Demand Response Markets for Project RESPOND

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Abstract— **Project RESPOND (integrated demand REsponse Solution towards energy POsitive NeighbourhooDs) aims to integrate demand response in domestic users' consumption routine. Its integration requires the study of the different electrical markets and their operational characteristics, to define the necessary adjustments for each of them.**

Index Terms **— RESPONSE, demand response, energy savings, monitoring consumptions, electricity markets**

I. Introduction

DEMAND RESPONSE (DR), according to the Federal Energy Regulatory Commission, is defined as: [1] "Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

Following up on this idea, the project RESPOND (integrated demand REsponse Solution towards energy POsitive NeighbourhooDs) is being developed. It has received funding from the European Union's Horizon 2020 research and innovation programme.

The aim of this document is to describe the electric markets in which the software RESPOND under the demand response principles can operate; to present their different time scopes and to define their operating characteristics and necessities.

Fig. 1 shows several demand response programs according to the different electric markets. These programs are divided into price-based and incentive-based models.

On the one hand, the price-based models rely on the consumer's reaction to price signals, as they decide to re-distribute their consumption along a certain time period, knowing in advance the estimated price for electricity.

On the other hand, incentive-based models economically compensate final clients for agreeing to interrupt or curtail their demand, either manually or automatically if required.

Both ways, customers reduce costs as they consume in cheaper hours and flatten the supply-demand curve, for which they can be compensated. Furthermore, they might be able to reduce the contracted power, as they will not need it in peak hours, where it is more expensive. [2] It is calculated that they can achieve significant net reductions in electricity bills (from 3% to 15% in some cases).

For its part, utilities can attract more clients, and ultimately reduce costs as they do not need to build extra power plants to assure they can meet the highest levels of energy demand, that they only end up using a couple hours throughout the year. If they already own them, they can even sell a fraction.

The final idea is that grid operators spend less on demand response than they would on a power plant, and participants enjoy a new revenue stream.

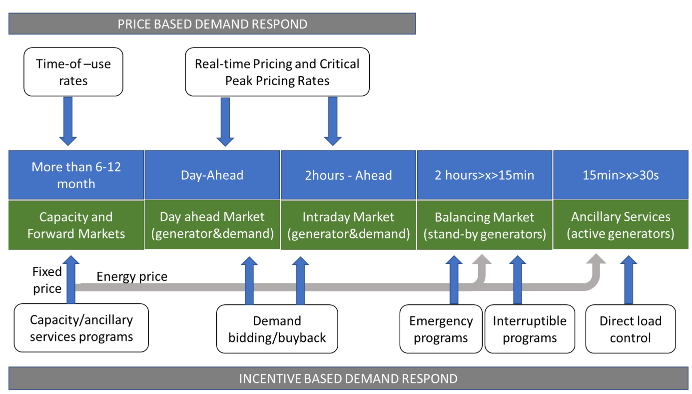

Fig. 1. Demand response operation in the different time-scope electric markets, divided into price-based and incentive-based models.

II. Electric Markets for Demand Response

In this section, the benefits of integrating RESPOND in the different electric markets are studied. Demand response is nowadays impossible for domestic users in some markets; nevertheless, they are analysed as it is expected its integration will be possible in the future, thanks to the new figure of the demand aggregator. To help develop this analysis, the Spanish Electric Market and some 2019 and 2020 results are presented.

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Fig. 2 shows the average consumption curve for 2019, of tariff 2.0 users (domestic users). The average consumption per hour is of 0.375kWh. In 37.5% of the hours in the day, the consumption is lower than the average, while in the other 62.5%, the average consumption is exceeded. In terms of energy, 12.5% (1.11kWh) of the total consumption corresponds to hours higher than the average.

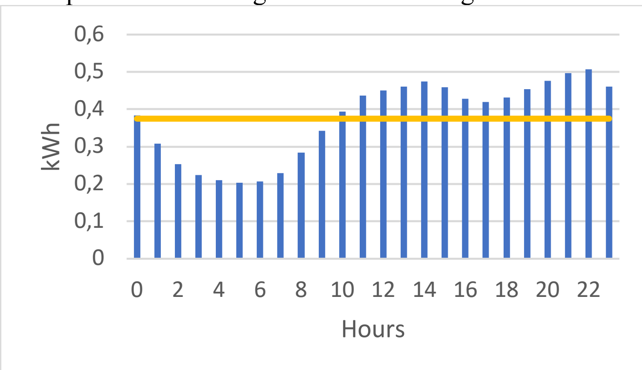

Fig. 2. Average consumption curve for tariff 2.0 in Spain, for 2019

The aim of demand response would be to allocate this consumption to moments of non-peak demand. Assuming an average energy consumption breakdown of a household as the one shown in Fig. 3, it does not seem unreasonable the aim of reducing the 12.5% mentioned. Assuming some of the peak demand moments correspond to laundry (7%) and cooking (29%)[1] users could modify their habits and perform these actions at another time, achieving to reduce this 12.5%. In order to not be overly optimistic, a reallocation of a 10% of the daily consumption will be used for the numerical analysis. If an average domestic user consumes around 270kWh/month [2] (9kWh/day), the daily 10% corresponds to 0.9kWh.

In addition, the same study is developed for reallocations of 5% of the demand, to compare it with a more unfavourable case. It is included in section "Possible cases pricing summary".

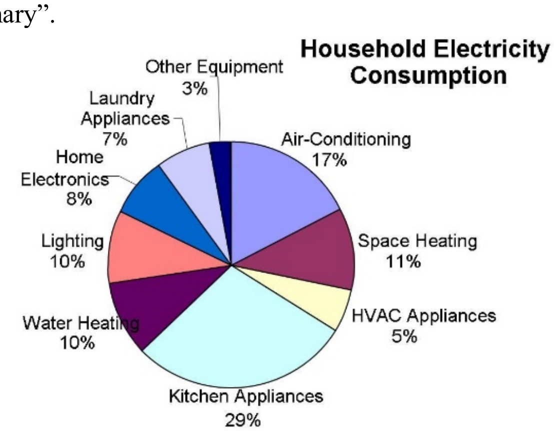

Fig. 3. Household electricity consumption **[1]**

In regard with the abovementioned time-markets in which demand response can operate, the profits for the users, relative to the non-consumed energy, would be as explained in hereafter.

A. Price – based model

1) Capacity and forward markets: TOU

In case of the price-based model for capacity markets (Time of Use programs), users would choose their consumption based on the time-period fixed rates facilitated by their energy retailer and would not need any home appliances for automatic disconnection, nor would they be rewarded for this option. They would save a certain sum for this, depending on the distribution and transmission tariffs, that are constant throughout the year, and depend on the two time periods. In 2020, these tariffs were 62.01€/MWh at peak demand periods, and 2.22€/MWh at non-peak ones, as represented in Fig. 4.

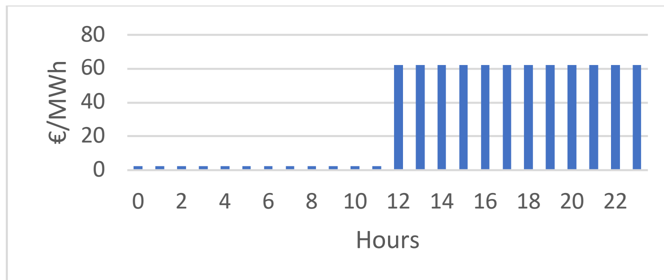

Fig. 4. Transmission and distribution tariffs in Spain, for 2019, according to time frames (0h – 11h, 12h – 23h)

Therefore, users would save 62.01 – 2.22 = 59.79€ per MWh reallocated from peak-demand moments to off-peak ones. As mentioned, this would correspond to about 0.9kWh per day or 27kWh per month, which would mean monthly savings of 1.61€ or 19.37€ per year, as explained in the following line:

$$59.79e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=1.61€/month \rightarrow 1.61*12=19.37€/year$$

2) Day ahead and intraday markets: RTP &CPP

With the real-time pricing or critical peak pricing rate methods, users would modify their consumption if they decided to, as they would have been informed about hourly prices. Thus, they would not need any home appliances for automatic disconnection, nor would they be rewarded for this option.

Fig. 5 shows the average hourly energy pool-price in Spain in 2019. The maximum price is of 55.3€/MWh, reached at 10PM, followed by the time period around 10AM with a price of 53.59€/MWh, and the minimum price is of 43.52€/MWh, reached at 5AM.

[1] Of this 29%, there is a certain percentage that cannot be reallocated, as the functioning of the refrigerator or freezer. It can be, though, the operation of the oven, microwave, or dishwasher.

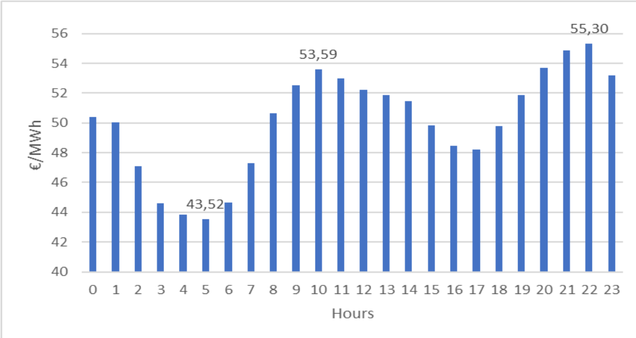

Fig. 5. Average hourly energy price in the pool of the Spanish Electric Market, for 2019.

Users would save an average of 55.3 – 43.52 = 11.78€ per MWh reallocated from maximum peak-demand moments to minimum off-peak ones. As mentioned, this would correspond to about 0.9kWh per day for domestic users, or 27kWh per month, which would mean monthly savings of 32cts, or 3.8€ per year.

$$11.78e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.32€/month\rightarrow 0.32*12=3.8€/year$$

If they moved 5% from the 10AM period and the other 5% from the 10PM period, they would save 30cts monthly, or 3.6€ yearly (10.92€/MWh). This more realistic case-scenario is the one that will be considered.

$$10.92-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.295€/month\rightarrow 0.295*12=3.55€/year$$

B. Incentive – based model

1) Day ahead and intraday markets: demand bidding/buypack

With the demand bidding/buypack, users would have agreed to disconnect either manually or automatically any device requested to in case of need, with a response time of 2h up to 1day, and would be rewarded for it with an incentive yet to be determined.

In Spain, there is no such model for incentive-based programs, but it could be implemented in a price-based-like manner. Fixed tariff utilities buy in an hourly price market and charge a fixed bill to their clients. They could follow a similar model as the RTP one, rewarding customers with a beforehand agreed percentage if they moved their consumption from peak hours to off-peak ones. Assuming users could be passed 70% of the savings calculated in the previous section (10.92€/MWh), their yearly bill could be reduced in 2.48€ (20cts/month, 7.64€/MWh):

$$70\%*10.92e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.2€/month\rightarrow 0.2*12=2.48€/year$$

2) Capacity and forward markets: capacity/ancillary services programs

In the case of the incentive-based model for capacity and forward markets, users would be paid a rate for making available a strategic reserve, and an extra one when they activated this reserve in the balancing markets or/and ancillary services. Fig. 6 shows the tariff for Ancillary Services and Capacity Payment in the Spanish Electric Market in 2019.

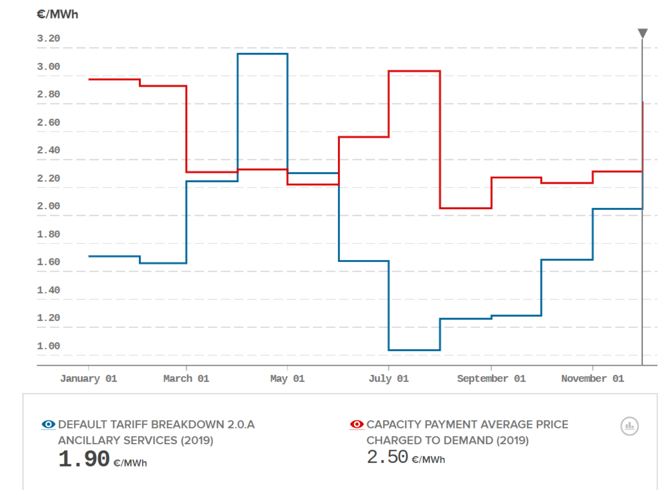

Fig. 6. Capacity payment average rate and ancillary services tariff in the Spanish Electric Market, for 2019. [3]

In the first place, for participating in the capacity market, users would be paid a rate of 2.5€/MWh. If they made available a reduction of 0.9kWh per day, it would correspond to 7cts per month, or 81cts per year.

$$2.5e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.065€/month\rightarrow 0.065*12=0.81€/year$$

With regard to the participation also in the ancillary services, a draft order has been developed (date of submission: July 30th, 2020): «draft order that creates the strategic reserve quick response to the backing of services of adjustment of the electric system».[2] It states that the remuneration of the strategic reserve service is made up of two components: a fixed one, associated with the availability of the strategic reserve (capacity market), and a variable one, associated with the effective execution of a request to activate the strategic reserve (ancillary services). Moreover, the draft order states that:

- the assignation of the reserve is done through an auction procedure managed by the system operator.
- the auction allocates blocks of bids of a minimum size of 1 MW of power per installation, for each delivery period.
- the time to activate the power is less than 1 minute.

These restrictions imply that domestic users could not participate in ancillary services currently. However, savings have been calculated in line with possible future changes in regulation, or with other countries that may not have this particular regulation, with average prices that have been retrieved. They are included in the section of ancillary services markets.

Moreover, users could decide to participate also in balancing markets instead of in ancillary services (time of response of 15min - 2h instead of less than 1min). However,

[2] Available at https://energia.gob.es/enus/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=339.

in Spain this case is non-existing. It does exist the option to enter the balancing market of course, but users are not rewarded for being part of the capacity one as well. This is explained in the following section of balancing markets.

3) Balancing markets: interruptible and balancing programs

Balancing markets are operated under the incentive-based mode and can be interruptible programs (or interruptibility services) or emergency programs. Users modify their demand for a certain time period, with a time of response of 15min up to 2h.

a) Interruptibile programs

In the first place, as stated by REE, the Interruptibility Service is established as follows:

> In the peninsular system exists a competitive allocation mechanism managed by Red Eléctrica, under the supervision of the CNMC (National Commission of Markets and Competition). In order to allocate the service, an auction system with face-to-face bidding is used. It is a competitive and efficient mechanism, similar to that used in other known markets, such as the wholesale fish markets or the Dutch flower auctions.
>
> Two interruptible capacity products are auctioned, one consisting of reductions in consumption of 5 MW and another of 40 MW. This is done using a computerised auction system based on descending price.[3]
>
> Starting from an initial price, the amount goes down in each round at a previously established price. The service is assigned to the last competitor remaining in the auction and who hasn't withdrawn and, therefore, is willing to offer the service at the lowest.
>
> In the non-peninsular systems, the allocation of the interruptibility service is established by the sign of a contract between REE and the provider, once authorized by the regulator.

The use of the interruptibility service as an adequacy last-resort mechanism is carried out by simply reducing the demand when necessary. When this situation takes place, the demand does not set the market price. Therefore, the day-ahead market price is usually reduced after applying the interruptibility service. Fig. 7 shows the average price of the interruptibility service in Spain from 2014 to 2019.

[3] For the Peninsula: Order IET/2013/2013 of the 31st of October, published in «BOE» num. 262, of 01/11/2013. For the Islands: Order ITC/2370/2007 of the 26th of July.

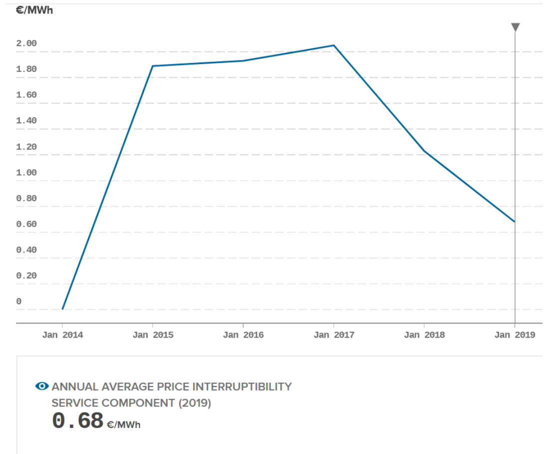

Fig. 7. Annual average price for nterruptibility service in the Spanish Electric Market, from 2014 to 2019. [3]

On 2019, on average, users would be paid 0.68€ per MW not consumed in peak-demand. However, as stated in the REE article above, this would only be possible for reductions of 5MW, or 40MW, thus not for individual domestic users. As for now, it would be aimed at big industries or for big communities of domestic users. Moreover, in the case of Spain, to participate in interruptibility services, consumers should operate on high tension, as stated in Order IET/2013/2013 of the 31st of October, published in «BOE» num. 262, of 01/11/2013:

> Article 2. Scope of application.
>
> This order shall apply to consumers of electrical energy connected at high voltage who contract their energy on the production market, either directly or through a marketer.
>
> It shall also apply to the system operator, "Red Eléctrica de España, S.A.", as the party responsible for managing the interruptibility service and carrying out the competitive mechanism for its assignment.

Therefore, domestic users could not participate in it unless regulations changed. Savings are calculated in light for this future possibility.

In case of the minimum reduction of 5MW, when participating in the capacity market, assuming each dwelling reduced 0.9kW in one hour, it would mean that 5556 dwellings would be necessary for this reduction. For the 5MW reduced, 10.2€ would be paid per day, thus 6cts per month per dwelling (70cts/year).

$$\frac{5[MW]}{0.9e-3[MW/dwelling]} = 5556 dwellings$$

$$In\ total: 0.68e-3\left[\frac{€}{kWh}\right] * 5[MW] * 3[h] = 10.2€/day$$

$$Per\ dwelling: \frac{10.2\left[\frac{€}{day}\right] * 30\left[\frac{days}{month}\right]}{5556\ dwellings} = 0.06€/month \rightarrow 0.06 * 12 = 0.70€/year$$

b) Emergency services

Technical constraints are incidents in the electricity markets produced in situations where the married market supply is not able to cope with the demand in certain areas or zones, either because of a lack of generation in the given area, or by other system failures, mainly due to deficiencies or failures in the transmission grid.

In Spain in 2019, the annual average price for technical constraints was 0.96€/MWh [3]. Thus, if users made 0.9kWh available per day for this purpose, the savings would be of 30cts per year.

$$0.96e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.02€/month\ \rightarrow 0.02*12=0.30€/year$$

4) Ancillary services: Direct load control

As it has been explained, users can provide ancillary services by participating in the capacity market, or just in the ancillary itself.

In the first case, as Fig. 6 showed, users would be paid the average rate of 2.50€/MWh for committing to providing pre-specified load reductions, and the variable one 1.90€/MWh for the activation of this reserve. If the same 10% of domestic users' monthly consumption were to be this reserve, their savings would sum up to 12cts/month (1.43€/year), as it is explained hereafter.

$$(2.5+1.9)e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.118€/month\ \rightarrow 0.118*12=1.43€/year$$

The case of only participating in the ancillary services, without entering the capacity market, is non-existing in Spain nowadays, but if it did exist, the reward would be as follows:

$$1.9e-3\left[\frac{€}{kWh}\right]*0.9\left[\frac{kWh}{day}\right]*30\left[\frac{days}{month}\right]=0.51€/month\ \rightarrow 0.51*12=0.62€/year$$

III. POSSIBLE CASES PRICING SUMMARY

A summary table with all the possible cases and combinations is here presented (Table 1) [4]. The price is calculated with the 10% of energy consumption reallocation.

Table 1. Possibilities of integration of demand response

	PRICE-BASED			**INCENTIVE-BASED**			
	TOU	RTP	Capacity Market	Demand Bidding /Buypack	Interrup	Emerg	Direct Load Control
Case 1	x						
Case 2		x					
Case 3	x	x					
Case 4				x			
Case 5			x				
Case 6					x		
Case 7						x	
Case 8							x
Case 9			x		x		
Case 10			x				x

[4] In red, the cases that do not currently exist in Spain

A. Domestic users

The savings per dwelling are calculated, as well as the total savings for final clients in the case of Fenie Energía (Table 2). It has around 400.000 clients, of which about half are domestic users. It is estimated that at least 10% of them would contract the demand response service, thus 20.000 final domestic customers.

Table 2. Savings with the different possibilities of integration of demand response for domestic users (10% of energy reallocation)

	SAVINGS/CLIENT		**SAVINGS FOR 20.000 CLIENTS**
	[cts/month]	[€/year]	[k€/year]
Case 1	161,43	19,37	387,44
Case 2	29,48	3,54	70,76
Case 3	190,92	22,91	458,20
Case 4	20,63	2,48	49,51
Case 5	6,75	0,81	16,20
Case 6	0,06	0,72	14,40
Case 7	2,59	0,31	6,22
Case 8	5,13	0,62	12,31
Case 9	6,81	0,82	16,33
Case 10	11,88	1,43	28,51

As mentioned in the introduction of this section, the same analysis is carried out for energy reallocations of the 5% of the total daily consumptions, instead of for the 10%. The results are the ones summarized in Table 3.

Table 3. Savings with the different possibilities of integration of demand response for domestic users (5% of energy reallocation)

	SAVINGS/CLIENT		**SAVINGS FOR 20.000 CLIENTS**
	[cts/month]	[€/year]	[k€/year]
Case 1	80,72	9,69	193,72
Case 2	14,74	1,77	35,38
Case 3	95,46	11,46	229,10
Case 4	10,31	1,24	24,75
Case 5	3,38	0,41	8,10
Case 6	0,03	0,33	6,61
Case 7	1,30	0,16	3,11

Case 8	2,57	0,31	6,16
Case 9	3,40	0,41	8,17
Case 10	5,94	0,71	14,26

B. *Industrial clients*

Although RESPOND aims to reach domestic users as the final client, it is considered interesting to study its deployment among big companies too. There already exist companies that use similar software for industrial needs, thus it is a feasible option. The general profit can be expected to be higher and, as it has been explained, nowadays domestic users cannot operate in certain.

The consumption of industries depends highly in the size of the industrial client, but an average consumption in Spain has been estimated. In 2018, the 19,460 clients adhered to the 6.1 tariff (≥ 1 kV and < 30 kV) consumed a total of 53,946GWh [4]. Therefore, each client consumed an average of 2,772MWh yearly, which makes 231MWh each month. The same 10% of the modification in the consumption due to demand response, as in the case of domestic users, is assumed.

For the case of Fenie Energía, that has around 200.000 industrial customers, a summary table for the possible benefits obtained with RESPOND has been developed. It is estimated that at least a 10% of them would contract the demand response service, thus 20.000 final industrial customers. Table 4shows the global savings for each presented case-scenario.

Table 4. Savings with the different possibilities of integration of demand response for industrial clients (10% of energy reallocation)

	SAVINGS/CLIENT		**SAVINGS FOR 20.000 CLIENTS**
	[cts/month]	[€/year]	[k€/year]
Case 1	1381,22	16574,67	331493,46
Case 2	252,27	3027,19	60543,71
Case 3	1633,49	19601,86	392037,17
Case 4	176,59	2119,03	42380,60
Case 5	57,75	693,04	13860,74
Case 6	15,71	188,51	3770,12
Case 7	22,18	266,13	5322,52
Case 8	73,46	881,54	17630,86
Case 9	43,89	526,71	10534,16
Case 10	101,65	1219,75	24394,90

As done with the case of domestic users, the same analysis as the previous one is carried out for energy reallocations of the 5% of the total daily consumptions, instead of for the 10%. The results are the ones summarized in Table 5.

Table 5. Savings with the different possibilities of integration of demand response for industrial clients (5% of energy reallocation)

	SAVINGS/CLIENT		**SAVINGS FOR 20.000 CLIENTS**
	[cts/month]	[€/year]	[k€/year]
Case 1	1381,22	16574,67	331493,46
Case 2	252,27	3027,19	60543,71
Case 3	1633,49	19601,86	392037,17
Case 4	176,59	2119,03	42380,60
Case 5	57,75	693,04	13860,74
Case 6	15,71	188,51	3770,12
Case 7	22,18	266,13	5322,52
Case 8	73,46	881,54	17630,86
Case 9	43,89	526,71	10534,16
Case 10	101,65	1219,75	24394,90

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