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TECHNICAL ECONOMIC STUDY: A Collective Photovoltaic Installation

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Abstract:

Since the recognition of self-consumption in Spain in 2019, self-consumption photovoltaic installations have experienced significant growth. This fact, together with a rise in energy prices, has allowed the development of both individual and collective distributed photovoltaic generation. Collective installations allow several consumers to benefit from a single photovoltaic installation. The use of dynamic distribution coefficients of the photovoltaic energy among the different consumers for each hour of the period is allowed and can be determined according to the criteria considered most appropriate by the participants. This article makes a technical and economic study of a photovoltaic installation for collective self-consumption of a group of houses located in Tafira - Gran Canaria, with different possibilities of photovoltaic energy distribution coefficients, both fixed and dynamic, to study the profitability of the different energy distribution and optimize the energy distribution, taking into account the different consumption curves and electricity contracts of each of the consumers. Eight cases of energy sharing are studied, the most characteristic and with which the best results are the cases with coefficients based on previous consumptions and current consumptions (in situ).

Keywords:

Shared Self-Consumption, Photovoltaic Energy, Renewable Energy.

1. Introduction

The Canary Islands are rich in natural resources, especially the wind and sun. The Canary Islands has abundant hours of light that allow the production of a photovoltaic panel installation to be much higher than in other areas, photovoltaic energy in the Canary Islands is an opportunity for the economy since, the installations of photovoltaic panels in hotels or other establishments provide savings and companies can offer more competitive prices.

Anthony Roy [1], Jean-Christophe Olivier, François Auger [1], Bruno Auvity [1], Salvy Bourguet [1], and Emmanuel Schaeffer [1] mention that collective self-consumption is especially useful in places that lack lands such as the Canary Islands, the Balearic Islands, large cities such as Madrid and Barcelona, or industrial estates. Thanks to this mode of self-consumption, consumers can benefit from a shared investment, which means that many consumers can have clean electricity at an affordable price. On the other hand, with collective self-consumption, you can obtain savings of up to 70% in the electricity bill, and reduce greenhouse gas emissions, and emissions of polluting gases, therefore, the carbon footprint of consumers. In addition, this type of facility will allow us to move towards a market of real flexibility, cleaner, decentralized, and less dependent on fossil fuels.

The collective self-consumption of photovoltaic solar energy has great advantages for the consumer, however, there are many unknowns when executing a project of this type. For example, the calculation and allocation of the distribution coefficient β among final consumers, which represents the proportion of the net energy generated that corresponds to each consumer.

On April 5, 2019, Royal Decree 244/2019 was approved, which regulates electricity self-consumption in Spain. This Royal Decree recognized collective self-consumption for the first time [2]. This change in the regulations allows several people to join and consume from the same generation plant. Royal Decree 244/2019 provides for the existence of coefficients to distribute energy in collective self-consumption. The value of these partition coefficients depends on the agreement between the participants, with the only requirement that they be constant values. These criteria and coefficients must be included in the agreement between the participants

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and each consumer must send to the distributor or through its marketing company. The annex I of Royal Decree 244/2019, of April 5, establishes that: [2]

"The value of these coefficients may be determined according to the power to be billed by each of the participating associated consumers, the economic contribution of each of the consumers for the generation facility, or any other criterion provided that there is an agreement signed by all the participants and provided that the sum of these coefficients β i of all consumers who participate in collective self-consumption is the unit. In any case, the value of these coefficients must be constant" In addition, on November 15, 2021, Annex I was modified, which allows each participant to have a dynamic energy distribution coefficient under any criterion, as long as all consumers agree.

Villalonga [3], Serrano [3], Riquellme [3], Alvarez [3] and Roldan [3] mention that despite the fact that this normative represents ¨an advance over the previous regulatory framework, this new regulation introduces a series of inefficiencies with respect to the criteria for sharing the energy produced by the collective generation system. These inefficiencies are associated with an economic cost for the members of the collective self-consumption community, which to a certain extent may discourage its deployment, with the consequent negative impact on the development of renewable energies and the achievement of climate objectives´´.

That said, taking into account Royal Decree 244/2019 and order TED/1247/2021 [4] , an analysis is carried out to determine the different benefits that can be obtained with permanent and dynamic energy distribution coefficients for the case of collective self-consumption of 15 homes located on the Island of Gran Canaria (Spain). Using these homes, the economic viability and benefits of each of the dwellings obtained from different methods of distributing the PV energy generated will be analysed.

2. Methodology:

In this work, a technical economic study of a photovoltaic installation for collective self-consumption in a housing development with 15 houses located in Tafira - Las Palmas De Gran Canaria (Spain) is carried out.

For this study, 2 main scenarios have been considered. The first scenario assumes that the neighbours decide to invest in a self-consumption installation individually. Each one contracts the same installation company. In turn, as it is individual self-consumption, each house will have its own single-phase inverter and photovoltaic panels.

The second scenario is collective self-consumption, in which all the neighbours make a joint investment in photovoltaic solar panels and a connection inverter for all the installed power. Making a joint investment could reduce costs since the purchase and installation is cheaper the larger the investment.

In order to carry out this work, a series of steps were followed. First, we obtained the actual consumption of the fifteen houses, hour by hour during the period of one year. After this, we studied the consumption profiles, from which we obtained the percentage of consumption in hours of sunshine, the houses with the highest percentage will take more advantage of the energy produced by the photovoltaic panels.

In each of the houses, we chose to study their annual energy consumption and the availability of the roofs to estimate the peak power installed in the individual case. In the case of collective installation, an identical installation was simulated for each house. In order to study the electricity generation obtained in each installation, the photovoltaic production is estimated based on the solar radiation of the area. Table 1 shows the peak power that would correspond to each house according to the annual energy consumption, both for the individual case and the cases of collective self-consumption.

Table 1. Summary peak power to be installed in each home in the case of individual and collective self-consumption.

House N.º	Consumption Annual (kWh/year)	Hsp	P. Peak individual (kW)	P. Peak Collective (kW)
House 1	9948	2025	5.46	3.51
House 2	6000,6	2025	3.51	3.51
House 3	5397	2025	3.12	3.51
House 4	4599	2025	2.8	3.51
House 5	5610	2025	3.12	3.51
House 6	3361	2025	2.34	3.51
House 7	7970	2025	4.68	3.51
House 8	5610	2025	3.12	3.51
House 9	5610	2025	3.12	3.51
House 10	3361	2025	2.34	3.51
House 11	9948	2025	5.46	3.51
House 12	4599	2025	2.8	3.51
House 13	5610	2025	3.12	3.51
House 14	5610	2025	3.12	3.51
House 15	5610	2025	3.12	3.51
Total consumption	88844		51.23	52.65

Once the peak photovoltaic power for each case study has been estimated, we use the data obtained in the weather stations installed by the University of Las Palmas de Gran Canaria in the city of Las Palmas. From these data, the electrical energy produced using the described model is calculated. [5] [6] [7]

On the other hand, the different types of electricity billing that the owners had, according to the electricity market, which can be free market or regulated market (PVPC) were studied. The difference between these two markets is that the free market allows having a constant energy price during the contracting period, while in the regulated market the price of electricity changes hour by hour and day by day according to the supply and demand between the producers and marketers. In addition, the compensation price of surpluses also depends on the type of contract of the owner, in the same way as the purchase price of energy.

For the calculations, the data for the purchase and sale of electricity in the regulated market were obtained from the Sistema De Información Del Operador Del Sistema (eSios) website [7], while for the free market, a fixed purchase price of 0.16 €/kWh and a fixed sale price of 0.06 €/kWh were established. Once all these data were obtained for each of the homes, different cases of coefficients of distribution of energy generated by collective self-consumption were studied. From these coefficients, the calculations of the net energy balance were made in each hour, surplus (€) and network consumption (€) with which we will study the profitability of the installation in each case. In addition, other terms of the electricity bill such as power or electricity tax were studied, in order to make an approximate calculation of the price of this for each home in order to determine the savings in the electricity bill. In order to decide the best installation in each case, budgets were made, the economic feasibility study (NPV) and the results obtained were analyzed.

3. Cases of study

According to [2] "the net hourly energy generated individualized of those subjects 'i' that carry out collective or consumer self-consumption associated with a nearby installation through the network, ENG h, 'i' it Will be:

$$\boldsymbol{ENGh, i = \beta i . ENGh}$$

$ENGh$: total net hourly energy produced by the generator(s).

βi: Coefficient of distribution of the energy generated among consumers who participate in collective self-consumption.

For each consumer '*i'* participant of collective self-consumption, this coefficient will take the value that appears in an agreement signed by all consumers participating in collective self-consumption and notified to the distribution company as responsible for reading consumption. The value of these coefficients can be determined with any criterion, provided that there is a signed agreement for all participants and provided that the sum of the beta coefficient of all consumers participating in collective self-consumption is unity."

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The generic formula established by the royal decree to find the coefficient of energy distribution is as follows:

$$\beta i = \frac{Pci}{\sum Pcj}$$

Pci: Maximum power contracted to the associated consumer i.

∑PCJ: Sum of the maximum powers contracted by all consumers who participate in collective self-consumption.

Based on the above, the following cases of energy distribution coefficient are proposed:

1. **Individual Self-consumption with surplus and Compensation (ISC):** Each owner of a home invests in a photovoltaic self-consumption installation individually, that is, each home will have its own single-phase inverter and photovoltaic panels.
2. **Collective self-consumption with distribution coefficient according to the number of houses (CFC-NH):** In this case, it has been decided that the beta energy distribution coefficient will be the same for all houses at all times of the year and the criterion is the total number of houses that will participate in self-consumption (15 dwellings), the way to calculate it is as follows:

$$\beta i = \frac{1}{15} = 0.06666666667$$

3. **Collective self-consumption with a distribution coefficient based on the contracted power in the electricity bill (CFC-PEB):** In this case, the criterion for choosing the beta coefficient of energy distribution will be according to the contracted power that each of the 15 dwellings has in the electricity contract, in this way each dwelling will have its own beta coefficient that will be the same for each hour of the year. The formula for calculating the beta coefficient is as follows:

$$\beta i = \frac{contracted\ power\ i}{\sum contracted\ power\ of\ the\ dwelling\ j}$$

4. **Collective self-consumption with distribution coefficient according to peak installed (CFC-IPP):** For this case study it has been decided that the criterion for calculating the beta coefficient will be the peak installed power of each of the dwellings, this power will be the same as that used for the case of individual self-consumption. In this case, the formula used for calculating the beta coefficient for energy distribution is the following:

$$\beta i = \frac{PV\ power\ installed\ i}{\sum \text{PV}\ power\ installed\ of\ the\ dwelling\ j}$$

5. **Collective self-consumption with dynamic distribution coefficient according to monthly consumption ex ante (CFC-MCE):** As mentioned in section No. 5, on November 15, 2021, Annex I of RD 244/2019 [3] was modified. Said modification allows the use of dynamic distribution coefficients, these coefficients may be different for each hour of the billing period as long as the coefficient βi is unity. The ex-ante monthly consumption is the criteria selected to determine the dynamic allocation coefficient.

   The term ex-ante means "before the event", in the case of collective self-consumption it will be a coefficient of distribution prior to the energy consumption. For calculating this coefficient we have decided to take the monthly consumption ex-ante for two months. The coefficient will be constant for all the hours of the same month but will adopt a different value for each month.

   It is taken as ex-ante data for two previous months because normally the billing comes every two months. In this way, the process for the new allocation of the betas coefficients would not be delayed every month. The formula to find the ex-ante dynamic allocation coefficient is:

$$\beta i(marzo) = \frac{January\ dwelling\ consuption\ i}{\sum January\ dwelling\ consuption\ j}$$

   The previous formula indicates that if we want to know what the coefficient βi is for the month of March I will have to use the consumption for the month of January.

6. **Collective self-consumption with distribution coefficient according to hourly consumption ex-ante (CFC-HCEA):** This coefficient is similar to the dynamic monthly ex-ante with the difference that there will be a different distribution coefficient for each hour. For the calculation of this coefficient we have decided to take the ex-ante hourly consumption two months prior to the month for which we want to calculate the coefficient, i.e., if we want to find the distribution coefficient in January, we will use the hourly consumption for the month of November. The formula to find the dynamic ex-ante allocation coefficient is:

$$\beta i = \frac{hourly\ ex\ ante\ consuption\ of\ dwelling\ i}{\sum hourly\ ex\ ante\ consuption\ of\ dwlling\ j}$$

7. **Collective self-consumption with distribution coefficient according to hourly consumption ex-post (CFC-HCEP)**: Despite the current regulation does not allow using these distribution coefficients, as a study, this work will calculate the ex-post dynamic coefficient in order to compare them in the future with the other cases of energy distribution coefficients and see which of them is more convenient for collective self-consumption. The term ex post refers to consumptions based on real and on-site readings. The calculation will be the same as the one used to find the dynamic distribution coefficient ex with the only difference that we take the hourly consumptions of the same hour from which we want to calculate the coefficient, i.e., if we want to find the distribution coefficient at 13 o'clock we will use the consumptions of that same hour 13. The formula to find the dynamic distribution coefficient ex-post is:

$$\beta i = \frac{hourly\ home\ consuption\ per\ hour\ i}{\sum hourly\ home\ consuption\ per\ hour\ j}$$

8. **Collective self-consumption with distribution coefficient according to hourly consumption ex-post with consumption improvement in a dwelling (CFC-IMP):** Solar energy generation occurs during daylight hours, so it is crucial to self-consume as much of the energy produced as possible since surplus energy is not paid for at the same price as the energy purchased. Therefore, the best option is to use as much of the energy produced by solar panels as possible.

   In order to demonstrate that consumers adapt their consumption to sunny hours the results will improve. For the demonstration, we have chosen house No. 1 for the ex-post sharing coefficient case.

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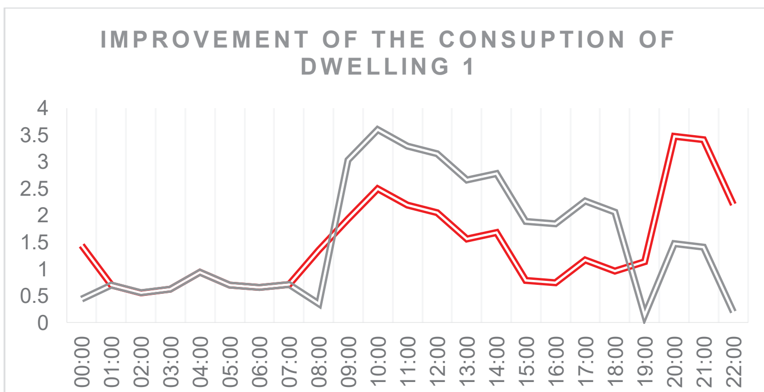

Figure. 1. Consumption before (red) and after (grey) the improvement of the consumption of dwelling No. 1 for 02/28/2021.

In the case of the ex-post dynamic distribution coefficient, as house 1 will adapt its consumption to the hours of sunshine, its beta coefficient will be higher compared to the rest of the houses. This will result in a higher energy distribution, a decrease in grid consumption, an increase in surpluses and an increase in the percentage of self-consumption over total consumption.

4. Economic study

4.1. Electricity bill

The changes suffered by electricity bills if the photovoltaic installation is carried out will be analyzed in order to visualize the economic savings that it would mean for the owners in each of the cases studied. As mentioned above, the electric bill has fixed terms that will be present even with no electricity consumption. The variable term is where the economic savings for self-consumption are visualized. Greater self-consumption translates into a decrease in the energy purchased from the grid, and therefore lower cost. In addition, to the variable term is added the fact that if there are surpluses of the photovoltaic generation they can be compensated in the monthly bill.

The term variable shall adopt the following formula:

- No photovoltaic installation:

Variable term= Network consumption (kWh) x Price (€/kWh)

- With photovoltaic installation:

Variable term= Network consumption (kWh) x Price (€/kWh)- Compensable surplus (€/kWh)

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For the estimation of the annual bills of the houses, the following price assumptions have been used:

Table 2. Data used for electricity bills on the regulated market

Electricity tax	5.11%
Canary Tax	7.0%
Power	0.083 €/kWh
Energy Price	eSios
Compensated energy price	eSios

The regulated market prices correspond to the year 2021 and, as mentioned above, were obtained from the website of Red Eléctrica [8] de España eSios [9]. While the data used for the free market electricity bill are shown in Table 3.

Table 3. Data used for the free market electricity bill.

Electricity tax	5.11%
IGIC	7.00%
Contracted power	0.083 €/kWh
Energy Price	0.168662
Compensated energy price	0.0663 €/kWh

4.2. Investment

An estimated budget is made for the case of individual installation and collective self-consumption. In addition, ways to distribute investment in cases of collective self-consumption are proposed.

The economic distribution is made as follows:

$$\textit{Individual investment for fixed coefficents } \beta i = \text{total } \textit{investment x } \beta \textit{ fixed i}$$

$$\textit{Individual investment for dynamic coefficents } \beta i = \frac{\textit{total investment}}{\sum \textit{dwelling}}$$

in the following table, we can see a summary of the investment for each case and each home.

Table 4. Summary of the investments of each of the houses for the different case studies.

House N.º	CASE 1	CASE 2,5,6,7	CASE 4	CASE 3
House 1	9.454 €	4.621 €	7.763 €	4.666 €
House 2	7.841 €	4.621 €	4.683 €	4.666 €
House 3	7.810 €	4.621 €	4.212 €	4.243 €
House 4	6.738 €	4.621 €	3.589 €	4.243 €
House 5	7.810 €	4.621 €	4.378 €	4.874 €
House 6	6.473 €	4.621 €	2.623 €	4.243 €
House 7	8.579 €	4.621 €	6.219 €	4.874 €
House 8	7.810 €	4.621 €	4.378 €	4.874 €
House 9	7.810 €	4.621 €	4.378 €	4.874 €
House 10	7.810 €	4.621 €	4.378 €	4.874 €
House 11	9.454 €	4.621 €	7.763 €	4.666 €
House 12	6.738 €	4.621 €	3.589 €	4.243 €
House 13	7.810 €	4.621 €	4.378 €	4.874 €
House 14	7.810 €	4.621 €	4.378 €	4.874 €
House 15	7.810 €	4.621 €	4.378 €	4.874 €

5. Results

Several conclusions can be drawn from the cases studied, either from an economic point of view, referring to the NPV, or from the point of view of savings in the electricity bill, which will depend on several factors such as consumption, type of market or contracted power.
In order to be able to understand the reason for the results, Table 5 shows the data for each house, which will be used to identify them and see their main differences:

Table 5. Summary of characteristic data of the dwellings

House N.º	Annual consumption (kWh/Año)	% Sun Hours Consumption	Contracted power (kW)	Electricy market	Electricity Bill no PV (€)
House 1	9948	48%	5.5	Free	2084
House 2	6000	61%	5.5	Regulated	1481
House 3	5397	61%	5	Regulated	1338
House 4	4599	52%	5	Regulated	1143
House 5	5610	54%	5.75	Free	1272
House 6	3361	56%	5	Regulated	938
House 7	7970	63%	5.75	Free	1719

The importance of the % consumption in hours of sunshine was mentioned previously since the consumers who have a higher percentage will benefit more because they will consume more energy from the photovoltaic panels than energy from the electric grid. House No. 7, 2 and 3 have the highest consumption in sunlight hours; on the contrary, houses No. 1, 4, 5 and 6 have a slightly lower percentage, meaning that they consume more energy at night than during the day.

5.1. Economic feasibility

Several economic parameters were studied to determine the feasibility of each case, such as NPV, ERP and savings obtained in the electricity bill. Below, we can see the results obtained for the houses with the highest consumption (1;11) and the houses with the lowest consumption (6;10)

***Table* 6.** Summary of economic results obtained from housing 1 and 6.

Colours scale from worst to best.

Nº DWELLING	1	6	1	6	1	6
	NPV €		SAVINGS%		ERP	
Cfc-Nh	10048	4835	55%	52%	9	9
Cfc-Peb	9511	6687	40%	71%	6	8
Cfc-Ipp	8679	9655	38%	66%	6	6
Cfc-Mce	9501	5581	53%	52%	7	6
Cfc-Hcea	15329	3633	56%	53%	4	10
Cfc-Hcep	14604	4530	54%	58%	4	9
Cfc-Imp	13724	4410	48%	57%	5	9

Table 6 shows that cases with fixed coefficients benefit homes with higher consumption, while houses with low consumption obtain better benefits with fixed distribution coefficients.

5.2. Percentage of distribution of electrical energy over the total produced

This percentage indicates the electrical energy that corresponds to each dwelling annually as agreed. The following table shows how the distribution of energy improves or worsens according to the distribution coefficients adopted. The homes that have a higher percentage mean that it corresponds to more photovoltaic energy.

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Table 7. Percentage of distribution of photovoltaic energy of each dwelling part of the total energy production of the installation.

% PV allocation energy/ Total PV production						
	CFC-NH	CFC-PEB	CFC-IPP	CFC-MCE	CFC-HCEA	CFC-HCEP
House 1	7%	7%	11%	11%	10%	9%
House 2	7%	7%	7%	8%	8%	8%
House 3	7%	6%	6%	7%	7%	7%
House 4	7%	6%	5%	5%	6%	6%
House 5	7%	7%	6%	6%	6%	6%
House 6	7%	6%	4%	4%	4%	4%
House 7	7%	7%	9%	9%	11%	11%
House 8	7%	7%	6%	6%	6%	6%
House 9	7%	7%	6%	6%	6%	6%
House 10	7%	6%	4%	4%	4%	4%
House 11	7%	7%	11%	11%	10%	9%
House 12	7%	6%	5%	5%	6%	6%
House 13	7%	7%	6%	6%	6%	6%
House 14	7%	7%	6%	6%	6%	6%
House 15	7%	7%	6%	6%	6%	6%
Total	100%	100%	100%	100%	100%	100%

We can see that the CFC-NH case is the same for everyone, this is because the distribution is made equally. The CFC-PEB case depends on the contracted power that each house has, we can see that there is not much variation, the reason is that all houses have a very similar power (between 5 to 5.75 kW).

$$\uparrow \boldsymbol{Contracted\ power} \uparrow \%\ \boldsymbol{PV\ energy\ allocation}$$

In the case of CFC-IPP, if we can see the difference, the houses that have greater installed power will have a higher percentage.

$$\uparrow \boldsymbol{Power\ installed}\ \uparrow \%\boldsymbol{PV\ energy\ allocation}$$

The CFC-MCE case benefits more households with the highest monthly consumption. House 1 has the highest consumption in all months of the year, which is the reason why this house corresponds to a higher percentage of photovoltaic energy.

$$\uparrow \boldsymbol{Monthly\ consumption}\ \uparrow \%\ \boldsymbol{PV\ energy\ allocation}$$

For the cases CFC-HCEA and CFC-HCEP the order of preference that will define whether a house corresponds to more or less a percentage of the distribution of photovoltaic energy will be:

1. Houses with high consumption and also do it on sunny hours.
2. Houses with high consumption, but do most of it at night
3. Houses with low consumption, but make most of it in sunny hours

5.3. Percentage of self-consumption over total consumption

Having a higher percentage of self-consumption means having greater savings in the electricity bill, since the consumption of the network is reduced, in addition, knowing that the compensable energy is paid worse than the price of energy from the network, the importance of everything generated is self-consumption is visualized and surpluses are avoided. The table below shows the percentages of self-consumption, these percentages correspond to the fraction of total consumption that is consumed during the hours in which the PV system is generating energy and the remaining percentage is obtained from the grid.

Table 8. Percentage of self-consumption for each of the case studies

	CFC-NH	CFC-PEB	CFC-IPP	CFC-MCE	CFC-HCEA	CFC-HCEP	CFC-IMP
House 1	35%	33%	32%	35%	38%	35%	39%
House 2	40%	38%	38%	35%	44%	46%	50%
House 3	42%	42%	41%	43%	40%	33%	50%
House 4	43%	47%	46%	4%	42	46%	46%
House 5	41%	42%	40%	40%	41%	47%	44%
House 6	43%	47%	30%	44%	43%	45%	47%

5.4. Overall results

In view of the results of the investments shown in Table 5, it can be concluded that opting for any case of collective self-consumption is more economical than individual self-consumption since savings of up to 50% can be made on the investment.

The cases with fixed coefficients, especially CFC-NH and CFC-PEB are the ones that benefit less to houses with high consumption because the distribution is made in equal parts without taking into account the consumption of the house, in these cases, it can happen that while a house with low consumption produces surpluses, another with high consumption will need to consume from the electricity grid.

We have taken the consumption and energy distribution of houses 1 and 6 for case 2, in this case, the two houses have the same amount of energy, house 6 has more energy than it consumes and house 1 needs to consume energy from the grid to meet its demand. This is the reason why these cases obtain the lowest savings in the electricity bill. The houses with low consumption, which in turn consume energy during sunlight hours, tend to have better results with fixed coefficients.

Table *9*. Comparison of houses 1 and 6 for Cfc-Peb case.

House	Hour	Hourly Consumption (kWh)	Cast Fv (kWh)	Net Balance (kWh)	Energy Price (€/kWh)	Compensation Price (€/kWh)	Network (€)	Surplus (€)
House	10	2.21	1.79	-0.41	0.168662	0.0663	0.07	0
House	10	0.25	1.79	1.54	0.22122	0.08266	0	0.128

Table 9 compares a house with high consumption versus a house with low consumption for the cases with fixed coefficients, it is observed that the house with low consumption is supplied with photovoltaic energy and even has surpluses. On the contrary, house 1 has a higher consumption and cannot be supplied with photovoltaic energy, so it has to consume energy from the electric grid.

Houses with a higher percentage of sunshine hours will obtain greater benefits with dynamic distribution coefficients. Since they have a higher beta coefficient compared to the rest of the houses and, therefore, they have a higher energy distribution.

consumers who adapt their electricity consumption to the hours of sunshine will be able to achieve a higher percentage of self-consumption and therefore greater savings. In addition, they will obtain better economic results and will recover their photovoltaic investment in less time. The study was carried out in the months of January and February with house 1.

The results are shown in Table 10, comparing the case of self-consumption with ex-post coefficient without improvement versus ex-post with improvement in the months of January and February.

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Table 10. *Comparison of the results obtained before and after the improvement in consumption.*

House 1	January		February	
	No Improvement	With improvement	No Improvement	With improvement
Consumption Month (kWh)	1305	1305	999	999
Energy Distribution (kWh)	792	1235	837	1241
Mains consumption (kWh)	861	615	584	389
Surpluses (kWh)	25	545	29	630
% Self-consumption	32%	53%	40%	61%

Energy consumption through the grid decreased by 30% in both January and February. However, surpluses increased by 31% due to the increase in energy sharing. In addition, energy sharing increases because the sharing coefficient increases. Table 11 shows the variation of the energy sharing percentage, while for house 1 it increases from 12.59% to 19%, and for the rest of the houses it decreases

Table 11. photovoltaic energy allocation percentage before and after the improvement of the consumption of house 1.

% Energy Distribution		
	No Improvement	With improvement
House 1	12.59%	19,00%
House 2	6.09%	5.98%
House 3	5.48%	5.14%
House 4	5.38%	5.1%
House 5	4.86%	4.35%
House 6	4.66%	4.15%
House 7	14.45%	14.01%
House 8	4.86%	4.35%
House 9	4.86%	4.35%
House 10	4.66%	4.15%
House 11	12.59%	12.21%
House 12	5.38%	5.1%
House 13	4.86%	4.35%
House 14	4.86%	4.35%
House 15	4.86%	4.35%
Total	100%	100%

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6. Conclusions

In view of the economic results, it is concluded that opting for collective self-consumption is an economically more beneficial decision than individual self-consumption.

The cases with dynamic coefficients are better than permanent coefficients. Because dynamic coefficients take into account the consumptions of the houses, then the distribution of energy will be done in an efficient way. On the other hand, fixed coefficients distribute the energy equally, without taking into account this important aspect.

The cases of collective self-consumption with permanent distribution coefficients are suitable for houses with low consumption during sunlight hours. If the consumptions are very low, these houses will have many surpluses and this will not be convenient because the purchase price of these surpluses is very low. On the other hand, houses with high consumption do not benefit from this coefficient because the distribution of energy is not very efficient since, while the houses with low consumption produce surpluses, the houses with high consumption will have to consume from the grid.

The problem of the efficient distribution of consumption is solved with the dynamic coefficients, these coefficients optimize the allocation of energy that corresponds to the different consumers. For example, they allow adjusting the distribution of photovoltaic energy to different casuistry, for example, to adjust to different daily consumption habits.

In addition, if consumers adapt their electricity consumption to the hours when the installation is generating energy, it is found that self-consumption increases and therefore the savings on the electricity bill is higher.

The results obtained in this study will help communities of neighbours to make a decision on which distribution coefficient to choose. However, the ex-post coefficient is recommended because the distribution of energy is made according to instantaneous consumption, thus, if a house increases its consumption in sunny hours, it will obtain greater energy savings.

The acceptance of dynamic coefficients is an important step towards the ecological transition in Spain. Even so, governments must continue to take measures and seek solutions to encourage photovoltaic self-consumption if they Xant to meet the targets set.

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