

When Uncertainty Hurts – Decision to participate in a Collective Self Consumption operation – Evidence from France

Key Words: Energy; Regulation ; Decentralization.

Abstract

Achieving carbon neutrality in Europe requires a significant expansion of renewable electricity generation and new mechanisms to valorize decentralized production. Traditional support schemes such as feed-in tariffs and net metering have been criticized for their economic inefficiencies, particularly their inability to reflect temporal, spatial, and system value differences. In France, collective self-consumption (CSC), introduced in 2015, enables locally produced electricity to be shared among nearby participants organized within a legal entity, potentially creating a form of local energy market.

Despite the rapid growth of CSC projects—half of which are initiated by local authorities—the determinants of participation in open CSC operations remain largely unexplored. Existing literature mainly focuses on the profitability and internal governance of energy communities, emphasizing the role of self-consumption rates, load profile complementarity, and sharing rules. However, little attention has been paid to the initial decision of public producers to engage in such arrangements.

This article develops a theoretical model in which a local authority chooses between selling its surplus electricity to EDF OA or creating an open CSC operation with a backup sale to EDF OA. The model highlights the role of surplus volume, internal electricity prices, and participant recruitment costs in shaping this decision. It derives the conditions under which local electricity exchange becomes economically preferable, contributing to the literature on distributed energy incentives and the emergence of local energy markets.

Introduction

According to RTE, achieving carbon neutrality in 2021 would require a significant increase in renewable energy production capacity (*RTE, 2021*) and a major overhaul of energy systems in France and Europe. To support this transition, the European RED II and RED III directives defined four fundamental strategic objectives: increasing renewable production capacity, mobilizing private capital, increasing consumer participation, and bringing flexibility to the electricity system (*Vernay et al., 2023*).

Furthermore, the inefficiencies of mechanisms such as net metering and feed-in tariffs make it necessary to implement new market mechanisms (*Newbery et al., 2018*). In France, these two mechanisms, known as the purchase obligation and individual self-consumption, have been offered by EDF OA and local distribution companies (ELD) since 2000 for installations of less than 500 kWc. The proposed feed-in tariffs vary depending on the mechanism (total sale for the purchase obligation and surplus sale for solar self-consumption)

and the power of the installations. The economic efficiency of these mechanisms is questioned in the literature: prices do not take into account the temporal dimension (prices determined well in advance), the spatial dimension (no local variation), or externalities (additional services provided to the grid) (Newbery et al., 2018). Furthermore, these feed-in tariffs create a risk of over-subsidization when the tariff level is poorly adjusted, thus leading to economic inefficiency (Madlener, Neustadt, 2010). Khorasany, Mishra, and Ledwich (2018) also highlighted a disincentive effect when the electricity purchase price is lower than the retail market price. In France, the rollout of collective self-consumption (CSC) is directly in line with this dynamic, although it only partially meets these ambitions. While CSC is intended to increase installed capacity, particularly through solar photovoltaics, and to mobilize private savings or local investment, its impact on active citizen participation remains modest and largely dependent on third-party facilitators. Furthermore, research highlights that CSC currently has no tangible effect on the flexibility of the French electricity system (Vernay et al., 2023).

The CSC is a market mechanism implemented in 2015 in the “Transition Energétique pour la Croissance Verte” law. It enables the valorization of decentralized electricity production theoretically within a Local Energy Market. Collective self-consumption (CSC) refers in French law to the supply of electricity organized between one or more producers and one or more end consumers, who must be linked within a legal entity (often referred to as the *Personne Morale Organisatrice*, PMO). This legal framework anchors CSC in a “regulated” local sharing system (rather than a liberalized peer-to-peer market), where collective organization, internal rules, and information exchanges with the network operator become structuring factors for member participation (Law No. 2025-391 of April 30, 2025). The Energy Code distinguishes between “patrimonial” operations, where the producer, consumer, and PMO are a single entity and the electricity is shared between several buildings, and “open” operations, where several entities exchange electricity within a framework constrained by criteria of geographical proximity and power. These criteria are defined by ministerial decree after consultation with the Energy Regulatory Commission. The regular evolution of these criteria reflects an institutional framework that is still being adjusted, which directly influences the potential size of communities and their organizational costs.

Within the operation, the energy is shared among participants thanks to a “sharing rule”. There are 4 different types of sharing rules allowed:

- Static determined by the PMO: the value of the distribution key for self-consumed production is assigned to a consumer according to a fixed percentage for each time step
- Dynamic determined by the PMO: the value of the distribution key may vary for each time step. It can be either:
 - o Simple dynamic and apply to all consumers
 - o Fully dynamic and differentiated for all consumers
- Default dynamics calculated by Enedis on a pro-rata basis according to each consumer’s consumption.

CSC has become a new renewable production valuation mechanism, alongside with Individual Self-Consumption (ISC) with resale of the production surplus (one consumes on one site and resale the surplus to a third party) and resale in full.

Since 2021, the number of active operations has been increasing.

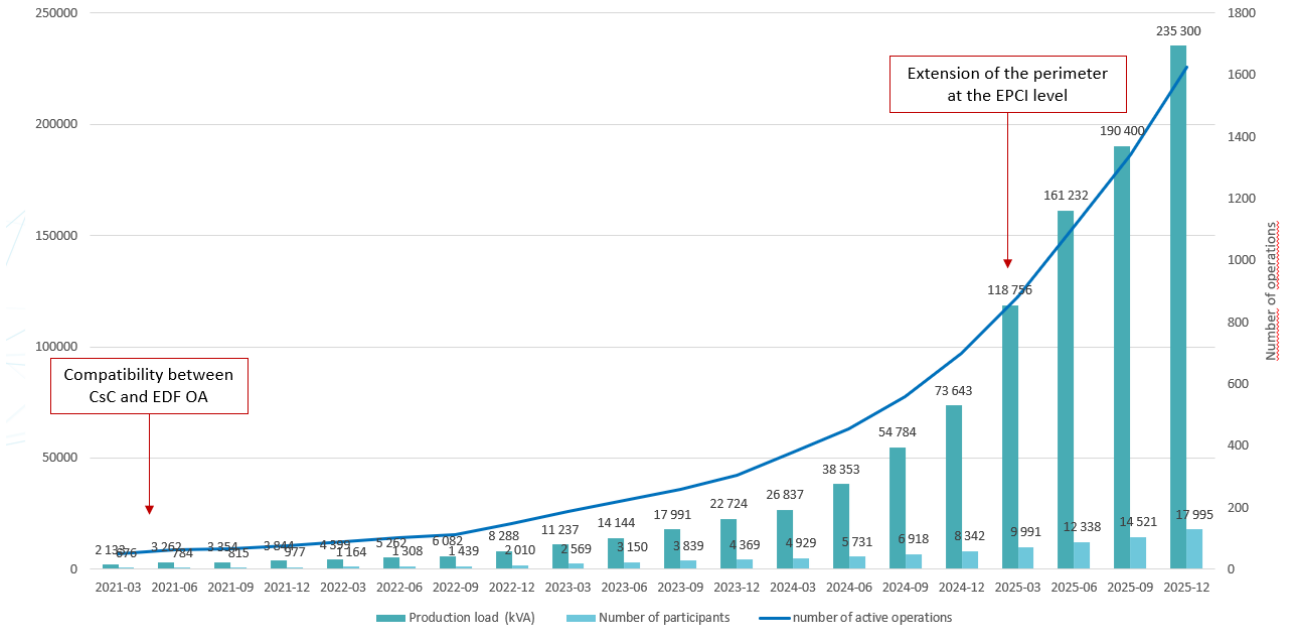


Figure 1: Evolution of CSC, power load generation and number of participants (2021-2025). Enedis Open Data.

During the same period, the prices offered by EDF OA in exchange of surplus production have collapsed. In this perspective, CSC can be seen as a way to enhance the PV panels' return on investment by selling a portion of the production at a higher price than the one offered by EDF OA.

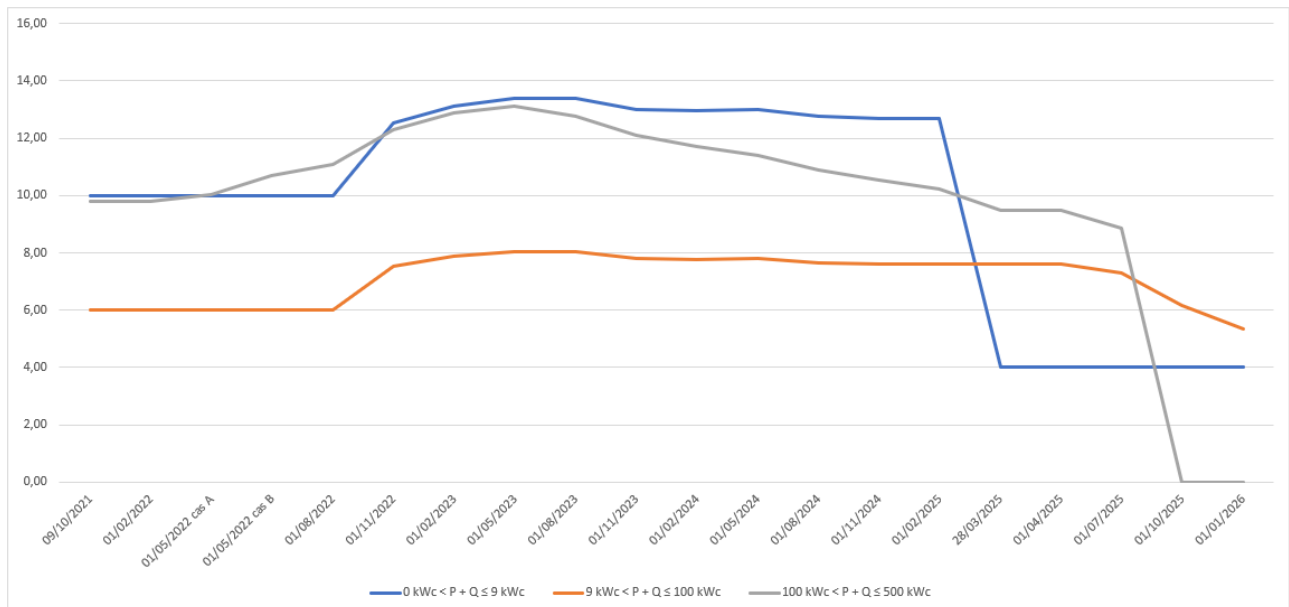


Figure 2: Evolution of surplus prices offered by EDF OA per c€/kWh, excluding investment subsidies by installation capacity. CRE Open Data.

According to Enedis, 50% of CSC are organized by public authorities and most of them are Patrimonial ones which means that the value creation of this operation is shared only among one participant/organizer. On top of that, the potential for local positive externalities remains limited whereas that could have been one of the main objectives of public authorities. To our understanding, Patrimonial model cannot be seen as a Local Energy Market, because there's no transaction among participants while Open one has the characteristics of LEMs such as the creation of a local price and the management of supply and demand at a local level.

The preliminary question can be the following: Does the CSC mechanism as defined in France encourages local authorities to participate in a LEM?

Literature Review and Research Gap

CSC literature, and in a more widely perspective Local Energy Market Literature, are growing fields of interest, especially in Europe thanks to the RED II and RED III Directives. Frieden and al. (2021, 2020) highlight the diversity of national choices (scope, rights, sharing arrangements, roles of third parties), as well as the legal and organizational frictions caused by these transpositions.

Recent economic literature finally formalizes CSC as an arrangement where the value created depends not only on physical electricity flows, but also on internal governance instruments (sharing rules, internal pricing schemes, membership fees, etc.).

More specifically on CSC's profitability, it is widely accepted in the literature that it is strongly correlated with the rate of self-consumed or collectively consumed energy, measured by the "self-consumption rate." This is because the economic value comes largely from the difference between locally consumed electricity (which avoids purchase at retail price) and surplus electricity (often less valuable) (D'adamo and al., 2022). In this perspective the higher the self-consumption rate, the higher the total value creation of the operation is. This rate can be maximized by two main elements: complementarity of load profiles and the choice of an appropriate sharing rule. Those two objectives can be antagonist because the dependence on the self-consumption rate raises the issue of the heterogeneity of consumption profiles within the community. Beyond aggregate profitability, the literature emphasizes the viability of communities: a collective can create value but fail to stabilize if sub-coalitions have an interest in leaving or if the sharing rule is deemed unacceptable. Abada et al. (2020) draws on cooperative game theory and show that, despite potential gains (including aggregation gains related to network costs), there is no guarantee that a community will be stable; stability depends in particular on coordination costs and the sharing rule. Thus, the heterogeneity of profiles within a coalition seems to play an ambiguous role: it can improve stability by increasing profitability, but it can also increase divergent interests (antagonistic interests between prosumers and simple consumers) and make the coalition unstable (Gautier and al., 2025). In this perspective, internal transaction price(s) (p) must meet the following criteria to satisfy both producers and consumers: National Retail Regulated Price (TRV) $< p <$ Surplus price offered by EDF OA. Furthermore, Bauwens (2016) highlights the fact that the members of an energy cooperative do not form a homogeneous group. Two categories of member motivations emerge: "egocentric"

(material, financial interest) and social or moral norms (environmental concern, interpersonal trust, identification with the group). Long-standing members tend to be more norm-oriented and have a higher level of commitment in terms of finance and governance (*Bauwens, 2016*).

Some sharing rule can maximize this rate, as the dynamic rule (*D'Adamo and al., 2022; Abada and al., 2020; Llera-Sastresa and al., 2023*) but jeopardize the stability of the coalition. For *Abada et al. (2020)*, pro-rata and static rules fail to stabilize the coalition because they do not sufficiently reward members whose consumption profile is most beneficial to the group. *Jacqmin and al. (2026)* analyze the French case in detail: the default rule is a dynamic distribution proportional to consumption, and the authors emphasize that adherence to the default is reinforced by behavioral biases and community governance. They discuss several limitations: the risk of inequity when profiles/flexibilities differ, price signals that may encourage counterproductive behavior (e.g., rebound effect), and tension between a top-down approach and the logic of commons governance.

Pro rata consumption keys tend to maximize self-consumption (and therefore total value) but can result in distributions that are unfavorable to small consumers or less synchronous profiles, thereby reducing heterogeneity and long-term profitability (*Balegamire and Gautier, 2025; Villalonga Palou and al., 2023; Camblong and al., 2023*). Similarly, the per capita rule is considered simpler, more transparent, and fairer, but it undermines the profitability of the operation (*Balegamire and Gautier, 2025; Villalonga Palou and al., 2023*). However, internal sharing rules influence the performance and acceptability of operations (*Camblong and al., 2023*). It is therefore necessary to question the long-term viability of these operations within the framework of the sharing rules defined above.

To conclude, much have been said about the impact of complementarity of load profiles, sharing rules and, to a lesser extent, about the definition of internal prices on the profitability and the stability of the CSC coalitions. Nevertheless, few articles examine the choices made by local authorities between entering a CSC operation or not, even though they account for 50% of CSC projects. Moreover, to our knowledge, no article differentiates between the patrimonial model and the open model. Those topics haven't been seen neither through a Transaction Cost Economics perspective.

Research question: Under what conditions of expected cost and revenues do public authorities decide whether to integrate an open CSC operation?

Contributions:

- Literature on DER-generated electricity market incentives. In Europe, metering and feed-in-tariffs have encouraged the deployment of these technologies among various players, securing their long-term investments (*Dusonchet and Telaretti, 2015; Londo et al., 2020*). But these mechanisms are becoming less and less effective (non-use of grid service potential; lower feed-in tariffs) (*Khorasany, Mishra, Ledwich, 2018*) (*Tushar and al., 2018*).
- Growing literature on CSC

Theoretical framework and main hypothesis

2.1 Mains assumptions and and justification of the scope of the study

1. Difference between patrimonial and open CSC models

Local energy markets are widely studied in the literature as theoretical mechanisms aimed at optimizing the management of distributed energy resources. In this context, LEMs aim to encourage small consumers, producers, and prosumers to exchange energy among themselves in a competitive market environment, ensuring a local balance between supply and demand (*Capper and al., 2022*). From our perspective, the patrimonial CSC does not fit this definition, while the open ACC appears to meet these characteristics.

2. Interest of the field: public authorities in France

The objective of the model is to understand the choice of production valuation within an open collective self-consumption operation in the presence of an alternative valuation method, individual self-consumption or patrimonial self-consumption. The feed-in tariff mechanism, which requires an obligated agent (mainly EDF OA) to purchase the total production, is excluded from the analysis because the set of choices is not uniform: under the feed-in tariff, the producer does not think in terms of surplus production.

Among producers, local authorities are of interest because they have the following characteristics:

- Strict producer. In France, local authorities cannot be prosumers or consumers within a collective self-consumption operation since they are subject to the Public Procurement Code and, in the absence of the possibility of competition between several operations within a given perimeter, they cannot purchase production directly from the operation.
- They account for 50% of collective self-consumption operations, which provides a representative sample of participants in operations at the national level.
- They are characterized by significant heterogeneity in terms of size, land ownership, investment capacity, information system and flow management skills, political orientation, and contestability, among other factors. All of these factors could influence participation in a collective self-consumption operation and could be analyzed.

They are faced with choices constrained by regulations:

- Choice between patrimonial CSC and open CSC, is subject to perimeter restrictions. By their very nature, they have the ability to enhance the value of their production through patrimonial operations. The diversity of uses of their land promotes self-consumption rates. Since 2021, they have had the

option of expanding the scope of their operations to the entire EPCI (public establishment for intermunicipal cooperation). However, this can only be done as part of a patrimonial operation. As soon as they open their operations to other entities, they “lose” their right to exemption.

- They are also subject to solarization obligations that promote surplus generation and force them to consider how to monetize this surplus. In a constrained budgetary environment, it is reasonable to assume that they are interested in opportunities to maximize their return on investment in renewable electricity generation capacity. The solarization obligations to which they are subject under the Climate and Resilience Act (2021) and the Act on the Acceleration of Renewable Energy Production (APER) (2023) concerns:

Asset concerned	When	Obligation	Threshold	Deadlines	Source
Roofs of public buildings (schools, gymnasiums, administrative buildings, hospitals, sports facilities, etc.)	New construction, extension, or major renovation	Renewable energy sources, vegetation, or equivalent	More than 500 m ²	Minimum 30%; then 40% as of July 1, 2026; then 50% as of July 1, 2027	CCH art. L.171-4 ; Service-Public Entreprendre (Légifrance)
Publicly accessible covered parking lots	New construction	Renewable energy sources, vegetation, or equivalent	More than 500 m ²	Minimum 30%; then 40% as of July 1, 2026; then 50% as of July 1, 2027	CCH art. L.171-4 ; Service-Public Entreprendre (Légifrance)
Outdoor parking lots associated with a building project	During the construction, extension, or major renovation of a building concerned	Renewable energy sources, vegetation, or equivalent on at least 50% of the surface area.	More than 500 m ²	Requirement already in effect	CCH art. L.171-4 ; Service-Public Entreprendre (Légifrance)
Existing outdoor parking	Existing public parking lot owned or managed by the local authority	Install shade structures that produce renewable energy on at least 50% of the surface area.	More than 1,500 m ²	Gradual compliance between July 1, 2026, and July 1, 2028	Service-Public Entreprendre ; loi APER art. 40 (Service Public Entreprendre)

In conclusion, local authorities appear relevant to the analysis insofar as they have the option of choosing between the patrimonial model (not considered a LEM) and the open CSC model (considered a LEM), while being subject to solarization obligations that should increase their surplus production to be exploited. Furthermore, the fact that they are strictly producers simplifies the modeling.

2.2 Model

1. Justification of assumptions (interviews conducted + literature)

- The model assumes that if there is a collective self-consumption operation in a given location, consumers will subscribe to this offer at a participant recruitment cost and if, and only if, the price offered within the CSC is $<$ National regulated retail price (TRV)
- Surplus valuation prism (*Balegamire and Gautier, 2025*) and since producers who resell directly are excluded. Possibility of a mixed model for communities: ISC + CSC.
- Presence of a learning effect. Patrimonial model as a prerequisite for expansion, which is why the patrimonial model is considered a simple way of revaluing surplus via EDF OA.
- We assume that the public authority is in charge of the creation of the CSC operation. That is why we not going to pay attention to the feasibility or the stability issue for the simplicity of the model.

2. Set up

Definition of the conditions for switching from a surplus valuation method with EDF OA to a surplus valuation method within an open transaction. It is important to determine the conditions for the creation of a LEM by a public actor, which would allow for reflection on the cost of a decentralized system versus a centralized system.

Key points from the literature:

1. The higher the self-consumption rate within the operation, the higher the total value extracted from the operation
2. Internal prices and the sharing rule determine the feasibility, stability, and distribution of value within the operation

Main goal - comparison of two contracts for the valuation of a local authority's surplus production. Comparison between two options for a local authority: valuing its surplus with EDF OA or **creating** an open CSC operation. This also entails the cost of recruiting participants.

Temporality: it is considered that a local authority can reallocate the value of its surplus production once every 20 years, which is the maximum duration of a contract with EDF OA and the average duration of ACC contracts.

Consider a public authority A that has x consumption points and y production units and that chooses between two contracts on date 0 to monetize its surplus for 20 years.

$$S_t = \max(P_t - C_t, 0)$$

1 pas de temps T = 15 minutes

Instant profit with OA

$$\Pi_t^{OA} = S_t \cdot p^{OA}$$

For 20 years of contract

$$NPV_i^{OA} = \sum_{y=1}^{20} \frac{S_{i,y} p^{OA}}{(1+r)^y} - K_{OA}$$

Instant profit within CSC with an OA backup

- β_i St sold within CSC
- $(1-\beta_i)$ St sold to EDF OA

$$\Pi_t^{ACC} = S_t [\beta_i p^{ACC} + (1 - \beta_i) p^{OA}] - C_{ACC}$$

For 20 years of contract with cost of recruitments:

$$NPV_i^{ACC} = \sum_{y=1}^{20} \frac{S_{i,y} [\beta_i p^{ACC} + (1 - \beta_i) p^{OA}] - C_{ACC}}{(1+r)^y} - K_{ACC} - K_i^{recruit}$$

$$\Delta NPV_i = \sum_{y=1}^{20} \frac{S_{i,y} \beta_i (p^{ACC} - p^{OA}) - C_{ACC}}{(1+r)^y} - (K_{ACC} + K_i^{recruit} - K_{OA})$$

The Public Authority choose CSC if :

$$\Delta NPV_i + \varepsilon_i > 0$$

$$Pr(ACC_i = 1) = \frac{1}{1 + \exp(-\lambda \Delta NPV_i)}$$

The surplus is central to the decision, then the threshold is:

$$S_i^* = \frac{(K_{ACC} + K_i^{recruit} - K_{OA})}{\sum_{y=1}^{20} \frac{\beta_i (p^{ACC} - p^{OA})}{(1+r)^y}}$$

2.3 Theoretical implications

What we could learn from the modelisation is that:

- The central role of the volume effect of the surplus. The model could have been complexified by differentiating the value of the surplus on the moment it happened (daytime, weekend, etc.)
- The central role of B in the decision. To make its decision, the public authority has to know its probability to sell its production to the CSC operation. In that perspective, The levers for calculating B are: internal probability calculation capacity or outsourcing this calculation via a study. In both cases, calculating B represents a cost for the public authority.

Testables hypothesis

On the supply side:

- Do solarization obligations, which will increase the volume of surplus energy produced by public authorities, have an impact on public authorities' decision to participate in an open CSC operation?
- Will a decline of EDF OA resale prices lead to an increase in the number of CSC operations or a voluntary reduction in surplus energy?

On the cost side of the decision:

- Is it the capacity to increase local competition (integration of a large consumer, etc.) or the capacity to increase the probability of B that makes it more likely for public authorities to enroll in an open CSC operation?
- Can a reduction in initialization and fixed costs make it more likely for public authorities to choose CSC?
- Cost reduction (pooling) - Could lower information costs on local consumption profiles lead to an increase in the number of open CSC?
- Regulatory shock: Did the possibility for public authorities to create patrimonial CSC at the level of their EPCI favor patrimonial ones over open CSC? Since this potentially increased the relative cost of opening a CSC because as soon as they open it they lose the advantage of the derogation.

On the internal characteristics of public authorities:

- The larger a community is, the more land it has, etc. => impact on its decision to integrate an open CSC operation?

- The effect of the characteristics of the public authority (Town hall, public establishment for intermunicipal cooperation, energy syndicate, department, etc.) and thus the nature of its buildings (town halls are often in charge of swimming pools that are heavy consumers even on the weekends), on the capability to enroll in an open CSC operation? Regarding their financial capabilities (town halls are often the weaker in terms of financial capabilities)

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