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# Technical Obstacles to Innovation Analysis

D2.4

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# Deliverable

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# D2.4

# Technical Obstacles to Innovation Analysis

## Revision: v1.0

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# Version History

| REVISION | DATE | AUTHOR | ORGANIZATION | DESCRIPTION |
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| V0.7 | 28.06.2021 | Konstantinos Kotsalos | ED | 2nd Revision of report comments by UoP and S5 |
| V1.0 | 30.06.2021 | Konstantinos Kotsalos | ED | Draft submitted to EC by the PC |

# Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

# Legal Disclaimer

# Executive Summary

The aim of this deliverable is to capture the technical barriers that are hindering the massive implementation of Demand Response (DR) schemes in the context of smart grids. This deliverable starts with an overview on the evolution of demand-side management programmes, presenting a taxonomy and the origins of DR schemes in particular. An exploration is also performed on the versatile importance of demand-side flexibility, the evolution of legislative framework as captured in EU commission's directives as well as the current implementation of DR across Member States of EU. In this report the barriers to DR implementation are organized into primary and secondary; as primary barriers are considered social (i.e., behavioral concerns), economic (i.e., market failures and market barriers) and technological barriers, while in the class of secondary are those related to design markets, regulatory aspects and physical (referring to electrical network), covering the impacts of institutions/authorities and/or system feedbacks. The analysis focuses on the importance of equipping the grid and end-user premises with efficient technological solutions such as high-frequent sensing devices, smart meters and home energy management systems. Additionally, the general issue associated with all technological barrier to DR implementation is standardization, that applies to all solutions meant to be employed (i.e., hardware and software), as a matter of resolving interoperability issues on communication and semantic layers. Overcoming the technical barriers can be achieved by improving sensing and computing devices along with proper communication infrastructures and quite importantly covering the learning of end-users to nascent technologies. Beyond technological barriers, massive DR implementation implies adequate regulatory framework, while there is a pivotal need to create sustainable business models to attract flexibility providers.

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# Index

# List of Figures

# List of Tables

# 1 Introduction

## 1.1 General information and structure of the deliverable

This deliverable aims to provide a comprehensive landscaping of the technical barriers hindering the successful implementation of demand response business models and schemes. This deliverable reports the outcomes from the methodological approach followed in Task 2.5, as highlighted in Figure 1.

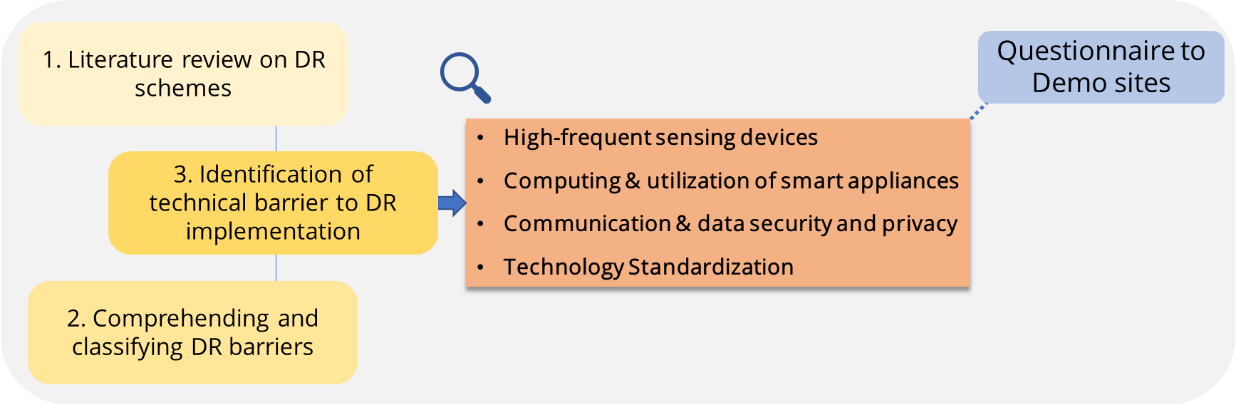

Figure 1. Methodological approach for the landscaping of technical barriers to demand response implementation

The approach that was adopted, is essentially composed of the following steps:

- **Literature review on DR schemes**: these parts (Chapters 2 – 3) provide a brief, yet, explanatory overview of the DR response schemes, a taxonomy and their evolution as well as forming the background of the evolution on the legislative framework in the EU context (*step-1*)
- **Comprehending and classifying DR barriers**: this essential part of the report is covered in Chapter 4, by identifying the primary and secondary barrier for the implementation of DR (*step-2*)

- The in-depth analysis by zooming-in on the core objective of the report that is the analysis of technical barriers of the technical barriers hindering the rollout of DR implementation (*step-3*)
- A survey conducted to capture the current situation of technical solutions deployed in the demo sites.

The report is, basically, organized as follows:

- **Chapter 2** consists of an overview on demand-side management focusing particularly on DR classification,
- **Chapter 3** presents the versatile importance of demand-side flexibility, the evolution of legislative framework as captured in EU commission's directives as well as the current implementation of DR across Member States of EU
- **Chapter 4** explores the technical barriers hindering the massive implementation of DR schemes, contextualizing also the barrier in the demo sites' countries.
- **Chapter 5** which provides the general remarks of the report.

## 1.2 Abbreviation list

Table 1 presents the main abbreviations used in this document.

Table 1. Abbreviation list

| Acronym | Full Name |
|---|---|
| **AMI** | Advanced Metering Infrastructures |
| **CEMS** | Customer Energy Management System |
| **CPP** | Critical Peak Prices |
| **DER** | Distributed Energy Resources |
| **DG** | Distributed Generation |
| **DSM** | Demand-Side Management |
| **DR** | Demand Response |
| **DSI** | Demand-Side Integration |
| **DSF** | Demand-Side Flexibility |
| **DSO** | Distributed System Operator |
| **ESD** | Energy Services Directive |
| **EED** | Energy Efficiency Directive |
| **FRR** | Frequency Response |

| | |
|---|---|
| **HEMS** | Home Energy Management System |
| **IBR** | Inclining Block Rates |
| **ICT** | Information Communication Technology |
| **IoT** | Internet of Things |
| **RTP** | Real Time Prices |
| **SM** | Smart Meter |
| **SOC** | State of Charge |
| **TOU** | Time-of-Use Rate |

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# 2 An Overview on Demand Response Schemes

## 2.1 Origins and evolution of demand response in the smart grid context

Demand Response (DR) schemes are generally regarded as programs for the engagement of customers in which prices or incentives are used to motivate customers to voluntarily respond in ways that benefit the power system. Demand response has been initially used in the 1970s due to the increased cost of producing energy (i.e., impact of fear for nuclear meltdown, natural gas shortages and oil embargos) along with the rapid residential load growth in the US. The National Energy Act of 1978 imposed utilities to provide energy conservation audits and other services towards energy consumption reduction. Such practices brought up the demand response programs as a matter of engaging large consumers, typically commercial and industrial, to contribute on peak shaving [1]. The next and most important era for DR schemes came along with the Smart Grid concepts.

The advent of Smart Grids brings advanced automation and communication infrastructures into the low voltage distribution network premises in addition to smart meter (SM) apparatuses. Such Advanced Metering Infrastructures (AMI) aim at establishing a conceptual and technical vision of the grid operation for the new reality set forth by the integration of DERs. Besides, these breakthroughs impart intelligence along with network operation and management. In the frame of the end-user, intelligent load management (LM) is emerging by smart appliances capable of interrelating with the SM. Moreover, the SM infrastructures are the key enablers linking-up real-time measurements to the system operator or even to the end-user itself. Therefore, arises the possibility to dispatch multiple tariffs for the purchase of electricity to the smart meters releasing the capability of the DERs participation in distribution networks operation.

These trends lead to radical changes to the end-customers' standpoint on the electricity grid and, conversely, the view of the sector on the end-customer, residential, commercial and industrial customers alike. Concurrently, the electricity end-user is gradually becoming prosumer in the sense that produces energy through micro-generation units that owns at its premises. Paving this way, the prosumers and generally the end-users will strive to adapt more their own sources delivering flexibility to some extent to the grid operation. The latter has been recently recognized as a key enabler for smart energy management in the grid. This can be explicitly accomplished in favor of Home Energy Management System (HEMS) which is a house-centered system able to coordinate its consumption, storage and production (if exist) in the most cost-efficient way, while meeting end-users' comfort preferences. This sort of flexibility might be of significant importance contributing to the balance between demand-supply in the grid. The increasing integration of intermittent generating sources (i.e., wind and sun) create the need for such flexible units that possibly compensate the temporal and spatial variability (i.e., provision of ancillary services namely reserve services). Nowadays, electricity markets that are liberalized, include this type of balancing services and are cleared in the wholesale clearing process. Nevertheless, the residential sector is usually comprised of small sized individual LM sources of considerably lower rated power compared to the total demand. Therefore, the need to establish new entities -the so-called aggregator- is elicited. The aggregators will then act as a market delegate to bid in the marketplaces the aggregated flexibilities. Such contractual relationships follow the form of explicit DR schemes due the intermediate role of the aggregator. DR schemes can occur in an implicit manner where the end-user is compensated in the form of reduced electricity bills via dynamic pricing schemes

The importance of DR may be versatile, as it will be presented in the following sections; nonetheless, it is substantial, to highlight that there is an increased need for reserve capacities due to the continuous connection of renewable sources. Demand responsive grids can provide a high degree of flexibility transcending the technical challenges of intermittency brought by renewable units. The renewable technologies' intermittency on the produced power output, is not an issue if proactive measures are taken. Accurate forecasters and respectively increased flexibility via DR programs may cover this operational gap.

Prosumers, or more generally active consumers, are foreseen to be the only category of end-user by the upcoming decades based on the 3rd Energy Package [2]. Furthermore, the same report prescribes that the final end-users to be solely prosumers, while the wholesale customers are not considered as prosumers. Key enablers towards this direction are considered residential storage system as well as demand response programmes.

The theoretical potential of DR in Europe was considered to reach close to 100 GW in 2016 and 160 GW by 2030, the practical and actual potential is constrained to about 40% [3]. This tardy implementation of DR is due to several insisting technical and economic barriers. The technological barrier will analytically be explored in this report in Chapter 4; yet, some conceptual interpretations of them are connected to the controllability of smart appliances and legacy household appliances along with the need for more advanced Information and Communication Technologies (ICT). Additionally, DR requires advanced methodologies and algorithms which need to be accommodated typically in HEMS, implying dynamic-tariff schemes for the end-users' compensation.

There are several countries in Europe that have already introduced dynamic pricing schemes in retail markets as a matter of increasing competition among retailers, as well as to impart more benefits to end-users. The establishment of dynamic-tariff policies has been achieved by taking advantage of modern technologies (e.g., smart meters) to inform the end-user for the change of tariff. Out of the 100 GW -theoretical potential demand response in 2016-, residential end-users with dynamic-pricing contracts could provide demand response of about 6 GW; accordingly, the potential flexibility capacity for large industrial end-users could reach up to 15 GW based on direct market participation [3]. Approximately 2600 DSOs provide services to about 260 million end-users, of which, residential and small businesses account for about 90% in the European context [3]. Nonetheless, the distribution system area is still a rather concentrated sector where typically one DSO has a dominant role.

A primary challenge of electric grids is to increase the hosting capacity for renewable energy technologies and more broadly of Distributed Energy Resources (DER). A possible and potential manner to achieve this, is to control the flexible use of DER as well as to engage end-users to adjust their demand profile due to a command signal by the grid operator. This is typically referred to as Demand Response (DR), which can be implemented to proceed to quick actions (Fast DR) of electric loads to cope with frequency regulation. DR essentially introduces an interactive dialogue of the end-users with the utilities. The smart reaction to these evolving changes is to involve DR in the control mechanisms of the electricity system. This substantially implies that changes in electric usage by end-users from their normal consumption patterns occur in response to changes in the price of electricity over time, or to incentivize payments designed to induce lower electricity use at times of wholesale market prices or when system stability is jeopardized [4].

There are three main categories of DSM: 1) On-Site Backup and Storage, 2) Energy Efficiency and Conservation, and 3) Demand Response (DR). Nonetheless, several studies make use of both terms interchangeably; the confusion among these terms is sourced by the early development stages of DSM and DR. It should be noted that the official definition states that DR is only a subset of DSM; in Figure 2, one can clearly may notice the differences between DR and the energy efficiency concept [4], [6]. On-site back up refers specifically on providing certain capacity for demand-side generation and storage to offer for load-balancing and/or ancillary services.

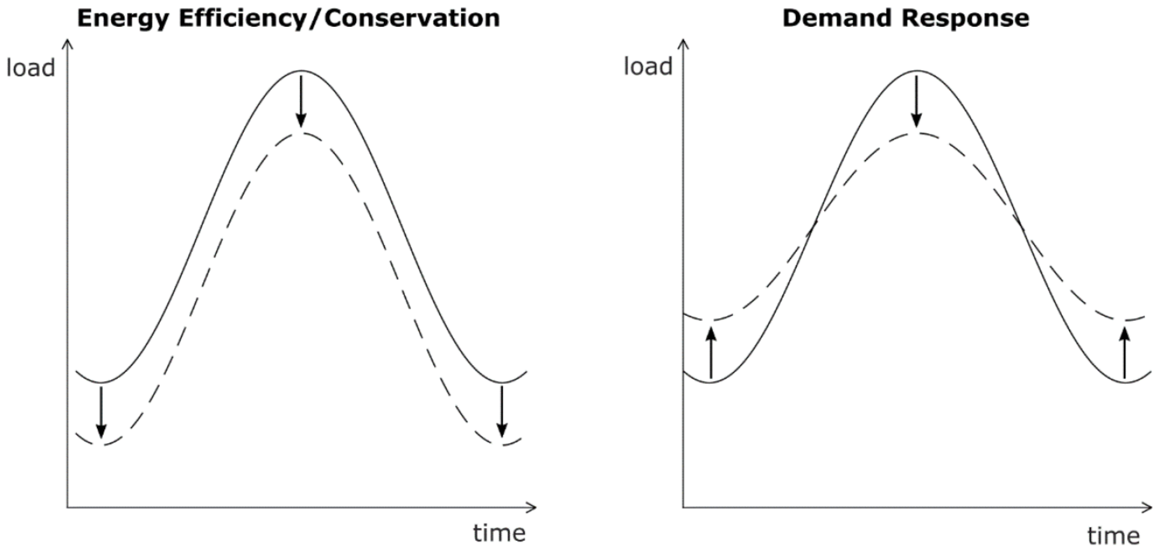

Figure 2. Comparing Energy Efficiency/Conservation vs Demand Response

The notions of demand response, and generally, load management are not new, since several implementations were launched in the early 70s as a result of oil crisis (fears of nuclear meltdown) together with the abrupt increase of demand growth. Since the beginning several program designs have been proposed and implemented to promote the end-user engagement in such a way to progress a cost-effective LM for both sides (i.e., the end-users via bill reduction and the system operator assuring load-shedding capacity).

In the decade of 1990's, the increasing integration of Distributed Generation (DG) and more generally DERs have brought out electricity consumers as active participants in power generation. Concurrently, the gradual electricity market liberalization movement globally, has led a shift from the supply to the demand side, viewing electricity consumers as active participants in the industry [6]. The latter resulted on a great interest in demand-side

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management (DSM). The subsequent evolution of Smart Grids and the proliferation of advanced communication infrastructures and sensory devices, have contributed to DSM to become more sophisticated towards enhancing power system's efficiency.

## 2.2 A taxonomy of demand response schemes

In the Smart Grid context DR schemes mainly refer to the actual engagement of end-users in the grid's operation in an implicit manner via price signals. The DR can occur following different business models such as the intermediate role of aggregator handling end-users' flexibility or utilities and other evolving actors within local concepts e.g., energy communities and condominiums. The subsequent aim of emerging third-party actors with respective business model is to leverage DR with connected residential DERs (e.g., (shared) battery storage system, charging points station, flexible loads, microgeneration) towards the optimization of energy management in the grid, resulting also to reduced end-users' bills.

Some different types of DR objectives are summarized in Figure 3 regarding the reshaping of load curves as proposed by Gellings [5]. The DR, primarily, targets on shifting load demand from peak-demand periods -when costs tend to be highly rated-, to off-peak periods when costs are lower (e.g., nightly period). DR is also referred to as Demand Side Response (DSR) or Demand Side Integration (DSI).

The most common program designs may be distinguished in two broad categories based on the remuneration and end-user engagement design of the DR: contracted response and price or incentive-based response [7].

1) *Contracted DR programs*: The contracted response programs were historically referred to commitments between the consumer and the system operator, where the second might curtail (intrusively or after a short-term warnings) the load in exchange to a discount fee.

2) Price-based DR programs: On the other hand, the price-based DR programs allow the customer to voluntarily adapt its load in response to price or incentive signals sent from the utility. Such programs can be found with different formats as Peak Demand Charges,

Time-of-Use Rate (ToU), Critical-Peak Prices (CPP), Variable Prices or Real-Time Prices (RTP). The incentive based might be Peak-Time Rebate or the Inclining Block Rates (IBR).

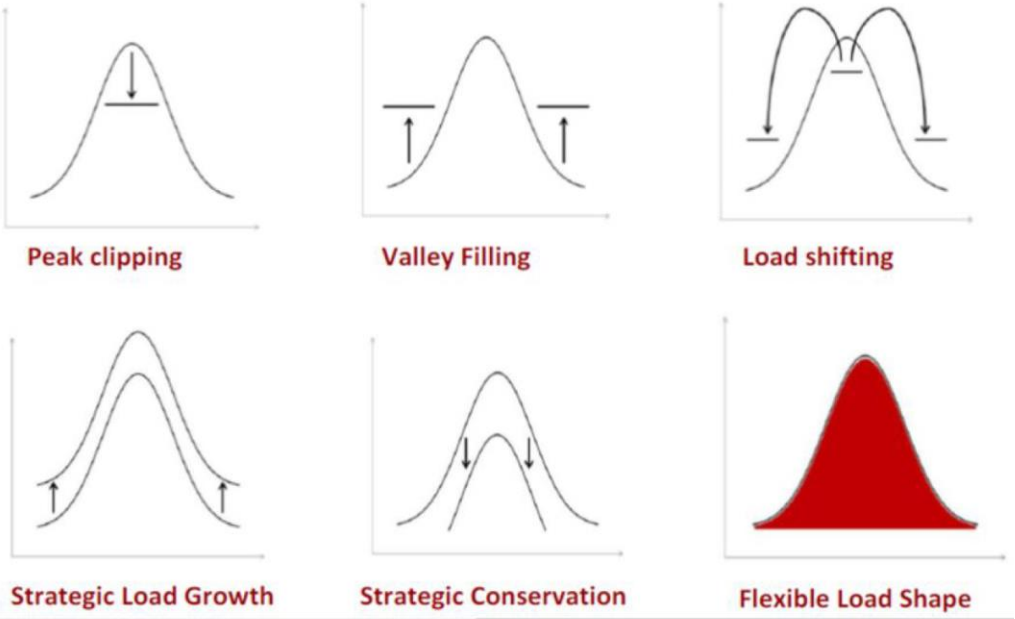

Figure 3. Demand response: set of different objectives (shaping the demand profile) [5]

DR finds multiple applications in microgrid context and local energy communities; based on forecasts of load and RES outputs that will very likely vary from day to day. A requirement for the successful application of microgrid DR measures is the adoption of smart metering and smart control of household, commercial and agricultural loads within the microgrid. Depending on the criticality of the target load, DR measures can generally be divided into shiftable loads and interruptible loads. The integration of DSI measures is expected to maximize their benefits in potential "smart homes", "smart offices" and "smart farms" within microgrids.

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# 3 Evolution of Demand Response in Europe

## 3.1. Demand Response in active network management

The value of DR might be multi-faceted providing several key features for operational scopes. A comprehensive reporting of such operational scopes for the power system might be found in [7]. Some brief discussion points on the operational flexibility that it is imparted on the operation of power system in regard to DR are:

1) *The importance of Peak Demand*: Utility companies raise capital to construct infrastructure required to meet their obligation to serve customers in their service area. The cost of this infrastructure is directly related to its capacity, which must be sized so, to meet peak demand, usually with some additional safety margin. This peak demand is much higher than the average level of demand at nearly every point in the power grid (peak load appears for less than 400 hours per year) [7]. Therefore, substantial amounts of infrastructure only exist to serve peak loads, which occur relatively few hours each year; hence, introducing DR to shift some of the load during those hours to other off-peak times is crucial and can defer investment cost for grid reinforcement.

2) *Reducing wholesale electricity production (purchase costs)*: Another primary effect of shifting load from peak demand periods when cost tend to be high, to off-peak periods when costs are lower (i.e., later in the evening or night). Thus, operational cost savings result from the difference in on-peak wholesale prices.

3) *Decoupling the need for generation reserve to supply Ancillary Services*: In addition to meeting the need to generate sufficient electricity to meet demand, generation capacity is also treated for services that grid operators use to keep the grid stable

and secure. There are numerous causes for differences between expected and actual load to occur, and a different way that each is resolved. Collectively, known as ancillary services, to varying degrees the means of resolving them to require that extra power plant capacity exist, as briefly described: Spinning Reserve which implies the requirement that the grid is still capable of absorbing the loss of any single asset without causing a wide-scale blackout. This typically refers to the fact that power plants with extra available output capacity and the ability to rapidly increase their output must be up and running (i.e., spinning) at all times to compensate for the loss of the largest power plant in the system. Regulation stands for the fluctuation of the demand on a minute-by-minute basis, which manifests a deviation on the frequency in itself. Intra-hour Balancing and Load Following refers to the availability of power plants to rapidly adjust their output to match to the actual (i.e., uncertainty of forecasts) with a little notice or no notice, getting paid a premium amount. Analytically, comprehensive examples of these services addressed by flexibility DERs are presented on the last section.

4) *Mitigating impacts from the intermittency of Renewable Generation*: The enduring integration of Renewable Generation evokes the necessity for additional reserves to support the intermittency provoked by them. This is because, while renewable resource forecasting is increasingly accurate, missing the timing of a change in output leaves the grid without a prearranged schedule to dispatch plants accordingly, and must be made up by more expensive intra-hour imbalance reserves or spot markets. In the particular concept of microgrids DR may have a pivotal role; DR measures in a microgrid are based on forecasts of load and RES outputs and will very probably vary from day to day. A requirement for the successful application of microgrid DR measures is the adoption of smart metering and smart control of household, commercial and agricultural loads within the microgrid. Depending on the criticality of the target load, DR measures can generally be divided into shiftable loads and interruptible loads. The integration of DR measures is expected to maximize their benefits in potential "smart homes", "smart offices" and "smart farms" within microgrids. More analytically as it is described in [8] load management in Microgrid premises during autonomous operation mode may be required for two distinct situations: (i) Microgrid with insufficient generation reserve. Loads, in these cases, will have to be curtailed until the system reconnects to the upstream network or the generation increases. (ii) Microgrid with sufficient reserve: Although microgrid has sufficient reserve, it may happen that, for a certain disturbance, the storage units

State of Charge (SOC) is not able to ensure secure operation, or the frequency deviation expected for a given disturbance surpasses admissible limits. The implementation of a temporary load curtailment will help improve the microgrid's frequency regulation capacity and reduce the solicitation from the storage unit(s).

## 3.2. An overview on the legislation of Demand Response in Europe

The three major players that contributed to the essential evolution of DR programmes are USA, UK and the EU; since they were the first to apply and implement incentivization schemes. Based on the survey conducted in [9], there might be a classification of five stages in the development of DR programs in legislation as:

- **Stage 1** Market deregulation/liberalization
- **Stage 2** Incentivization of RES and DER
- **Stage 3** Implementation of DSM schemes
- **Stage 4** Rollout and exploitation of smart metering devices and emergence of DR as an additional DSM schema
- **Stage 5** DR schemes in smart grids context.

The legislative frameworks pertaining these five stages towards DSM and DR evolution may be summarized by Table 2. In EU context the electricity market liberalization was introduced in the Directives of 1996 [10]. Accordingly, the next steps are regarded with the definition of the target for the penetration of renewable technologies in 2001, the primary incentives for the DSM schemes and the enhanced measures towards liberalization of electricity markets in 2003. The forthcoming directives for the determination of EU 2020 goals for the reduction of CO2 with the clear efforts to promote small-scale renewable generation by introducing the Feed in Tariff.

Table 2. List of EU legislation framework towards the emergence of DSM and DR.

| Year | Legislation Title | Description |
|---|---|---|
| 1996 | **Directive 96/92/EC** [10] | - Market liberalization and unbundling requirements of electric utilities |
| 2001 | **Directive 2001/77/EC** [11]Σφάλμα! Το αρχείο | - Initial targets for renewable energy generation technologies |

| | | |
|---|---|---|
| | προέλευσης της αναφοράς δεν βρέθηκε. | |
| 2003 | **Directive 2003/54/EC** [12] | - Enhanced liberalization and unbundling requirements for electricity market<br>- First mention of DSM schemes and directs for its exploitation |
| 2009 | **Directive 2009/28/EC** [13] | - Directives for EU 2020 goals for CO2 emissions<br>- Feed-in-Tariff for the propelling of renewable energy generation |
| 2012 | **Directive 2012/27/EU** [14] | - Clear use of DR<br>- Statements towards deployment of SG |

In Figure 4 the consecutive evolution of the legislative framework is illustrated. Clearly, there was a gradual framing of legislative measures towards the massive integration of smart sensing devices (i.e., to enhance end-users' awareness) to achieve demand-side participation for energy efficiency. Conducting the liberalization process of electricity energy markets -towards the vision of a single European market-, EU has also prescribed smart metering apparatuses as key enabler to improve transparency and competition on retail markets for electricity, providing also effective functionalities for the integration of residential DER (e.g., micro-generation, residential storage, demand-side flexibility).

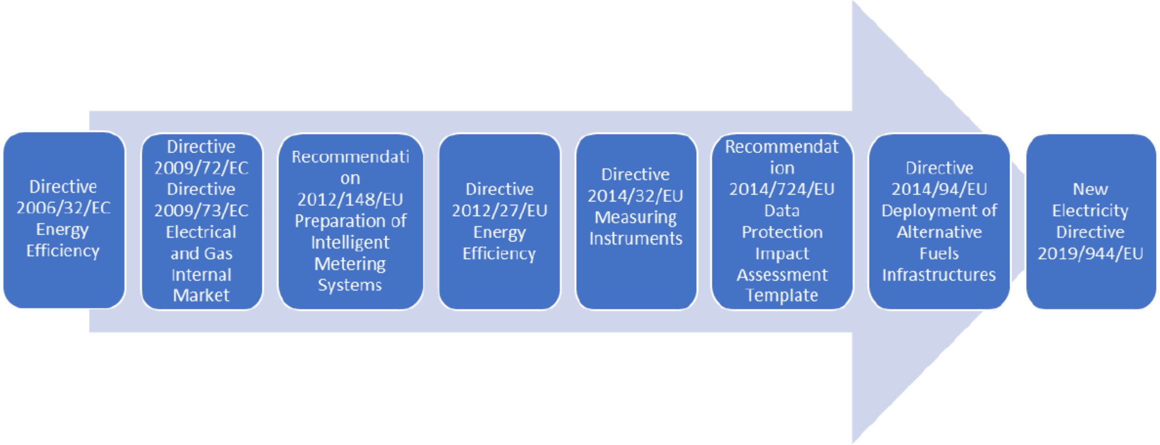

Figure 4. Evolution of European Legislation from the 2006/32/EC Energy Efficiency Directive, the Third Energy Package to the Clean Energy for all Europeans Package [15]

A brief, but closer outlook on the evolving legislative guidelines follows:

- On Directive 2006/32/EC26 there is particular focus on energy end-use efficiency and energy services, by providing specification on the use of cost-effective technological

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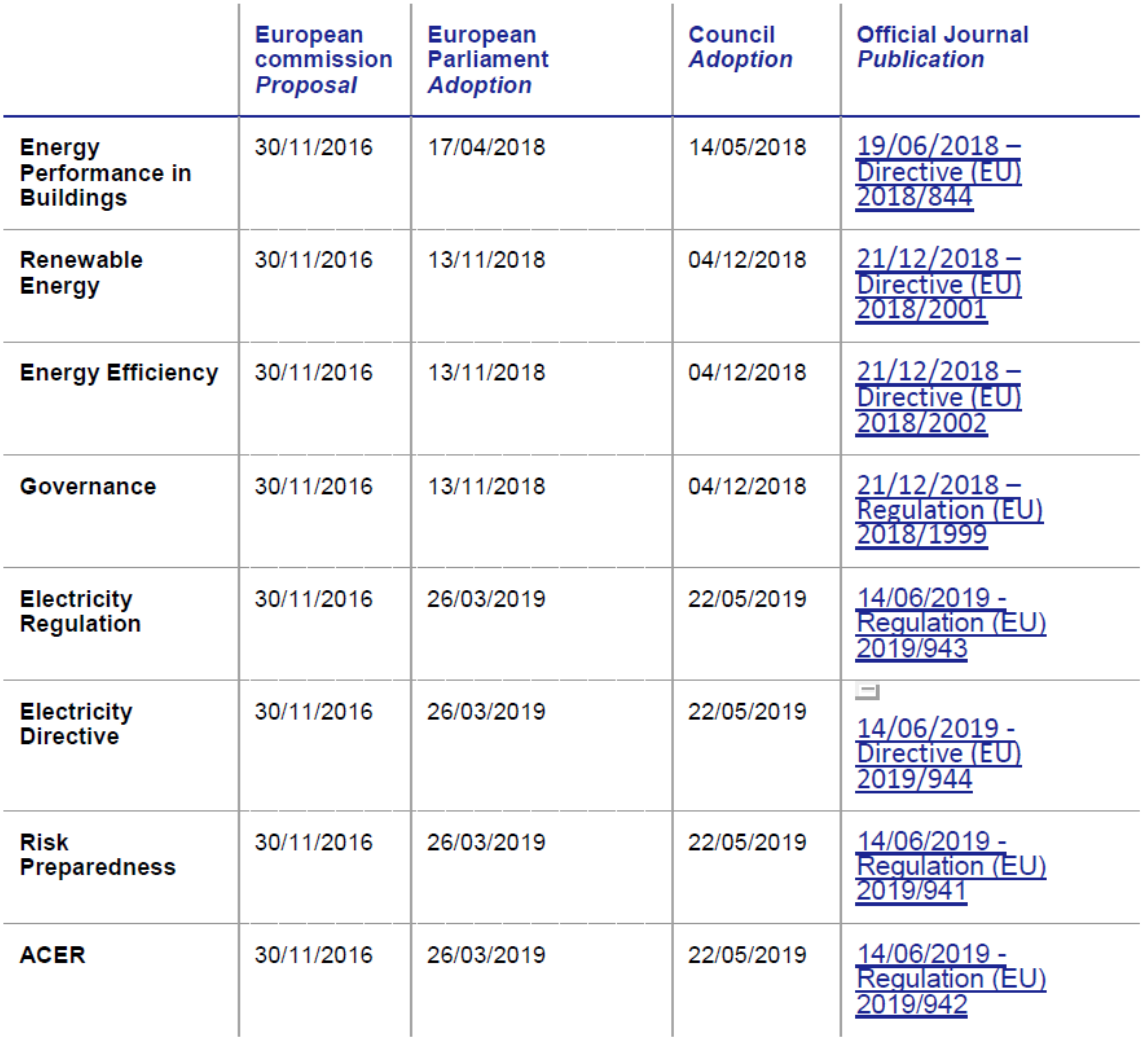
innovations (i.e., SM installation) to achieve the foreseen energy saving target of 9% on the upcoming nine years. The Article 13 of this Directive, entitled "Metering and informative billing of energy consumption", prescribes that electricity end-users, natural gas, district heating and cooling and domestic water should have the opportunity to face competitively priced individual meters that gives them access on actual consumption on actual time of use.

- The Directive 2009/72/EC and Directive 2009/73/EC – which, also, compose parts of the Third Energy Package- state that Member States and regulatory authorities should recommend energy undertakings to optimize energy use by introducing intelligent metering systems or smart grids technical solutions where and when appropriate.

- In Directive 2012/27/EU on energy efficiency there are specific updates in regard to energy saving target to 20% by 2020. Additional remarks are set in place commenting the limited effects of the provisions on metering and billing in Directives 2006/32/EC, 2009/72/EC and 2009/73/EC on energy savings [15].

- Within 2014/724/EU35 specific provision introduced measures on the promotion of use of a Data Protection Impact Assessment Template (called the "DPIA Template"), in to order to assure that "*fundamental rights to protection of personal data and to privacy in the deployment of smart grid applications and systems and smart metering roll-out*".

European concern on environmental issues to promote the energy transition has led the European Commission to present a set of measures called the Clean Energy for all Europeans Package (see Figure 5).



| | European commission *Proposal* | European Parliament *Adoption* | Council *Adoption* | Official Journal *Publication* |
|---|---|---|---|---|
| **Energy Performance in Buildings** | 30/11/2016 | 17/04/2018 | 14/05/2018 | 19/06/2018 – Directive (EU) 2018/844 |
| **Renewable Energy** | 30/11/2016 | 13/11/2018 | 04/12/2018 | 21/12/2018 – Directive (EU) 2018/2001 |
| **Energy Efficiency** | 30/11/2016 | 13/11/2018 | 04/12/2018 | 21/12/2018 – Directive (EU) 2018/2002 |
| **Governance** | 30/11/2016 | 13/11/2018 | 04/12/2018 | 21/12/2018 – Regulation (EU) 2018/1999 |
| **Electricity Regulation** | 30/11/2016 | 26/03/2019 | 22/05/2019 | 14/06/2019 - Regulation (EU) 2019/943 |
| **Electricity Directive** | 30/11/2016 | 26/03/2019 | 22/05/2019 | 14/06/2019 - Directive (EU) 2019/944 |
| **Risk Preparedness** | 30/11/2016 | 26/03/2019 | 22/05/2019 | 14/06/2019 - Regulation (EU) 2019/941 |
| **ACER** | 30/11/2016 | 26/03/2019 | 22/05/2019 | 14/06/2019 - Regulation (EU) 2019/942 |

Figure 5. State of play of the Clean Energy for all Europeans Package as of June 2019 [15]

## 3.3. Current status of Demand Response in Europe

It has been almost a decade that EU Directives established a set of binding measures to help the EU reach its 20% energy efficiency target by 2020, implying that the total EU consumption should be less than 1483 million of oil equivalent of primary energy usage [14]. The key element that has been amended in the following directive of 2018 is a headline energy efficiency target for 2030 of at least 32.5%. Demand Response has been greatly recognized within those EU directives as key enabler to steer security of supply, RES integration, enhanced market competition and essential end-user empowerment. The latter has been reflected in the recent European Energy Efficiency Directives and Network Codes by considering, also, the DR implementation within legislative proposals on Electricity Market Design [16]. To achieve the EU's energy goals it is already comprehended that DR (i.e., implicit and explicit) schemes at residential, commercial and industrial level have to be exploited along with demand-side resources at competitive prices.

Towards the implementation smart grid, the major expected evolution foresees the active participation of DER, including users' participation -via DR programs- in energy markets and network's operation by providing different types of flexibility capacities. The benefits from better price condition, in the sense of dynamic tariff schemes that might be implemented, could contribute to higher operational efficiency for the grid along with the maximization of integration of RES. According to the EU Directive 2009/72/EC, it is stated that electricity markets have to be based on the real possibility of choice for all consumers and access to new business opportunities for all. Nonetheless, in Europe, such efforts for DR deployment have been following a tardy pace (see Figure 6) comparing with United States status, as stated in [6].

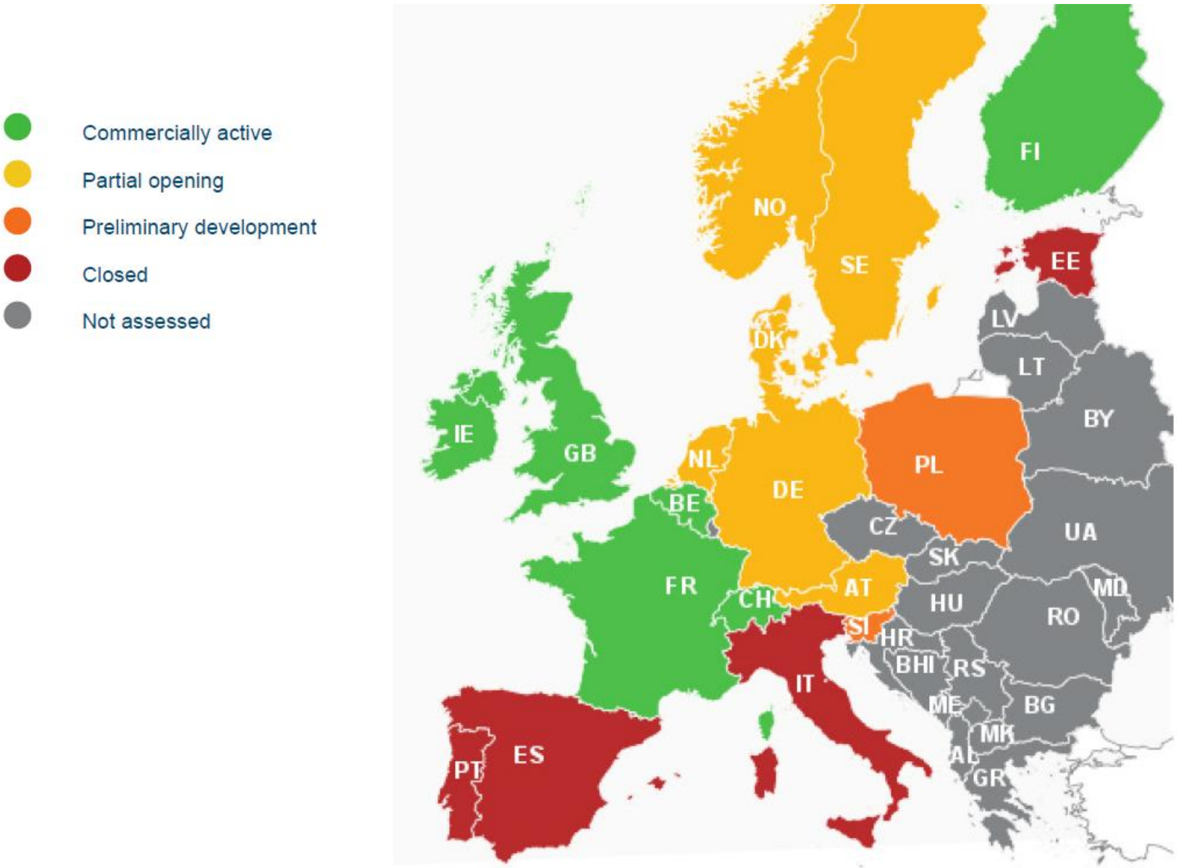


Figure 6. Map of Explicit Demand Response development in Europe year 2017 [2].

The regulatory status along Member States regulation towards DR implementation may be classified into three groups as per [16].

Within the first group there are those who have not essential commitment with DR reforms; despite DR may be adopted in the legal framework of such Member States, there is no clarity on the definition for aggregators to offer demand side resources or no way to measure or pay for the flexible resources, and most importantly no market in which end-users or aggregators can offer their flexibility capacities.

The second group refers to Member States that rely on their effort of DR enable through the retailers solely. This group, essentially, limits the market offers -since aggregators are limited to the role of service provider to retailers instead of allowing independent parties offer to end-users. There are clear implications within the category that consumers will not have the anticipated engagement, acknowledging their flexibility's capacity due to the fact that electricity bill is accumulated.

The last group, substantially, entails the drastic emergence of DR programs and independent aggregation models, by defining the roles and responsibilities of them. These markets, also, work along the specification of technical modalities and market entry requirements towards the promotion of customer participation.

In spite of the barriers persisting today, in most EU Member state customers have the capability to participate in DR schemes. Certain recommendations on regulatory initiatives towards DR implementation are presented in [16], [17]. The report proposes that role and responsibilities of independent aggregators have to be defined by providing neat framework which allows the consumer to opt freely their service provider. The market design to allow the participation of DR and any type of DER (e.g., via aggregation models such as virtual power plants). Finally, to establish the technical modalities (e.g., consumer capabilities and market requirements, aggregation in all markets, allow customers' load to compete against generation units in all marketplaces).

The following Chapter addresses the technical barriers to innovation of DR.

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# 4 Pathway Towards Demand Response Implementation and Technical Barriers

In the previous Chapter the Demand Response (DR) programs were introduced in order to pinpoint the essential emergence of Demand-Side Management (DSM) into competitive markets and exploiting customers' potential flexibility. The increasing integration of renewable technologies and the endeavors on EU context level to democratize the electricity sector, posing citizens as the central players into the energy markets future, are part of the decarbonization effort and targets of 2050, [18]. The transition to smart grids arises opportunities - especially from the technical standpoint- for the implementation of Demand Response (DR). Nonetheless, there are several barriers that may prevent the massive implementation of DR. This chapter particularly investigates the technical/technological barriers.

## 4.1. Technical framework for the Demand Response implementation

A Demand Response system is typically comprised of DR master station, the end-users' energy management system (also referred as DR substation) along with the communication layer network that provides the connectivity among DR master and the substation. This technical description is illustrated in Figure 7, as proposed in [18]. The end-users might be typical consumers of any type (e.g., residential, commercial, industrial) or end-users with installed DERs.

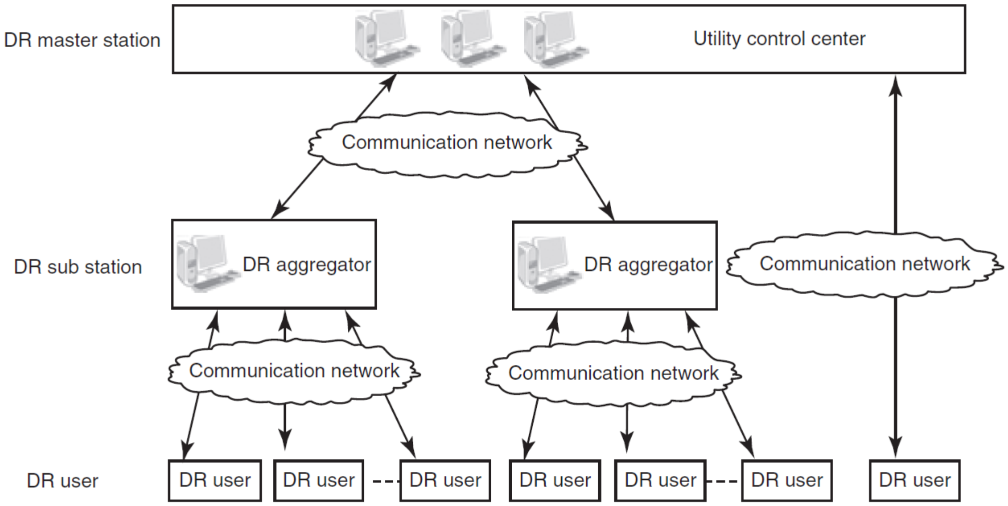

Figure 7. Typical demand response technical system [18].

Depending on the system architecture DR master station may be deployed either in the side of grid control center (i.e., SCADA), or on the Aggregator's side. Its main objective is to deliver functions related to the aggregation of data and information derived from a cluster (i.e., on a specific grid area) of users, the user management (contractual relationships), aggregated load forecast and price release as well as control signals -if applied- for instance for direct load control. The DR master station may be integrated with the respective communication infrastructures and considered as unique system. The core functional process of DR master foresees the utilization of AMI to communicate with downstream connected DR users.

The Customer Energy Management System (CEMS) or home energy management (HEMS) when referring to residential DR applications. These systems are composed of a computer management system and local AMI infrastructures including sensory devices (e.g., IoT based) as illustrated in Figure 8. The CEMS/HEMS is a device that is typically provided by the Aggregators to deliver an efficient gateway between the end-users and the Aggregators. Its main objective is to provide analysis and reports regarding data obtained from connected sensors and devices, as well as to accommodate user-preferences such as user-comfort, internal temperature, preferred temporal use of household devices, status of installed DER etc. The CEMS/HEMS system may have built-in custom schedulers to derive certain flexibility from the end-users along with the release of price signals. It is important to stress that DER installed at the end-user's premises may be used to provide non-utility generation on customer side impacting the potential of DR. DER capabilities might provide various types of flexibility that can be commercially used via aggregation to provide ancillary grid services.

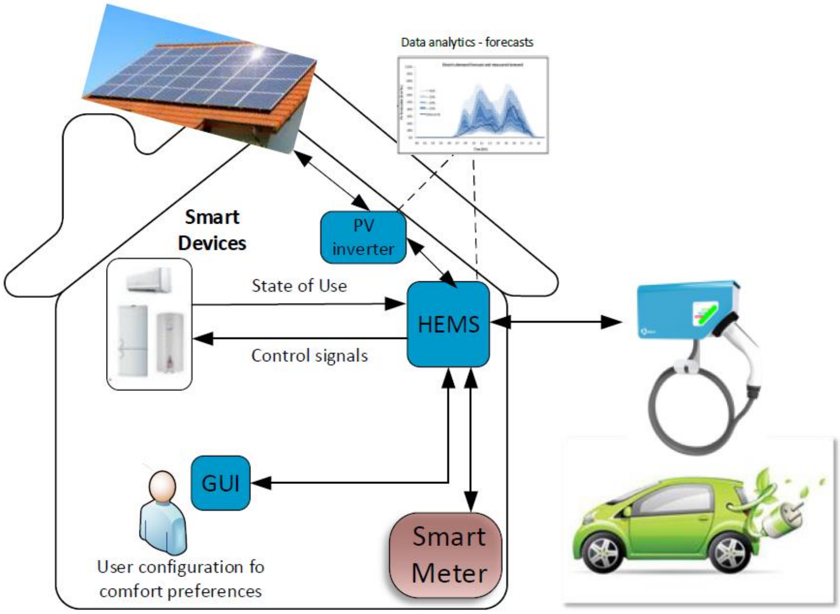

Figure 8. End-user equipped with smart meter infrastructure, microgeneration unit and Home Energy Management System apparatus [19]

## 4.2. Technical barriers to apply DR schemes

There are several barriers identified in the literature that are hindering the massive implementation of DR in EU. As illustrated in Figure 9, there is a categorization enlisting all potential barriers to DR implementation. The mapping of the barriers presents a distinction between fundamental (in the core) and secondary barriers based on the literature [20], [21].

Fundamental barriers to DR implementation are considered social (i.e., behavioral concerns), economic (i.e., market failures and market barriers) and technological barriers, while in the class of secondary are those related to design markets, regulatory aspects and physical (referring to electrical network), covering the impacts of institutions/authorities and/or system feedbacks [22]. As fundamental barriers are generally regarded those relating to intrinsic human nature, or essential to enabling technology. It is of great importance to understand the sources of barriers, and provide counteracting measures as enablers towards the actual deployment of DR.

Within this investigation, fundamental barriers can be classified as any economic, social or technological elements, covering both power system and Information and Communication Technologies (ICT) perspectives of the Smart Grid. Secondary barriers may be regarded those relating to regulatory and political standpoints, market design and the subsequent definition of DR business models. The following sections particularly focus on the determination of the technical barriers to DR massive implementation.

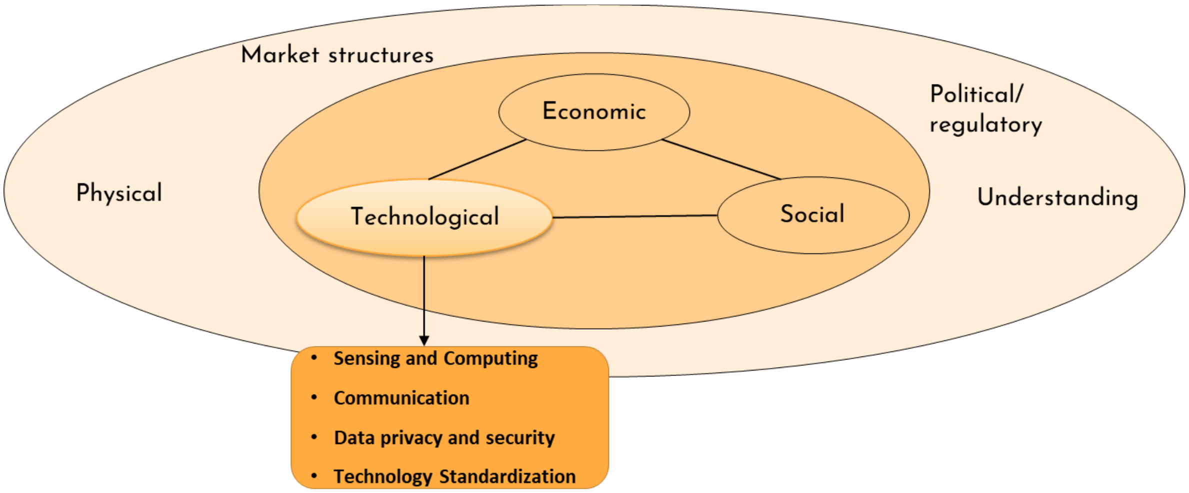

Figure 9. Classification of DR barriers

Technological issues are fundamental elements to DR and broadly to the whole concept of Smart Grids, that both necessitate the utilization of advanced ICT. Ubiquitous usage of sensory devices and IoT based smart appliances rely on ICT infrastructures for the successful implementation of DR schemes. For instance, ICT appears on the local metering functionalities (i.e., sensing to derive DR flexibility and its delivery), transactional and contractual communications (i.e., among DR flexibility provider and the aggregator/prequalification party/clearing party) as well as at premises for the activation of flexibility.

### 4.2.1. High frequent sensing devices

Smart grid infrastructure needs automated controls, sensing and metering technologies. The ongoing transition of EU Member States accommodating Smart Grid solutions enabling end-users active reactive to the grid operation, increases the opportunities for demand response. Smart Grids are defined as an electricity network that can intelligently integrate actions of all users connected to it in order to deliver sustainable, economic and secure electricity supply. They are able to monitor the state of a grid in real time and use the information to operate in a secure, reliable and stable way at a low-cost following energy efficiency principle [19]. Flexibility can be considered as an output from DR, which participation in the Smart Grid schemas can not only provide benefits to the grid, but also monetary incentives to participants in these campaigns. Nevertheless, DR is highly distributed among the Smart Grid schemas. Consequently, complex relationships with the participants, and the requirements for data exchange as well as for enabling sensing and advising technologies are a challenge. Furthermore, DR and the whole Smart Grid system needs consideration of adequate Information and Communication Technologies (ICT) fact which needs to explored in the context of technological barriers. For instance, Internet of Things (IoT) devices generally allow the information exchange among the different components in the system; yet, there are processes that need to be investigated in regard to sensing, computing, and communication that can act as technical barriers [21]. In this section of the document the focus is on sensing aspects. However, the remainder aspects (i.e., communication, data exchange, standardization issues) are examined in the following sections as well.

Employing sensors for real-time monitoring allow to deal with the power management of distributed energy resources, as well as it improves the smart's grid reliability throughout the enabling of flexibility. Sensing process presumes the following conditions:

- accurate and granular metering, that is essential for identification of flexibility,
- to accurately measure and ensure correct actuation of devices (e.g., thermostat) which has direct implications for the flexibility identification.

The accurate sensing is essential for the correct flexibility and availability identification and the release flexibility as well as to assess the released volumes of flexibility for settlement processes. Measuring on demand response source consists of observing the load during the time of reduction/incrementation to the estimated load that would have occurred without these effects. The types of loads participating in a DR program may affect the process of settlement a campaign [21]. For instance, measuring business or customer type loads have direct impact on the accuracy of DR schemes based on its operational characteristics. Whereas industrial customer loads might be consistent and have no dependency on weather-load patterns, customer loads such as air conditioning may be dependent on weather conditions, resulting in variable load. Consequently, weather sensitivity measurement is crucial to determine the predictability of the loads related to thermal comfort during a DR campaign. In addition to that, it is important to determine the granularity of measurement in seasonality loads involved in the campaigns. These types of loads may have variations in operating patterns unrelated to weather conditions. Furthermore, some loads tend to be highly variable apart from the weather response. They tend to be a challenge for any form of prediction. Customized baselines in DR events could be used for this prediction. However, this information should come from operational data that could result in a meaningful baseline.

Another aspect to consider related to sensing devices is their implication in the grid reliability in the Smart grid's schema. The integration of distributed generation into the grid could cause problems in the protection schemes related to the bidirectional power flows. Due to this issue, it is remarked the importance of developing protection schemes to deal with renewable energy impact on fault currents. Since smart sensors are built to acquire, register process measured data, they play an important role in smart grid protection. Their incorporation in protection schemes can reduce the activation time of network breakers and improve the Smart Grid reliability [22]. The fact of sensing in the Smart Grid context must deal with the issues beforementioned at an acceptable cost. This poses a technical and standardization challenge, mostly since actuators and sensors involved belong to the electrical energy domain, and they require the correct identification of flexibility and impact on users. That is why, standardization is a central issue for the heterogeneity for different manufacturers and their protocols involved. Although this part will be further addressed at the section 4.2.4, it is important to remark the standardization issues for the correct operation of sensing technology. The election of standards of communication between the different components could prevail as a barrier underlying interoperability issues [21].

In order to solve the possible technological barriers presented at the sensing domain, some propositions are presented that could possibly act as enabling factors. In the first place, metering at the required resolution to achieve the optimization of application in DR is remarked. The delivery of this functionality to the frequency at which consumption data can be updated and make it available is quite challenging. Nevertheless, it is a development that smart sensing must consider in order to allow the participation of DR resources in fast reserve markets such as frequency regulation. Particularly, this market requires high resolution in metering [21].

As previously explained, DR campaigns consider the use of final energy services such as thermal energy use, thermal comfort, air quality *etc*. For this reason, it is crucial to highlight the incorporation of final energy use monitoring in which user preferences could be reflected. This issue defies the selection of the appropriate sensing and DR-related technologies that assist in the correct identification of the desired service. The problem lies in the correct commissioning of the infrastructure based on the scope of DR campaigns. To avoid this technical barrier, it must be ensured that clear guidelines are established, in order to proceed with the appropriate deployment of the required sensors in each use case [21].

Having reviewed how important are some of the technical barriers regarding highly sensing infrastructure, the following discussion on high-frequent sensing devices is focused on the importance of Smart Meters (SM) as the intermediate element between the grid and the end-user domain. SM are commonly understood as the combination of an electronic meter with a communication link. The electronic part computes the amount of energy consumed whereas the electronic signals send the information to the rest of devices in the domain. These components in most of the cases are based on wireless technologies to allow two-way communication between the end-user and utility suppliers. Table 3 presents the most commonly met technologies used in SM for its communication technology in place [23]. Nevertheless, it must be regarded that SM are characterized in two-ways as a technological system [23]. On one hand, SM is designed to provide utility customers information on real-time basis about the energy consumption. On the other hand, SM as a technological system is focused on some guide principles. These are listed as follows:

- the improvement of customer service and retail market functioning,
- the offering of a right balance and functionalities,
- and finally, the opportunity to act as a downstream innovation at home, through the participation in DR campaigns.

Despite the fact that SM meters can be used to measure different energy vectors (e.g., thermal, electrical), this report to be aligned with the purpose of the TwinERGY scope, focuses on electrical SM even though regulations in Energy Services Directive (ESD) and in the Energy Efficiency Directive (EDD), in which all energy streams are considered.

Table 3. Communication technologies in SM in the EU

| Connection type | Technology Category | Technology Category |
|---|---|---|
| Wireless | RF-Mesh | |
| | Cellular | 3G-4G |
| | | GSM |
| | | GPRS |
| | IEEE 802.15 Group | ZigBee |
| | | 6LoWPAN |
| | | Bluetooth |
| | IEEE 802.11 Group | WiMAX |
| Wired | Power Line Communication (PLC) | NB-PLC |
| | | BB-PLC |
| | xDSL | ADSL |
| | | HDSL |

| | | |
|---|---|---|
| | | VVHDSL |
| | Euridis | IEC 62053-31 |
| | PON | |

Regarding the technical aspects for SM. On a first stage, the Smart Meters Coordination Group (SM-CG) developed a technical report in which it was described the necessary interfaces and functional entities by the system [24]. Hereafter, in 2012, the European Commission launched a document in which the recommendations on the preparation for the commissioning of smart metering energy systems were reflected. These foundations were addressed on threefold issues:

- Protection and security of personal data,
- long-term economic assessment,
- specification of a minimum functionalities of smart meters.

These specifications were focused on three different areas: Customer, Metering operator and commercial aspects of energy supply and a third block in which commercial aspects of energy supply, security, data protection and distributed generation are considered.

Regarding the customer area, as minimum functional requirements, the EC settled the possibility of providing readings directly to the consumer or third parties assigned by them. In addition to this, it was intended to allow the customer to update readings referred to information to be used in achieving energy savings. In terms of the metering operator area, the specifications of the EC regarding the functionalities of smart meters intended to allow the remote reading of meters by the operator, the delivery of a two-way communication between the smart metering system and external networks for maintenance and control purposes, and the allowance of readings to be taken frequently for the network planning. Lastly, the third block intends to allow the users to have access to advanced tariff systems, allow the control of supply and power limitation, provide secure data communication, and allow the possibility to import or export reactive metering. Despite the foundations on the functionalities that the previously mentioned document has established, new regulation concerning SM were provided as a consequence of the appearance of the common rules for internal market (EDR) as part of a legislative packaged "Clean Energy for all Europeans" in 2016 [9], [25]. Based on this document, SM should provide output for consumer energy management systems, which is strongly related to DR campaigns. Furthermore, this document has, also, highlighted some other new functionalities requirements regarding the operation of the different energy markets across the different countries in EU. These functionalities are presented as follows:

- Remotely readability
- Secure and data communication
- Advanced tariff systems integration
- Near real-time consumption
- Bills based on actual consumption
- Historical consumption
- Mandatory interface
- Request for change in timing interval possibility
- Mandatory in-home display
- Maximum time granularity

These functionalities have been set by the regulation instrument to define functional requirements for standardization of the spread of Smart Meters at an EU level. However, these specifications have been claimed to act as general guidelines. To correctly address the full exploitation of these services, the correct interoperability must be assured between the components deployed not only in the smart grid's domain, which will also be related to the sensing assets in the relevant installed domain.

The SM infrastructures do enable a large set of business modes for all actors across the power system's value chain, which are yet important to be recognized by all stakeholders [16]. The EU directives towards the decarbonization of the energy system, its digitalization and decentralization, finds the SM metering a technology as a key driver.

The most fundamental sensing device required for demand response is smart meter, for which EC has set the provisions towards the definition of a standardized technical architecture [26]. Typically, energy markets' trading period are in the interval between 15 minutes to 1 hour, requiring granular metering data at this resolution for their participation in such marketplaces. It is then consequent that technical barriers to DR may arise in the cases where inadequate SM and generally metering infrastructures are not yet deployed. The latter is not directly a technological barrier, but rather an implementation issue relating to technology. The granular metering of sensing devices may have implications for other demand-side flexibility schemes, such as the participation on ancillary grid services e.g., frequency response (FRR, FCR) where there is need for metering data on the order of seconds to minutes. The specific metering granularity requirements, beyond billing processes, is needed to support processes on the identification of flexibility (e.g., temporal availability), the settlement of released flexibility volumes actuation and to measure related factors associated with the delivery of flexibility energy services. On this topic, there are relevant DR barriers pertaining insufficient systems (e.g., Customer Energy Management Systems- CEMS). Several CEMS are generally proposed for the optimization of end-users' smart appliances; yet, there are issues associated with flexibility availability calculation as well as how the system may interfere with DR schemes providing a streamlined end-user's experience e.g., comfort/ convenience/cost, but also issues in regard to the settlement of flexibility.

A fundamental issue on high frequent sensing devices is the high reliability, as a matter of providing the capability to accommodate multiple smart grid services and interoperability with other devices. The latter issue does pose a technical and standardization concern; from one side the primary sensing devices (e.g., SMs & PMUs) do provide interoperable characteristics whereas any sensors behind-the-meter vary technology. This technology issue might be more severe when considering the heterogeneity of having multiple vendors and protocols. These concerns are also captured in section 4.2.4. Standardization issues.

### 4.2.2. Computing and utilization of smart appliances and home energy management systems

Needs for enhanced computing functionalities at end-users' premises

High frequent sensing is a vital, but not a sufficient condition, for optimal DR. Sensing can lead to aggregation of large volumes of data, whilst uncertainty, e.g., in the determinants of DR potential and in DR prices can increase the computational load of any stochastic/robust optimization that may be needed to effectively cope with uncertainty, especially when at scale.

Additional computing entities at end-users' premises could act as fail-safes and provide redundancy in case remote services are disrupted. Such computational abilities for HEMS at a household level could be realized with simple single-board computers, such as a Raspberry Pi or similar equivalents. These should provide sufficient means to store data and system configurations, while enabling basic visualization functionality, such as dashboards and low-level analytics of processed data. By executing most trivial computational tasks locally and transferring more complex computational operations to remote services (if at all necessary), the overall system infrastructure can be made more reliable and less dependent on externals services.

Low user acceptance on HEMS and smart appliances

The utilization of Home Energy Management System (HEMS) aims at steering consumers to optimize their demand profile (or net-load profile) based on real-time information of supplied electricity price. To this end, HEMS provides information on the electricity consumption of each household and the electricity rate of each household that can be understood by the consumer in real time. Additionally, HEMS can be interconnected with multiple smart appliances which communicate their temporal flexibility to be used for optimal scheduling. Nonetheless, currently is observed the low user acceptance of smart appliances and HEMS by end-users. This phenomenon is strictly connected to the easiness of utilization, identified as the main barrier for the end-users to adopt such technologies. The characteristics of these IT application products are not readily accepted if they are not proven effectively. Therefore, the role of early adopters who are innovative in using IT application products is important. Therefore, it is critical to establish measures to meet these expectations and to consider the ease of use in HEMS product design.

Without providing any decisive incentives for utilizing DR, there is essentially no benefit for investing into smart appliances and HEMS. As a result, very few homeowners would be willing to pay more than what a standard home energy system would cost. For example, homeowners in Germany that do not have access to a second cheap energy source, such as PVs, would have no incentive in deploying such systems. This is because most heating systems in Germany still rely on gas or oil instead of utilizing heat pumps or HVAC systems, and thus have no need for HEMS. But even households with PV systems are not guaranteed to benefit from HEMS. In Germany previous PV systems were issued flat compensations which lead to situations where feeding all of the generated energy into the power grid was more profitable than utilizing it locally and reducing the amount of energy consumed from the grid. While these problems are slowly being alleviated by new laws, making PV generated energy less valuable and thus motivating homeowners to not sell it all off, the change from full feed-in to self-consumption with part feed-in, still requires expensive modifications to existing electric meters. The insurance cost of older PV systems is also considerable and could further lower their benefits.

Furthermore, owners of older PV systems are often bound to a specific inverter manufacturer or smart meter supplier. Similar problems can be observed with residential battery storages that tend to use separate systems and are only compatible with the charging systems from the same provider. But even with newer systems owners are at risk of binding themselves to certain manufacturers or are forced to deploy systems recommended by their electricians and plumbers, which might be incompatible with each other.

Another issue is the commonly long lifecycle of large home appliances. Big energy consumers like HVAC systems are expected to stay in use for at least 25 years. Similarly, electric charging stations should function for a minimum of 10 years. However, many homeowners still have older generation appliances that will continue to stay in use for some time and are not designed to be integrated with HEMS. Such hardware upgrades often also require extensive modifications to other parts of the home energy infrastructure. These kind of house refurbishments only happen at a rate of around 1%-2% per year [31]. A house is expected to undergo major refurbishment only once every 50-100 years. This poses a major obstacle in deploying new HEMS technologies.

On the other hand, HEMS and other smart appliances often suffer from too short lifecycles, which directly conflict with the long lifecycles of the previously mentioned home appliances. New iterations of certain products sometimes make the older generation incompatible to the updated ecosystems and therefore obsolete. This could be observed with the SMA Sunny Home Manager [28] or Philips Hue product lines [29], [30]. The offered warranty periods for these products are also often too short, considering they are expected to be in use for much longer time periods.

Many of the HEMS are also very complex and lack easy installation and maintenance. With each home being more or less unique, these solutions have to be tailored for each use case resulting in very expensive installation and maintenance fees.

Lastly, data driven services that are not designed with data minimization in mind, might repel end-users. Data security and privacy became particularly important topic across all domains over the last decade. Data from HVAC systems for example could be exploited by deriving information about occupation times of homes and increasing the risk of house invasions.

### 4.2.3. Communication, data security & privacy issues

DR in the smart grid involves transfer of personal information related to energy consumption, making security and privacy concerns crucial considerations for the smart grid. Nowadays, SMs are in or are being in use or being rolled out in large parts of Europe [15]. It is generally recognized that SMs are essential for many types of demand side flexibility, especially when different actors (supplier, independent aggregator) have to engage with the customer simultaneously. With the implementation of new privacy legislation (GDPR and future e-Privacy regulation), it is not always clear to the relevant stakeholders, which smart meter data, for which purposes and under which restrictions, should be used without customer consent. As the privacy legislation applies horizontally to a number of different sectors, it is sometimes unclear for which particular use cases or under which circumstances smart meter data could be used in grid operators' legal tasks on grid operations and planning (even after having performed a DPIA). Due to this lack of clarity, there are different interpretations emerging in the different Member States, which, as a consequence, may hinder the development of demand-side flexibility in the European energy market.

The use of flexibility required increased sharing of data, both existing data and new types of data. This brings with it, a need to ensure there is appropriate privacy and security controls.

Privacy usually means one's ability to make independent decisions about whether or not to disclose information about oneself. Privacy also involves making decisions about who can have access to one's information and who cannot. Often, privacy is achieved through statistical methods of data aggregation. Security on the other hand involves putting physical, technical and network safeguards in place. Securing data means protecting the data from potential attackers and protecting data from being misused.

Security is necessary to achieve privacy. Security is the action, and privacy is the result. In the context of data transmission between smart meters and the utilities, a network attack to the security might compromise privacy. If the cryptographic protocols used in the network are not secure enough, personal data and consequently privacy may be compromised. However, some degree of privacy may be still preserved if strong mathematical tools are used for data aggregation. In a nutshell, strong security can protect privacy and using privacy-enhancing statistical tools can take us a step further in preserving consumer privacy.

It is clear that in any area, data privacy must be appropriately protected. Private data needs to be protected at source, in transit and at rest, with appropriate arrangements to securely destroy the data in a timely fashion. As part of this, who can have access and their routes of access needs to be defined and specified, as well as what level of granularity they can get. As a principle, having appropriate data privacy rules in place has broad agreement. However, there are not always clear views on who should have access to what information – some argue for making information more accessible, while others argue only one party, for example, the TSO should have access, and not disclose details to potential competitors. Consumers also need to have access to their smart meter or other household level data, and give others access to it. In some cases, access to customer data has been identified as a barrier. This data will need to be made available in adequate formats for further use by multiple stakeholders. As above, this needs to appropriately protect data privacy. And consumers need to trust that this will happen. There are a number of questions that do not have clear and consistent answers, such as:

- ⇒ Who gets access to the data?
- ⇒ What data is made public?
- ⇒ Who obtains the permission from the customer to share the data?
- ⇒ Who has responsibility for that data?

As customer assets become part of the energy system of the future and will need to be connected in a reliable and cyber secure way to platforms of markets and system operators, it becomes clear that also the data communication perspective needs to be better addressed. From the use case analysis, it becomes clear that a robust, secure and embedded communication channel will be required in order to support reliable demand-side flexibility market interaction and grid operations, which is today not the case. This communication channel should also ensure confidentiality. Also, future smart meter developments will require new communication solutions, taking into account future opportunities from IoT developments and new communication technologies (e.g., 5G, etc.,), while also the topic of reducing dependencies (cyber-security) between critical infrastructures (Telecoms and Energy) need to be examined. Today, no clear and integral European vision exists on how to realize a reliable infrastructure, required to access to data and functionality of smart customer assets which are relevant from an energy system perspective.

In addition, greater usage of aggregators is expected to facilitate customers' participation in flexibility markets. However, this requires customers to trust that the aggregators' equipment and communications will be secure against cyber security risks, and that the aggregators will appropriately protect any personal data. Where customers do not have this trust, they will not engage in the market.

Regarding data privacy at **EU level,** systems and markets need information to work efficiently. Further studies should be done to consider and clarify what (and how) information should be made transparent and available in the energy sector. On EU level, it may be also useful to map which categories of energy related data fall under the scope of data protection regulations and what this entails, to ensure consistent interpretation across member states.

At **National level**, more granular work is recommended to be done to identify data needs and who can access the data and how. Different market arrangements, for example who collects metering data, mean that the detailed discussions of data access make uniform applicability across the EU of more granular details difficult.

As for data security, it is widely accepted that information must be secured appropriately, e.g., by encryption, and must fulfil all national and EU regulations. For example, the communications between the flexibility provider and TSO/DSO, and any algorithms used in market places, must be reliable and secured.

At **EU level**, policy makers and regulators must work together across policy areas. EU safety, security and liability policies and regulations should be updated to address new risks arising from the use of digital technologies in the energy sector. Cyber-security is necessary to assure the confidentiality, authenticity and integrity of the data. Additionally, privacy practices, including data protection, are also essential to ensure that the handled data are exchanged and accessed in accordance with the contractual agreements between involved actors. The above, are necessary conditions for General Data Protection Regulation (GDPR) policies as far as citizen data are concerned.

At **National level**, regulators across sectors should collaborate more in order to address the new complexities that flexible electricity services will bring. Customers must also have confidence that there is data security to foster trust for anyone who participates in the system. Hence, any party interacting with customers must seek ways of demonstrating that a customer can trust them. This could be through contracts or, for example, through following an applicable code of conduct, which includes demonstrating that they are following all appropriate privacy and security regulations. When considering market arrangements, for example pre-qualification rules, data security should be considered. However, given the range of markets arrangements across Europe, it is not recommended that a standard application to energy market is pursued, above the existing data security work.

### 4.2.4. Standardization issues

DR programs do increasingly rely on IoT technology due to the fact that end-users are installing smart appliances within the house premises. IoT essentially, leverages, increasingly sensing apparatuses (AMI), both cloud-based and embedded computation along with ICTs. Transiting to this technological path may imply difficulties that are not simply connected to technological advancements but rather into standardization adoption.

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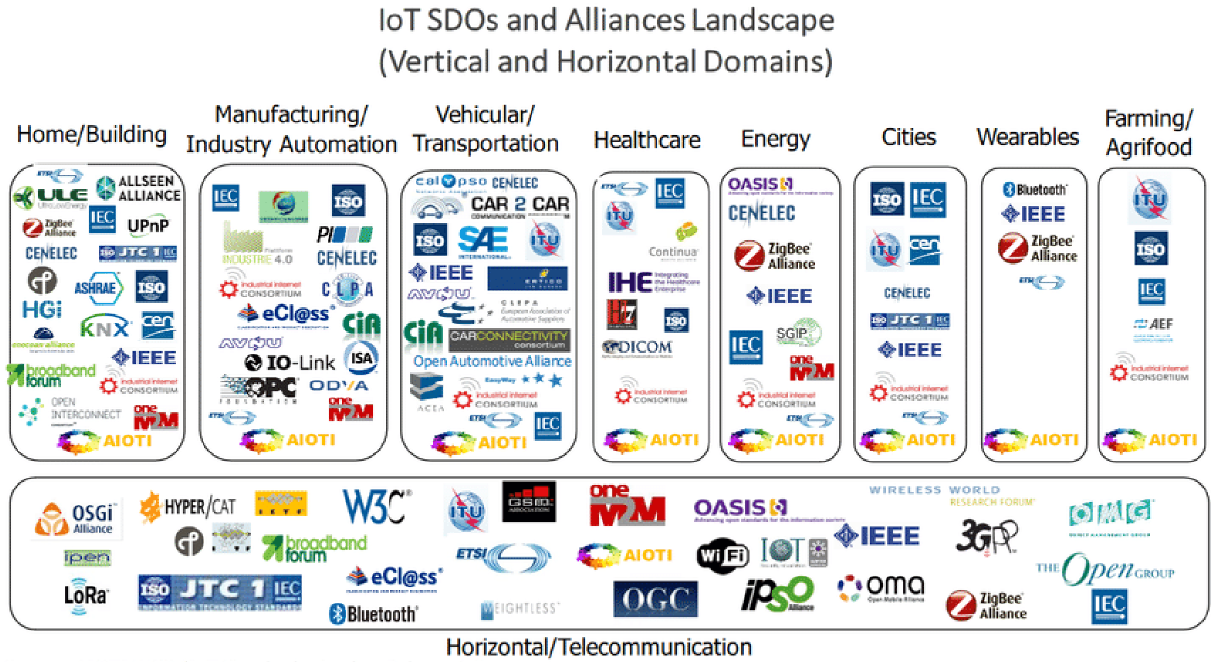
Regarding standardization on technological issues (e.g., platforms, devices etc) there is much discussion on the technology fit. The various proposed IoT reference models and architectures arise the complexity of what to be in massively implemented. Relevant concerns arise on whether architectural solution should follow centralized cloud-based solutions against decentralized approaches offering holistic visibility or scalability or even hybrid approaches.

The designation of appropriate computing and communication solutions/protocols might affect DR implementation. For instance, communication specifications have to be robust enough, offering an adequate quality of service such as response rate to DR service calls [21]. Similarly, IoT components to efficiently communicate with each other, e.g., to send relevant DR control signals or to submit bids and offers on flexibility services. This implies clear utilization of stable and secure communication infrastructures providing proper link between participating DR stakeholders.

As presented in previous sections, demand-side flexibility relies on interconnection of multiple sensing wired and non-wired devices which need to connect to edge compute and cloud compute services following a standardized manner. This topic of interoperability is relevant to standardization topic and is two-fold in the sense of communication and semantic layer interoperability. In regard to semantic layer device abstraction technologies are foreseen as the option in compute and sensors interchanged to rely on multi-protocol service necessary DR services. Some specific semantics relevant to sensing devices are related to SensorML (Sensor Model Language) to provide semantically-tied of defining processes and processing component including pre and post processing functionalities enabling syntactic and semantic interoperability; the SensorSSN (Semantic Sensor Network) is also commonly prescribed to be used for ontological inferences among sensors according to [30].

Across the EU there are various potential interoperability issues due to different standards. For example, in Germany the EEBUS protocol is growing in popularity for providing standardized interfaced among electrical consumers, producers, storages and managing entities, while in Italy the Energy@Home standard is more prevalent. This issue extends to other domains, such as communication standards (ZigBee, BLE, WiFi, DECT, LoRaWAN, Ethernet, LTE, KNX) or more general home automation solutions (openEMS, homematicIP, AVM Smart Home, Devolo Home Control, Apple HomeKit, Amazon Alexa, Google Home *etc*) that can be either open or proprietary. A comprehensive illustration mapping IoT alliances in presented in Figure 10.

The actual grid technology can also differ for each country, such that smart meter infrastructures or similar technologies might have different functions. On top of that, one must consider the differences in the energy markets and designs between different countries in the EU. Germany is still lacking proper flexible energy tariffs that could be incorporated with HEMS to create actual financial benefits for the end-user.



Source: AIOTI WG3 (IoT Standardisation) – Release 1.3

Figure 10. IoT standardization [21]

## 4.3. Overview of technical barriers

This section aims at providing a collective approach of all the identified technical barriers for DR implementation. Table 4 provides a comprehensive summary of all the identified technological barriers for the efficient implementation of DR as well as some key points to mitigate persistent barriers. The technical barriers are presented in the classes as presented in the previous sections i) High frequent sensing ii) Computing issues & utilization of smart appliances & HEMS iii) Communication, data security & privacy and iv) Standardization concerns.

Technology barriers are not only derived from not having the technology (e.g., AMI, interoperability among devices *etc.*) needed to deploy DERs, lack of experience with the technology (this can be addressed by social barriers as well) and needing to learn how to use nascent technologies.

Table 4. Overview of technical barriers of Demand Response implementation & potential solutions to overcome them.

| Title | Brief description | Potential Solution(s) & Practices |
|---|---|---|
| **High frequent sensing conditions** | | |
| Metering devices | The metering devices shall have specific granular and accurate capabilities to serve flexibility services and grid monitoring services | • Installation of metering at necessary resolution/granularity<br>• Clear guidelines need to be established for DR business models and services in order to proceed with the appropriate deployment of the required sensors in each use case |
| Smart Metering specific | Electrical smart meters need to follow the regulations in Energy Services Directive (ESD) and in the Energy Efficiency Directive (EDD) | • Member States should comprehend and adopt the requirements that are prescribed (protection & security of personal data, long-term economic assessment) and specify the minimum functionalities of SMs in accordance with the needs of DR business schemes.<br>• Consider cross-border functionality requirements |
| Energy Service sensors | The need for energy service sensors to harvest build automation as a matter of releasing flexibility | • Monitoring of energy services (e.g., comfort, appliance availability etc.).<br>• DR schemes compensate according to user preferences on various energy services.<br>• Utilization of smart plugs |
| **Computing issues & utilization of smart appliances & HEMS** | | |
| Computing power | The increased need for computing resources to achieve energy management given the evolving use IoT devices that imply large volumes of data that need to be processed and optimized. | • Computing entities at end-users' premises could act as fail-safes and provide redundancy in case remote services are disrupted<br>• Edge level solutions and generally distribution of computation load.<br>• Utilization of external resources steering at cloud-based systems |

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

| | | |
|---|---|---|
| HEMS & smart appliances | HEMS & smart appliance are essential components to DR implementation, their deployment might be time and resource-intensive for end-users. | • Focusing on the role of early adopters<br>• Think creatively about Demand Response via campaigns restrain the need for actual engagement<br>• Provide techno-economic assessment for end-users to comprehend the impact of DR in their energy savings. |
| **Communication, data security & privacy** | | |
| Interoperability (Communication & semantic) | The interconnection of multiple devices and actors is fundamental for DR, fact which implies the necessity for interoperability at communication and semantics level. | • Open, agnostic technologies<br>• Plugin-based architectures<br>• Alliances/collaboration to develop standards<br>• Alignment on semantics, to develop a common language across industries. |
| Data security & privacy | Data driven services that are not designed with data minimization in mind, might repel end-users. Data security and privacy became particularly important topic across all domains over the last decade. new privacy legislation (GDPR and future e-Privacy regulation). | • Privacy is achieved through statistical methods of data aggregation.<br>• Adopt Security & Privacy by design<br>• Strong security can protect privacy and using privacy-enhancing statistical tools can take us a step further in preserving consumer privacy<br>• Have a data life cycle management strategy<br>• Allow for intuitive end-user configuration tagging of data |
| **Standardization** *(this class is pertinent to all the above elements, relevant standardization issues are also presented above)* | | |
| | Standardization is a central issue for the heterogeneity for different manufacturers and their protocols involved. | • Harmonization and alignment of standards considering electricity sector, integrated with other potential sectors (e.g., gas, water, mobility) |

## 4.4. Contextualize technical barriers into the Demo areas

As discussed in the previous sections, there are several barriers identified hindering the massive implementation of DR in EU. A survey was conducted (*see Annex*) in order to landscape the current state of technical solutions in the Demo sites. The recorded responses aimed at capturing the technical implementation of breakthrough technologies that act as key enablers toward massive adoption of DR.

An outlook of the response reported regarding the current state of demo countries is provided in Table 5. One can notice that the SM rollout is not completed in none of the four demo countries, while the reported frequency sampling is typically not less than 30-minutes for the deployed SM devices. In the particular case of Germany, it was reported that the binding directive on the massive deployment of SM devices is currently stopped by the National Regulatory Authorities since the minimum requirements of SM provision were not met. Therefore, most households have an old ferraris meter or a newer digital meter without any communication. The obligation is given, if a household has a yearly energy demand greater than 6MWh, a producer with more than 7kW or a controllable load (e.g., controllable Heatpump) based on the response collected in the survey. Due to higher cost of the metering device, an incentive for customer is currently not given. As per the discussion, followed in previous sections, advanced schemes of demand-side management might require granular data from 1minute up to 15 minutes. The typical case in most sites where there is no smart meter rollout yet, most of the inhabitants have a flat energy tariff.

In general, the majority of Member States (e.g., UK, France, Spain, Italy, Sweden, Austria) in EU follows the path towards the view of the Commission's 80% approach [27]. In such countries, the strategy is focuses on "full roll-out" – the comprehensive, nation-wide installation of SMs. Nonetheless, the national strategic plans of Member States are typically different, resulting to different levels of SM implementation along countries. Only a few Member States e.g., Belgium and the Czech Republic have concluded negative long-term assessment on the massive introduction of smart meters. Accordingly, in the demo areas the absence of SM devices is meant to be overcome with the installation in the majority of participating dwellings. Furthermore, as per the analysis provided earlier that the selection of SM apparatuses has to take place by comprehending the needs of DR business models to be served. The latter refers to minimum requirement in regards to sampling rate as well as subsequent functionalities of the SMs to receive price signals, to be compliant in terms of communication protocols as well as to provide granular and accurate metering for the release flexibility volumes.

Table 5. Aggregated responses on technical solution that impact DR implementation.

| | Smart meter roll-out | Frequency of sampling | IoT sensors/actuators | Building-Customer-Home Energy Management (BEMS/CEMS/HEMS) | IoT alliances in place |
|---|---|---|---|---|---|
| *Athens, Greece* | Not completed. | Hourly/ Semi-structured | Not widely | Not deployed | ZigBee Alliance, Bluetooth, WiFi |
| *Bristol, United Kingdom* | Not completed. End-users have rudimentary access to data via an on-device display and/or via an app/web interface. | - | Not widely: smart plugs are generally used | Not deployed | - |
| *Sardegna, Italy* | Not completed | 15-minutes | Not widely | Not deployed | - |
| *Steinheim, Germany* | In Germany the binding smart meter rollout was currently stopped by the Oberverwaltungsgericht Münster (higher administrative court Münster), because the smart meter do not fulfill the minimum requirements. | Once a year yet, if the rollout starts 15 minutes or lower than 1 minute in value-added services | Not widely | Not deployed | WiFi, LoRa/LoRaWAN |

In regard to IoT sensors/actuators and actuators it was observed that in the demo sites there are not, currently, widely installed and used. Accordingly, HEMS are not also currently deployed in the demo countries. Considering IoT alliances in place in the demo countries ZigBee, Bluetooth, Wifi and LoRa/WAN are utilized in order to interconnect any smart appliances. From the responses obtained, it can be observed that all within the national frame of all demo sites the massive rollout of SM is an ongoing process apart from Germany that the process is temporarily paused due to SM not meeting the minimum requirements [31]. The latter, has direct implication to DR implementation since SM devices are an essential component (e.g., receive tariff signals, perform energy calculations), given specific requirement on the frequency of sensing. Furthermore, smart appliances, and generally, IoT are not yet widely accepted by the end-users, while HEMS are not also in place. As per the previous sections, such components can have an instrumental role on the massive implementation of several DR schemes.

For the purposes of the TwinERGY project, there will be certain technical provisions to promote and validate DR schemes either by installing IoT devices or by the adoption of typical smart plugs. Some specific information regarding the identified technologies to be used in each demo site follow:

### *Athens, Greece*

Although there are IoT devices already installed in several premises of energy customers of Mytilineos measuring energy related data as well as ambient data (temperature, luminance, humidity), new installations are planned to be deployed. The reason for that is mainly to avoid technical difficulties linked to the maintenance of the existing equipment, as the technical partner responsible for them is not involved in the TwinERGY consortium. Other than that, some of these users already participating in other H2020 projects no longer will to be involved in new energy efficiency activities.

Regarding the data collected from the IoT devices of Mytilineos' pilot users in previous H2020 projects, the frequency of reporting used to be hourly with a 6-month update capability. The collected measurements are semi-structured data in the form of an excel file. New frequency of sampling is still to be defined with the installation of new equipment in the frame of the project.

The HEMS utilized within several premises of Mytilineos is related to the UtilitEE solution [32]. It is developed around a combination of ICT technologies to support the project's context-aware, human-centric behavioural change framework. At the base of the solution lies on a customizable IoT system employing off-the-shelf metering, sensing, and actuating equipment for the continuous monitoring of the end-user premises, supported by a cloud-based information management system responsible for preprocessing and storing the collected raw data. The raw data pre-processing aims at ensuring the quality of the information through the implementation of self-learning cleansing algorithms. These algorithms eliminate incorrect values which can degrade the accuracy of the UtilitEE modelling mechanisms. In addition to that and to prevent data loss due to disruptions of network connection or IoT equipment malfunctions, a sensor health monitoring tool was developed, to support the maintenance activities performed by the system's business stakeholders.

### *Bristol, United Kingdom*

Within this demo site it was reported that some participants have smart meters already supplied to them by their energy suppliers as part of ongoing effort for a national rollout. However, in the

UK market these are not open and allow consumers only rudimentary access to data via an on-device display and/or via an app/web interface. To that end we will use standard of the shelf smart plugs to capture consumption and in particular any loads of interest (e.g., washing machines, kettles). The frequency of sampling of SM has not been determined yet, but smart plugs allow for a variety of configuration options including anything from e.g., every 1min to twice-hourly measurements.

The smart plugs in themselves can be considered IoT devices. Other than that, within this demo there might be installed supplementary devices to capture parameters of comfort such as ambient temperature, noise and light, as well as PM2.5/10 and CO2 emissions (in particular the Smart Citizen Kits v2.1, see https://www.seeedstudio.com/Smart-Citizen-Starter-Kit-p-2865.html). The use of smart appliances (e.g., fridges, washing machines) is not foreseen to be explored within this demo. Concerning relevant technical solutions to HEMS device, this demo will be built with emonPi components of the Open Energy Monitor project (see https://shop.openenergymonitor.com/emonpi/ ).

### *Sardegna, Italy*

In the Italian demo site, there will be smart metering devices capable to monitor (not control) each building the following parameters:

- Energy Demand
- Energy Production by PV plants
- Energy emission in the power grid

Both Active energy [kWh] and Reactive Energy [kVar] are available. The frequency of sampling the above parameters is set to 15-minutes. Smart appliances are going to be installed in every building within the TwinERGY project.

### *Steinheim, Germany*

The German Demo will consider some end-users with installed SM solution, while there will be a HEMS device to be tested based on in an in-house developed solution. In terms of possible standards for demand response in the demosite, the eebus seems to make the race in Germany. We assume that each home also uses WiFi and some possibly ZigBee for smart home appliances. However, more precise information can be obtained while carrying out interviews with the involved in the pilot households. LoRa/LoRaWAN is heavily used to interconnect IoT-devices for various local smart city concepts in the surrounding area (not specifically at the demo site), such as heat meters, parking sensors, environmental sensors.

# 5 Concluding remarks

The technology was never, directly, a barrier to a massive implementation of Demand Response (DR) schemes. The bottlenecks, though, are met basically on the absence of adequate regulatory framework to adopt DR schemes, while there is a pivotal need to create sustainable business models which will involve incentives to the end-user. The main drivers to further implement DR programs would be to promote the end-user's acceptance and engagement on such schemes by providing noticeable cost savings in a fair and appropriate manner. Therefore, efforts should be done to include socio-economic factors within developments of new models for flexibility management at local network levels.

From the technical standpoint, it is clear that to achieve a successful implementation of DR schemes there is further need to complete the roll out of Smart Metering (SM) and sensing devices, providing an adequate sensing frequency. Nonetheless, as pinpointed in previous chapter it is essential to establish the demand response schemes and their subsequent requirements for granular metering of flexibility capacities and availability of end-users and their households. The selection of proper equipment in regard to energy service sensors is also substantial to account for the identification of end-user's comfort level and availability. In this regard the absence of sophisticated sensory devices might be replaced with the use of smart plugs.

Employing demand response has also direct implication for multiple data exchanges among several actors and devices, fact which presumes that certain data security and privacy policies will have to applied. It was identified that with the implementation of new privacy legislation (GDPR and future e-Privacy regulation), it is not always clear to the relevant stakeholders, which smart meter data, for which purposes and under which restrictions, should be used without customer consent, fact which creates bottlenecks in flexibility services accommodation in general. As the privacy legislation applies horizontally to a number of several sectors, it is sometimes vague for which particular use cases or under which circumstances smart meter data could be used in grid operators' legal tasks on grid operations and planning.

Semantic and communication interoperability is a key element on DR implementation assuring successful data exchange among actors and devices. This can be properly addressed only by establishing alliances to develop/enhance standards for both semantics and communication layers.

In the demo sites it was observed that there is lack of proper technological equipment to validate DR schemes. For this purpose, certain technical solutions such as equipping the end-users with adequate SMs, smart plugs and in some cases, HEMS are foreseen necessary. The technological solutions are essential enablers to DR implementation in the smart grid context related to the improvement and investment on sensing and computing infrastructure with ICTs' incorporation. Socio-economic factors might include consumption or production patterns, the consumer perspectives on sustainability, investment costs for enabling technologies like smart metering and in-home automation and the price elasticity of the end-user or DER from whom flexibility is being demanded. An important social factor relevant element to technological barriers is lack of adoption of HEMS, smart appliances as well as the lack of knowledge and skills. This can be gradually mitigated by focusing on the role of early adopters as well as to provide comprehensive techno-economic facts on the adoption of such technologies and their participation in DR schemes.

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# Annex

*Questionnaire survey to capture Demo site specific information on the technical implementation of Demand Response*

# Brief Questionnaire on Technical Obstacles to Innovation Analysis for Demo Cases

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

**General scope of the questionnaire:**

There are several barriers identified in the literature that are hindering the massive implementation of Demand Response (DR) in EU. Amongst fundamental barriers, are those relating to intrinsic human nature, or essential to enabling technology. Without an understanding of these barriers, there is no chance to substantially revert DR barriers to enablers.

Technological issues are fundamental elements to DR implementation and broadly to the whole concept of Smart Grids, that both necessitate the utilization of advanced Information & Communication Technologies (ICT). Ubiquitous usage of sensory devices and IoT based smart appliances rely on ICT infrastructures for the successful implementation of DR schemes. For instance, ICT appears on the local metering functionalities (i.e., sensing to derive DR flexibility and its delivery), transactional and contractual communications (i.e., among DR flexibility provider and the aggregator/prequalification party/clearing party) as well as at premises for the activation of flexibility.

The aim of this questionnaire is to capture the landscape of **current state** of DR implementation and effort in the Demo sites.

**Please provide the Demo site you are representing:**

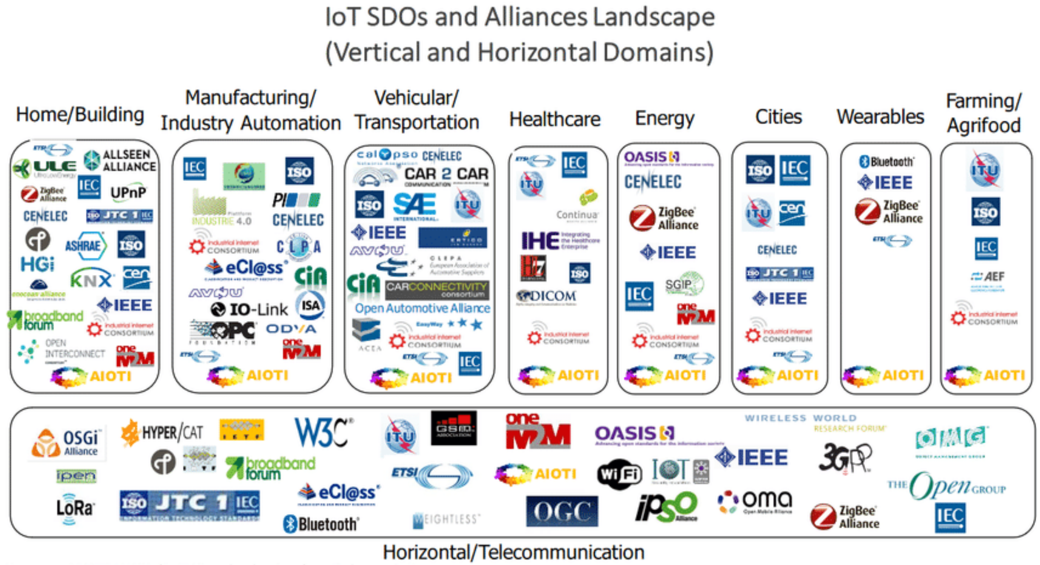
1) **Please provide information regarding smart meter rollout explaining what is the current status as well as current efforts for their installation:**

2) **Please provide information regarding the frequency of sampling of SM in the Demo site:**

3) **Are there IoT based sensors/actuators widely used by consumers in your Demo site, if yes could you provide some examples:**

**4) Are there smart appliances and Home Energy Management System devices used in your Demo site?**

**5) In terms of IoT alliances please mark/enlist which are generally adopted for DR application in your Demo site?**



Source: AIOTI WG3 (IoT Standardisation) – Release 1.3