D5.4 The interplay between P4P and demand response incentives

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Abbreviations and Acronyms

Acronym	Description
AEPC	Active Building EPC
BMS	Building Management System
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EE1st	Energy Efficiency First Principle
EEM	Energy Efficiency Measure
EPC	Enhanced Energy Performance Contract
ESCO	Energy Service Company
EU	European Union
H2020	Horizon 2020 EU Framework Programme for Research and Innovation
IPMVP	International Performance Measurement And Verification Protocol
M&V	Measurement And Verification
P4P	Pay-For-Performance
RES	Renewable Energy Sources
SRI	Smart Readiness Indicator
TSO	Transmission System Operator

Executive summary

This deliverable identifies how a P4P scheme can incentivise the implementation of EE (Energy Efficiency) Measures that also improve demand flexibility potential. The main objective is to update the SENSEI model developed in T5.2 to integrate the values of DR (Demand Response) services in P4P, quantifying the flexibility that may be performed in force of a specific EEM or a set of EEMs, considering the efficiency first principle.

The growing share of energy produced from non-programmable renewable sources has stimulated the need for electricity system operators to implement DR projects. These projects also involve residential users, ready to change their consumption profiles following the System Operator’s needs. Also, in this case, an adequate automation system is introduced in the building capable of integrating with smart grids.

Many scientific works and research projects discussed in this deliverable have addressed how the introduction of EEMs and DR services at user level can be a risk or an opportunity and how they interact in the pursuit of different goals. As a result, several research projects have been financed under the H2020 program, including participation in DR programs in the Energy Performance Contracts.

This deliverable suggests some methods to evaluate the interplay between EE and DR. The first method evaluates the “intelligence” of residential buildings through the SRI qualitative-quantitative indicator (Smart Readiness Indicator). As a result of this degree of automation, the building can participate in DR programs with a specific performance. Therefore, the idea is to associate a DR index built similarly to the SRI index, which will give a qualitative/quantitative performance evaluation in terms of the building’s DR capabilities.

The second method employs a data-driven simulation to verify how the DR availability varies as a consequence of the energy efficiency measure implementation and the benefits in terms of power system security. It is clear that to assess the interdependence between DR and EE interventions, it is necessary to adopt quantitative methods based on real or simulated results in authentic contexts. Through these two methods, tools that can evaluate how an EE intervention influences the availability of DR resources requested by the dispatching manager have been developed.

Following the introduction of DR services, a P4P model that includes these services will be formulated in the subsequent chapters, introducing the Flexible Energy Aggregator.

1. Introduction

This first section focuses on the state of the art of the interaction between EE and DR. Subsequently, a targeted analysis of the critical factors that determine the interaction between EE and DR is carried out. Furthermore, how the DR is managed in the so-called H2020 sister projects is discussed and the vision of the DR in the SENSEI project is obtained.

1.1 State of the art

With population growth in cities, environmental and energy challenges have increased. Our energy consumption model is progressively destructive because it mainly depends on fossil fuels that compromise the planet and are the cause of many international conflicts. Since energy is at the base of a country's development strategies and affects its sustainability, progress, and degree of well-being, the energy system of the future aspires to be fair, safe, clean, efficient, and democratic. From this point of view, the need for a significant decrease in greenhouse gas emissions, an increase in the share of renewable energy, and the improvement of energy efficiency are among the main objectives of the millennium. So, electricity consumption is constantly rising. Currently, electricity production is still highly centralised and often located long distances from end consumers. The levelling of the load is entrusted to hydroelectric and natural gas plants, regulated by daily and seasonal consumption forecasts.

To improve the entire system and protect the environment, we should try to make the most of renewable sources by combining them with intelligent systems that the "Digital Disruption has introduced". These can modulate the energy loads between producers and consumers, consequently reducing dependence on fossil fuels. Although renewables are abundant, they are unstable by nature and difficult to synchronise with energy demand, as they are characterised by erratic behaviour. As a result, imbalances are created between energy production and consumer demand. It is a path that includes digitising the energy sector, lowering the cost of renewable energy, and developing new models of distributed energy generation. In particular, with the increasing decentralisation of energy generation, households, individuals and businesses can play a proactive role in the energy system, allowing new resource management schemes and consequent business models to emerge. The European Union (EU) has recognised energy and environmental issues as key and critical components, leading to the European Commission's decision to move forward with an unprecedented step towards a so-called zero-carbon economy. However, buildings as a whole - whether homes, workplaces, schools, hospitals, libraries or other public buildings - are the largest consumers of energy in the EU and a significant contributor to carbon dioxide emissions. Overall, EU buildings are responsible for 40% of energy consumption and 36% of greenhouse gas emissions [1], mainly due to construction, use, renovation, and demolition. Therefore, improving the energy efficiency of buildings is critical to achieving the ambitious goal of carbon neutrality by 2050, as defined in the European Green Deal.

Today, about 75% of the EU building stock is energy inefficient [2]; much of the energy used is wasted. This percentage can be minimised by upgrading existing buildings, looking for smart solutions and energy-efficient materials when building new homes. Renovating existing buildings could reduce total EU energy consumption by about 5-6% and carbon dioxide emissions by 5%. However, on average, less than 1% of the national building stock is renovated each year. (Member state percentages range from 0.4% to 1.2%.) [3].

In this sense, the initiatives undertaken by the European Commission have been considerable. However, these are mainly action plans and strategic documents covering the different areas included in the European green Deal [4].

Among the various policies envisaged by the Green Deal, we are going to focus on those aimed at improving the energy performance of buildings and their upgrading. Of great importance is the principle of energy efficiency first (EE1st) (Recommendation of the European Commission of 28.9.2021) [5]. This principle aims to treat energy efficiency as the "first fuel", i.e., the energy source in its own right. The public and private sectors can invest before considering other more expensive and complex energy sources.

This recommendation encourages and stimulates the shift from the traditional energy production and consumption model.

This model is based on large suppliers, which mainly use fossil fuels, where the consumers are passive and suffer the price. The alternative is a more flexible model that integrates innovative technologies, renewable energy sources and focuses on energy consumers who have a proactive role.

The EE1st principle implies taking a holistic approach, for example, considering the overall efficiency of the integrated energy system, which promotes the most efficient solutions for long-term climate neutrality across the entire value chain (from energy production to grid transport and the final energy consumption).

All this is to achieve efficiencies in primary and final energy consumption. This approach examines system performance and dynamic energy use, where demand-side resources and system flexibility are considered efficiency solutions. In addition, to improve the whole system and protect the environment, efforts are being made to make the most of renewable sources by connecting them with intelligent systems capable of modulating energy loads between producers and consumers, thus reducing dependence on fossil fuels.

Established practice in the literature is the study of energy efficiency applied to buildings and the involvement of DR as another variable to be considered in evaluating the entire system. Specifically, improving EE is defined as a persistent and steady reduction in energy consumption and requires providing a fixed level of service. DR is defined as "Changes in the use of electricity by end customers compared to their normal consumption patterns, in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use in periods of high wholesale market prices, and when the reliability of the system is compromised" [6].

Changing consumption patterns to optimise energy supply utilisation is usually referred to as DR. Specifically, it aims to improve power plants and grids and it is a way to use power systems more efficiently.

The introduction of "Smart Grids" technologies in the electricity distribution system brings additional value in moving energy and information in various directions, involving and making many new participants proactive, that give rise to new business models such as DR. Through DR, consumers may respond to market signals by modulating their energy consumption in an increase or decrease, intending to reduce peaks in supply and demand for electricity simultaneously, and ensuring greater stability and flexibility of the network, more rational and efficient use of infrastructure and the same resources.

Established practice in the literature is the study of energy efficiency applied to buildings and the involvement of DR as another variable to evaluate the whole system. In this sense, DR is also a fundamental tool to improve EE [7], emphasising that EE and DR are not isolated and should be considered in parallel. EE and DR aim to modify user consumption profiles to ensure a zero-emission, resilient and efficient energy system. Therefore, it is critical to analyse their interferences and synergies. This is a 'hot' topic and it has been addressed by several studies and researchers [8,9].

With the growing importance of demand flexibility to the grid, it is essential to take a more integrated approach to EE and DR, avoid unintended competition, promote complementarity between EE and DR, and minimise overall costs and emissions. EE can produce significant benefits, even if it competes with DR, by reducing overall generation both day and night.

However, competition with DR can erode the benefits of EE to some degree, for example, by requiring more effective use of peaking generation units. So, an integrated approach between EE and DR that focuses on complementarity could increase the benefits of EE. These benefits include reducing and/or shifting load to increase system capacity factors or to facilitate economic or security dispatch of generation resources [10,11,12,13]; deferring investments in the generation, transmission, and distribution system; and reducing fuel and purchased energy costs for utilities and electricity end-users [6]. In addition, EE programs typically cost less per kilowatt-hour than average retail electricity rates [12,13, 14,15].

From previous studies on the interaction and integration of EE and DR, it is clear that there is a solid theoretical foundation. But limited empirical data focused primarily on institutional and market barriers, driving customer acceptance and participation, improving behaviour-based programs targeted to EE and DR goals, and optimising EE and DR resources [7].

In this regard, the scholarly debate focuses on identifying EE and DR attributes, technological factors, and system conditions that are likely to drive EE and DR interactions. In addition, some studies on the EE and DR relationship have focused the analysis on the direction of the relationships between the two, i.e., the positive and negative aspects. EE programs produce energy savings, and DR programs make demand reductions at critical times, which usually correspond to periods of peak power demand or can be triggered by events at off-peak times (such as transmission problems). But these programs display overlapping effects: energy efficiency can permanently reduce the need for energy and DR, and with proper control strategies, also produces some energy savings.

The study of [7] highlights a conceptual framework that explicitly identifies how EE and DR interactions can occur in four ways. First, EE and DR interactions can occur when a change in a resource increases (complements) or decreases (competes with) the size of the available resource. Second, EE resources might encourage greater (complementary) or lesser (competing) participation as a DR resource. Third, changing the amount of EE or DR may alter the utility system's need for the other resource. Third, EE and DR interact in terms of resource availability. An increase in EE can decrease (supplement) or increase (compete with) the need for DR resources to balance the supply and demand of the utility network in real-time. Fourth, utility system operators use dispatchable resources to meet network demands that reflect near real-time conditions.

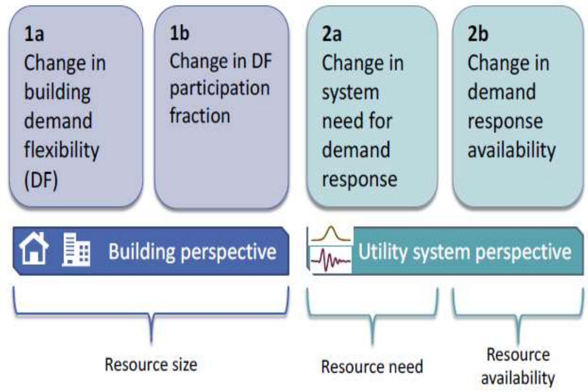


Figure 1 - Interactions between different perspectives and outcomes. [7]

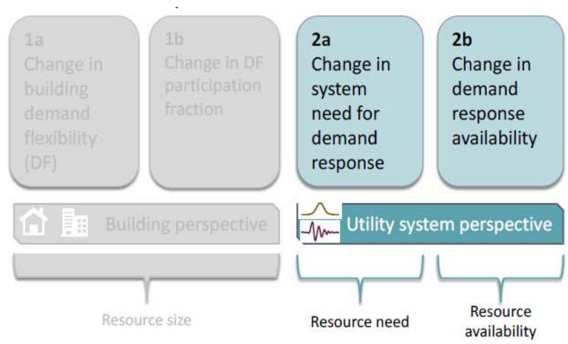


Figure 2 - When EE changes the utility system needed for DR availability. [7]

In particular, the study by [8] shows how energy efficiency affects the decarbonisation of energy markets. It is known that improvements in EE reduce the relative price of electricity and therefore have a rebound effect, which depends fundamentally on the response of demand in the short term, i.e., on the ability of consumers to adapt their demand in the current period (demand reduction) and reprogram demand intertemporally (changing demand).

It is also clear that EE will reduce electricity demand by 10% in 2050 and contribute by 11% to the decarbonisation of the European electricity market. In the short term, investments in EE and DR will decrease the price of carbon almost equally with a reduction of 8 or 9 EUR / tCO2). Sub-additive effects are found when the measures are combined (reduction of 22 EUR / tCO2) so that the final price of carbon will be 51 EUR / tCO2 in 2050 [8]. Energy efficiency reduces the baseload and, therefore, gas energy generation. In turn, gas energy remains crucial for marginal abatement technology because it provides the flexibility needed to integrate intermittent renewables. As soon as short-term DR is assessed in addition to the ability to deal intermittently, rather than gas supply playing this role, the drop in the prices of carbon will be reinforced. The effect of energy efficiency on electricity demand is evident. Buildings and equipment that consume less energy (less kilowatt-hours) because they are more efficient, impose lower power loads on the system (lower kilowatts of demand). More than 20 years of data on efficiency programs have documented this effect. Because most of the technologies promoted by EE programs (e.g., lighting, air conditioning) work during peak demand hours, typically hot summer afternoons in most United States, they reduce the system peak [16].

In the study by K. Wohlfarth, E. Worrell, W. Eichhammer, the two types of measures have been compared: EE and DR about the dissemination of the actions taken and the possible driving factors and obstacles that affect adoption, trying to outline recommendations to promote the measures more effectively and synergistically.

The results of a survey of more than 1500 companies in the service sector in Germany and some on policy research aimed at promoting EE and how these could also complement the promotion of DR were analysed using logistic regression models to evaluate and compare influence factors.

The results show that EE measurements are much more prevalent than DR measures, while most factors influencing both are comparable. In the future, more information and standardisation will undoubtedly be needed to make the most of the potential to respond to demand. As a starting point, we could assume that the tools and policies that have been applied to EE measures could also be used to promote DR. In particular, tools such as EE networks could be redesigned to include DR. The same applies to other established and effective regulatory instruments such as energy audits, which could be enhanced by adding the answer to this issue. In synergy with the existing EE policy, the integration and promotion of DR measures could be opted for.

A sustainable energy system must involve both EE and DR. Analysis of the surveyed data revealed comparable factors influencing the intention to implement EE or DR. However, DR is much less well known; only 4% of the companies included in the sample were familiar with DR compared to 48% in the case of EE [17]. The information relating to the building refers to the energy characteristics of the building. As for the building and its DR potential as a whole and the intelligence indicator, this type of information can also be used to assess the potential of DR.

Tools combining information with regulatory measures aim to systematically provide the necessary background to encourage their implementation, namely smart metering of energy consumption and the obligation to audit energy. Both can be used to provide helpful information about DR options. These aspects could be easily integrated into existing EE policy instruments.

1.2 Experience and view of sister project

This subsection summarises the results of the collaboration of ongoing H2020 projects and propose ways to incorporate DR into the SENSEI model by analysing the business model implemented in the NOVICE, and AMBIENCE FRESCO projects.

It has been observed that to allow the large-scale integration of renewable energies, with the aim of proceeding with the decarbonisation of electricity systems without endangering the security of supply, it is necessary to guarantee greater flexibility on the demand side through appropriate DR programs. Therefore, it is essential to distinguish between explicit and implicit DR.

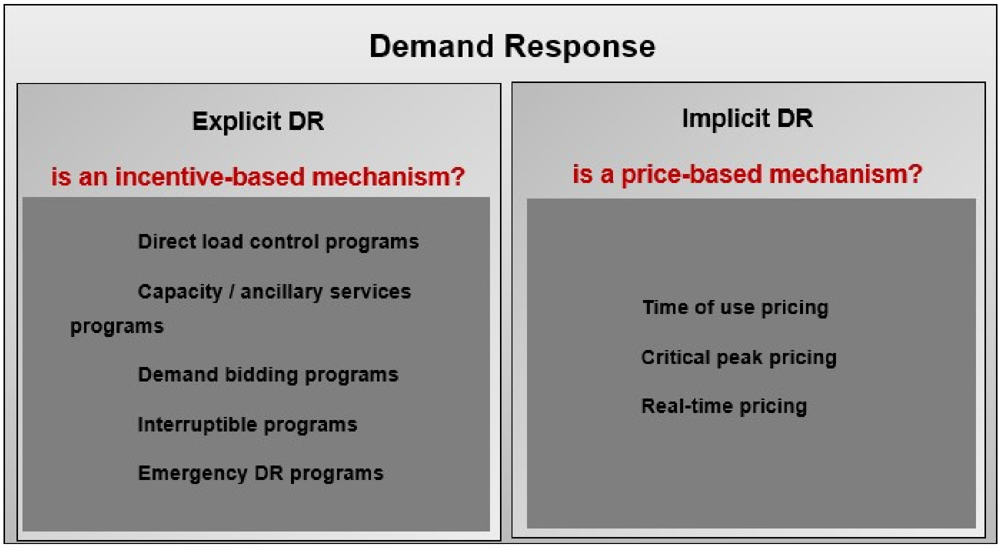


Figure 3 - Concepts of implicit and explicit DR programs

Implicit DR (also called "price-based") is, in fact, a Demand Side Management (DSM) service. It refers to consumers choosing to be exposed to time-varying electricity prices that reflect the value and cost of electricity in different periods. On the basis of this piece of information, consumers can decide – or automate the decision – to shift their electricity consumption away from times of high prices, thereby reducing their energy bill. Time-varying prices are offered by electricity suppliers and can range from simple day and night prices to highly dynamic prices based on hourly wholesale prices. Examples include time-of-use pricing, critical peak pricing, and real-time pricing.

In the explicit DR (also called "incentive-based"), the aggregate load is traded in electricity markets with similar supply-side services and obtains the same prices. Usually, this happens within balancing markets; consumers receive direct payments to change their consumption due to a request, which is typically triggered by the activation of balancing services, differences in electricity prices or a constraint on the grid. Consumers can gain from their flexibility in electricity consumption and support the system, as shown in Figure 4.

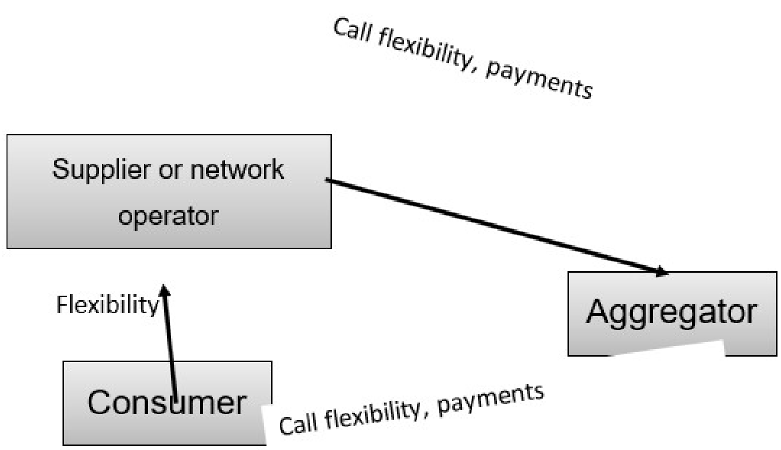


Figure 4 - *Explicit DR program*

Consumers receive an income on committed flexibility in order to change their consumption upon request. The high prices of electricity or a constraint on the grid (such as interruptions in the grid line or investments in new lines that the system operator wants to avoid) are the causes that can trigger this type of request. If the request for flexibility is not complied with, the user will pay a fine. The requests by the Operator System for a remodulation in order to go up or down can also take place for other reasons that have nothing to do with the reduction of CO_2.

1.2.1 NOVICE PROJECT

The project's primary mission is to develop and demonstrate an innovative business model for energy service companies (ESCOs) that will provide energy savings to buildings and DR services to the grid after renovating buildings or building blocks. The NOVICE dual services model adds a DR component to the traditional EPC utilising the implicit DR.

The NOVICE project implements the dual EE/DR scheme in non-residential buildings. In addition, a dual revenue stream can reduce the payback period for investments in buildings renovations and accelerate the much-needed market uptake of the P4P based financing model. Figure 5 shows the combined model that provides new dynamics between market players.

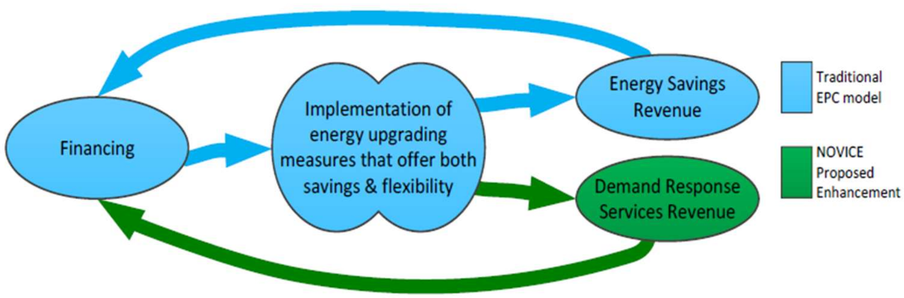


Figure 5: *NOVICE proposed the new EPC model;* Source: Deliverable No. D1.4 Final Report.

Electricity data employed in the project was provided by a local aggregator who used it, together with the energy resource data of the site. This was done to determine which DR programs the site could participate in, and to estimate the potential annual revenues. The aggregator identified that the HVAC and refrigeration equipment found at a supermarket could be used in programmes requiring fast response time and short duration. In contrast, the on-site backup generator can provide flexibility for more extended duration events. It was estimated that by participating in the combination of DR programmes recommended by the aggregator, the pilot project, that had originally developed for a supermarket, could further generate €13,000 a year of additional revenues. Figure 6 presents the result of the analysis in the Novice Project regarding the impact of demand response.

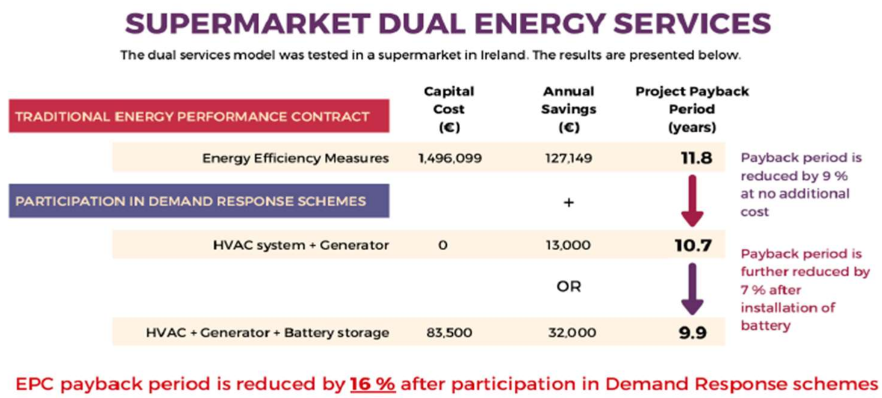


Figure 6. *Effect of DR services on the payback period of traditional EPC Source: Deliverable No. D1.4 Final Report.*

It was found that the overall project payback period reduces from 11.8 years to 10.7 years simply by selling the site's flexibility to the electricity grid. This equates to a 9.3% improvement in the payback period by combining.

In this case, EE with the DR is compared to EE alone. This decrease in project length comes at no additional cost to the building owner. It uses the assets already installed in the building, and the aggregators usually provide the DR equipment at no charge.

1.2.2 AMBIENCE PROJECT

The project's mission is to improve the economic attractiveness of building emission reduction measures by combining EE improvements with electrification and active control. In this way, the EPC Active Building concept applies to a wider range of residential buildings and develops a tool to support DR value flow forecasting in the EPC trading phase.

Actively Managed Buildings with Energy Performance Contracting (Ambience) - is an H2020 project that aims to extend the concept of energy performance contracting (EPC) for active building and make the model available and attractive to a broader range of building typologies Figure 7. In the generic Active Building EPC (AEPC) Business Model, an ESCO delivers an AEPC service consisting of guaranteed energy cost savings based on EE and (renewable) energy supply measures and active control of flexibility of an end customer. In the case of classic EPC, energy savings (kWh) are guaranteed and are typically multiplied by a contractually agreed (average) energy price. This is done for each energy vector (electricity, gas, fuel, etc.). However, in the case of AEPC, because of the more dynamic pricing, the business model is about providing cost savings. These cost savings will come partially from EE and partially from flexibility. In the AEPC contract, the new features added include flexibility and DR in the contract; therefore, they provide guarantees of savings on energy costs which is the standard guarantee in EPCs.

Cost saving is a result of implementing implicit and explicit DR services. By integrating DR in the Ambience contract, the ESCO assumes a more active role in contract management. The ESCO will have to be responsible for providing the means for the customer to trade flexibility on the market based on the existing technical possibilities and on what the customer is willing to accommodate. This means that the ESCO is responsible for providing the algorithm and automation to govern the DR. Then, the customer acts on the market via an aggregator responsible for sharing the profits obtained. In conclusion, the ESCO could mainly act either as an actuator or an aggregator in what DR is concerned, depending on how this service is offered.

Figure 7: The new EPC model proposed by AMBIENCE

1.2.3 FRESCO PROJECT

The frESCO project introduces the deployment of innovative business strategies based on novel energy and integrated energy service bundles that properly combine and remunerate local flexibility as energy savings and demand-side management. Such new business models will extend the traditional EPC contracts to novel Pay for Performance Contracts by offering specific energy service bundles to potential consumers and/or prosumers, as shown in Figure 8.

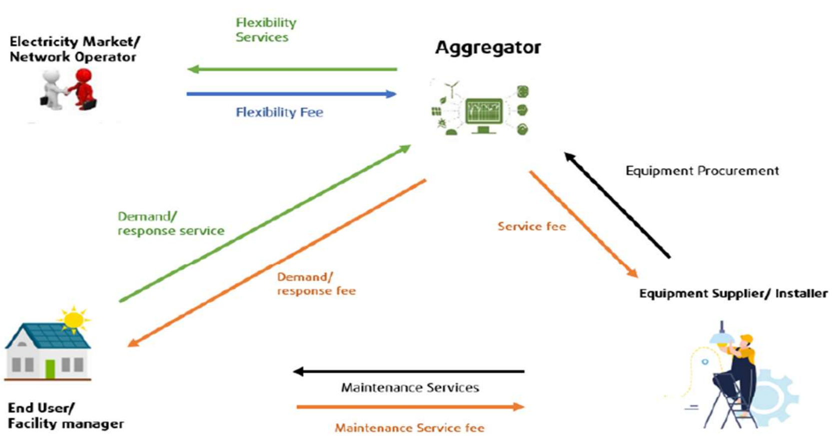


Figure 8: *The Aggregator BM proposed by frESCO*

The frESCO energy service portfolio is divided into four main groups. One of them is the Demand flexibility services. These services enable users to participate in DR markets to provide flexible services to a grid operator and get paid for it. The expected outcome is revenue coming from the aggregated flexibility supply to the grid. This set of services is dedicated to extracting the flexibility of demand from domestic users and is used in network management in two ways:

a) balancing services to DSOs, TSOs and BRPs,

b) grid congestion management to alleviate transport and distribution congestion problems at local and global levels and avoid costly grid expansion investments and storage systems to accommodate an increasing amount of renewable energy sources with high generation uncertainty.

In the frESCO model, the flexibility services are expected to provide indirect revenues to the consumer. The Aggregator represents the consumer in the markets, aggregates the required flexibility, handles all transactions with the grid or market operators and is the initial beneficiary of the compensation. On a second level, the aggregator shares the benefit with the consumer according to the proportion stated in the contract. In this case, flexibility services with implicit and explicit DR are considered as a single service in the frESCO Project. The DR is used as a whole by the aggregator to be able to take full advantage by buying and selling energy and providing direct services.

1.2.4 SENSEI DR view

As it is well known, decarbonization of electric systems requires care so as not to jeopardize the safety of the electric system. To do this, we need to provide greater demand-side flexibility through appropriate DR programs' needs.

DR service can be either explicit or implicit. In explicit (incentive-based) DR programs, the aggregate load is traded in dispatch service markets operated by the electric system operator, along with similar supply-side services, and receives the same prices. Consumers receive direct payments to change their consumption as a result of demand, which is typically triggered by the activation of balancing services or violation of one or more constraints on the grid. Consumers can take advantage of their flexibility in electricity consumption individually or by contracting through an aggregator.

In implicit (price-based) DR schemes, consumers who have chosen to be exposed to time-varying electricity prices or grid tariffs (or both) react to these price differences according to their possibilities and constraints without a binding commitment.

The aspect that best distinguishes the SENSEI Project from its sister projects is precisely the type of DR service used. The other projects, in fact, have focused more on addressing the implicit DR service, where energy costs are optimised with benefits for the energy supplier and the customer.

SENSEI aims to gain an advantage from the interaction between explicit DR services and their remuneration with EEs in P4P contracts.

Implicit DR services are easier to integrate into classic EPC contracts as they are remunerated with a lower energy price. In particular, they do not conflict with the results obtained from EE interventions. On the other hand, in the SENSEI model, the implicit DR is already taken into account in the P4P contract. At the same time, the explicit DR can go against the EE intervention. To avoid running into this problem and for the sake of better clarification, it is necessary to evaluate the interplay between EE interventions and DR to understand how much DR can be made available to the system when actually required and its remuneration.

In SENSEI, the figure of the EE aggregator is central as it has the task of promoting EEM and managing the benefits associated with making attractive investments in the EE of multiple buildings.

The role of the aggregator in DR services, is also fundamental. It is a versatile actor as it can provide both demand and generation flexibility with a customer portfolio composed of consumers and producers.

These two aggregators perform complementary services. In section 3.1, the integration of EE and DR aggregators in a single figure that performs both functions have been proposed, these will be called Energy Flexibility Aggregator (EFA);

In order to include DR management concurrently with a P4P contract handled by EFA, it is necessary to:

A. **Study quantitative methods to evaluate the interplay between EE interventions and DR**

B. **Modify the business model scheme to include the possibility of participating in the dispatching services markets.**

2. Methodologies to evaluate the DR performance in building after implementing energy efficiency measures

From the analysis carried out in the previous section, it is clear that to assess the interdependence between DR and energy EE, it is necessary to adopt quantitative methods based on real or simulated results in real-life contexts. So, considering the types and locations of users and system requests, tools will be developed that can evaluate how an EE influences the availability of DR resources requested by the dispatching manager.
For this purpose, two tools have been developed, the first, described in paragraph 2.1 below, a is web app through which, by utilising the results obtained from simulated or real pilots, it is possible to evaluate the SRI efficiency index and also the so-called DR index related to demand response, in order to obtain a measure of the interplay value between EE and DR.
Paragraph 2.2 describes the second evaluation tool through which it is possible to simultaneously evaluate the performance in terms of EE and DR results, starting from the pre-and post-intervention load profiles of energy efficiency. The evaluation in terms of EE is done by measuring the CO2 saved, and the DR is evaluated in terms of energy available for the DR. The advantages in terms of the electrical system's reliability were also included by estimating the variation of the quantity of energy in critical hours, as at the final aim is to include DR service in P4P contract.

2.1 SRI-DR based evaluation

Given the difficulty of establishing the relationships and interactions between EE and DR, and also because the evaluation of the interaction between the two is based on data-driven information, appropriate tools are needed.
Therefore, the goal is to collect data through the web app created from relevant ongoing H2020 projects, experiments present in pilot projects, other demonstrations, etc. which foresee and carry out interventions of EE and DR at the same time in order to obtain a measure of the interplay value between EE and DR.
Figure 9 shows the web- app interface, which can be found at the following link http://93.67.178.74:4300.

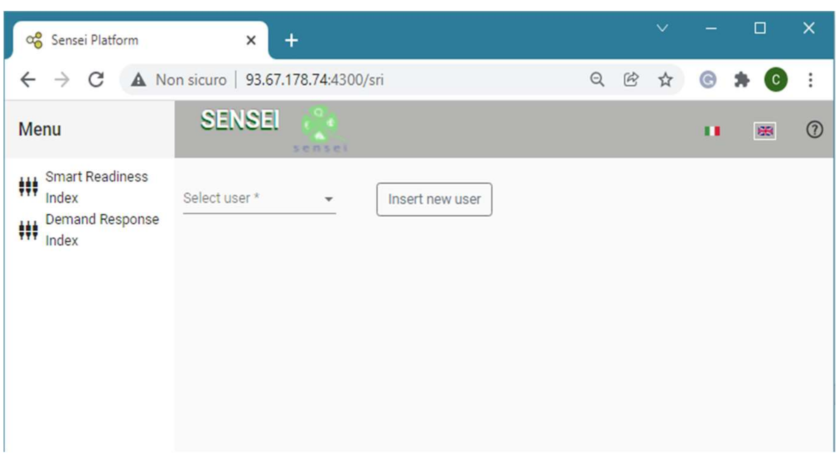


Figure 9: *The Web App interface*

The purpose is to allow relevant ongoing pilot Projects to use this service and contribute to the SENSEI discussion on the interplay between P4P and DR incentives. Through this approach, a service to evaluate the impact in terms of DR in consequence of EE has been developed.

The Web app was created to collect data referring to the SRI and DR for each pilot, which can quickly calculate and share the Smartness Readiness Indicator and DR assessments and the resulting revenues from providing flexible services.

It is a tool that allows us to investigate interventions carried out in the field to give a measure of the value of the existing interplay between EE and DR, establishing a relationship based on the intervention of EE and allowing us to say how much DR managed to was able to provide based on EE's intervention. All excel files, development services and calculation methodology of the SRI index have been provided by OFFIS. Also, we considered the information and results reported in Deliverable D5.1 of the Sensei Project about the Selected buildings, SRI and comfort assessments.

This data collection can be helpful as it can be used to evaluate the interplay and, consequently, the relationship between DR and EE interventions more simply and directly.

In practice, two indicators are used in the web app:

1. SRI indicator related to EE intervention
2. DR index that can evaluate the performance of the building in terms of DR.

2.1.a SRI Definition

Implementing one or more so-called EEMs is necessary to increase the share of renewable energy and improve energy flexibility. Some examples of EE interventions concern installing photovoltaic systems, storage, thermal insulation, heat pumps, etc., as well as interventions for the building's cooling and heating. Among the various methods to estimate the level of energy efficiency, the European Commission has introduced the "Smartness Readiness Indicator" (SRI). The SRI index directive was presented in June 2018 with the specific EU Directive 844 (EPBD).

This directive favours the most effective use of smart technologies, allows saving energy in building management without sacrificing comfort, and also introduce an optional standard system for the Member States to create the directive on buildings on "smartness", with the ability to improve EE and overall performance with an integrated view. In recent years, interest in the term "intelligent building" has also grown in Europe, to the point of developing a related indicator to measure the intelligence of the building. This task is entrusted to the SRI indicator. The term had already been used in the United States in the 1980s to indicate a facility equipped with sophisticated telecommunication and interconnection systems that provided shared services to its users. This growing interest in innovative technologies that will result in significant and cost-effective energy savings, improving occupant comfort and satisfaction by enabling buildings to play a crucial role in smart energy systems, is expected to increase. SRI introduces building automation systems for calculating efficiency; the more significant the automation, the greater the flexibility, and the greater the efficiency.

SRI assesses the "smartness" of buildings and it is an indicator of the buildings' predisposition to interact with intelligent systems. Intelligent technologies allow significant energy savings in facilities management without sacrificing comfort.

Occupants, owners, and investors of existing and planned buildings directly benefit from this valuable information on potential improvements. Thus, the SRI is designed for a wide range of stakeholders.

In the SRI calculation methodology, the overall score describes the average of three scores in the impact category. These are the average scores of the respective impact criteria. Thus, seven criteria are divided between categories, as shown in Figure 10.

The services in the building service catalogue translate into different impacts related to the three key functionalities, namely the energy performance of the building, the building users and the energy grid. Below, is a description of the seven impact criteria identified as pillars for calculating the SRI index.

1. **Energy savings** refers to the impacts of smart ready services on energy-saving capabilities. It is not the whole energy performance of buildings that is considered, rather only the contribution made to this by smart ready technologies, e.g. energy savings resulting from better control of room temperature settings.

2. **Maintenance and fault prediction** Automated fault detection and diagnosis have the potential to improve the maintenance and operation of the TBS significantly. It also has potential impacts on the energy performance of TBSs by detecting and diagnosing inefficient operations.

3. **Comfort** refers to the impacts of services on occupants' comfort, being the conscious and unconscious perception of the physical environment, including thermal comfort, acoustic comfort and visual performance.

4. **Convenience** refers to services' impacts on occupants' convenience, i.e. the extent to which services "make life easier" for the occupant, such as by requiring fewer manual interactions to control the TBS.

5. **Information to occupants** refers to the impacts of services on the provision of information on a building's operation to occupants.

6. **Health and well-being** refer to the impacts of services on the well-being and health of occupants. Not being harmful in this respect is a strict boundary condition required of all services included in the SRI assessment.

7. **Energy flexibility and storage** refer to the impact of services on the energy flexibility potential of a building. The former acknowledges services that provide either demand-side flexibility (the ability to shift loads in time) or the ability to store energy, with a clear focus on the advantages of the energy grid. The latter also rewards services that allow for energy storage, but from a user perspective. The focus is shifted towards providing more autonomy regarding the security of supply. It can be argued that autonomy should be seen as a convenience for the occupant (e.g. guaranteed continuity in energy provision).

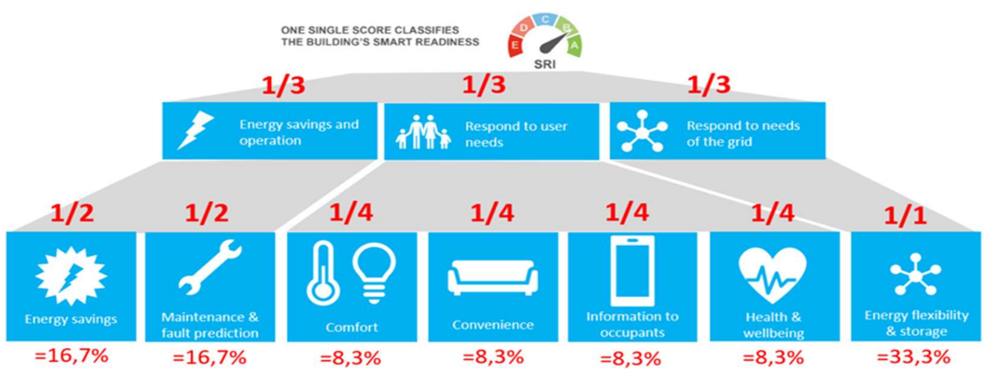


Figure 10: *Composition of impact criteria and impact categories based on SRI score*

Each criterion score is calculated by combining a weighted sum of nine domain scores. The percentage distribution depends on which of the three impact categories the criterion falls, see Figure 11. While most of the percentage contributions are constant, some are preferably determined by an Energy Balance Method, setting the weights of the domains to their relative share of the building's energy consumption.

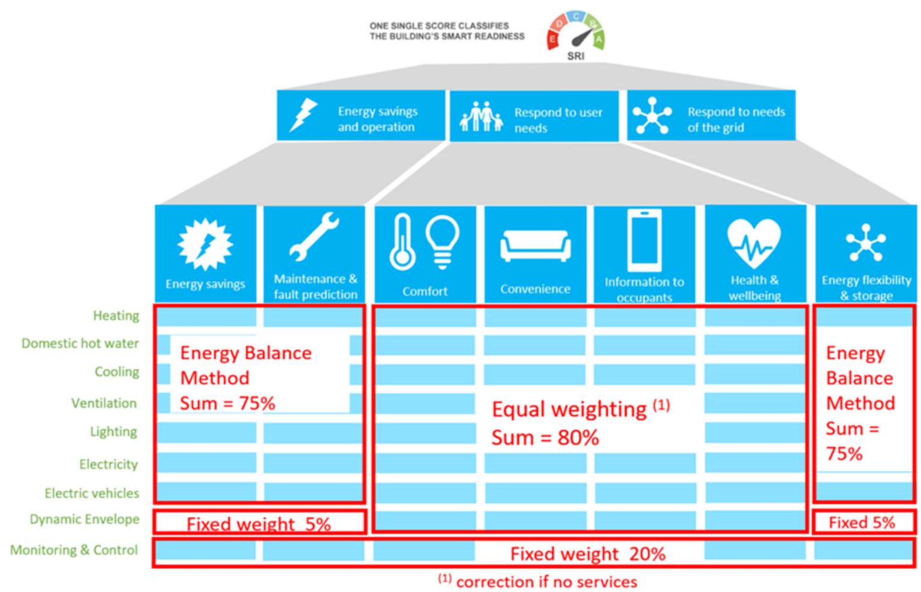


Figure 11: *The SRI domain weighting by impact criterion*

The reference catalogue of all intelligent services considered by the SRI consortium is the primary resource of the SRI assessment, providing guidance descriptions of requirements for individual layers. Unnecessary or unrealistic smart services for the building considered will be ignored so that only the relevant services contribute to the SRI score of the building. Services not yet implemented but desirable will be placed at level 0, and the total number of levels varies among the different services.

Content-related breakdowns will be briefly described to better understand structured calculations and detailed results. Starting from the impact categories, "energy-saving and operation" relates to the financial aspects more directly.

Besides, the homonymous impact criterion of "energy-saving" also includes "Maintenance and fault prediction." The impact category "Respond to user needs" covers more social aspects, such as "Comfort," "Convenience," "Information to occupants," and "Health and well-being." Finally, the category "Responding to the needs of the network" addresses the interaction with the energy environment of the building. It consists only of the impact criteria "Energy flexibility and storage" and prominently emphasises services related to demand management.

On the domain side, "Heating", "Cooling", "ACS", "Controlled Ventilation", "Lighting", "Electricity Generation" and "Electric Vehicle Charging" are, for the most part, self-explanatory. "Monitoring and control" include what feedback on energy consumption is communicated and how much overall coordination of equipment takes place (e.g., via BACS or BEMS and for DSM). Finally, the "Dynamic building envelope" is designated for the controllability of the windows of the building. In Figure 12, the SRI score on a coloured scale and critics' sub-scores that provide additional information about how "smart" the building is.

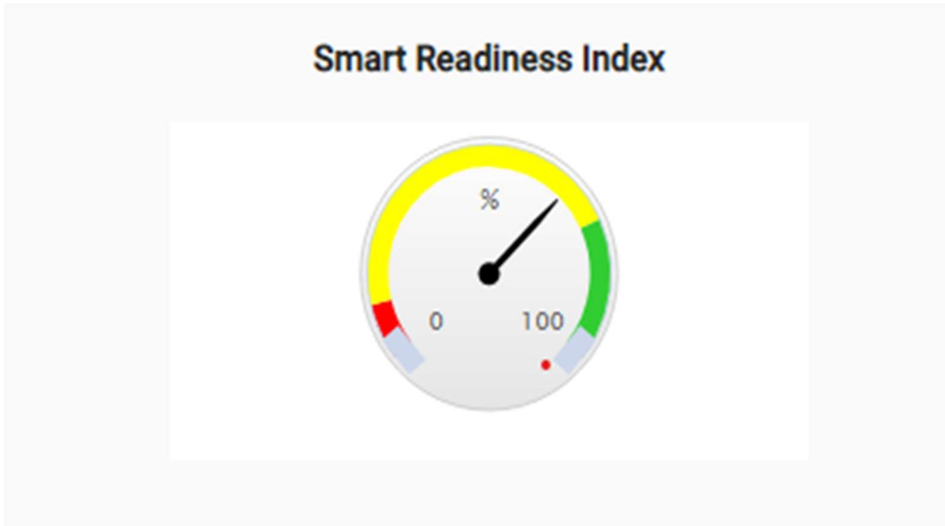


Figure 12. *The colourful scale indicating the final SRI score*

From the assessment perspective, in terms of SRI ascertainment, it is only necessary to:

1. Decide which smart services from the catalogue are suitable and worthwhile for the building under inspection.
2. Assign a functionality level to each selected service, judging by the indicators listed in the catalogue.
3. Acquire information about the building's yearly energy consumption by domain, if possible, to allow for relative rather than default domain weights in the pending calculation.

After that, the SRI score can be deterministically assessed, as written in the prior section.
Going into further detail in the catalogue, each service entry holds much additional information, such as classifying a group and prerequisites for inclusion. Especially useful when deciding which functionality level best describes the situation for the building is the section with comments and reference standards that are applicable. The usual scale of impact may serve as orientation when designing measures addressing common shortcomings in tested structures. The level indicators themselves are a good source of potential technological synergies in buildings as they name other services and specific installations. Many of the services are marked as an advanced assessment only for reasons such as being difficult to inspect or having a low impact.

2.1.b DR Index

Starting from the data provided by the SRI index, a new index for evaluating the performance of the building in terms of DR (DR Index) has been developed. Specifically, it expresses how close (or far) the building is to the highest performance in DR. The higher the result, the better response the building to the DR. The methodology for calculating this overall score is simple, with a bottom-up approach considering the weighted average of each impact category. The impact score is measured through the energy made available for the DR specific service as a percentage of the energy consumed in that domain. If there are no impact scores for a domain, the value sets to zero. The DR index score is the weighted sum of the two major impact categories: one for TSO, consisting of two impact criteria, and one for DSO, consisting of three impact criteria. For each impact category, the assignment of impact criteria as follows:

Impact criteria for the TSO:

- Frequency regulation – indicates the percentage of energy that the TSO requested.
- Energy reserve - indicates the percentage of energy reserve obtained after the intervention.

Impact criteria for DSO:

- Congestion reduction (service served at kWh) - measures the percentage of congestion reduction obtained for each domain.
- Voltage regulation (DSO) measures the percentual energy the DR displaces.
- Power peak reduction - measures the percentage of reduction that there is in the peak.

The methodology of calculation for the DR Index:

1. First, it evaluates ready smart services individually. Subsequently, the services available in the building are inspected, and their level of functionality is determined. For each service, this leads to an impact score for each of the five impact criteria indicating the percentage of Frequency regulation, Energy reserve, Congestion reduction, Voltage regulation, and Peak Power Reduction.

2. Once the impact scores for these individual services are known, an aggregate impact score is calculated for each of the nine smart-ready domains. This domain impact score is computed as the weighted sum of the individual scores of the services of the respective domain.

3. For each impact criterion, a total impact score is then calculated as the weighted sum of the domain's impact scores. In this calculation, the weight of a given domain will depend on its relative importance for the impact considered and assigns weights according to the relevant domains 'consumption distribution. For example, the single results of the domains Heating, Domestic hot water, Cooling, Controlled ventilation, Lighting, Electricity Generation, and Electric vehicle charging are sum weighted according to the amount of energy totalised by this domain multiplied by a fixed weight of 75%.

The two remaining domains, have a fixed weight of 5% for Dynamic Building Envelope and 20% for Monitoring and Control. The percentages introduced in these two domains are the result obtained in the SRI index relating to the "Flexibility and energy storage" impact criteria. These findings prominently emphasise services related to demand management. Furthermore, these results are considered data and are introduced as a percentage in the two domains for all impact criteria in the calculation of the DR index.

The following is the formula to be applied for each impact category score = $\frac{\Sigma \, of \; the \; impact \; criteria}{number \; of \; criteria}$

4. The DR index score is then derived as the weighted sum of the two total impact scores. Fixed weights are assigned for both impact categories: the TSO (Transmission System Operator) and the DSO (Distribution System Operator), with the sum weighted by 50 %.

$$\text{DR FORMULA} = \frac{\Sigma \, of \; the \; values \; obtained \; for \; the \; two \; inpact \; categories}{2}$$

2.1.b Example of SRI and DR Index Calculation using the Web App

Real-time simulations performed in a laboratory environment are essential to test and validate innovative services before applying them in the real field. Furthermore, the development of adequately configured real-time simulations allows emulating real-world scenarios and conditions to verify the impact of new technology on the overall system behaviour and assess benefits or potential drawbacks led by its implementation.

Through data from the FLEXMETER pilot project, which includes a set of offline simulations with simplified controlled appliances integrated with the DR. In the Turin residential pilot, between 30 and 50 residential users were provided with different devices able to detect energy consumption at higher sample rates. However, considering the Italian Regulatory constraints (Unbundling), these devices have been installed as Retailer devices providing only raw and not certified data (i.e. not suitable for billing purposes).

The considered grid is a portion of the distribution network in Turin, and it is composed of 20 nodes, 15 of which are connected to residential customers. The total number of households is approximately equally distributed among the nodes so that each node subtends between 20 and 28 customers. The size and the ratio of the MV/LV transformer in the upstream secondary substation are 250 kVA and 22/0.4 kV, respectively. For this scenario, daily power consumption profiles of the households were created using the load profile generator created in the FLEXMETER project. For each customer, a set of appliances in their house was extracted, taking into account user-defined percentages of diffusion of the appliance. For example, 100% of the customers have been assumed to own a fridge, whereas only 50% of the customers have been considered for a dishwasher. The overall power consumption profile is obtained as the aggregation of the single appliances' consumption, including a large set of devices such as a fridge, washing machine, dishwasher, microwave oven, TV, etc. In particular, in the performed simulations, the following appliances are considered smart devices shift able through DR policies: fridge, standalone freezer, washing machine, tumble dryer, dishwasher and electric water heater.

It is an intervention that involves the control of electrical appliances to reduce the load peaks in the network as much as possible. In particular, in the performed simulations, the following appliances are considered smart devices through DR policies.

The table below reports the data introduced in the web app for calculating the SRI and DR Index.

Surface: 3000 (in m^2)	**Energy consumption (in MWh)**
Room heating	0
Domestic hot water	271
Cooling	0
Controlled ventilation	0
Lighting	194
Electricity generation	3.035
Electric vehicle charging	0
Dynamic building envelope	0

Table 1. *Input data on energy consumption used to calculate the SRI and DR Index example.*

Below are all the services and their selected levels:

☑ hot water storage recharging system with integrated electric heat pump (Level 3) - Automatic charging control based on local availability of renewables or information from the electricity grid (DR, DSM)

☑ hot water storage recharging system by means of hot water generation (Level 3) - Automatic charging control based on signals from the district heating grid (DR, DSM)

☑ pump for sanitary water circulation (Level 2) - Demand-oriented control

☑ control of equipment's consumption demand of the (Level 1) - Domestic Hot Water production subject to Demand Side Management
For the **Lighting** service group, the following smart ready service was selected:

☑ control of the interior lighting system (Level 3) - Automatic detection (manual on / dimmed or auto-off)

For the **Electricity Generation Section** service group, the following smart ready service was selected:

☑ integration of smart appliances (Level 4) – Grid-based optimisation

For the **Building Section** service group, the following smart ready service was selected:

☑ control of opening and closing windows and doors with air conditioning system – (Level 0) - Manual operation or only fixed windows

For the **Monitoring and Control Section** service group, the following smart ready service was selected:

☑ control of the consumption demand of the equipment - Smart appliances or DHW subject to DSM control.

The following services were not taken into account: Cooling section, Room heating, Controlled ventilation, and Electric Vehicles section. After compiling the above data in the web app, has been obtained an SRI Index of 48 %.

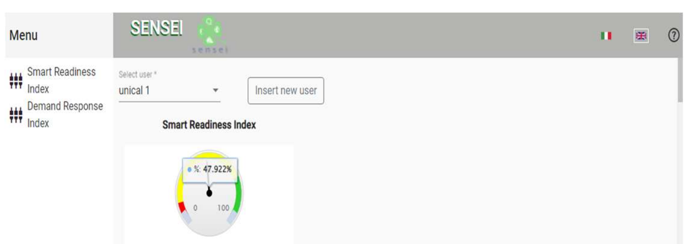


Figure 13. *The colourful scale in the Web app indicates the final SRI score.*

In order to proceed with the calculation of the DR index, the following data relating to DR from D6.4 were taken into consideration, see Table 15 - which discusses the flexible smart metering for multiple energy vectors with active prosumers in the Report on evaluation against defined metrics and scaling issues - FLEXMETER project.

Metrics	Reference Scenario	Scenario after DR
PMAX	480.0294 kW	471.8194 kW
Power Reduction Percentage	100.00%	98.29%
E-moved (Total Energy Moved)	0 kWh	90.3912 kWh

Table 2. *Metrics related to the DR from the FLEXMETER project.*

Based on the results previously obtained in the SRI index and considering the following values related to the DR from the FLEXMETER Project, it is possible to calculate the DR Index.

In addition, based on the result obtained in the SRI index for the impact criterion "Flexibility and Energy Storage" with a score of 33% for the Monitoring and Control domain, it is possible to calculate the DR index.

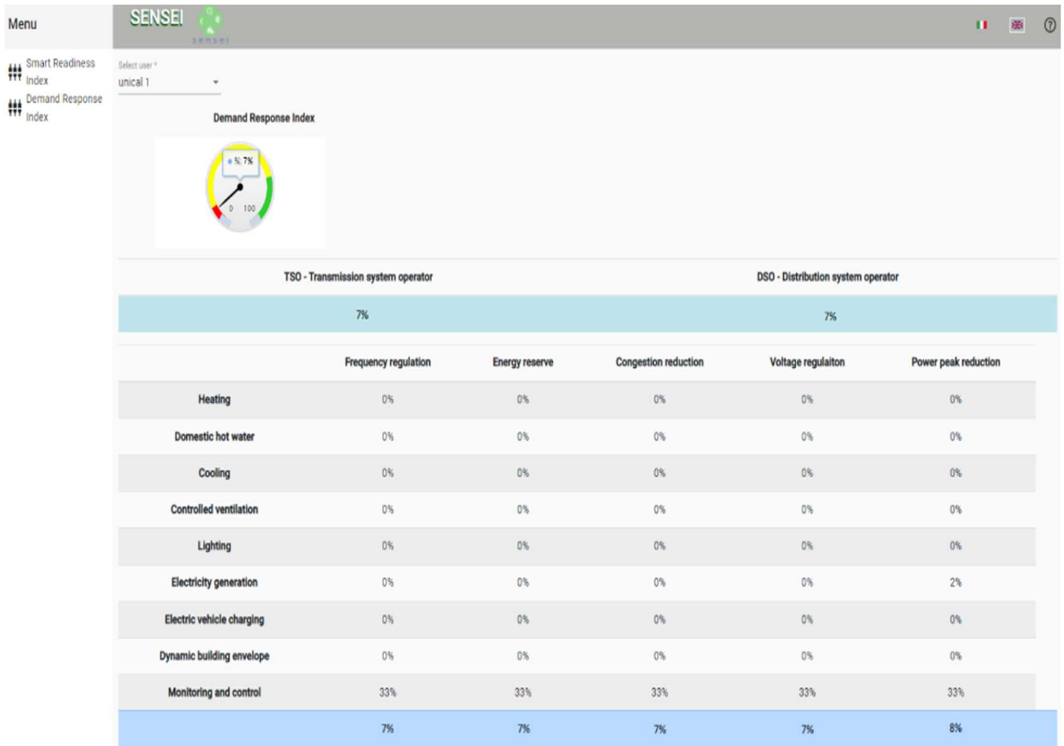
For the following impact criterion: ***Frequency Regulation, Energy Reserve, Congestion Reduction, Voltage Regulation***, obtaining the same result; Impact Criterion= (0.2*0.33) = 0.66 and representing 7%.

Therefore, lack of data for the other domains was set to zero because the percentage of 33% is only valid for the domain Monitoring and Control.

Knowing the amount of variation power from the reference profile, which is 100%, and the percentage of 98.29% for the profile after the intervention, a reduction in the power peaks that amounts to 1.71% (rounding up at 2%) is obtained.

So, calculating the impact criterion ***Power Peak Reduction*** also utilising this data = $\left[\frac{1.71*3035}{3500}\right]*0.75+(0.2*0.33)=0.011+0.66=0.077\ that\ is\ 8\%$**.**

Now, by proceeding with the calculations, a weighted sum for the impact category TSO and DSO equal to 7% is obtained. Finally, calculating the weighted sum of the two results obtained by the TSO and DSO, the DR index is 7%.



TSO - Transmission system operator	DSO - Distribution system operator
7%	7%

	Frequency regulation	Energy reserve	Congestion reduction	Voltage regulaiton	Power peak reduction
Heating	0%	0%	0%	0%	0%
Domestic hot water	0%	0%	0%	0%	0%
Cooling	0%	0%	0%	0%	0%
Controlled ventilation	0%	0%	0%	0%	0%
Lighting	0%	0%	0%	0%	0%
Electricity generation	0%	0%	0%	0%	2%
Electric vehicle charging	0%	0%	0%	0%	0%
Dynamic building envelope	0%	0%	0%	0%	0%
Monitoring and control	33%	33%	33%	33%	33%
	7%	7%	7%	7%	8%

Figure 14. The Web-app indicates the final DR Index score.

Based on EE's intervention on smart appliances, it can be said that 7% of DR was delivered. However, it is not easy to accurately assess the flexibility obtained from buildings accurately. This tool offers only a measure, not the accuracy of the value of the interplay between EE and DR.

2.3 Data-driven DR-EE interplay simulation

This paragraph considers a tool for the evaluation of the benefits of EEMs. It takes into account the characteristic load profile of the user, the composition of the national fuel mix in electricity production and the data of the electrical system, calculating the validity of energy efficiency interventions in terms of DR service, reliability of the electrical system and reduction of emissions. The methodology was tested in the Italian case scenario, considering the consumption profile measured in a reference year.

2.3.a Methodology

The proposed evaluation methodology uses the hourly profiles of the base users (before an EE intervention) and the measured profiles (after an EE intervention) as input data; it also employs the National Average Fuel Mix used for the production of the electricity fed into the electricity system, the number of annual peak hours estimated by the TSO, and the demand for availability terms of DR. Input concepts are briefly explained below:

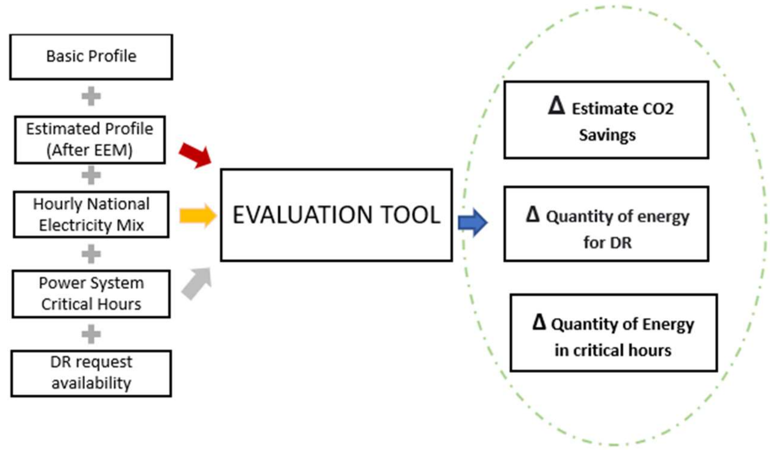


Figure 15. *Evaluation tool of energy efficiency*

- **A basic hourly profile:**

  This is a utility profile on which no EE interventions have been made;
- **A measured hourly profile:**

  This is a user profile on which EE interventions have been made;
- **The hourly National Energy Mix:**

  This is the set of primary energy sources used to produce the electricity that is subsequently fed into the national electric system for sale to the end-user.
- **The number of critical hours in the electric system:**

  The peak is defined as the set of the number of hours in the year where the probability of system inadequacy is greatest, i.e., the hours when there is a poor ability of the system to meet the demand for electricity within predetermined levels of safety and quality. The TSO determines them for the capacity market. In particular, therefore, adequacy assessments verify the ability of the Electricity System to cover the demand for electricity with the necessary reserve margins at all times during the period under consideration. For this reason, annual peak hours are identified as the hours with the lowest adequacy margin on a national basis for each calendar year.
- **DR demands from the electric system:**

  Reliable operation of the electric system requires a perfect balance between real-time supply and demand. This balance is not easy to achieve since both demand and supply levels can change rapidly and unexpectedly due to many reasons, such as forced outages of generating units, transmission and distribution line outages, and sudden changes in load. Electric system infrastructure is capital intensive; Demand-side response (load) is one of the cheapest resources available to operate the electric system.

After processing the listed data, the assessment tool will calculate:

1. CO2 emissions change as a result of EE interventions

In order to estimate social benefits, an estimate of CO2 savings will be made, taking into account the hourly energy production mix in the system

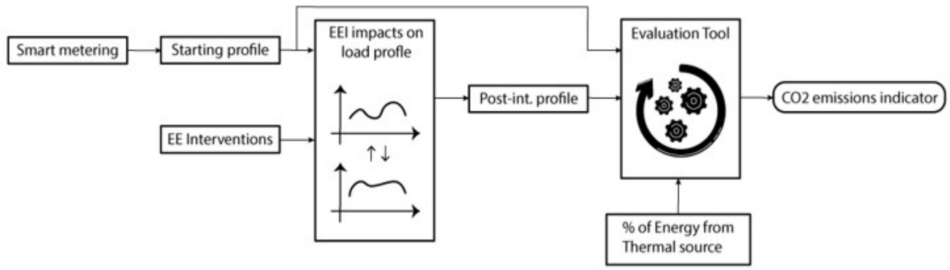


Figure 16. *CO2 change as a result of EE interventions*

2. Change in System Demanded Energy (DR) as a result of EE interventions

To estimate DR benefits, the amount of energy made available for DR service will be evaluated by considering the historical demands of the electric system.

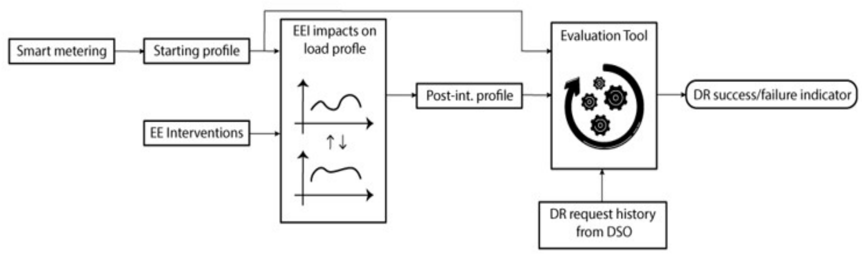


Figure 17. *Change in System Demanded Energy (DR) due to EE interventions*

3. Change in energy reflecting on critical hours after EE interventions

In order to estimate the benefits of the electric system, evaluating the difference in the amount of energy that occurs during critical hours after the EE intervention.

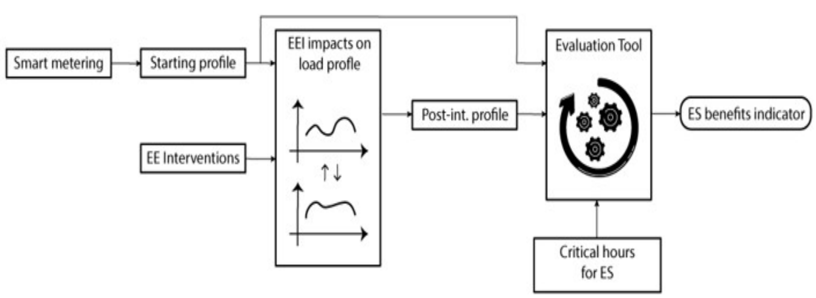


Figure 18. *Change in energy reflecting on critical hours after EE interventions*

2.3.b Italian dispatching market framework

The national blackout that left the whole of Italy in the dark on September 28, 2003, sparked a heated debate on the adequacy of Italy's energy production capacity and led to the enactment of Legislative Decree no. 379/03, which resulted in the launch of a system aimed at "guaranteeing an adequate level of electricity production capacity". In the meantime, the energy sectors in Italy and abroad have undergone major transformations: in particular, the considerable reduction in installed thermal energy capacity and the great development of non-programmable renewable energies have led to a chain reaction of effects at the source of the problem of energy production capacity. The ensuing debate led to the adoption in Italy - and earlier in other European countries (GB, Ireland, France, Poland) and non-European countries (USA) - of mechanisms to remunerate production capacity. The second half of 2019 represented a watershed. A ministerial decree of approval was first issued within six months, and then the final technical rule was published (after years of partial versions).

The mechanism came into force with the first call procedures. This sets of activities affected the entire electricity sector and ERG, in particular, and also made the Capacity Market the topic of the year: the term is now well known among those working in the energy world. In fact, the Capacity Market is a new market tool and is in addition to a series of other measures already in place, including, for example, DR Resolution 300/17 / R / eel of ARERA), or the possibility for end-users to access the market for dispatching services (MSD).

Demand Response, however, is designed to ensure the stability of the network in the short term, with the shedding of a load or the entry of a certain amount of energy into the system by a customer, who receives remuneration for this.

The "capacity market", on the other hand, was designed for a more extended period and to make programmable energy sources more competitive on the market; the latter, in fact, would otherwise find it difficult to remain operational, with the risk of being abandoned, thus increasing inadequacy beyond alert levels.

As already foreseen in the Integrated National Plan for Energy and Climate, the objective of the Capacity Market is "to direct investment choices, also in new capacity, coherently with the decarburisation process of the sector". Accordingly, remuneration is provided for all establishments that undertake to guarantee availability for energy production.

It appears to be clear how this mechanism arises from the need to guarantee the adequacy of the electrical system.

The decarbonisation of the electricity system is one of the main objectives of energy policies in Europe and even in Italy to achieve and create better environmental, social and economic sustainability. Because of a typical decarbonisation scenario such as the one outlined at the Italian level (Integrated Energy and Climate National Plan - PNIEC), it was estimated that in the electricity sector more than 55% of renewable sources will be reached by 2030. Programmable production capacity is increasingly essential with the role of backup to compensate for the fluctuations in electricity production from intermittent Renewable Energy Sources (RES) to guarantee the safety and constant coverage of the entire demand energy.[1]

[1] Note Capacity Market; EF 20 June 2019; Future Electricity. Italian Electricity Companies

Therefore, the Italian electricity market must evolve, on the one hand, to allow the increase in renewable electricity generation, and the phase-out of thermoelectric plants with the highest climate-altering impact, and – on the other – to meet the need for adequacy of the electricity system, with adequate price signals. The "capacity market" was born to integrate the energy markets to respond to this need.

Specifically, the Italian "capacity market" still represents a transitional mechanism (not by chance it was approved for a period of 10 years), given that in 2040/2050, the new technologies, starting from batteries, will guarantee the adequacy of the system.

According to the Ministry of Economic Development MISE, without the "capacity market", there would be an economic increase in the Italian electricity bills. The reasons would be the inadequacy of the system and less competition. In addition, the traditional plants would often remain obsolete, polluting and not very efficient, which would be used by Terna at prices higher than those expected in the presence of the capacity market.

With the capacity market, a lower wholesale market price is expected, without considering the environmental benefits of CO2 reduction and the limiting of the risk of power failure. Furthermore, without the Capacity Market mechanism, it is possible to achieve: lower ecological benefits in terms of reduction of emissions of CO2 and other pollutant and an increase in the number of hours of power failure risk with the connected costs related to non-supplied energy.

Let now consider the capacity mechanism specifically. First, it is described as an electric market scheme where holders of generation assets make a production capacity available for Terna through participation in auctions held by Terna, receiving remuneration in return.

The model provided by TERNA defines the objective of the adequacy of the national electricity system in terms of the objective value of the probability of power failure of the load (LOLE - Loss of Load Expectation).

The LOLE - Loss of Load Expectation – is one of the valuable indicators to measure the adequacy of the electrical system. It represents the number of hours per year when the load will probably be disconnected, caused by the electricity demand that exceeds the resources available to satisfy it, in other words, the disconnection of the load due to a lack of resources or transit capacity.

Terna monitors electricity flows in real-time, correcting input and withdrawal levels and balancing them. Then, if necessary, it send orders; at this stage the aggregator in the Dispatching Services Market comes into play in order to reduce or increase the energy fed into the network to the production units.

Terna is entrusted with assessing the adequacy of the capacity and monitoring the effects deriving from the entry into operation of the capacity market.

For a "capacity market" mechanism to be efficient and to guarantee the safe operation of the electricity grid, the following elements should be taken into account within the electricity market:

- System adequacy at an efficient cost thanks to competitive market mechanisms, acting as "insurance" towards extreme and expensive events such as blackouts;
- Consumer protection from volatility and substantial price spikes;
- Efficient medium-long term price signals to guide investment/divestment decisions in systems in line with the needs of the system;
- Reduction of overall costs in the Dispatching Services Market;
- Better coordination between network development and development of production capacity;

- Certainty of supporting the growth of the FER generation towards the decarbonisation objectives;
- An indispensable tool to target the coal phase-out to 2025;
- Participation of renewable sources, demand and imports consistent with the inclusive approach of the mechanism;

The Capacity market operates through a system of auctions: the plants participate in a system of auctions managed by Terna on a voluntary basis, providing a given production capacity. The plants that win the auction obtain “option” contracts and will be awarded a prize in € for each MW of power used. The auctions will determine the value of the euro prize awarded to the winners.

The auction phases are the following:

a) Mother Auction: main insolvency procedure;

b) Adjustment Auction: insolvency procedure aimed at adjusting the adequacy objectives as the delivery period approaches and allowing the renegotiation of positions taken by Market Participants;

c) Secondary Market: it is a market based on continuous trading every month, aimed at allowing the renegotiation of positions taken by market participants.

Insolvency procedures are configured as multisession auctions to go down to maximise the net value of the transactions on the entire system, in line with compliance with the transit limits between the Areas.

The request to participate must be submitted (50 days before the date of the first phase of the market) through the Terna portal; users requesting the production unit usually register on the portal by means of their own credentials. The request must be drawn according to the scheme provided by the decree and be signed by the legal representative, having the necessary powers to act as such. The requests is valid for all the subsequent phases and must only be resubmitted in the event of a change. Each applicant must present data and documentation for the production units following the provisions of Article 8. Terna must also verify the regularity and completeness of the requested documents and subsequently communicate the admission or refusal to candidates. Furthermore, Terna notifies candidates about the procedures necessary to complete the documentation within the set terms in case of data irregularity or incompleteness.

In the 60 days before the execution of each insolvency procedure, Terna publishes the following on its website:

- the subdivision into Areas and the relative transit limits;
- information on peak hours;
- the demand curves of each area;
- the indicative range of derating rates applied to the production units;
- the extra-derating factor for the UCMCs;
- information on the load factor;
- the percentile of accepted offers for sale on MSD and on MB.

At least 60 days before the Auction, Terna publishes the results on the assessment of and compliance with the regulation of the applicants’ documentation; in addition, it also publishes a report focussing on the adequacy analysis over a ten-year horizon. The technical provisions are submitted to the MISE, which then approves them. If no opinion is communicated within thirty days upon receipt of said documents, it shall be deemed approved. In the 15 days before the parent auction and six days before each secondary market session, Terna notifies each applicant of the qualified capacity values for each type of CDP. Finally, within the second working day before the execution of each parent or secondary market session, Terna communicates the admission or exclusion of the applicants.

MSD, in particular, is the instrument through which Terna S.p.A. procures the resources necessary to manage and control the system (resolution of intra-zonal congestion, creation of energy reserve, balancing in real-time). On the MSD, Terna acts as a central counterparty and the accepted offers are remunerated at a price presented (pay-as-bid).

Since energy is not a preservable or storable good, it is necessary that the quantity of energy produced is available continuously and that there is always a balance between supply and demand. Therefore, MSD can be defined as an innovative DR form that allows the user, through the aggregator, to choose whether to withdraw or sell, store or consume energy, based on the price of energy on the market.

The aggregator is the intermediary between the end-user and Terna, whose responsibility is to ensure the balance between the electricity supplied against the one withdrawn at any time.

Therefore, the objective is to guarantee the safe continuity of electricity supply. Specifically, the MSD is the Italian market that procures the resources necessary for the management and control of the system. It is divided into the ex-ante MSD for forwarding contracts and the Balancing Market (MB) for the intraday trade in power reserves. Both markets thus constitute a simplified model for the electricity market: the ex-ante MSD is comparable to the day-ahead market (MGP), the MB, instead, can be compared to the intraday market (MI).

Failure to participate in the Dispatching Service Market for the Capacity Market for the Dispatching Market would cause situations of inadequacy, less competition in the market, lower environmental benefits, and an increase in the number of hours at risk of power failure.

Industrial consumers can access the MSD by modulating their energy consumption to respond to electricity supply or demand peaks.

The ex-ante MSD and the MB work closely with the MGP and the MI in a fixed commercial scheme that is repeated every day. Thus, the transmission grid operator Terna intends to balance possible fluctuations and congestion in the network promptly and above all in the most economical way, particularly between north and south Italy.

The MSD ensures a stable electricity supply system in Italy by preparing power reserves. The transmission grid operator Terna uses these resources to balance any drops in the energy network that cannot be covered even following short-term negotiations on the Intra- Day Market (MI). Therefore, trade on the day-ahead market (MGP) and the intra-day market (MI) are interconnected by nature.

Under Article. 57 of the TIDME (Integrated Text of the Electricity Market Rules), the hours of the activities relating to the ex-ante MSD and MB sessions are defined in the Technical Rules (Operating Technical Provisions) following the provisions of the dispatching regulations.[2]

The ex-ante MSD is divided into six programming sub-phases: MSD1, MSD2, MSD3, MSD4, MSD5 and MSD6. On the ex-ante MSD, Terna accepts offers to buy and sell energy to resolve residual congestion and set up reserve margins.

The MB is divided into several sessions in which Terna selects offers referring to groups of hours on the same day in which the relative MB session is held. The MB is currently divided into six sessions. On MB, Terna accepts

[2] Integrated text of the electricity market regulation. D.M. 19/12/2003

offers to buy and sell energy to perform the secondary regulation service and maintain the balance, in real-time, between the input and output of energy on the network.

- Terna, in its capacity as manager of the national electricity system notifies the aggregator's need for a balancing order in case of grid stability problems.
- The aggregator, also known as BSP (Balance Service Provider), responsible for providing the service offered on the Dispatching Services Market, modulates the load/generation of MSD participants to increase or decrease energy use.
- Customers who make their flexibility available to the BSP implement modulation plans (manually or automatically).
- Customers receive remuneration for the modulation carried out.

In this way, a share of energy is made available to the network operator without ever interrupting production, thus optimising energy consumption and guaranteeing a sustainable profit. The conditions and requirements necessary for users' participation in the Dispatching Services Market - MSD are contained in chapter 4 of the Network Code issued by Terna.

2.3.c Italian Case

In the Italian context, Terna, is the TSO. Terna's Statistical Office, that is included in the Sistan (National Statistical System), is responsible by law for processing the official statistics of the entire national electricity sector and is therefore also responsible for our country's official statistical communications to international bodies such as Eurostat, IEA, OECD, UN [13].

The Market for Dispatching Services (DSM), in particular, is the instrument through which Terna procures the necessary resources to manage and control the system (intra-zonal congestion resolution, creation of energy reserves, real-time balancing). Terna, together with the Regulatory Authority for Energy Networks and Environment (ARERA), has started the process of gradually opening the DSM to small-scale demand, as well as programmable and non-programmable generation plants, and storage. Although being part of an experiment, pilot projects are, to all intents and purposes, true regulations that define the technical specifications and procedures which the new resources must comply with in order to provide services. In accordance with what is defined in Resolution 300/2017/R/eel, pilot projects provide for participation in the DSM as follows:

1) In single form for relevant production units (RUEs);

2) In aggregate form for mixed enabled virtual units (UVAMs).

UVAMs must be characterized by a modulable up- (increase in input or decrease in withdrawal) or down- (increase in withdrawal or decrease in input) capacity of at least 1 MW. The UVAM must be capable of sustaining modulation for at least 480 consecutive minutes.

As regards the procedure for forward procurement of UVAM, there are three annual products, such as: a) an annual afternoon product or with strike price equal to 200 €/MWh, b); an annual evening product with strike price equal to 400 €/MWh; and an annual evening product with strike price equal to 200 €/MWh. The range of hourly availability is shown in the table below:

Product	**Availability range**	**Price**
Afternoon	3 p.m. to 5:59 p.m.	200 €/MWh
Evening 1	6 p.m. to 9:59 p.m.	400 €/MWh
Evening 2	6 p.m. to 9:59 p.m.	200 €/MWh

Table 1 - UVAM availability range.

2.3.d Simulation Results

The test cases refer to an aggregation of users that implement specific EE interventions and participate in the UVAM project (Virtually Aggregated Mixed Units); by definition UVAM can be made up of a set of sites able to modulate their production and consumption of electricity through an aggregator, representing a virtual generation/consumption plant. In the test nine smart meters for real residential users located in the Calabria region, in southern Italy, were considered. The data collected were structured in hourly profiles covering the period from January 2020 to August 2020. Based on the data collected, two different aggregations were evaluated:

I. The number of first aggregation members – by assuming the same profile for all the members of the aggregation – was obtained by dividing 1 MW (amount of regulation contracted by UVAM with TERNA) by the average power of the considered profile.

II. The number of second aggregation member was obtained considering the average of 9 different users as a basic profile. Also, by means of this aggregation, the number of members was obtained by dividing 1 MW (amount of regulation contracted by UVAM with TERNA) by the average power of the considered profile.

As discussed above, the simulation considers three types of profiles:

1. **A Basic Profile** - Residential utilities use natural gas boilers in this profile;
2. **The heat pump (HP) profile** - involves an EE intervention that replaces the gas boiler with a heat pump;
3. **The profile HP + thermal insulation (TI)** - involves an EE intervention that replaces the gas boiler with the heat pump and also provides for the installation of a thermal coat.

Results were obtained by comparing the three profiles under three factors: the amount of change in energy made available in the DR, the amount of CO_2, and the change in the amount of energy at critical hours.

I. First aggregation

Below is a comparison before an EE intervention and after EE interventions: Fig.19 shows the differences between the baseline profile (blue colour) and the profile obtained after EEI for a single utility (orange colour) throughout the year. The assumed changes cause, as expected, an increase in load. This effect is most noticeable during the winter and summer months.

Importantly, after EE interventions, load shape is higher in some hours, increasing EE availability and encouraging greater participation in DR programs; in this case, EE and DR complement each other.

The Table 3 shows the results obtained, considering the single case.

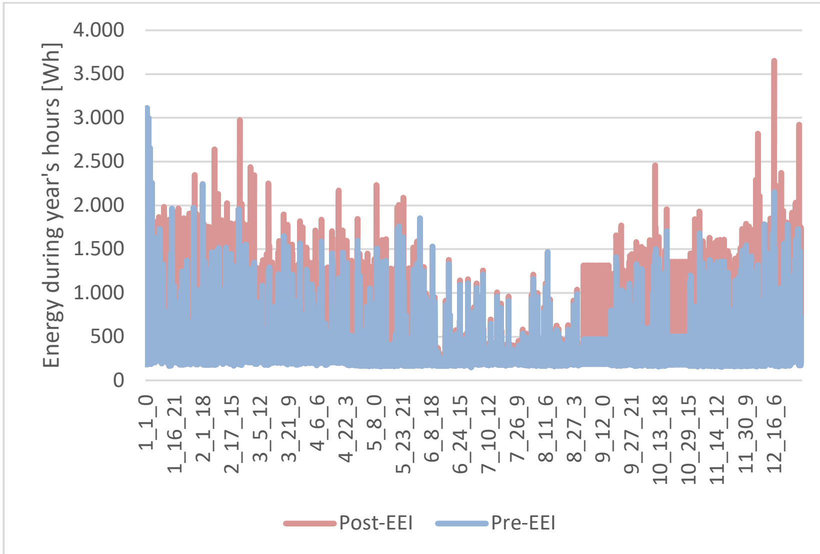


Fig.19 - Comparison of pre/post intervention (HP+TI): Load profile.

		BASE Profile	HP Profile	HP&TI Profile
DR	Nr. Successes	726	1306	1306
	Nr. Failures	974	394	394
	En. Successes (MW)	726	1306	1306
	En. Failures (MW)	974	394	394
	Remuneration Successes [€]	14769,97	23383,83	23383,83
	Remuneration Failures [€]	-148877,4	-62738,8	-62738,8
	Total remuneration [€]	-134107,43	-39354,97	-793965,93
CO2	Total tonnes CO2	10017	2600	2508
Critical hours	Nr. critical hours with higher load HP (max. 500)	-	442	419
	Tot. Higher load (MW)	-	471,5	240,2

Table 3. *Comparison of profiles under three factors: the amount of change in energy made available in the DR, the amount of CO2, and the change in the amount of energy during critical hours.*

Concerning the **first factor** related to the **energy made available in the DR**. It evaluates the profitably in participating in dispatching market. In the basic profile, no intervention of EE is made. However, since a contract is stipulated with the UVAM, upon request of the system operator, megawatts must be cut, consequently decreasing the amount of energy required from the electricity system. If this request is not respected, the aggregations pays a penalty.

- In the basic profile, the number of successes in providing this service is 726, i.e. significantly lower than the number of failures recorded, which amounts to 974. This data tells us that users are unable to provide this service. They participate in the DR but only record losses as the penalty is paid for failing to comply with the service provision stipulated through a contract with UVAM.
- Instead, after the EE intervention with the heat pump; the number of faults decreases, recording only 394 failures, and 1305 services were delivered with successes. In this case, with the heat pump, electricity consumption rises, so the availability given to the electrical system to cut the load is increased.
- It was also observed that the HP + TI profile, shows exactly the same data as the HP profile with 394 failures and 1305 successes in delivery. Therefore, the addition of the thermal insulation brings advantages in terms of EE but does not give any benefit in terms of DR because the load reduction may occur in time slots when the DR service is not required. Furthermore, it has no impact on the demand response, and that is why the two profiles record the same results.

For example, Figure 19 shows the January response of the aggregate to DR requests. In this graph, for each hour between 5 pm and 11 pm in January, a value can be either 1 or 0. The value is one of the aggregates that can respond positively to a 1MW load reduction DR request, otherwise it is 0. The figure shows the values before (in blue) and after (in orange) EEI. Before EEI, in some cases, the DR request is not met. Otherwise, after EEI, all requests are met during the month of January.

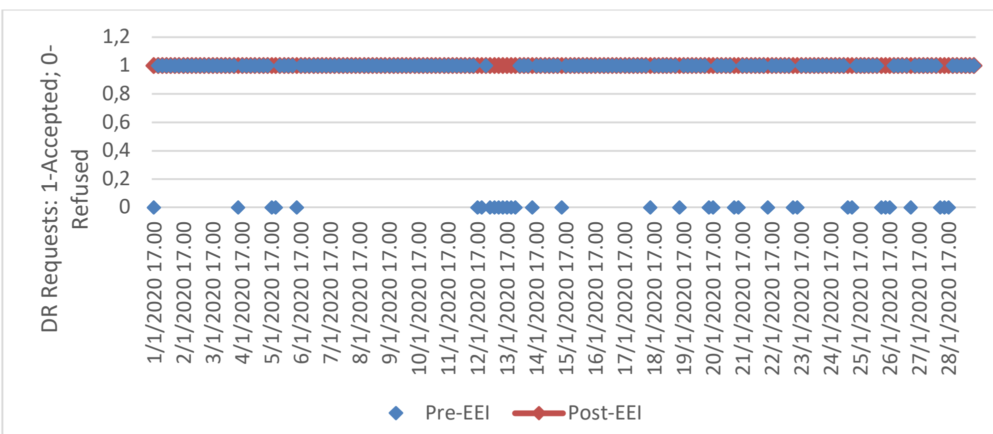


Fig.20 - Comparison of pre/post intervention (heat pump and external coat): Accepted (1) and refused (0) DR requests.

Fig. 21 is a good example to understand the differences in DR requests. These figures are focused on one day, the 30th of August, and the profiles pre and post EEI are considered. Curves in the first graph of the figure represent the basic profile (in blue) and the same profile after the load shedding (in orange). The profile post EEI (in blue) and the same profile after the load shedding (in orange) are reported in the second graph.

Focusing on the hours between 17.00 and 23.00 (DR hours), it is possible to notice important differences between the two cases. The area between the curves in both graphs is the energy provided for DR services. In the second graph, this energy is more than the basic case. Because of to the increased load caused by the EEI, the post EEI profile has a better response to the DR requests.

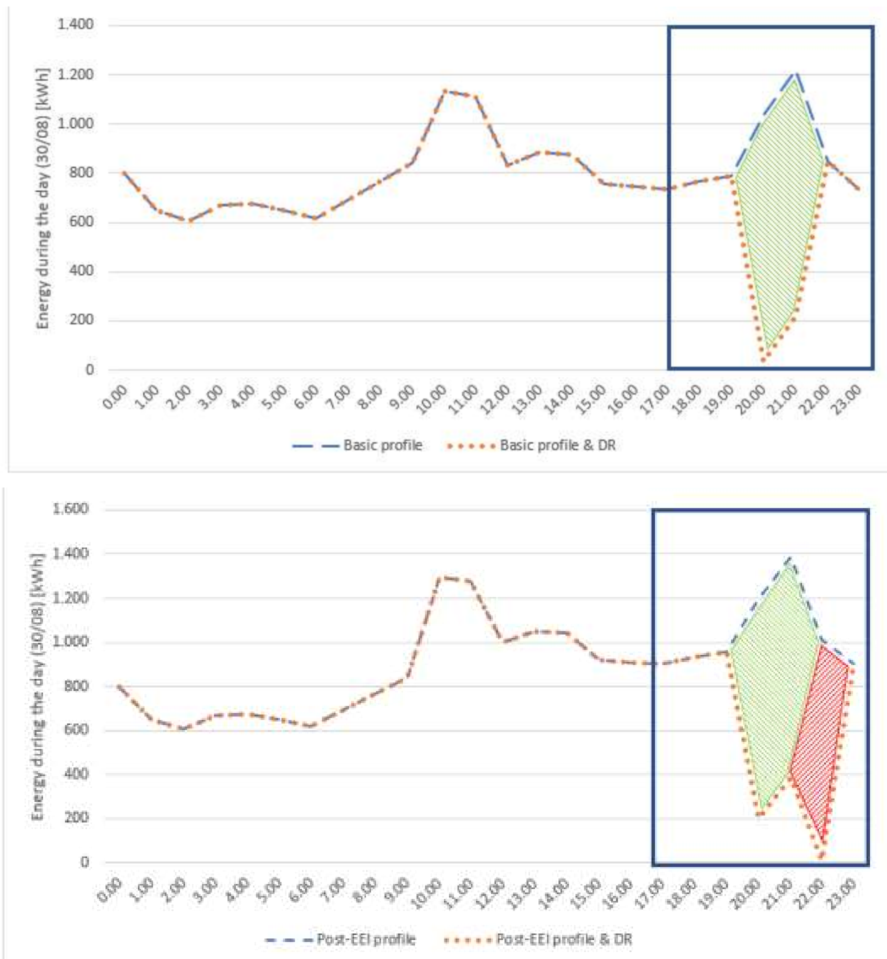


Fig.21 - Comparison of basic and post-EEI profile: DR requests (basic vs heat pump and external coat).

The second measured aspect is the efficiency of the interventions carried out by evaluating the **reduction of CO2 emissions** associated with the energy needs of this aggregation of users.

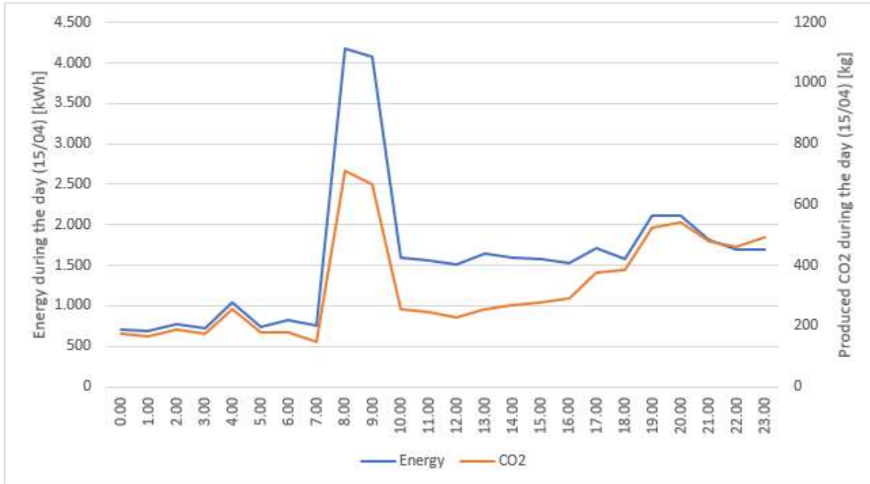


Fig.22 – Graph CO2 aggregate obtained by single user

A focus on the amount of CO2 produced on a single day (15/04) is shown in Fig. 22. The graph shows that the relationship between energy consumption and CO2 changes throughout the day. As expected in the middle of the day, the energy consumption is high but the CO2 produced is not so different from the morning hours when the energy consumption is very low. This is due to the energy produced by RES (especially photovoltaic systems). In the evening hours, when there is no more availability of renewable energy the energy consumption drops again but the CO2 produced remains high.

		BASE Profile	HP Profile	HP & TI Profile
CO2		10017	2600	2508

Table 4. *Comparison of the efficiency of the interventions carried out by evaluating the reduction of CO2 emissions associated with the energy needs of this aggregation of users*

The gas boiler is used in the base profile with no heat pump, and consequently, more methane is burned. Therefore, it is possible to calculate the total amount of CO2 inherent to the energy consumption, considering the thermal gas needs with the CO2 emissions and also considering the hourly basic profiles of users to observe the CO2 content of the hourly electricity that is absorbed and this means that obtaining a total of 10017 CO2 tonnes.

As a result of the EE intervention by replacing the gas boiler with the heat pump, there is a reduction in CO2 emissions. Therefore, there is an advantage in obtaining a total amount of 2600 tonnes of CO2 for the HP profile. Furthermore, by removing the consumption of methane, more electricity is used, which is absorbed according to the production mix of the electricity system. If the electricity system were 100% renewable, the emissions, in this case, would be zero. However, unfortunately, this does not happen as part of the energy of the electricity system comes from conventional sources; therefore, there is always CO2 emission.

Even more, it can be observed that by adding the thermal insulation, there is a more significant reduction of CO2, as less energy is consumed because there is less dispersion of electricity thanks to this EE improvement.

Consequently, for the HP+TI profile, obtaining a total quantity of tonnes of CO2 equal to 2508, which is lower than the value obtained from the previous profiles.

The **critical hours** are the **third aspect** that is evaluated, seeing the critical hours for the electrical system, hours in which there is a more significant load and therefore a greater risk to having a system blackout.

	BASE	**HP**	**HP & TI**
Nr. critical hours with higher load HP (max. 500)	-	**442**	**419**
Tot. Higher load (MW)	-	**471,5**	**420,2**

Table 5. *Comparison of critical hours compared to the base case*

Analysing the critical hours in the HP profile compared to the base profile, the number of DR related failures decreases, but the number of critical hours where we have higher load increase increases to 442.
Considering the HP+TI profile, the number of critical hours decreases to 419, so a benefit from the power system perspective can be observed.
Fig. 23 is a good example of the effect of EEI on critical hours. Critical hours were considered during the period between January 1 and January 20. As expected, with the installation of the heat pump, energy consumption increases even during critical hours. On the contrary, the energy consumption slightly decreases by adding the external coat for building insulation.

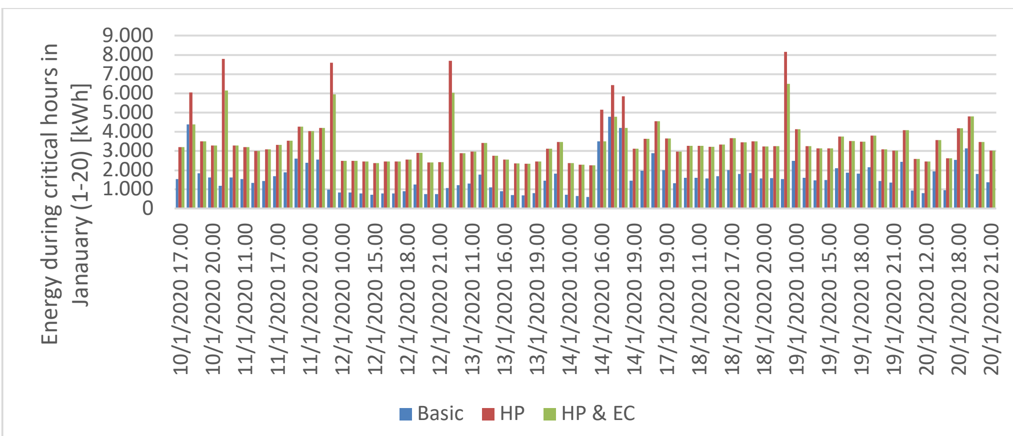


Fig.23 - Comparison of pre/post intervention: Critical hours on January 1st-20th.

I. Second Aggregation

Fig. 24 illustrates the differences between the baseline profile, in blue, and the profile after the EEI, in orange to the second aggregation. The assumed changes cause, as expected, a sharp increase in load that is most noticeable during the winter and summer months.

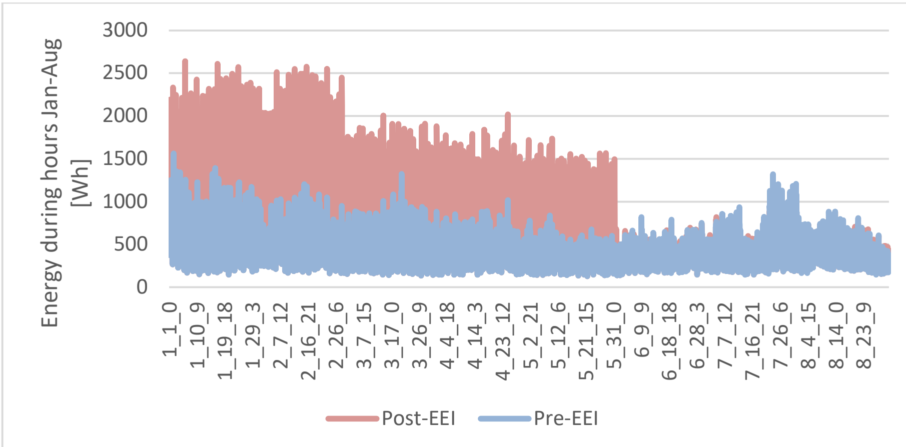


Fig.24 - Comparison of pre/post intervention (heat pump and external coat): Load profile.

Let us now analysed the effects of EE interventions on the aspects taken into consideration, listed in table 6.

		BASE Profile	HP Profile	HP&TI Profile
DR	Nr. Successes	911	1391	1385
	Nr. Failures	789	309	315
	En. Successes (MW)	911	1391	1385
	En. Failures (MW)	789	309	315
	Remuneration Successes [€]	18752,61	24964,2	24872,1
	Remuneration Failures [€]	-109051	-46935,1	-47856,1
	Total remuneration [€]	-90298,39	-21970,9	-793965,93
CO2	Total tonnes CO2	10008	2256	2125
Critical hours	Nr. critical hours with higher load HP (max. 500)	-	442	379
	Tot. Higher load (MW)	-	320	241,8

Table 6. *Average profile comparison*

Concerning the **first factor** related to the **energy made available in the DR**, it can be observed that:
In the HP case with the heat pump, the number of failures decreases compared to the basic profile, which translates into a more significant gain through the DR.
In HP+TI case the registered number of failures increases to 315 compared with 309 failures obtained for the HP profile. Therefore HP+TI respect to HP one reduces the availability of intervention in terms of DR (fig.24).
These results are different with respect to the previous aggregation and they demonstrate as the results strongly depend on the load profile considered.

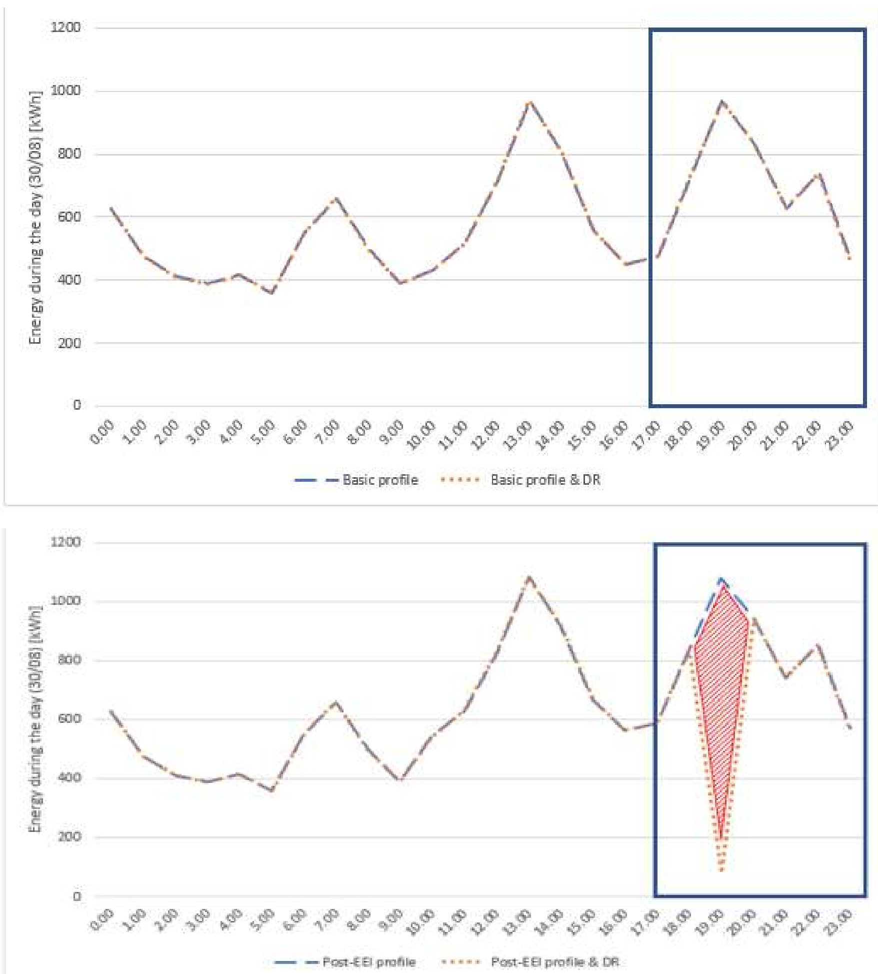


Fig.25 -Comparison of basic and post-eei profile: DR requests (basic vs HP+TI)

In conclusion, the loss in DR recorded in the HP+TI profile is recovered, in security terms, for the electrical system thanks to users' virtuous behaviour towards the system. All this is achieved by reducing the amount of energy required by the aggregation users following the intervention of EE so that the electricity system will have extra energy available during these critical hours. This service that is made available to the system by the aggregation may be valued by a P4P contract covering the losses due to the DR services (fig.26).

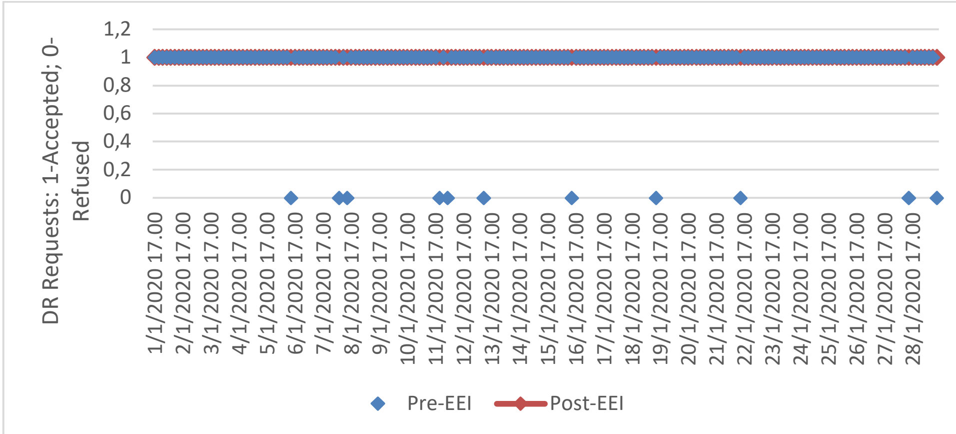


Fig.26 -Comparison of pre/post intervention (heat pump and external coat): Accepted (1) and refused (0) DR requests.

The **second aspect** is the efficiency of the interventions carried out by assessing the **reduction of CO2 emissions** associated with the energy needs of this aggregation of users.

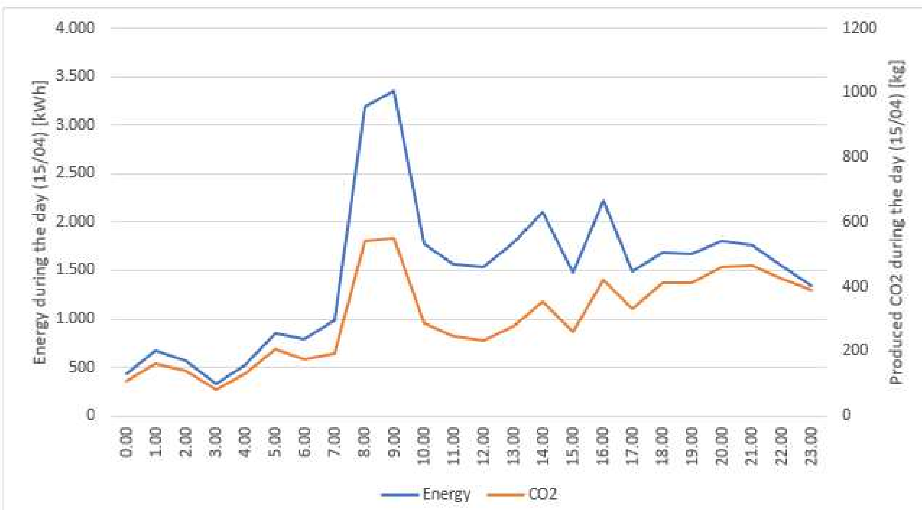


Fig.27 - Aggregate CO2 graph obtained from average users

A focus on CO2 produced on a single day (15/04) is shown in Fig. 27. From the graph, it can be seen that the relationship between energy consumption and CO2 changes throughout the day. As expected in the middle of the day the energy consumption is high, but the CO2 produced is not so different from the morning hours when the energy consumption is very low. This is due to the energy produced by RES (especially photovoltaic systems). In the evening hours, when there is no more availability of renewable energy the energy consumption drops again but the CO2 produced remains very high.

CO2	Total tonnes CO2	10008	2256	2125

Table 7. The Total tonnes of CO2 emissions obtained for each profile

The gas boiler is used in the base profile without a heat pump, and consequently, more methane is burned. So, it is possible to calculate the total amount of CO2 inherent in the energy consumption by considering the thermal gas demand with the CO2 emissions and considering the users' hourly base profiles to see the CO2 content of the hourly electricity that is absorbed. From this calculation, a total of 10008 tons of CO2 was obtained.

Following the HP intervention, a reduction in CO2 emissions was noticed. Therefore, the total amount of 2256 tons of CO2 produced an advantage for the second profile. In addition, by eliminating the consumption of methane, more electricity was used, which is absorbed according to the production mix of the electric system. Therefore, if the electrical system were 100% renewable, the emissions, in this case, would be zero. However, unfortunately, this is not the case because some of the power in the electric system comes from conventional sources. Therefore, there is always some CO2 emissions.

In HP+TI case there is a more significant reduction in CO2 since less energy is consumed because there is less electricity loss due to this EE improvement. As a result, the total amount of CO2 tons is 2125, lower than the value obtained from the previous profiles.

However, even if the profile is pejorative from this point of view, it recovers on the front of the critical hours with a significant advantage in terms of benefit for the electricity system security, recording only 379 critical hours compared with 442 hours registered for the second HP profile.

The third aspect is related to critical hours. Looking at the HP and HP&TI profiles, it can be seen the considerable benefit for the safety of the electric system, recording only 379 critical hours compared to 442 hours recorded for the second HP profile. In conclusion, the DR loss recorded for the HP+TI profile is recovered in terms of safety for the electric system.

Critical hours	Nr. critical hours with higher load HP (max. 500)	-	442	379
	Tot. Higher load (MW)	-	320	241,8

Table 8. Comparison of critical hours to the base case

The effect of EEI during critical hours is illustrated in Fig. 28. Therefore, the considered critical hours were between January 1st and January 20th. The HP significantly increases energy consumption during critical hours. This statement becomes evident when considering the energy before and after switching on the heat pump, represented by the blue and orange columns. The HP+TI profile slightly reduced the consumption with the addition of the external coating compared to the HP profile. However, it remains higher than the basic profile almost in every critical hour; this can be seen from the grey columns in Fig. 28.

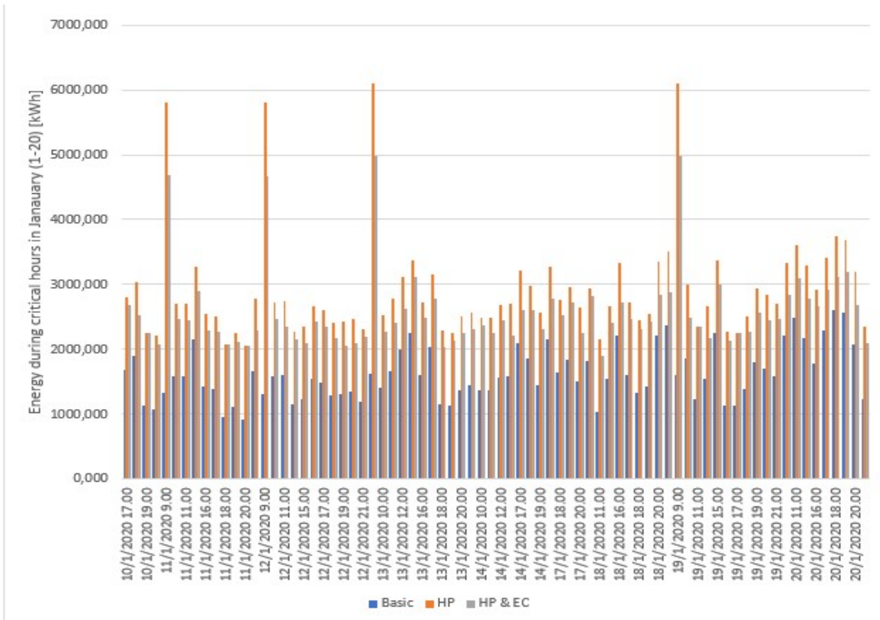


Fig.28 Comparison of pre/post-intervention: Critical hours from the 1st to 20th January.

3 Elaboration of the Guidelines for incentive design for the P4P scheme application, including DR

In a P4P scheme for financing energy retrofit projects, the financial flows between the parties involved are tied to actual - measured - energy savings and normalised by time. The business model therefore combines flexibility at the residential building level with P4P contracts, by mixing DR with EE interventions.

To this end, and because of the increasing importance of demand flexibility in the grid, it is vital to take a more integrated approach to EE and DR as shown in the previous section and avoid unintended competition, promote complementarity between EE and DR, and minimize overall costs and emissions. EE can produce significant benefits, even if it competes with DR, by reducing overall output both day and night. However, competition with DR can erode the benefits of EE to some extent, for example, by requiring greater use of peaking generation units. Thus, an integrated approach between EE and DR that focuses on complementarity could increase the benefits of EE. These benefits include reducing and/or shifting load to increase system capacity factors or to facilitate economic or security dispatch of generation resources [18,19,20,21]; deferring investments in the generation, transmission, and distribution system; and reducing fuel and purchased energy costs for utilities and electricity end-users [22]. In addition, EE programs typically cost less per kilowatt-hour than average retail electricity rates [23,24,25,26]. It should be considered that, by definition, EE is a persistent and steady reduction in energy consumption required to provide a fixed level of service; whereas, in contrast, it defines consumption reduction as an active change in energy demand or consumption on a time-limited basis, in response to an incentive or command signal, that may result in a reduced level of service.

As shown in last section, the interactions between EE and DR depend on the size and technology specifications, including building type and targeted end-use, and also on the conditions of the utility system. We also find that EE-DR interactions are defined not only by variation in discretionary load (i.e., DR potential) but also by variation in the probability of participation in DR programs and by variation in system need and overall availability of DR resources. The analysis shows the increasing complexity of evaluating EE and DR interactions as one moves from stand-alone equipment to integrated systems.

EE affects the load available for load reduction or load shifting. An EE measure may reduce the total amount of load available for load reduction or load shifting, may shift load from peak to off-peak periods or vice versa, or increase the potential for flexibility.

EE affects the power system's need for demand flexibility. EE can reduce demand during hours when the probability of load shedding is high and/or hours when known and persistent variability in net load leads to ramping events. Some examples show that an increase in load may be beneficial (e.g., during periods of renewable energy curtailment). If EE reduces the load during those hours, the need for DR for the system will increase. Although both aim at changing the consumption profile, they act on different time bases.

The scholarly debate focuses on identifying EE and DR attributes, technological factors, and system conditions that can drive EE and DR interactions. Some studies on the EE and DR relationship focus analysis on the direction of the relationship between the two, i.e., the positive and negative aspects of this interaction. As a way of illustration, see the following:

A. After an EE intervention, there is a load reduction in some hours, especially during peak hours, which in turn generates a reduction in terms of DR. In this sense, therefore, greater EE translates into less DR availability. In these terms, the relationship is negative

B. Conversely, following an EE intervention (suppose the installation of a heat pump), the load shape is higher in some hours, increasing EE availability and incorporating more participation in DR programs; in this case, EE and DR complete each other.

The next paragraph focuses on how a P4P improved business model may manage the interplay minimising the negative interaction and maximizing positive ones

3.1 The role of the Energy Flexibility Aggregator in the model of business P4P

In these types of positive and negative relationships P4P programs might come into play precisely. There is no system benefit in the case of positive interaction between EE and DR, so no revenue will be generated. However, the EE aggregator can play the same role as the DR aggregator by offering flexible services via BSP to the utility system. Payments will be obtained for the DR services provided. This type of aggregator, which incorporates both the functionality of an EE aggregator and a DR aggregator, is called an EFA (Energy Flexibility Aggregator).

There are different types of aggregators based on the various resources allocated. For example, a demand aggregator might collect DR resources from all customers; a load aggregator mainly collects load flexibility from residential customers; a generation aggregator groups numbers of small generators; an EE aggregator groups buildings, energy providers, and investors in order to make EE investments attractive.

The primary role of an EE aggregator is to promote EEM and manage the benefits associated with it with the task of making multi-building EE investments attractive. It will act as an intermediary between the PFE (public funding entity), ESCOs and building owners in order to help them enter into agreements aimed at purchasing EE technologies.

However, the main central role of a classic DR aggregator is to enable commercial and industrial consumers to increase or decrease energy consumption in response to peaks in electricity supply and demand, thereby ensuring greater flexibility and stability of the grid and more efficient use of energy infrastructure and resources. It tends to receive a balanced order from the grid operator and uses special algorithms to optimise the distribution of demand among participating customers to reduce or increase their energy consumption; In this way, the designated customer modulates the level of consumption / generation; this load modulation is made available to the grid operator; Thus, following the verification of the proper provision of the service, the customer receives the payment established in the contract.

The EFA provides a channel of communication between end-users and other actors in the electricity system. In practice, it is an entity that purchases “system services” (load shedding, variation of active power fed into the grid by generators/accumulators, etc.) from widespread customers to sell to the Transmission System Operator (TSO) or Distributor (DSO), ensuring to its “customers” (TSO and DSO) that the services offered by its suppliers (widespread customers) are available when they are needed. Figure 29 explains the P4P business model that includes DR services. The model starts with the benefits provided by EE investments that produce actual electricity savings that translate into costs saved by the electric system. These savings will form the monetary fund through which those who participate in P4P programs will be funded.

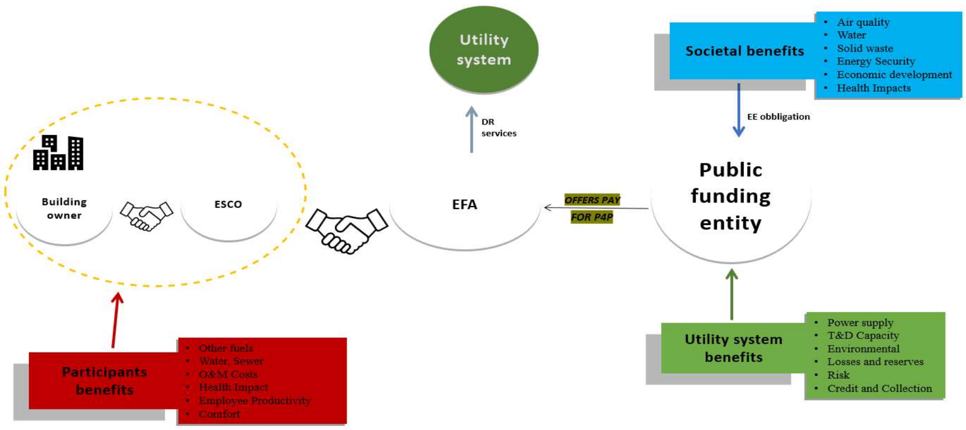


Figure 29. *P4P business model that includes DR.*

As shown in Figure 29, a very important role is played by the EFA aggregator, which can also offer DR services to the electric system, in addition to providing incentives to help ESCOs and building owners entering into agreements to switch to a new EE technology.

More specifically, EFA, allows small users to offer DR services to the Balancing Service Provider (BSP), which provides flexible resources for system utilities in the dispatch market. It is the entity responsible for providing ancillary services and the holder of the relevant contract with the TSO. The aggregator has its own control system to provide DR services based on utility requests. The DR revenues that result from the load flexibility introduced by the EEM allow for increased profit through intervention and reduced payback time. Of course, this only happens if the EEM has a positive interaction with the DR. No benefit can be achieved if the interaction is negative.

Figure 30. *EFA's role.*

Figure 30 illustrates the role of EFA in detail, and how it interacts with the various identities in our scheme. It receives funds from our PFE and uses them to provide incentives to help ESCOs and building owners enter into agreements to switch to a new EE technology.

Using the defined tools discussed in the previous section and the M&V system, EFA can:

- evaluate the interplay between EE measure implemented and DR;
- determine the rates related to EE and DR for the participant;
- offer flexibility as a Balancing Service Provider to the Power System operator;
- obtain services from PFE for effective environmental impact (co2 reducing) and to power system reliability empowerment.

4 Conclusions

EE and DR represent a resource for the system and for the user, it used in aggregated form but negative interplay may occur. The interplay between EE and DR requires the development of qualitative and quantitative methods able to "capture" this interdependence through endogenous and exogenous variables such as consumer behaviour that is decisive for the outcome. These methods need to take several factors into account: user consumption and habits, type of energy efficiency interaction and power system reliability data. Two quantitative methods have been proposed in order to validate this interplay.

P4P is a sustainable model as it is able to manage EE and DR resources as measured performances are used for paying users and so, to maximize both benefits. Nevertheless, to achieve this goal, the P4P has to include DR resources management. The developed methodologies allow EE aggregator to perform this aggregation. This type of aggregator, which incorporates both the functionality of an EE aggregator and a DR aggregator, is called an Energy Flexibility Aggregator (EFA). EFA provides a communication channel between end users and other actors in the electric system. In practice, it is an entity that buys "system services" (load shedding, change in active power fed into the grid from generators/accumulators, etc.) from widespread customers to sell to the Transmission System Operator (TSO) or Distributor (DSO), ensuring its "customers" (TSO and DSO) that the services offered by its suppliers (widespread customers) are available when they are needed.

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