BALANCING SOCIO-POLITICAL ACCEPTANCE AND ECONOMIC EFFICIENCY OF ELECTRICITY PRICE SIGNALS FOR RESIDENTIAL END USERS: LESSONS LEARNT FROM THE PIONEERING SPANISH EXPERIENCE

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Abstract

The decarbonization of power systems would be more efficient if, among other developments, it would be possible to achieve a significant activation of electricity end users. But the political unwillingness to fully expose those later to market prices has been repeatedly proven worldwide, particularly when these prices are sustained in time, as for example it was evidenced during the energy price crisis that affected the European Union from 2021 to 2023. Thus, unavoidably, end-user retail prices design need to properly balance the orthodox pursuit of economic efficiency with the perennial sociopolitical perception of electricity supply as an essential service.

Back in 2008, the Spanish National Energy Commission developed a ground-breaking electricity default tariff proposal to fully expose the country's nearly thirty million residential end users to hourly market prices. During the decade that followed, this methodology was gradually implemented, and was subject to deep controversy particularly during the referred energy crisis period, to the extreme to be subject to a new reform.

We provide a detailed assessment of the evolution of this default tariff, a pioneering and unique real case example on how to widely and fully expose households to accurate market price signals, showing how residential consumers -and maybe more importantly politicians- reacted, and shedding also light on the main alternatives for future-proof tariff design.

Among the many sound lessons that can be extracted, the pioneering Spanish experience shows how interventions in retail tariff design are not so much aimed at mitigating the cost of price volatility to end users, but rather at the significant risk aversion of governments in dealing with public opinion displeasure when these events occur.

1 INTRODUCTION

Electricity tariff design has always had to comply with several theoretical principles at the same time. Cost-recovery, efficiency, equity, transparency, simplicity, or stability have always guided ratemaking in the power sector, often forcing regulators to seek a balance between principles that push tariff design in different directions. But beyond these often conflicting objectives, the key challenge in designing retail pricing methodologies is how to reconcile the orthodox pursuit of economic efficiency with the perennial sociopolitical perception of electricity supply as an essential service. The energy price crisis that affected several regions and the European Union in particular since 2021 (first due to the recovery from Covid-19, then due to the war in Ukraine and the significant unavailability of French nuclear power plants) has demonstrated the political unwillingness to bear sustained high electricity market prices. European institutions have emphasized the need to implement measures to keep electricity prices within "acceptable" limits, either through direct intervention in market prices or, eventually, through the promotion of price hedging instruments.

In the context of the energy transition, the tension between these two seemingly irreconcilable policy and regulatory objectives is increasingly acute. The decarbonization of power systems would be more efficient if, among other developments, it would be possible to achieve a significant activation of electricity end users. For instance, demand-response services provided by for example load-shifting capability of electric vehicles or electric space heating systems could help to absorb, at least in part, the short-term price volatility linked to the large variability of renewable resources. But also, during sustained price crisis, as in the case of the previously referred, it is instrumental that demand also perceives the actual opportunity cost of electricity. The activation of this reaction must be driven by efficient economic signals conveyed by electricity tariffs, which should prompt consumers to change their loads according to the conditions of the system.

The 2021-22 price crisis is likely to be followed by other price shocks during the long decarbonisation process ahead. Electricity tariff design may not be able to achieve both the conflicting regulatory objectives mentioned above (efficient activation of demand and protection from price volatility), but it will certainly have to seek an efficient balance among them.

The Spanish pioneering experience

In 2008, in order to make the most of the full rollout of electronic meters in the coming years, with the support of a couple of the authors of this paper, the Spanish Energy Commission developed and promoted what was (and still is) a radical redesign of electricity tariffs for the country's nearly thirty million residential consumers. The reform, proposed after a wide public consultation process[1] (CNE, 2008) and, as described later, gradually implemented during the following years, focused on improving price signals along three key dimensions:

i) Network charges, through an update of the existing demand charge (in €/kW-year, per amount of contracted peak consumption) and a time-of-use (TOU) network charge (€/kWh);

ii) a dynamic hourly energy price (direct pass-through of the short-term market prices cleared the day before) and,

iii) a novel method of allocating the cost of RES subsidies, which at the time amounted to almost one-third of full retail prices, by distributing it among final energy consumers in proportion to their consumption, regardless of the type of final energy consumed (liquid fuels, gas, electricity or coal)[2].

The reform of the access-to-the-network charges and the dynamic energy price component, as we review in the next section, was implemented in two steps: first in 2014 (fully dynamic energy prices plus an optional/voluntary two-block TOU network tariff); and fully in June 2021 (time-differentiated demand charge plus a three-block TOU network tariff for every residential consumer in the country).

This tariff design was in force during almost a decade amidst a notable indifference from the part of residential end user. But during the 2021 energy price crisis, it was subject to significant and, as we will discuss later, unjustified criticism, particularly from the Government itself. Later in 2024, this latter promoted a reform to introduce partial annual

[1] Public consultation of the National Energy Commission on the methodology for the establishment of access to the network tariffs and last resource prices in the power sector (in Spanish).

[2] We will not discuss here this later dimension, for a description of the original proposal, see Batlle (2011). The method was finally developed in 2022 in the Royal Decree-Law 6/2022, via the so-called National Fund for the Sustainability of the Power System.

price hedging in an attempt to mitigate in the short term the potential impact of a future price crisis, while at the same time trying not to lose all the benefits of dynamic pricing.

A detailed assessment of the evolution of the default tariff in Spain provides sound lessons about how residential consumers (and policymakers) react to 100% market-based price signals, and also sheds light on the main alternatives for future-proof tariff design. We begin by reviewing the whole process, with a particular focus on the current efforts to balance the conflicting policy objectives that can be summarized as "how to expose end-users to short-term signals without exposing them too much".

Price hedging for consumers in the reform of the European electricity market design

The energy price crisis that started in 2021 has somewhat changed the perspective on electricity retail tariff design that reigned in the EU since power systems restructuring. While dynamic pricing is still seen as an important tool to drive the activation of electricity customers, European regulators have also defended the need to protect customers from sustained price spikes such as those experienced in 2021 and 2022. The current proposal to reform the electricity market design (EC, 2023) gives customers the right to sign either a dynamic electricity price contract (if they have a smart meter installed) or a fixed-term, fixed-price electricity price contract of a duration of at least one year and requires any supplier with more than 200 000 final customers to offer both types of contract. In addition, it states that customers should be informed not only of the potential savings that can be achieved through dynamic price contracts, but also of their risk in terms of affordability.

The proposal also includes specific guidelines on supplier risk management and requires Member States to monitor that long-term contracts in the retail market are backed by appropriate risk-hedging strategies by suppliers. The proposal continues to consider price interventions as market-distortive measures whose use should be limited. However, it also sets out rules for declaring Union-wide electricity price crises, during which Member States will be allowed to temporarily set regulated prices below cost, although in principle this price regulation should be limited to a certain percentile of each customer's historical consumption.

As previously explained, in this context, we describe build the pioneering Spanish experience during the last decade and build an in-depth analysis of the sound lessons that can be extracted from it. In the next section, we start by describing the gradual process in which the methodology was developed, also illustrating its diverse impact on four different categories of residential consumers. Then in section 3, we put forward the discussion that quickly arose when the energy crisis started in the fall of 2021, that ended up leading by a new reform, promoted by the Government and blessed by the EU Commission. This reform is described and criticized in section 4. This review is also supported with a detailed quantification of the actual impacts that the reform would have had in case it would have been implemented prior to the (by then unexpected) energy price crisis. Finally, section 5 succinctly wraps up the main conclusions that can be extracted.

2 THE RESIDENTIAL DEFAULT TARIFF EVOLUTION AND THE END USERS (AND POLITICAL) RESPONSE

The Spanish default tariff for residential end users is unorthodox compared to other European cases. It has been chosen as the main case study for this article because it represents the pioneering experience to openly expose all residential end users to pure market prices, aiming at promoting the activation of consumers through efficient signals.

The Spanish electricity market was fully liberalized on 1 July 2003, so since then all consumers have been able to choose their supplier. Particularly since 2007, the efforts have been focused on designing a transparent default option for residential end users that guarantees that end users pay the full energy market price.

Between 2007 and 2013, this energy component was set through centralised default service auctions (Loxley & Salant, 2004). The so-called CESUR auctions (*Contratos de Energía para el Suministro de Último Recurso*, in Spanish, or Energy Contracts for the Supply of Last Resort) were held quarterly to cover part of the demand of consumers under the default tariff. Baseload and peak (8am-8pm) products over a three-month horizon were procured ten days before the start of the quarter. The resulting contract prices were used by the regulator to calculate a fixed energy price for the upcoming quarter. The underlying objective of the CESUR auctions was to promote competition in the provision of price-hedging products for regulated demand.

At the end of 2013, in a context in which gas prices were above the average levels, this mechanism was abruptly cancelled by the Government. The allegation was that the auctions were subject to manipulation, arguing that, at that time, the liquidity of the Iberian futures market as well as of the auctions themselves was not enough to guarantee a sufficiently competitive price (Ciarreta et al., 2017; Palacio, 2020). The alternative to directly pass through the actual spot price in the Iberian Power Exchange, OMIE, as proposed back in

2008 by the National Regulatory Authority (CNE, CNMC[3] since October 2013) appeared as the best approach to minimize the risk of lack of competition, for it is by far the most liquid market.

2.1 The PVPC 1.0 (2014)[4]

The controversy around the CESUR auctions gave momentum to finally implement the tariff reform promoted by the CNMC. The Act 24/2013 of the Power Sector and the Royal Decree 216/2014 modified the regime of the last resort supply and introduced the PVPC for consumers with a contracted capacity connection below 10 kW. It is a default tariff of which consumers can opt out of and subscribe to another supplier or contract structure.

The PVPC was calculated for each day and hour by adding up the following three components:

i) a dynamic pricing rate, 100% market based to recover the energy costs, via a daily direct pass through of the hourly prices resulting from the Iberian day-ahead and ancillary services markets Besides the objectives previously highlighted, the aim was to increase transparency, eliminating the participation of the Government in setting the energy costs of electricity, while at the time reducing prices by lowering the cost of hedging[5].

ii) an optional time-of-use (TOU) network tariff designed to better complement the already existing demand charge (in €/kW), with the aim to better reflect the different impact on the long-run marginal network costs of the consumption in different time frames. The demand charge was paid according to the capacity contracted for any hour of the year (maximum instantaneous consumption, sustained for 10 minutes). The demand charge payment was significantly increased, evolving from 0.06 €/kW·day (+ 21% VAT) in 2013 to

[3] National Markets and Competition Commission (*Comisión Nacional de los Mercados y la Competencia*, CNMC).

[4] The PVPC design has been reformed two times. We will denote these three formats with 1.0, 2.0 and 3.0. This denomination is not official, we just came with it to facilitate the discussion.

[5] Strictly speaking, the cost of hedging in OMIP, in any case, by no means can be considered relevant. In principle, the cost of fees and collateral does not exceed 50 cents of a euro per MWh. However, the bid-offer spread, risk aversion (particularly to volume risk, i.e. the potential cost of losing customers and being unintentionally long) and even the cost of potential market imperfections might imply larger costs. One of the advantages considered when coming with the original PVPC design was that there was not need for the retailers providing under the default option to incur in any of these costs.

0.1233 €/kW day (+ 21% VAT) in 2020. For example, contracting 4.6 kW implied a cost for the end user of 20.60 €/month.

iii) a regulated retail margin (3.11 €/kW per year, with a variable component of around 0.2 c€/kWh, Morell et al., 2020).

The first figure below illustrates the evolution of the sources of costs recovered with the system charges, and the second figure below how the weight of the system charges has evolved in comparison with the energy component resulting from the energy market prices.

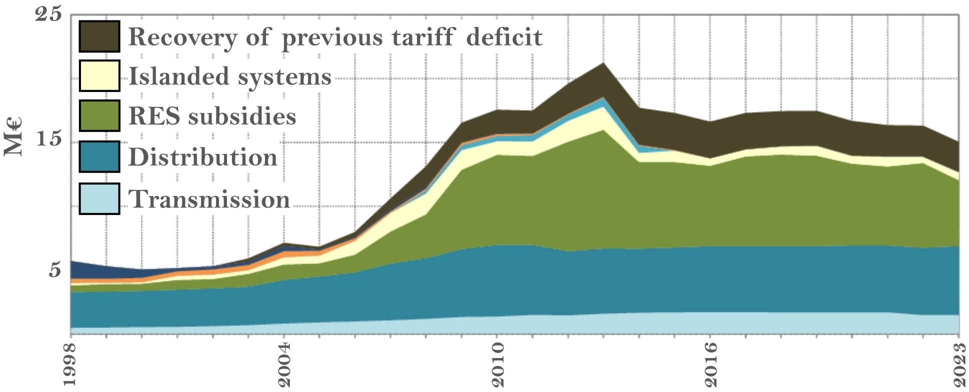

Figure 1. Evolution of system charges (CNMC, 2023a)

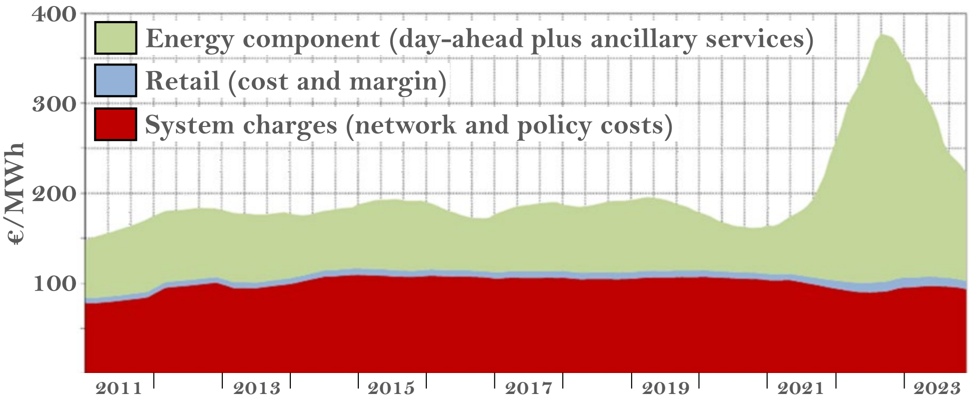

Figure 2. Evolution of energy costs, system charges and retail costs for PVPC end users (CNMC, 2023a)

These regulated charges ii and iii apply to any residential end-user, regardless of whether they are under this PVPC option or have contracted with a retailer in the market. They were billed according to their actual hourly consumption and could choose between three types of network access tariff structures: i) 2.0 A, flat rate for the 24 hours of the day; ii) 2.0 DHA, two-period tariff, valley (am) and peak (pm) and iii) 2.0 DHS, with super valley (1am to 7am) aimed at promoting overnight charging of electric vehicles.

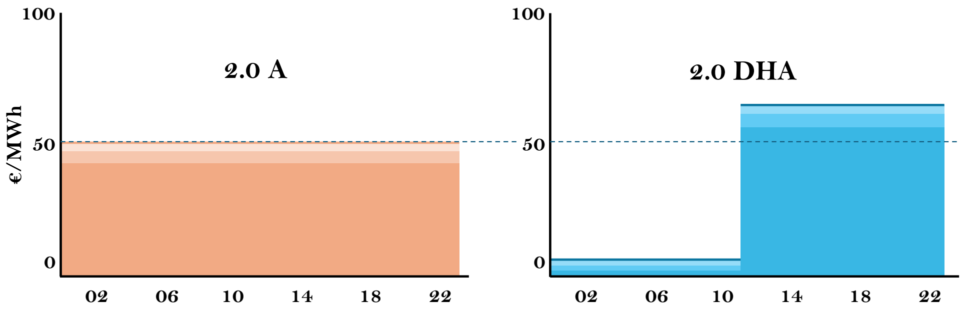

Figure 3. PVPC 1.0: Network access component published in the web page of REE for May 31, 2021

The figure below shows the composition of both signals, the network-access tariff (illustrated in the previous figure) plus the energy component, applied to all residential customers under this default option, resulting from the prices cleared each day in short-term markets (day-ahead and reserves).

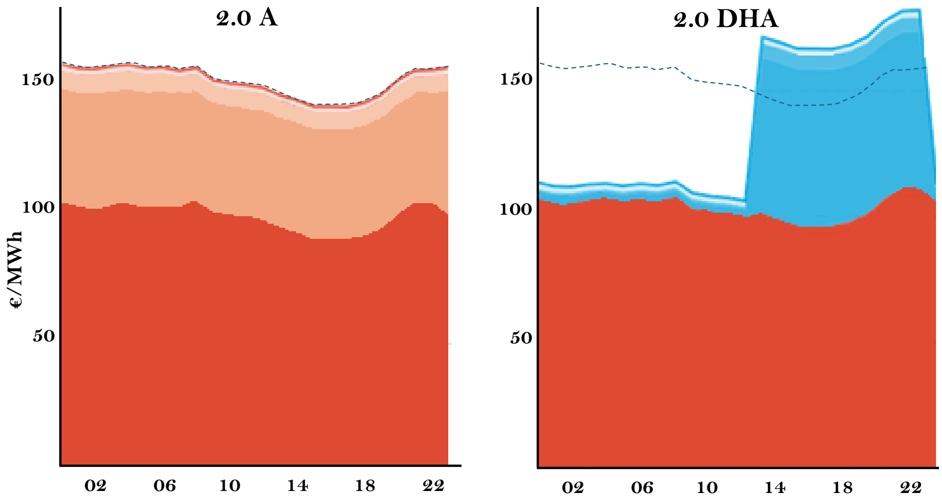

Figure 4. PVPC 1.0: End-user hourly prices published in the web page of REE for May 31, 2021

To allow consumers to know the price of the product before consuming it, in the evening (8:15pm) of each day, once the day-ahead market and the subsequent ones, intraday and ancillary services markets close, the hourly prices to be paid by each residential consumer the day after are published in the web page[6] and app of the system operator (*Red Eléctrica de España, REE*), as shown in the figure below.

[6] https://www.esios.ree.es/en/pvpc

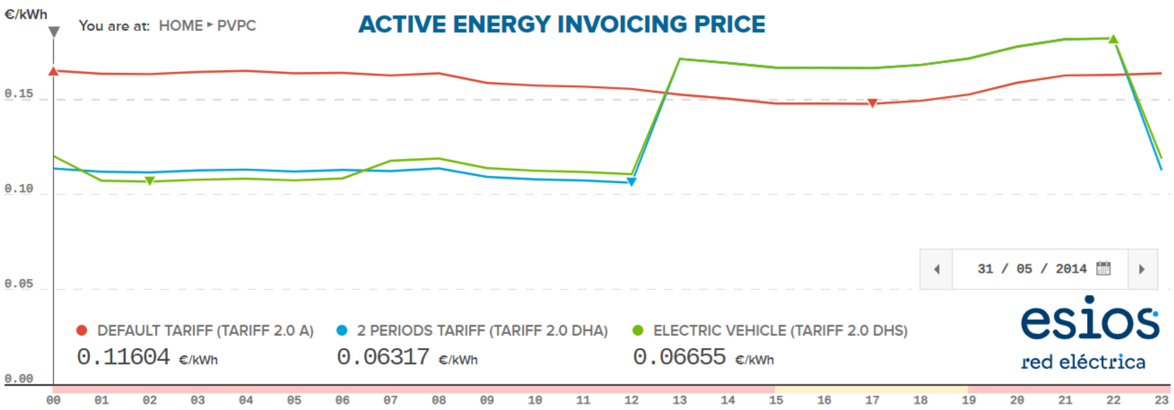

Figure 5. PVPC 1.0: Hourly prices published for the day after (May 31, 2014) in the web page of REE

Until the summer of 2021 (as illustrated in the figure above), energy market prices were moderated and the intraday energy price spreads were low, so the main economic incentives for PVPC consumers to change their consumption patterns could only come from TOU access tariffs rather than daily market volatility.

The tariff design was aimed at changing consumer attitudes. At the time of implementation, an extensive advertising campaign was launched to explain to consumers that the cost of electricity is different in each hour and that from that moment on it was possible to choose a format that allows savings to be made by shifting consumption to off-peak hours. To further promote the two-tier tariff among consumers, the TOU prices were deliberately calculated to encourage end-users to opt for it. Under "regular" energy prices, such as those on May 31 shown in the figure above, the end-user prices under the 2.0DHA option were almost 50% lower in off-peak hours than under the flat option, and just over 20% higher in peak hours. According to the CNMC's calculations, 70% of residential end-users would have saved money simply by switching to the 2.0 DH TOU (all it took was a 5' call to the reference retailer to arrange it), without having to change their consumption patterns.

Despite efforts to promote the change, the initial response from PVPC end users was almost negligible. The vast majority remained on the network flat rate. Soon after, however, market retailers began to take advantage of the arbitrage opportunity: they could offer savings by simply moving customers to the TOU option. According to the CNMC, by May 2021, more than 40% of households were on TOU. The problem was that in the vast majority of cases, consumers did not even know that their market retailer had signed them up for this TOU option (in many cases, see later, they did not even want to know or care), so no meaningful shift in demand was detected. Indeed, sadly, one of the successful commercial strategies of market retailers to engage new customers was to offer them fully flat rates (particularly after the PVPC 2.0 was implemented and, as we explain later, it was more notorious that electricity prices were different in each hour). Contrary to the objective of the reform and to what the system would need, it was evidenced that a large number of customers, especially the most intensive (wealthier) ones, feel more comfortable (and to some extent are willing to pay a higher price, or simply prefer not to know it) for not having to think that their consumption could have a different cost at other times.

2.2 The fully developed PVPC 2.0 (2021)

On 1 June 2021 a fully developed network tariff methodology was introduced, with the declared objective of simplifying the structure eliminating optionality while at the same time reinforcing the price signal, The format kept unaltered the dynamic energy component, but developed the network components mandatory for every residential consumer in the country:

i) A new TOU demand charge (€/kW) allows users to contract two different values of capacity for peak and off-peak periods (see the prices at the time of being implemented in the figure below) and

ii) a mandatory three-block TOU network tariff, applicable in the working days (weekends are considered valley hours).

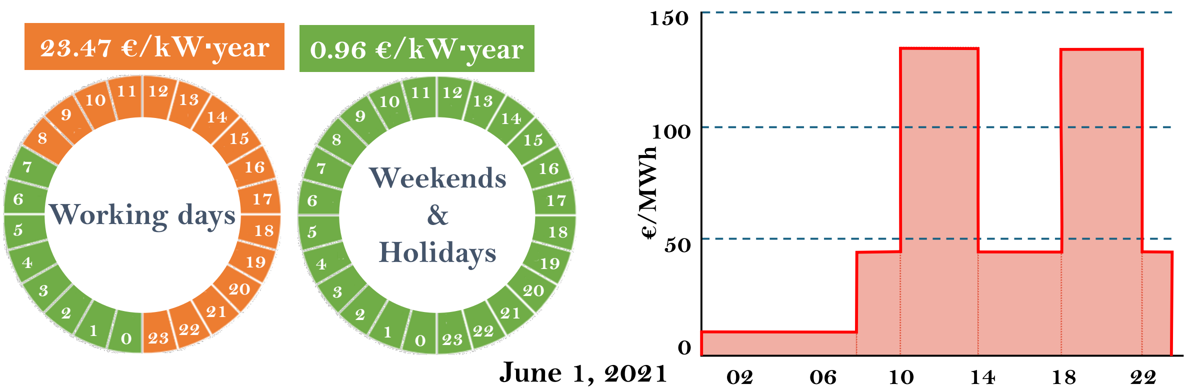

Figure 6. PVPC 2.0: TOU demand charge (left) and TOU network charge (right)

Similarly to the dynamic energy component, discussed later, the tariff design aims at providing end users with the right incentives to hopefully modify their consumption patterns to maximize the efficient use of networks (minimizing the need for network reinforcements). The figure below shows the end-user prices for three days in April 2022, and below, the consumption profile on those days of the real consumer owning a Plug-in Hybrid Electric Vehicle (PHEV) that we introduce in next section.

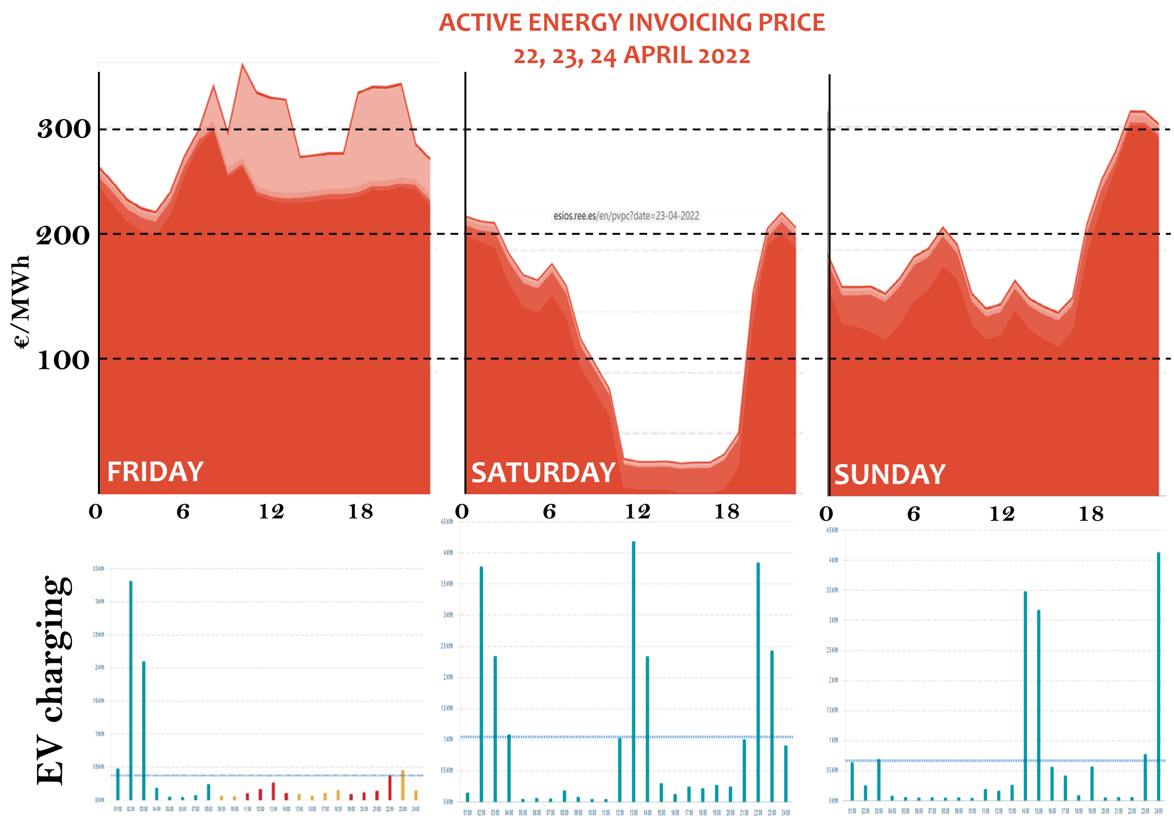

Figure 7. PVPC 2.0: End-user prices published in the web page of REE for May 31, 2021

In the next subsection, on the basis of a real case example,we illustrate the beneficial impact of the tariff design on different types of end users.

Impact and incentives of the TOU demand charge and network charges on different types of residential end-users

The case example is built considering the real hourly data for 2021 to 2023 of four households connected to the same voltage level but with different consumption characteristics:

i. A medium-consumption family (EVC hereafter) but with a Plug-in Hybrid Electric Vehicle (PHEV) with a 20 kWh battery, charged at night almost every day.

ii. A holiday country house (HH) 200 m^2, equipped with an electric heat pump.

iii. A high-consumption family (HC), a three-child family, residing in a three-floor detached house (350 m^2, electric heat pump, air conditioning, dryer, etc.).

iv. A low-consumption family (LC hereafter), a single-child family living in a small apartment (60 m^2, with only fridge and washing machine, gas-fired heating).

The main objective of this sample selection is to illustrate how the tariff design reflects the cost-causality principle, and as a result, the diverse price signals perceived by the four end users, as they significantly differ in their consumption patterns.

The figures below show the hourly consumption of the four end users during the whole year 2023 (left) as well as an illustrative week in the same year (right).

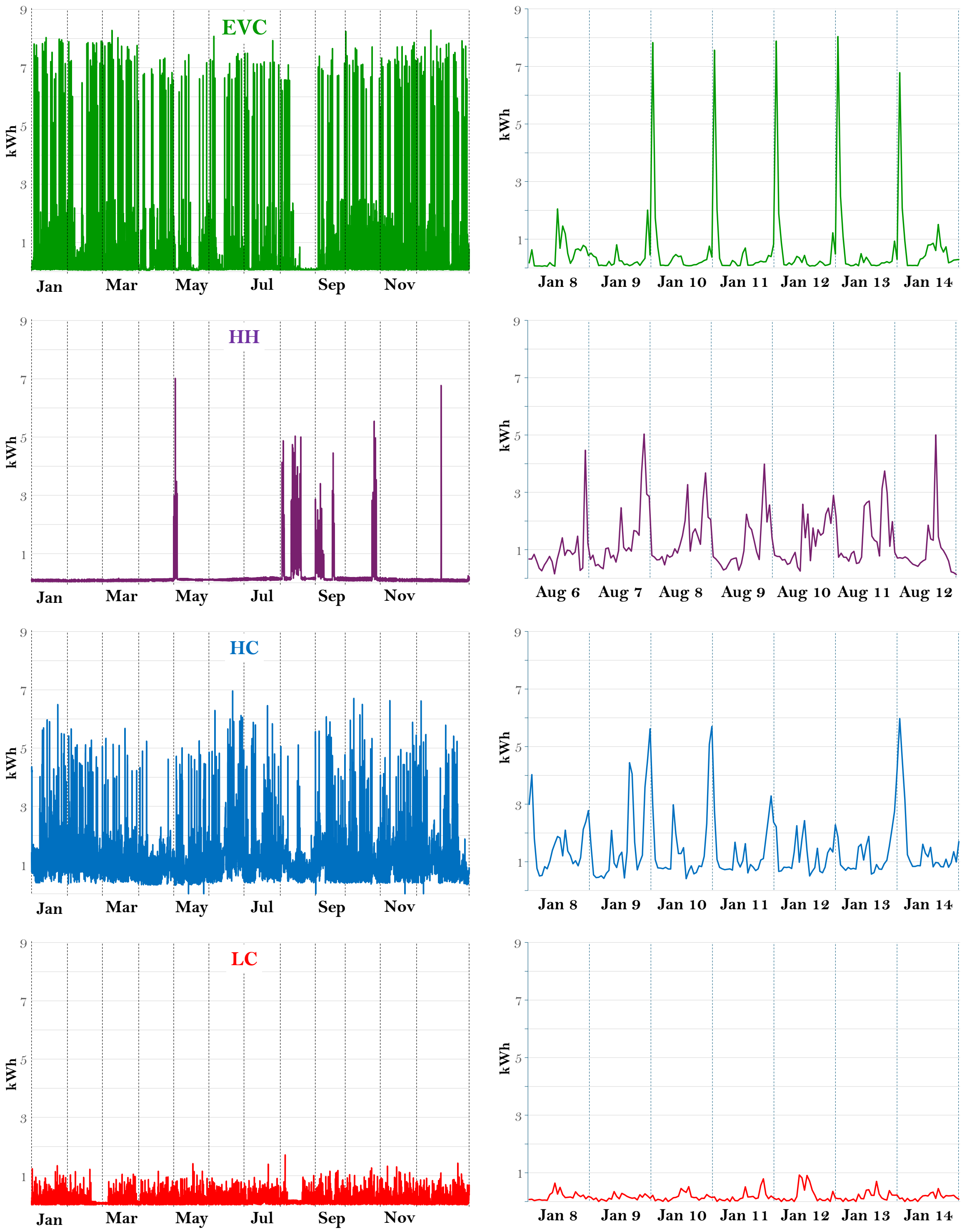

Figure 8. Hourly consumption during 2023 (left) and detail during one week of that year (right).

The table below quantifies how these different consumers ended up paying also different amounts, illustrating first how the network charges relate to the actual "use" of the network (capacity contracted and consumption at the peaks) and how the ability to shift consumption to the off-peak hours leads to lower average prices at the end of the year.

Table i. PVPC 2.0 tariff settlement for year 2023

		Demand charge				Network charge					Energy (spot)		Annual
	€	Peak	Off peak	Total		€/kWh	0.00641	0.03171	0.08108	Total	Total	Avg.	average
	kWyear	25.32	0.97	€/year		Year	Off peak	Shoulder	Peak	€/year	€/year	€/MWh	€/MWh
EVC	kW	3	9	**85**	kWh	14580	8664	2853	3063	**394**	565	38.78	**71.63**
HH		7	7	**184**		1745	562	513	670	**74**	178	102.23	**250.21**
HC		7	7	**184**		31932	6986	10924	14023	**1528**	1218	38.14	**91.76**
LC		2	2	**53**		4482	333	1713	2436	**254**	183	40.79	**109.19**

For instance, it shows how the resulting average price for the holiday house is high, due to the relative large impact of the demand charge (a direct consequence of the efficient cost-causality principle, since the network has to be designed to cope with the maximum capacity contracted, no matter if consumption only happens rarely). It also reflects how consuming in the peak hours leads to higher prices. The final average price calculated for the EVC customer is significantly lower than the rest, thanks to her ability to charge her PHEV in the off-peak hours, in which the networks are unutilized and energy market prices tend to be lower.

At the same time, the fact that annual average price paid by the low-consumption customer (LC) happens to be higher that the supposedly wealthier customers (EVC and HC) gives room from some controversy. In this case, it is important to remind that what actually matters to make the right comparison is to consider not the average price but the marginal energy price. But in any case, implementing this sort of price signals does not preclude that some sort of additional support could be provided to low-income customers if necessary (Heller et al., 2024).

The PVPC 2.0 went into effect on June 1, 2021. But this time, the surrounding context deeply conditioned the public reaction. Since early Spring, energy market prices started to rise. CO2 prices went from levels in the twenties in November 2020, to the fifties, and gas prices began their escalation. These increases coincided with a dry year, which put significant pressure on electricity market prices. The opposition political parties loudly criticized the tariff reform (shockingly, some even argued that it was one of the reasons for the price increases).

At least, the great controversy that arose had one very positive effect: for the first time, due to the intense campaign launched by the opponents of the measure, both in the media and on social networks, a very significant part of the population finally became aware that the cost of electricity varies depending on when it is consumed. This fact had two immediate effects (a good one and a not-so-good one): it began to awaken the demand response of a few households to shift some of their consumption, but, in line with what it was mentioned above, it increased the willingness of a sector of consumers to enter into fixed-price contracts with market retailers. But it allowed to hope that the time granularity of the PVPC could finally play the role for which it was designed.

Unfortunately, prices continued to rise inexorably, quickly reaching high levels in all hours of the day, in such a way that shifting consumption could not help much. As described next, policymakers rushed into different sorts of market interventions and months later, promoted various reforms. One of these was a redefinition of the methodology for calculating the energy component of PVPC. Next, we describe, analyze, and criticize these changes.

3 ENERGY PRICE CRISIS AND DYNAMIC HOURLY PRICES

In addition to removing government involvement in tariff setting through transparent pass-through of spot market prices, the design aimed at leaving room for market retailers to offer different types of price hedging contracts to those end users who could value price stability. The PVPC design also offered retailers the opportunity to attract new customers by helping them better tailor their tariff parameters to their particular consumption patterns. For example, as publicly disclosed by the CNMC (2023), the weight increase of the demand charge has had a positive effect on residential end users, since from 2013 to 2023 the average contracted capacity by residential users decreased from close to 4.1 kW to 3.80 kW. But there is still room for efficiency gains, since at the end of 2021, 78% of domestic electricity supplies had excess contracted capacity in off-peak hours (average excess of 1.6 kW) and 65% in peak hours (average excess of 1.4 kW, which could mean an average saving of €35 per year). Only 1.6% of households (under the PVPC or in the retail market) had contracted two different capacities, which somehow shows that retailers did not consider it worthwhile to persuade end-users of the possibility to benefit from it.

Despite all, according to analysis made by the CNMC[7], "only one out of four Spanish households knows the difference between the free and regulated electricity market", as for the start of 2021, 17 out of the 29 million residential customers had contracted their energy consumption with a market retailer.

The claim that the PVPC would lead to raises in prices did not actually materialize, indeed, right the contrary. As illustrated by the data provided by the CNMC, included in the table below, only when the unprecedented energy crisis took place, PVPC consumers, fully exposed to short-term ended up paying more than the ones who had an annual hedge with a retailer in the market. Indeed, during the whole period, despite the extreme prices in 2021 and 2022, households under the PVPC saved a significant amount of money.

Table ii. Final average prices (€/MWh), including taxes (CNMC, 2022)

Households	2015	2016	2017	2018	2019	2020	2021	2022
PVPC	237	215	236	240	224	203	285	374
Market Retailers	257	254	257	264	269	272	259	316

These spreads were at the time justified due to the fact that since the first implementation of the PVPC in 2014 and until 2021, prices had been (maybe) abnormally moderated. Finally, in the period that spans from January 2021 to December 2023, the day-ahead market price in Spain experienced significant, unexpected and unprecedented price shocks, reflected in the futures prices with more or less delay.

The first shock happened in January 2021. The Iberian peninsula was severely affected by the so-called Filomena storm, which brought unusually heavy snowfall to many parts of Spain, with Madrid recording the heaviest snowfall in more than a century. Electricity demand spiked, resulting in abnormally high day-ahead market prices (illustrated in Figure 12 later) for slightly more than a week (Añel et al., 2024). Significant criticism arose in the mass media, arguing that it did not make sense that electricity prices could sky rocket precisely in the moment in which consumers needed electricity the most to keep their homes warm. The polemic did not last much, as the price shock did not last enough to significantly impact the bill at the end of the month, so PVPC did not feel particularly affected.

But since April 2021, the Spanish electricity market, like many European markets, started registering a sustained price increase. At first, it was assumed that the worldwide economic

[7] https://www.cnmc.es/prensa/cnmc-panel-energ%C3%ADa-20201204

recovery from the Covid-19 pandemic caused a global surge in gas and CO2 prices. But soon it was evidenced that the Russian gas provider was not storing the amount of gas usually needed to pass the upcoming winter. This time the price shock, since it lasted for more than a month, was reflected in the bills of the PVPC customers, and the Government panicked. In September and October 2021 (Batlle et al, 2022; Uría Menéndez, 2021), as at that time it was supposed that the EU legislation impeded directly intervening the short-term market prices, the Spanish Government implemented the so-called "windfall clawback" mechanism. The objective was to cut end-user retail prices (initially the PVPC ones, later on also the retail market ones) by reducing the alleged "unjustified" remuneration received by non-greenhouse gas emitting technology production facilities in the Iberian market. Roughly speaking, the claw back implied that those plants had to return any income perceived above 67 €/MWh, unless the output had been previously committed/sold in a contract.

The measure initially had in mind to "protect" the PVPC consumers, immediately exposed to short-term market prices. But later the Government realized that consumers under annual contracts in the retail market were also exposed to these prices (at the time of renewing their contracts). So new regulations extended the "windfall clawback", mainly implying that no contracts could be signed with customers at a price above 67.

When it was clear that the price crisis could last indefinitely, after weeks of negotiations with the EU Commission, the Spanish and Portuguese Governments introduced the so-called Iberian exception, a mechanism that allowed the electricity market to be decoupled from the gas market, artificially lowering the marginal price (Linares and Gómez, 2023). The Iberian exception was in force from June 2022 and throughout 2023[8]. However, since April 2023, the day-ahead market price followed a slow decrease, making the Iberian exception redundant.

The energy turmoil not only led the Government to implement the just mentioned interventions, it also motivated a new reform of the PVPC, mainly led to partially shield residential users under this option against short-term market prices. Next we review in detail and dispute the new design.

[8] The Iberian exception had an impact on both the day-ahead price and the price of futures (which are based on the expected spot price). Therefore, the impact of this mechanism in the simulation is not considered to be significant.

4 PVPC 3.0 (2024): THE NEW HYBRID DESIGN OF THE DEFAULT TARIFF

4.1 Mitigating the efficient short-term market signal

Royal Decree 446/2023 did not introduce a completely new design, as the access-to-the-networks fees kept their double TOU format (both for the demand charge and the volumetric component), but significantly modified the original setting of the energy component of the PVPC. The aim of this new reform of the default tariff was to introduce a partial price hedging for the enrolled customers, but trying not to fully distort the efficient signals that were conveyed by the previous fully dynamic-price design.

As sketched in the figure below, the main idea consists of weighing the price levels with a partial reference to the average value of a basket of futures (up to a year duration), but trying to keep at the same time the hourly profile of spot prices. In a nutshell, the alteration of the hourly profile distorts the maximum price levels, affecting the proper energy saving signals, but at least does not alter the intraday spreads, which in practice should keep for instance the incentives to charge the battery of an electric vehicle in the right hours.

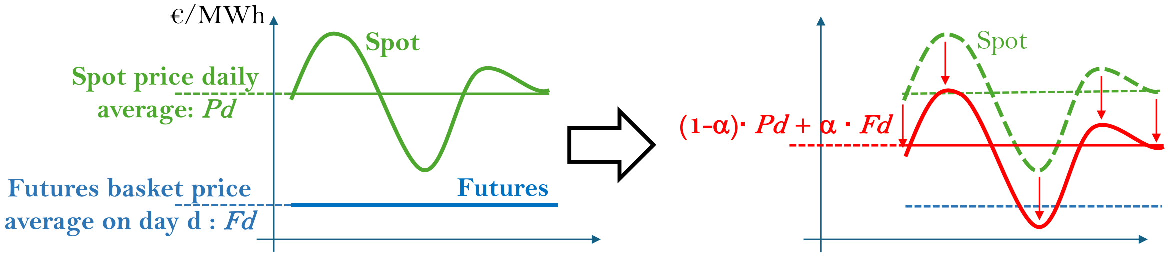

Figure 9. Adjustment of the hourly prices based on the prices of the basket of futures

The energy component of the new PVPC can be expressed as follows[9]:

$$ECh = \Delta Ph + (1\text{-}\alpha) \cdot Pd + \alpha \cdot Fd \qquad \text{Eq. 1}$$

The energy component is a weighted average of the mean daily price of the short-term market and the price of a basket of futures traded in the medium-term market (no longer than a year). α is the weight of the forward index resulting from the basket of futures defined by the Energy Ministry for this scope. This weighted average varies from day to day, as the sub-indices show. However, the first term on the right-hand side of equation keeps the hourly

[9] The so-called "energy production cost" component of the new PVPC also includes a term for the pass-through of the costs of ancillary services and a term for the recovery of other costs (e.g., system and market operation). However, these terms were not subject to the reform and are not considered in this analysis.

intraday spread resulting from the short-term markets. Thus, the hourly price profile is maintained, but shifted downwards when the daily average of the short-term market price is higher than the basket price, or upwards when the opposite is true.

The weighting factor α is established to evolve during the first three years of implementation of the new PVPC, increasing 25% in 2024, to 40% in 2025, to reach the final value of 55% from 2026 onwards. Thus, after a transitional period, the medium-term market will have a greater weight in the final energy price than the short-term market.

Royal Decree 446/2023 also specifies the composition of the basket of futures called to represent the futures market. The basket includes annual, quarterly, and monthly futures. These contracts are traded in OMIP derivatives market[10], whose operator publishes daily prices for the three products. The price of the basket for day d is the weighted average of the prices of the futures for the year, quarter, and month containing that day.

$$Fd = 0.54 \cdot Fy + 0.36 \cdot Fq + 0.10 \cdot Fm \quad \text{Eq. 2}$$

- Fy *is* the index related to the annual future for year y, calculated as the average of the daily prices of the annual future published during the six months preceding the start of year y.
- Fq is the quarterly future index for quarter q, calculated as the average of the daily prices of the quarterly future published during the three months preceding the start of quarter q.
- Fm is the index of the monthly future for month m, calculated as the average of the daily prices of the monthly future published during the month preceding the start of month m.

The reason to calculate these values as the average of the six/three/one months preceding the start of the year/quarter/month is to try to avoid potential alterations of these indexes to condition the final PVPC 3.0 prices, as the Government argued at the time of the CESUR auctions discussed above[11].

One of the justifications alleged by the Ministry for Ecological Transition and Demographic Challenge for the change was "to encourage generators and traders to trade energy

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[10] OMIP is a regulated market operator that provides a trading platform for energy derivatives products, namely Futures, Forwards, Swaps, Options and FTR, which underlying asset is electricity and natural gas.

[11] At the same time, these methodology makes difficult for the reference retailers to perfectly hedge against the potential fluctuations of the PVPC prices.

production on long-term markets, in order to obtain greater certainty about the return on their investments, this change will lead to greater stability in consumers' electricity bills". At this stage, it is sufficiently well known that medium-term contracts (one, two years duration) have no impact on the largely capital intensive generating plants project financing...

We next quantitatively evaluate and illustrate the impact of weighing the efficient hourly price signal with an index based on a basket of futures, through a backward application to the evolution of the Iberian electricity market for three years, from 2021 to 2023. This simulation is supported by public data published by the Iberian electricity market operators (OMIE for the short-term market and OMIP for the futures market, and by REE).

4.2 Assessing the actual impact on efficient price signals and consumer protection

The simulation focuses on the energy component of the PVPC 3.0, which is the term that has been reformed, and allows to compare the old design with the new one, in order to shed a light on the potential advantages and disadvantages of both approaches.

The simulation considers the Iberian day-ahead market prices, leaving aside intraday and ancillary market prices, and the weighting factors that will be applied from 2026 onwards, i.e., α equal to 0.55. The underlying data for the simulation are shown in Figure 3.

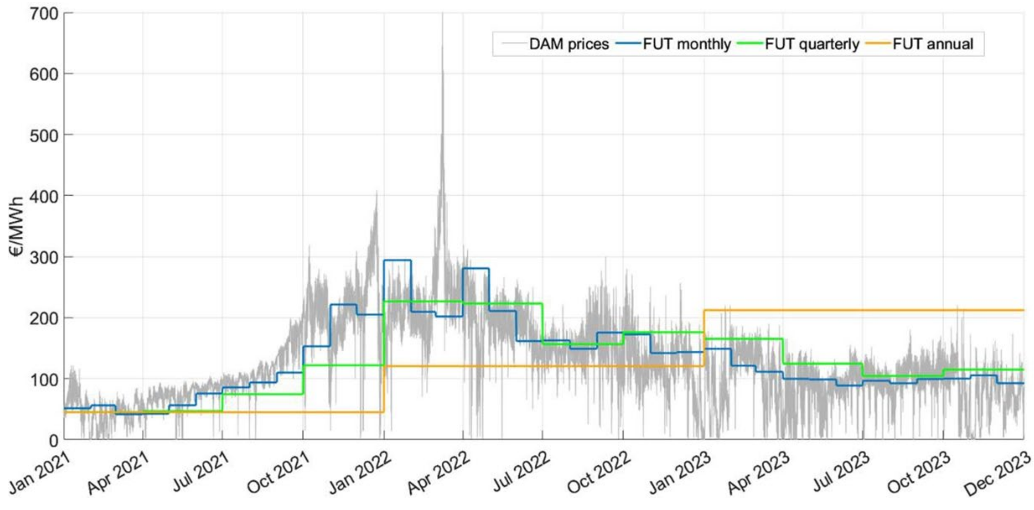

Figure 10. Day-ahead and retrospective calculation of the futures products indexes considered in the new PVPC

The colored lines in Figure 3 show the evolution of the indexes related to the three products that make up the futures basket in the new PVPC formula (calculated using the methodology previously introduced). As the circumstances driving the day-ahead price dynamics were not easily predictable, futures prices tended to immediately adapt to the short-term pattern, but with a significant lag that increased with the time horizon of each product.

Impact of the on price efficiency signaling

In the 2021-2023 period, the customers enrolled in the PVPC 2.0 were exposed to the full volatility of the short-term market. The first exercise is to compare what the customers under the PVPC 2.0 paid and what would have paid at that time under two design approaches: i) if the energy component of their electricity was calculated in a more traditional way, i.e. as a simple weighted average of short-term and futures markets signals (as reflected in equation 3 below) and ii) if the new PVPC design would have been implemented (following equation 3, with $\beta = 0.55$). The result for a week in December 2021 is shown in Figure 4.

$$ECh^* = (1\text{-}\beta) \cdot Ph + \beta \cdot Fd \qquad \text{Eq. 3}$$

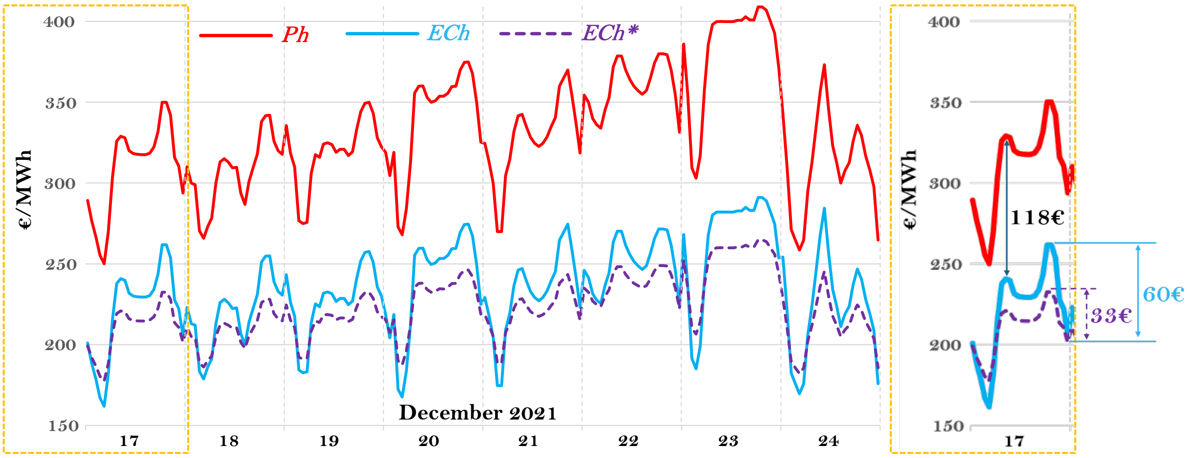

Figure 11. Hourly price signal and profiles resulting from weighing with futures indexes

As it can be observed in the right hand side of the figure, in which the profiles for one of the days are zoomed, weighing the prices results in a significant alteration of the efficient price signal, shifting prices downwards by a very significant amount. The figure shows that new PVPC formula at least keeps the intraday price spread signal, preserving the incentive to for example displace the charging of an electric vehicle to the night hours.

The evidence shows that this approach, in a context where short-term demand response and flexibility will be much needed in the near future, has a significant impact on the expected demand efficiency. However, the reform is allegedly designed to provide protection to residential end-users in return.

Hedging price risk inevitably involves a cost, the so-called risk premium. This expense is well justified if the hedge enables the buyer to avoid scenarios that could lead to any sort of financial distress. A small bakery or pizzeria relies heavily on electricity for its daily operations, from powering ovens to maintaining refrigerators. If electricity prices were to spike unexpectedly, the increased costs could for example severely impact the profit margins, potentially putting the business at risk of financial strain or even closure.

For end users who have the right to be on the PVPC (mainly regular households), the question arises as to whether the cost of the hedge is actually worthwhile. The potential costs and effectiveness of this supposed protection are examined below.

Risk aversion and risk premium costs

We first make a back testing exercise to evaluate the potential benefits that would have been obtained if the new PVPC 3.0 approach had been implemented during the periods in which price reached abnormally high levels (the scenarios that are supposed to justify to expense in the risk premium).

To do so, we take advantage of the historical prices recorded in the Iberian market, which include two price shocks of different nature, a sudden increase lasting less than a couple of weeks (corresponding to the storm Filomena in January 2021) and another lasting several months (corresponding to the EU energy crisis suffered from mid 2021 to the end of 2023).

Figure 12 shows the backward application of the new PVPC to the Filomena storm and its comparison with the short-term market price (representing the old PVPC energy component).

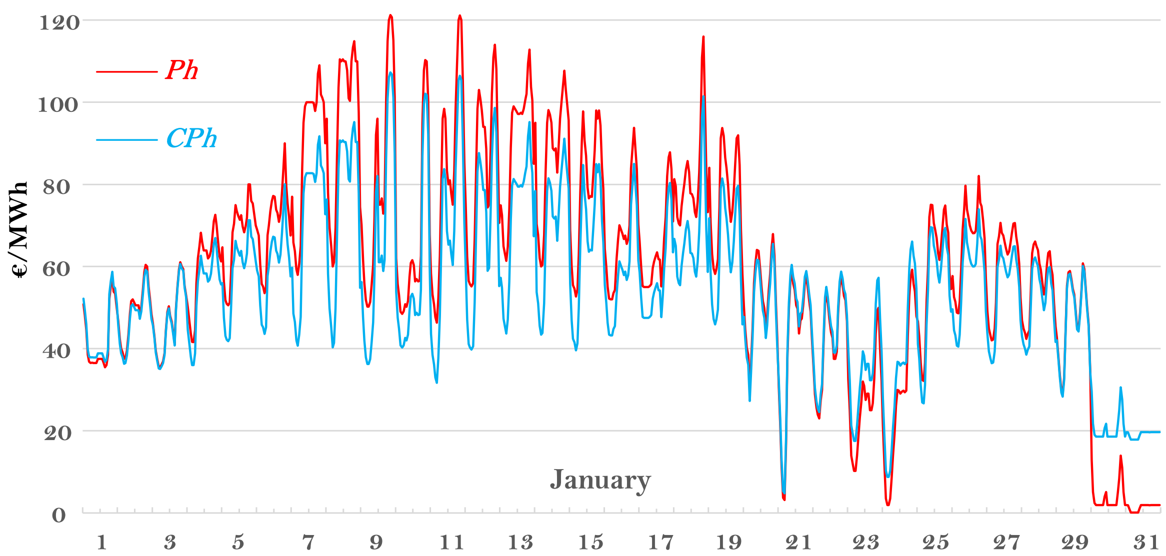

Figure 12. Day-ahead market prices (*Ph*) and new PVPC energy component (*CPh*) during the Filomena storm

With the new PVPC formula, the growth in the day-ahead price during the extreme weather event would have been only partially passed through to customers, due to the hedging provided by the basket of futures. The static and dynamic implications of such a price event can be assessed straightforwardly.

A rough calculation of which the direct economic benefits for the by then 11 million consumers under the PVPC 2.0[12] would have been if the new PVPC 3.0 formula had been applied in January 2021 results in savings of close to 30 million € compared to the direct pass- through of short-term market prices of the original PVPC design in force at that time. As we will later discuss in larger detail, it would have implied an average saving of less than 3 euros per household in that month of January, something that certainly does not appear to be a very significant amount (particularly taking into account that the lower the consumption of the customer, the lower the savings).

The potential dynamic impacts that the storm prices had on the subsequent futures market is also worth reviewing. The Filomena storm caused a brief and temporary increase in the short-term electricity prices, but as it was considered as once-in-a-century event, it did not have a significant immediate impact on the futures market prices. Therefore, contrary to what we observe for the energy crisis period that we study later, the positive price hedging is not followed by a tail of negative price hedging.

Contrary to the storm event, the energy price crisis was a long duration event that went largely beyond the yearly maturity of the futures used in retail power markets. As illustrated in the following figures, price hedging would have been positive in the second half of 2021 and throughout 2022, as the price of the basket of futures, with a significant weight of the annual product (54%, see equation 2) did not yet reflect the price spike experienced in the day-ahead market. Conversely, this futures price inertia that at the start of the crisis would have led to benefits for consumers, in 2023, would have turned into loses. When the day-ahead price returned to a more conventional range, the futures price remained very high (especially the annual future contract, see Figure 10).

[12] According to the Spanish National Regulatory Authority (CNMC, 2022) "As of December 31, 2020, almost 11 million consumers were under the PVPC with an annual consumption of 25 TWh."

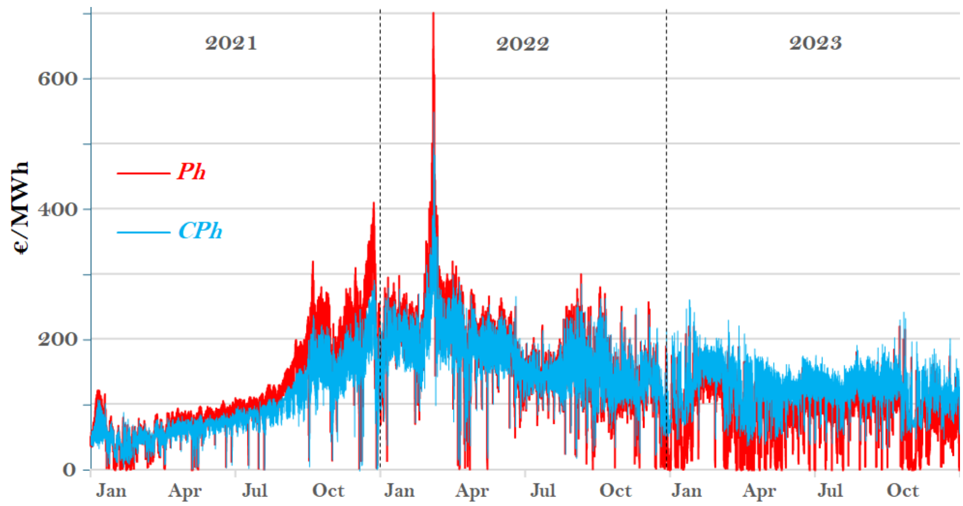

Figure 13. Day-ahead market prices (*Ph*) and new PVPC energy component (*CPh*) during the energy crisis

These hourly prices translated and would have translated into the energy bills reflected in the graphs below, where we show the monthly installments the customer we denoted as HC (high-consumption family) and LC (low-consumption one) paid under the PVPC 2.0 and the ones they would have paid in the PVPC 3.0 would have been previously implemented.

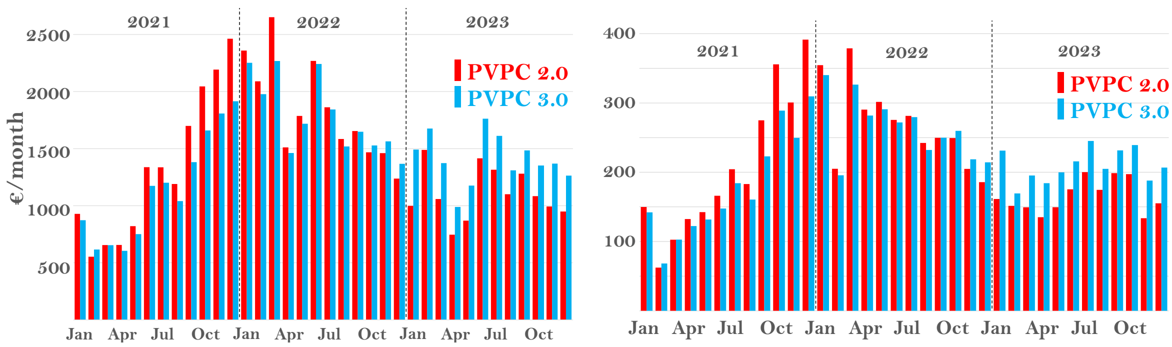

Figure 14. Monthly bills for consumers HC (left) and LC (right) under PVPC 2.0 and PVPC 3.0

These results should come as no surprise. Futures are risk-hedging instruments, whose price incorporates a risk premium that the seller wants to monetize when offering the contract, reflecting her risk aversion to the missing opportunity to make significant profits during these high price events. This risk premium for long-term electricity contracts has proven to be higher than for other commodities (Shawky et al., 2003; Botterud et al., 2010).

Between July 2021 and December 2023, PVPC consumers would have paid 86.8 million € more with the new PVPC formula than with the original direct pass-through (not big deal either if seen in averaged terms per consumer, around 8 € in total during the whole period).

In principle, from this perspective, the conclusion could be that promoting a regulated hedge is a cheap choice to avoid consumers' (and more importantly) politicians' discomfort when prices go beyond the regular bounds.

Short-term efficiency versus "consumer protection"

But what the quantitative assessment also illustrates is that, contrary to the popular understanding behind the objective of "consumer protection", in case of long-term price shocks, as the EU gas crisis that triggered the reform, consumers end up paying the same (even slightly more). The presumed advantage of hedging is limited to the mitigation of short-term volatility, which at the time is the incentive to promote the much needed demand response. In practical terms, for residential end users, this translates into avoiding a sudden monthly bill (or a series of them during a few months) that could endanger the short-term solvency of the some households. But the fact is that, as the experience showed, the vast majority of households can financially afford price increase as the ones occurred, so at least for these latter, the hedge has no practical value.

The two objectives are clearly conflicting. The way to better hedge end users against price shocks that last for more than a few days or weeks is to increase the weight of the longer-termed contracts (or the index related to them). But the larger this weight, the farther the price signals from efficiency.

In the context of the PVPC 3.0, this can be clearly illustrated by playing with the factors that define the weight of each product within the basket of futures. Regulators can create different tariff designs by acting on these weighting factors. Figure 15 shows the price evolution of two different baskets of futures, based on the Spanish electricity prices used in the simulations. Basket 1 gives a higher weight (0.7) to the annual future, while basket 2 gives a higher weight to the monthly future.

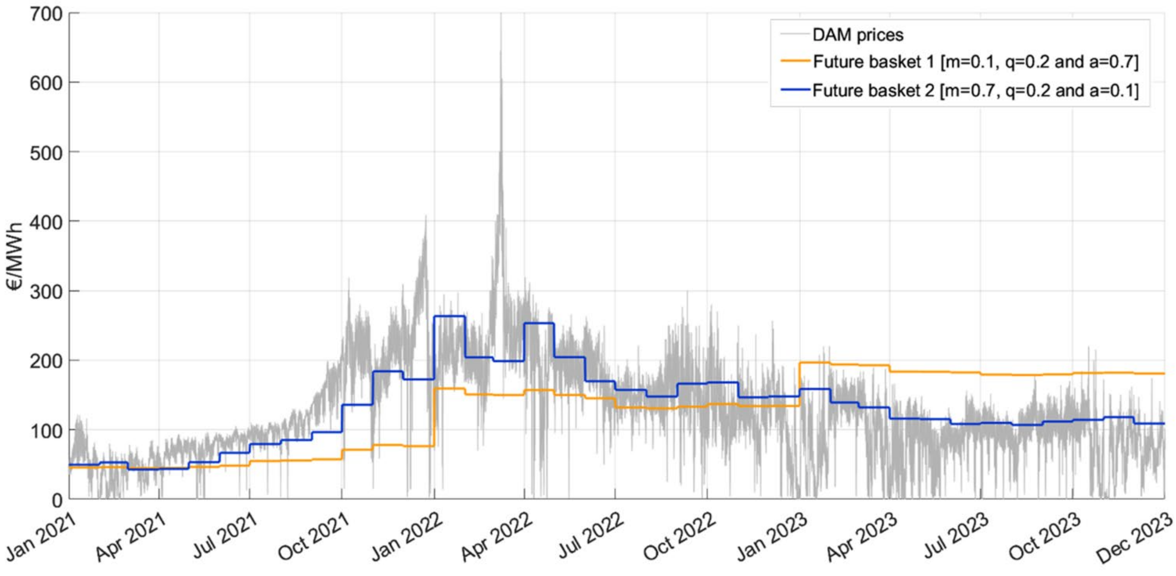

Figure 15. Price of different baskets of futures for the energy component of the tariff

As shown in the chart, a basket that is more oriented towards longer-term futures provides a better shield against short-duration price spikes, enhancing the stability of the electricity tariff. This stability also means that high prices are maintained for longer after a long-duration price crisis. A basket that is more oriented towards shorter-term futures tracks the spot market price more closely. This implies less price hedging during spikes, but also a faster reduction in the energy component of the tariff when the short-term price falls.

It is therefore evidenced that a regulatory solution along the lines of the PVPC 3.0 is rather ineffective when it comes to help end users to deal with a long-term price crisis. The proposal for a regulation to amend the Union's electricity market design (EC, 2023) confirms the inability of short- to medium term hedging to help end users during electricity price crisis: article 66a allows Member States to intervene market prices if the Commission declares an electricity price crisis (e.g. if prices are at least two and a half times the average price during the previous 5 years, and it is expected to continue for at least 6 months)[13].

The major question that remains is if imposing this sort of hedging to soften the gradual increase of monthly electricity bills for all sorts of residential end users justifies losing a significant part of the efficiency of the short-term price signal (once again, in a context in which it is highlighted as instrumental to promote smart charging, behind the meter storage and many other sorts of the much needed flexible solutions).

4.3 Other features related to the PVPC 3.0 design

Fixed-quantity price hedging

The PVPC has not only an open term but also an open quantity for the price hedging. Customers pay the hourly PVPC price for all their consumption, without any limit. This adds uncertainty to the estimation of the demand of the reference retailer.

In an alternative design, the price hedging could be provided by a purely financial contract with a fixed quantity. A certain proportion of the end-user's usual consumption could be covered by a fixed-price financial contract or indexed to the price of a basket of futures. This design would not alter at all the efficient signals from the short-term market and would provide similar price hedging to the current PVPC design. However, as the settlement of this contract is completely decoupled from the actual demand of the end-user, it may lead to unusual results in the electricity bill. For instance, in a billing period of abnormally low

[13] See Batlle et al. (2023) for a discussion on this solution.

demand (e.g. a two-month leave), the customer may still be subject to the settlement of the financial contract, with an outcome that could be even positive (or negative) depending on the evolution of electricity prices.

Inefficient discontinuities

The new PVPC formula also introduces some peculiarities in the price profile for regulated customers that deserve some attention. As the energy component is based on the daily average spot price and the gap between it and the futures price, discontinuities can be observed in the transition from one day to the next. Figure 16 shows an example of these discontinuities, with the PVPC energy component experiencing an artificial spike of 50 €/MWh from one hour to the next.

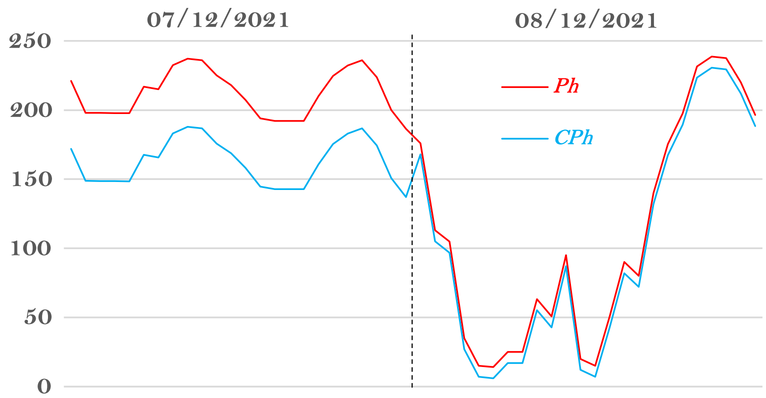

Figure 16. Discontinuity in the PVPC energy component in the transition between December 7 and 8, 2021

Negative prices and efficient signals for storage

A tariff design such as the PVPC 3.0, which shifts the price profile of the short-term market up or down depending on the price of a basket of futures, may lead to artificially-negative prices. Figure 10 shows a daily profile of the day-ahead market price, with a high intraday volatility and a high average daily price. If the long-term price in the energy component were 50€/MWh, the resulting PVPC price profile would include negative prices in a few hours.

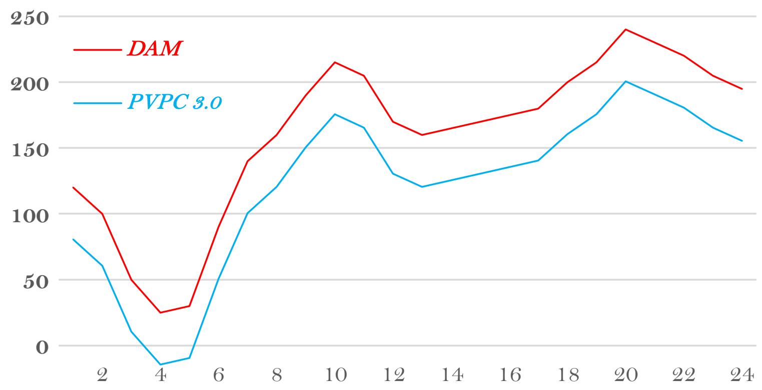

Figure 17. Discontinuity in the PVPC energy component in the transition between December 7 and 8, 2021

Although the PVPC profile retains the shape and hourly gaps of the day-ahead profile, it artificially creates negative prices that may induce inefficient demand behaviors. For example, a behind-the-meter storage asset (a stand-alone battery or an electric vehicle providing services to the grid) may decide whether to run a charge/discharge cycle according to the ratio between the charge and the discharge prices (which should be at least lower than the efficiency of the cycle). If the charge price is artificially negative, the storage asset may run a cycle that it would not have run if it had been exposed to the day-ahead price.

5 CONCLUSIONS AND POLICY IMPLICATIONS

In the decarbonisation process that the energy sector is undergoing, the design of electricity tariffs will have to find an effective balance between two conflicting regulatory objectives: to provide electricity consumers with efficient signals that can drive their activation and demand response, while at the same time protecting consumers from the volatility of the electricity market through price-hedging instruments that improve the affordability of the electricity supply. The first objective has traditionally been the declared aspiration of European policy makers and regulators, but the energy price crisis has forced them to face the reality, and to try to find ways to balance both.

The review of the Spanish case, a paradigmatic example of undisputable search for a fully price reflecting tariff for residential end users illustrates how difficult is to activate residential customers, particularly because the ones with larger flexibility potential, the wealthy ones, are the less motivated by the potential price savings that could be obtained (to the extreme to prefer flat tariffs not to even have to care). Along these lines, the experience also shows how the commercial strategies considered successful by market retailers lead to offer those flat tariff alternatives, instead of taking advantage of the dynamic and TOU prices to promote end users' demand response.

Our analysis also evidences the actual low value of price hedging for residential consumers (except for vulnerable ones), and its negative impact on energy efficiency, since it disconnects them from real system opportunity costs (market prices) signals in each moment. For those consumers for which the volatility in their electricity bills does not represent a financial distress (the vast majority, particularly taking into account that at least in Spain, the average household's electricity bill represents less than 5% of the family budget), a medium-term (e.g. annual) hedge has very little value (and a prove cost), and if the hedge applies to all of the consumer's real time energy consumption (as opposed to a pre-determined amount), it weakens any potential incentives to optimise consumption patterns based on short-term signals.

The discussion presented in this article should also stimulate reflection on the status of the retail market[14]. European legislation has always treated regulated tariffs as price interventions that tend to supply consumers with electricity below cost, artificially reducing the space for competition in the free retail market. Under the Clean Energy Package, an end date for regulated prices may be proposed by 2025. Regulators, if not keeping or promote, should at least ensure that electricity customers are always offered tariffs based on pure dynamic pricing. As illustrated, these tariffs result in lower costs for the majority of customers, for which an annual contract does not imply any significant benefit, eliminates the cost of hedging for retailers and keeps open the floor to develop some sort of automated control that might result in benefits for the consumers themselves and the system as a whole.

A default dynamic option or at least a standardised tariff format would also improve the comparability of different offers. This issue is part of a wider discussion on innovation in the retail electricity market (such as the recent call for evidence of the British Government; DESNZ, 2023) and should be the subject of future work.

ACKNOWLEDGEMENTS

This article partially benefitted from the support of the DEFINER research project, funded by the Spanish Ministry of Science and Innovation and the Spanish State Research Agency (grant number CPP2021-008786).

[14] A highly recommended way to start this reflection would be to revisit the visionary work developed by Prof. Joskow (2000).

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