WP6 – Synergic grid interaction and automatic energy savings

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Abstract:

This document describes the progress done about Grid flexibility services on project PHOENIX. Although other deliverables will come with a more exhaustive description of the services per-se, this document shows the situation in which those services will be developed, and how the tools are being implemented to make sure that those services are relevant for the objectives of the project.

Keywords:

Grid; Electricity; Utilities; Flexibility; Demand response; Use Case; Services.

Revision History

The following table describes the main changes done in the document since created.

Revision	Date	Description	Author (Organization)
0.1	06/07/2021	Preparation of the skeleton of the document	UMU
0.2	10/07/2021	Integration of several implementation parts	UMU
0.3	15/07/2021	Development of the state of the art and context	UMU
0.4	19/07/2021	Description of conclusions and further work	UMU
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Executive Summary

This document explains the situation of grid services on the context of Project PHOENIX. The current scenario shows that the transition to a new paradigm of electric grid is coming, a new paradigm in which the grid and the consumers will take other roles, as well as other agents will enter into the electricity value chain. The document shows how PHOENIX project has completed the provision of tools to make an effective development of grid services; presenting the preliminary services that have been taken into consideration. In M19 of the project, the deliverable 6.2 will describe more in detail the planned services that will be developed for the project.

Disclaimer

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1. Introduction

1.1. Scope of the Document

This document presents the first deliverable about services for energy utilities and the grid of project PHOENIX. The deliverable shows the framework in which the services of grid flexibility will be developed, and at the same time shows the rationale of them.

The relationship between the grid and the consumers (or prosumers) is going to change relatively quickly and rather soon. The new paradigm will have a variety of agents on the electrical system that act as providers and clients at the same time. Within that change, citizens will become important players on the new equation, either by themselves or in the form of energy communities. The document covers the state of the art, where a review of the trends is carried out. Additionally, EU projects related to this topic are reviewed and described in relation to PHOENIX project.

As an important part of the process that will lead to the services for grid flexibility, the third-party data is explained and the initial connections with the PHOENIX platform are described. Currently there are APIs to connect to TSOs and DSOs that facilitate the creation of services for grid flexibility as these offer the possibility of knowing the CO_2 impact that a given kWh is going to have in a specific hour on the next day, or it allows to estimate the price of electricity at a given time of the next day.

The development has been done in parallel with a conceptualisation of the data models needed for the new paradigm of smart grids. In this document is presented how those developments have started and how new models and connections have been created to ensure data interoperability within the platform.

For the development of this work package a synthetic grid simulator has been created. The idea of the simulation is necessary as it is rather difficult to attempt demand response events and other grid flexibility programs within the resources of this project. With the simulator we are capable of doing agent-based modelling that, taking into consideration the behaviour of the building users, allows us to test different programs.

Two main facets of services for grid flexibility appear in this document, one for grid flexibility and one for self-generation and energy storage. With this we cover the new challenges that are going to appear in the new paradigm of the electrical system of Europe. The document shows how these services have been defined in terms of the requirements that they may fulfil and the connections that they may have with other components of the platform, users and stakeholders.

1.2. Relevance to other deliverables

Deliverable 6.1 is highly related to Deliverable 5.1. Both create the basics of the services that will be developed in PHOENIX project. The deliverables will be followed by two deliverables namely Deliverable 6.2 and Deliverable 5.2 that will be more explicit about the services that are being developed. This will occur because at that stage the services will be more on development phase as the piloting will be up and running.

1.3. Structure of the document

The document is separated on three technical sections that are Section 2, Section 3 and Section 4, where the contextualisation and framework of the three technical developments involving WP6 are described, namely the interface for communication with the grid and smart contracts, the services for grid flexibility oriented to demand adjustment and the services for self-generation and energy storage. The document is closing with a conclusion and further work section and a references section.

2. Interface for communication with the grid and smart contracts

2.1. Introduction

The PHOENIX platform will contain the necessary developments to offer services that will be needed in the new paradigm of smart buildings. A large part of this is the transformation of building into smart entities. These smart entities will communicate with the grid either via aggregators, energy communities or other stakeholders. This implies that the PHOENIX platform needs to offer the possibility of using the great deal of data that is going to be collected for producing contracts and tariffs within them that are optimised for this more active and mobile electricity system. This, will be integrated within the section of the solution that is in charge of dealing with the connections to the grid, and it will include the interface for communication. This interface will be a common point for the different agents to carry out the transactions materialised with the smart contracts, at the same time that the intelligence of the platform will autonomously generate new options for these commercial movements.

2.2. State of the art

The European Union has the aim of decarbonising the energy system to meet climate goals. This will have to be done with a higher share of renewables and greater energy efficiency with an **integrated** energy system.

On this new paradigm the buildings have been seen as an important agent as they can provide flexibility to the grid. This is made possible thanks to the deep penetration of smart devices inside the buildings. The smart devices allow to schedule the operation of field devices on a much larger context, that include, the production of local electricity and the storage depending on the situation of the grid (i.e. congestion).

The smart devices and the rest of the Information and Communication Technologies (ICT) ecosystem will have an impact on three important areas according to the Technical Report on smart home and appliances[1].

- Buildings – Buildings will be equipped with integrated management systems that will be capable of communicating with the grid and other third parties.
- Energy Grids – The so-called Smart Grids are those that, helped with ICTs, are capable of making an optimal operation and to integrate intelligently renewable energy, storage and active buildings.

[1] *Smart home and appliances: State of the art. JRC Technical Report, 2019.*

- Households – Buildings seen as dwellings for households bring an extra dimension of active interaction within the familiar habits. This relies on behavioural change thanks to increase of energy literacy and overall awareness.

In the following figure (Fig.1) is presented the new scenario in accordance with the Digital Single Market strategy.

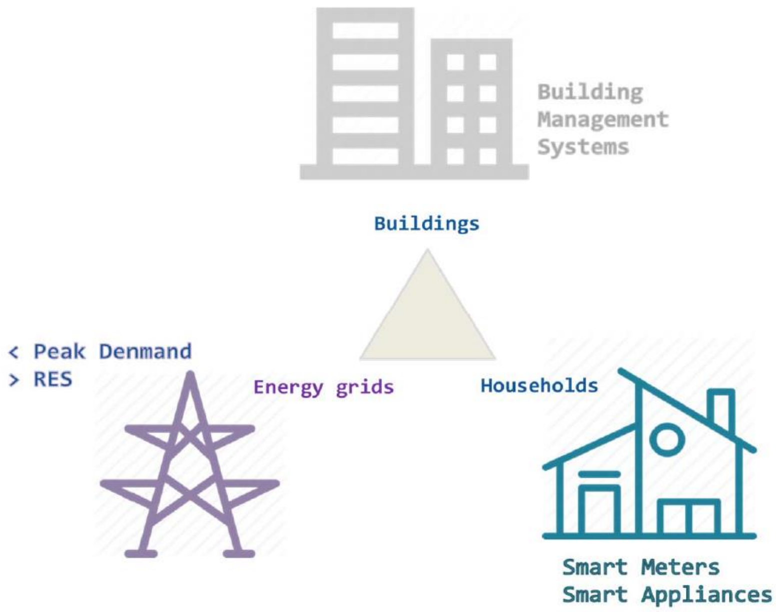

Figure 1 . ICT and energy (from Smart home and appliances: State of the art. JRC Technical Reports).

On this new scenario, the grid is more distributed, and instead of having a centralized grid with large power plants as it was at the end of the 20th century, the proliferation of renewable energy plants and cogeneration make the grid more distributed as it can be seen on Figure 2.

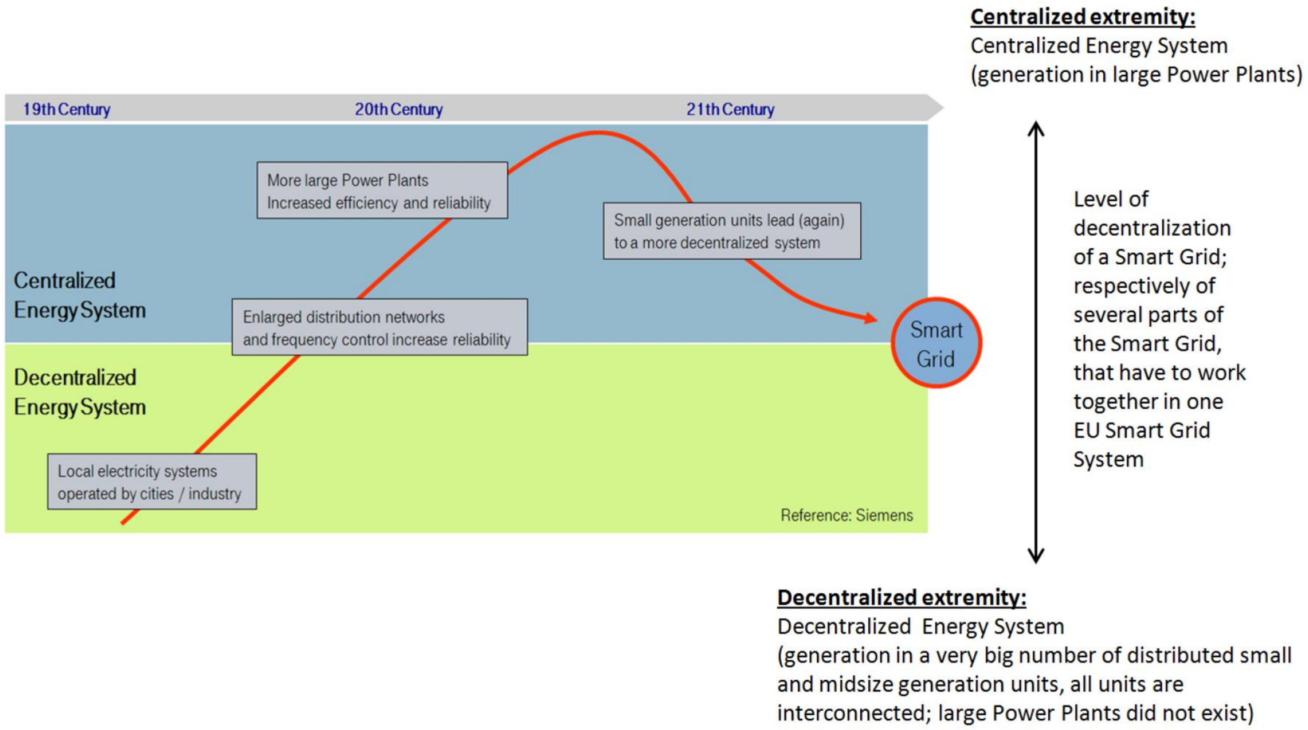

Figure 2. Evolution of the grid in the last three centuries in terms of centralization. Taken from CEN-CENELEC-ETSI Smart Grid Coordination Group Smart Grid Reference Architecture.

The new situation has led to a new conceptual model of the grid, that was necessary to define in order to conform to the reference architecture for the new paradigm. The new model has been reported on the Smart Grid Coordination Group Smart Grid Reference Architecture of the CEN-CENELEC-ETSI, and it highlights the current situation in which the distributed energy resources are a component of the total ecosystem. Bulk generation that was before on the bases of electricity production now needs to be put together with the small, distributed generators that also get inside the markets, play a role on the operations, and influence the distribution and the provision of services. Distributed Energy Resources (DERs) is the distinctive element of the new model compared to the NIST model that was proposed by the National Institute of Standards and Technology (NIST). This can be seen on Figure 3.

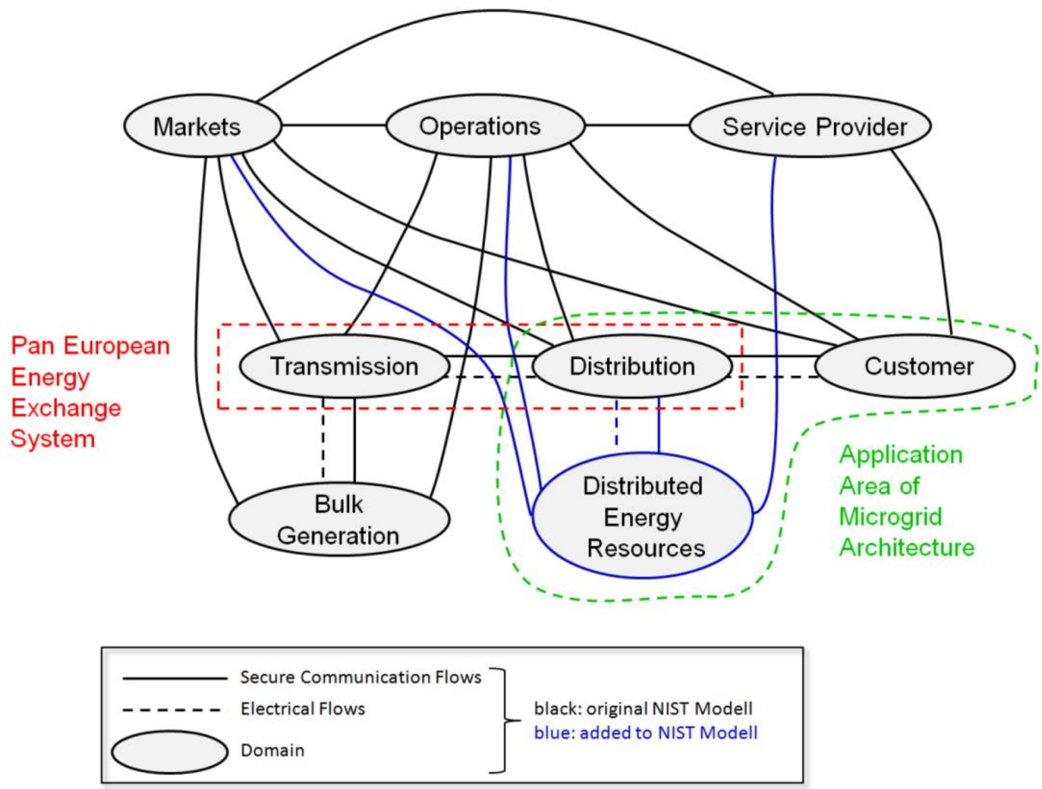

Figure 3. EU extension of the NIST model. Taken from CEN-CENELEC-ETSI Smart Grid Coordination Group Smart Grid Reference Architecture.

The new electricity system where flexibilities are an asset, will need new agents and new tools for those agents to perform their roles. Examples of these are the new scheme of the aggregator, the balance responsible party or the Energy Services Company ESCo. With the purpose of enabling the work of the new agents, the Universal Smart Energy Framework (USEF) has been developed since 2015.

This framework is particularly relevant for explicit Distributed Flexibility, that corresponds to the so-called explicit demand response events, where the active customer receives a request of changing their demand in exchange of an incentive. USEF has been defined to create the framework that makes this possible, as opposed to the implicit Distributed Flexibility that would correspond to implicit Demand Response motivated by a variable cost of the supply. A graphical description of these two scenarios can be seen on Figure 4 and Figure 5.

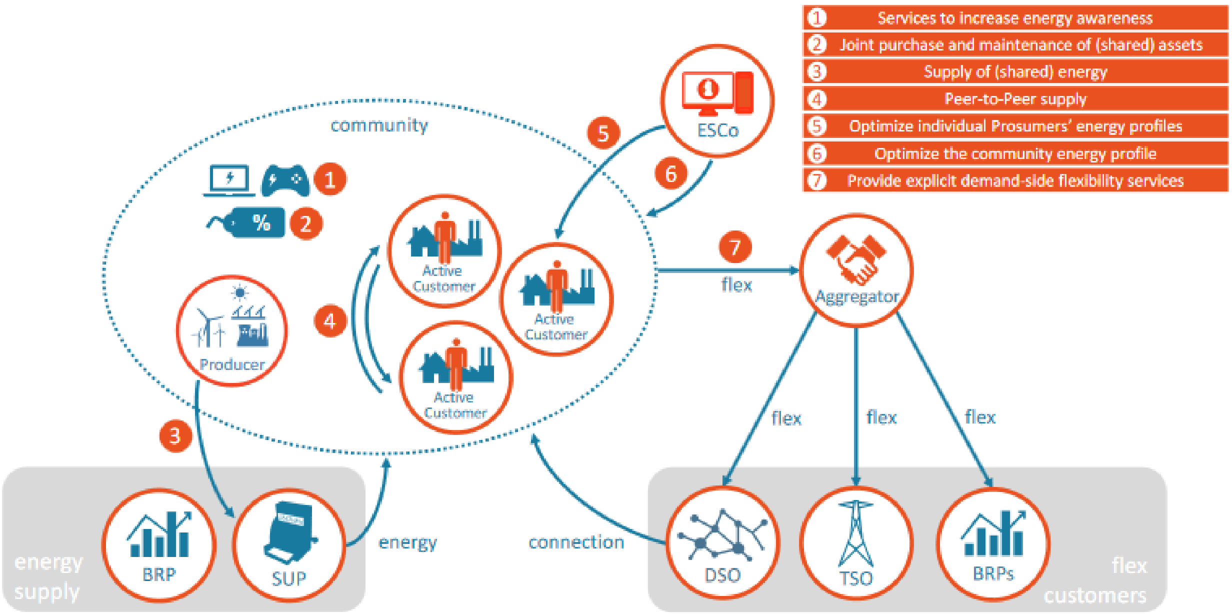

Figure 4. Potential services appearing as a result of energy communities. From USEF White book.

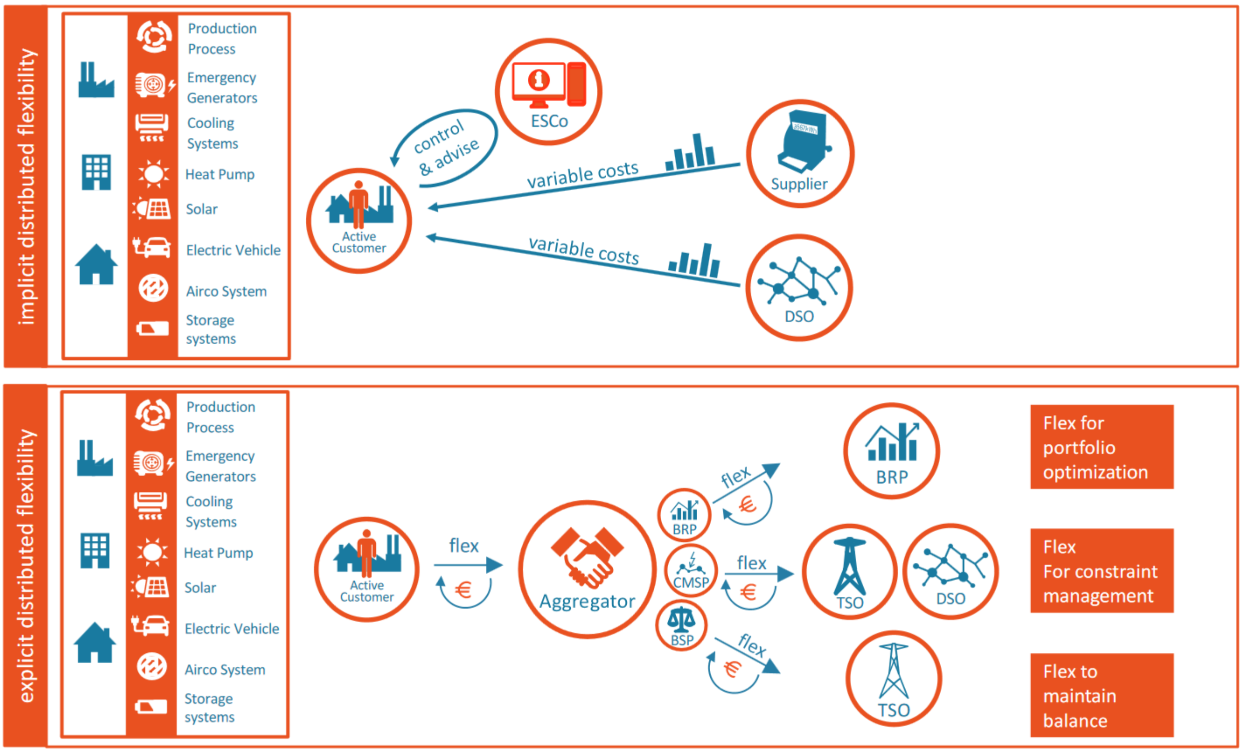

Figure 5. Implicit distributed flexibility (top) and explicit distributed flexibility (bottom). USEF offers a great deal of tools for managing the complexity of the second scenario. Taken from White book USEF The Framework Explained 2001.

The USEF framework allows to have more complex schemes of flexibility, but more importantly it creates a flexibility value chain, implying that profit is generated at the different stages and transactions, that makes possible the appearance of new business models that are self-sustained and promote efficiency on the grid.

2.3. Requirements' overview based on the social barriers and enablers

In the following table (Table 1.), the technical requirements for the Smart Contracts component have been detailed.

Table 1. List of requirements.

Req. ID	Description
T_SC.01	The component needs to be in connection with the context broker in real time
T_SC.02	The component needs connection to the dashboard to facilitate performing the transactions to the building users
T_SC.03	The component needs connection to the dashboard to facilitate performing the transactions to the building managers
T_SC.04	The component needs connection to the dashboard to facilitate performing the transactions to the grid operators
T_SC.05	The component needs connection to the dashboard to facilitate performing the transactions to the aggregators
T_SC.06	The component needs to gather data in real time of the electricity price each hour
T_SC.07	The component needs to be secured in terms of access, making possible the access to different options depending on the role of the users of the platform
T_SC.08	The component needs to be secured in a way that the privacy of the users is preserved
T_SC.09	The component needs to fulfil the standard format of messaging between actors of the new electricity paradigm (smart grid)
T_SC.10	The component needs to be capable of archiving the transactions for accounting purposes
T_SC.11	The component needs to fulfil the standard format of contract among the different entities
T_SC.12	The component needs to provide a flexible template for the establishment of contractual agreements among the different entities.

With this, the definition of the necessary elements of the smart contracts modules and interface has been defined. Also, the social barriers are important for defining the services and how they will be designed. On this, the following barriers have been identified.

Barriers

Privacy concerns the interface of communication and the creation of smart contracts, require that the users allow the access to a great deal of information about them and their habits that in some cases could make them reluctant to participate on such initiatives. It is expected that this will be a social barrier for the services relative to communication and smart contracts.

Lack of perceived control on the technology is also another one of the barriers, as it could be the experimentation of users that they are losing the control of their buildings. It is important to realise that smart contracts and intelligent interfaces represent a certain level of autonomy being given to the platforms, diminishing the control of the users.

The services that lead to a selection of the contracts and the interactions that are controlled by the platform may have indeed a barrier due to this perception. It is important to take this into consideration and therefore design the services in a way that the user feels comfortable with the control of the platform and not vice-versa.

Enablers

Monetary savings can be considered as one of the strengths of services towards saving energy, and so has been seen on the results of the social enablers. According to the survey's results, the possibility of financial benefit in terms of saving money is a very strong incentive in order to participate in actions and services related to smart building upgrades. Considering the electricity prices in the last year, this is going to become more important in terms of smart contracts and other initiatives directly related to the purchasing of electricity.

Perceived qualities & attributes is very important factor for the majority of respondents in order to deal with the energy upgrade of their buildings and is the convenience offered by smart devices. This is particularly relevant with electricity contracts and the provision of intelligent interfaces that can explain to users a rather complex market as it is the one of the electricity prices. The arrival of micro-generation renewable sources or local domestic storage equipment can make this even more complex, and a solution that can helps with the understanding of this, will be highly beneficial.

Tendency to change. It is clear that the there is a tendency to change the electricity market. The increase in number of digital natives taking part on the system, will bring the change of the norm on the use of digital tools. This has been seen on the surveys performed on Del 2.2. A large share of respondents has declared positive tendency to change. It is expected that this naturally will also help with the incorporation of new solutions that could be offered as services for communication and smart contracts.

2.4. Interface for communication with the grid and smart contracts specifications

The Interface for communication and Smart Contracts services will be designed to offer smart contracts to building users based on adjusting as much as possible to user profile. Since managers/ESCOs, retailers, aggregators and building users are PHOENIX end users, Smart Contract Management Engine will be in charge of proposing contracts adjusted to the user profiles, user behaviours, energy consumption and market conditions. The Interface for communication will help connecting the different parties involved in the process of grid transactions.

The following schema (Figure 6) shows how the engine for smart contracts have been designed in the PHOENIX solution.

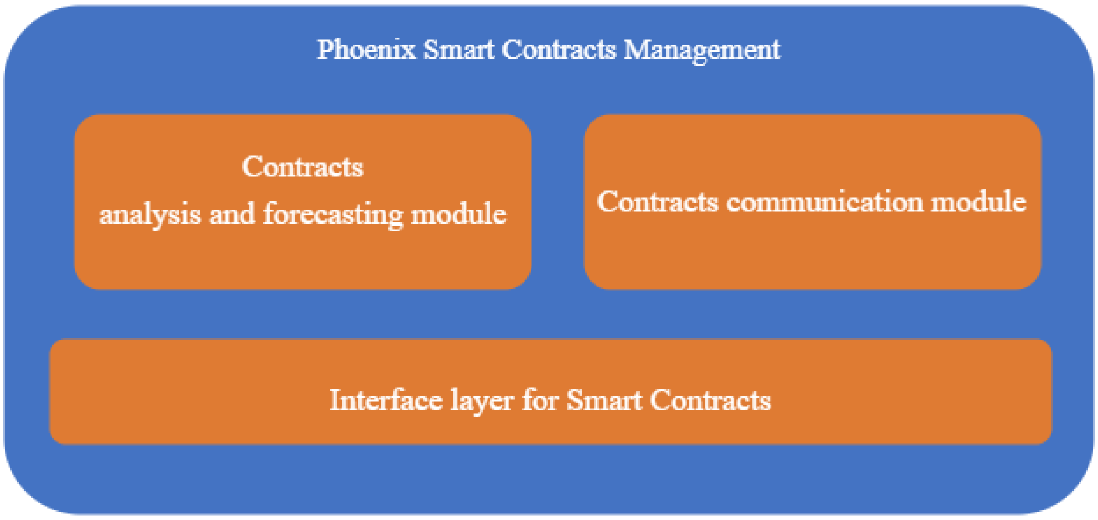

Figure 6. PHOENIX Smart Contracts Management Engine.

The description of the functional elements is as it follows:

- **Contracts analysis and forecasting module:** This module is responsible of proposing custom-made contracts to the building users based on its behaviours and energy consumption profile achieved by analysis and forecasting.
- **Contracts communication module:** This module provides communication and interaction regarding the contracts proposed. This module will perform the contracts transaction between building users and business actors.
- **Interface layer for Smart Contracts:** The smart contract engine will have connection to other third-party components to make possible the realisation of its tasks. This includes the

dashboard of the platform, in which the users could voluntarily decide to perform transactions with other agents.

Dependencies/ Inputs/Outputs

For the core functionalities of the Smart Contract Engine to work, it is necessary to have a series of dependencies with other components as well as receiving inputs and outputs from other sources. The details of these connections are shown below:

- PHOENIX Real-Time Data Broker:
    - Get access on real time data associated with the contextual conditions in building environment and the operational status of the different building services components. Furthermore, provides information about electricity market rate.
- PHOENIX Platform Data Repository:
    - Get access on real time data associated with the contextual conditions in building environment and the operational status of the different building services components. Historical data is required for comprehensive analysis and forecasting.
- Grid - centric services Analytics Engine:
    - Get access on data associated with grid conditions and provide required information about grid integration and flexibility to achieve more adjusted and realistic contracts.
- User-centric Services Analytics Engine:
    - Get access on the results of the analytics engine related to the extraction of behaviour profiles and energy consumption profiles to obtain personalised information about building users and offer more custom-made contracts.
- Building Occupants/users Visualization Dashboard:
    - Inform building users about the contracts proposed and provides an interaction way to perform the transactions.
- Business Stakeholder Interface Engine:
    - Provide the access to business actor in order to perform contract transactions.

3. Services for grid flexibility oriented to demand adjustment

3.1. Introduction

Within the set of services developed for PHOENIX, Task 6.2 includes the services oriented to demand adjustment. These services are at the core of converting buildings from passive agents to active agents within the new paradigm. This will be done via the offering of flexibility to the aggregators, ESCOs or other entities, but also via the use of specific demand response events that shape the demand to the desired values.

These services will help on project PHOENIX accomplishing the KPIs relative to load shifting, or allocation of loads to high renewable generation periods to decrease carbon emissions of the energy consumption. The services for grid flexibility will be connected to the flexibility engine, that with the knowledge about the devices from the context broker, and other dashboard information, is capable of calculating the demand that can be modified via signalling from the aggregator. The services will offer added value to the final users, that allow them to interact with the demand response event programs and helps them understanding how they work, and how they can benefit from them, and to the aggregators, that can obtain personalised DR policies using the knowledge extracted from the PHOENIX platform.

3.2. State of the art analysis

Demand response programs are strategies that aim to curtail the electric consumption of the end-users in response to changes in the price of electricity or to contingencies that threaten the stability of the grid. The load curtailment is related to both the reduction of the overall demand and the shifting of consumption in non-peak hours. Several variants of the programs have been designed and tested, normally grouped into nine main categories (Figure 7).

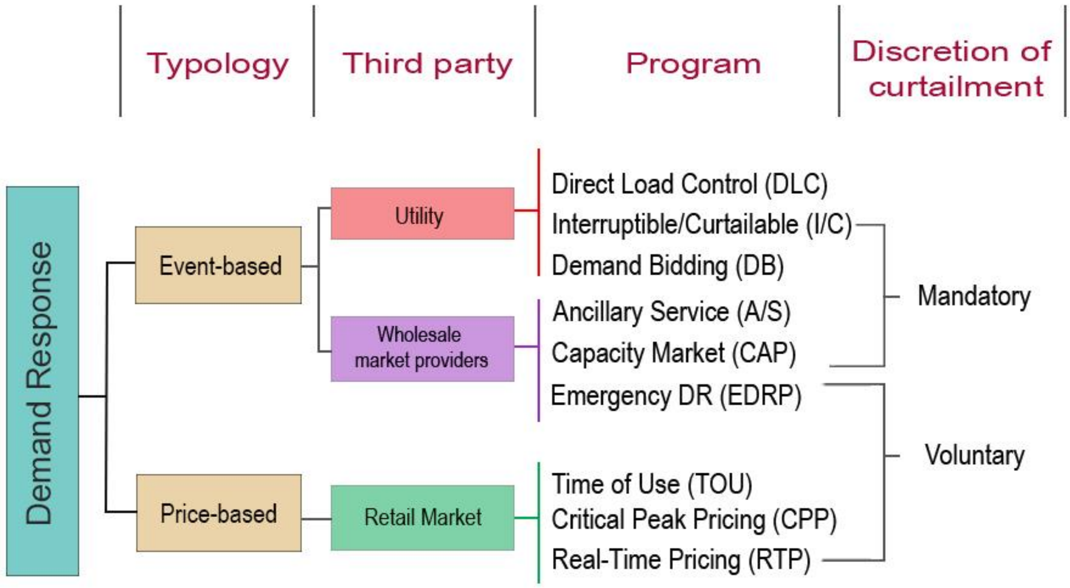

Figure 7. Schematic view of the demand response programs.

Classifying the programs is not trivial since the classification criteria found in the literature are manifold (e.g. purpose, trigger factor, origin of signal, targeted customers and so forth) (Siano, 2014). First of all, DR programs are divided into incentive-based or event-based and price-based programs. Price-based programs are related to time-based rates, and they rely on the responses of end-users to prices. Such responses are not easily predictable, so incentive-based DR programs represent a more active tool[2] that is based on the concept of *event*. In exchange for incentives, the third party is allowed to trigger an event, i.e. a timeframe for load curtailment. The third party can be the electric utility (also intended as the system operator or the load-providing entity) or the wholesale market providers (commonly Independent System Operator or Regional Transmission Organizations (ISO/RTO). On the other hand, price based models are more related to the retail market.

Time of Use (TOU). The most used price-based program, in which fixed rates are designed in the tariff. The end-users can voluntarily shift their consumptions.

Critical Peak Pricing (CPP). Behind the fixed rates, in critical conditions the price is substantially raised over a short timeframe. The notice is typically short day-of or day-ahead depending on the variant of the program. The participation of the end-user is voluntary since they can choose whether to shift their consumption or not.

Real-Time Pricing (RTP). A price-based program in which rates change over short time ranges (typically hourly) depending on real-time supply cost. The consumers receive short notice (day-of or day-ahead).

Direct Load Control (DLC). In exchange for incentives, the consumers give control over their electrical equipment to the utility. Through remote switch, the third party can shut down appliances or change the set-point temperature of the HVAC system during the timeframe of the event. Afterwards, the temperature setting, or the appliances' cycles are readjusted to the pre-event level. The event can last up to several hours and the notice is commonly expected the day-ahead. Users are free to interrupt the event without penalties, although there exist some mandatory variants of the program.

Interruptible/Curtailable (I/C). This incentive-based program is reserved to larger consumers, although it is not suggested for customers with continuous demand (24 hours-a-day operations) nor school, hospital, and so forth. Users receive discounted rates if they agree to reduce loads on

[2] *https://www.ferc.gov/*

request. The curtailment is mandatory (penalties apply otherwise) and a notice of 30 to 60 minutes is given.

Demand Bidding (DB). Large consumers can bid for curtailment when the prices of the wholesale market are high. The prices are evaluated on a day-ahead basis. Once accepted by the utility, the curtailment is mandatory (penalties apply otherwise).

Ancillary Service (A/S). Ancillary service programs aim to maintain grid reliability. The users accept to shut their electric equipment for 10 to 30 minutes in exchange for payments. The payments commonly depend on customers' bids in the wholesale market. If accepted, users are paid for committing to be on standby and to curtail when needed. The notice is very short (minutes ahead or no notification at all in some variant). The variants of the program depend on the type of service it is offered (e.g. frequency regulation, spinning reserve).

Capacity Market (CAP). Large customers accept to curtail their load during contingencies in exchange for guaranteed payments. That works as an insurance, i.e. the users receive their bonus to be on call even if the events are not triggered. The notification is commonly two hours ahead. The basis to participate in the program is a minimum load reduction of 100 kW over a minimum timeframe of four hours. The events are mandatory (penalties apply if the basic conditions are not reached).

Emergency DR (EDRP). In exchange for incentives, customers accept to reduce their consumption in emergency situations (e.g. severe weather). Depending on the emergency, the users can receive a day-ahead notice or a two hours' notice. The events are voluntary, so consumers can forgo the payment without being penalized.

It is noteworthy that most programs are meant to be applied only to industrial buildings. Although there are some first attempts of applications, the Building Performance Institute of Europe BPIE explains that demand response is not yet available for residential and commercial sectors. According to the Joint Research Centre (JRC) report on Demand Side flexibility, there are three key factors necessary for the development of DR strategies in Europe, namely establishing independent aggregators to offer more options in the energy service providers' selection, introducing market designs that allow participating to the programs, defining a technical framework that can be used in a standardised way throughout Europe.

Up to now, the regulatory status of DR programs presents some important differences among European countries. The same JRC report maps a "three-speed-Europe":

▪ The first group of Member States have not yet enabled the consumers' participation in the markets. Besides, the role of an independent aggregator and DR service provider is not established.

▪ Another set of Member States achieved to enable Demand Response programs through the energy retailer. (Austria, Finland, Denmark, Germany, the Netherlands and Sweden) The retailers in these Member States offer a “bundle packaged offer” with their electricity bill, which the consumer can only accept or refuse entirely, with some lack of transparency.

▪ The third group of Member States (Belgium, France, Ireland and the UK) enables both Demand Response and independent aggregation. In some cases, (Belgium and France), there is already a clear definition of the roles of independent aggregators, whose responsibilities are also delineated. To that third group, the Smart Energy Demand Coalition[3] adds Finland, as the country allows independent aggregation in at least ancillary service programme and is experimenting through pilot projects with independent aggregation in other parts of the balancing market.

3.3. Requirements’ overview based on the social barriers and enablers

After the work developed on WP2, it is possible to know the requirements that will be found for developing the services proposed on this section, those relative to grid flexibility. With respect to the occupant’s’ requirements, the ones that are relevant to grid flexibility can be seen as the ones on Table 2.

Table 2 User requirements regarding grid flexibility.

Req_ID	Description
1	PHOENIX should provide services to building occupants to promote energy savings
2	PHOENIX should provide services to building occupants to enable participation in smart energy programmes
3	PHOENIX should provide services to building occupants to increase awareness about energy efficiency and smart programs
4	PHOENIX should provide information to building occupants about total energy consumption
5	PHOENIX should provide information to building occupants about historical consumption
6	PHOENIX should provide information to building occupants about energy savings and waste

[3] *Explicit Demand Response in Europe Mapping the Markets, SEDC 2017*

7	PHOENIX should provide information to building occupants about consumption of similar peers
8	PHOENIX should provide to building occupants information about local generation and the level of self-consumption
9	PHOENIX should provide to building occupants information about total energy waste
10	PHOENIX should provide to building occupants the option for remote control of smart devices
11	PHOENIX may provide to building occupants the option for scheduling the operation of devices

As can be seen on the table, the grid flexibility revolves around energy consumption. This demonstrates that the concept of power, of great importance for the grid, it is still an unclear concept for the final user. It is important therefore to first of all develop tools that help with the occupant literacy on power.

Also, as a result of WP2, it was possible to identify social enablers and barriers relative to grid flexibility programs. On that respect, the following is a summary on what can be considered barriers on services of this field.

Barriers

- As on most of the interventions for smart buildings, the adoption of grid flexibility programs implies giving away data to the grid about energy use from behaviours such as conditioning use, domestic hot water of devices use. This can create a privacy concern on users, and therefore can be a barrier for grid flexibility programs. A system that ensures the users that the information provided is limited and anonymised could be a way of overcoming this barrier.

- The creation of grid flexibility services cannot always look at providing a training program attached to it. In the previous paragraphs we saw that the literacy about energy concerns such as the difference between power and energy can be rather low. A grid flexibility program mainly looks into reducing power peaks, and therefore the occupant has to understand what power is and how it can be reduced. This gap on knowledge can make the occupant unable to carry out this kind of services.

Enablers

- With respect to the enablers that can be identified with respect to grid flexibility services, one of the most appealing enablers will be the monetary savings. This is particularly true in countries such as Spain in which the prices of electricity are escalating up to the point to registering the second highest price anytime in history for the country[4]. This is rising awareness about the price of electricity, and any measurement that can make the user reduce the electricity bill is expected to be received with favourable attitude.

- Energy conservation. The surveys carried out on Deliverable 2.2. has shown that energy conservation is one of the drivers of occupants when replacing appliances for smarter ones. Although this may be an indirect desire of saving money as in the previous paragraph, one can also think that there is a genuine desire to save energy due to environmental awareness. The use of grid flexibility services can be a way of being helped to do this.

- Social norms and lead user. As on other services, grid flexibility services can benefit to the philosophy of the building sector of obtaining certificates and good scores to valorise the product. This is also true for grid flexibility services. Certifications such as the Smart Readiness Indicator, give a great deal of points thanks to the enabling of grid flexibility. Although other standards such as LEED, BREAM and Passive House do not cover this aspect so exhaustively, it is expected that those start introducing them on their assessment, and with it motivate the sector to adopt these initiatives.

3.4. Services for grid flexibility oriented to demand adjustment definition

Considering the contextual information about the services of grid flexibility and how they should operate within the context of the PHOENIX platform, it has been seen that the connection between them can be considered as the one on the following diagram (figure 8).

[4] *https://cincodias.elpais.com/cincodias/2021/07/19/economia/1626697958_527745.html*

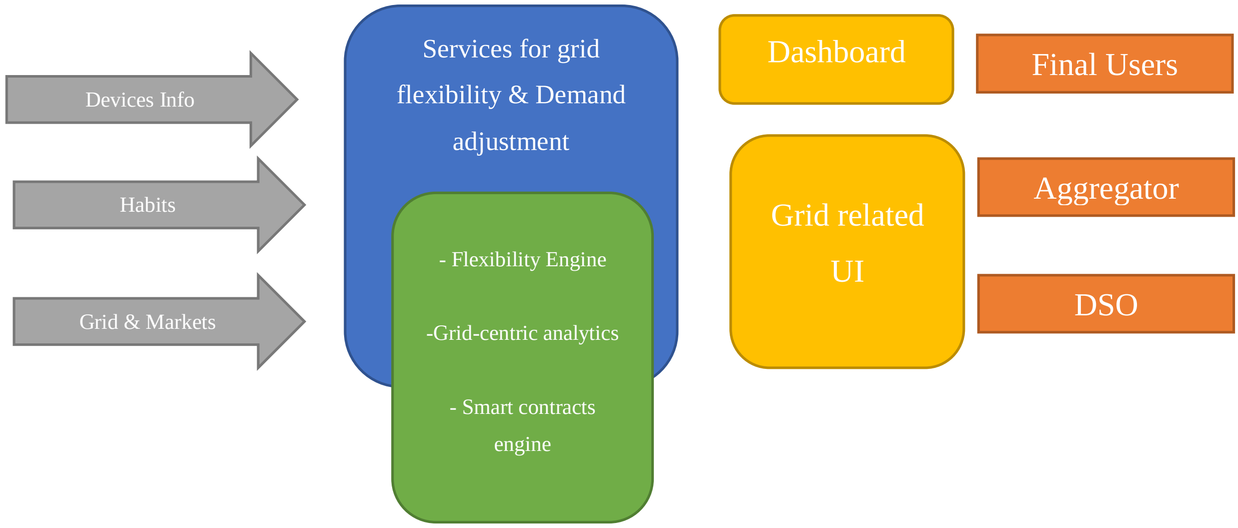

Figure 8. Diagrammatic view of the Connections for the Services for Grid flexibility. Target Groups and Scope are represented as well as the principal internal components.

The definition of the services for grid flexibility and demand adjustment will therefore have the following dependencies with other modules:

- PHOENIX Platform Data Repository
  - Get access to the historical data associated with consumption of the different devices that could provide flexibility
- PHOENIX Real Time Data Broker.
  - Get access to the data associated with the devices data models to estimate flexibility potential.
  - Trigger control strategies to the controllable devices in case of demand side management strategies
- Demand Flexibility Management Engine
  - Get access to the estimations performed by the engine that inform about the modifications that one can do on the demand.
- Grid - centric services Analytics Engine
  - Get access to the baseline information required for the extraction of demand flexibility profiling of controllable assets
- Smart Contracts Engine
  - Connect to the potential contracts of the users to evaluate the possibility of offering extra services within the plan of the contract that contributes to grid flexibility and demand adjustment
- Business Stakeholder (grid) Interface Engine
  - Get access to (grid related) demand response requests triggered by 3rd party entities (e.g. Aggregator)

- Building Occupants Visualization Dashboard
    - Information about the demand flexibility potential at the building environment to be made available through the dashboard to the building occupants

3.5. Services for grid flexibility oriented to demand adjustment examples from PoC

A few grid flexibilities services were developed at the early stage of the project, making them coincidental with the Proof of Concept PoC. The services are rather general, but as they are results of this work package, they were considered relevant to be included on this document.

3.5.1. Demand Adjustment service oriented to power contractual value

As a preliminary service for grid flexibility oriented to demand adjustment, a tool has been created that it is available to check the possibility of selecting a given power for a domestic installation and it provides, with combination of devices, what should be avoided. With this, it is intended to do the first stage of demand adjustment based on an increase of energy literacy.
The tool is meant to have a simplified version and a detailed one, depending on the information the users possess.

Description of the service
The user is asked to fill the following fields:
Location: choose a region from the list (up to now, implemented just for Spanish regions);

House dimensions: from the list, choose a normal size (<110 m^2), a big size (110 m^2 < Area <180 m^2) or a very big size (>180 m^2);

Contracted power: from a list, choose among several ranges from 1.15 kW to 14.5 kW.

Appliances with continuous use: the user is asked whether or not she/he owns a refrigerator and/or an electric water heater;

Appliances with a discrete use: a list of 11 common appliances is presented and the user is asked to check the boxes corresponding to the appliances she/he owns;

HVAC: the user is asked whether or not their home is equipped with electric heating and/or electric cooling system; eventually, how many rooms are involved.

The tool will analyse all the possible combinations of use of the appliances selected by the user. If some combinations would cause a power cut, then they will be listed in the same spreadsheet. Hence, the appliances reported should not be used at the same time. The combinations are divided into lists basing on the number of devices.

If the users are not satisfied with the result, because they need to use at the same time the appliances that appear in one of the not-possible combinations, they are suggested to change the contracted power. In that case, they can use the main list of appliances to select which ones they are willing to use at the same time, and a suggested contracted power will be showed in another table. In that way, comfortable use of their appliances is assured. This is meant in particular for billing systems that differentiate time frames: the user could evaluate contracting a higher contracted power for the cheapest time frame and shifting to it the use of some appliances.

Hello!	
Where do you live?	Murcia
Which is the size of your home?	110-180 mc
Do you own a refrigerator?	yes
Do you own a electric water heater?	no
Which is your contracted power?	10.35 - 11.5 kW
Which appliances do you use?	
Washing Machine	☑
Clothes Dryer	☑
Dishwasher	☑
TV	☑
Hair Dryer	☑
Clothes Iron	☑

Figure 9 - Questionnaire of the tool.

Add-on for building conditioning demand

In the same sheet of the document, there is a field called ‘Detailed version’ with a check box. If checked, it will be possible to fill other two fields:

- The thickness of the insulation layer of the envelope.
- Double-glazed windows.

These fields are left to a detailed version so that users who do not have such information can still use the tool without being discouraged.

In addition, people who know the specific power of one or more appliances can change them through the second sheet of the document, simply replacing the values in the appropriate table. In the same table it is possible, if needed, to replace one of the appliances that the user does not own with another one that is not on the list. For instance, if the home is not equipped with a tumble dryer, but there is a second refrigerator that is used often, then the user can replace the corresponding name and power in the table. Contrariwise, adding extra appliances to the list is not possible in the current version. Also, insert an appliance in one of the heating/cooling fields is not suggested.

APPLIANCES	NOMINAL POWER (W)			DEMANDED POWER (W)	NUMBER APPLIANCES
Washing Machine	2240			2240	1
Clothes Dryer	2250			2250	1
Dishwasher	2200			2200	1
TV	200			200	1
Hair Dryer	1950			1950	1
Clothes Iron	2050			2050	1
Vacuum cleaner	1000			1000	1
Electric Cooktop	3000			3000	1
Oven	2000			0	0
Microwave	1450			0	0
Other	800			0	0
Heating	1500	X ROOM		6000	1
Cooling	1800			0	0

Figure 10 - Table of appliances and the corresponding power with their default value.

Grid services were developed for the PoC that represent basic applications with the data that was available. These services do not have high complexity, but they were implemented to serve as a proof that the data was arriving properly and that the mechanisms to extract that data and generate value from it were in place.

3.5.2. Energy consumption monitoring

For the evolution of the PoC, and the potential use of the data for grid services, a basic energy monitoring service was integrated. The services obtain the data about energy consumption in NSGI-LD format from the context broker and plots a graph of the energy consumption for the building. The output can be seen on Figure 11.

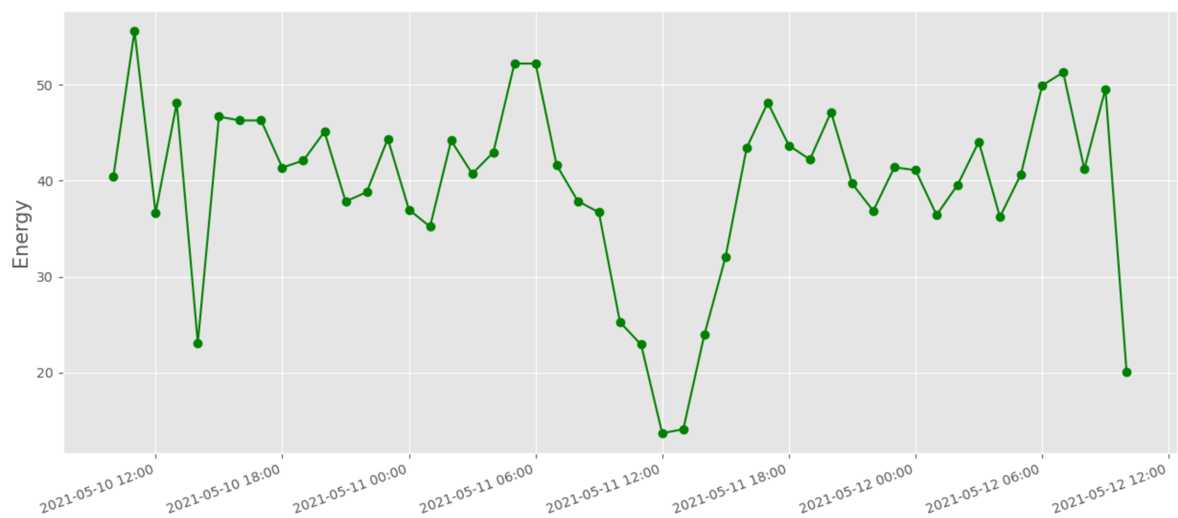

Figure 11. Example of Power time-series. (y axis on kWh)

3.5.3. Forecasting of power

A more complex service, but still without the complexity of the final services, was a service that uses the time series of power consumption and makes a forecasting of power using ARIMA algorithms. This algorithm takes into account the seasonality of the series of power to produce a prediction that serves as baseline and that can help detecting variances on the consumption. This can be seen on Figure 12.

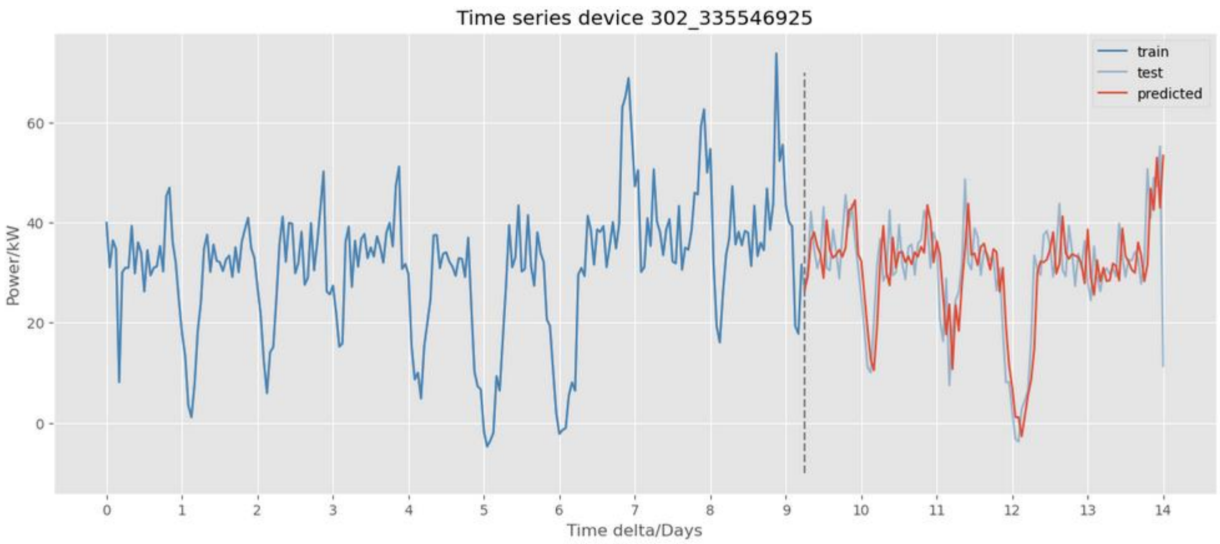

Figure 12. Time series used for forecasting.

4. Services for self-generation and energy storage

4.1. Introduction

Within the set of services that will be developed for PHOENIX, Task 6.3 includes the services for self-generation and energy storage. The relationship between the building energy generation, energy consumption and energy storage at an hourly level, is the basis for designing the optimization on self-consumption. The accurate calculations on these three entities regarding day-ahead forecasts, will improve the day-ahead self-consumption estimation. The design of the optimization algorithm is scenario-based, according to the use cases that each demo partner wishes to showcase and is extensible for any future scenario that might be added in the PHOENIX project. Moreover, part of 6.3 task is also the calculation of energy savings and energy waste and the demonstration of all aforementioned results to the relevant stakeholders in a simple and intuitive way.

4.2. State of the art analysis

The new energy system has been designed to be more human-centric, and so is the motivation on the PHOENIX project. The rise of the prosumer puts the citizen on the centre of the system, by making the consumer be an integral part of the development process regarding the data-driven energy services. The general idea is to increase the self-sufficiency of the energy prosumer via the adoption of smart services and at the same time decrease the energy demand during peak hours with the use of energy storage technologies such as batteries.

This novel role of the prosumer is summarized in the European Commission legislative proposals, through the adoption of the new directive “On the promotion of electricity from renewable energy sources” on 2018, which was one of the eight legislative acts of the “Clean energy for all Europeans” package in 2019. So, the prosumer and not the energy company will be at the centre of the distributed energy economy and will contribute on the energy democracy and justice.

However, there is another movement that is making the citizen even more relevant, and this is the creation of the Citizens Energy Communities (CECs). The CECs are starting to be more popular, and the idea is to create them to make sure that the benefits are social, environmental and economic, not only financial.

According to the European Commission, CECs are an important steppingstone to the clean energy transition[5]. It is expected that communities are more prone to invest on renewable energy generation to make the community self-sustained and resilient against price rise that can affect the vulnerable groups.

At the same time, the community can promote energy efficiency efforts on building and other facilities, making sure that the use of the energy is effective, and that no inefficiencies are getting into the equation.

According to the Clean energy for all European Package, the EU has now new legislation for energy communities within Europe[6]. This was done with the concept of Citizens Energy Communities and Renewable Energy Communities. The Directive on common rules for the internal electricity market[7] make possible active consumer participation either as individual or as part of a community. This can be done by accessing all markets with the production of energy, buying energy or offering flexibility services on demand. The regulation is likely to ease the

[5] *https://ec.europa.eu/energy/topics/markets-and-consumers/energy-communities_en*

[6] *https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en*

[7] *https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/electricity-market-design_en?redir=1#the-electricity-directive-and-electricity-regulation*

participation of citizens directly into the energy market without the need of large DSOs as intermediate agents.

4.3. Requirements' overview based on the social barriers and enablers

A high-level objective in PHOENIX project, is to address the need for "Prosumers to enjoy the value and benefit of innovative energy and non-energy services by increasing the smartness of their building premises". Based on the use cases and questionnaire survey circulated in D2.1, a list of specific functional requirements (inspired from D2.3 and refined here) regarding the set of services of task 6.3 has been extracted taking into account not only the needs of the prosumers but also the needs of the utilities/ESCOs that will need access to relevant insights to better grasp how the synergic grid-building interaction will lead to the definition of new business opportunities.

Table 3. Table of requirements.

Req. ID	Description	Relevant stakeholder
01	Real-time and historic data regarding energy generation, storage and consumption should be made available at a single occupant/prosumer level.	Prosumers
02	Historic/aggregated data regarding energy generation, storage and consumption should be made available at a cluster of prosumers level.	ESCOs
03	ESCOs should benefit from the maximization of self-consumption as a Service by gaining new insights.	ESCOs
04	Self-consumption optimization forecasts at a day-ahead level should be provided.	ESCOs, prosumers
05	Calculation of the energy savings should be provided.	ESCOs, prosumers
06	The self-consumption optimization engine should be flexible enough to support the existing use cases formulated by the partners' feedback and adapt to new ones if needed in the near future.	ESCOs, prosumers
07	Calculation of the energy savings should be provided.	ESCOs, prosumers

08	Calculation of the energy waste should be provided.	ESCOs, prosumers
09	Visualization information should be provided in the Building Occupants Visualization Dashboard for reporting purposes.	prosumers
10	Visualization information should be provided in the Business Stakeholder Interface Engine for reporting purposes.	ESCOs

The above requirements can directly be linked to the social barriers and enablers extracted from D2.2:

Privacy concerns: Any private information regarding energy production, use, energy savings, energy waste etc. raises concerns about how this kind of data can be accessed and exploited in a harmful way. To tackle this, and according to Deliverable 9.1, customized informed consent forms will be provided to the prosumers, depending on the participating country, before the users make their official registration to the Building Occupants Visualization Dashboard.

Lack of perceived control on the technology: For the non- tech savvy users and participants of energy programs using smart systems (especially for over 65 years old), there exists a substantial gap of knowledge on how the optimizations on self-consumption can lead to an improvement in the building energy performance thus an increase in the energy and cost savings. There might also be a fear and a lack of confidence on the automation actions that might arise after such an optimization process. Specialized graphs in the Building Occupants Visualization Dashboard and in the Business Stakeholder Interface Engine shall cover this aspect.

Energy conservation and monetary savings: More than 70% of the occupants that participated in the questionnaire of D2.1 expressed a genuine interest in increasing energy and cost savings, so a clear before and after the adoption of Phoenix solution landscape, should be highlighted through comparative graphs and continuous monitoring and optimization on the respective measurements.

Enabling customer control: The automation actions that might arise after the self-consumption optimization process combined with the adoption of recommendations to change manually a certain behaviour, promote the sense of control of a smart and fully customizable home with examples ranging from deciding on an optimum period for EV charging, optimum battery charging from energy produced in the PV and load shifting regarding HVAC, DHW and other flexible assets.

4.4. Services for self-generation and energy storage specifications

The active participation of the consumers in energy micro-generation through the installation of PV and battery equipment creates a new target group of beneficiaries, named prosumers and novel business models (prosumer-oriented business models). The role of the prosumers in PHOENIX project is to promote the energy efficiency by using as much as possible of the power generated on the building (maximizing the self-consumption) and minimize the excess of energy given back to the grid. The formal definition of self-consumption is the share of the PV energy production consumed in the dwelling that the PV is installed compared to the total PV production. Besides the prosumers, the services for self-generation and storage are also targeted to ESCOs as they will have the opportunity to gain useful insights to develop new business models and improve existing ones for their customers.

Managing and optimizing self-consumption of on-site or off-site PV electricity, can be achieved either through local storage (battery use) or by load shifting of certain flexible assets to limit the grid feed at peak times where the price of electricity also increases. More importantly, the predicted day-ahead self-consumption optimization can guide the prosumer into making decisions based on the road of maximizing his energy cost savings.

Under the scope of task 6.3 as described in the proposal we mainly focus on the below scenarios:

Scenario 1, PV and battery: If the day-ahead predicted energy generation (taking as a total or average) is greater than the day-ahead total predicted energy consumption (taking as a total or average) then an excess of self-generated energy event is established. In presence of a battery in the system, the battery acts as a buffer between the PV and the grid and starts charging (until maximum capacity is reached) in case of excess of energy produced and discharging (until the lower state of charge is reached) in case there is electricity demand. It should be noted that the state of the battery poses a serious constraint in the optimization problem, like if the battery is empty, full, charging, testing etc.

Scenario 2, PV and EV: If the day-ahead predicted energy generation (taking as a total or average) is greater than the day-ahead total predicted energy consumption (taking as a total or average) then an excess of self-generated energy event is established. In presence of an EV in the system, the excess of energy produced is used to charge the EV (considering that the EV is not away from home) until fully charged or until the EV is taken out for driving and thus is in the state away from home. In the EV case some extra information is needed regarding the charging schedule, the average driving time each day, the average electricity used when driven etc.

As far as scenarios 1 and 2 are concerned, the aim is to increase self-consumption of PV power by either controlling the charging pattern of a battery or an EV respectively, either time-wise (find an optimal timing for battery charge when there is a power peak generation) or find an optimal plan to charge the EV and use energy from the EV for any arising load demand. The above can be described as a linear optimization problem with constraints and solved by using linear programming techniques.

Scenario 3, PV, EV and battery: Furthermore, we can combine scenarios 1, 2 under a more general case where all aforementioned elements are present, PV, EV and battery. The optimization problem now becomes more complex as it has more constraints from the one hand and from the other hand it can be divided into sub-cases, e.g. if there is an excess of power generated, the battery must be put on “charging state” until a certain percentage which is less than the maximum capacity and the remaining power should be used to charge the EV, if the EV is not in the “driving state”. Once more, for all the sub-cases that we will examine and integrate in the PHOENIX platform, the problem is again a linear optimization problem under constraints, and only one optimal sub-case will be selected amongst all others available. More complex scenarios taking into account other external sources of information such as the buying and selling price of electricity will also be served here but will be analysed in a newer version of this deliverable.

The impact of optimizing self-consumption covers mainly the area of reducing the electricity costs and therefore reducing the overall cost savings for the benefited prosumer. Not only the installation of a PV system can contribute to this reduction through self-consumption of self-generated PV energy but also the combination with a battery energy storage system can contribute even more to that aspect. Selective load shifting of assets such as EV, HVAC, heat pumps and other shiftable loads, can also contribute to the self-consumption optimization problem, aspect that will also be explored in a newer version of this deliverable.

Having adopted this strategy in the Phoenix project towards maximizing the energy savings, a new role is promoted, and a greater impact is highlighted. The new model of the prosumer that has a central role in the energy market and is no longer a passive receptor of energy services without being able to understand his energy behaviour and patterns, his control over the smart assets of his dwelling and how he can actively improve his energy use at a daily level. The model of the single prosumer can also be expanded to prosumer communities that can act in a dependent manner exchanging produced/stored energy and interact with the grid as a group and not as single entities.

5. Conclusions and further work

This document shows the current situation of grid flexibility services. After a revision of the state of the art, one can see that the services that can be created for grid flexibility will be in most cases breaking new ground. This is because the field of grid flexibility is a rather nascent field. This goes together with the fact that the grid is about to undertake an important transformation. On the new paradigm there will be many more agents in the grid, and the citizens either as individuals or as communities will have their say on the system.

As far as we can tell after the work carried out for this work package, the data sources for grid flexibility services are sufficient, and efforts on other projects have made possible the provision of data that are relevant for the services of grid flexibility. Within these data, it was found day ahead predictions of price of electricity that is a fundamental input for optimising the energy use with respect to the energy cost. Also, it was seen that it is possible to obtain the generation mix each day at an hourly resolution what allows to obtain the Carbon intensity on each hour. This makes possible the design of grid services taking into consideration the CO_2 emissions derived from each kWh that is used.

The scientific literature has provided a great deal of documentation about human behaviour with respect to energy use. This includes habits on appliances use, occupancy, or conditioning use. This allowed us to create the synthetic simulator that we have considered a very powerful tool for testing demand response programs and other interventions before they are tested on the real world. And with this obtaining lessons learnt about the figures that one may expect when applying this programs on realistic set ups. The simulator includes high fidelity features such as the thermal inertia of the buildings. And it contains the electricity appliances that one may find on a building.

In summary, we consider that the opportunity to create new services is large, and that the situation of PHOENIX is adequate. Although grid flexibility services are difficult to implement, the situation with third party data, the synthetic simulator and the pilots under consideration on PHOENIX, will allow the investigation of this interventions. In the months of the project new services will be outlined and designed for their development during the second year of the project.

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