consumers contributes to

reducing generation peaks and consequent congestion problems, also benefiting network operators [19].

The requirement to increase the number of photovoltaic self-consumption installations at a minimum cost for the electrical systems in different EU countries is highlighted per the guidelines of good practices on the self-consumption of renewable energy. However, the transition to a zero-emission and renewable energy scenario is not cost-free. It raises the need for incentive mechanisms, reflected in energy tariffs and the payback scheme [20], especially when new stakeholders are involved as prosumers.

Regulations have to make the procedures for self-consumption facilities easy and ensure that renewable energy prosumers, individually or through aggregators, are not subjected to any double charge.

Thus, the detailed study of the required investments for these facilities has a particular interest today.

2.1. Financial Resources and Self-Consumption Investments

To date, the economic–financial analysis of self-consumption has been mainly focused on the determining factors for investments such as the payback period [21–23], their costs [11,15,24], the different billing schemes [24,25], or the volume of public incentives [13,26]. However, there is not a thorough characterisation of the financial resources applied to the investments in self-consumption.

The approach used in this study is not specifically theory-driven. Nevertheless, in this topic, the theoretical framework of the trade credit contextualises the seminal view of trade credit as a type of financing made available by the seller to the buyer introduced by Emery [27].

Previous research has identified some motivations and barriers that affect the adoption of microgeneration, including funding. Despite the numerous financial incentives, the results indicate that the most significant obstacles are still high capital costs, low cost-effectiveness, and the risk of losing money if they moved home [7]. Capital cost has repeatedly been found to be the main barrier to installing microgeneration by different authors [28–30]. The capital cost is often unaffordable [31], or potential owners cannot earn enough money from the installation to warrant the investment [32]. In the United Kingdom, the government has attempted to address the capital cost and house resale value barriers with the introduction of specific incentives (the so-called “Green Deal”) so that the risk associated with an upfront outlay is reduced by providing a capital cost loan because the financial barriers were dominating the adoption decision [11].

Regarding photovoltaic self-consumption installations, the main barriers that hinder investment for private investors [33] or younger and smaller companies [34,35] include its high cost, their own insufficient resources to cover the investment and difficulty in accessing other financial resources (in acceptable amount and cost).

Besides these barriers to the widespread investment in renewable systems, some studies identify an inaccurate economic assessment, lack of proper financial appreciation, and administrative bureaucracy related to energy and non-energy services [36].

Masini and Menichetti [12] point out the need for policies to stimulate investments in renewables more effectively by removing barriers and leveraging all the investment decision drivers. Mazzucato and Semieniuk [37] highlight the role that different financial actors can play in developing renewables and their impact on the policies to foment these energy sources.

Due to the previously mentioned parallelism to other related research fields, it is interesting to enlarge the analysis to those financial resources applied in eco-innovation or circular economy [16]. In the literature, the relationship between financial resources and eco-innovation has been explored [38]. Furthermore, the influence of different parameters inherent to these resources on eco-innovative investments has been demonstrated in more dimensions, such as the volume, availability and other qualitative aspects of financing and the allocation of public subsidies [16].

From a CE perspective, similar conclusions were achieved by Aranda-Usón et al. [39] when analysing the relationship between the financial resources of firms and their circular scope. In addition, from a technological innovation systems framework, financial capital has also been added among those complementary resources relevant to system performance [40].

More specifically, private investment has so far played a relatively marginal role in the renewable energy industry. Moreover, mobilising private capital to support investment projects in renewables is challenging, particularly in the current economic context, as investors are reluctant to allocate resources to new technologies that guarantee uncertain returns in the short term [12]. Nevertheless, the installed PV capacity system depends on its investment costs, yearly running costs and financing conditions, the interest rate [12] and other financing costs [13].

According to PV's high upfront capital investment, the adopted financial support measures are often a liability. Therefore, the cost of external financing is a parameter that conditions the economic viability of the projects. If the government can support the emission of "green bonds", it will decrease the interest rate [41]. Tax benefits are also suggested in the case of a PV system installed in conjunction with the purchase or construction of a private home. Moreover, these facilities could attract private capital and investments (especially PV suppliers or investors) to develop rooftop PV power plants, as Song et al. [41] affirm for the case of Hong Kong. Nevertheless, further monetary incentives are required to achieve a reasonable payback period that, in particular, needs to be less than the lifetime of the solar panels [42], and it demonstrates the current character of this research.

As far as the type of resources is concerned, their proportion and the cost of proper financing to fund the PV investments have been the subject of interest in analysing potential viability scenarios for different investment segments [13,24]. The investment volume can be a barrier in the model's decision-making [8,43] and the lack of adequate financing resources.

Investment in self-consumption is a topic for consideration. Prosumers manage private capital having lower expectations in terms of rate of return compared to pure financial investors, and, consequently, they could make the energy transition cheaper.

The idea that the prosumers are partially financing the electricity system is not new. Some analysis on the effects of different regulation schemes on the financial viability of self-consumption systems on residential and industrial prosumers is reported [24]. Moreover, a proper harmonisation between the consumption and production of energy achieves could increase earnings [44]. Still, reducing the specific investment cost is the factor that provides the most remarkable financial results.

It is accepted that the main factors that make easy decision-making are: the availability of own resources, and the accessibility to different formula funding renewables such as loans or public financial incentives (subsidies, soft loans, reduced tax rate, exemptions, etc.) [45–47]. The introduction of financial incentives has improved payback time, and the significant increase in solar PV uptake suggests that the changing economic landscape has further motivated people to adopt [7]. Vilaça Gomes et al. [48] state that financing mechanisms to facilitate access to the capital required to invest in PV systems can be a good path since there are no instruments available in some countries. Balcombe et al. [7] demonstrate that a capital grant of 24% of the installed cost of the whole microgeneration system is required to make the system financially viable for households with a limited average electricity demand (around 3300 kWh/year).

Song et al. [41] provide a complete classification of PV subsidy policies and other financial instruments helping investors to reduce the investment threshold, subsidising PV installations to minimise upfront capital input and reduce the financial cost. The possibility of achieving public funds at a lower cost has become a central issue, making it necessary to examine the efficiency of the instruments used to promote PV [49]. Referential loans and tax incentives are also used to reduce power generation costs from renewables and overcome high upfront project costs [50]. In China, a specific fund was established to provide additional financial support for renewable energy development, including a

subsidy of solar photovoltaic application in buildings [41]. In general terms, capital grants provide a valuable subsidy by mitigating the financial burden of renewable energy because they reduce the risk, increase the leverage of the investments, and enhance returns.

In this framework, R&D programs applied to renewable energy technologies are also helpful when they are based on a deterministic forecast of costs and performance of renewables [50]. Some examples can be found in Italy, where a public program provided financial support, up to 75% of the total capital costs, to install a PV system with peak power between 1 and 20 kWp [41]. However, it must be considered that the evolution of technology (installation cost reduction, larger storage capacity devices) will benefit the economic savings, entailing the need to review the financial aids.

Avril et al. [49] pointed out the necessity of a controlled level of expenditures and balanced allocation of the public support for PV when analysing the subsidies in five representative countries (France, Germany, Japan, Spain and the US). They found that subsidies require matching the profitability of the model with minimum standards that make it attractive for potential investors. Thus, it is demonstrated that public funds can promote self-consumption development [51]. As a summary, Table 1 shows the authors that analysed financial decisions and financial resources applied to renewables at a small scale.

Table 1. Main studies focused on investment and financing decisions of financial resources applied to renewables at a small scale.

Investment Decisions	
Investment volumes	[8,11,48,50,51]
Cash Flows: Financial aspects of energy prices and tariff (regulation)	[41,44]
Return of the investments and uncertainty about the cash flows	[12,13,23,25]
Financing Decisions	
Availability of capital	[52–54]
Financing conditions	[13,14,27,36]
Capital cost	[28–31]
Financial incentives and public funds	[12,14,28,43,44,49,50,53,55]
Alternative financial sources	[24]

Balcombe et al. [7] present the results of a simulation of 30 households with different energy demand profiles in the United Kingdom. Gimeno et al. [52] study 35 photovoltaic self-consumption installations in Spain during 2016 and 2017 to analyse information about their technical characteristics and economic and financial aspects.

From another perspective, Li et al. [50] analyse the policy effectiveness of economic instruments for PV using a panel dataset of yearly data from 1996 to 2013 for EU countries. Additionally, in the EU, Mir-Artigues and Del Río [45] propose a financial model to provide an economic analysis of the combinations of investment subsidies and soft loans applied to renewable electricity. In addition, Cucchiella et al. [44] evaluate the profitability of PV systems in the residential sector in Italy using a mathematical model. Finally, in the same country, Palmer et al. assess the evolution of residential PV systems over the 2012–2026 period through a model structure [13].

After this literature review, it can be concluded that there are two main gaps regarding investments in self-consumption. First, there is a general lack of detailed analysis of the characteristics of those specific financial resources needed for the investments in renewables at a small scale that will involve an increasing number of investors in the short term. Second, previous studies have been focused on financial theories and do not offer a specific analysis of the influence that alternative financial sources can display in the decision-making process. Therefore, the following research question is considered:

RQ1. What are the characteristics of the financing sources used to invest in self-consumption?

Based on the characterisation of the financial sources mobilised for self-consumption, these investments' decision-making will be subsequently analysed.

2.2. Decision-Making Investment

The adoption of innovative systems in a territory is determined by different elements identified in the literature, such as the intrinsic characteristics of innovation, the structure of the social system where adoption occurs, the dissemination and level of information in the territory, and the time frame of the innovation [55,56]. In particular, the decision to invest in self-consumption facilities is influenced by several types of factors. Most of them are linked to the profitability of the investment and the impact on risk [8].

Profitability will be affected by the investment size, the economic horizon and the savings otherwise linked to self-consumption and surplus management.

In a framework of the energy transition, risks will be related to the dependence on the power network, the volatility of electricity prices and environmental impacts. Needless to say, self-consumption is still an immature technology with room for improvement, with more efficient systems and lower cost [51], and regulation is accepted to be influential on the assessment of the expected savings.

At present, motivations for installing microgeneration are a field of debate. The decision to install PV systems in Mediterranean areas is influenced by economic issues such as the volume of household income or the rates of return of the investment and the environmental benefit, communication with other agents, and technology diffusion [8,13]. Therefore, it is necessary to add motivations for the investors in PV other than the energy dependence reduction to minimise the increasing energy supply prices.

In the case of self-consumption, the perception of households of the environmental component of these facilities may be relevant for the investment assessment. In addition, the concern about the risk of an imminent "energy gap" over the following years may further increase the motivation of households to be self-sufficient and avoid increasing power cuts [7,14]. Some authors show that improving the environment is a far greater motivation for adopters than rejecters [7]. In a different position, Palmer et al. [13] affirm that the adoption decision is assumed to be influenced by the payback period of the investment, its environmental benefit, the household's income, and communication with other agents. As a result, small coefficients for the payback period weight indicate that innovators are willing to take more risk. Thus, in a rational evaluation of the economics of the investment opportunities, various non-financial factors affect the decision to invest in renewables [12].

In addition, trade credit financing has a significant positive impact on sustainable growth because private enterprises generally encounter credit constraints and have harder access to bank loans [53]. Unfortunately, the existing literature does not seem to have shed light on all the economic-financial factors that influence investment decisions in self-consumption. This study tries to cover this gap through a second research question that has been defined as follows:

RQ2. What are the economic-financial factors that influence decision-making for self-consumption?

Given that other agents may take part in investment decision-making, a section of this study is proposed to analyse the role played by installers in fostering the investment in self-consumption.

2.3. The Role of Installers and Alternative Sources

Within a restrictive policy of access to new loans context, one of the barriers faced by self-consumption investors is the limitation of the sources of financing to undertake this investment. Furthermore, an inadequate adaptation of the traditional credit instruments offered by financial institutions can affect their final profitability [54]. Thus, the insufficient adjustment between the repayment terms and the return rate of the financed

investments [35] can increase its cash flow risk and endanger its survival if the repayment terms focus on the short term and the rates of return are longer.

It should also be mentioned that access to financing formulas offered by financial institutions requires the fulfilment of specific solvency parameters by borrowers [35], whether they are homeowners or SMEs. This financing mechanism is highly exposed to economic recession scenarios in which cash flow restrictions are marked. As numerous public grants depend on the budgetary figures, the possibility of accessing alternative arrangements outside the traditional ways becomes a driver for the transition to the new model. However, the possibility of accessing other channels to finance these investments is still underexplored [57,58]. Thus, the professionals involved in installing self-consumption systems are an enabler of financial resources for investors. The mediation of the installers allows the commercial operation to be temporarily linked to the loan maturity and offers a different and simplified process and scoring compared to the traditional banking model.

Within the financing of trade credit theory framework [59], suppliers are willing to finance the operations to their clients, considering its financial repercussions (financial profitability and impact on the credit risk to the provider). Moreover, trade credit reduces the problem of asymmetric information associated with bank financing since private communication between suppliers and customers is incorporated [34]. Additionally, they could both do it like that if this improves their commercial relationship [60], contributing to its consolidation, taking advantage of the synergies between infrastructure and climate finance [61]. Thus, the different mechanisms applied to self-consumption can contribute to its penetration, even eliminating the barrier of resource scarcity for potential investors and providing alternative financing sources to traditional ones offered by financial intermediaries.

In this line, Burkart and Ellingsen [59] and Mateut and Chevapatrakul [62] associate a negative relationship between the financial strength of customers and the financing use of their suppliers. Thus, simplifying investment resource access favours adopting this technology and models in which the disbursement or ownership of the investment in this type of facility can be deferred and would drive the adoption of this technology [14].

Installers make the process easier for investors, who may have difficulties accessing traditional financing to invest in self-consumption because they have a weaker position to meet credit requirements. This relation allows them to take advantage of both the technical knowledge of the installations financed through the installers and the associated commercial and operation funding terms. O'Shaughnessy [58] points out that the complexity associated with the financial transaction, from a legal, administrative and financial point of view, exceeds the small-scale company capacity, thus contributing to the market concentration. Likewise, requirements of these formulas allow the attraction of new investors [57], and installers can be a driver by becoming a financing enabler as an alternative to bank intermediation.

However, the role of installers contributing to the elimination of financial barriers is still poorly studied in the literature. Thus, given the previous reflections, the following research question is defined to broaden the knowledge about alternative financing sources and how other agents take part in the decision-making in self-consumption investments:

RQ3. What role do installers play in decision-making and accessing financing in self-consumption investments?

The study case that was carried out to obtain the contributions both for academics and practitioners is described in the following section.

3. Methodology

The analysis was carried out in the case of Spain, as an EU country in which self-consumption has experienced some delay compared to other Member States [8]. Spain exemplifies the development of renewable energy, particularly in photovoltaic solar energy, influenced significantly by public regulation [63]. Likewise, this country represents an interesting case due to the entry into force of the national regulation to allow self-consumption in Spain [63,64], and administrative, technical and economic conditions of these facilities are regulated. It is also identified the fundamental role that installers play in the penetration

of this type of facility in countries like Spain, where self-consumption development has experienced numerous barriers [8].

At this point, it should be added that the decision-making information of small consumers cannot be collected through databases. Therefore, a qualitative methodology development is required to analyse and collect information in the territory, which can only be obtained through a case study.

To this end, a broad professional network was involved in the empirical work and data collection. In addition, installers who had directly and indirectly promoted self-consumption in the region, either by selling customised electricity supply for customers or budgeting a self-consumption installation provision, were asked to complete a questionnaire (Appendix A).

For this case study, answered questionnaires were collected in 2018 during training activities specifically aimed at professionals and small-scale renewable energy installation companies. The primary purpose of the training sessions was the specific qualification of professionals to contribute effectively to the promotion and installation of self-consumption facilities in the Spanish territory. A total of 8 sessions of 4 h were delivered in the framework of a training programme funded and led by a national retail energy company with an average of 30 participants per session.

The surveys were designed to obtain specific data for an in-depth analysis of the main characteristics of the financial resources used in self-consumption investments and collect primary data about the installers' role in promoting this type of facility (Table 2). In addition, the decision-making investors and the financial barriers faced in Spain were explored.

Table 2. List of variables of the survey of self-consumption installers.

Variable	Variable Type	Description
CODE	Numerical continuous	Survey alphanumeric code
SES	Discrete	Training location
AGE	Numerical continuous	Respondent age
GEN	Dichotomous	Respondent gender
LAB	Dichotomous	Respondent employment situation
TRA	Discrete	Respondent qualification
EXP	Numerical continuous	Respondent professional experience as an installer
POS	Discrete	Respondent job
TYPE	Discrete	Mostly executed installation type
CMAT	Discrete	% average cost dedicated approximately to the material and equipment purchase necessary for the installation
GRA	Continuous	% public aid received on average
COS	Discrete	Average cost EUR/Wp of the total self-consumption facilities executed by the respondent
FIN	Discrete	Primary financing source used by clients for the facilities payment
EXT	Numerical continuous	The average percentage of external financing applied to the facilities
B01–B10	Discrete (Likert from 0 to 5, with 0 being not relevant, 5 highly relevant; NA)	Assessment by the installer of the relevance of barriers in Spain for self-consumption installations: Regulation; Distributor administrative procedures; Installation complexity; Lack of interest of the client; Installation maintenance; Prices of photovoltaic modules; Cost of the batteries; Financing difficulties; Payback period; Investment volume

Table 2. Cont.

Variable	Variable Type	Description
I01–I10	Discrete (Likert from 0 to 5, with 0 being not relevant, 5 highly relevant; NA)	Assessment by the installer of the relevance of possible incentives for self-consumption installations in Spain: Regulation changes; Administrative procedure simplification; Installation incentives; Development plans; Environmental awareness; Facilities' price reduction; Tariff reduction; Network connection rate reduction; Public grants and incentives; Electricity price rise; Reduction in maintenance costs
SA	Dichotomous	Economic saving estimates in executed installations
ENV	Dichotomous	Emissions saving estimates in executed installations
C.11–C.15	Discrete (Likert from 0 to 5, with 0 being not relevant, 5 highly relevant; NA)	Assessment by the installer of the relevance of different factors in investment decision-making in self-consumption in Spain: Environmental improvement; Energy/economic savings; Type of building; Property; Technical knowledge; Other facilities nearby

The surveys were delivered at the end of the training sessions. They were answered voluntarily and anonymously by 90 of the 243 participants (37%), which can be considered a representative sample of the analysed group. Eighty-one observations of the collected surveys were valid, and 10% of the respondents were women. Thus, the profile of the respondents combines 84% of self-employed persons and 16% of employees. In terms of training, 52% had a Compulsory Secondary Education Certificate, and 36% were university graduates, aged between 20 and 55 years and with a level of professional experience of more than 20 years in most cases, while 7% of respondents had been working for less than ten years (Table 2).

The installed self-consumption systems by the respondents are distributed among isolated facilities without network connection (77%), connected facilities without selling the surplus to the grid (15%) and other facilities (8%). Their clients were from the agricultural sectors—23%—(mostly isolated facilities for irrigation systems), domestic prosumers—31%—and secondary and tertiary sector companies—46% divided into 30% isolated, 8% connected without selling to the grid and 8% of other types.

4. Results

The first phase of analysis is based on the installers' answer data regarding the barriers in Spain for self-consumption.

The barriers can be classified into two types (Figure 1): technical or regulatory (regulation, administrative procedures, the complexity of the installation, lack of interest of the client, installation maintenance), and economic–financial (PV module price, cost of batteries, financing difficulties, investment rate of return, investment volume).

Barriers for self-consumption	%	Average value	Std. Dev.
B.03) Prices of photovoltaic modules	18%	2.4	1.17
B.04) Cost of the batteries	52%	3.5	1.07
B.05) Financing difficulties	41%	3.1	1.31
B.06) Investment rate of return	53%	3.5	1.16
B.10) Initial investment	71%	3.8	1.06

Figure 1. Results of the survey to gather the installers' opinions about the economic–financial barriers to self-consumption development in Spain.

The average and the frequency of the obtained responses were calculated for each variable. The percentage of answers with the highest levels of relevance (ratings of 4 and 5 on a 0 to 5 scale) was also calculated.

Based on their experience with prosumers, 71% of the surveyed installers consider that the factor that slows down the deployment of these installations the most is the high investment volume (Figure 1). The second relevant barrier set by 53% of respondents is the investment rate of return. It is also noted that the price of the batteries has the most significant impact among the components of investment (52%) and no longer those of PV modules (18%). Finally, the problematic access to financial resources (41%) is also very relevant.

Concerning economic–financial drivers, the analysis shows that any measure that improves the competitiveness, such as tariff modifications (82%), a reduction in the price of the components (67%) or a rise in the cost of the electricity (61%), is a powerful incentive for self-consumption deployment.

Among the drivers with the highest significant impact on these facilities' deployment, the reduction in investment through subsidies is pointed out by 76% of respondents (Figure 2).

Drivers for self-consumption	%	Average value	Std. Dev.
I.03) Facilities prices reduction	67%	4	1.05
I.04) Network connection rates reduction	82%	4.3	0.85
I.05) Public grants and incentives	76%	4.2	1.08
I.06) Electricity price rise	61%	4.9	7.42
I.09) Reduction of maintenance costs.	30%	2.9	1.26

Figure 2. Results of the survey to gather the installers' opinions about the economic–financial drivers to self-consumption development in Spain.

This first approach to the questionnaires confirms the expected relevancy of the economic–financial aspects of the self-consumption investments.

As summarised in Table 3, more than 50% of the prosumers financed their installations with their own sources.

Table 3. Information provided by the installers about the primary financing sources used for self-consumption facility investments in Spain.

Main Financing Source	% Facilities
Own financing	54%
External financing	38%
Others	8%

The requested average external financing from credit institutions is very high (80%), with around 50% provided by the retail energy company when this is considered the primary external source of investment financing. The collected information shows that the facilities receive some public grants or subsidies (38% of the facilities) in more than a third of the cases. This means that the government supports approximately 35% of the self-consumption investment (Table 4). It is worth mentioning that prosumers employ more than one source in many cases during the investment period, in line with Mazzucato and Semieniuk [37].

Table 4. Information provided by the installers about the primary sources of external financing used for self-consumption facility investments in Spain.

Financing Sources	% Facilities	% Funded
External financing (credit institutions)	19%	80%
External financing (retail energy company)	19%	52%
Grants and subsidies	38%	35%

Some differences can be observed among prosumer profiles. As Figure 3 shows, prosumers of the agricultural sector use mostly external financing (credit institutions and instruments provided by the retail energy company); however, domestic prosumers mostly use their own funds. Remarkably, leasing is used in isolated facilities without a network connection (Figure 3).

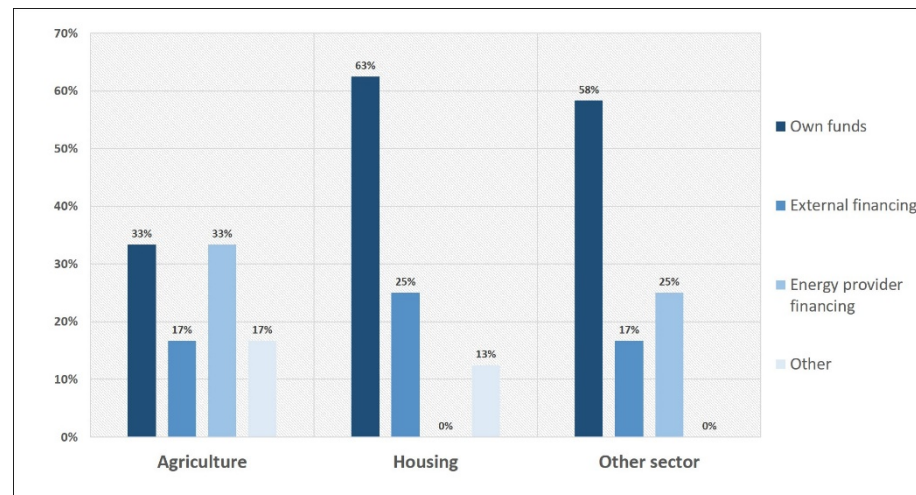


Figure 3. Information provided by the installers about the primary financing sources used for self-consumption facility investments in Spain.

Delving deeper into the first research question posed in this study (RQ1), the primary financial sources for these facilities are their own funds. In other cases, they are externally financed through credit institutions or provided by the retail energy company, subsidies or public aid and, finally, other sources and instruments (for example, leasing).

Interviewees were also asked to rate the main factors that influence the investor decision-making, and Figure 4 summarises the obtained results as the answer to RQ2. As it can be seen, energy savings and economic savings are the major contributing factors to investment decision-making (Figure 4).

Assigned value	Environmental improvement	Energy / economic	Type of building	Technical knowle	Other facilities nearby
0	0	0	0	0	0
1	1	1	0	0	0
2	4	0	4	6	3
3	12	3	9	8	8
4	6	14	8	8	11
5	3	8	5	4	4
Average	3.2	4.1	3.5	3.4	3.6
Median	3	4	3.5	3	4
Mode	3	4	3	3	4
Typ. Dev.	0.99	0.89	0.99	1.02	0.90

Figure 4. Main contributing factors on the investment decision-making in self-consumption.

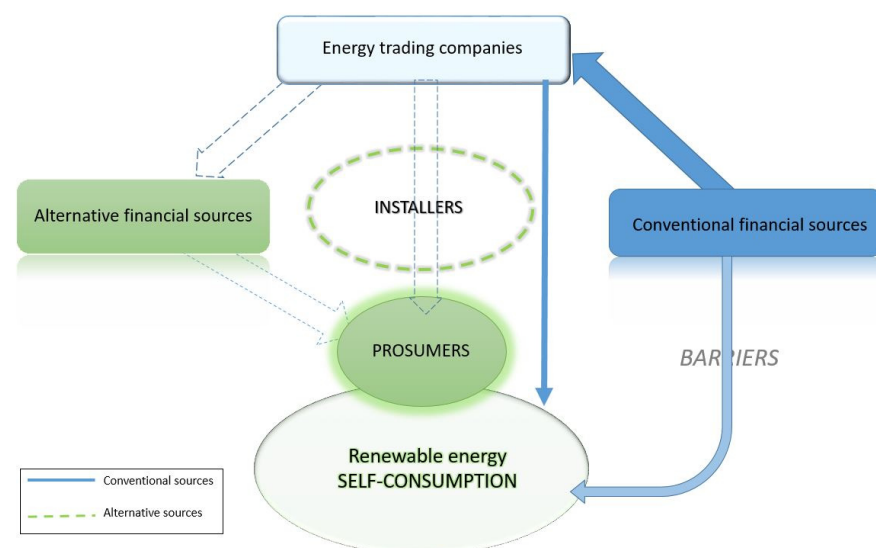
Through the data collected, the role exercised by the installers in both the promotion of self-consumption systems and in the electricity supply in grid-connected facilities is also remarkable. More specifically, the intervention of the installer is decisive in the prosumer decision-making (RQ3) in terms of the estimated saving that can be obtained with self-consumption, being one of the most relevant aspects for investors (Table 5).

Table 5. Information provided by the installers about energy and estimated economic savings obtained through the self-consumption facilities.

Estimated Economic Saving	Not Calculated	% Estimated Saving		
		20%	25%	30%
The prosumer does not require estimated saving	27%			
The prosumer requires estimated saving		35%	31%	8%

In the analysed case study, the function of the collaborative business model operation stands out: installers have continuous participation with the retail energy company promoting the facilities. These installers combine both a commercial and technical job and maintain a relationship with the prosumer over time through contracting energy supplies and facility maintenance. In addition, through the information collected, we can highlight the proactive role exerted by the self-consumption installers, in both technical and economic–financial terms, within the energy company, offering alternative instruments in financing or co-financing.

As detected from the collected information, self-consumption faced several legal barriers in the territory and a traditional need for awareness campaigns for renewables' depletion [65]. Consequently, investors carried out investment in self-consumption facilities using their own funds and external financial resources from the retail energy company, thanks to the installers. These alternative financial mechanisms or ways allow them to solve the lack of financial resources by adapting to the nature of the investment, simplifying the process and reducing the traditional financing procedures (Figure 5).

**Figure 5.** Graphical description of the alternative financing mechanisms.

In a more favourable regulatory framework (than the current one in Spain), the role played by the installers will take on even greater relevance as a mechanism to facilitate the energy transition, allowing a greater expansion of self-consumption facilities in Spain. This growth will also imply the need for retail energy companies to seek alliances to increase the fund volume requested by investors, which could be obtained through new frameworks within collaborative fund management or even through traditional financial institutions. These results are mainly correlated to previous studies focused on financial resources and incentives for renewables of Balcombe et al. [7], Gimeno et al. [8] and Plewnia [9]. In addition, these results are in line with Huang et al. [53], who demonstrate that trade credit can also be used as an effective alternative mechanism of bank credit to ease the financing constraints for the enterprise.

In summary, the main factors determining the profitability of PV installations are solar irradiation intensity, the share of self-consumed electricity, installation costs, financing costs

and electricity prices [24]. Not only the resource availability influences the deployment of self-consumption. Thus, the results of the case study analysed could be applied to other European and non-European regions promoting these energy solutions if they want to overcome the financial barriers.

5. Conclusion and Policy Implications

This article analyses the economic–financial problems these small-scale renewable energy systems pose for investors and the active role that installers play in investment decision-making through a qualitative analysis of self-consumption implementation in Spain. The obtained data allow a novel analysis of self-consumption's inherent aspects, previously unexplored and complementary to the prior studies. First, the mediating role of installers is also analysed for the self-consumption installation implementation as an example of small-scale renewables deployment in a territory. Further to this, the incorporation of non-energy services, such as alternative financing channels, into the process of self-consumption expansion for energy sustainability is analysed.

Through the analysis of the information provided by the installers, the relevance of the availability of different financial channels is shown (traditional or alternative) to access the financing sources necessary to undertake the investments. In economic terms, the main barriers of the investment can be summed up in the uncertainty of rates of return, investment volumes (still high due to storage equipment cost), and difficulties in accessing financing for small investors and companies.

The results also highlight that alternative financial sources are a mechanism to reduce the existing barriers and the active role of the installer, helping the energy transition and the deployment of renewables at a small scale. From a theoretical perspective, we can observe that trade credits serve as a significant financing source for the sustainable growth of self-consumption in a circular model. For academics, it is a contribution within the framework of theory regarding the definition of non-financial services as resources for prosumers. Furthermore, it is a new vision of trade credits since a volume of financial resources is made available to prosumers through non-financial channels, increasing the available volume and investment.

Based on the definition of the financial sources applied to self-consumption, its impact on investor decision-making is analysed as one of the contributions of this study. These results partially fill a gap in the literature, providing a detailed analysis of the characteristics of those specific financial resources needed in the decision-making process for investments in sustainable energy at a small scale that will involve an increasing number of investors in the short and medium term. In addition, a clear vision of the influence that alternative financial sources can display in the decision-making process and in the banking disintermediation to withdraw funds from intermediary financial institutions for the deployment of renewables is also provided. Finally, yet importantly, this study tackles other aspects that could hinder the investment in sustainable energies, such as the lack of financial appreciation or inadequate valuation.

As a general reflection, it should be underlined that renewable policies must focus on self-consumption and microgeneration by increasing the availability of financial resources and alternative financing sources appropriated to the investment size and requiring simplified procedures and lower guarantees, when necessary. As a possible priority, self-consumption promotion could be considered through co-financing models such as the analysed one in this case study. The retail energy company could provide financing to prosumers for grid-connected facilities and training the installers.

Regarding public administration, it follows from the analysis that the high cost of some equipment actuates a scheme of incentives or aids to favour the current extra cost derived from storage. On the other hand, actions must ease the access to financial resources from bank intermediation to the extent that they reduce the risk of the operation being financed. In addition, innovative policy measures have to be developed to introduce a sharing

culture in the CE model and educational strategies are needed to combine zero-emission technologies with the circular principles.

Our research sheds new light on the economic–financial and behavioural factors that determine the penetration of renewables by increasing the number of retail investors in the territory. The achieved results have important implications for both investors and policymakers, suggesting that distributed renewables still suffer from a series of biased perceptions and barriers that favour status quo financial resources over alternatives. An upgrade for legislation could include specific financing schemes for a household to overcome the barriers to financing the investments in self-consumption.

This study, whose limitations are mainly associated with the territoriality of the analysis and the number of surveyed installers, provides new lines of future research to deepen the characterisation of alternative financing resources in other territorial areas and applied to different sustainable technological solutions. However, this study offers a methodological contribution to the novel approach of analysing decision-making from the perspective of installers and professionals that could be applied to other geographical areas.

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Appendix A

Profile	
Self-employed <input type="checkbox"/> Employed <input type="checkbox"/> Age ____ Gender: ____ Education _____	Professional experience: ____ (years)
Position: Director/manager <input type="checkbox"/> Eng./technician or similar <input type="checkbox"/> Installer <input type="checkbox"/> Administration <input type="checkbox"/> Other: _____	
Name and family name (optional): _____ Company (optional): _____	

Read carefully the following questions and select one of the values, taking into account that “0” means that the described factors are not relevant, and “5” means that they are very relevant (“NA” means that you do not know or do not answer).

BARRIERS		No relevance or little relevance					Very relevant	
B.1	To what extent is the REGULATION an obstacle to self-consumption installations?	0	1	2	3	4	5	NS
B.2	To what extent do THE FORMALITIES with the electricity distribution company hinder self-consumption?	0	1	2	3	4	5	NS
B.3	To what extent is the PRICE OF THE PHOTOVOLTAIC MODULES an obstacle?	0	1	2	3	4	5	NS
B.4	To what extent is the PRICE OF THE BATTERY an obstacle?	0	1	2	3	4	5	NS
B.5	To what extent is the difficulty of obtaining FINANCING an obstacle to installation?	0	1	2	3	4	5	NS
B.6	To what extent does THE PAYBACK PERIOD OF THE INVESTMENT hinder self-consumption?	0	1	2	3	4	5	NS
B.7	To what extent does the COMPLEXITY of the facilities hinder self-consumption?	0	1	2	3	4	5	NS
B.8	To what extent does the lack of INTEREST on the part of customers hinder self-consumption?	0	1	2	3	4	5	NS
B.9	To what extent does subsequent MAINTENANCE hinder the installation of self-consumption?	0	1	2	3	4	5	NS
B.10	To what extent is the high volume of initial INVESTMENT an obstacle to self-consumption?	0	1	2	3	4	5	NS

INCENTIVES		No relevance or little relevance					Very relevant	
1.1	To what extent would a substantial change in LEGISLATION encourage self-consumption?	0	1	2	3	4	5	NS
1.2	To what extent would simplification of ADMINISTRATIVE PROCEDURES encourage self-consumption?	0	1	2	3	4	5	NS
1.3	To what extent would lower TECHNOLOGY PRICES increase self-consumption?	0	1	2	3	4	5	NS
1.4	To what extent would the downgrade of network CONNECTION RATES involve more installations?	0	1	2	3	4	5	NS
1.5	To what extent would SUBSIDIES encourage self-consumption?	0	1	2	3	4	5	NS
1.6	To what extent would rising the PRICE OF ELECTRICITY mean more self-consumption?	0	1	2	3	4	5	NS
1.7	To what extent would making easier the INSTALLATION PROCESS increase self-consumption?	0	1	2	3	4	5	NS
1.8	To what extent would INFORMATION CAMPAIGNS encourage self-consumption?	0	1	2	3	4	5	NS
1.9	To what extent would lower MAINTENANCE COSTS increase self-consumption?	0	1	2	3	4	5	NS
1.10	To what extent would greater ENVIRONMENTAL AWARENESS facilitate self-consumption?	0	1	2	3	4	5	NS

FACILITIES		or little relevance		relevant
Type) What type of facilities has you installed?				
Price) What medium price had facilities you executed?				
Costs) What is the % average cost dedicated approximately to the material and equipment purchase necessary for the installation?				
Grants) What is the % of public aid received on the average?				
Total) Average cost € / Wp of the total self-consumption facilities executed				
Average % of external financing received by prosumers: _____ %		Average % of public grants received by prosumers for financing the investments: _____ %		Average size of the installations executed (peak power): _____ kWp

Please indicate if some of the following calculations were performed in the installed facilities

Economic saving obtained through the facility	<input type="checkbox"/> Yes - Estimated percentage _____ (% €)	<input type="checkbox"/> NO	<input type="checkbox"/> NS
Emission saving obtained through the facility	<input type="checkbox"/> Yes - Estimated percentage _____ (%CO ₂)	<input type="checkbox"/> NO	<input type="checkbox"/> NS

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