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REGULATORY ANALYSIS AND INDEPENDENT AGGREGATOR MODELS IN THE PENINSULAR ELECTRICITY SYSTEM

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Regulatory Analysis and Independent Aggregators Models in the Peninsular Electricity System

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Master Thesis

REGULATORY ANALYSIS AND INDEPENDENT AGGREGATOR MODELS IN THE PENINSULAR ELECTRICITY SYSTEM

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Abstract: Regulatory analysis of the regulatory framework surrounding the figure of independent aggregators and their possibility of participating in the explicit demand flexibility services of the national peninsular electricity system. Focus on the development of the product applied to the evaluation of independent aggregation models and their relationship with system agents, to conclude in the proposal of the model that generates the most value.

Keywords: Electricity System, Electricity Market, Regulatory, Explicit Flexibility, Prosumer, Demand Response, Independent Aggregator, Product Development

1. Introduction

The European Union (EU) electricity systems need to make their consumers' demand more flexible to achieve a higher penetration of renewable energies, abandoning fossil generation, which until now has allowed a simple adaptation of centralized generation to demand, to make the EU economy sustainable [1]. In the case of the Spanish peninsular electricity system, with high distributed renewable generation, the current regulation still lacks a defined model of independent aggregation, despite the urgency of its implementation.

Since the implicit flexibility of demand is not sufficient to provide a solution to all the needs of the grid, the figure of the independent aggregator (IA) [2] will be implemented to manage the demand of those active consumers (prosumers) who are willing to vary their net energy balances in exchange for financial compensation. Depending on the technical needs of the electricity system and the economics of their markets, these prosumers will be able to participate in the Technical Restriction Services, Balancing Services, Balancing Services and Wholesale Markets.

During the last decades, electric power has traditionally been managed under a centralized approach, where large generation infrastructures and colossal companies have dominated this energy market, with a few main roles being shared among the players of this oligopoly. However, this should not come as a surprise to the reader, as it is important to remember that the Spanish electricity sector was liberalized only 25 years ago [3].

However, technological evolution, decentralization of generation sources and digitalization are reshaping the energy landscape, giving rise to the emergence of new players, such as Energy Service Companies (ESCOs), Energy Communities or Independent Aggregators (IAs), about to enter the scene. These latter actors, capable of coordinating and optimizing demand according to supply, present a tremendous potential for improving the efficiency of the electricity system [4], as studied in this project.

The impact capacity of these aggregators becomes more tangible as the decentralization of electricity generation increases, as is the case in the peninsular, where Distributed Energy Resources (DERs) are proliferating and are expected to continue to increase fiercely, especially during the current decade [5]. The following Figure 1, are MITECO's targets for the penetration of self-consumption in the country [6] (of course, they represent only a part of the expected DERs, but the estimate is included because of its intrinsic relationship with domestic consumers).

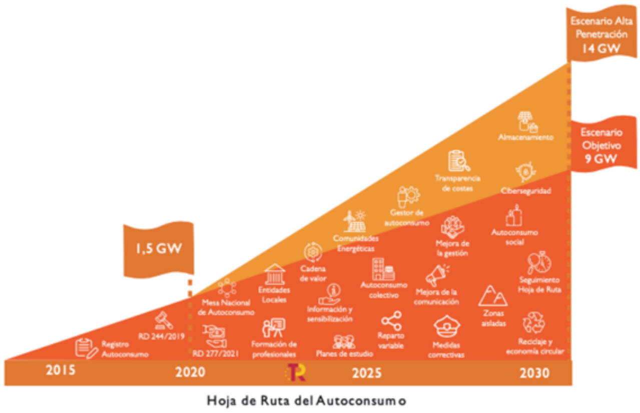


Figure 1. Roadmap for self-consumption in Spain

In fact, the growing adoption of solar PV triggers a worrying phenomenon, cannibalization, where the mismatch between the high energy produced versus the low energy demanded (compared to supply) at certain times of the day can depress wholesale electricity prices, negatively impacting the profitability of these installations [7]. Consequently, this lack of profitability of investments in renewables (in this case solar photovoltaic) is a factor that can hold back consumers and other agents from investing in renewable energy sources of these characteristics, delaying the decarbonization objectives.

To solve this potential problem, business innovation, public-private collaboration, and the willingness of citizens to adopt bold measures are the tools that will make it possible to transform challenges into opportunities. Hence the need for the market to favor the figure of the aggregator, becoming the system agent that brings consumers together and pushes them to shift their consumption from the most expensive hours, generally associated with higher fossil generation, to the cheapest, generally associated with this renewable surplus.

Contrary to what some citizens may think, this interest in decarbonizing the electricity system is not recent, but came along with the liberalization of the electricity system itself, 25 years ago: "The basic purpose of this Law is therefore to establish the regulation of the electricity sector, with the triple and traditional objective of guaranteeing the electricity supply, guaranteeing the quality of said supply and guaranteeing that it is carried out at the lowest possible cost, all this without forgetting the protection of the environment, an aspect that acquires special relevance given the characteristics of this economic sector" [3].

A statement also ratified in the reformulation of said Law, 10 years ago: "[...] this whole process has been framed within the principles of environmental protection of a modern society" [8]. It is perhaps worth mentioning that, at least according to the 2013 Law itself, [...] *Law 54/1997, of November 27, has contributed significantly to the fulfillment of the commitments derived from the Energy and Climate Change package, which establishes as objectives for 2020 the reduction of greenhouse gases by 20 percent in the European Union with respect to 1990* [8].

In line with this, it is shown that regulation plays a crucial role in the successful integration of independent aggregators in the electricity market, thanks to its power to change the rules of the scenario. Therefore, this paper will go into a comparative analysis of the regulations proposed in the European Union (EU) (and other states of interest), for which it will be necessary if it wants to become the first climate-neutral continent by 2050, as promoted by the European Green Deal [1].

To defend these economic benefits of Demand Response (DR), attached below are estimates from the EC (European Commission), who published in July 2016 the *Impact Assessment Study of Price Flexibility, Demand Response and Smart Metering [9]*, in which they published the following Table 1, according to their own calculations (but based on Gils [10] and ENTSO-E [11] calculations):

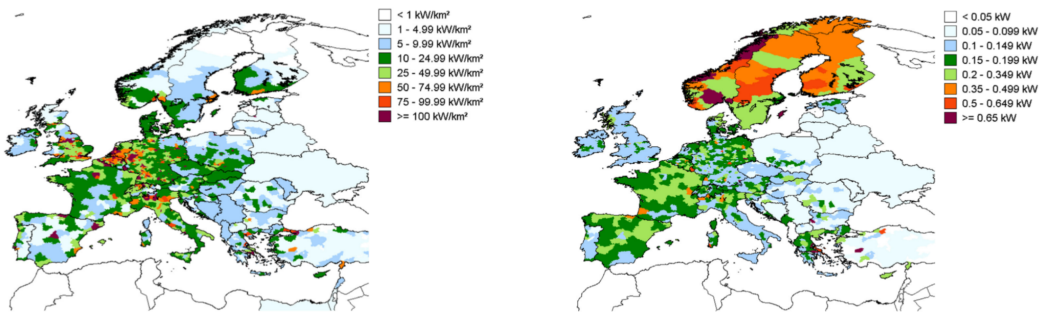
Table 1. *Peak Consumption, Theoretical Maximums and Business-As-Usual (GW) - Demand Response*

Capacities	**2016**	**2020**	**2030**
Peak load (current and estimated)	486	500	568
Total maximum theoretical DR potential	110	120	160
In % of peak load	22%	24%	28%
BAU	21	23	34
In % of peak load	4.3%	4.6%	6.0%

[1] [9]

This Table 1 illustrates how it is necessary to radically change the current models to allow the electricity system to reduce peak demand, generally with greater penetration of carbon-intensive technologies such as natural gas. Although it is logical that this theoretical maximum cannot be reached, it shows how there is great potential for decarbonization and economic savings through demand flexibility.

A geographical distribution of the load reduction potential, according to the average density in kW/km^2 [10], could be as shown in Figure 2 (a), which shows the enormous capacity to relieve the distribution networks in the large Spanish metropolitan areas, such as Madrid and Barcelona. On the other hand, the geographical distribution of the load reduction potential that can activate the DR, according to the average per capita, in kW, can be seen in Figure 2 (b), where a greater potential can be seen in the most depopulated regions of the Spanish region, as well as in the north of the Basque Country.



(**a**) (**b**)

Figure 2. Geographical Distribution of Load Reduction Potential,: (**a**) Average Density (kW/m^2); (**b**) Average per capita (kW/m^2) [10]

With this, the present project reflects the need for Europe [12] to design a new internal electricity market, which will allow the increase of electrification and the full integration of distributed renewable energies. In addition, it will have to face the change in the patterns of electric energy use, derived from the adoption of technologies such as the Electric Vehicle (EV), electric air conditioning systems or self-consumption installations in the daily life of domestic consumers.

2. State of the Art

One solution to decouple energy generation from fossil fuels, avoid unnecessary infrastructure costs and in turn allow European citizens to efficiently manage their own energy, is to introduce a radical paradigm shift, in which demand adapts to generation, and not vice versa, as has been the case so far. In a society immersed in its mobile devices, of constant connectivity, the potential of these actors to revolutionize the generation, distribution and consumption of energy is not only undeniable, but stands as a focus of hope in the staging of this remastered play that is the disruptive improvement of a smart, decarbonized, and affordable electricity system for all.

Of course, this is not the only definitive solution, because as we have seen previously in Figure 1, the solution to the challenge of the energy transition is not only to correctly implement the figure of the Independent Aggregator (IA), but it is linked to many other tools that must be developed before and during the implementation of the figure of the IA. In line with this, the current state of the question has put many technologies on the table, since the problem generated by the decarbonization and decentralization of generation encompasses many different factors, so the reader should not fall into the utopian phenomenon of Maslow's Hammer [13].

However, the implementation of aggregation models that favor the flexibility of the European electricity system, and in each state, has emerged as a crucial issue in the energy panorama. In the case of Spain, although there is no direct mention in Goal 7 "Affordable and Non-Polluting Energy" of the Action Plan for the Implementation of the 2030 Agenda [14], it is mentioned in many other official documents, such as in consideration 24 of the Law 7/2021 [2]

It is expected that, as the energy sector moves forward with the energy transition to a more renewable generation matrix, the role of these emerging actors, the IAs, will gain more strength. However, it is a topic that has been arousing great interest in the academic community and the business sector for years, but the lack of a consolidated regulatory framework that clearly defines their operation is evident. Even though it's possible contribution in the context of the electricity market has already been sufficiently analyzed from a theoretical perspective, as demonstrated by the large number of scientific research studies that can be found on the subject, which greatly surpass those referenced in this project, the regulations remain unresolved.

2.1. Flexibility Value Chain

Distributed flexibility will be useful for multiple purposes, being able to serve different types of customers in different electricity markets; however, it is an indispensable requirement that it be managed efficiently, and this is where the figure of the demand-side IA appears, to group DERs, managing them jointly to ensure that they generate value for the system. Of course, this demand management will not be altruistic, otherwise there would be no reason for companies to join these new markets, so they must receive fair economic remuneration, while at the same time being subject to certain responsibilities that must be fulfilled if they want to ensure their success.

The grouping of these DERs allows aggregators to regulate their portfolios so that, in the event of non-activation of a particular resource that was waiting to be activated, they can use other resources in their portfolios to make up for these deviations. The owners of DERs, generally retail consumers, are unable to access wholesale markets due to their low leverage, which would also be unprofitable for them in the face of the great efforts they would incur, due to the marginal gains that a single one-time activation entail.

These flexibility assets (whether loads, controllable local generation units or storage) can provide value to different grid actors, including [15]:

1. The prosumer, or active consumer, who can make his energy consumption more flexible to optimize monetary expenditure through grid tariffs (implicit flexibility), by increasing his own generated energy, or by obtaining remuneration for stopping electricity consumption at critical times (explicit flexibility), either due to generation cost overruns in the markets or for technical reasons;
2. The energy supplier, or/and its Balance Responsible Party (BRP), which seek to reduce their supply costs to maximize the profit on their income, for which it is also important to avoid financial penalties for errors in their previous estimates of their customers' consumption; therefore, being able to make their customers' consumption more flexible at specific times would allow them to optimize their energy portfolios;
3. Distribution System Operators (DSO), who are responsible for the installation and maintenance of such networks, could avoid inefficiencies in their operation by reducing loads at times of congestion; they could also avoid the need for reinforcement of such networks;
4. The Transmission System Operator (TSO), in charge of the installation and maintenance of the transmission network, as well as the System Operator (SO), in charge of system stability, could apply flexibility to increase the efficiency of network operation, ensuring balancing or avoiding congestion. Moreover, it could even avoid the need for the TSO to reinforce these transmission grids. It is important to clarify that, in most European national electricity systems, both tasks are carried out by the same company, as is the case of "Red Eléctrica de España (REE)", in the Spanish national scenario.

One of the indispensable requirements of the Energy Transition lies in placing the citizen at the center of the electricity system, evolving from a passive consumption attitude towards a much more active role. In this sense, there are already many consumers who alter their consumption patterns depending on the price of electricity (implicit flexibility), especially those prosumers with solar photovoltaic generation installations who want to make the most of the generation from their panels (as the remuneration for the sale of energy during these peak production hours is usually considerably lower than the purchase price at other times of the day).

On the other hand, the prosumer aggregator would grant financial compensation to the active consumer for its flexibility, while selling this flexibility to the network agents (DSO or TSO) or to the marketer itself or its BRP in exchange for financial remuneration.

The following Figure 3 shows a diagram of the relationship of these aggregators between the prosumer and the rest of the agents in the electricity system.

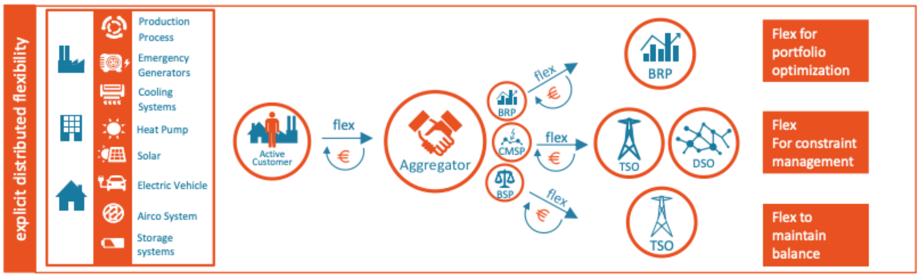


Figure 3. Value Chain for Flexibility

2.1.1. Implicit Distributed Flexibility Services

With regard to this management of the implicit flexibility of the prosumer by the IA, some of the main benefits are listed below, which can already be done by the prosumer [15]:

1. Optimization of consumption equipment usage times, depending on the consumer's tariff. In the case of domestic consumers, this equipment can be divided into three groups, according to their ability to be flexible: non-flexible (such as household lighting or TV), semi-flexible (such as washing machines and dishwashers) and flexible (such as EVs and heat pumps) [16];
2. Use of self-consumption, if available;
3. Management of storage, if available;
4. Optimization of contracted power, if necessary;
5. Detection of the ideal tariff, according to the user's consumption pattern.

2.1.1. Explicit Distributed Flexibility Services

On the other hand, explicit distributed flexibility can provide multiple solutions to the electricity grid (increasing grid efficiency and security, avoiding unnecessary investments, etc.) but also to the electricity markets. According to USEF, DERs could add value by providing solutions to the following services [15]:

1. Constraint management. Helping grid operators (TSO and DSO) to optimize grid operation by considering physical constraints and market-agreed energy supply needs by managing peak grid flows, to services like:
    a. Voltage Control;
    b. Network Capacity Management;
    c. Congestion Management;
    d. Controlled Islanding.
2. Adequacy. Ensuring sufficient and reliable generation capacity to meet demand, especially at peak times, to services like:
    a. Payments for Capacity;
    b. National Capacity Market;
    c. Strategic Reserves;
    d. Coverage.
3. Wholesale services. Optimizing the purchase and sale of electricity in the wholesale market (since it’s a marginal market) thru:
    a. Daily Optimization;
    b. Intraday Optimization;
    c. Autonomous/Passive Balancing;
    d. Generation Optimization.

4. Balancing. Maintaining the stability and reliability of the grid, guaranteeing the balance between electricity supply and demand, ensuring the frequency of the system by means of:
   a. Frequency Containment Reserves (FCR);
   b. Automatic Frequency Restoration Reserves (aFRR);
   c. Manual Frequency Restoration Reserve (mFRR);
   d. Replacement Reserves (RR).

As for the joint potential to reduce the different peak loads (GW), as well as to shift the annual demand (TWh) of different demand sources surrounding the prosumer, either implicitly or explicitly, it will depend greatly on the type of prosumer (domestic, industrial, commercial, or institutional). Also, its geographical location and many other variables, such as the aggregation model it implements; however, it is interesting to analyze the case estimated for the UK (a country where explicit flexibility is already being implemented), for 2050. As can be seen in Figure 4, EVs and heat pumps represent, by far, most of the potential for EVs and heat pumps.

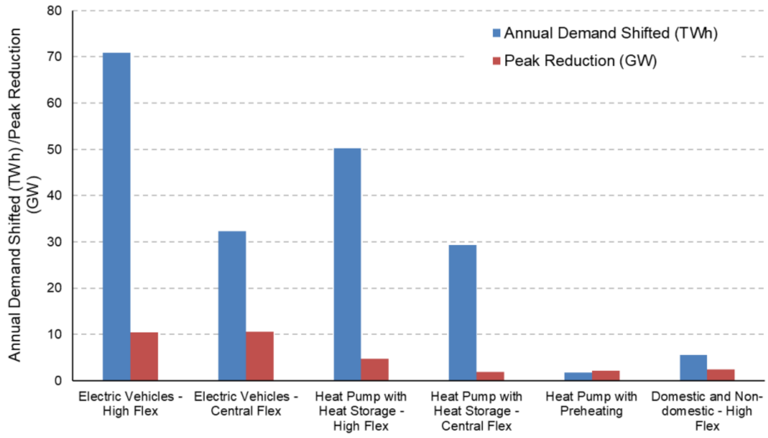


Figure 4. Reduction Potential of Different Peak Loads (GW) and Annual Demand (TWh) of Different Demand Equipment [17]

3. Objectives

Now that the opportunities for demand-side flexibility in distributed electricity systems with high penetration of renewable energy have been captured, we can proceed to analyze the regulations related to the implementation of the independent aggregator (IA).

Consolidated Spanish legislation is far from reaching the definition of a regulatory framework that really allows for a system in which the flexibility of end consumers can be activated, as can be seen in bulletins such as *Royal Decree-Law 17/2022, of 20 September, which adopts urgent measures in the field of energy, in the application of the remuneration system to cogeneration facilities and temporarily reduces the rate of Value Added Tax applicable to deliveries, imports and intra-Community acquisitions of certain fuels* [18] .

The clearest example of this in this document is the restriction of the *Active Demand Response Service Providers to demand-side installations (identified by their CUPS) that make up the scheduling unit providing the service must individually accredit a supply capacity greater than or equal to 1 MW in the periods in which the service is provided*. This, by definition, leaves out most of the national CUPS (Universal Supply Point Code), i.e., it rejects domestic, most commercial and a small part of the industrial ones; even more so, when only those consumptions that really make sense to be the object of these explicit flexibility services are considered.

The latter may make sense in the initial stages of the implementation of the figure of the IA in the sector; however, according to *Law 7/2021 of 20 May on climate change and energy transition [2], within twelve months of the entry into force of this law, the Government and the National Commission for Markets and Competition, in the exercise of their respective powers, will present a proposal to reform the regulatory framework in the field of energy to promote [...] the participation of consumers in energy markets, including demand response through independent aggregation*, which has not been achieved. This lack of legislation is partly due to the complexity of the challenge faced, as it would first have to be decided which model of independent aggregation is to be implemented in the national electricity system.

On the other hand, in February 2023 the MITECO opened the *Preliminary Public Consultation on the drafting of the Royal Decree regulating the conditions for the supply and contracting of electricity and establishing regulatory principles for the independent aggregator* [19], in which the need is expressed to address a regulatory development that includes, among other aspects, the regulatory framework of the new subjects of the electricity system, and in particular the independent aggregator, so it is understood that the intention is to continue advancing in the matter, despite there being no new developments in this respect.

On 19 April 2021, the *Draft Order creating a capacity market in the Spanish electricity system* [20] was published, as there is still no capacity market in Spain; however, after having been submitted for public consultation, no significant progress has been made. In this document, the capacity market is proposed as a centralized system through which the System Operator (SO), REE, can contract the firm's power needs (in MW), after having detected the need in the demand coverage analysis.

On 28 July 2021 the CNMC approved this Draft Order [21]; however, it included several recommendations, among which is the one regarding the duty of the Draft Order to allow the participation of the independent aggregator in such capacity markets. Since then, there have been hardly any developments on this issue by the national bodies in charge of moving forward with the definitions of the regulatory frameworks (except for the mentioned *Prior Public Consultation on the drafting of the Royal Decree regulating the conditions for the supply and contracting of electricity and establishing regulatory principles for the independent aggregator*, opened by the MITECO [19], which it’s only a Prior Public Consultation).

If the interest of the electricity system is to achieve the Energy Transition, and for this it is necessary to make demand more flexible, then the regulations that are defined must be in line with these interests. Therefore, the consumer must be placed at the center, activating them, and turning them into prosumers.

Furthermore, in addition to looking after the interests of prosumers, the aim is to increase the efficiency of the decarbonized electricity system, making the grid resilient while avoiding the economic costs related to increased investment in infrastructure. Meeting these requirements, in addition to allowing private companies operating in the sector to continue generating economic value for society, will be the definition of the pursuit of the common good.

Moreover, when reference is made to a common good, reference must also be made to a time, since to achieve the solution that is best for all parties as a whole in the medium and long term, sacrifices may have to be made in the short term. In this sense, of course, one can say that the solution should not be immutable over time, but that it must evolve during its implementation, and indeed.

With this long-term horizon, the product to be addressed (demand flexibility) should be developed based on simple pilots, including the proposal of new solutions as problems are detected, but not as definitive until they are properly validated by the system. Therefore, and to avoid solutions to problems that are not real, the following premises are formulated, the whole of which will be named "the product sphere" [1].

3.1. The Product Sphere

1. Why is demand flexibility being sought?

Because it will result in a common good for all stakeholders in the electricity system.

2. How do you intend to make the demand side of the electricity system more flexible?

Through technological products that allow stakeholders to interact explicitly in the electricity market.

3. What is going to develop in the electricity market?

A business model in which independent aggregators make it easier for consumers to offer their electricity flexibility in the markets, in exchange for financial compensation.

While these are the three basic questions that a company must ask itself when developing a product, according to this logical order, around which it must gravitate at (almost) all times, a fourth one is proposed, which would be the company's reason for being.

4. For what should independent aggregators participate in this market?

[1] Inspired by Simon Sinek's theory "The Golden Circle". https://simonsinek.com/golden-circle/

To generate wealth by adding value to the stakeholders of the electricity system.

While these premises may seem overly logical, it is important to make them clear to always maintain the objective of the flexibility of the task, which is to impact on a common good for the entire electricity system. By this, reference is made to saving the total cost for consumers, developing a decarbonized energy model that allows perpetuating the use of energy by the people that make up society, as well as by the companies that oversee producing goods and providing services to society.

3.1.1. Why?

With the goal of demand flexibility in mind, which is to create value for the electricity system and its users (consumers), the optimization of the electricity system will be sought to meet this objective, leaving behind less efficient generation technologies. Although these generation plants based on burning fossil fuels made it easier for the system to generate the electricity always needed to meet society's demand, they had a negative impact on society by releasing greenhouse gases that would ultimately have a devastating negative effect on society.

To avoid this negative effect, other generation methods are chosen which, although they also have the positive characteristic of being more economically efficient, have the technical restriction of generating energy that is less adaptable to demand. However, if the purpose of electricity consumption is to provide a solution to a need, this need can be displaced over time without harming the well-being of those who consume it.

There is an objection to this last premise, and that is that this temporary displacement of consumption implies an effort and a reduction in comfort for consumers, who expect to receive something in return for this sacrifice. Up to now, it has been common for certain consumers to plan their consumption according to the price of energy, known as implicit demand flexibility, producing an economic saving that compensates for the inconvenience, otherwise they would not do so.

In line with this consumer rationale of getting a reward for their effort, it has been shown that these price signals are not always sufficient to change the national consumption pattern to always match generation and must be taken further. However, this type of behavior is not new, as the electricity system already contemplated the case of non-delivered energy [22], in which large consumers are rewarded for not consuming during the most expensive hours of generation.

In This economic sacrifice faced by the system, paying for not consuming, represents a total saving for the system by avoiding an increase in the price of energy (since this is a marginalist price system in which the last offer sets the final price of the energy unit sold). In a similar way to the one described above, the aim is now to shift this energy away from consumers, resulting in much greater savings for the system.

In line with this, since not all consumers are willing to change their consumption patterns in exchange for savings on their energy bills (implicit flexibility), it is necessary that they receive sufficient economic income to give up this consumption during this time period (explicit flexibility). To provide a solution to this problem, the figure of this new actor, the demand-side AI, comes into play, in charge of bringing together those consumers willing to sell their energy flexibility at the times required, at the lowest possible price.

To show more visually how explicit demand flexibility can significantly improve price reduction in wholesale markets, a graphical representation of this reduction is shown in Figure 5. This demonstrates how all consumers will benefit from the reduction in the cost of energy resulting from the explicit activation of demand flexibility, and not only those who directly sell their flexibility in the markets [23].

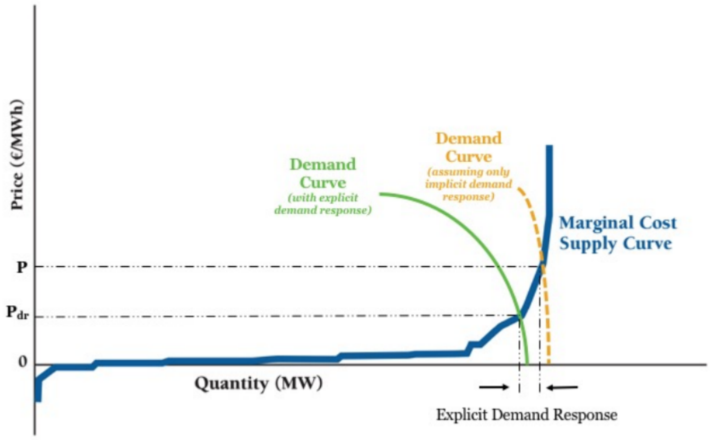


Figure 5. Explicit Demand Response Reduces Wholesale Electricity Prices [23]

In this Figure 5, it can also be seen how the price reduction will be more notable the steeper the slope of the marginal energy supply curve in the markets, as well as the greater the reduction in demand for that period. Furthermore, it can be seen qualitatively how the total amount of energy traded in the flexibility markets does not necessarily represent a very representative amount compared to the total amount of energy dispatched in that period of time.

Having demonstrated the rationale for explicit demand-side flexibility, further thought needs to be given to how independent aggregators will be able to mobilize these consumers to bid their flexibility in these markets.

3.1.2. How?

Any major paradigm shift involves a technological disruption, as was the case with the introduction of smart meters in the Spanish electricity system, where, by the end of 2019, 99.22% of domestic consumers (less than 15 kW of contracted power) already had one [24]. Today, with this milestone already reached, the electricity system can go further, with the help of the technology industry, if it manages to convert this energy data into useful information for consumers.

It is true that consumers can access their smart meter data through the portals of their corresponding distribution company, as well as through some retailers and other ESCOs, but few companies are trying to go beyond the merely informative process and convert the data into personalized recommendations for the user. Moreover, today's society already has what is probably the most disruptively affordable technological tool at its fingertips, the mobile phone. We can increasingly see how this tool continues to replace other technological devices, such as the credit card or the computer, to become the ideal digital medium to drive the business model of companies [2].

This tool, so ubiquitous in the lives of today's modern citizenry, has surpassed the reach expected a decade ago, when it was not believed that older people would not be as fluent as they are today. However, it will be important for these companies to promote the education of society in these aspects of energy, which are generally unknown to a large majority of the population. In this sense, it is perceived that certain very old generations may suffer exclusion because of the existing digital divide in our society, which will have to be solved in one way (business altruism) or another (public services).

Thanks to this, the electricity sector will have the possibility to interact with consumers in a much more dynamic way than it has done so far, creating a niche market particularly welcoming to IAs, as other ESCOs are already doing. Moreover, as artificial intelligences and other algorithms in the energy and technology industry expand, the opportunity arises to learn to predict, inform and recommend behavioral patterns to align consumers with their energy efficiency and cost-saving goals.

[2] Inspired by the book "What is your digital business model? Six questions to help you build the next generation company" by Peter Weill and Stephanie Woerner.

Therefore, having the right tool to solve the problem demonstrated, it only remains to explain what can be done to increase the efficiency of the electricity system through the mobile device.

3.1.3. What?

Now that it is clear why the objective of making the electricity system's demand more flexible will be good for the stakeholders that participate in one way or another in the electricity system and its markets, and knowing the tools that will be available to achieve it, "only" what is needed is to define what is going to be done to achieve it. As previously mentioned, consumers will be encouraged to become more flexible in their consumption if they receive some reward in return, and the more reward for consumers, the more they will want to participate and the greater their efforts will be.

The first thing to be clear about the product to be marketed is that it has two very different approaches, depending on who the customer is in each case:

Explicit Flexibility for the Electricity System and its Markets. From the point of view of the electricity system, the objective of purchasing this flexibility is to reduce the total cost of the energy supplied to national consumers, while at the same time decarbonizing generation sources, increasing the security of the system, etc. Therefore, while the system is willing to offer a financial reward for flexibility that brings them value, to achieve this increase in efficiency and resilience of the system, its mission will be to achieve it at the lowest possible cost.

Explicit flexibility for consumers. From the opposite point of view, consumers will be willing to offer their flexibility in markets if the economic reward they perceive for it is high enough to be worth the effort. Therefore, consumers will aim to change their consumption patterns only when the economic remuneration seems sufficient.

This is the fundamental value that the IAs will bring to both parties, the economic meeting of this point of equilibrium, as shown in Figure 6, and the assurance that the flexibility that they have committed to provide to the system will be realized. Once again, this figure in charge of aggregation must have a monetary remuneration associated with his or her professional performance, otherwise there would be no incentive other than altruism (which is insufficient) to take responsibility for this commitment.

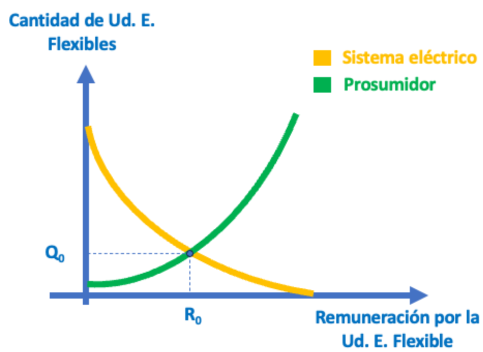


Figure 6. System-Prosumer Balance Point [3]

The method of sharing the revenues generated in the market from the sale of the flexibility of their associated consumers that the IMs will realize will depend directly on the methodology to be defined in the regulatory frameworks. Within the proposed models for this sharing, the one chosen will be crucial for this, as the relationship they will create with their associated consumers and with the BRPs in charge of supplying consumers will depend on it.

[3] Own elaboration - As can be seen in the curve offered by the prosumer, there is a very small number of them who will offer some flexibility without expecting economic remuneration in return (ecological altruism).

Likewise, the model chosen will have to take into account the avoidance, as far as possible and recommended, of economic conflicts arising from the activation of this flexibility, respecting the business models of suppliers (at least for the time they need to adapt to the new reality), but at the same time ensuring that the remuneration to consumers is sufficient to generate the attraction of participating in such events. Of course, this split will have to be divided into a third part, corresponding to the IAs for taking on the risk associated with balance sheet liability, which gives rise to the most superficial layer of the product sphere.

3.1.3. For What?

Most of these new players on the electricity scene have not yet decided to venture into the new business of managing the explicit flexibility of consumers in the system, as this is a new business model for the energy transition whose legislative framework has not yet been defined. The number of participants willing to enter the game will depend on the estimated profit potential of this new sector, so the market should ensure that, in the long run, it is as close to perfect competition as possible.

It would make no sense to establish the figure of the aggregator as independent of the energy suppliers to encourage good practices in the sector (or rather, to avoid bad ones) if it ends up resulting in a sector that is more oligopolistic than the former.

In short, the main motive that drives companies to compete is the generation of wealth for themselves, which they must achieve through the generation of value for others. In this case, the more value IAs contribute to the electricity system and, therefore, to consumers, the more economic benefit they should consequently reap.

However, it is worth noting a change in industry trends, with more and more companies developing sustainable business models through:

- The definition of a decarbonized strategy;
- whose core business is based on sustainability;
- through digital transformation.

Although these attitudes can be approached from a utilitarian philosophy, as suggested by Larry Fink (CEO of BlackRock) in his letter "A Structural Change in Finance" [25], they are valid for generating value for society, despite not having a purely deontological motivation. In other words, more and more companies know that they must generate value for their stakeholders if they want to make sustained profits over time, which is, of course, acceptable.

4. Methodology and Models

Next, the characteristics of the possible independent aggregation models that may come into force in the peninsular electricity system are defined:

- A first ratification of the independence of the aggregator will be made,
- The need or unnecessary need to compensate the supplying BRP for this flexibilised energy will be discussed,
- And the convenience or inconvenience of correcting the deviations derived from the imbalance.

4.1 Aggregator Independence

The European Parliament and the Council of the European Union, through the previously mentioned *Directive (EU) 944/2019* [26], which deals with *common rules for the internal electricity market and amends Directive 2012/27/EU, explicitly refers in Recital 39 to the fact that Member States should be free to choose the appropriate implementation model and governance approach for independent aggregation* [18] . This already protects the independent figure of the aggregator, separating it from the figure of the energy supplier, a position that has been defended throughout this project.

4.2 Financial compensation

The independent aggregator, by activating the prosumers' explicit flexibility, has modified the energy consumption that was supposedly foreseen by the supplier, who has (or has not) purchased this energy prior to the activation. In this sense, the term compensation refers to the need for the IA to cover the full cost of the activated energy to the supplier, a case which has been applied in Switzerland [27].

According to Article 17.4 of the same Directive, *Member States may require participating electricity undertakings or final customers to pay financial compensation to other market participants or their balancing settlement agents if these market participants or their balancing settlement agents are directly affected by the activation of demand response [26]*. According to this wording, it will be left to the drafting legislation to decide whether or not to include this need for compensation from the IMs to the affected BRPs.

A clear example is given in cases where the IA is given the signal to reduce the consumption of its customers, which could have been foreseen and purchased by the supplier, so that it would now have a quantity of energy that it has not been able to place on the markets, generating economic losses. Generally, this energy is bought the day before by the trader (or his representative) on the markets and, in this case, in which he has not been able to sell it on the intraday markets, the trader's perimeter would be modified.

In line with this potential problem, Recital 39 of the Directive analyzed here also addresses it with the following wording: *such a model or approach could include the choice of regulatory or market-based principles that offer solutions to comply with the provisions of this Directive, including models in which [...] perimeter corrections have been introduced* [26].

In this respect, the author of the project believes that the opposite situation should also be considered, where thanks to the activation of prosumer flexibility, the supplier has been correct in its consumption forecasts. Returning to the previous example, in which the IA is given the signal to reduce the consumption of its customers, for example due to an unexpected increase in the total demand of the network, it could be the case that the supplier had not predicted such a consumption peak by its customers, so that thanks to the activation of the demand by the IA, it would avoid the imbalance of its portfolio.

On the other hand, if the supplier had correctly estimated the consumption of its customers, and had this surplus energy, it could try to sell it as tertiary reserves or to other suppliers that had failed in their forecasts. However, this would require a system of aggregated information that would allow the IM to inform the BRP of the flexibility foreseen for its customers, without, on the other hand, revealing confidential information.

This reporting requirement should not be imposed but should emanate from a close collaboration between the two actors, with the BRP being in charge of opening the discussions with the different IAs participating in the system, as it would be the beneficiary of the information exchanged. On the other hand, the IM may have a certain interest in opening the talks, since, having detected the latent need on the part of the BRPs, he will be aware that he can ask for financial remuneration for such collaboration. It is preferable not to pursue this collaboration further, since, depending on the business model of the traders, they could also become direct competitors of the IM, in terms of implicit flexibility or in terms of vertical extension of the business models of the business group to which the trader belongs. In fact, due to the powerful financial muscle that these utilities may have, it is not surprising that acquisitions may take place at the corporate level, especially in the earlier scenarios (the business strategy that the IA may pursue in the long run will be mentioned at the end of the project).

That said, the trade-off, to be fair (the fruit of reason), should consider both situations, both positive for the suppliers and negative. In any case, if this compensation were to be implemented, it would be going against the efficiency of the system in the long term, as it must be the task of energy suppliers to learn to foresee these changes in the consumption patterns of their customers.

This task of learning to foresee the new consumption curves of prosumers is fundamental, because although compensation for the explicit activation of their customers' flexibility is still being considered, at no time will compensation be considered for the mismatches linked to implicit flexibility. This implicit flexibility, which will become increasingly significant as fossil generation is economically locked in at peak times and renewables are cannibalised at peak times, will also pose a challenge for these BRPs charged with forecasting the new load curves of end-consumers. Therefore, a framework must be created that pushes suppliers to innovate in their business models, and not one in which it is indifferent whether they improve their tasks or become obsolete.

In line with this, if suppliers were to be compensated for the mismatch in their portfolios following the explicit activation of demand flexibility, they would have no incentive to innovate in their forecasting methods, thus slowing down the technological development of the electricity system. This goes against the core of this project, in which the guiding maxim of this disruption in the energy sector is the search for overall system efficiency. On the other hand, a compensated model would be much more costly to implement, with administrative and economic obstacles for the new independent aggregation figures, with many more tasks for the regulatory body and for the rest of the system's agents.

Furthermore, if the IA had to compensate the supplier for this energy not supplied to its end customers, the resulting economic amount to be shared among prosumers who have made their consumption more flexible would be much lower, which would slow down prosumers' participation in these events of explicit activation of their flexibility. Likewise, the remuneration that IAs could receive for their energy management would be greatly reduced, which would be a barrier to the entry of new market players competing in this new business modality, slowing down the overall efficiency of the system. Ultimately, a model with compensation would curb the interest of private companies and citizens to actively take part in the energy transition, delaying and even preventing it.

Legislation is therefore urged to design policies that focus on a model of implementation without compensation, that encourages companies to disrupt by creating new technological business models for the energy transition and that places consumers at the center of the electricity system; leaving the politics to drive innovation, rather than to perpetuate the unproductive practices.

4.2.3 Net Benefit Principle

This principle refers to the assumption of part of the responsibility for the ToE (Tranfer of Energy) on behalf of the IA, which is responsible for assuming the cost of compensation up to an economic figure per energy unit activated; beyond that figure, the cost would be socialized. Again, this is a system of compensation to the retailer, but with the exception that it would avoid that, in cases with very high energy prices, this would not have to be completely assumed by the IM; a case which has been put into practice in the United States [27].

Following the previous reasoning, this would not make much sense in the author's opinion either, as the IA would be paying for energy that has not been consumed, and which it does not have the capacity to sell in any market. It is important to remember that the aggregator's task is to adjust DERs on the demand side to match supply, whether for technical or market reasons, but at all times providing value to the system and the electricity market.

What this principle makes clear is that, as in most cases where demand is activated, it will be downward and mainly driven by high electricity prices, the activity may not be profitable. In these compensation cases, the price of the ToE would be excessively high, either for market or technical reasons, which could make the IA unwilling to participate in the auctions.

It is important to remember that the IM does have several responsibilities, in that it has committed to provide the system (or the BRP) with flexibility, and in the event of non-compliance it will have to pay the cost of its own deviations. These deviations should be the sum of the cost of the energy that has been necessary to supply this uncontrolled demand, plus a surcharge in the form of a penalty for the mismatches caused. This, and no other, is the responsibility of the IM.

4.3 Correction of Deviations

Furthermore, in this Recital 39, it is included that *such a model or approach could include the choice of regulatory or market-based principles that offer solutions to comply with the provisions of this Directive, including models in which the deviations have been resolved* [26]. This refers to the possible correction of deviations resulting from the imbalance of the BRP, which means that within the proposed models, there may or may not be a need to compensate the energy supplying BRP for deviations that the explicit activation of demand flexibility of its customers may have caused it.

In this sense, the author wishes to emphasize the double direction that this correction should take, as there is also the possibility that the supplier has not incurred deviations thanks to this activation of demand. This approach is little or not at all mentioned by the groups of marketers who refer to the need to correct the deviation to these BRPs in charge of buying energy in the markets, but who do not refer to those cases in which they do not incur in such deviation thanks to the activation of flexibility by the aggregator. Of course, without taking into account the possible sale of energy in the markets closest to the time of consumption, there should always be a responsible party, either for the balance achieved (thanks to the activation of the IA), or for the imbalance caused (derived from the activation of the IA).

This means that, in the case of applying a corrected model in which possible penalties for imbalance are avoided for the BRP of prosumers activated by the IM, it makes sense to the author that the opposite case should also be weighed in some way. This would vary depending on which figure would be responsible for correcting such deviations, as one could opt for a contractual model, in which the IM itself would be responsible for the deviation; or for a central settlement model, in which the TSO would be the one to modify the marketer's programmed for the purposes of the deviation caused.

4.3.1 Deviation Correction by the TSO

In the case where a corrected model is chosen by REE, it would be this agent who would oversee modifying the marketer's programmed, being able to assume responsibility in the event that it would be necessary to pay the economic amount derived from the mismatch, as is the case in Ireland [27]. The author believes that this would have little effect in a competitive market because, as explained above, it is possible that other suppliers would be able to place this surplus energy (in case of DR to fall) in the tertiary markets, so only those who have not been able to manage the mismatch correctly would be remunerated.

This methodology of rewarding those BRPs that are less efficient would result in a reduction of efforts by the rest of the BRPs that have complied, as there would not be sufficient motivation to solve the mismatch. This inefficiency of the system goes against the core of what has motivated the electricity system to promote demand flexibility in search of an increase in efficiency, so that the net benefit for the grid would be almost non-existent.

In the case of seeking to assist BRPs in the most initial scenarios of implementing a demand flexibility system, one could envisage a model in which they are compensated for their customers' participation in flexibility events, as a correction for deviations, but regardless of whether these deviations have occurred. This approach would be fairer to those BRPs that have been able to hedge their portfolios efficiently, placing excess energy bundles more boldly than their competitors, while subsidizing the inefficiency of those BRPs that have not been able to adapt to regulatory change.

However, while this expense would be borne by the OS/TSO, it would end up being indirectly passed on to the entire electricity system, i.e., to all consumers, who ultimately make the power purchase payments. In one way or another, wherever the economic losses of any of the agents in the electricity sector are compensated, an economic debt will be generated that will not have been directed towards the generation of added value, but rather towards the subsistence of those fewer dynamic actors.

Therefore, the TSO should not be responsible for assuming this cost derived from the lack of adaptation of energy suppliers, as it is not responsible for the fact that the BRPs have not been able to correctly balance their energy portfolios. If anything, the implementation of the independent aggregation model should be staggered and spread out over time, so that all actors in the system could adapt to the changes introduced and can iterate their strategies until they can validate them. If anything, it is to carry out the implementation of the independent aggregation model in a staggered and relaxed manner over time, so that all actors in the system could adapt to the changes introduced, being able to iterate their strategies until they manage to validate them.

4.3.2 Deviation Correction by the IA

In the same way that has just been analyzed for the TSO, the correction of the BRP deviations supplied by the IM would be totally inefficient, even more so than the correction by the TSO. In this case, it does not make sense to the author that the same agent in charge of adjusting demand to the conditions of the electricity system should be responsible for bearing the economic cost of the BRP portfolio mismatch.

Again, if the idea is to encourage the prosumer to offer its flexibility in the energy markets (which it is), measures cannot be taken that reduce its potential profits, just as neither should the profits of the agents directly responsible for increasing the system's performance be reduced. This line of thinking is closer to the search for culprits for the potential economic loss of the supplier, than to focusing the network strategy on an efficient system that makes all agents responsible for their activities.

Therefore, it should not be the IA that is responsible for assuming the penalties for the imbalance of the BRP, as it is not responsible for the fact that they have not been able to adapt to be able to correctly balance their energy portfolios. The maximum commitment that this new figure can acquire is to be implemented gradually in the electricity markets, so that the impact of its initial activations is negligible due to its negligible size compared to the volume of energy displaced by the BRPs. In this sense, it would be positive to continue creating pilot projects in controlled environments, so that the positive impact of their actions can be validated, and energy marketers are given a temporary margin to adapt to the change in the electricity scenario.

5. Results

Now that the approach to dealing with regulation has been defined, it is possible to proceed to analyze the different models of independent aggregation.

The maxim pursued by this project is the search for the common good for all stakeholders in the electricity system; furthermore, it must be emphasized that the achievement of these objectives should not be short term, but that a correct implementation that is sustainable over time should be pursued. This nuance is considered very relevant, because although some measures may be positive ipso facto from the moment of their implementation, they may prove to be a long-term obstacle to achieving what is intended.

A myriad of examples could be given below, most of them being policy measures taken to intercede in the electricity sector in a way that directly had a positive effect, but whose second and third consequences of the action taken point to a setback in the indicator that was intended to be improved. However, as this is not the objective of the project, it will be avoided; while brushing up policies may be the objective, politics will be avoided.

Having clarified this long-term approach to the goals to be pursued in the analysis of the different IA models, based on the concept of innovation as the ability to generate value in the future, it is also necessary to delve deeper into the relationship between the IA and the energy supplier. The analysis of this relationship will occupy much of the analysis, as well as the analysis of the responsibility of the balance, as other variables have been studied, which will allow the framework of the different possible relationships between the aggregator and other agents in the system to be delimited.

At the outset, it is necessary to point out that there is no specific methodology suggested or established at the global level that would lead to a model suitable for all electricity systems. As a result of this lack of global consensus, and as the best possible case to support the validity of all of them, each national electricity system is opting for a different approach to the same problem.

Although each electricity system is different in terms of generation technologies, the degree of distribution of generation and consumption points, level of interconnection, and a long etcetera, it is believed that each of them brings a series of advantages and disadvantages which, depending on how they are evaluated, may weigh more heavily on one or the other.

5.1. Models

Returning to the Impact Assessment Study on Price Flexibility, Demand Response and Smart Metering [9], from which Table 1 has been extracted previously, the forecasts are attached in this document, and shown in Table 5, according to these three options:

1. **Option 1:** DR is promoted through legislation giving all EU consumers the right to demand access to smart meters and dynamic pricing;
2. **Option 2:** DR is promoted through legislation as in Option 1 and EU standardized market rules for DR providers are established;
3. **Option 3:** As Option 2, but where the DR service provider has the right to offer its services without compensation to the supplier/BRP;

Table 2. Estimated DR Under Policy Alternatives (GW)

Capacities		2016	2020	2030
	Price based	5.8	6.4	15.4
	Incentive based	15.6	16.3	19.0
BAU		**21.4**	**22.7**	**34.4**
	Price based	5.8	6.9	17.9
	Incentive based	15.6	16.3	19.0
Option 1		**21.4**	**23.3**	**36.8**
	Price based	5.8	6.9	17.9
	Incentive based	15.6	20.3	34.6
Option 2		**21.4**	**27.2**	**52.4**
	Price based	5.8	6.9	17.9
	Incentive based	15.6	21.4	39.3
Option 3		**21.4**	**28.4**	**57.1**

[1] [9]

As can be seen in Table 2, for any of the options, the achievable potential remains well below the theoretical maximum for 2030, but exceeds the estimate that Europe was aiming for at the time of the EC document (2016). It also shows that Option 1 only improves the previous existing model by 7 %, while Options 2 and 3 improve it by 52 % and 66 % respectively.

As for the environmental part associated with these energy forecasts, for the estimation of the total reduction of CO2 emissions possible by 2030, according to this same document, reference is made to a reduction of around 3.4% of total emissions for the three models, giving a minimal advantage to the 2nd over the 3rd, and to the 1st over the 2nd. However, these calculations may be quite outdated, as current generation models have become much more sustainable; for example, in the case of Spain, renewable production in the electricity system has been 46.7% and 42.2% in the years 2022 and 2023, respectively [28].

As for the economic estimation, this EC document provides estimates of the costs and benefits up to 2030 of the different policy options described above, which are attached in Table 3.

Table 3. Quantitative Estimation of the Costs and Benefits of each of the Policy Options

MEUR/y	Costs	Benefits			Net benefit
		Network	Generation	Total	
BAU	82	980	3,517	4,497	4,415
Option 1	303	1,068	3,772	4,840	4,537
Option 2	322	1,383	4,588	5,971	5,649
Option 3	328	1,444	4,736	6,180	5,852

[1] [9]

A priori, the choice of option 3 may seem obvious due to the net benefit of its implementation; however, in Table 4, an overall comparison of the policy options can be qualitatively observed, showing that inconsistencies may exist, according to the following assessment criteria [10]:

- Effectiveness: how much additional RD is achieved;
- Efficiency: cost-benefit analysis;
- Coherence: how the options fit with EU policies, with EU objectives.

Table 4. Qualitative Estimation of the Costs and Benefits of Policy Options

	Effectiveness	Efficiency	Coherence
Option 1	+	+	++
Option 2	++	+++	+++
Option 3	+++	+	-

Note: + means positive effect of increasing magnitude

[1] [9]

According to this Table 4, Option 3 succeeds in triggering higher DR, but may lead to inefficiencies in the system, due to the risk it allegedly introduces in balancing markets. Therefore, **Option 2 is more attractive for this EC analysis**, in that it triggers DR (both through price signals and incentives) and respects the EU's internal market and fair competition policy objectives.

To better understand this phenomenon of fair competition in existing markets, Table 5 is attached below, wherein:

- Generators (with special reference to fossil fuel-based generators) lose profits in marginal markets during DR hours;
- Network operators (OS/TSO) reduce CAPEX expenditure, but their profits should not be altered;
- Suppliers reduce risk the more consumption is reduced at peak hours, as the prices at which they buy are higher than the prices at which they usually sell to their customers;
- The supplier's BRP tends to generate losses and increase financial risk when it has to rebalance its positions after DR activations;
- IAs will make more money the less they have to compensate BRPs;

- Consumers will always make money, the more profit the more total profit is generated for the electricity system.

Table 5. Distributional Effects of Policy Options for Electricity System Actors

Actor	Option 1	Option 2	Option 3
Generators	Will lose profit on intra marginal generation at peak load	Will lose profit on intra marginal generation at peak load	Will lose profit on intra marginal generation at peak load
Network operators	Reduced need for investment – no change in profits	Reduced need for investment – no change in profits	Reduced need for investment – no change in profits
Suppliers	Potentially, reduced risks as consumers reduce peak load demand where wholesale prices are high and exceeding the retail prices.	As Option 1 plus effect from more even wholesale prices. Both gains and losses.	As Option 2 though possible larger effects on wholesale prices.
BRP	No change	No change	Will lose on extra balancing costs (increased financial risk)
Aggregators	No change	Increased business opportunities	Increased business opportunities (more than in option 2)
Consumers	Reduced electricity bill	Reduced electricity bill (more than in option 1)	Reduced electricity bill

[1] [9]

6. Discussion

As can be seen in the European Commission's results, none of the three options refers to the correction of deviations, neither by the System Operator nor by the Independent Aggregators, nor jointly. This is an issue that would also have to be addressed, as it implies an economic amount that will have to be assumed by one of the agents, as the energy suppliers would bear this cost.

On the other hand, Option 3 should generate more benefits than those shown in Table 3 in the case that suppliers/BRPs would not have to be compensated for the energy they have not been able to sell in the markets, due to the reduction in energy demand expected from the activation of demand by independent aggregators.

Since the author believes that these are not the only variables that should be considered, but that the qualitative analysis should be broken down, a proposal of his own elaboration is attached in Table 6.

Table 6. Model Weighted Points

	WEIGHTING	OPTION 1	OPTION 2	OPTION 3
Easy to Implement	2	-	1	2
Increasing Competition among IA	1	-	1	3
No Cost to the System	2	-	3	3
Encourages Consumer Involvement	3	-	2	3
Secures Existing Business	1	3	3	1
Promotes Innovation	2	-	1	2
RESULT		X	20	27

[1] Own elaboration

As can be seen in Table 6, the most highly valued feature is consumer participation, as this is the most relevant characteristic for the electricity system, which needs to make demand more flexible to be able to accommodate increasingly renewable generation. In this aspect, a higher score was given to those models that pass on a higher remuneration to the consumer for explicitly activating their flexibility.

After this primary characteristic, the aim was to make it easy for the electricity system to implement, at the lowest possible economic cost. In this respect, Option 3 requires less technical requirements for cross-checking information related to the responsibility of payments between agents for the energy compensated.

The author is aware that Option 3 would be a major challenge for marketers, many of which will not be able to adapt to the technological challenge. Although this may seem a negative aspect for the marketing sector, it is only negative in the short term, and it is more positive for the system that those that can adapt to the new changes that the technological era and the energy transition represent remain in business. For this reason, it has been valued that innovation in the sector should be favored over ensuring that all the companies currently operating in this market will perpetuate their activity without contributing value to their customers or to any other agent in the system.

Finally, if one were to include in this assessment which actor should be responsible for the diversion, one would conclude that it should be the suppliers/BRP, following the same model as for balancing. In this case, it would not be the independent aggregators who would directly (and consumers indirectly) bear this cost in the case of the TSO; however, this economic cost would ultimately be passed on to consumers, so it would not be advisable to follow this logic.

However, with this economic amount, money could be allocated to these same suppliers/BRPs to invest in innovation, to improve their capacity to anticipate incidents, or even by using other sustainable technologies to store the possible surplus caused by the diversion between energy purchased in the markets and energy finally sold to their customers.

7. Conclusions

This project has been motivated by the need for the peninsular electricity system to implement demand flexibility, increasing the technical efficiency of the grid and its electricity markets, with the resulting benefit for all consumers. Furthermore, this activation of demand would end up generating added value for all agents linked to the electricity system, from the transmission and distribution grid managers themselves, to the suppliers, their BRPs and the new companies in charge of carrying out independent aggregation of demand, with the consumer benefiting from all these improvements.

This activation of consumers, turning them into prosumers, places them at the centre of the electricity system, taking them out of their current comfort zone, in which they passively consume energy without getting involved in the system, thus allowing them to be the protagonist of the energy transition towards a decarbonized model. This transition will make the electricity system sustainable, reinforcing the environmental level, avoiding the emission of greenhouse gases; the social pillar, by favoring a reduction in energy prices for all citizens; and the economic base, by making the electricity system and its markets more efficient.

This active consumer, who will become the prosumer, will be rewarded for his efforts through implicit flexibility, in which he will reduce his energy expenditure by shifting his consumption to cheaper (and less carbon-intensive) time slots; as well as through explicit flexibility, in which he will receive a monetary income for sacrificing his consumption interests to signals from other agents in the system. Moreover, this active behavior will also allow other passive consumers to reduce their electricity bills, as energy prices are reduced for all buyers in the market (being marginalist).

To achieve these objectives, the figure of the independent aggregator will have to be correctly defined in the national regulatory framework, allowing it to deploy its full potential to generate value for consumers and for the rest of the electricity system agents. Among the activities that it will undoubtedly be able to carry out are these explicit services of distributed flexibility in which, through the representation of its customers in an aggregated manner, it will be able to make them participants in balancing services, adequacy and management of other technical restrictions of the system; it will also be able to do so in the wholesale markets.

As expected, defining the regulatory model through which the independent aggregator will be able to interact with the system operator and transmission system operator, with the distribution system operators, and with the suppliers and their RTOs is crucial to build the path that will link the consumer to the electricity markets. Therefore, the student has decided to rethink the questions that were being formulated in the state of the art, and to face the needs of the regulatory model as he would do in his working life, defining the problem with a product approach.

Thus, the problem has been understood from the core, focusing the solution on the sustainability of the electricity system, impacting on a common good for all stakeholders, defining the optimal way to make prosumers' demand more flexible through the market and allowing them to be the main actors in this transition, for which independent aggregators will be their representatives.

With this, and after an analysis of the models of independent aggregators proposed by the experts, the methodology to be followed has been defined in order to achieve the objective of increasing decarbonized energy and making it more affordable for all those who consume it, whether in their homes, businesses, industries or institutions. In addition, the operational complexities that may arise during the implementation of this new electricity system of active consumers have been detected and are necessary to conclude in the proposal of a solution.

As a result, a model has been chosen which, with its pros and cons, has been positioned as the optimal one to maximize the efficiency of the electricity system and generate the greatest common good for all agents in the medium and long term. This model, without compensation and uncorrected, results in one that is easy to implement, that drives innovation in the sector, and that positions the prosumer as a key cog in the operation of this quasiperfect machine that will be the decarbonized and smart electricity system of 2050.

While there is no definition of a possible regulatory framework that is beneficial to all stakeholders, it is necessary to start early to learn from mistakes and iterate the standard so that it can be improved over time. In short, this great challenge requires legislation that is alive and can be adapted in a cycle of continuous improvement to increase the value generated for the electricity system and all its stakeholders, especially for prosumers who strive to embrace renewable energies and the challenges of adapting demand to the generation that this entails.

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Appendix A - DEFINITIONS OF INTEREST

It is considered appropriate to include a small number of definitions:

- ***Demand Side Flexibility (DSF)***: *is the ability to modify the production or consumption of different distributed energy resources in response to different signals: the price of electricity determined by the market; an established schedule; commitments made such as participation in a capacity auction; or decisions made by a third party performing aggregation functions in order to manage efficient energy consumption* [29].

  In short, it could be said that *DSF* is the ability of the electricity consumer (or his representative) to change (raise, lower, bring forward or postpone) his net consumption.

  Depending on the form of this economic benefit, either through the reduction of the economic expenditure associated with direct energy consumption, or by obtaining income from the direct sale of its flexibility, it is divided into these two types:
    - **Implicit Flexibility:** the consumer responds voluntarily to price variations, either because of his hourly tariff in the free market, or because his tariff is linked to the regulated one.
    - **Explicit Flexibility:** The consumer, usually through an aggregator (either independent, or the marketer itself), offers its flexibility in the market;
- **Aggregation:** According to *EU Directive 2019/944*, "aggregation" is defined as *a function performed by a natural or legal person that combines multiple customer consumptions or generated electricity for sale, purchase or auction on any electricity market* [26];
- **Aggregator:** The company in charge of carrying out the aggregation. This company may be the marketer itself, or it may be independent of the marketer;
- **Independent Aggregator:** Market participant that provides aggregation services and is not related to the customer's supplier [26].

Appendix B –

The Sustainable Development Goals (SDGs) stand as a global roadmap, an urgent call to transform the world and the way people relate to each other in it. Thus, on 25 September 2015, the world's top leaders pledged to strive for 17 global goals to eradicate poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda [30] [31].

Among these Goals, SDG. 7 Affordable and Clean Energy or SDG. 13 Climate Action occupy more central positions of focus in more developed societies, which are closer to meeting other

Goals even more essential to human life, such as SDG 2 Zero Hunger or SDG 16 Peace, Justice, and Strong Institutions. However, in the knowledge that these Goals are global, the scope of this project has not been able to address the latter, as they are beyond the student's reach at the present time.

However, this project does try to shed a little light on the definition of a decarbonized electricity system, which favors SDG 11. Sustainable Cities and Communities or SDG 9. Industry, Innovation, and Infrastructure. In addition, demand flexibility opens a window of opportunity for collaboration with the most disadvantaged sectors of national society suffering from Fuel Poverty.

This is defined in the *National Strategy Against Fuel Poverty 2019 - 2024* as *the situation in which a household finds itself in which its basic energy supply needs cannot be met, because of an insufficient level of income and which, where appropriate, may be aggravated by having an energy inefficient dwelling* [31]. Thus, this Strategy fulfils the mandate established in Article 1 of *Royal Decree-Law 15/2018, of 5 October, on urgent measures for energy transition and consumer protection* [18].

However, there's a long way to go, because while this document shared the figure that 8.0% of the population could not keep their homes at an adequate temperature in 2017, and the target for 2025 was to reduce this indicator to 4.0-6.0%, as can be seen in Table 7, the figure that can be extracted in Eurostat for 2022 is 17.1%, as can be seen in Table 8.

Table 7. Energy Poverty Reduction Targets in the Framework of the National Energy Poverty Strategy (2019-2024)

INDICADOR (%)	2017	OBJETIVO MÍNIMO PARA 2025	OBJETIVO BUSCADO PARA 2025
GASTO DESPROPORCIONADO (2M)	17,3	12,9	8,6
POBREZA ENERGÉTICA ESCONDIDA (HEP)	11,5	8,6	5,7
TEMPERATURA INADECUADA DE LA VIVIENDA	8,0	6	4,0
RETRASO EN EL PAGO DE LAS FACTURAS	7,4	5,5	3,7

[1] [31]

Table 8. Inability to Keep Home Adequately Warm - EU-SILC Survey

GEO \ TIME	2019	2020	2021	2022
Bulgaria	30.1	27.5	23.7	22.5
Cyprus	21.0	20.9	19.4	19.2
Greece	17.9	17.1	17.5	18.7
Lithuania	26.7	23.1	22.5	17.5
Portugal	18.9	17.5	16.4 (b)	17.5
Spain	7.5	10.9	14.2	17.1
Romania	9.3	10.0	10.1	15.2
France	6.2	6.7 (b)	6.0	10.9 (p)
European Union - 27 countries (from 2020)	6.9 (e)	7.5	6.9	9.3

[1] [32]

On this issue, it is pertinent to stress the importance of addressing fuel poverty in an integrated way [33] , so that the problem is tackled from the point of view of policies and not only politics.

By linking the value that explicit demand flexibility triggers can bring in their fight against fuel poverty, especially on the air conditioning front in Spanish households, a direct relationship can be created between explicit demand-boosting trigger events and the electric radiators of the most vulnerable households. Of course, many other opportunities could arise from optimizing the implicit flexibility of these consumers, as well as their participation in explicit demand-side trigger events to generate an additional source of income to reduce the total cost of electricity bills at the end of the month.

From the good energy behavior that these people can adopt, many other policies can be linked to reinforce the efforts made by these families, but, unfortunately for the learner, it is beyond the scope of this project to go into this matter. It will be the responsibility of people working in sectors related to this energy issue to ensure that the companies in which they work on a day-to-day basis direct part of their efforts to developing solutions in this field, whether on ethical or utilitarian grounds.

To go beyond the national level and relate the subject to other countries much less developed than Spain, it has been demonstrated in the student's field of work (at least in his opinion) that there is an opportunity to export the demand flexibility technologies developed in the peninsular economy to other electricity systems that are much less technologically advanced. However, it is certainly too early to consider this task firmly, but it is certain that the business models validated here can be implemented (with the necessary adaptations) in regions on other continents.

In this sense, the Goal to which the project is most related is SDG 7, but also indirectly to others such as:

- SDG 1. End Poverty

Although this social Goal is a long way from being achieved, it will make it possible to fight it reliably, at least as far as Energy Poverty is concerned.

- SDG 8. Decent Work and Economic Growth

The energy transition will bring with it the creation of specialized jobs, the training of which will have to be supported so that all people can have access to these jobs after a quality education. However, this technological transition brings with it a specialization of work that may have a rather negative counterpart if it is not well managed at the level of education, as the labor economy is heading towards a new paradigm in which many jobs may be automated, which will destroy many jobs located in the middle class of the most developed societies. Fortunately, it will also create many others, but access to them will generally require a high level of education, as is currently the case, which cannot be afforded in all households. In this sense, great efforts will have to be made from the public and private spheres to make a just transition that favors the fulfilment of this economic Goal.

- SDG 9. Industry, Innovation, and Infrastructure

Demand-side flexibility will create a new and innovative industry in the technology and energy sector that will strengthen the resilience of electricity systems. Once the IA is successfully implemented, it will bring great value to consumers, both domestic and industrial, reinforcing the fulfilment of this economic Goal.

- SDG 11. Sustainable Cities and Communities

An increase in the electrification of cities, derived from the advantages of a flexible electricity system, allows for a higher quality of life in cities by facilitating the removal of combustion vehicles from the roads. Furthermore, the figure of the IA will favor much greater integration of DERs in distribution networks, favoring sustainable communities and helping in the fulfilment of this social Goal.

- SDG 13. Climate Action

The full integration of renewables into electricity systems is a challenge that must be met if society is to make further progress in the decarbonization of energy, which is key to reducing greenhouse gas emissions. Therefore, in a direct way, the figure of the IAs will favor the achievement of this crucial Goal for the conservation of the biosphere.

- SDG 17. Partnerships to Achieve the Goals

As has been seen in this project, the different EU countries are collaborating with each other to make a much stronger joint electricity system. This collaboration is both public and private and is an example of how different institutions need to work together to achieve much larger goals that, in isolation, could not be achieved [34].

In this economic challenge of energy transition, which will be accompanied by technological transition, it will be essential to redefine current business models, for which entrepreneurship and social innovation will have a meeting point to address energy poverty to accelerate and ensure a just energy transition [35]. This project will encourage all economic actors in society (the state, businesses, and consumers) to join freely to assume the responsibility of all people to preserve the biosphere and improve society by driving the economy towards a more prosperous and fairer one.

References

[1] Comisión Europea, «El Pacto Verde Europeo - COMUNICACIÓN DE LA COMISIÓN AL PARLAMENTO EUROPEO, AL CONSEJO EUROPEO, AL CONSEJO, AL COMITÉ ECONÓMICO Y SOCIAL EUROPEO Y AL COMITÉ DE LAS REGIONES». diciembre de 2019.

[2] J. del E. BOE, «Ley 7/2021, de 20 de mayo, de cambio climático y transición energética.».

[3] J. del E. BOE, «Ley 54/1997, de 27 de noviembre, del Sector Eléctrico.», 1997.

[4] S. Burger, J. P. Chaves-Ávila, C. Batlle, y I. J. Pérez-Arriaga, «A review of the value of aggregators in electricity systems», *Renew. Sustain. Energy Rev.*, vol. 77, pp. 395-405, sep. 2017, doi: 10.1016/j.rser.2017.04.014.

[5] MITECO, «Hoja de Ruta del Autoconsumo». diciembre de 2021.

[6] «Ministerio para la Transición Ecológica y el Reto Demográfico». https://www.miteco.gob.es/es/ (accedido 16 de julio de 2023).

[7] J. Finke, V. Bertsch, y V. Di Cosmo, «Exploring the feasibility of Europe's renewable expansion plans based on their profitability in the market», *Energy Policy*, vol. 177, p. 113566, jun. 2023, doi: 10.1016/j.enpol.2023.113566.

[8] «Ley 24/2013, de 26 de diciembre, del Sector Eléctrico.».

[9] European Comission, «Estudio de Evaluación del Impacto de la Flexibilidad de los Precios, la Respuesta de la Demanda y la Medición Inteligente». julio de 2016.

[10] H. C. Gils, «Assessment of the theoretical demand response potential in Europe», *Energy*, vol. 67, pp. 1-18, abr. 2014, doi: 10.1016/j.energy.2014.02.019.

[11] entsoe, «entsoe - European association for the cooperation of transmission system operators (TSOs) for electricity». https://www.entsoe.eu/ (accedido 29 de agosto de 2023).

[12] Directorate-General for Energy (European Commission), *Clean energy for all Europeans*. LU: Publications Office of the European Union, 2019. Accedido: 20 de agosto de 2023. [En línea]. Disponible en: https://data.europa.eu/doi/10.2833/9937

[13] I. Agile, «Sesgos cognitivos, el martillo de Maslow o ley del instrumento.», *Instituto Agile*, 7 de abril de 2023. https://www.instituto-agile.com/post/sesgos-cognitivos-el-martillo-de-maslow-o-ley-del-instrumento (accedido 15 de agosto de 2023).

[14] Gobierno de España, «Plan de Acción para la Implementación de la Agenda 2030. Hacia un Estrategia Española de Desarrollo Sostenible». junio de 2018.

[15] U. D. Team, «USEF - The Framework Explained».

[16] Ö. Okur, P. Heijnen, y Z. Lukszo, «Aggregator's business models in residential and service sectors: A review of operational and financial aspects», *Renew. Sustain. Energy Rev.*, vol. 139, p. 110702, abr. 2021, doi: 10.1016/j.rser.2020.110702.

[17] Department for Business, Energy & Industrial Strategy, «Electricity System Flexibility Modelling». julio de 2021.

[18] J. del E. BOE, «Real Decreto-ley 17/2022, de 20 de septiembre, por el que se adoptan medidas urgentes en el ámbito de la energía, en la aplicación del régimen retributivo a las instalaciones de cogeneración y se reduce temporalmente el tipo del Impuesto sobre el Valor Añadido aplicable a las entregas, importaciones y adquisiciones intracomunitarias de determinados combustibles.», sep. 2022.

[19] MITECO, «Consulta Pública Previa relativa a la elaboración del Real Decreto por el que se regulan las condiciones de suministro y contratación de energía eléctrica y se establecen principios reguladores del agregador independiente», febrero de 2023. https://energia.gob.es/es-es/participacion/paginas/DetalleParticipacionPublica.aspx?k=584 (accedido 28 de agosto de 2023).

[20] G. de E. MITECO, «Ministerio para la Transición Ecológica y el Reto Demográfico - Proyecto de Orden por la que se crea un mercado de capacidad en el sistema eléctrico español», abril de 2021. https://energia.gob.es/es-es/participacion/paginas/detalleparticipacionpublica.aspx?k=409 (accedido 25 de agosto de 2023).

[21] CNMC, «Informe sobre el Proyecto de Orden por la que se crea un mercado de capacidad en el sistema eléctrico español». julio de 2021.

[22] REE, «Energía no suministrada (ENS) y tiempo de interrupción medio (TIM) de la red de transporte | Informes del sistema», enero de 2023. https://www.sistemaelectrico-ree.es/informe-del-sistema-electrico/transporte/energia-no-suministrada-ens-y-tiempo-de-interrupcion-medio (accedido 28 de agosto de 2023).

[23] P. Baker, «Unleashing Demand Response with Effective Supplier Compensation», jun. 2017.

[24] N. de prensa CNMC, «Casi el 100% de los consumidores domésticos en España tenían un contador inteligente al final de 2019 | CNMC»,

octubre de 2020. https://www.cnmc.es/prensa/cnmc-contadores-integrados-20201021 (accedido 24 de agosto de 2023).

[25] L. Fin, «A Structural Change in Finance», *BlackRock*. https://www.blackrock.com/cl/larry-fink-ceo-letter (accedido 29 de agosto de 2023).

[26] «DIRECTIVA (UE) 2019/ 944 DEL PARLAMENTO EUROPEO Y DEL CONSEJO - de 5 de junio de 2019 - sobre normas comunes para el mercado interior de la electricidad y por la que se modifica la Directiva 2012/ 27/ UE».

[27] A. y F. Entra, «Posición entra agregador independiente – Entra», julio de 2020. http://entra-coalicion.com/posicion-entra-agregador-independiente (accedido 28 de agosto de 2023).

[28] REE, «Generación renovable de energía eléctrica 2022 | Informes del sistema», enero de 2023. https://www.sistemaelectrico-ree.es/informe-del-sistema-electrico/generacion/generacion-de-energia-electrica/generacion-renovable-de-energia-electrica (accedido 28 de agosto de 2023).

[29] I. Zamora Santa Brígida, «Regulando la transición energética. Hacia un modelo sostenible, flexible y distribuido», marzo de 2022. https://editorial.tirant.com/es/ebook/regulando-la-transicion-energetica-hacia-un-modelo-sostenible-flexible-y-distribuido-ignacio-zamora-santa-brigida-9788411132770 (accedido 15 de agosto de 2023).

[30] N. U. Asamblea General, «Transformar nuestro mundo: la Agenda 2030 para el Desarrollo Sostenible». 21 de octubre de 2015.

[31] G. de E. Ministerio para la Transición Ecológica, «ESTRATEGIA NACIONAL CONTRA LA POBREZA ENERGÉTICA 2019-2024». 2020.

[32] D. B. Eurostat, «Inability to keep home adequately warm - EU-SILC survey», julio de 2023. https://ec.europa.eu/eurostat/databrowser/view/ILC_MDES01__custom_4564689/default/table (accedido 27 de agosto de 2023).

[33] R. Barrella, «Addressing energy poverty in an integrated way - An interdisciplinary characterisation of Spanish vulnerable households and proposal for implementing feasible technical and policy solutions». mayo de 2022.

[34] United Nations, «Objetivos de Desarrollo Sostenible», *Desarrollo Sostenible*. https://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/ (accedido 27 de agosto de 2023).

[35] M.-J. Manjon, A. Merino, y I. Cairns, «Business as not usual: A systematic literature review of social entrepreneurship, social innovation, and energy poverty to accelerate the just energy transition», *Energy Res. Soc. Sci.*, vol. 90, p. 102624, ago. 2022, doi: 10.1016/j.erss.2022.102624.