RESPOND

DEMAND RESPONSE FOR ALL

Integrated Demand REsponse SOlution Towards Energy POsitive NeighbourhooDs

WP 1: Pilot site characterization

T 1.4: Demand Response actions for each pilot

D1.4 Pilot specific demand response strategy

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AUTHOR (S)	Iker Esnaola (TEK) Francisco Javier Diez (TEK) Lisbet Stryhn Rasmussen (AURA) Avril Sharkley (ARAN) Rodrigo Lopez (FEN) Nikola Tomasevic (IMP)
OFFICIAL REVIEWER(S)	Laura Martinez (DEX)

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EXECUTIVE SUMMARY

This deliverable presents the set of DR actions suggested for each pilot site. Towards these suggestions, input from pilot sites have been really useful.

For the purpose of writing this deliverable and the suggestions represented in it, a very detailed analysis of many factors have been performed. First of all, the appliances and equipment available in each pilot site have been analysed, as these are considered to be one of the limiting factors. Then, the existing DR action types have been described. Furthermore, the singularities of the RESPOND pilot site (e.g. user habits, RES availability, etc.) have been taken into account in order finally suggest the DR actions that best fits and exploit each pilot site's capabilities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

CPP	Critical Peak Pricing
DR	Demand Response
DHW	Domestic Hot Water
IT	Information Technology
TOU	Time-of-Use
RES	Renewable Energy Source
RTP	Real-time pricing

1. INTRODUCTION

The purpose of this document is to discover suitable DR actions for each pilot site. It is part of the *WP1: Pilot site characterization* and a direct output of *T1.4: Demand response actions discovery for each pilot* which started in month 4 and ends in month 12.

Towards the writing of this deliverable, tasks and deliverables from *WP1: Pilot site characterization* have been crucial. For example, having a clear vision of what are the devices each pilot site will count on, or the previous study of different DR action strategies have played a key role in the definition of possibilities for each pilot. More specifically, this task is closely related to the identification of operational scenarios done in *Task 1.1* and reflected in deliverable *D1.1 Pilot technical characterization.*

One of the main objectives of the project related to this task is conducting the characterization and behavioral analysis of household inhabitants to enable the suggestion of actions that the occupants are able to perform.

The implementation of the adequate DR actions is just one part of the iterative approach proposed in the RESPOND project. Figure 1 places the DR strategy within RESPOND's measure-forecast-optimize-control approach, which consists of monitoring, forecasting, optimization and control actions. This approach will further be explained in *D2.1: RESPOND system reference architecture* and implemented in the *WP4: ICT enabled cooperative demand response model*.

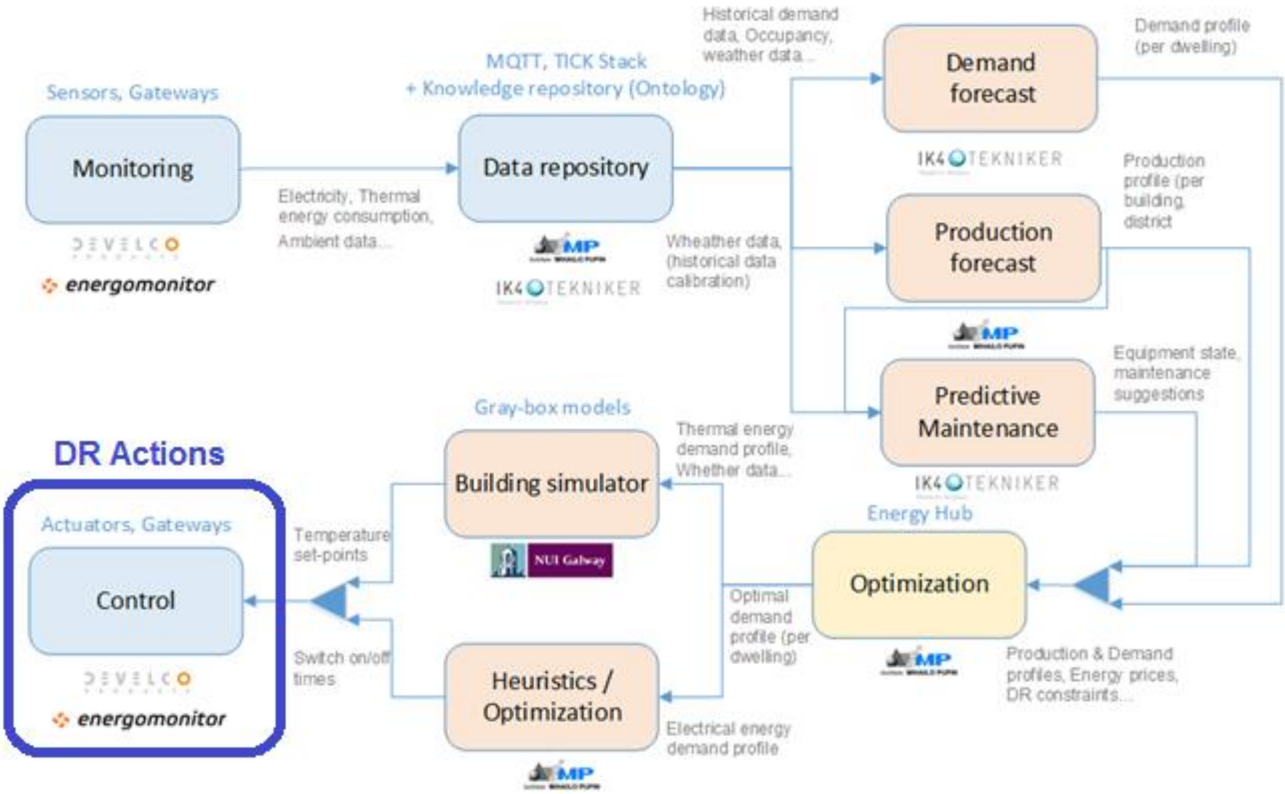

Figure 1: DR Actions within RESPOND's measure-forecast-optimize-control iterative approach

The optimization phase will determine the DR actions that the system will suggest. These suggestions are aimed to have an impact both at dweller and neighbourhood levels, therefore, RESPOND will focus on different metrics and KPIs to determine the effectivity and impact of these suggestions at these two levels.

The rest of the deliverable is structured as follows. Section 2 describes the equipment available in each pilot. For this section, information collected in *D2.3: Initial deployment plan* and *D2.4: Early deployment activities report*. Section 3 explains the different DR possibilities. This section uses information described in *D1.2: Demand response programs overview* and extends it with some thermal considerations. Section 4 introduces a set of DR action types. Section 5, which is nuclear to this deliverable, details the possible DR actions for each pilot site. In order to reach to these recommendations, a deep analysis of the characteristics of each pilot and the possibilities offered by deployed devices has been necessary. Finally, conclusions of the deliverable are drawn in Section 6.

2. AVAILABLE EQUIPMENT

In this section, information gathered in *D2.3* and the latest updates of the equipment installed is used to represent the equipment that is expected to be installed in each test house. This list will be updated in deliverable *D2.4 Early Deployment Activites Report*.

2.1 AARHUS (DENMARK)

A general overview of energy generation and consumption in Aarhus pilot site is shown in Figure 2:

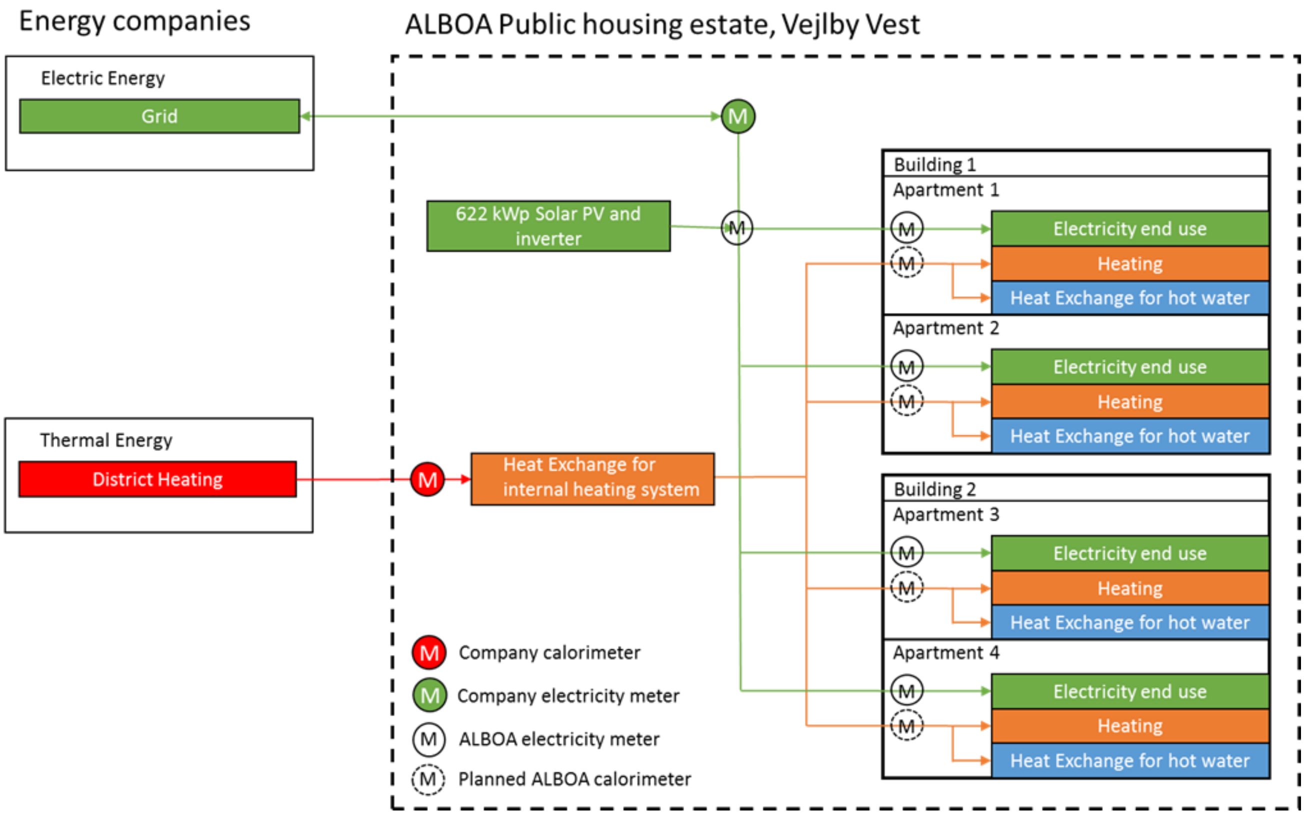

Figure 2: General energy flow in Aarhus pilot site

Figure *3* shows the equipment expected to be available in each house of the Danish pilot site. Figure *4* shows the equipment of the common areas in Aarhus.

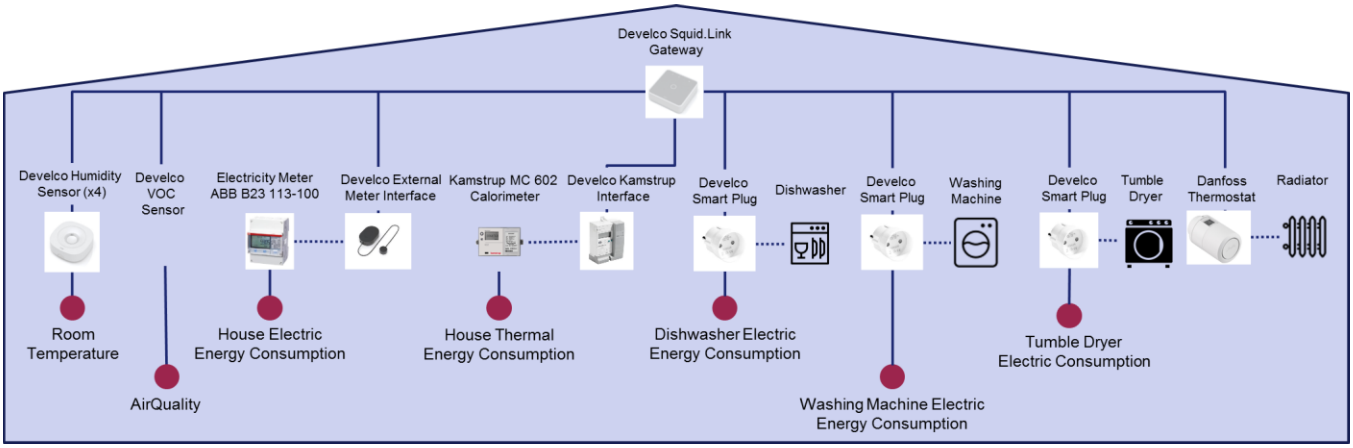

Figure 3: Equipment available in Aarhus houses

In order to monitor the comfort conditions within the houses, two sensors are mainly used: on the one hand, four Develco humidity sensor installed in different rooms of the house (namely in the bedroom, kitchen, bathroom and living room) to measure the humidity and temperature of the room, and on the other, a Develco VOC sensor to measure the air quality of the room. Regarding the monitoring of the energy consumption of Danish houses, different devices are used. For the thermal energy consumption, the Karmstrup MC 602 calorimeter will be used, alongside with a Develco Karmstrup Interface to transmit the data monitored by the calorimeter. As for the house electric consumption, a Develco External meter Interface is used to access the readings of the ABB B23 113-100 Electricity meter installed. In order to monitor dishwasher's, washing machine's and tumble dryer's power consumption, three Develco Smart Plugs will be used. The Danfoss Thermostat, by contrast, will be used to individually control the radiators' activation according to DR actions. Finally, each house will count on a Develco Squid.link gateway to send all the gathered information.

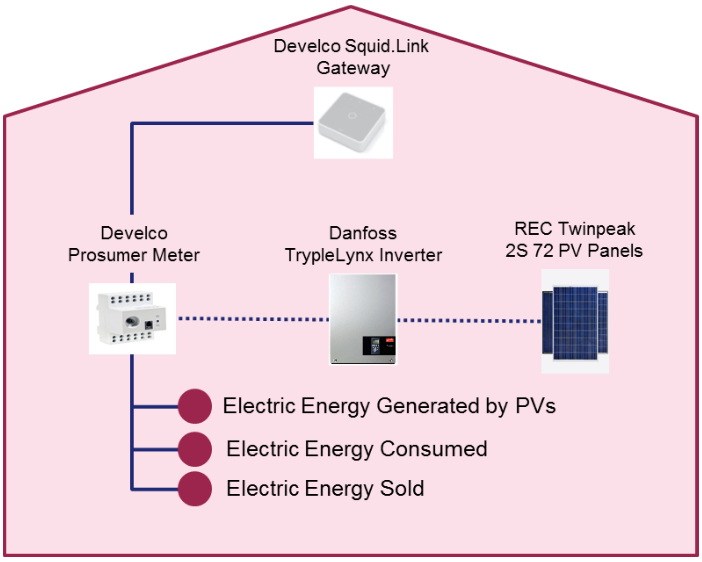

Figure 4: Equipment available in Aarhus common areas

In the common areas of the Aarhus pilot site, PV Panels (model REC Twinpeak 2S 72) will be in charge of generating electric energy out of solar energy. A Develco Prosumer meter will monitor the electric energy generated by these PV panels, the electric energy consumed out of this generated energy, and the electric energy sold to the utility. The Danfoss TripleLynx Inverter will convert the direct current (DC) output of a PV, into an alternating current (AC). Finally, likewise the houses, the common area has a Develco Squid.link gateway to send all the information gathered by the aforementioned equipment.

2.2 Aran Islands (Ireland)

The general energy flow in Aran Islands pilot site is shown in Figure 5:

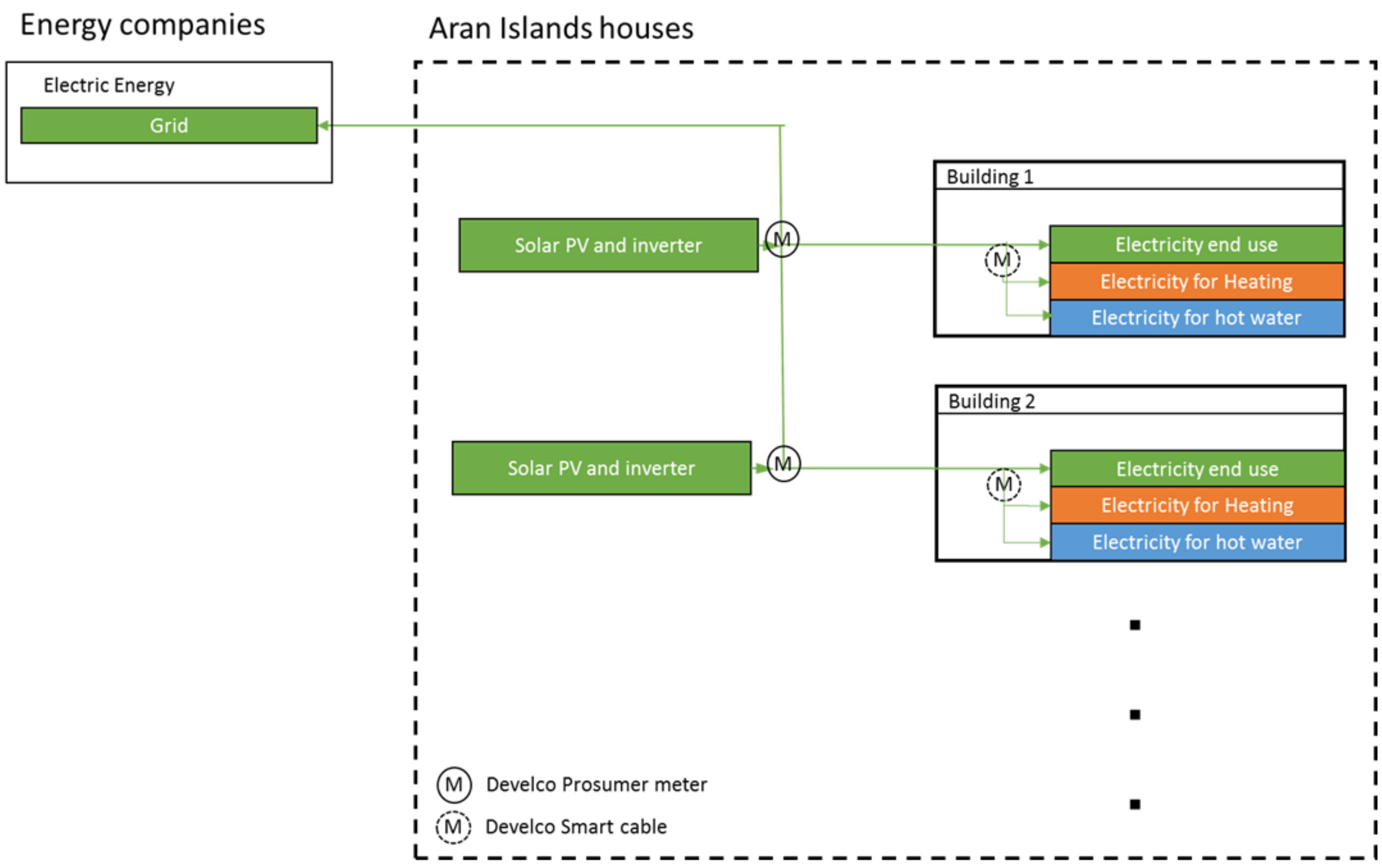

Figure 5: General energy flow in Aran Islands pilot site

In the Aran Islands, each house has its own topology and available equipment differs from one house to other. At the moment of writing this deliverable, 5 houses have been recruited for the RESPOND project. Figure 6 shows the equipment deployed or expected to be available in the Irish house 2. The equipment deployed in other houses is a subset of this equipment.

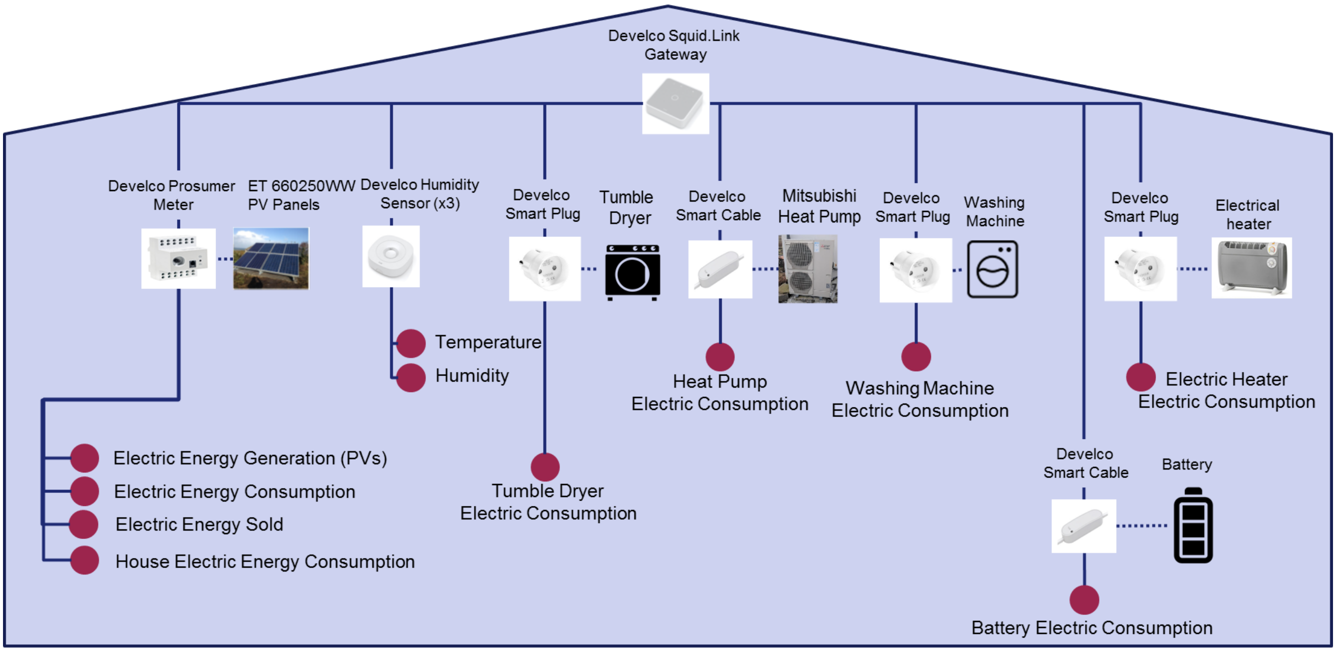

Figure 6: Equipment available in Aran Island houses

In order to monitor the comfort conditions within the houses, three Develco Humidity sensors are used, measuring the temperature and humidity of the room in which they are installed. In order to monitor tumble dryer's, washing machine's and electrical heater's power consumption, three Develco Smart Plugs will be used. In Houses 1, 3 and 4, one of those Develco Smart Plugs will control and monitor the dishwasher instead of the electrical heater, while House 5 will only count on two Develco Smart Plugs to control and monitor the tumble dryer and the washing machine. Furthermore, Develco Smart plugs connected to electric heaters will also control their activation according to the DR actions. Regarding the monitoring of the energy consumption of the house, a Develco Prosumer Meter will be used. Furthermore, this Develco Prosumer meter will also monitor electric energy generated by the ET 660250WW PV panels, the consumption of this generated energy, and the electric energy sold. Last but not least, two Develco Smart Cables will monitor the power consumption and control the activation and deactivation of a Mitsubishi Heat Pump and a battery. In case of the House 1, instead of a battery, one of the Develco Smart Cables will be attached to an electrical heater. As for House 3, 4 and 5, there will only be one Develco Smart Cable in charge of the Mitsubishi Heat Pump. Finally, each house will count on a Develco Squid.link gateway to send all the gathered information. Last but not least, it is worth mentioning that House 1 will also have an Electric Vehicle Renault Fluence.

2.3 Madrid (Spain)

The general energy flow in Madrid pilot site is shown in Figure 7:

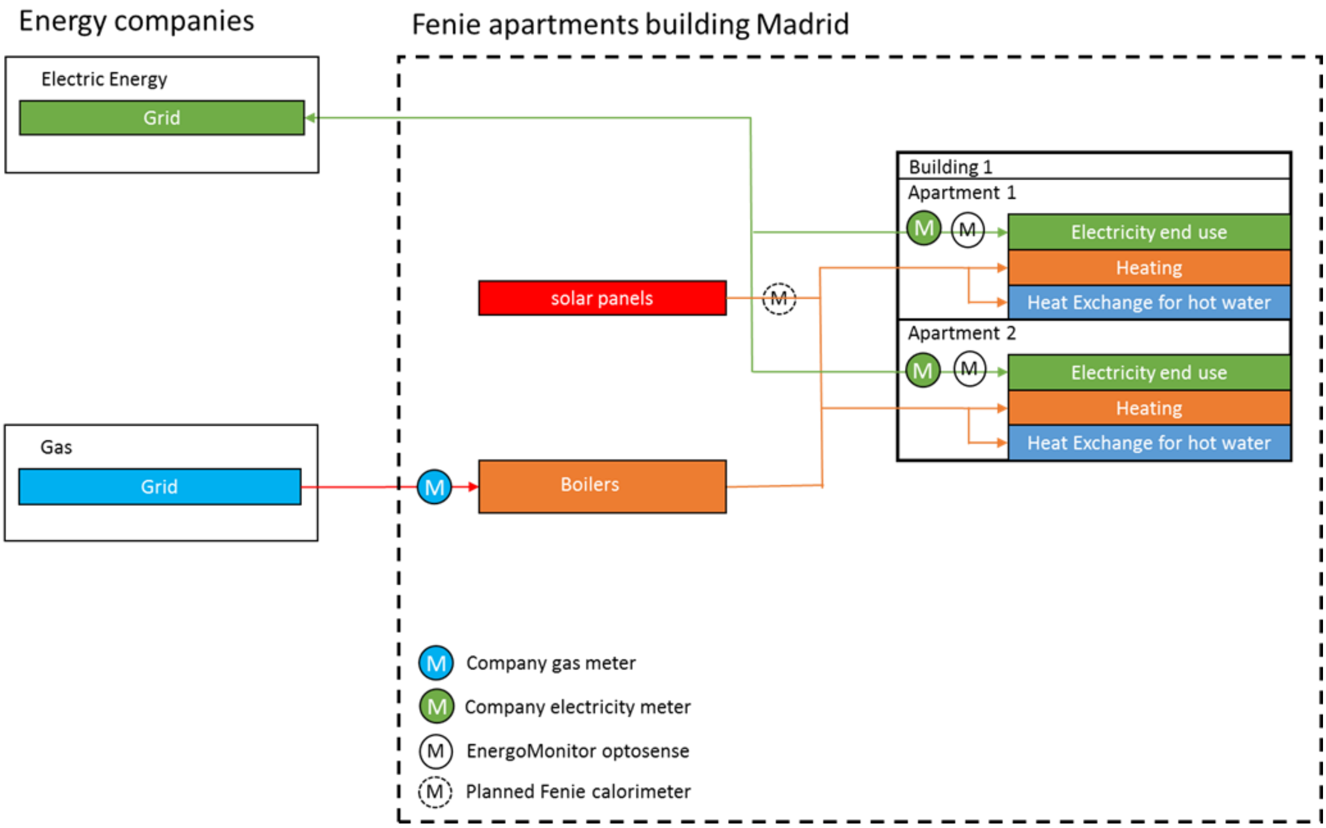

Figure 7: General energy flow in Madrid pilot site

Figure 8 shows the equipment expected to be available in each house of the Madrid pilot site. As for Figure 9, it shows the equipment of the Madrid common areas.

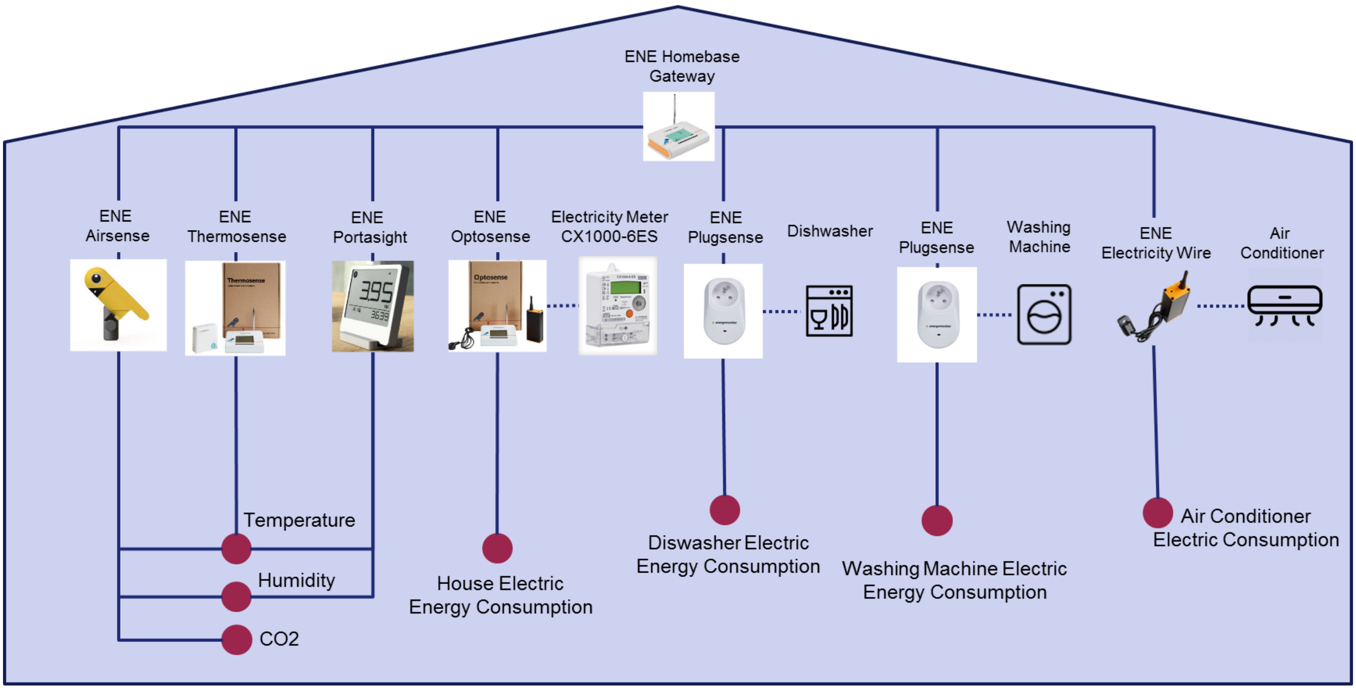

Figure 8: Equipment available in Madrid houses

The Energomonitor Homebase will be installed in the living room, near the router's location, in order to ensure Internet access. In this room, the Energomonitor Airsense (measuring temperature, CO2 and humidity) will also be installed, while the Energomonitor Thermosense (measuring temperature) will be located in the bedrooms to compare variations among locations. The kitchen will host the Energomonitor Portasight display (measuring temperature and humidity) as well as the Energomonitor Plugsenses installed in the dishwasher and washing machine. The electricity wire sensor will be installed in the main electrical panel of the house monitoring air conditioner circuit, while the Energomonitor Optosense will be installed in the utility electricity meter (Sagemcom CX 1000-6ES) located in the building's common meters room (in the basement).

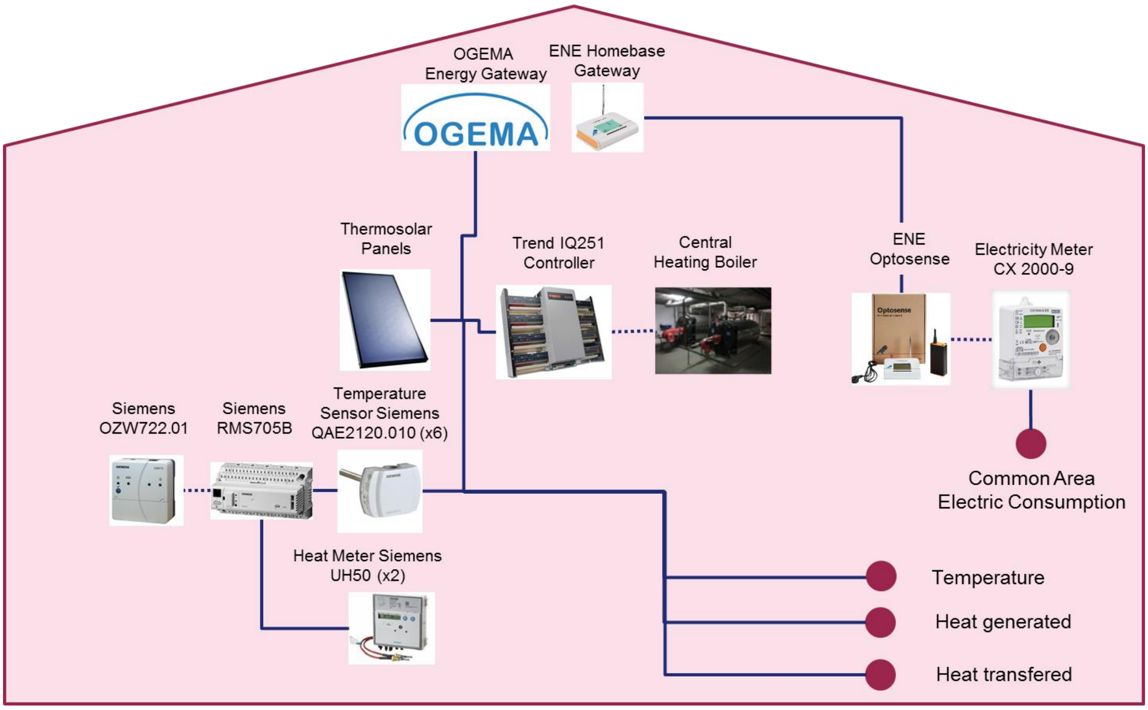

Figure 9: Equipment available in Madrid common areas

In order to measure the electric consumption in common areas, various Energomonitor Optosenses will be installed to read the consumption measured by Sagemcom Cx2000-9 electricity meters. An Energomonitor Homebase that acts as a gateway for transmitting all the collected information. A Trend IQ251 controller will be installed for monitoring the central heating boiler. As for the performance of the thermosolar system performance, it will be monitored by 6 Siemens QAE2120.010 temperature sensors. They will be installed in the cold-water input, solar panels input and output, thermosolar circuit water tank, SHW water tank and SHW output. This way, in addition to enabling the adjustment and measurement of thermosolar system's performance, it will provide trials participants with thermosolar SHW availability and production, in order to modify their consumption timeframes. Furthermore, 2 Siemens UH50 electronic heat meters are installed: one of them in the primary thermal circuit in order to measure the real solar production, and the other one in the return circuit to quantify circuit lose. All of them are expected to be connected to the Siemens RMS705B solar regulation control unit that will be available for remote access through the Siemens OZW722.01 web server for remote communications. All Siemens devices will use KNX communication protocol.

3. DR POSSIBILITIES

The study of different DR programs has been made in *Task 1.2 Demand response programs*. This section shows the main characteristics of each option, in order to identify the potential DR actions that can be leveraged. A more complete description can be found in deliverable *D1.2 Demand response programs overview*. Figure 10 shows an overview of the DR programs classification.

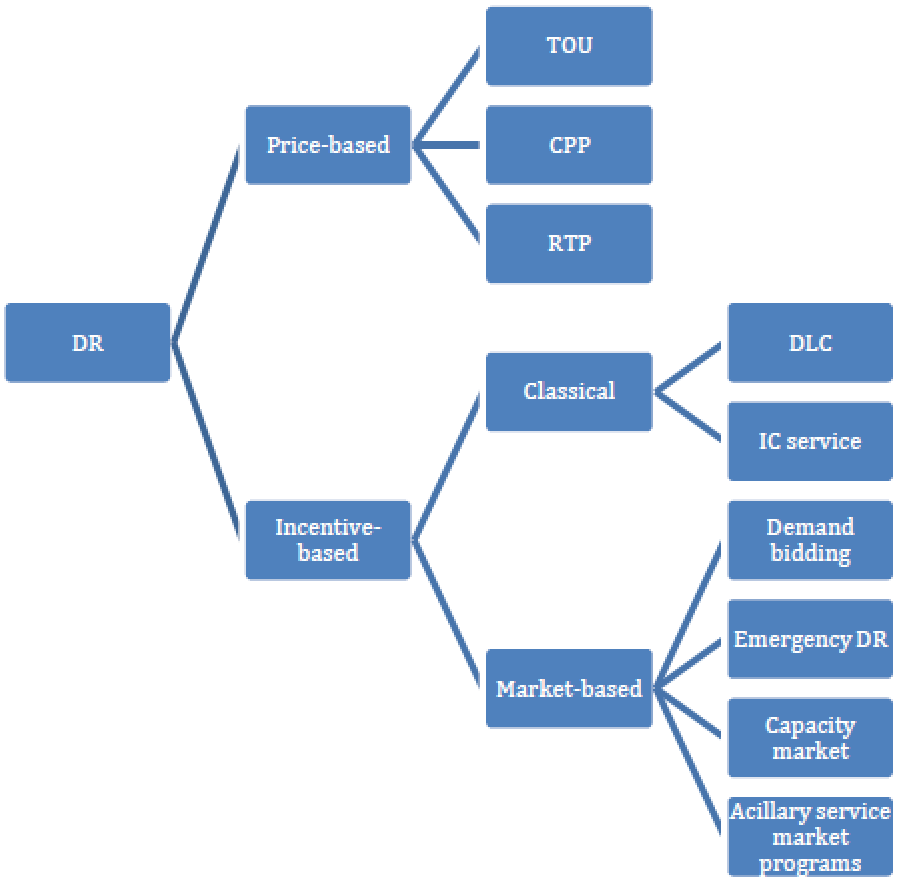

Figure 10: DR programs classification

3.1 PRICE-BASED

3.1.1 PRICE-BASED

In price-based DR programs, electricity price is not fixed, but it varies in time. The common goal is to reduce the electricity consumptions over a certain period of time.

3.1.1 Time-of-use (TOU)

The TOU tariffs work following the variations of the electricity cost previsions in different time domains (from hour to season). TOU works dividing the day in time spans and assigning a different price for each time-span. This way, customers are subsidizing to shift their consumption from high demand periods (which corresponds to high energy price) to low demand periods (typically with lower energy prices).

3.1.2 Critical Peak Pricing (CPP)

In this type of DR programs, the energy price is strongly raised during peak demand periods. In turn, the user participation is compensated with a lower base tariff. Since the critical peaks are not known, they are usually forecasted and the users receive the communication of the events only shortly in advance. The user participation is compensated by offering a lower base tariff. CPP is the most suitable pricing method for peak reduction.

3.1.3 Real-time pricing

It is a price schema where only the maximum and minimum prices are defined in advance, so the current price can vary continuously between them. The energy price is updated in a very short notice, typically hourly. In some RTP programmes, a price period with a fixed duration (for example of 1 h) is included, and the tariffs are communicated to the customer one day in advance, thus creating a form that has some characteristics of TOU rates and is known as quasi-RTP.

3.2 Incentive-based

End users get a recompense to reduce their electric loads on request or for giving permissions to regulate their electric loads. This typology of programs began with industrial and large commercial customers. Recently, residential customers have been included to those programs as well.

3.2.1 Direct load control

This type of programs reduces the household electrical loads, shutting down appliances on a short notice. The loads are distinguished as controllable and not controllable or critical. The loads include space heating/cooling, washing machines, dryer machines, water heaters and Electrical Vehicles (EVs).

3.2.2 Interruptible/Curtailable service

These services include a discount or bill credit to the customers for agreeing on load reduction to a certain level (predefined by a contract), for a short period of time, during system contingencies. These programs are mandatory: in case of failure to respond, the customers may be charged with penalties or excluded from the program.

3.2.3 Market-based Demand response

In market-based DR programs, participants are rewarded with money for their performance, depending on the amount of load reduction during critical conditions.

Demand Bidding (also called Buyback) are programs in which consumers bid on specific load reductions in the electricity wholesale market. In Emergency DR Programs, participating customers are paid incentives for measured load reductions during emergency conditions. Capacity Market Programs are offered to customers who can commit to providing pre-specified load reductions when system contingencies arise. Another option are the ancillary service market programs, which allow customers to bid on load curtailment in the spot market as operating reserve. When bids are accepted, participants are paid the spot market price for committing to be on standby and they are paid spot market energy price if load curtailment is required

3.3 Thermal Considerations

DR programs are usually only applied to electricity because not only is it the more controllable energy type, but also because electricity consumption has commonly the highest total price in the energy bill. Furthermore, the heating and cooling of a dwelling can be responsible for the most expensive energy usage during some months of the year on some geographical zones. Thermal energy is many times overlooked, but it is also controllable and has some features that makes it appealing for DR programs.

Depending on the features, dimensions and materials of used, each building has given thermal inertia. The thermal inertia is a characteristic used for modeling heat transfers and it is a property of mass material related to thermal conductivity and capacity volumetric heat. That is, a building with a great amount of mass is able to time-shift and flatten out heat flow fluctuations [1].

Thermal mass is effective in improving building comfort in any place that experiences these types of daily temperature fluctuations both in winter as well as in summer. When used well thermal mass can play an important role in major reductions to energy use in active heating and cooling systems.

The combination of the thermal mass with the external environmental conditions (e.g. external temperature or solar radiation) as well as indoor factors (e.g. occupancy or the residual heat of the appliances) can further reduce the use of heating and cooling systems to ensure adequate indoor conditions.

According to ANSI/ASHRAE Standard 55-2017, thermal comfort is defined as follows: “that condition of mind that expresses satisfaction with the thermal environment and is assessed by subject evaluation”. Therefore, being a subjective sense, under the same conditions a person may be shivering while another may break a sweat. Furthermore, the thermal comfort may involve many different parameters apart from the temperature, such as the exposure to direct air flow.

Although many times being an overlooked factor, extensive research has been conducted proving the impact of thermal comfort on humans. It has been proved that there is a direct relation between indoor environment conditions and inhabitants' morale, health, and well-being [2]. Therefore, it is an important factor to bear in mind when considering the application of DR strategies in dwellings.

4. DR Action Types

In this section, four DR action types are identified. For each of them, a brief explanation and an example are provided.

4.1 Descriptive Actions

Descriptive actions consist in showing information to the user. For instance, via a message such as: "tomorrow, the lowest electricity price will be at 6 p.m."

Descriptive actions have the lowest value for the user because they must be inferred by the user. These actions will be used when no other action can be done. Furthermore, they should be customized to the user environment because if they are very generic, the user will think that the action is not appropriate for him or her. For the rest of the document, the following icon will be used to represent descriptive DR actions:


[1]

4.2 Prescriptive Actions

Prescriptive actions are suggestions regarding the DR actions that could be undertaken: For example, with a notification such as "you should put your dishwasher tomorrow at 6 p.m., because it will be cheaper".

These action adds more value to the information sent to the user, since they indicate which concrete action should be performed by the user and when. This action is adequate when the system has enough information to take a decision, but the corresponding equipment cannot be controlled.

The value added by the action must be significant to the user because, if the user receives a lot for prescriptive actions with low added value, he/she will not rely on the system. Furthermore, the direct feedback from the used to the system, would be interesting for improving this aspect. For the rest of the document, the following icon will be used to represent prescriptive DR actions.


[1]

[1] Made by Smashicons from www.flaticon.com

4.3 AUTOMATIZED ACTIONS

These are actions that are executed by the system in an automatic manner.

This type of actions would be the most comfortable ones for dwellers, as they don't need to interact with the system. Furthermore, the automatized actions are also the preferential ones because they are expected to provide the optimal results.

However, it is the most difficult action to implement because, on the one hand, the equipment must be adequately controlled, and on the other, the user must rely totally in the system. Reaching such a degree of reliability is considered as one of the biggest hinders in this sense, and proofing its performance could contribute in this matter. The execution of hybrid actions explained next, could be a good enabler. For the rest of the document, the following icon will be used to represent automatized DR actions.

[2]

4.4 HYBRID ACTIONS

These are the type of DR actions executed after the confirmation of the dweller.

These actions are a mix between prescriptive and automatized actions, where the system is able to control thee equipment and perform the action, but it needs the user's agreement.

The main advantage of this type of actions is that the system knows if the prescription is accepted by the user, thus getting direct feedback about the matching of the action with the user preferences.

In several cases the system does not have all the information to evaluate whether the decision taken is the best or not. These actions could also be used to learn about the user behavior and therefore, for adapting the level of prescriptive actions and getting the certainty to do what the user prefers. For the rest of the document, the following icon will be used to represent hybrid DR actions.

[2]

[2] Made by Smashicons from www.flaticon.com

5. RESPOND CONCEPTUAL APPROACH

The RESPOND conceptual approach goes beyond the classical conservative approach and is aimed to take into account the behaviour of inhabitants as well as their motivation possibilities. This innovative approach must identify how to influence the behaviour of target end users and how to adapt corresponding business models.

The conservative approach shown in Figure 11 consists in reducing the consumption only in designated DR intervals according to a DR event sent by the utility. In the case of the electric reduction, the suggested action will be switching off all appliances (non-critical load) and in the case of thermal energy, the deactivation of the heating/cooling system or the change of the temperature set-point to the lower boundary of comfort requirements. In this approach there is no scheduling of the activities such as the use appliances in other periods of time or the heating or cooling of a given space in other period of time. Therefore, there is no supply/demand optimization.

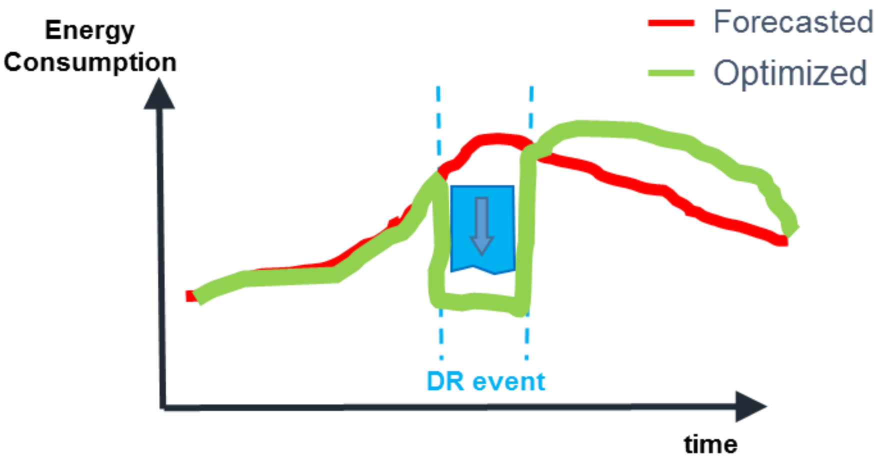

Figure 11: Conservative DR approach according to DR events

The RESPOND approach is aimed at achieving the optimization of supply/demand profile 24/7, as shown in Figure 12. For that purpose, focus is placed on peak curtailment and load shifting to non-peak hours towards the consumption reduction in designated DR intervals. This approach is expected to provide an optimal demand profile combining electricity and thermal energy to be followed by the user. The system will guide to the occupant to reach the optimized demand profile through recommendations, semi-automatic and automatic control actions.

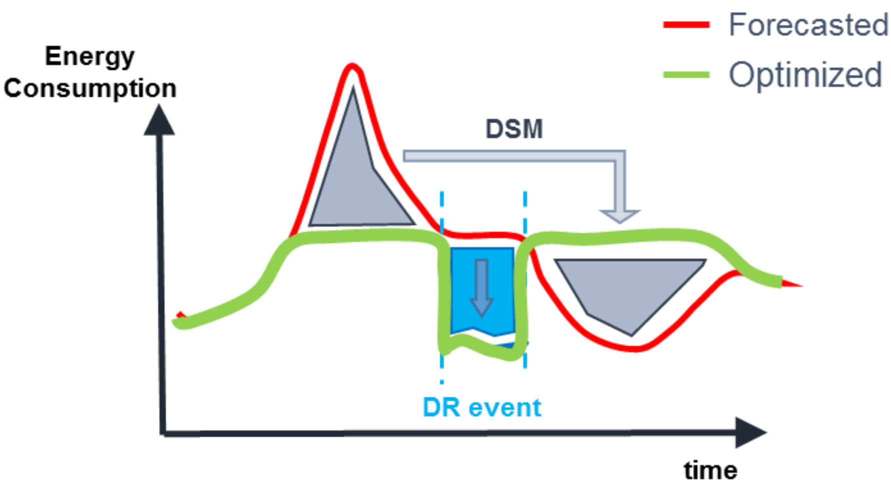

Figure 12: RESPOND's optimization of supply/demand

This approach is iterative measuring, forecasting and optimizing energy every hour. Furthermore, RESPOND will set up two high-level conceptual approaches for DR integration:

- Feasible approach – it can be deployed and demonstrated on pilots.
- Research approach – it is a case study which could be at least emulated (if not even tested in pilot operation conditions).

Each of these approaches could be verified under different scenarios (for electricity solely, for thermal energy solely, or for both, considering DR events, price or quantity based…).

DR events will be sent to the occupant by messages but the complete workflow of offers, bids, contracts and so on will be simulated in the research approach. The next chapter shows what type of actions will be planned in the feasible approach.

The RESPOND approach will also take into account the occupant preferences all the time, following the Comfort Satisfaction Loop shown in Figure 13.

Figure 13: Comfort Satisfaction Loop

These preferences will cover the type of actions suitable for every home, sending only the suitable actions depending on the available equipment. Furthermore, following the recommendations of the *Tasks 3.2 User engagement approach* and *Task 3.3 Detailing the user context and improvements of user interaction*, the system will send only the right information in the right moment to the user, thus avoiding spamming or bothering with irrelevant information.

5.1 Significant Energy Users (SEU)

The notion of Significant Energy Use (SEU) has been defined by the ISO 50001 [3] standard on energy management systems. The standard defines SEU as energy use that represents a large proportion of the energy consumption and/or a considerable potential for improving energy performance.

The next table shows the share of final energy consumption in the residential sector in Europe by type of end use:

	Space heating	Space cooling	Water heating	Cooking	Lighting and appliances	Other end uses
EU-28	64,7	0,5	13,9	5,7	13,8	1,5
Belgium	:	:	:	:	:	:
Bulgaria	53,2	0,5	17,6	8,8	19,8	0,1
Czech Republic	67,3	0,1	17,2	6,5	7,4	1,5
Denmark	61,0	0,0	21,6	1,9	15,2	0,2
Germany	68,2	0,2	14,5	6,2	7,3	3,6
Estonia	:	:	:	:	:	:
Ireland	61,0	0,0	18,3	2,3	17,4	0,9
Greece	61,9	3,3	11,6	5,9	17,3	0,0
Spain	44,2	0,9	17,6	7,4	29,8	0,0
France	64,7	0,1	11,3	5,8	18,0	0,0
Croatia	68,3	2,6	8,0	9,0	12,1	0,0
Italy	68,5	2,1	11,7	6,2	10,2	1,5
Cyprus	:	:	:	:	:	:
Latvia	64,1	0,0	18,6	7,3	9,3	0,7
Lithuania	71,0	0,0	9,8	4,4	14,8	0,0
Luxembourg	78,0	0,3	7,8	2,4	11,5	0,0
Hungary	73,3	0,1	12,6	4,6	9,4	0,0
Malta	16,4	6,6	24,5	12,6	38,9	1,1
Netherlands	63,1	0,2	16,7	2,2	17,8	0,1
Austria	69,1	0,0	15,2	2,7	9,7	3,4
Poland	64,7	0,0	17,0	8,3	10,0	0,0
Portugal	21,4	0,6	19,7	39,4	18,9	0,0
Romania	66,1	0,3	12,9	6,6	14,0	0,0
Slovenia	65,3	0,6	16,1	3,9	14,1	0,0
Slovakia	:	:	:	:	:	:
Finland	64,9	0,2	16,0	1,2	12,6	5,1
Sweden	55,3	0,0	13,7	1,4	17,7	11,9
United Kingdom	68,5	0,0	12,1	2,2	17,2	0,0
Norway	33,5	0,0	14,0	0,0	36,8	15,6
Serbia	59,1	0,5	14,5	7,8	18,0	0,0
Albania	32,4	5,7	21,2	28,8	12,0	0,0
Kosovo*	11,8	0,0	11,0	10,9	13,5	52,8

*This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.

: not available

Figure 14: Share of final energy consumption percentage in the residential sector by type of end-use in EU-28 (2015)

In the three countries of the pilots Denmark, Ireland and Spain the higher percentage of consumption are space heating, water heating, lighting and appliances.

The possibilities of use of appliances for demand response is shown in the next table [4]:

AC	Air Conditioner
CP	Heating Circulation Pump
DW	Dishwasher
EH	Electric Storage Heating
FR	Freezer
OS	Oven & Stove
RF	Refrigerator
TD	Tumble Dryer
WH	Electric Water Heater
WM	Washing Machine

	WM	TD	DW	OS	RF	FR	AC	WH	EH	CP
Specific load during operation	high	high	high	high	low	low	mod.	high	v. high	low
Availability	low	low	low	low	high	high	low	mod.	mod.	mod.
Shifting flexibility	mod.	mod.	high	low	low	low	low	mod.	high	mod.
Convenience for consumers	low	low	mod.	low	high	high	low	mod.	high	mod.

Source: Seebach et al 2009

Figure 15: Qualitative assessment of the suitability of appliances for load management

Taking into account this information, the following SEUs are suitable for DR actions in the three pilots sites:

- Heating system
- DHW
- Heat pump
- Washing machine
- Dishwashing
- Tumble dryer

In the case of Madrid pilot site, the air conditioning has also a high importance since its usage is higher than Spain's average due the continental climate and the urban heat island effect.

6. DR ACTIONS FOR EACH PILOT

In this section, a set of suitable DR actions are recommended for each pilot site. For these recommendations, the initial analysis made on D1.2 has been very valuable. For each pilot's potential DR actions, the following information is given:

- DR Action: The name used to refer to the DR action.
- Description: A brief explanation of the DR action.
- Equipment involved: The equipment and appliances that enable the implementation of the DR action.
- Pre-condition: The conditions necessary to enable the execution of the DR action.
- Services involved: The RESPOND services that enable the implementation of the DR action.
- Recommended DR Type: The type of DR action (as shown in Section 4) recommended for an optimal operation of the DR action.
- Feasible DR Type (optional): The type of DR action (as shown in Section 4) that may also be applicable for the operation of the DR action. In case there are more than one DR Type, they are sorted according to its suitability.
- DR Type Unfeasible (optional): The type of DR action (as shown in Section 4) that cannot be applied for the operation of the DR action.

Table 1 shows a brief summary of the DR Actions that can be applied in each pilot site.

Table 1: Summary of DR Actions per pilot site

DR Action	Aarhus	Aran	Madrid
Load control switches for smart appliances leveraging PV panels			
Load control switches for appliances leveraging PV panels			
Load control switches for smart appliances leveraging electricity price			
Load control switches for appliances leveraging electricity price			
Smart thermostats for heating systems			
Ventilation control			
Thermal load shifting			

Smart load shift control for solar photovoltaic			
Load control switches for heat pumps			
Neighbourhood electric load shifting			
Thermal inertia for optimizing heating systems			
Thermal inertia for optimizing cooling systems			
Neighbourhood DHW shifting			

6.1 Aarhus (Denmark)

In this section, the DR actions applicable to the Aarhus pilot site are shown.

DR Action: Load control switches for smart appliances leveraging PV panels
Description: This DR action consists in activating the washing machine, tumble dryer and/or the dishwasher in periods when the PV panels are producing energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. This action is feasible since the washing machine, the tumble dryer and the dishwasher are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment. Furthermore, the smart plugs will provide valuable consumption information and user habits information that will be used to further personalize the prescriptions to dwellers. For example, the washing machine's activation will prioritize periods preceded by sunny weather in order to enable hanging up the laundry, and the proposed activation times of the dishwasher will only be after meals.
Equipment involved:
PVs (to generate energy from the sun), Develco Prosumer Meter (to know both the energy generated and consumed from PVs), Washing machine, Develco Smart Plug connected to the washing machine (to monitor its consumption), Tumble dryer, Develco Smart Plug connected to the tumble dryer (to monitor its consumption), Dishwasher, Develco Smart Plug connected to the dishwasher (to monitor its consumption)
Pre-conditions:
PV panels receive enough solar radiation to generate energy The target smart appliance is not activated The target smart appliance has not been activated in the current day
Services involved:

Weather Forecasting service (to know if it is going to be sunny or not), Energy Production Forecasting service (to know the expected energy generation from PVs), Energy Demand Forecasting service (to know the expected energy demand at a home and neighbourhood level), Global Optimization service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable. The washing machine, the tumble dryer and the dishwasher require from manual actions such as putting the dirty clothes in the washing machine or putting the dirty dishes in the dishwasher. Therefore, this DR action is not automatable. Hybrid. Even though the smart plugs allow the turning the power on in the smart appliances, they need to be manually started because the user needs to select the program, etc.

DR Action: Load control switches for appliances leveraging PV panels
Description: This DR action consists in activating the other appliances in periods when the PV panels are producing a surplus of energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. This action is feasible for appliances which are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment.
Equipment involved:
PVs (to generate energy from the sun), Develco Prosumer Meter (to know both the energy generated and consumed from PVs), Appliances
Pre-conditions:
PV panels receive enough solar radiation to generate energy The target appliance is not activated The target appliance has not been activated in the current day
Services involved:
Weather Forecasting service (to know if it is going to be sunny or not), Energy Production Forecasting service (to know the expected energy generation from PVs), Energy Demand Forecasting service (to know the expected energy demand at a home and neighbourhood level), Global Optimization service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable, Hybrid. These appliances do not support the use of Smart Plugs that allow their automatic activation/deactivation.

DR Action: Load control switches for smart appliances leveraging electricity price ([*])

[*] At the moment of writing this deliverable, the partner in charge of the Danish pilot is negotiating a new contract, so it is not guaranteed that a variable (e.g. hourly) electricity price tariff can be negotiated with the electricity grid. Therefore, this DR action cannot be confirmed until the contract is signed.

Description: This DR action consists in activating the washing machine, the tumble dryer and the dishwasher in periods when the electricity price is lower. This way, the total expense for the electricity consumed is reduced. Furthermore, this DR action can also consist in activating the dishwasher and/or the washing machine in periods when aggregated electricity demand peaks are avoided. This action is feasible since the washing machine, the tumble dryer and the dishwasher are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment.

Equipment involved:

- Washing machine,
- Develco Smart Plug connected to the washing machine (to monitor its consumption),
- Tumble dryer,
- Develco Smart Plug connected to the tumble dryer (to monitor its consumption),
- Dishwasher,
- Develco Smart Plug connected to the dishwasher (to monitor its consumption),
- Develco External Meter Interface (to monitor home's electricity consumption)

Pre-conditions:

- The electricity price is cheaper during the necessary period
- The target smart appliance is not activated
- The target smart appliance has not been activated in the current day

Services involved:

- Weather Forecasting service (to know if it is going to be sunny or not),
- Energy price service (to know the price of the electricity at a given time),
- Energy Demand Forecasting service (to know the expected energy demand at a home level),
- Local Optimization service (to know the expected energy demand at a home and neighbourhood level)

Recommended DR Type: Hybrid

Feasible DR Type: Prescriptive, Descriptive

Unfeasible DR Type: Automatable. The washing machine, the tumble dryer and the dishwasher require from manual actions such as putting the dirty clothes in the washing machine or putting the dirty dishes in the dishwasher. Therefore, this DR action is not automatable. Hybrid. Even though the smart plugs allow the turning the power on in the smart appliances, they need to be manually started because the user needs to select the program, etc.

DR Action: Load control switches for appliances leveraging electricity price (*)

Description: This DR action consists in activating appliances in periods when the electricity price is lower. This way, the total expense for the electricity consumed is reduced. Furthermore, this DR action can also consist in activating appliances in periods when aggregated electricity demand peaks are avoided. This action is feasible for appliances which are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment.

Equipment involved:

- Develco External Meter Interface (to monitor home's electricity consumption),
- Appliances

Pre-conditions:

*At the moment of writing this deliverable, the partner in charge of the Danish pilot is negotiating a new contract, so it is not guaranteed that a variable (e.g. hourly) electricity price tariff can be negotiated with the electricity grid. Therefore, this DR action cannot be confirmed until the contract is signed

The electricity price is cheaper during the necessary period The target appliance is not activated The target appliance has not been activated in the current day
Service involved:
Weather Forecasting service (to know if it is going to be sunny or not), Energy price service (to know the price of the electricity at a given time), Energy Demand Forecasting service (to know the expected energy demand at a home level), Local Optimization service to know the expected energy demand at a home and neighbourhood level
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable, Hybrid. These appliances do not support the use of Smart Plugs that allow their automatic activation/deactivation.

DR Action: Smart thermostats for heating systems
Description: This DR action consists in leveraging the thermal inertia of the room to minimize the heat consumption. For example, if it is forecasted that weather will be warm, the thermostat set point could be lowered or even deactivated in advance, thereby capitalising on the thermal inertia of the buildings. By making it easier for the tenants to adjust the heating and making time schedules for every room, it is expected to motivate the tenants to reduce their overall heat consumption.
Equipment involved:
Develco Humidity Sensor (to measure temperature and humidity indoors), Smart Thermostat (to control the radiators' activation/deactivation)
Pre-conditions:
External weather conditions are adequate Heating system is activated
Services involved:
Weather Forecasting service (to know the predicted weather), Energy Demand Forecasting (to know the expected thermal energy demand at a home level), Building Simulation (to simulate the behaviour of the home), Local Optimization Service (to support optimal decision-making)
Recommended DR Type: Hybrid
Feasible DR Type: Automatable, Prescriptive, Descriptive.

DR Action: Ventilation control
Description: This DR action consists in opening windows to ventilate a room when the indoor conditions demand it.
Equipment involved:
Develco VOC sensor (to know the room's air quality), Develco Humidity sensor (to know room's temperature and humidity)
Pre-conditions:
External weather conditions are adequate Windows are not already opened There are occupants in the dwelling

Services involved:
• Weather Forecasting service (to know if external conditions are good), • Building Simulation service (to simulate the behaviour of the room), • Local Optimization Service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable and Hybrid. There are no window actuators, so windows have to be opened manually.

DR Action: Housing thermal load shifting
Description: This DR action consists in leveraging thermal inertia of the building to minimize the heat consumption in peak hours.
Equipment involved:
Develco Humidity sensor (to know room's temperature and humidity), Smart Thermostat (to control the heater's activation/deactivation)
Pre-conditions:
There is enough heating power to reach the setpoint in advance There are occupants in the dwelling Heating system is activated
Services involved:
Weather Forecasting service (to know the predicted weather), Building Simulation service (to simulate the behaviour of the room), Energy Demand Forecasting (to know the expected thermal energy demand at a home level), Local Optimization Service (to support optimal decision-making), Global Optimization service (to support optimal decision-making)
Recommended DR Type: Automatable. Otherwise, it would be very difficult coordinating all dwellers of the neighbourhood.
Feasible DR Type: Hybrid, Prescriptive, Descriptive.

6.2 Aran Islands (Ireland)

In this section, the DR actions applicable in the Aran Islands pilot site are shown.

DR Action: Load control switches for smart appliances leveraging PV panels
Description: This DR action consists in activating the washing machine, tumble dryer and/or the dishwasher in periods when the PV panels are producing energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. This action is feasible since the washing machine, the tumble dryer and the dishwasher are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment. Furthermore, the smart plugs will provide valuable consumption information and user habits information that will be used to further personalize the prescriptions to dwellers. For example, the washing machine's activation will prioritize periods preceded by sunny weather in order to enable hanging up the laundry, and the proposed activation times of the dishwasher will only be after meals.

Equipment involved:

PVs (to generate energy from the sun),
Develco Prosumer Meter (to know both the energy generated and consumed from PVs),
Washing machine,
Develco Smart Plug connected to the washing machine (to monitor its consumption),
Tumble dryer,
Develco Smart Plug connected to the tumble dryer (to monitor its consumption),
Dishwasher,
Develco Smart Plug connected to the dishwasher (to monitor its consumption),
Electrical Heater,
Develco Smart Plug connected to the electrical heater (to monitor its consumption and activate/deactivate it according to DR actions)

Pre-conditions:

PV panels receive enough solar radiation to generate energy
The target smart appliance is not activated
The target smart appliance has not been activated in the current day

Services involved:

- Weather Forecasting service (to know if it is going to be sunny or not),
- Energy Production Forecasting service (to know the expected energy generation from PVs),
- Energy Demand Forecasting service (to know the expected energy demand at a home level),
- Local Optimization service (to support optimal decision-making)

Recommended DR Type: Prescriptive

Feasible DR Type: Descriptive

Unfeasible DR Type: Automatable. The washing machine, the tumble dryer and the dishwasher require from manual actions such as putting the dirty clothes in the washing machine or putting the dirty dishes in the dishwasher. Therefore, this DR action is not automatable. Hybrid. Even though the smart plugs allow the turning the power on in the smart appliances, they need to be manually started because the user needs to select the program, etc.

DR Action: Load control switches for appliances leveraging PV panels

Description: This DR action consists in activating the other appliances in periods when the PV panels are producing energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. This action is feasible for appliances which are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment.

Equipment involved:

PVs (to generate energy from the sun),
Develco Prosumer Meter (to know both the energy generated and consumed from PVs),
Appliances

Pre-conditions:

PV panels receive enough solar radiation to generate energy
The target appliance is not activated
The target appliance has not been activated in the current day

Services involved:

Weather Forecasting service (to know if it is going to be sunny or not),
Energy Production Forecasting service (to know the expected energy generation from PVs),

Energy Demand Forecasting service (to know the expected energy demand at a home level), Local Optimization service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable, Hybrid. These appliances do not have Smart Plugs that allow their automatic activation/deactivation.

DR Action: **Load control switches for heat pumps**	✓
Description: This DR action consists in activating heat pumps in periods when the PV panels are producing energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. Furthermore, this DR action consists in leveraging the thermal inertia of the room to minimize the use of heating systems. For example, if it is forecasted that weather will be warm, the heating systems can be deactivated.	
Equipment involved:	
PVs (to generate energy from the sun), Heat Pump, Develco Prosumer Meter (to know both the energy generated and consumed from PVs), Develco Smart Cable (to control heat pump's activation/deactivation and monitor its consumption), Develco Humidity Sensor (to monitor temperature and humidity indoors)	
Pre-conditions:	
PV panels receive enough solar radiation to generate energy The heat pump is not activated The weather forecast follows the trend	
Services involved:	
• Weather Forecasting service (to know if it is going to be sunny or not, and the external temperature), • Energy Production Forecasting service (to know the expected energy generation from PVs), • Energy Demand Forecasting service (to know the expected energy demand at a home level), • Building Simulation service (to simulate the behaviour of the home), • Local Optimization service (to support optimal decision-making)	
Recommended DR Type: Automatable	
Feasible DR Type: Hybrid, Prescriptive, Descriptive	

6.3 MADRID (SPAIN) (FEN)

In this section, the DR actions applicable in Madrid pilot site are shown.

DR Action: **Load control switches for smart appliances leveraging electricity price**	✓
Description: This DR action consists in activating the dishwasher and/or the washing machine in periods when the electricity price is lower. This way, the total expense for the electricity consumed is reduced. Furthermore, this DR action can also consist in activating the dishwasher and/or the washing machine in periods when aggregated electricity demand peaks are avoided. Thus, allowing the negotiation of a lower index tariff (the price for each hour is different, depending on the wholesale market price) with the	

electricity provider. This action is feasible since both the dishwasher and the washing machine are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment. Furthermore, the simulation of extreme electricity prices will also be considered (i.e. very cheap and very expensive tariffs), in order to study users' reactions.
Equipment involved:
Dishwasher, Energomonitor Plugsense connected to the dishwasher (to control dishwasher's activation/deactivation and monitor its consumption), Washing Machine, Energomonitor Plugsense connected to the washing machine (to control washing machine's activation/deactivation and monitor its consumption), Energomonitor Optosense (to monitor home's electricity consumption)
Pre-conditions:
The electricity price is cheaper during the necessary period The target smart appliance is not activated The target smart appliance has not been activated in the current day
Services involved:
Weather Forecasting service (to know if it is going to be sunny or not), Energy price service (to know the price of the electricity at a given time), Energy Demand Forecasting service (to know the expected energy demand at a home level), Local Optimization service (to support optimal decision-making)
Recommended DR Type: Hybrid
Feasible DR Type: Prescriptive, Descriptive
Unfeasible DR Type: Automatable. Both washing machine and dishwasher require from manual actions such as putting the dirty clothes in the Washing Machine or putting the dirty dishes in the Dishwasher.

DR Action: **Load control switches for appliances leveraging electricity price**
Description: This DR action consists in activating appliances in periods when the electricity price is lower. This way, the total expense for the electricity consumed is reduced. Furthermore, this DR action can also consist in activating appliances in periods when aggregated electricity demand peaks are avoided. Thus, allowing the negotiation of a lower index tariff (the price for each hour is different, depending on the wholesale market price) with the electricity provider. This action is feasible for appliances which are flexible in terms of their moment of use. That is, it is not necessary for the user to have them activated at a certain moment. Furthermore, the simulation of extreme electricity prices will also be considered (i.e. very cheap and very expensive tariffs), in order to study users' reactions.
Equipment involved:
Energomonitor Optosense (to monitor home's electricity consumption), Appliances
Pre-conditions:
The electricity price is cheaper during the necessary period The target appliance is not activated The target appliance has not been activated in the current day
Service involved:
Weather Forecasting service (to know if it is going to be sunny or not), Energy price service (to know the price of the electricity at a given time), Energy Demand Forecasting service (to know the expected energy demand at a home level),

Local Optimization service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable, Hybrid. These appliances do not have Plugsenses that allow their automatic activation/deactivation.

DR Action: Neighbourhood electric load shifting
Description: This DR action consists in shifting appliances activation to another period of time to avoid aggregated electric demand peaks. This would allow negotiating lower index tariff (the price for each hour is different, depending on the wholesale market price) with electricity provider.
Equipment involved:
Energomonitor Optosense (home electric consumption), Energomonitor Optosense (common area electric consumption)
Pre-conditions:
Most of the occupants follow the demand profile Time shifting is less than 1 day
Services involved:
Energy price service (to know the price of the electricity at a given time), Energy Demand Forecasting service (to know the expected energy demand at a neighbourhood level), Global Optimization service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive.
Unfeasible DR Type: Automatable, Hybrid

DR Action: Thermal inertia for optimizing heating systems
Description: This DR action consists in leveraging the thermal inertia of the room to minimize the use of heating systems. For example, if it is forecasted that weather will be warm, the heater could be deactivated. The equipment involved will depend on the room where this DR will be applied.
Equipment involved:
Energomonitor Airsense (to monitor the temperature of a room), Energomonitor Thermosense (to monitor the temperature of a room), Energomonitor Portasight (to monitor the temperature of a room), Central Heating System
Pre-conditions:
The indoor conditions are within the preferred range The external forecasted temperature is in an ascendant trend The heating system is activated
Services involved:
Weather Forecasting service (to know the predicted weather), Energy Demand Forecasting (to know the expected thermal energy demand at a home level), Building Simulation (to simulate the behaviour of the home), Local Optimization Service (to support optimal decision-making)
Recommended DR Type: Prescriptive

Feasible DR Type: Descriptive	
Unfeasible DR Type: Hybrid, Automatable. The heating system do not have any device that allows its automatic activation/deactivation.	

DR Action: Thermal inertia for optimizing cooling systems
Description: This DR action consists in leveraging the thermal inertia of the room to minimize the use of cooling systems. For example, if it is forecasted that weather will be cool, the air conditioner could be deactivated. Furthermore, this DR action can also consist in activating air conditioner in periods when electricity price is lower. This way, the total expense for the electricity consumed is reduced. The equipment involved will depend on the room where this DR will be applied.
Equipment involved:
Energomonitor Airsense (to monitor the temperature of a room), Energomonitor Thermosense (to monitor the temperature of a room), Energomonitor Portasight (to monitor the temperature of a room), Air conditioner, Energomonitor cable wire (to monitor air conditioner's consumption)
Pre-conditions:
The indoor conditions are within the preferred range The cooling system is activated The external forecasted temperature is in a descendent trend
Services involved:
Weather Forecasting service (to know the predicted weather), Electricity price service (to know the price of the electricity at a given time), Energy Demand Forecasting (to know the expected thermal energy demand at a home level), Building Simulation (to simulate the behaviour of the home), Local Optimization Service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Hybrid, Automatable. The air conditioner does not have any device that allows its automatic activation/deactivation.

DR Action: Ventilation control
Description: This DR action consists in opening windows to ventilate a room when the air conditions are optimal.
Equipment involved:
Energomonitor Air Sense (to know room's temperature, humidity and CO2 levels), Air conditioner, Central Heating System
Pre-conditions:
The external weather conditions are adequate
Services involved:
Weather Forecasting service (to know if external conditions are good), Building Simulation service (to simulate the behaviour of the room),

Energy Demand Forecasting (to know the expected energy demand at a home level), Local Optimization Service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive
Unfeasible DR Type: Automatable and Hybrid. There are no window actuators, so windows have to be opened manually. Furthermore, there are no heater or air conditioner controllers either, so when windows are opened, they have to be deactivated manually.

DR Action: **Neighbourhood DHW load shifting**
Description: This DR action consists in shifting the use of DHW to another period of time when the Thermosolar panels are producing energy. This way, the energy coming from renewable sources is used more efficiently, avoiding wasting it or having to a higher consumption from the gas grid. Furthermore, this DR action can also consist in shifting DHW use to another period of time to avoid aggregated DHW demand peaks. This would allow negotiating lower tariffs with DHW provider.
Equipment involved:
Thermosolar panels (to generate thermal energy), Energy gateway OGEMA (to monitor thermosolar panel generation)
Pre-conditions:
Thermosolar panels receive enough solar radiation to heat up DHW The shifted time could be allocated in one day The shifted time is not a peak time
Services involved:
Weather Forecasting service (to know if it is going to be sunny or not, and the predicted weather), Energy Production Forecasting service (to know the expected energy generation from thermosolar panels), Energy Demand Forecasting (to know the expected thermal energy demand at a neighbourhood level), Building Simulation service (to simulate the behaviour of the room), Global Optimization Service (to support optimal decision-making)
Recommended DR Type: Prescriptive
Feasible DR Type: Descriptive.
Unfeasible DR Type: Automatable, Hybrid. The DHW does not have any device that allows its automatic activation/deactivation.

7. CONCLUSIONS

RESPOND pilot sites are very different between them not only with respect to the location, but more importantly in terms of the climate associated to each of these locations, the type of houses (e.g. single-family homes in the Aran Islands or apartments in Madrid) and dwellers habits. Furthermore, houses in each pilot site count on different appliances and equipment, as well as different renewable energy sources (RES) and exploitation modality. For example, the Aran Islands exploit individually the electricity generated by their PV panels, Aarhus use collectively the electricity coming from common PV panels, and in Madrid, Thermosolar panels installed in common areas allow the use of thermal energy at building level.

The characterization done in *task 1.1 Operational scenarios and technical characterization of pilot sites* has provided the starting information to identify clearly the possibilities of energy generation and grid distribution by one hand and the significant energy users (SEUs) by other hand. With this information in parallel with *task 2.3 Design of the initial deployment plan* we have defined the main DR actions for each pilot.

This idiosyncrasy of each RESPOND pilot site makes them unique. Therefore, a plethora of DR actions are envisioned to be implemented in the project, each of them implemented in the site that best fits. The success and the optimal operation of these proposed DR actions will be directly influenced by dwellers' degree of commitment and the IT solutions developed throughout the project. The former, is foreseen to be tackled with the tasks being performed in the *WP3: User engagement process*, specially with the mobile app to enhance the interaction of the user with the system (*T3.4: Smart mobile client and personal energy performance assistant design*). The latter is directly related to tasks that comprise the *WP4: ICT enabled cooperative demand response model* and *WP5: System Integration and Interoperability.*

REFERENCES

RESPOND DOCUMENTS

D1.2 Demand response programs overview

D2.3 Initial Deployment Plan

D2.4: Early deployment activities report

EXTERNAL DOCUMENTS

[1] S. Verbeke y A. Audenaert, «Thermal inertia in buildings: A review of impacts across climate and building use,» *Renewable and Sustainable Energy Reviews,* vol. 82, pp. 2300 - 2318, 2018.

[2] K. Parsons, Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance, CRC, 2014.

[3] «Norma ISO 50001,» [En línea]. Available: https://www.iso.org/standard/69426.html.

[4] C. T. D. D. Seebach, «Cost and Benefits of Smart Appliances in Europe,» de *A report from the Smart-A project*, 2009.