Demand Response Opportunities and Programs for Europe and Brazil

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Contents

1. Introduction

The present report presents a summary of demand response implementation in some of the major existing electricity markets, namely, the European and Brazilian. European markets have been detailed by country. Also, an introductory framework, the demand response definition, and the aggregator role, have been accounted in this report, more clearly presenting the discussed subjects.

Demand response's huge potential for flexibility is one of the major reason for its implementation interest, besides the fact of an active role for consumers can cause a significant reduction in power systems network's operation costs, thus consequently enabling a more sustainable environment for all participating parties.

This report shows that demand response resources have been gradually developed to a point where its integration has become reasonable.

Europe, on one hand, has made a huge effort to reach an adequate level of demand-side management measures, along with a significant amount of penetration regarding distributed generation, especially based on renewable energy sources.

Brazil starts its demand response path with the introduction of economic programs, and in this way promoting awareness amongst consumers for flexibility. In what concerns distributed generation, Brazil is mainly dependent on hydro power on which their operation affects considerably the energy prices and therefore grid operation.

In this way, the present report is meant to be updated whenever necessary, and therefore maintaining its content as recent as possible.

2. Overview and Context of Demand Response

2.1. Demand Response Framework

During recent years, electricity consumption has been trending to raise due to the constant development of new technologies and consumer habits [1]. While residential consumers become larger, also commerce and industrial consumers grow considerably in a fast consumption environment as products reduce their life cycle or are over past. These issues cause the generation-side to be also updated, with the installation of more capacity in existing power plants or by building new power plants, with high investment. In order to obtain a sustainable power system, fossil fuels use is decreasing, while introducing distributed generation (DG), renewable energy sources (RES) and demand response (DR) [2] as the main sources. The concept of having consumers actively participating in the network operation is the basis of DR, considering several kinds of programs. According to Figure 1, one can see that the highest amount of CO2 emissions are obtained from electricity generation, followed by industry and transport sector. China, United States and the European Union are the most pollutant regions.

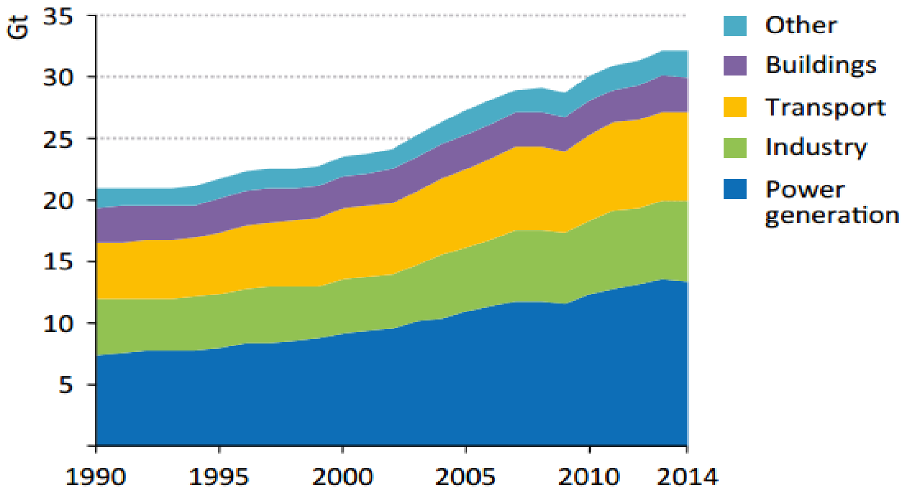

Figure 1. Carbon emissions per sector [3].

The adoption of low-carbon technologies in energy systems can improve these to be more sustainable, less expensive and flexible. In fact, by using a decentralized generation system several advantages come to surface, namely, if the generation is closer to the consumption areas, less distance is needed to be travelled in order to supply the consumers, thus much lower energy losses and network congestion. With the use of sustainable technologies, an improved energy system can be obtained using at the same time, DG and DR.

The main challenge of adopting distributed energy resources (DER), such as DG and DR, is their integration in existing energy networks, since they present very different

characteristics from conventional power plants [4] and require new control and management approaches.

The first feature represents a serious issue for their economic reliability, since they are most likely to be out of the wholesale market by lack of sufficient energy. Also, most of the public-own infrastructures in DG and DR, are normal consumers without any knowledge in energy markets and sources management.

In this way, the integration of DER has to be accompanied by the modification of current energy infrastructures, namely, by the inclusion of aggregation entities capable of gathering a substantial amount of energy from several DER, including the management and remuneration of these resources. The aggregator concept is defined in the 2012/27/EU directive, as follows: “demand service provider that combines multiple short-duration consumer loads for sale or auction in organized energy markets” [5]. In Figure 2, one can see how an aggregator is implemented in the energy market as well as it objectives and duties.

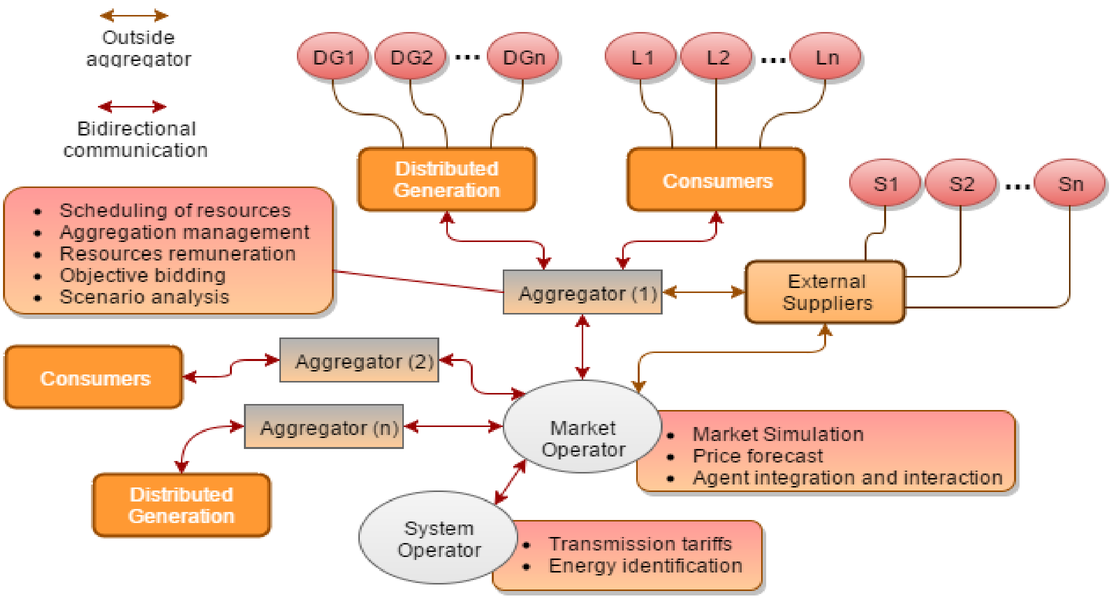

Figure 2. Aggregator, DG and DR implementation into energy systems [Source: GECAD].

The existence of an aggregator to represent consumer’s reduction capacity in energy markets, is a key feature for the successful implementation of demand response. There are several types of DR service providers: independent (usually called, third-party aggregators, suppliers), retailers, distributors, amongst others.

Preferably, the inclusion of third-party aggregators together with retailers in energy markets, causes a competition environment benefic for the growth of DR, in terms of participants and market rules. The addition of aggregators into energy infrastructures allows several possibilities to raise, namely, the management of distributed resources by these entities. In this way, aggregator’s can provide services to distinct resources and aid them in their operation and profit maximization. At the same time, the operators are

also able to benefit from this, since their task becomes easier, dealing with just an entity that has the knowledge of how energy activities and traded are assembled, as shown in Figure 2 and Figure 3.

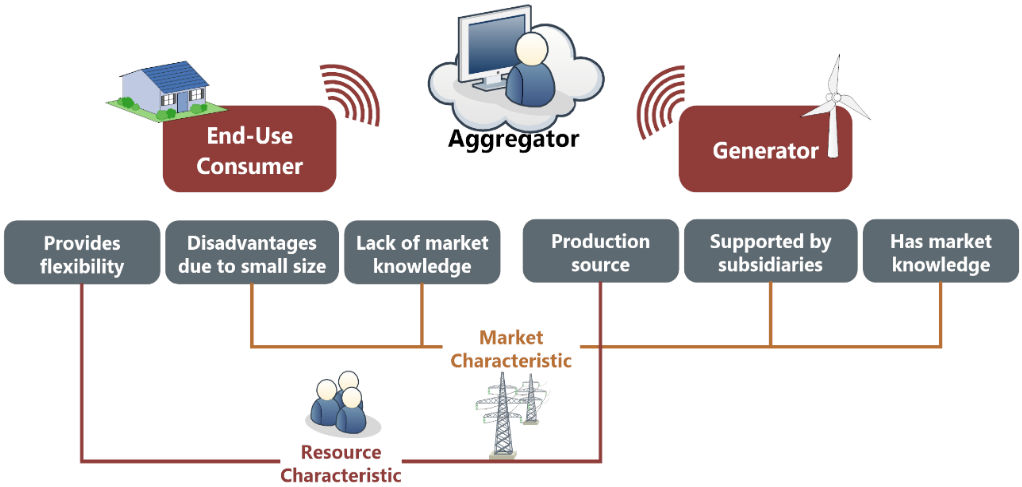

Figure 3. Distributed resources energy features [Source: GECAD].

DR becomes important to provide flexibility capacity to energy systems, since the introduction of DG causes some issues, affecting the normal operation of the network. Flexibility is defined in [6], as follows:

"On an individual level, flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system." – the statement also includes the description of the mains parameters used to define flexibility:

- How much amount of power can be enabled by the resource?
- What is the duration/availability time of the resource?
- How often can the resource participate?
- What is the response time of the resource to participate?

Several research works have been developed in order to ease the integration of DR into energy infrastructures, considering several approaches to the issue, such as the works presented in [7], [8].

In [7], an application of DR is made considering more focused point of view, namely, the energy management of a small building relative to new housing construction in France, in the context of Microgrid integration. In this case, it is not just about minimizing costs considering own generation and DR activation, but also, taking into account the living conditions of the householders, such as, thermal comfort, lighting, day and time of the day, air quality, amongst others. The work is performed using a deterministic mixed-integer linear programming, bearing in mind a planning horizon of two weeks, with steps

of one hour each. Having a multi-objective optimization criteria, results show that this may be difficult to achieve, as shown in Figure 4. This model takes into account the energy price at which the consumers pays for the use of electricity in his building. Also, one can see that it is never reached a point of absolute comfort or discomfort (axis intersection), but only a point close to the same. However, paying for almost 100 euros for thermal comfort seems over the edge for a regular residential consumer. The results for minimization conditions are always influenced by the actual generation of wind and PV.

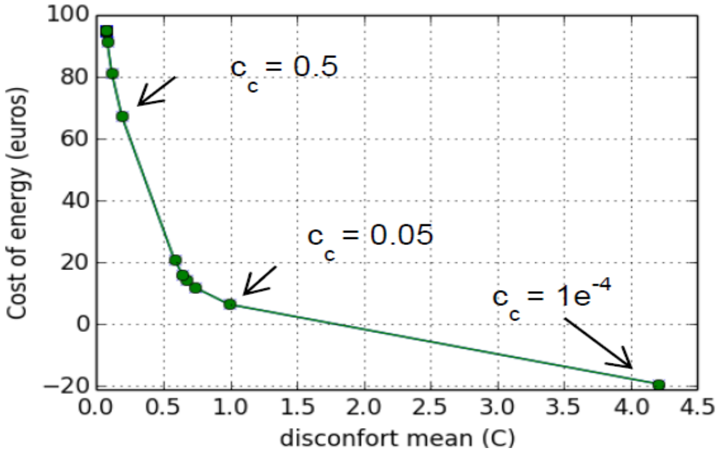

Figure 4. Relation between the minimization of operation costs and comfort living [7].

In [8], a model for low voltage distribution networks is presented, considering the integration of distributed generation, especially, the uncertainty caused by them in the normal network's operation. In this way, the work intends to present methods that can integrate flexibility and its benefits into low voltage networks, and not just on medium and high voltage, as is commonly performed by the system operator. Inside the focus of the work, load shedding and its possible effects are addressed, taking into account mostly residential consumers, since these are the big share of existing connections in distribution networks.

Considering that these can also be a form of flexibility, new solutions arise besides electrical vehicles and storage units. The author refers to DR as better solution than electrical vehicles or store management for flexibility actions, namely because, of their cost, number of deployments, electric vehicle lack of predictability, raise of peak demand in certain periods with the introduction of electric vehicles large deployment. The work proposes a load shedding model to simulate with real consumer data, namely, three households. Another scenario, was the application of peak shaving methodologies and its simulation, resolving a 29% reduction of peak load, along 29 days of operation - Figure 5.

As one can see by the previous examples, flexibility solutions offered by DR, allow energy operators to reduce costs from investment and operation:

- Investment – having the possibility to reduce load's, investment costs related to the upgrade of existing energy sources and/or construction of new power plants and storage management infrastructures to meet demand raise, can be avoided or delayed;
- Operation – reduce costs related with the contracting of expensive producers, just to provide small amounts of energy for system balance and regulation. Also, lines and transformers would not have to operate in extreme conditions, thus reducing operation losses.

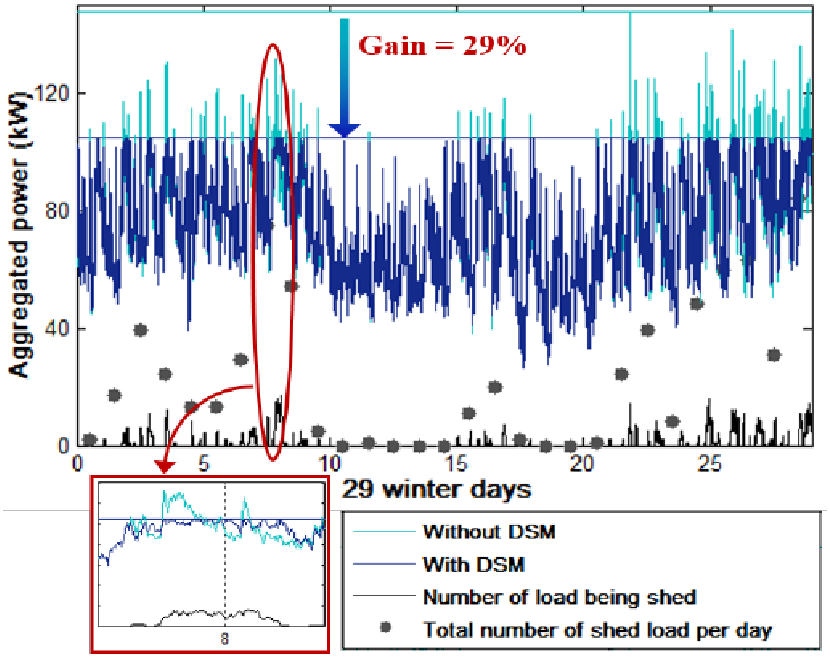

Figure 5. Winter peak minimization shedding residential consumer [8].

DG, through renewable sources, is characterized by having a fluctuating production, due to the sources being dependent from uncontrollable natural conditions (e.g. low/high wind speed, cloudy/sunny/rainy day, etc.). Therefore, in growing energy systems focusing on the development of DG, the need for flexibility becomes essential to face fluctuation.

Occurring generation and demand fluctuations at the same time, can be difficult to manage. In this way, someone needs to be responsible for the imbalances created in the network because of these resources, enabling small/medium corrections to the energy balance almost in real time horizon.

The entity responsible for these corrections is the Balance Responsible Party (BRP), existing several of them inside an energy market, since these entities operate considering perimeters, i.e. they only correct imbalances related with resources

included in its region/perimeter of activities. The work performed by these entities is vital for the appropriate and safe operation of energy systems [6].

The Transmission System Operator (TSO) is the manager of the transmission network, normally dealing with energy contracting of large commercial and industrial consumers, however no balances are made by these entities. TSO's are, normally, regular users of flexibility since it allows them to easily deal with: possible demand peaks during operation, restoring frequency deviations to normal, reactive power control, etc.

Distribution System Operators (DSOs) can benefit from flexibility services, namely, for voltage control, grid losses, and congestion management. They can also use flexibility to reduce peak demand and adequate generation fluctuations.

The above entities can use flexibility to provide appropriate energy solutions and reduce their operation costs, improving consumer's features.

After this introductory section, the following chapters will address, in more detail, several features of DR, namely:

- What is the role of DR in current and future energy power systems?
- What advantages will DR bring to the normal/emergency operation of power systems?
- Will DR cost more or less than actual solutions? If more, will the advantages have significant relevance that make this solution worth it?
- What changes have to be (if any) made in energy markets to support the introduction of DR programs and the active participation of consumers?
- Which entities are influenced by DR's implementation? Is there the need to change responsibilities or create any new role/entity?

These are just some of the important questions approached.

2.2. Smart Metering

Smart metering implementation has been growing significantly in Europe, where the major investment will be reached on 2020 – 35 billion euros (195 million meters), corresponding to 72% on average deployment of smart meters (SM) in Europe. The current state of the European SM integration can be seen in Figure 6.

In this way, EU defined a set of ten functionalities that SM should include [9], i.e. the countries have to certify that the equipment installed meets the demands of the EU, in relation to the concept of SM.

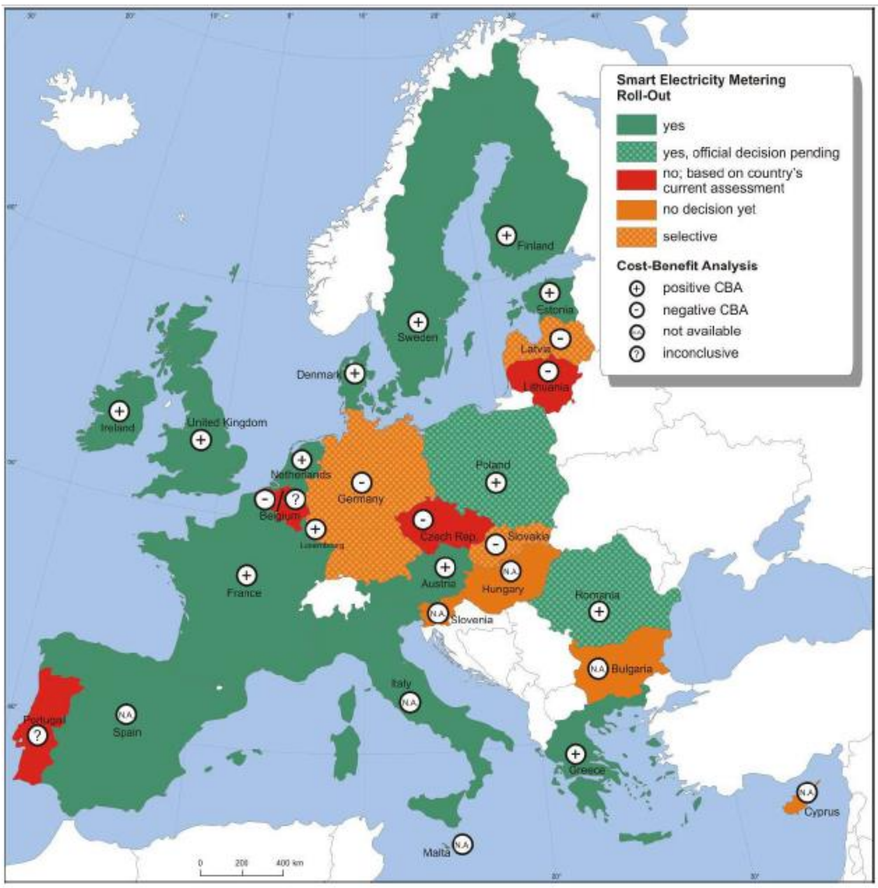

Figure 6. Current European state of smart meter integration [9].

- Provide measurements to consumer and/or any third party;
- Keep energy profiles updated, so that energy saving schemes can be implemented;
- Allow operators to read energy activities remotely;
- Tolerate bidirectional communication between consumer and operator, to perform maintenance and control procedures;
- Allow frequent readings so that network planning can be possible;
- Support simple and complex tariff programs;
- Allow for remote control applications (e.g. supply control, flow and power limitations, amongst others);
- Communications must be secure;
- Defense mechanisms against fraud;
- Provide import/export and reactive metering.

An interesting point is that the use of SM can be regulated (even in liberalized markets) or competitive. The advantage behind competition in a smart metering market is the

descent of metering costs, being that each company would be responsible for the installation of SM in their respective customers. In most European countries, the meters are applied by the local DSO, however, in non-regulated metering markets, the meters are implemented by the respective supplier company. Moreover, the metering data is accessed by the DSO when regulated, or sent to a central hub when competitive markets exist, as in [10].

In sum, SM are another way of contributing for DR implementation, since they allow remote operations that can facilitate the intervention of internal and external entities, and giving access to relevant consumer's data (such as, consumption profile, real-time availability, amongst others). In this way, consumers can also gain consumption awareness with real-time information about energy prices, while their participation in DR events is made easier due to the bidirectional communication with the organizer entity. Also, SM will allow the end of energy consumption estimations thus reducing the costs of it for consumers and energy companies.

Although all these benefits make SM very attractive, this also comes with high cost, such as, production of this equipment, the replacement of the traditional meters, and installation. With the installation of these meters, on one hand, consumer's consumption data and profile are exposed to operators and other entities, on the other hand, who owns this information, and shall it allow a free use of it or not? These are questions that today's studies about DR deployment into energy setups, try to answer, besides economic reliability [83]. Other works are mainly improving existing business models or suggesting new approaches for the consumer's interaction with the several internal market entities needed for DR participation.

Table I presents the positive and negative aspects of smart metering implementation in some European countries [9]. One can see the differences between countries belonging to Europe, namely, the energy savings potential, investment, installation cost, etc. Each country needs to evaluate the major benefits and costs of its smart meter implementation, in order to decide on the adequate value of investment that will be sufficient to fully take advantage of DR (this includes considering cultural and social, economic, legal, and organizational variables). When using different programs into distinct situations, may prove that diverse reactions occur for each one.

Table I. Benefits and costs of smart metering in some European countries [9].

State	Benefits	Costs
DK	- Saved metering investment (29%) - Increased competition (21%) - Energy savings (16%)	- Capital costs (smart meter, installation, communication infrastructure, IT system) - 67% - Tax distortions (8%) - Operational costs (data collection, validation and delivery to central data hub) - 4%

State	Benefits	Costs
FR	- Avoided Investment in installing existing meters: 30% of total benefits for the DSO - Avoided network losses: 25% for the DSO - Avoided meter reading costs: 15%	- Meter procurement and installation cost – 80 % - Procurement and installation cost of data concentrators – 10 % - IT systems – 10%
DE	- Energy savings (33%) - Load shifting (15%) - Avoided distribution grid investments (13%)	- Investments in smart metering systems (meter, gateway, communication infrastructure) 30% - Communication costs (20%) - IT costs (8%)
PT	- Demand reduction (55.3%) - Peak reduction (13.3%) - Commercial losses reduction (11.1%)	- Supplier profit reduction - by consumer demand reduction — (47.4%) - Acquisition and installation of smart meters (31%) - Communication infrastructure (14.6%)

Per example, Germany has a negative Cost-Benefit Analysis (CBA), meaning that the value of integrating smart meters will actually cost more than the current strategy of energy measurement, thus, Germany has not yet decided on the implementation of smart metering on a big scale. One can see by Table I that Germany reveals a high investment is needed, for developing and operating a communications structure, however several savings can be attained by integrating smart meters into the energy infrastructure.

Figure 7, shows the benefits and costs of implementing SM for some European countries [9].

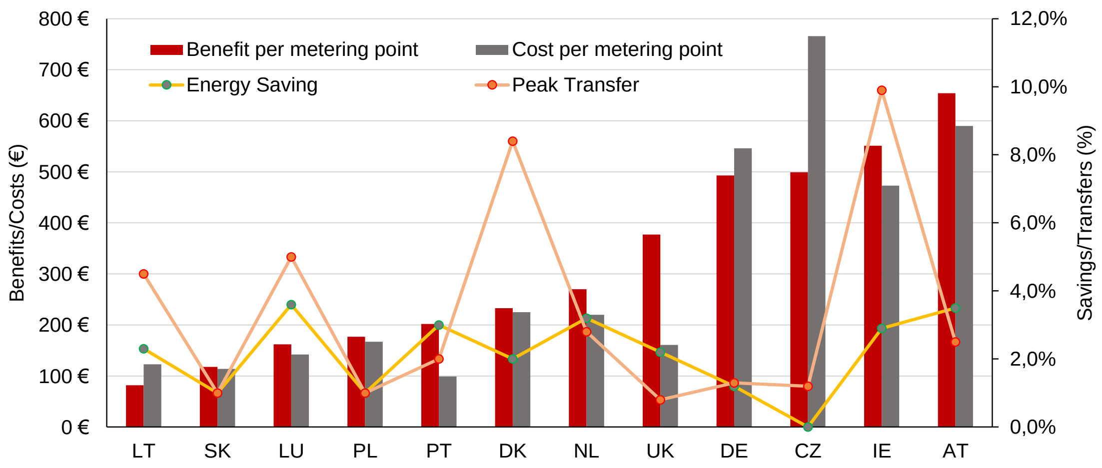

Figure 7. CBA of some European countries, and savings/peak load transfers [9].

One can see that in some countries, the cost per meter is higher than the benefit it causes. However, one must consider the peak load transfer and energy savings that are

obtained. Some benefits and costs only regard the DSO's operation, while others are related to the whole system operation. The consumers' benefits are not shown in Figure 7; however one can obtain that information in [9]. In this way, countries that have a negative balance between benefits and costs, smart metering may not be an immediate profit maker, but is always a problem solver.

Now discussing the structure of SM implementation, most European countries use a 3-agents' architecture composed by the smart meter, data concentrator (DC), and data management system (DMS). The SM collects information about many parameters (consumption profile, consumer balance, price applied, amongst many others), sending it to the data concentrator, located in medium/low voltage substations, that although no analysis is made, the data from consumers/prosumers is organized (e.g. by region) and sent to the DMS where it is managed. The most used technology to perform this communication, is Power Line Carrier (PLC) along with General Packet Radio Service (GPRS) [11]. This configuration allows an easier data treatment for the market entities, namely, the distribution system operator, that can regionally manage the consumers without costs of estimation, as mentioned before.

In what concerns Brazil, smart meter implementation is made considering two types [12]: in the first way, consumers that join the white tariff program have free installation of a smart meter, as for the second way, the consumer can choose a more complete smart meter solution including specific user information, however with more costs since a payment has to be made to the distributor. Either way, the consumer can always choose between installing a smart meter or keep the traditional one. Smart meters in Brazil become even more relevant when considering the high rate of energy thefts by meter alteration (commercial losses). The implementation of smart meters in Brazil is still limited, and will have a high cost for the energy companies (around R$ 200 per meter).

3. The Fundamentals of Demand Response

Demand response is defined as the modification of consumers' electricity patterns in response to a price signal or monetary incentive. DR can be seen in two ways, direct and indirect strategies. Direct strategies are programs that are in accordance with the definition mentioned in the beginning, since the consumer, in agreement with a third party entity, accepts to reduce its loads under certain circumstances. Indirect strategies are those who the consumer can perform by improving its energy consumption efficiency, without the addition of other entities.

This type of resource can serve many purposes, such as, voltage/frequency regulation, energy network decongestion, assure reliability when network is at risk, etc. One can see that this is a tool that can help operators in the network management and secure operation. Demand response can be implemented several types of programs, of which, the following are the most common to apply:

- **Time-based** – also called as dynamic pricing, this type of program is characterized by a fluctuating energy price for consumers, depending on the time interval (day, hour, etc.), and conditions of operation in the network. It is up to the consumer to choose to reduce or maintain its consumption pattern, taking into account that the electricity bill will be larger or small, depending on the time of consumption;
- **Incentive-based** – incentive programs rely on monetary incentives to appeal consumption reduction from consumers. This type of program tends to be more restricted to consumers, i.e., these have less flexibility to perform load reduction since usually a contract dictates the agreement conditions;

DR can present several improvements for consumers, in what concerns the payment of their electricity bill, such as, the reduction of network usage taxes, losses minimization, deduction on thermal power plants costs and fossil fuels, etc. However, the integration of DR into energy systems presents itself with some issues that have to be solved, as shown in Table II.

The following set of rules is shown in order to successfully include DR in current energy systems, so that all entities benefit from their integration [13]:

- **Rule 1:** The input of aggregated load should be legal, encouraged and enabled in any electricity market where generation participates;
- **Rule 2:** Consumers should have the right to contract with any demand response service provider of their choosing, without interference;

- **Rule 3:** National regulators and system operators should oversee the creation of streamlined, simple contractual and payment arrangements between retailers, BRPs and aggregators. These should reflect the respective costs and risks of all participants;
- **Rule 4:** The aggregated pool of load must be treated as a single unit and the aggregator be allowed to stand in the place of the consumer;
- **Rule 5:** Create unbundled standard products that allow a range of resources to participate, including demand side resources;
- **Rule 6:** Form proper and fair measurement/communication protocols;
- **Rule 7:** Ensure Demand Response services are compensated at the full market value of the service provided;
- **Rule 8:** Create market structures which reward and maximize flexibility and capacity in a manner that provides investment stability;
- **Rule 9:** Penalties for non-compliance should be fair and should not favor one resource over the other;
- **Rule 10:** Create and enforce requirements for market transparency within the wholesale and balancing market.

Table II. DR influences in energy structure

Sector	Influences
Entities relative to network operation	• Need for an entity responsible for the management of DR resources and their participation in energy markets; • An entity to be accountable for the data obtained from each consumer, is needed to protect privacy rights; • New roles for the distribution and transmission system operators (DSO and TSO, respectively) have to be implemented; • The participation of consumers and load aggregators in energy markets must be equally seen by operators in face to supply side; • Network features shall endure energy fluctuation, due to DR activation
Consumers	• Possibility of considerable electricity costs reduction plus incentive gain, considering near-zero investment, in opposite to DG; • Active role in the energy network operation, being able to participate in energy agreements.
Network tariffs regulation	• With DR, the network costs have to be adjusted, reflecting the influence of demand response programs; • Promotion strategies should be implemented to support the consumer’s participation in DR programs, in retail and wholesale markets; • Remuneration schemes must be implemented in order to promote certain types of DR programs according to the network operation (dynamic pricing); • DR usage will allow considerable savings in capacity expansion investment due to consumption raise; • Option of adjusting network voltage and frequency, to reasonable limits.

As one can see by Table II, consumer's active participation in energy markets, changes the way the entities are positioned in the energy infrastructure, namely, the TSO. This entity, although its activities are related to the physical validation of the whole network, he is usually the responsible for presenting DR programs to consumers and managing their participation in these events.

In this way, the flexibility offered by consumers can deliver several advantages to energy systems to network balancing, achieving it at lower cost. At this moment these problems are evident, however, with the continuous increase of renewable sources share in energy systems, their high unpredictability and fluctuation will cause serious problems in the electricity network operation if there are not resources that can quickly adjust to variations in supply/demand.

DR can be implemented considering three methodologies, namely, by reduction, curtailment, or shifting, as shown in Figure 8.

a) Regarding the first type, consumers are asked to reduce load between a certain interval, maximum and minimum reduction capacity.
b) In curtailment, the consumers are like digital relays where some of their loads are either on or off, without load regulation control.
c) Finally, shifting makes consumers shift their loads consumption in high prices or reliability risk periods, to other periods when the network is less congested and the energy prices are lower.

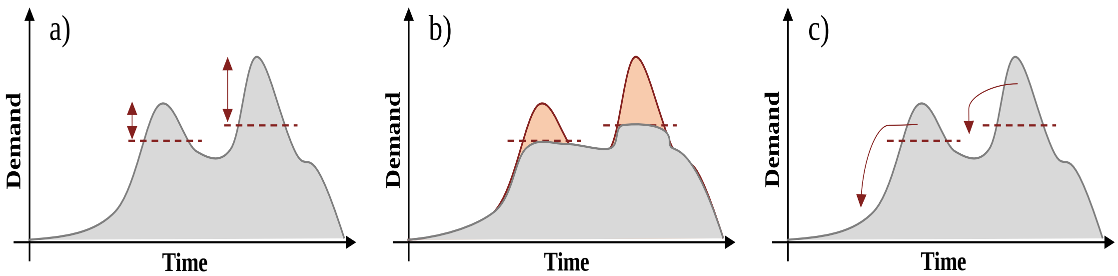

Figure 8. Types of DR application: a) reduction; b) curtailment; c) shifting [Source: GECAD].

3.1. Concepts

In this subchapter, the DR programs are detailed considering the time and incentive based perspective. One has seen before that the following programs can be applied in several ways, as shown in Figure 8, depending on the consumers and energy infrastructures. The following items describe each of the DR programs currently applied, according to OpenADR [14]:

- **Critical Peak Pricing** – it is a type of programs, that encourage the consumer to reduce its consumption during peak demand periods, concerning several distinct time intervals;
- **Capacity Bidding Program** – this type of program, allows consumers to bid in energy markets, specifying an amount of reduction, at a given time;
- **Direct Load Control** – in this program, the consumer's loads are controlled directly by the program organizer, usually, being activated on a very quick notice time;
- **Ancillary Services Program** – these programs provide monetary incentives to consumers, in order for them to reduce load during situations where the network's reliability is at risk;
- **Electric Vehicle DR Program** – basically, the same principle as CPP, however, applied to the charging of electric vehicles. In this program, the price of charging electric vehicles is modified in order to alter its consumption pattern;
- **Distributed Energy Resources DR Program** – related with the integration of distributed energy resources into a smart grid.

The inclusion of DR standards in energy infrastructures, allows a better communication between its components, and an easier understanding of what is happening in DR programs. A standard includes several features related to DR programs, namely, focusing on communication models. In [15], the following topics are presented to describe the OpenADR standard [16]:

- Continuous, secure, and reliable – two-way communication platform that allows consumers to receive DR event signals, and acknowledge its use;
- Automatic – pre-defined implementation strategies oriented to the consumer consumption habits and constraints, allows an automated and intelligent control of loads upon a DR event signal;
- Flexible – with the feature of Opt-Out, the consumer has the ability to regain control of the decision making at any time;
- Scalability and capacity – there is available a wide variety of DR programs that can be used (capacity), and can be scaled to higher or less consumption values (scalability).

This technology allows a wide range of solutions to be implemented within consumers, namely, by enabling a personalized interface connect directly with a TSO or aggregator. In this way, the DR event organizers can perform requests with a fast response time (automatic response) from consumers. The concept of OpenADR currently has a large following in the U.S., however, successful case studies have also been done in Europe and Asia. Some examples in the U.S. are: PJM (official energy entity), Walmart and Schneider Electric (private companies).

3.2. Entrusting Consumers

With consumers participating actively in energy markets, several rights and duties are entrusted to them:

- The interests and privacy of consumers have to be protected and treated equally by all players, as well as assisting them in their difficulties;
- The consumers have to be fully aware of what their choices and participation requires from them, as load curtailment or interruption;
- The incentives description has to be clear to consumers, so that payment is fair by their contribution into the network scheduling:
- Consumers, with this new role, begin to assume responsibilities towards the network operators since their participation is accounted for in the network scheduling. In case of failure, consumers assume a penalty.

What seems to be a considerable barrier for DR integration is the consumer itself, since the knowledge regarding energy markets and its activities is mostly unknown by residential and small commerce consumers. In this way, the first step for DR integration should be the education of consumers for these matters, raising the interest of consumers in energy reduction, curtailment and shifting. So, to ensure the consumer fulfills its obligations and duties, the entities in each region should promote the use of renewable energy and load resources participation into energy markets, in order to advance towards a viable future. Consumers have to be aware that the other existing internal entities are also dependable of them to successfully accomplish their activities, namely, the example of the BRP’s that have all their work developed in turn of the consumer’s consumption habits. Changing load causes BRPs several difficulties since predictions become less accurate, causing imbalances. Thus, consumers have to understand the market rules on which they’re in.

3.3. Managing Load Flexibility at System Level

The Smart Grid concept addresses several points in what it is expected from energy networks development and involvement with internal and external entities. Flexibility

will allow quick balance corrections and regulation, at a low level of investment and cost. The main requesters of flexibility are the system operators (TSOs in Europe, ISOs in the United States), since it is their responsibility, the validation of all technical restrictions related to the network, including that the schedule solution is possible and acceptable.

Also, at distribution level, flexibility can be used to delay expansion investments, ensuring quality in energy delivered, and help network reliability [17]. These issues can be solved by reserves (such as, spinning and non-spinning traditional suppliers – batteries, diesel generators, amongst others), however this becomes costly depending on the use, maintenance level, and life cycle. When this reserve concept is applied to common day electricity clients, the costs related with traditional reserves are dropped down to tariffs that are used when consumers, participating in DR events, are called to respond considering their availability.

In terms of system reliability, demand resources can overcome several difficulties encountered by actual energy grids, such as, peak load demand, emergency situations, and seasonal influences. For example, the New England ISO, in the US, has a DR program that implies a seasonal awareness – Seasonal Peak Program applied in summer and winter. Load peaks are usually affected, positively and negatively, by weather conditions. This reinforces the need for energy resources capable of responding to the system operator's calls without high availability and use costs. In Figure 9, the relations between entities (internal and external) are shown. The DR programs where consumers participate together with the aggregator, can be from the TSO or from the aggregator.

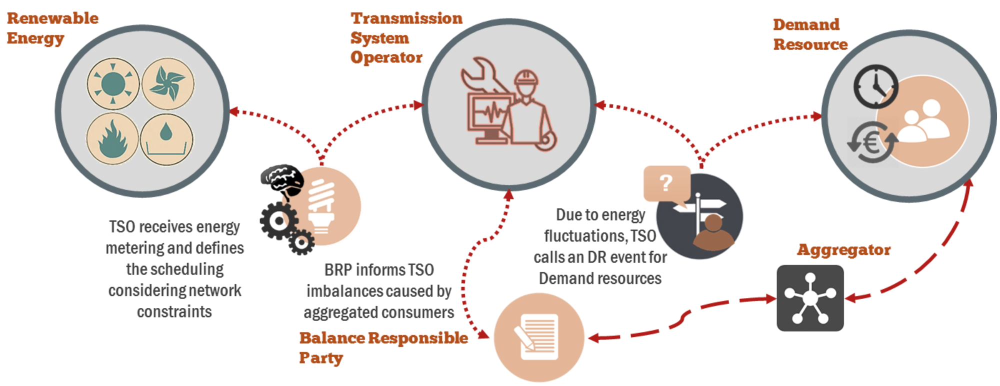

Figure 9. Relations between internal and external entities [Source: GECAD].

4. Enabling Demand Response from a market point of view

Currently, aggregators are neglected by market rules and are in a less relevant position when compared to retailers and generation-based entities. There is a need for a definition of new market roles and rules, so that DR can be integrated at the same level of the other resources. The main competitors for independent DR service providers, are the entities known as retailer and BRP, which are described below, retrieved from [5], [18]:

- **Retailer –** natural/legal person who sells energy to final consumers;
- **BRP –** means a market participant or its chosen representative, responsible for its imbalances. Takes financial responsibility for possible imbalances in its perimeter, i.e. between on one side, all consumers and sales, and on the other, all generation and purchases contractually included in its perimeter.
- **Consumer -** means a natural or legal person who purchases energy for own end use.

The use of consumers in demand flexibility can cause several issues for the entities referred above, namely by the following situation. Consumers in distribution networks are usually supplied by retailers, and their balance is managed by the local BRP. When an aggregator has an agreement with a consumer to provide flexibility capacity, this causes issues for the retailer and BRP entities if they are not advised of the aggregator activities.

For the retailers, their demand forecast becomes incorrect and they may have bought excess or lack of energy in the market. This causes the retailer to make adjustments to his scheduling and operation planning, being traduced into additional costs for its activities to comply with its role in the energy market. The influence of a third-party aggregator does not remain isolated in energy markets, affecting other entities as well.

For the BRP, the issue relies on the retailers forecast that now is incorrect, thus the balance predictions from the BRP are also incorrect and need, as the retailers forecast, to be adjusted once again. Several additional costs come from third-party aggregator's presence in the energy infrastructure.

In these situations, when the consumer's consumption is modified by an independent aggregator, this is considered an external situation to the retailer and BRP activities, and therefore, they must be fairly compensated for their additional efforts. In some countries, this does not exist, and therefore, agreements have to be made between the aggregator and the retailer/BRP in order to address this issue properly. This is the main reason for the resistance encountered by independent aggregators with retailers and BRPs, when integrating services into energy infrastructures.

Another form of accomplishing the satisfaction of all entities involved, is the approach proposed in [18], where an opened energy position of the aggregator is proposed to meet all requirements of the issues presented. Namely, the imbalances of the BRP and retailer can be addressed to the aggregator, which sells excess energy or buys energy (in case of lack) from the market. The proposed scheme of open energy position is shown in Figure 10.

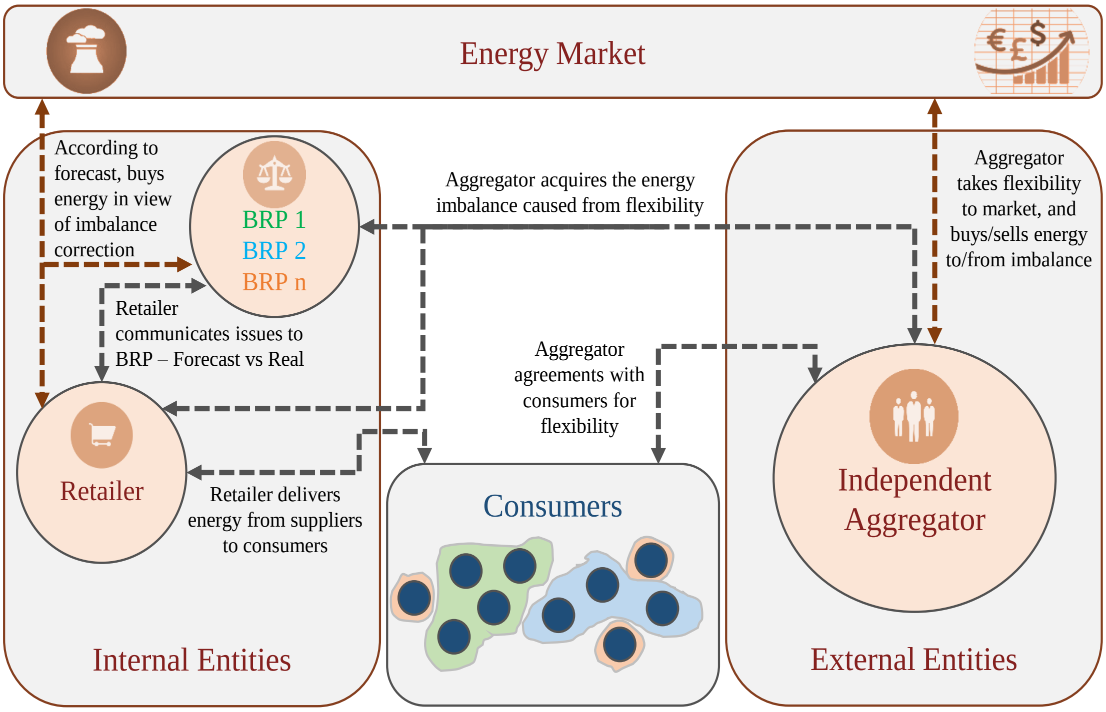

Figure 10. Open energy position for aggregators, Adapted from [18].

According to [6], the main entities involved in the flexibility activities are:

- Aggregation Service Provider (ASP) – it provides the possibility of consumers to join in capacity groups, enabling a larger amount of energy than by themselves alone;
- BRP & Balance Service Provider (BSP) – the role of the BRP is mentioned above, however BPS' role is not yet defined. The BSP is an entity that can provide energy for the balancing market and activities, so in this way, it is similar to an aggregator;
- Supplier – the suppliers, on the contrary of one may think, ensure a wide range of flexibility services to a varied range of consumers, offering programs such as dynamic pricing;
- TSO & DSO – their roles are already mentioned above;

- Regulators – the integration and promotion of DR programs is considered and defined by these entities, enabling the resources by applying subsidiary schemes and positioning them as an equal source of flexibility between the other parties in the market.

Regarding the above topics, one can see how these are related with the ones presented in beginning of the present section, namely, the role change in each one (e.g. the BRP gains additional responsibilities due to the flexibility introduction. The definition of these concepts and roles for each of the entities participating in the flexibility operation are important for the correct business models creation and successful integration of DR resources.

In Figure 11, one can see the roles that each network participant has, and the relations that exist between them. In this way, the aggregator role can be placed as the one representing the consumer on the network, protecting its interests and communicating with several entities on its behalf.

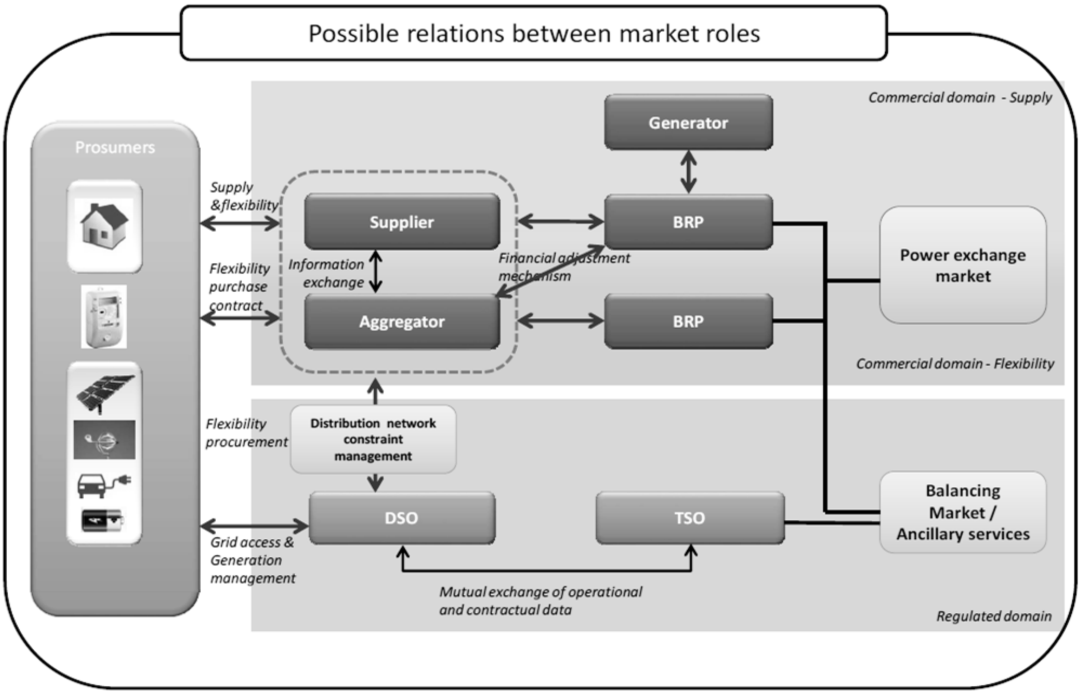

Figure 11. Market roles for the entities involved in flexibility activities,[6].

5. Demand Response in Europe

In this chapter, the DR European integration is detailed, considering several countries. Although the implementation of demand side management is not as developed in Europe as in the United States (US), the truth is that many projects are currently being exploited with the intention of providing more DR integration. Figure 12 presents demand response integration in Europe, by the end of 2014.

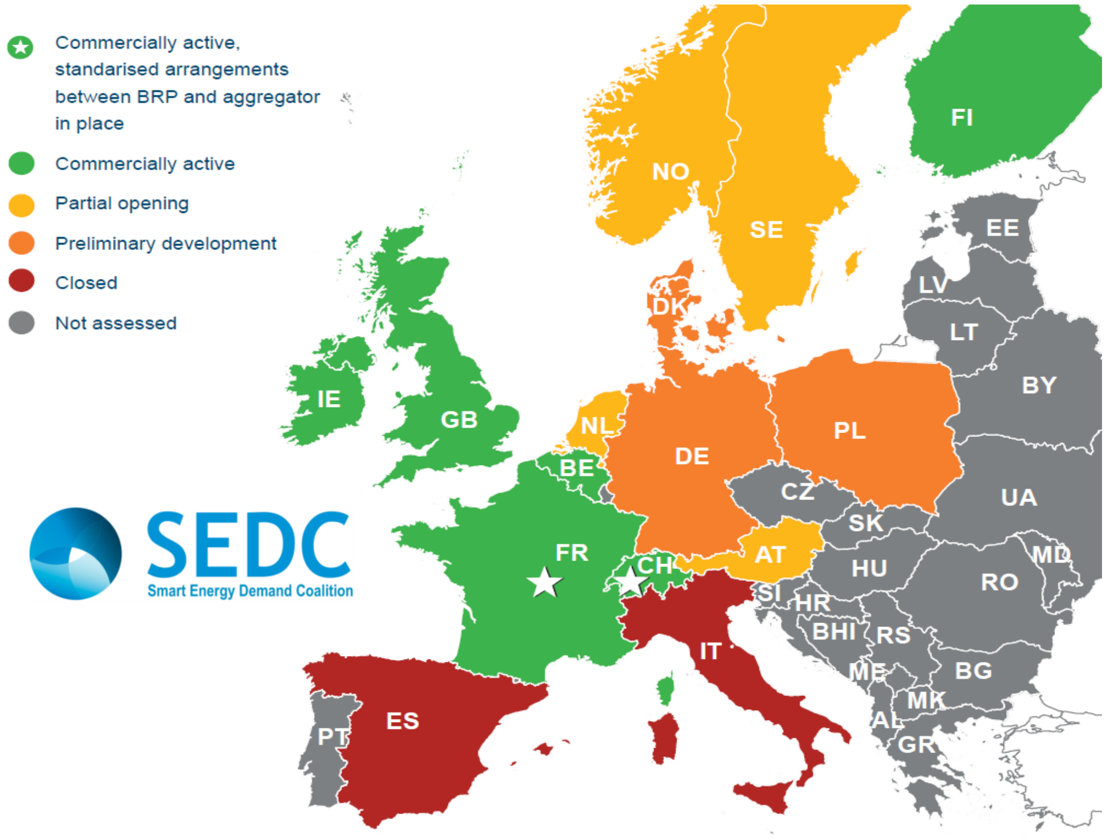

Figure 12. State of DR in Europe [19].

As one can see by Figure 12, the only countries currently active in DR are: England, France, Belgium, Switzerland and Finland. Countries like Norway, Sweden, Netherlands and Austria, are on the edge for opening DR integration into their energy markets. Other countries, are still proceeding on the development of energy infrastructures that can support the integration of DR, such is the case of Germany, Denmark and Poland. The rest of European countries seem to not be focused on the development of this technology scheme for consumers' active integration into energy systems.

After presenting the DR programs of each country, conclusions are made on the main trends of European applications and features.

5.1. Work Structure

In the following sections, related with each country's DR implementation, several tables are presented regarding programs summary. In this way, Figure 13 shows the explanation for each one of the columns considered throughout the document.

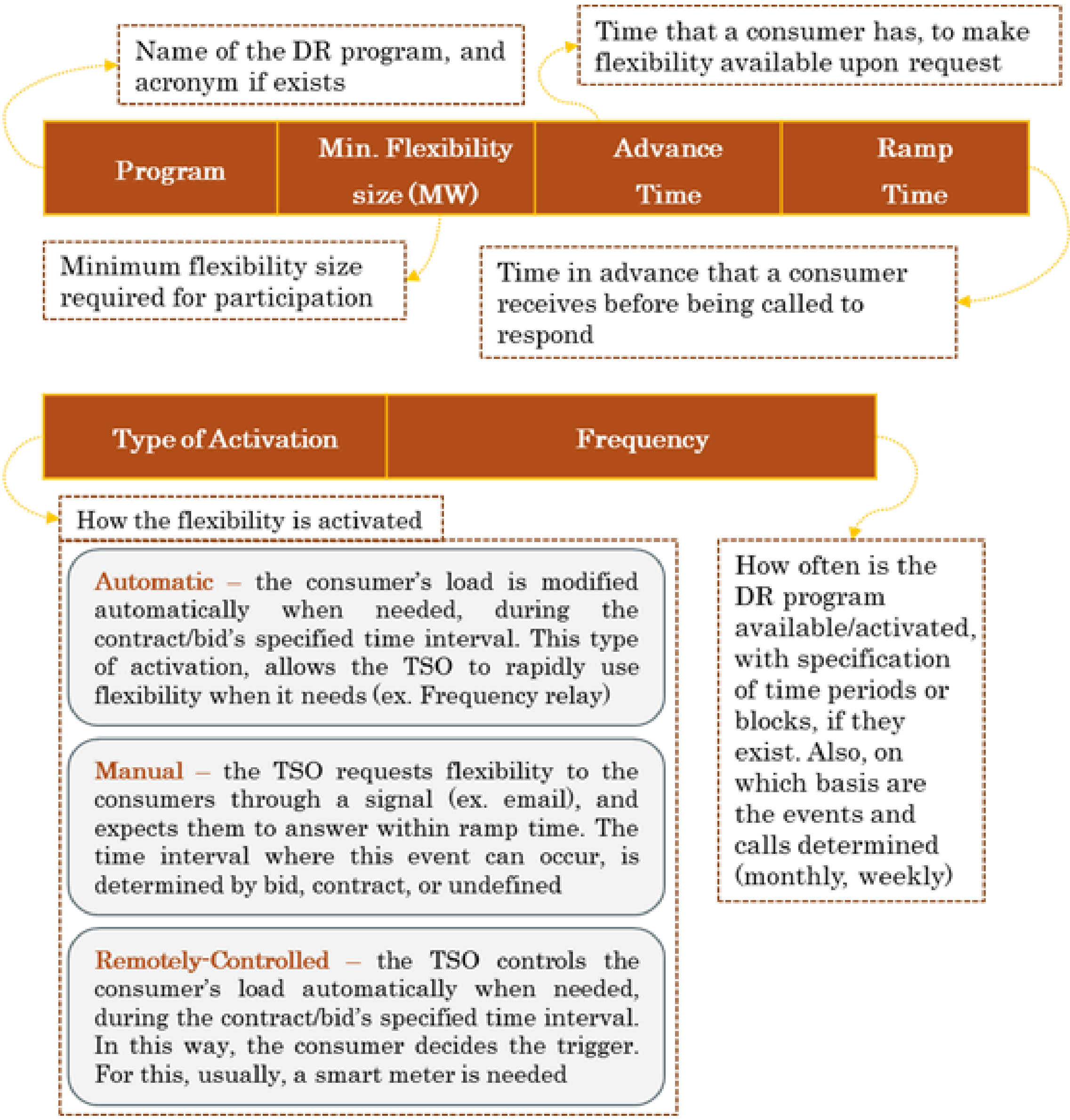

Figure 13. Template table description.

The same rules considered above, and that will be followed in the present chapter, are valid for the next chapter. Near tables the links to each transmission system operator will be placed, through the logo of each TSO.

5.2. Austria

In Austria, DR integration has become almost exclusively dedicated to balancing markets, as primary, secondary and tertiary reserves. Besides direct negotiation by consumers, is also allowed aggregation. Although this is allowed, several barriers face independent aggregators when joining Austrian energy markets, namely, the need for an agreement, in this case, a bilateral contract, with the BRP in order to be able to participate. This causes several disadvantages for independent aggregators, since it benefits the BRPs.

Also, the existing barriers are not all from the aggregator's side, but some from the consumer's side, e.g. the consumers, when joining in as flexibility resources, need the installation of a private telephone line to receive the signals from the TSO, which adds considerable costs to the consumer's. Table III, presents the summary of the DR programs implemented in Austria [19], [20].

Table III. Austrian DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Primary Control	2	Friday to Tuesday of the week before	Immediate	Automatic	• Tendered on a week basis, without different time windows • In some cases, has to be available for 30 minutes (Δfreq. > 0.2Hz)
Secondary Control	5	Tuesday of the week before	Acc. to bid and market conditions		• Tendered on a week basis, with 3 different time windows: peak, off-peak, weekend
Tertiary Control	5	Wednesday of the week before	Acc. to bid and market regulation		• Tendered on a week basis, separate for weekdays and weekends • Min. duration of 15 minutes • Max. duration of 4 hours

Although Austria is close to a huge wholesale market, EPEX (that mainly includes, France, Germany and Switzerland), its participation on it using DR does not exist which hardens the position of consumers in integrating these kind of programs, as well as, less variety of options for them. Some enablers for DR were also included, such as, the reduction of the minimum flexibility size from 10 to 5 MW, with an automatic activation of the loads. Also, and more considerably, the duration of flexibility usage has been reduced from 16

to 4 hours, allowing an easier management for the aggregator, and less affection of the consumers processes. Additionally, Austria needs to create reasonable and attractive conditions for consumers, so that DR participation in energy markets can growth.

5.3. Belgium

Belgium has, very recently, opened several markets to DR integration taking into account their requirements, namely, spot, ancillary and reserve (primary, tertiary, and strategic). Currently, the aggregators participation in conditioned by the need of an agreement with the consumer's supplier/BRP, which constitutes the major competitors. This considerably hardens the aggregator's integration in energy markets. The following Table IV presents the DR programs applied in Belgium [19].

Table IV. Belgian DR programs

Program	Min. Flex. (MW)	Ramp Time	Type of Activation	Frequency	Price (€/MWh)
Primary Reserve	1	50% in 15 s 100% in 30 s	Automatic	• At any given time • Used for frequency deviations above 0.1Hz • Amount available for at least 15 min	5-6 for availability
Strategic Reserve	1	6.5h (warm-up) 1.5h (ramp-down)	TSO's signal	• Maximum of 20-40 activations per year • Min. and Max. duration of 1 and 4-12h • Maximum of 130 hours in winter period	Not Public + 68 for use
Tertiary Reserve – Frequency Control	1	15 min	Remote control	• Maximum of 40 activations per year • Amount available for a maximum of 2 hours • Minimum time interval of 12h between interruptions	3.07 for availability
Tertiary Reserve – Interruptible Loads	1	3 min	Remote control	• Maximum of 4 activations per year • Minimum time interval of 24h between interruptions • Three types exist: A4, A8 and A12	1.41 for availability + 75 for use

The aggregator can additionally join the market by becoming a BRP, however the costs associated with this are considerable and may not be justified. In the spot market (BELPEX), the consumer's participation is mainly from large commercial, industrial consumers or aggregators. In this way, Belgium presents an attractive DR scheme for

consumers with reasonable conditions for their implementation. Also, the aggregators are still in a disadvantageous position when comparing to supplier/BRP, since these define the level of participation.

5.4. France

France has one of pioneer market structure for DR integration, having programs available since the new millennium. Mainly industrial consumers are used in DR programs, but residential have been developed also, because of aggregators. The following Table V presents the DR programs applied in France.

Table V. French DR programs [19]

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Primary Control	1	According to presented bids in annual contract	< 30 s	Automatic	• Very common to be used, at any time
Secondary Control	1		< 15 min	Automatic	• At any given time
Fast Reserves	10		13 min	Manual	• At any given time
Complementary Reserves	10		30 min	Manual	• At any given time
DR call for tender	10		2 h	Manual	• 60 days/year

Since 2013, the relationship between aggregators and suppliers/BRP, has been regulated in order to provide a framework for these entities interaction. This regulation allows consumers and aggregators the freedom from agreements with BRPs in order to provide flexibility in energy markets, where, in other European countries, this is a huge problem.

France has all the main energy markets open to DR; enabling consumer's participation and development of energy infrastructures in the path for more and more DR integration. In the ancillary services market, several improvements have been made in recent years, namely, by reducing the minimum flexibility from 50 MW (very common in other countries) to 1-10 MW, and also by facilitating aggregator's introduction without the influence of suppliers/BRPs in its activities, thus becoming an independent entity.

The capacity market is available to DR, under two types: consumers sign a contract with the suppliers becoming their resources, or enable direct participation through a certification process of their loads. In this context, the consumers need to be certified 1

year before their participation, while generators have a 3-year minimum. The wholesale market is available by participating in the NEBEF [21], [22], with at least 0.1 MW.

Regarding distribution programs, which are managed by EDF, there are two options for consumers: contract with tariffs defined by the regulator (called the blue tariff), or contract with tariffs defined by EDF. In the first type of contract, one has 3 options:

- Single tariff program, provides a unique tariff throughout any time;
- Double tariff program, provides a different tariff for two time periods: peak and off-peak hours;
- Tempo tariff program, provides several options for the consumers and considers three types of days: blue, white, and red.

In the Tempo tariff program [23], all days throughout the year are color coded being determined by EDF, taking into consideration the demand forecast and weather conditions (the transmission operator can also determine the day color depending on energy congestion). In this way, each day can be divided in two periods (on and off peak) being each one with a different tariff. This means that a total of six tariffs are applied through the year. Blue days have the majority with 300 days, white days with 43 days, and red days with 22 days. The consumers receive information regarding the color of the next day, at 20h00 through a ripple control system. The tempo tariff program allows consumers to better manage their consumption avoiding significant costs, according with the day color.

The second type of contract only allows two options, alike the ones considered in the first type of contract, single tariff or double tariff program.

5.5. Germany

Germany appears as one of the countries with more potential to integrate DR. With the raise to 35% of renewable energy share by 2020, Germany faces the issues related to them, namely, variable energy. Also, the current energy structure presents several barriers for DR implementation, as follows:

a) Bidding conditions are still adjusted to generators, and are difficult to be achieved by consumers;
b) The aggregator role is not yet defined clearly, as its interactions with consumers, suppliers, and operators. However, they are mandatory for consumer’s participation, i.e. consumers cannot participate alone;
c) Electricity fees related with the network operation, presents itself as a penalization.

Considering a), aggregators have a minimum bid size for participation, in the balancing and ancillary market, of 50 MW for a maximum of 5 aggregated units making it very difficult for the aggregator to participate. Other markets (capacity, wholesale, etc.) are closed for demand response. Further, the aggregator needs to establish a contract with competitor entities, making harder the establishment of agreement, as shown in Table VI.

Currently, Germany has implemented, since 2013, an interruptible loads program in consumers connected to high and very high voltage, i.e. mostly these are industrial types. In Table VII, the DR programs implemented in Germany are shown [13], [24].

Table VI. German aggregator's features

Entities	Features
Consumer	a contract has to be made with the consumer, in order to be able to negotiate in the energy market, taking into account the consumers characteristics
Consumer's BRP	the contract to be made with the BRP is the most difficult and presents itself as a barrier for the aggregators development and participation, since the aggregator has to obtain approval from the BRP (competitor because of the services offered that it does not have yet) in order to aggregate the consumers
Consumer's supplier	the contract with suppliers, defines the payment value for the consumers flexibility
DSO	a contract is made with the DSO, mainly to inform the non-availability (DSOs can also include demand response in their activities) of the consumer and the agreement made with the same
TSO	a contract has to be made with the TSO to clarify the flexibility of consumption by certain consumer(s), selling an amount as a positive energy injection

Table VII. German DR programs

Type of Load	Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Interruptible	Immediately	1 500 MW Tendered monthly Min. of 50 MW bid	Monthly, ~2 weeks before	1 s	Remote controlled	• Maximum of a hour per day at any time, for at least 4 times a week • Continuously at any time for at least 4 and 8 hours, once every 7 and 14 days, respectively
	Quickly	1 500 MW Tendered monthly Min. of 50 MW bid	Monthly, ~2 weeks before	15 min	Remote controlled	

Type of Load	Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Others	Primary Control Reserve	1	Tuesday of the week before, at 15h00	30 s	Automatic	Up to several times per day
	Secondary Control Reserve	5	Wednesday of the week before	5 min	Remote controlled	
	Minute Reserve	5	Day before	15 min	Automatic	

5.6. Iberian Countries

The Iberian countries include the following: Portugal and Spain. The legislations in both countries are intentionally similar, in order to, considering the MIBEL [25], become homogeneous. This causes several modifications between countries directives so that this may be possible, however, not always towards a better energy infrastructure.

Portugal

Portugal remains little developed in the DR integration, having only an interruptible loads program, much alike its neighbor country, Spain. Currently the government ordinances [26]–[30], define the DR interruptible programs conditions. These are made only for consumers connected to medium, high and very high voltage, i.e. connected to the transmission network, and a contract with the Portuguese TSO, has also to be made in order to participate. Additionally, measurement and control equipment has to be installed in the interruptible loads, paid by the consumers.

The summary of the Portuguese programs is described through Table VIII.

Table VIII. Portuguese DR programs

Program	Min. Flexibility size (MW)	Ramp Time	Type of Activation	Frequency
1	4	2 h	Manual (called by the TSO, and spread by the DSO)	• Max. duration of 12 h, divided into a max. of 3 periods, of 4 h/order
2	4	2 h	Manual (called by the TSO, and spread by the DSO)	• Max. duration of 8 h, divided into a max. of 2 periods, of 4 h, per order
3	4	1 h	Manual (called by the TSO, and spread by the DSO)	• Only one period, with a duration of 3 h, per order
4	4	5 min	Manual (called by the TSO, and spread by the DSO)	• Only one period, with a duration of 2 h, per order
5	4	Immediate	Manual (called by the TSO, and spread by the DSO)	• Only one period, with a duration of 1 h, per order

The interruptible programs can be of five types, changing between the ramp time, maximum accumulative duration, maximum number of periods and its duration. The payment of consumers considers two components: monthly availability, and an additional payment by usage of the available capacity. The transmission operator is limited in the use of DR programs, namely, 120 hours per year for the programs 1 and 2, and 120 hours for the programs 3, 4 and 5. Also, there is limits for their use by week – five orders per week, and by day – one order by day. In this way, Portugal presents an incentive-based DR program, with interruptible large consumers, however, their participation is eased through a low capacity requirement of 4 MW. Portugal also presents an economic based model for DR time-changing tariffs, for most types of consumers, allowing the consumers to choose between a single, two, or three time periods program, each with different tariffs. In this way, Figure 14 presents the Portuguese economic DR programs.

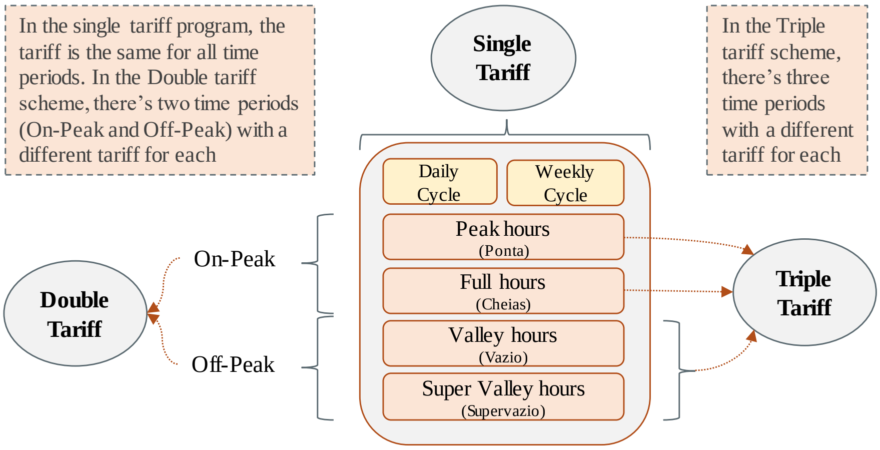

Figure 14. Economic DR Portuguese programs [Source: GECAD].

Day differentiation can be also considered in a so called Weekly cycle, where different time periods are considered for week days, Saturday, and Sunday. In a Daily cycle, are days have the same time periods. Although Portugal presents some options for consumers through incentive DR programs, these are still quite limited. The market is still mainly ruled by the previous owner of all activities regarding the electric system before market liberalization, EDP. In this way, the DR based on incentives is closed to most consumers due to its conditions, and no significant progress is under way. The processes for developing DR and DG, are currently stanched except for undergoing pilot projects.

Spain

Currently, Spain remains with many energy markets closed to DR integration, having only an interruptible loads program for large consumers, and the capacity market open. Aggregation is not allowed yet in none of the existing DR programs, however this subject is being developed to be implemented only for consumption side flexibility. Consumers can participate in the spot market with demand bids.

The interruptible DR programs are shown in the following Table IX [19]. Also, Spain is disadvantageous in the penalties applied for consumers that do not comply with the interruptible conditions, enabling the payment of 100 (islands) to 120% (mainland) of the availability price for the same program. The interruptible program is the responsibility of the Spanish TSO, thus, the imbalance occurred because of DR integration is corrected by it when performing the planning along with the other resources, namely production. In this way, the consumers participating have to be connected to the transmission network and have the necessary equipment to receive the TSO's signals to activation. Although, not many programs are available some pilot projects are ongoing for the same purpose [31], such as:

- PRICE – deployment of DR trials in households (Madrid community), to study consumers active interaction with the energy system;
- PERFILA – study and analysis of integrating smart meters in small consumers, and its influence in the energy trades on the market.

Table IX. Spanish DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency	Price Availability/Use
Interruptible Program (Mainland)	5	Yearly or monthly ~1 week before	Instant or 15 min or 2 hours	Automatic	• Max./year of 240 h • Max./month of 40 h	260k/Market €/MW per year
	90				• Max./year of 360 h • Max./month of 60 h	350k/Market €/MW per year
Interruptible Program (Islands)	0.8		-		• Max./year of 120 h	-

5.7. Ireland

Ireland presents itself as one of the few countries to address demand response integration into energy markets, in a successful way. Currently, Ireland is still improving the issues related with DR integration, in order to present more attractive conditions to consumers and aggregators participation in energy auctions, namely [32]:

- considering the wholesale market, guarantee an equal treatment level as generation side, storage and interconnection solutions;
- update the DSOs usage of DR providers and consumers, so that investments related to network operation can be avoided, such as, ancillary services;
- considering the retail market, several features have to be included to facilitate DR integration into this market, such as, the implementation of smart meters, not consider consumer profiles (e.g. residential), and introduce dynamic tariffs.

The following Table X presents the summary of DR programs in Ireland [19], [33], [34].

Table X. Irish DR programs

Program	Min. Flexibility size (MW)	Advance Time	Type of Activation	Frequency	Price Availability /Use
WDRI	None	Non	Manual	• During 2 hours, every day, 17:00 to 19:00, from November to February	-
DSU*	4	Called at any time during bid proposal	Manual	• Any given time of the day • Capable of delivering during at least 2 h	81.60 / non €/kW year
WPDR	None	Non	Manual	• From 1st of November to 22nd of March, during peak times – 17:00 to 19:00 hours • 3 ways of payment (incentive based): reliability and profile	-
STAR	None	Non	Automatic	• 10 to 20 unexpected and immediate interruptions with a duration of 5 minutes, by year • Triggered when frequency value drops to a threshold	Non / 8.20 €/MWh
Power Save	0.1	At least 30 min. before	Manual	• Activated at any time when demand is meeting available supply	Non / 0.38 (off peak), 0.95 (peak) €/kWh

* 4 MW for aggregators, not for individuals

In Ireland, DR programs are mainly present in the wholesale market. Balancing market will open for DR by 2017, while capacity market still does not exist (exists only as price based reserve, built-in the wholesale market). DR programs are without ramp time, with the exception of PowerSave, that has a 30 minutes ramp time.

Currently, Demand Side Units (DSU) have been referred as the DR program with more development, including aggregated consumers with a minimum flexibility capacity of 4 MW to 10 MW (high flexibility values due to wholesale market participation). However, consumers with a minimum flexibility capacity superior to 10 MW cannot be a part of an aggregator, having to participate in energy auctions individually. An aggregator DSU is not limited to size, i.e. can have multiple consumers with less than 10 MW.

Ireland has a DR program running for many years, known as Short Term Active Response (EirGrid STAR), an interruptible load scheme. Further on, the Winter Peak Demand Reduction (WPDR) scheme has been introduced to support the energy network through the worst demand months of the year [35]. The minimum quantity for a consumer to participate in a DR event, in Ireland, is 4 MW. Also, the Winter Demand Reduction

Incentive (WDRI) and PowerSave programs have been introduced. DSU's program allows a real-time availability measurement to the system operator. In this way, according to the accepted bid made by a consumer, the system operator is able to request a demand reduction – named Dispatch Instruction (DI). The request can be called at any given time, whereas occurs in the given time interval accorded in the bid [36], [37].

Another important issue is that consumers can participate in more than one DR program at once, i.e. consumers can be registered in more than one program, namely, the following bullets are presented:

- WDRI / WPDR – in this program, consumers cannot participate in other programs;
- DSU – consumers in this program, can also join the STAR program;
- STAR – consumers in this program can join a DSU or PowerSave program, but not both;
- PowerSave – this program does not allow its participants to join a DSU, however, it allows a consumer to participate in STAR program. Participants cannot be an applicant in the Single Electricity Market.

5.8. Italy

Although Italy has DR programs ready to be applied to consumers, the majority of its energy markets is closed for load curtailment, namely, balancing and capacity markets (capacity market intends to open for DR by the end of 2015). The spot market can be accessed by consumers, individually or through aggregators, using demand bidding. The Italian DR programs are summarized by the following Table XI [38].

Italy only has one type of demand response program, the interruptible load program managed by the TSO, where a minimum flexibility capacity of 1 MW is required to participate. Although no aggregator is allowed to participate in DR programs, there is the possibility of a consortium or association, to represent several consumers in the energy market. Also, all consumers need to have an agreement with a BPR before entering any demand response program [19].

Table XI. Italian DR programs

Type of Load	Program	Min. Flexibility size (MW)	Ramp Time	Type of Activation	Frequency
Mainland	Fast Response	1	200 ms	Remote controlled	No limit for frequency, i.e., the programs can be activated at any time by the TSO
	Emergency Response		5 s	Remote controlled	
Islands	Fast Response		200 ms	Remote controlled	

5.9. Netherlands

The Netherlands have made easy the integration of DR, mostly due to their ancillary market rules, namely, its access and the capacity required to participation. Consumers are mainly negotiated through the use of BRPs in their balancing services or negotiated directly (such as, in the reserve capacity market), however, this hinders the aggregators' inclusion and direct negotiation with consumers. Still some barriers exist, namely, the issue referred between aggregators and the BRP, and some DR programs have high minimum capacity constraints that difficult the inclusion of small clients. Aggregator's input is limited to replacement and capacity reserve - Table XII.

Table XII. Dutch DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Regulating Capacity	4	When day-ahead, 23h00 of the day before	30 s	Automatic and/or Manual	• The bids are made to and accepted by the TSO, in a yearly or instantaneous basis • It is called at any given time, constantly
Replacement Reserves	None	-	Depends on the bid	Market based	• Is based on a pay-as-bid pricing system

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Emergency Power	20	Based on contracts	15 min	Manual	• Obtained through annual tenders • Must be available at any given time • Used up to 40 h per year, having a maximum of 8 h for each call made
Reserve Capacity	4	When day-ahead, 23h00 of the day before	Depends on the bid	Manual	• This program is voluntary, being active depending on the bid conditions from the consumer

In sum, DR integration in the Netherlands is successful however still in development, where the main feature to be treated is the fact that, aggregators cannot provide consumers independently without a BRP in charge, i.e. the aggregator becomes a utility for the BRP, being this the only way for an aggregator to become a DR service provider. The Emergency Power program is detailed in [39].

5.10. Nordic Countries

The Nordic countries include the following: Denmark, Finland, Norway, and Sweden. These are known for their strong renewable energy integration and sustainable awareness.

Denmark

Denmark is one of the countries with less energy dependence in Europe due to distributed generation, so the integration of demand response into its energy market can bring several advantages in terms of network regulation, such as, voltage and frequency. In Denmark, the consumers can participate in energy markets with their flexibility capacity directly, or with an aggregator. However, the aggregator can only be a supplier, not allowing independent aggregators. This provides an inequality agreement towards consumers, since generation has advantage due to the managing entities. Also, the markets are designed for generation, which hardens the DR integration. DR can participate in the following Danish energy markets: wholesale, balancing and ancillary services market, whereas an agreement with the consumer's BRP is needed. Table XIII shows DR details [40]. Denmark has been gradually developing its energy infrastructures in order to enable active consumer's participation, namely, with the support of the EcoGrid EU project.

EcoGrid EU is implemented in Bornholm Island, that's connected to the Western Denmark energy system–DK2 (Eastern–DK1). The project intends:

- To enhance the participation of consumers in real-time programs with an automatic frequency control, by modifying appliances;
- To motivate the use of heat pumps with remote control, in private homes, using a monetary incentive of 2 700 €;
- To introduce 2 000 consumers to demand side management using smart meters that can be used to respond automatically to price signals sent by the network operator. The control can be manual, semi or full automatic.

Table XIII. Danish DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation
Primary Reserve (DK1)	0.3	15h30 of the day before – daily auctions	30 s	Automatic
Secondary Reserve (DK1)	1	Last day of the month or year before – Monthly/ Yearly auctions	15 min	Automatic
Frequency-controlled normal operation reserve (FCNOR-DK2)	0.3	(D-2) 16h00 of two days before (D-1) 21h00 of the day before	2.5 min	Automatic
Frequency-controlled disturbance reserve (FCDR-DK2)	0.3		5 s for 50%, and 25 s for remaining	Automatic
Tertiary Reserve (DK1 and DK2)	10 (5 from late 2015)	10h00 of the day before – daily auctions	-	Manual

In the FCNOR and FCDR programs, the consumers can submit their bids considering two options: two days or one day before the day of operation, D-2 or D-1, respectively. In this way, D-2 requests the consumers to submit their bids until 15h00 of two days before the day of operation, while in D-1 the bids must be submitted until 19h00, of the day before the day of operation. The energy price is supplied to the consumer every five minutes, obtained in the day-ahead Elspot market. The entity that supplies this to the consumers is named, Real-time market operator, however it is not needed a new operator, since this task can be performed by the TSO. In Bornholm case, two types of interactions with consumers are used, namely, individually and aggregated (this last implements the concept of an aggregator).

Finland

Finland is in the huge wholesale market of the Nordic countries, NordPool, together with Norway and Sweden. DR can participate in several markets. The programs are shown in Table XIV [19], [41]. The following markets are open to DR resources: Elspot (Elbas – wholesale intraday), balancing power, frequency controlled disturbance reserve (70 MW), fast disturbance reserve (354 MW), and power reserve (40 MW).

Table XIV. Finish DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency	Price (€/MWh)
Frequency controlled normal operation reserve	0.1	Yearly Market – Autumn and Hourly Market – 18h30 of the day before (D-1)	3 min	Automatic	• Several times a day, at any given time	15.8 + price of electricity
Frequency controlled disturbance reserve	1	Yearly Market – Autumn and Hourly Market – 18h30 of D-1	5 s to 50% 30 s to 100%	Automatic		4.03
Frequency controlled disturbance reserve (on/off model)	10	Long term contract	without	Automatic	• In average, once a year	580.5 + activation fee of 580
Balancing Power Market	10	45 minutes before operation hour - Hourly market	15 min	Market based	• According to bids, several times per day	Market price
Fast Disturbance Reserve		Long term contract		Manual	• In average, once a year	580.5
Strategic Reserves		Long term contract		Manual	• occasionally	-
NordPool Spot	0.1	Hourly market	1 or 12 h*	Market bids based	• depends on the market	Market price
Automatic frequency restoration reserve	5	Hourly market	30 s to 2 min (begin to max.)	Automatic	• Several times a day	Hourly market + energy price

* Depends on either the market is "Elspot" or "Elbas"

Regarding aggregators, these are available but with limitations. Finland energy infrastructure works with DR resources, using perimeters or zones, where a certain

number of consumers belong to a zone balanced by a BRP. Aggregators can combine several consumers as long as they have an agreement with the respective BRP, however, consumers from different BRP zonal entities cannot be combined by the aggregator. This is a major issue for the aggregator that is limited by regulation, causing difficulties in his activities.

This also causes inequalities for the consumers, since they are limited in the choice of a representative aggregator. As one sees, Finland is very well positioned for DR implementation (mostly, for industrial type consumers), missing only a more attractive business model for aggregators and, consequently, more choice freedom for consumers'.

Norway

Norway, has been focusing in DR solutions with great interest, ever since their share of renewable sources became considerably high. To face generation fluctuation, DR resources are implemented into several energy markets, such as, ancillary services and wholesale. Similarly to the Finish DR programs, the Norwegian DR programs are presented in Table XV [19].

Namely, many programs have been economically developed, in order to incentive more consumers to participate in them. The aggregator's situation in Norway is very similar to the one in Finland, with the exception that the aggregators have the possibility of working for the BRP, instead of the agreement to perform DR aggregation independently.

Table XV. Norwegian DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Frequency controlled normal operation reserve	5	Hourly or weekly market	50 % in 5 s 100% in 30 s	Automatic	• When frequency is different from 50 Hz, and between 49.9-50.1 Hz
Frequency controlled disturbance reserve				Automatic	• When frequency is less than 49.9 Hz
Automatic frequency restoration reserve		Weekly market	2 min	Automatic	• When frequency outside the interval 49.9-50.1 Hz
Balancing Power Market	10	Thursday 14h00 of the week before	15 min	Market bids based	• Several times per day
Fast Disturbance Reserve				Manual	• Called by TSO, and according with the bid conditions

Sweden

Sweden, as the other countries members of the NordPool market, integrated DR resources mainly to control the power and frequency fluctuation caused by a high share of renewable energies.

Aggregators that want to operate in electricity markets, need to register as a BRP (annual fee of 2 400€) and establish an agreement with the consumer's supplier/BRP [19], [42]. Sweden's main barriers are relative to the introduction of third-party aggregators and to the DR remuneration prices not being public.

The first barrier, as in many other countries, presents the inequalities made to third-party DR service providers, when facing local providers, such as, suppliers and BRPs. The existing dependence of aggregators in competitors, makes harder their addition into energy markets. In a similar way to Denmark, Sweden in the normal operation and disturbance frequency programs, allows the consumers to submit their bids considering two options: D-2 or D-1, respectively, as mentioned before.

Considering D-2 requests, the consumers can submit their bids until 15h00 of two days before the day of operation, while in D-1, until 18h00, of the day before the day of operation. Swedish DR programs can be seen in Table XVI.

Table XVI. Swedish DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency
Frequency containment reserves for normal operation	0.1	(D-2) 16h00 of two days before (D-1) 20h00 of the day before	63% in 60 s 100% in 3 min	Automatic	• when inside the interval 49.9-50.1 Hz
Frequency containment reserves for disturbances	1		50% in 5 s 100% in 30 s	Automatic	• when frequency is less than 49.9 Hz
Automatic frequency restoration reserves	5	11h00 of the day before	2 min	Automatic	• At any given time
Fast disturbance reserve	5 (SE4) 10 (rest)	14 days before the delivery	15 min	Manual by phone call	-
Balancing Market	10	-		Market based	• Market based
Strategic Reserves	5	-		Manual	• Less than 10 h/year

5.11. Poland

Poland considerably raised its development in DR, namely, by introducing DR emergency programs and opening the balancing market to it, showing positive results. However several barriers are still standing, such as, the lack of aggregators legislation (and therefore, their existence can be compromised), ancillary services are closed to DR, and it seems to exist several problems with the verification and measurement of DR in the balancing market difficult its integration – not adjusted for consumers [19]. Table XVII presents the DR programs implemented in Poland [19].

Although all these difficulties occur, the truth is that the aggregator enables its participation only by an agreement (bilateral contract) with the TSO, without the need of BRPs.

Table XVII. Polish DR programs

Program	Min. Flexibility size (MW)	Ramp Time	Type of Activation	Frequency	Price Availability/Use (€/MWh)
Balancing Market	1	-	Acc. to bid and market conditions	-	Non/30-50
Emergency DR programs	10	6 h	Manual	• Max. of 15 activations per 2 years • Max. of 1 activation per day, and 3 per week • Activations can have a duration of 2 to 4 hours	Non/220-276

5.12. Switzerland

Switzerland, member of the EPEX market, has become a front man in aggregation of consumer's flexibility, by removing the barriers encountered by the agreements between consumers and BRP, and between independent aggregators with consumers and BRPs.

Swiss DR programs are only available in the balancing market, with control reserves, namely, for primary, secondary and tertiary reserves. The EPEX spot market is available, however, similarly to Austria, Switzerland has not yet developed interest in this manner.

In the secondary control reserve, all the DR providers participating are called, causing many interruptions to the consumers that belong to those aggregates, therefore, this situation is disadvantageous for certain types of consumers that cannot be always interrupting their processes, namely, commercial and industrial consumers do not usually participate. With this type of energy infrastructure, consumption flexibility can

be easily implemented, directly or aggregated form, since most of the agreements that harden their inclusion, are related with the unequal competition between aggregators and BRPs. Table XVIII presents the DR programs implemented in Switzerland [19], [43], [44].

In this way, Switzerland may be the example for European countries in the implementation of flexibility resources, in what load access and aggregation is concerned. However, some issues still remain, such as, the lack of other DR programs, the bids type (symmetrical and asymmetrical, where the last is the most appropriate for DR), and finally, the nonexistence of DR participation in the EPEX spot market.

Table XVIII. Swiss DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency	Price Availability/ Use (CHF/MWh)
Primary Control	1	Sunday 24h00 of the week before – Weekly bid	30 sec	Automatic	• Tendered on a week basis, without time differentiation windows • Used up to several times per day	23.14 / Non
Secondary Control	5		5 min	Remote control	• Tendered on a week basis • Used up to several times per day	28.28 / Market based
Tertiary Control	5	Daily and Weekly bid	15 min	Manual	• Tendered on a day or week basis • Used up to several times per day	Differs between day and week Basis / Market based

5.13. United Kingdom

United Kingdom was amongst the first countries to open its markets to DR integration, beside France. Consumers and aggregators are allowed in the wholesale, balancing and capacity markets.

As in Germany, the aggregator position is not yet well defined and faces some issues related with equal rights when compared with generation providers. However, the aggregator does not have to establish an agreement with the BRP/supplier, thus facilitating the consumers' integration through DR providers in the energy auctions, in

the opposite of Germany's position towards the manner. Several DR programs are available for consumers and are summarized in Table XIX [19], [45]–[49]. In the wholesale market, DR consumers can participate directly in the day-ahead and intraday features, however, only as form of flexibility for supplier units or large industrial.

Table XIX. UK DR programs

Program	Min. Flexibility size (MW)	Advance Time	Ramp Time	Type of Activation	Frequency	Price Availability /Use (£/MWh)
Short-Term Operating Reserve (STOR)	3	3 tenders per year starting at March (with a 3 months interval)	4 hours	Manual	• daily weekday participation • 11 to 13 hours window for possible flexibility; choice of morning or evening	0.6 / 100
Firm Frequency Response (FFR)	10	Monthly tender ~2 weeks before delivery month	-	Automatic	• Dynamic – automatic continuous frequency regulation • Non-dynamic – triggered when a threshold frequency value is obtained	4.99 / 4.55
Fast Reserve Firm Service (FRFS)	50	Monthly tender ~2 weeks before delivery month	2 min	Automatic	• 10 to 15 activations per day • Minimum step of 10 MW per raise	3.67 / 0.94
Demand-Side Balancing Reserve (DSBR)	0.1 (1 for DR providers)	Yearly tender	2 hours	Manual	• From 16:00 to 20:00 hours, in winter weekdays • Payment of incentives up-front in relation with the Value of Lost Load (VLL) in the UK	(-) / 2 400*
Frequency Control by Demand Management (FCDM)	3	Declared available periods upon contract	2 s	Automatic	• Maximum duration: 30 min. • Triggered at a frequency of 49.7 Hz	> 4/ (-)

* STOR and DSBR programs, have penalties that are applied when the consumer fails to deliver 90% and 75% of the flexibility established in the contract, respectively.

In the balancing market, all DR programs can be applied by individual consumers or by DR providers, as shown in Table XIX. In the capacity market, DR is not equally seen as other resources, since the agreements established for DR providers is only of one year. This means that DR providers can only plan their consumers' integration and profitability in a one-year horizon, while generation providers can establish contracts of 15 years.

Also, the number of aggregators able to participate in this market, is not fairly accomplished, since in 2014, only one aggregator was able to establish a contract/agreement for consumers. Additionally to the DR programs shown in Table XIX, the Triad charges exist to support the network when its reliability is at risk. This program consists of 3 periods of 30 minutes, on 3 different days with an interval of ten days between one and another. These periods reflect the highest values of consumption across the UK.

In this way, the network operator has a capacity reserve to reduce consumption when the network reliability is in danger due to high demand.

In sum, UK is already commercially active in DR implementation, however, how these resources are seen in the several energy markets, is still a course to travel. Since the generation providers have more advantages in their integration when compared to load reduction/curtailment providers, some features of energy markets have to be reviewed and changed, in order to grant consumers more promotion strategies for their active role.

5.14. Other Demand Response Initiatives in Europe

Regarding research projects and pilots, these are essential to uncover the potential of DR in certain sectors that at first sight show implementation issues, such as, the residential and transport sectors. In this way, many countries choose to try new programs in small communities and cities rather than in the overall country, reducing therefore the investment costs in an initial phase. Table XX presents some of the pilot projects settled in some European countries [50].

Table XX. Reference example for innovative projects [50].

Country	Example Pilot Projects	Reference
Austria	Salzburg Smart Gid	[51]
Belgium	REstore – ELIA	[52]
France	NEBEF	[53]
Germany	Grid4EU, Smart Grid Solar	[54]

Iberian Countries	e-balance, SuSTAINABLE, Insmart, S3C, FlexilWatts, PRICE, PERFILA	[55]–[59]
Ireland	DS3 Program, NightSaver, Economy 7	[60]
Italy	ArrowHead, e-GOTHAM, INERTIA	[61]–[63]
Netherlands	CIVIS, Odysseus	[64], [65]
Nordic Countries	Denmark - EcoGrid.dk, The Cell Controller Project, Concept 2025,	[66], [67]
Poland	PSE/TAURON	[68]
Switzerland	EPIC-HUB, BPES	[69], [70]
United Kingdom	RESILIENT, NINES	[71], [72]

As one can see by Table XX, several pilot projects are being implemented in a European environment. Many of these projects involve numerous countries participation, mainly, in what concerns European projects, leading to exchange of knowledge between utility companies, research centers, and operators. In this way, more results can be found and several experiences can be crossed together to obtain better conclusions and methodologies for DR implementation. A list of the European pilot projects, can be found detailed in [50]. Regarding the U.S. and its ISOs, the pilot projects are mainly temporary programs that are made available for consumers, being studied their participation and actual commitment to load flexibility. Often, there are other companies (or corporations) that get involved and finance pilot projects for the DR implementation, such as, PEPCO, SDG&E, Duke Energy, ONCOR, Xcel Energy, amongst others [73].

5.15. Conclusions

European countries reveal to be progressively increasing DR integration into their energy infrastructures year after year. Europe has accomplished a notable work on updating the energy entities roles, namely, by defining through directives - [5] - their objectives to meet with the United States (US). Also, in similarity with the present work, some of the European DR programs have been presented and explained in [74].

The programs majority reveals that, smaller minimum flexibility requirements are in place (from 0.1 to 10 MW), thus smoothing the entrance of more consumers into the DR programs, namely, minor and medium commerce consumers. Also, one concludes that the main purpose of demand response use, in Europe, is related with ancillary services, balancing and regulation reserves. Most of the programs presented in this work, consider the implementation of automatic mechanisms (usually for frequency control) done by relay installation, however, a reasonable share of manual programs are also present. When outside the frequency control programs, the trend is to encounter many tender and auction structures, in order to address issues as energy shortage and

network reliability (e.g. balancing and regulation reserves, strategic reserves, emergency response, amongst others). A common DR type, in European countries, is curtailment or more usually called interruptible loads. As mentioned earlier, this type reduces specific amounts of load, i.e. by steps. Also, it is mostly applied for large consumers, connected to MV, HV, or VHV.

Regarding the inclusion of demand resources with energy markets, the presented information shows that these are integrating energy negotiations through bids and tender processes (e.g. Austria, Germany, and Spain). This shows the relevance that management entities (such as, aggregators, providers, retailers, and others) have in the successful implementation of these resources. Considering small consumers with few knowledge in energy negotiation, their interests are protected by such entities, providing with a management system, financial framework, and legal subjects understanding. The tenders and bids, usually consider four ways: yearly, monthly, day-ahead, and real-time. Results show that resources in yearly tender resources have less chance of being actually used, being only paid by availability, while, resources participating in the day-ahead and real-time are more common used (being for regulation or imbalances correction).

Payments in European countries are considered in two ways: availability and activation (e.g. Belgium, and United Kingdom), where the most common is to find both implemented together. Such that, the consumers are paid by making their load available for reduction at a certain time interval (considered in contract, bid or tender), and receive an extra remuneration if they are called to respond to an operator request. Also, some programs do not consider the payment of activation, while others do not consider the availability payment (e.g. Ireland, Poland, and Finland).

In this way, Europe is currently a better and more sustainable energy system than before, using several DR inputs into its markets (wholesale, balancing, ancillary, reserve, and others). However, Europe still needs to improve the agreements between consumers, aggregators and BRPs. This issue is making DR integration more difficult, since internal entities tend to see aggregators as competitors and entities that difficult their operation (e.g. BRPs).

6. Demand Response in Brazil

Brazil's potential to apply DR in its energy infrastructure is huge, since it is a large country with numerous consumers of all kinds. The Brazilian electrical system is very dependent on renewable power, mainly, large plants of hydro power - Figure 15 [75]. Also, the majority of energy production is located north, far from the major consumption centers down south – components of traditional markets [76].

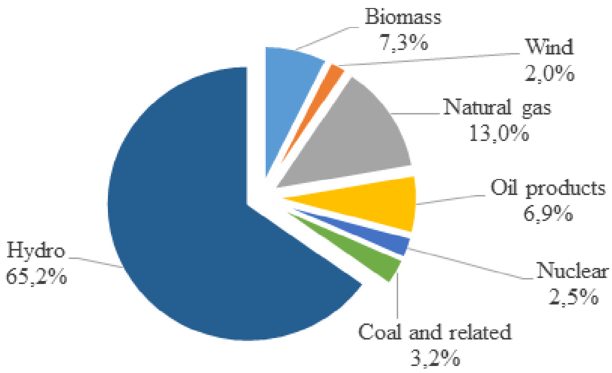

Figure 15. Brazilian energy mix of 2015 [75].

The Brazilian energy market began its privatization process in 1996, but stalled around the start of the 21st century, due to dry seasons leading to lack of hydro power. The privatization was very short, since the wholesale market remained under the government's control until 2004. Around this time, two energy markets were established:

- **Regulated Market** – distribution companies purchase energy from this market that is later sold to consumers considering the regulated tariffs defined by the regulator "Agência Nacional de Energia Elétrica" ANEEL.
- **Free Market** – The free market allows consumers with consumption over 500 kW, to negotiate directly with energy traders and producers under their own conditions (similar to bilateral contracts). The remaining types of consumers have to obtain their supply from distribution companies, belonging to the regulated market. All aspects from the energy delivery are accorded between consumers and energy traders/producers.

In Brazil, one can consider two types of energy auctions, regular and reserve. The first operates analogous to an asymmetric pool, since the distributions companies present an amount of consumption to meet demand that then is placed in the regulated market. The latter offers energy reserves to the system operation, complementing the energy contracted in the regular energy auction. In this way, energy can be traded considering several time intervals (day-ahead, spot market, amongst others). According to [77], Brazil has shown will to implement smart grid techniques with the publication of new legislation:

- Development of distribution infrastructures to allow communication networks, through RN 375/2009;

- Definition of distributed generation access to the distribution system with the publication of rules and proceedings, through RN 482/2012;
- Progress of smart metering implementation in low voltage consumers with the publication of guidelines, through RN 502/2012;
- Promotion of consumer energy consumption awareness through the programs of **flag tariffs** (RN 547/2013), **energy pre-payment** (RN 610/2013), and **white tariff**;
- Mandatory implementation of a geographic information system in the distribution network, through RN 395/2009.

In sum, Brazil considers that its consumers can be of two types: captive or free. A captive consumer (< 500 kW) cannot negotiate directly with producers and energy traders in the free market, being obligated to obtain supply from distribution companies. These companies obtain their energy contracts from producers through the regulated energy market. Free consumers (> 500 kW) can choose between obtaining supply from the regulated or free market. Moreover, the high penetration of renewable energy causes the energy system to be easily influenced of the weather conditions - mainly dry seasons due to hydro power. Therefore, the need for flexibility in the Brazilian energy system is high, moreover when it is so dependent in intermittent energy sources.

In the following subchapters, it is detailed the programs available in Brazil for economic DR, that allow consumers to reduce their costs, and gain awareness of their load profile effects on the energy system. The following programs are mainly made available by the distribution companies that exist by region. The programs addressed are: flag tariff, energy payments, and white tariff [12].

6.1. Programs

ANEEL
AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA

Flag Tariff Program

The flag tariff program is a strategy of economic DR, implemented by ANEEL from the beginning of 2015. It considers three flag colors (green, yellow, and red) that demonstrate the electricity cost in function of generation conditions, namely, if its capacity is close to consumption level (risk of production shortage) [78]:

- **Green (*Verde*) –** the conventional energy tariff is not affected by any cost raise, since generation conditions are normal;
- **Yellow (*Amarela*) –** generations conditions are not the best, therefore the energy tariff raises in R$ 0.025;

- **Red (*Vermelha*) –** generation conditions are even worse than in yellow, so the tariff raises even more, namely, R$ 0.045.

The flag tariff program allows consumers to have indirect information to the energy price, giving them the possibility of controlling energy costs by reducing or shifting their loads when the yellow or red flags are at play. The transparency of consumer's consumption pricing, therefore becomes higher and more accessible. The captive consumers are the only ones that can participate in this type of program, since the free consumers with contracts from the free market, do not have any interaction with distribution companies.

The flag color is defined monthly and applied to all consumers, independently of their behavior, including if they reduced or not their consumption. The definition of the flag's color depends upon the operation conditions that the system operator considers for each month, being influenced by cost of most expensive thermal power plant –see Table XXI.

Table XXI. Brazilian Flag's color program rules [78].

Variable Cost (R$/kWh)	Flag's Color	Tariff increase (R$/kWh)
$C_i \leq 200$	Green	0
$200 < C_i \leq 388.48$	Yellow	0.025
$C_i \geq 388.48$	Red	0.045

Energy Payments Program

Currently in Brazil, the consumer has the option of joining a program where he can buy a certain amount of energy supply, before or after consuming it. When payments are made before consumption, the consumer can buy monthly a certain amount of energy (e.g. 50 kWh), being able to buy more during the month if needed, with a minimum of 5 kWh of purchase. In this way, consumers can adjust their consumption, in order to meet with the energy bought from the distribution companies. The consumer, if its energy credit runs out, has the possibility of asking for immediate energy delivery of 20 kWh, made available by the distribution company for emergency situations.

When payments are made after consumption, the consumer defines the time interval to be taxed by energy consumed, whereas after that period a payment needs to be made to the distribution company, according to the energy consumed. This is the normal way of payment, but with the possibility of choosing the period of energy taxation.

In this way, consumers with these programs have more options for energy supply and payment, at the same time that they gain consumption awareness and benefits of keeping a low load profile. Also, for the distribution companies, costs are reduced

regarding measurement and consumer related activities (bills pressing, complaints, commercial losses, amongst others).

White Tariff

Brazilian energy agency ANEEL introduced consumers connected to low voltage networks, an economic-based demand response program named white tariff. The programs intends to influence consumers to consume energy in off-peak and intermediary periods, as shown in [79].

As one can see by Figure 16, the white tariff consists of a lower tariff that the consumers can take advantage, in exchange for consumption off the peak and intermediary periods. The consumers while using this program can shift their load from on-peak periods to off-periods, to reduce their electricity bill, however, the consumption that they may have in on-peak periods, will be applied a much higher tariff than considering the normal tariff. This is the main reason for this program to be considered an economic-based program: it is up to the consumer the decision of following the conditions of the program, because, in the end the consumer can have a more expensive electricity bill than before when participating in this program if the right adaption is not made.

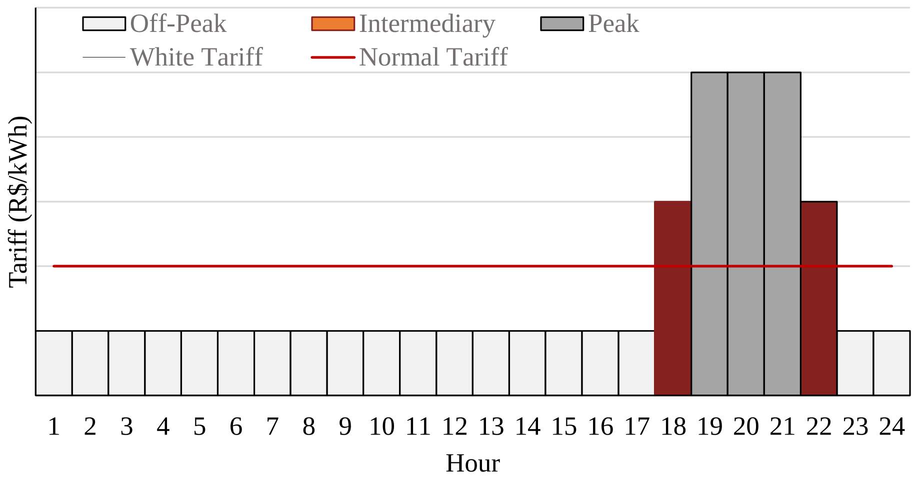

Figure 16. Brazilian White Tariff – work days [79].

Regarding the week schedule, in Figure 16 work days are represented, however, during weekends and holidays, the program becomes even more attractive since no difference is made between the periods, which means the reduced tariff shown in the previous figure remains the same for all periods (always less than the normal tariff). Although this tariff allows the network to better deal with energy congestion on its physical network, the reality is that this program in nothing helps the regulation of renewable energy in the Brazilian energy mix.

In this way, it is known that several problems occur regarding the quality and security of the energy delivered to the consumers (blackouts, long periods of interruption, parameters off limits, amongst others).

6.2. Conclusions

The differences between the models of energy systems are quite noticeable, especially when comparing countries from very different regions, or between continents. For instance, in [80] one can see a work considering the integration of DR into energy infrastructures of Germany and Brazil, namely, the interactions that exist between the several participants, the energy market structure and relations that occur, current and predictions of energy figures of the network operation. An example of this analysis can be seen in Figure 17, shown for the Brazilian scenario.

The main conclusions of the work in [80] are related to the actual markets implementation in the countries considered, namely, their ways of operation, energy mix, and DR availability and use. The work concludes that Germany benefits from international connections with other countries, since its high penetration of renewable sources causes several energy variations that request flexibility. However, Brazil's energy market is mainly regulated; thus the consumers cannot choose their supplier, nor is the energy negotiated in a pool.

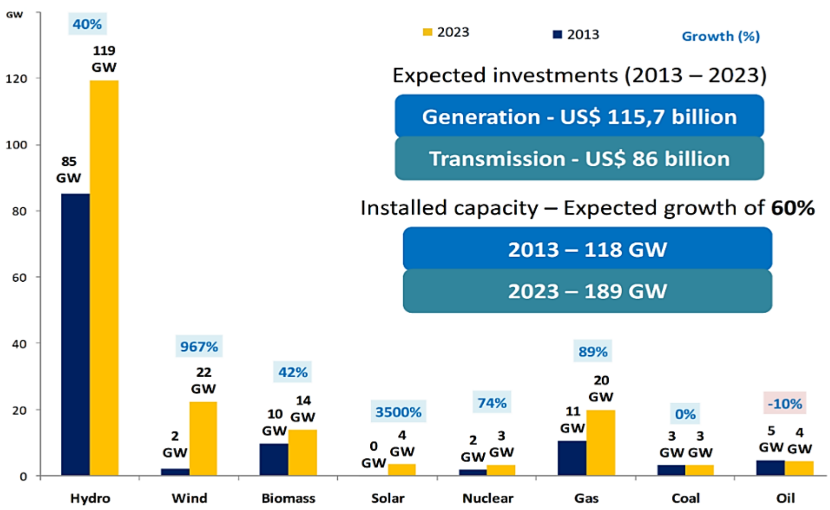

Figure 17. Current and future figures for the Brazilian electricity sector [80]

Due to the country's dimensions, the Brazilian transmission network is much larger than Germany's, leading to several issues such as energy losses, and production far away from consumption (frequency and voltage regulation becomes harder). Moreover, Brazil has a huge dependence on hydroelectric plants (close to 80% of the energy mix) that causes serious problems to the network's operation when drought years occur.

On an opposite way, Germany has excess installed capacity regarding its demand, however, considering a high volume of renewable energy reflects an urgent need for flexibility that it is not so evident in Brazil. In this way, DR can provide more of service in Germany than in Brazil, and therefore, Germany is more committed to DR implementation (interruptible loads and ancillary services) than Brazil (mainly the

application of the white tariffs seems insufficient effort for DR successful introduction, and consumer's persuasion).

Also, in terms of demand response strategies and usage, Brazil still remains with lack of options and applications for active consumers (emergency, ancillary services, regulation, production shortage, amongst others) focusing just on economic DR strategies. In terms of market organization, Brazil only has one system operator for all the regions.

7. Conclusions

This report has focused on the research concerning DR potential in different regions. These studies are normally related to the existing business model opportunities found in the residential, industry, and tertiary sectors.

It is important to notice that the application of DR programs differs on the different sectors it is applied, since the consumption patterns for industrial consumers is not the same as a residential consumer. For example, the introduction of a Direct Load Control (DLC) program into a residential consumer can be effective since no major constraints are imposed by these consumers; however, when dealing with a commercial or an industrial consumer, the situation becomes distinct due to the operational restrictions that these resources have [81], [82].

Another example is the Demand Bidding program. This one requires the consumers to present a bid to the operator coping several conditions to provide a volume of flexibility at a given price. These types of programs are not so adequate for residential consumers that lack the knowledge of energy markets. Industrial consumers are more open to participating in these programs, since they can adjust their bid to advantageous periods where the operational requirements are not so strict. Also, several scientific papers and studies focus on the countries potential for DR integration into their energy infrastructures, enabling a cultural and social perspective of DR fostering.

Regarding the countries implementation, in Europe, the present work shows that the programs are mainly targeted for large consumers (e.g. commerce, industry, large offices) since the minimum reduction amount is usually between 0.1 and 10 MW. Moreover, most of the programs are managed by a transmission system operator, and therefore consumers that are connected to higher voltage levels are the main target. This leads to disuse the potential of residential customers (or households). The ancillary services are the main focus of European DR programs, where automation is the most common type of active consumer intervention, namely, through frequency deviation relays. Not considering frequency response programs, the other implementations are focused in emergency and reliability issues, such as energy shortage, and other situations where the integrity and security of the grid is at risk. The most common DR program type is the direct load control with a high number of interruptible load programs.

The payments for DR services are made considering two parts: availability and activation. However, not all countries and/or programs consider both payments, making payment of only one of them. The use of DR programs in Europe is more often performed by the day-ahead and real-time market, whereas tenders (monthly and annually) tend to be less used.

In what concerns Brazil, the current DR programs are mainly economic-based programs. Three major programs are considered: flag tariff, energy payments, and white tariff. The first refers to a flag system with three colors, which define if a raise in the electricity price is being made in a certain month or not. The second program, energy payments, works as a pre-paid service, where the consumer can contract a certain amount of energy, controlling its energy expenses. The third program is a three period tariff program (e.g. similar to Portugal), where the week is split in two types of days: work days, and weekends. In work days, there are hours called peak and intermediate hours where the energy price is very high, when compared with the regulated tariff of each distributor, however, the electricity price in the remaining hours of the day is lower than the regulated price. In the weekends the price is always lower than the regulated price. In this way, consumers are attracted to lower prices but have gain awareness towards their consumption periods and amount.

Smart Metering is a concept that has recently started to be the target of many studies, on either or not this should be generally implemented across the world at a multi-level sector. Yet, the inclusion of smart meters raises some issues related with the data privacy and the owners of that information. These are issues that need to be clarified by each country before fully investing in a roll-out implementation of smart meters.

Considering the implementation of DR programs and smart metering, the active consumer's potential to a better energy system operation comes into play, as its benefits are uncovered. However, much is still needed for DR integration, namely, the value of this technology, communication and measurement infrastructures (although smart meters are a reasonable solution), and new sets of policies and procedures for each entity and DR provider.

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