RESPOND

DEMAND RESPONSE FOR ALL

Integrated Demand Response Solution Towards Energy Positive Neighbourhoods

WP6 VALIDATION AND REPLICATION OF PROJECT RESULTS

T6.5 IMPACT ASSESSMENT, LESSONS LEARNT AND RECOMMENDATIONS

D6.5 Best practices and lessons learnt

The RESPOND Consortium

2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768619

PROJECT ACRONYM	RESPOND
DOCUMENT	**D6.5 Best practices and lessons learnt**
TYPE (DISTRIBUTION LEVEL)	■ Public ☐ Confidential ☐ Restricted
DELIVERY DUE DATE	M36
DATE OF DELIVERY	30 Set 2020
STATUS AND VERSION	v1
DELIVERABLE RESPONSIBLE	NUIG
AUTHOR (S)	NUIG, AAU, FEN, TEK, IMP, AURA, DEV
OFFICIAL REVIEWER(S)	AURA

DOCUMENT HISTORY

	ISSUE DATE	CONTENT AND CHANGES
v0	31/08/2020	First Draft
v0.1	01/09/2020	First version of FEN contributions
v0.2	25/09/2020	Partners contributions
v0.3	27/09/2020	Final draft version
v0.4	28/09/2020	AURA review
v1.0	30/09/2020	Document release

EXECUTIVE SUMMARY (NUIG)

Task 6.5: This task will take as input the data derived from the operation scenarios and project pilots. Then it will give a report on the assessment of direct and indirect impacts of the deployment and integration of RESPOND platform. The direct impact will concern the mains aspects of the RESPOND solution such as the use of advanced technology, underlying methodologies and targeted DR control actions, with particular attention to the end-users and stakeholders. The indirect impact will take into consideration wider beneficiary communities. Furthermore, it will perform an analysis of the conducted demonstration activities and operation scenarios in order to report valuable experiences from both concept providers and technical project partners that will be exploited for potential further refinement and update of the user requirements. The analysis of the operation scenarios and lessons learnt shall result in recommendations and inputs to the future replication and exploitation activities. In summary, this task will deliver an analysis of the pilot results, estimate the performance indicators defined in WP1 and calculate statistics in order to assess the acceptance of the different components and core services. In this way, it will provide relevant feedback to future development processes and eventually update the requirements and specifications.

Purpose: The purpose of this document is to compilate the results of the project findings, in terms of quantitative and qualitative analysis of the Use cases results, technology assessment and User engagement characteristics. The main objective is to have in a full document all the learnings collected in the process described, for future replication in other residential demand response projects.

The inputs from previous RESPOND deliverables are described below:

- ➔ WP 06 - Deliverable 6.1 [1] – 6.2 [2] - 6.3 [3] - 6.4 [4]
- ➔ WP 07 – Deliverable 7.3 [5]

Key findings and Conclusion:

Ireland – Aran Islands

It was possible to analyze customers being involved in manual actions, achieving more than 10% of energy savings in all use cases. There is a possibility for automated actions in the pilot in UC2, UC3 and UC4, that can bring additional savings and load shifting. The individual ownership of PV panels resulted in higher engagement in the DR actions.

Denmark - Aarhus

The Danish demonstrators allowed to see results for both manual and automated actions. The results of UC05 (automated) show that there were only moderate negative impacts on the user's comfort. The manual actions expected in Use Case 06 were realized, and the app notifications with recommendations on DR actions was considered a helpful tool by the users.

Spain - Madrid

The Spanish results show the outcomes of the price incentive being applied as an efficient tool for rescheduling the electricity load. The participants of the project effectively changed the demand during the specified hours, especially when they received some contact informing about the DR event.

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ABBREVIATIONS AND ACRONYMS

ARP	Address Resolution Protocol
DHCP	Dynamic Host Configuration Protocol
DHW	Domestic Hot Water
DR	Demand Response
EDL	Eclipse Distribution License
EPL	Eclipse Public License
ESCO	Energy Services Companies
GHI	Global Horizontal Irradiance
HW	Hardware
KPI	Key Performance Indicator
MAC	Media Access Control
MQTT	Message Queuing Telemetry Transport
PV	Photovoltaic
R&D	Research and Development
SW	Software
TICK	Telegraf, InfluxDB, Chronograf and Kapacitor
ToU	Time-of-Use
UC	Use Case
VDSL	Very-high-bit-rate Digital Subscriber Line
WSK	OpenWhisk command line

INTRODUCTION

This deliverable presents a compilation of the results and findings of Deliverables 6.2 [2], 6.3 [3] and 6.4[4], reporting valuable experiences in the process of the demonstration activities and operation scenarios. The analysis includes aspects such as the deployment and integration of the RESPOND platform, analysis of the operation scenarios, lessons learnt results and recommendations, and inputs for future replication and exploitation activities. Deliverable 6.4 [4] already presented some risks and mitigations/recommendations about technical and social aspects, as can be seen in the adapted table of Annex I of this report.

1. PILOT RESULTS

The results of the project are based on the demand response event characteristics, the pilot individualities, and user behaviour during the process. The main project objectives expected to be validated using the Use Cases applied are:

- 100% of exploitation of renewable energy available
- Energy savings of 10%
- User comfort in accordance to prEN15251[1]

The achievements of each use case were analyzed in an individual description in topic 1.1.1, where it is possible to see a compilation of the results already described in Deliverables 6.2 [2] and 6.3 [3] of the project, the RESPOND objectives achieved in each Use Case, and assessment comments.

1.1.1 USE CASES IMPACT ASSESSMENT

The main assessment process was realized based on the characteristics of the Use Case, the pilot and the architecture related. Table 1 describes the most important achievements of each use case, focusing in the quantitative and qualitative analysis found in Deliverables 6.2 [2] and 6.3 [3], respectively, the RESPOND objectives that were achieved in the Use Case and assessment comments.

Table 1 - Use Cases impact assessment

UC 01 - IMPACT OF THE RESPOND APP TO THE USER Objective: To verify if customers change their energy usage behavior after having access to the data in the RESPONSE app. **Quantitative** The energy consumption and CO_2 emissions increased by 6.86% in the Madrid pilot. Aarhus and Aran Islands pilots presented a reduction of 4.72% and 20.28%, respectively. The air quality for Aran and Madrid presented enhancements, staying in the category III of prEN15251.

[1] prEN15251 standard: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

Qualitative

- The design of mobile apps should consider that in most cases only one person in a household uses the app – and that this person might not be the person who performs the household activities with the highest energy consumption.
- Age plays a role as older people in general tend to find it more difficult to download and use the app. Mobile apps should be designed to be easy to use also by older people.
- It is important that mobile apps are easy to navigate, fast and reliable.
- Many households find it interesting to compare their own energy consumption with that of their neighbours, and such comparisons can spur energy saving actions.

RESPOND objectives achieved

- Energy savings of 10% (Aran pilot)
- User comfort in accordance to prEN1525 (Aran and Madrid Pilots)

Assessment

Although the objective of this use case was not to save energy, Aran Islands contributed to the RESPOND objective. This use case was applied right after the users had access to the password to the app, what does not confirm if they had installed the app during the period.

The COVID 19 restrictions contributed to change the behaviour of the participants. As shown in Figure 1, from a consumption analysis in Madrid, the participants behaviour changed during the period that the lockdown started, increasing their consumption.

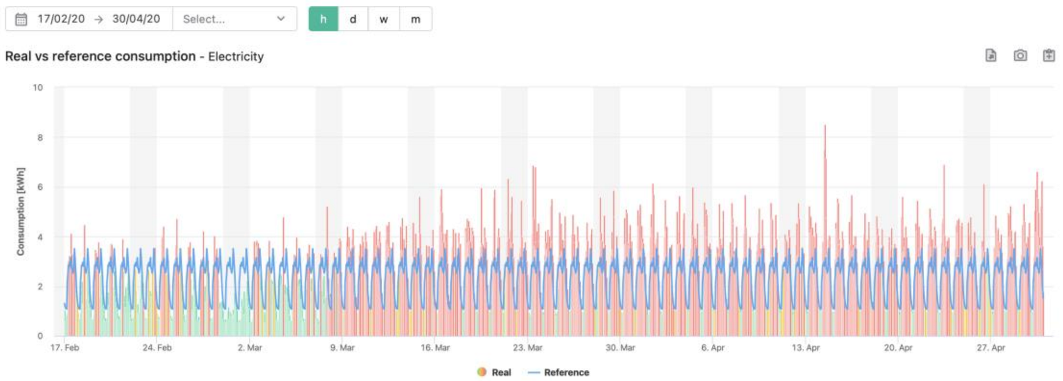

Figure 1 - COVID 19 interferences in the baseline – Madrid

UC 02 - MAXIMIZE AUTO CONSUMPTION CONTROL SWITCHES FOR APPLIANCES

Objective: Increase the energy usage in days with high PV production.

Quantitative

The energy consumption and CO_2 emissions decreased by 17.89% over the use case period. Regarding renewable consumption, on average 72.7% of the PV production was consumed in test case 01 (threshold for event activation: 900 W), and 79.6% in test case 02 (threshold for event activation: 600 W). Rescheduled demand had the best results in test case 01, with a 30% demand increase during the event hours. Compared to the baseline, 20% less energy from the grid was necessary to perform the actions.

Qualitative

- Individual ownership of PV panels appears to result in a more active engagement in demand response actions than shared ownership as in social housing associations. Thus, to engage tenants in such actions, it is important to allocate financial gains from time-shifting consumption to the individual tenants.

- App notifications with recommendations on demand response actions can be a helpful tool, especially as a reminder and learning tool for households that have not already established such DR practices.

RESPOND objectives achieved

- 100% of exploitation of renewable energy available
- Energy savings of 10%

Assessment

During the second part of the use case, there has been an increase in the number of houses participating in the project, due to a higher data availability as some technical issues were solved. It was not possible to make sure if the houses were doing the action based in the event messages, but the average of PV consumption increased during the second period of tests. All the participants with PV panels were included in this use case. In the Aran Islands pilot, each of the PV systems is installed in individual dwellings, hence the utilization relies on each of the individuals. However, due to the fact of DR events/notifications are centralized by RESPOND, the benefit is somehow extended to the community since the peak reduction can affect the whole grid.

UC 03 - OPTIMAL PROFILE OF USE FOR HEAT PUMPS

Objective: Increase the energy usage by using the heat pump during the period of high PV production.

Quantitative

The energy consumption and CO_2 emissions decreased by 29.77% over the test case. The rescheduled demand shows that the optimized model presented 54% more load activity in the event period, with renewable energy consumption 39.14% higher compared to the baseline.

RESPOND objectives achieved[2]

- 100% of exploitation of renewable energy available
- Energy savings of 10%

Assessment

The Use Case was performed in a simulated environment, but the results show its potential of energy savings, since DHW has a significant load contribution in a house. Additionally, this DR model is ideal for load shifting, since it consumes a high volume of energy in short periods, and there is a high incidence of heat pump actions early in the morning and right after the afternoon that could be delayed on anticipated to avoid the peaks and use more PV production.

There are two possible control strategies, the first is similar to UC02 and UC06, where users receive a message one day before the event and program the heat pump system according to the periods received. The second one is fully-automated, where the heat pump schedule could automatically be set by the RESPOND application, according to the PV production. This mode would need a previous user's acceptance. Also, an additional adaptor should be installed in the heat pump controller to allow remote actions.

UC 04 - PEAK SHAVING USE CASE

Objective: To verify if customers changed their behavior of energy usage after a message asking for not using energy to decrease carbon emissions.

[2] The Use Case 03 was realized only in simulations. Therefore, it not possible to evaluate the user behaviour and engagement.

Quantitative
The energy consumption and CO_2 emissions decreased by 14.73% over the use case period, which may be related to the COVID-19 (people staying home due to the restrictions). Rescheduled demand and peak load remained steady.

Qualitative

- If app notifications on peak-shaving actions shall have an effect on households' electricity consumption, these must be combined with some kind of incentive, most likely a financial incentive (e.g. high prices during peak hours or a bonus/premium for reducing power consumption).

RESPOND objectives achieved

- Energy savings of 10%

Assessment
The energy consumption decreased in the period, but it is not possible to confirm that this was only related to the event. Probably with more actions and campaigns in the period of the Use Cases application, it would be possible to see the real effect of this action.

The hour of the event can possibly clash with the hour where there is PV production, what can minimize the number of actions by the participants as they can prefer to use PV and save energy than reduce CO_2 emissions. Another methodology can be studied to define the best hour of the day for asking customers to decrease the energy usage, or even try some financial incentive model.

UC 05 - LOAD SHIFTING DISTRICT HEATING SYSTEM
Objective: Peak load shifting of the heating system by changing the set-point hours, without losing the comfort conditions.

Quantitative
The energy consumption and CO_2 emissions decreased by 14.36% on average in the participant houses over the use case period. The test case performed in the last two weeks of the use case achieved even more savings, reaching 27.46%. Peak load reduction of up to 50% was achieved in some of the week periods.

Qualitative

- The DR concept of time shifting heating in the morning by central (remote) control of radiator thermostats showed to be a usable solution for peak shaving.
- It is possible to create heat DR schemes with heating setback for up to three hours with only moderately negative impacts on the perceived indoor thermal environment in apartments.
- Knowing the plan and intentions behind a DR scheme can make the occupants more acceptant to changes in their indoor temperatures during DR actions – especially if the positive implications for the local neighbourhood or wider society (e.g. the environment) is communicated to them.
- Saving money (financial incentives) is a motivational element for households to participate – though, and importantly, not the only motivational element.
- The heat DR scheme should be designed in a way that allow occupants to adjust the temperature level to their preference and allow for some freedom to adjust the setback scheme and accepted temperature variations according to their individual needs.
- Heat DR schemes based on control of individual thermostats (radiators) implies a high level of technical complexity, which makes the system vulnerable to technical problems. This needs to

be considered and weighted against more simple and robust DR solutions based on e.g. central control.

RESPOND objectives achieved

- Energy savings of 10%

Assessment

Related to solutions for demand response and peak-shaving of space heating, occupants prefer to keep control of the temperature level and how much the room temperatures can drop during DR actions. They also prefer to be able to decide which specific rooms of the home that are included in the DR actions. It is recommended a design of heat DR scheme to allow occupants to adjust the temperature level to their preference and allow for some freedom to adjust the setback scheme and accepted temperature variations according to their individual needs. Pros and cons for individual control of thermostats versus a centralised control should be considered for each specific case where heat DR is considered.

UC 06 - MAXIMIZE AUTO-CONSUMPTION FROM GRID CONNECTED PV PANELS

Objective: Energy usage increasing in days with high PV production.

Quantitative

Total renewable energy consumption achieved up to 12.18% of increase over the use case period. The rescheduled demand analysis showed a 16.33% of more load activity in the event hours.

Qualitative

- Individual ownership of PV panels appears to result in a more active engagement in demand response actions than shared ownership as in social housing associations. Thus, to engage tenants in such actions, it is important to allocate financial gains from time-shifting consumption to the individual tenants.
- App notifications with recommendations on demand response actions can be a helpful tool, especially as a reminder and learning tool for households that have not already established such DR practices.

RESPOND objectives achieved

- 100% of exploitation of renewable energy available

Assessment

The best results were found when a more specific period of the event during the day was chosen. However, it is important to choose carefully the event range to avoid over stimulate energy consumption and create another energy peak. As the PV panel is shared by all the building occupants, including the ones that are not part of RESPOND project, it is not possible to assess the complete PV utilization. Financial incentives can possibility increase user's engagement.

UC 07 - PRICE BASED DR FOR ELECTRICAL ENERGY CONSUMPTION

Objective: To change users' behavior by stimulating energy consumption during a certain period during the day, based on financial incentives.

Quantitative

The energy consumption and CO_2 emissions were steady over the use case period, compared to the baseline. A peak reduction of 36.5% on average was achieved across the different test cases.

Qualitative

- Static Time-of-Use schemes with a significant economic incentive (like "happy hours" of free of charge electricity) motivate households to time-shift consumption away from peak-hours.
- The duration of low-price periods should be – at minimum – two hours in order to make it possible for households to run appliances such as dishwashers, washing machines and tumble dryers, which are the appliances that are in general most often time-shifted.

Assessment

This event ran for almost a year. During all this time, it was possible to see the user engagement increasing, and the project results improving. The prices have to be chosen to reflect the amount of energy expected to be dislocated to a specific time. For instance, low prices could over stimulate energy consumption in the period and create a new energy peak, depending on the number of participant houses. A further study can be carried out to identify what would be the minimum price discount in which users are still motivated to participate in the DR events.

UC 08 - MAXIMAL EXPLOITATION OF RENEWABLE RESOURCES

Objective: To analyze if the thermosolar heat water system is being used preferably during sunny hours and therefore it is decreasing the gas usage for domestic hot water (DHW).

Qualitative [3]

- There is a limited potential for making households time-shift their DHW consumption as a way to optimize the utilisation of local solar thermal energy production.

RESPOND objectives achieved

- 100% of exploitation of renewable energy available

Assessment

The qualitative assessment of this use case was not possible to be realized. Therefore, interviews were done to collect information about the Use Case and this way evaluate the costumer behavior during the period. Regarding DHW, some participants are flexible in regard to its consumption and willing to try to change habits, mostly children showering routines. However, many others cannot commit to changing showering hours due to their working routine. Solar thermal panels do not bring noticeable benefits for consumers, at least in the case of Madrid.

After the validation process, it was possible to see that results could be improved if the KPIs were included in the DEXMA platform before starting the DR events. This would allow KPIs to be calculated in an automated way, and also could have made possible to change important parameters or improve with real time decisions. For instance, the communication performance KPI could have a periodic analysis, as it is an important parameter to the reliability of the validation, detecting if some equipment stopped sending data.

Sending a message to the users does not assure that they will receive it. Monitoring which users are receiving the message or interacting to the use case in an active way can improve the validation process, removing the uncertainty of the actions.

Finally, having additional tests in different seasons can be effective and help to better understand the users behavior and DR potentials.

2. TECHNOLOGY

In technology topic, it is possible to find topics related to the demand response events - with possibilities of improvements, RESPOND platform components, semantic model, demand and production prediction models, RESPOND app, and equipment.

2.1 DR EVENTS FOR RESIDENTS

Although demand response is not a novel concept in grid management and stability maintenance, it has historically been predominantly employed in the industrial sector. Since factories often utilize large devices that consume a lot of energy, having the ability to agree upon a contract with an entity that maintains grid stability (grid operator directly, DR aggregator, etc.) has proven to be mutually beneficial. In exchange for monetary compensation, the industrial entity allows for some parts of its plant to be controlled for a maximum predefined number of times and for a limited amount of time. However, applying a similar concept has rarely been done and there are no widely accepted standards that would define a similar relation in a residential setting. Furthermore, the RESPOND consortium does not include a DR aggregator that would mandate what specific format should be utilized to formalize DR events. Nevertheless, DR had to be implemented within the optimization procedure somehow in order for the loads to be adjustable so that a more stable power supply can be facilitated.

In line with other formats that the optimization service utilizes, a format of DR messages was formulated. Namely, two types of DR messages are foreseen: implicit and explicit DR. In the context of the project, implicit DR refers to the utilization of a customizable ToU tariff so that the price of energy imports is higher when consumptions is supposed to be demotivated (e.g. during the afternoon consumption peak) and, conversely, the price is lower when consumption is to be motivated (e.g. during the peak of PV production). Since the optimization minimizes for end user monetary costs by default, utilizing a ToU scheme will comply as much as possible with the required modifications. On the other hand, explicit DR involves an artificial constraint that is to be introduced in the optimization. For this type of action, two formats are foreseen: indicator-based and value-based DR. The first format defines indicator values (-1/0/1) for each time step of the optimization (e.g. every hour) that signify whether the load should be decreased, does not have to be modified or whether it should be increased at the given time (see Table 2).

Table 2 - Indicator-based

time [h]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
electric load [ ]	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	-1	-1	-1	-1	0	0	0
thermal load [ ]	0	0	0	0	0	0	-1	-1	-1	-1	0	0	1	1	1	1	0	0	0	0	0	0	0	0
DHW load [ ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

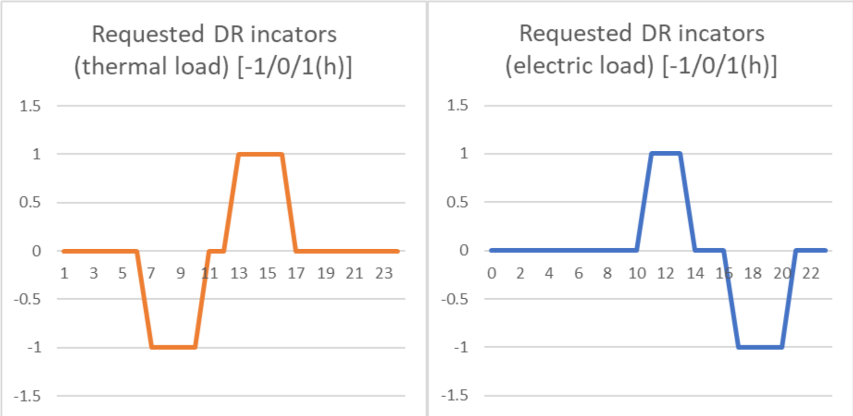

Figure 2 - An example of indicator-based explicit DR

On the other hand, in order to facilitate more precise load manipulations, value-based DR events are defined in a similar format, but with the modification that the simple indicators are substituted with power values by which the load should be adjusted (see Table 3). In this implementation, depending on the specific values of the expected production or the foreseen problems with the grid, and having in mind the forecasted profile, such DR messages can be formulated.

Table 3 - value-based

time [h]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
electric load [kW]	0	0	0	0	0	0	0	0	0	0	0	2.25	1.5	1.25	0	0	0	-1.3	-0.8	-1	-1.8	0	0	0
thermal load [kW]	0	0	0	0	0	0	-5	-8	-3	-4	0	0	6	8.5	9.5	3	0	0	0	0	0	0	0	0
DHW load [kW]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

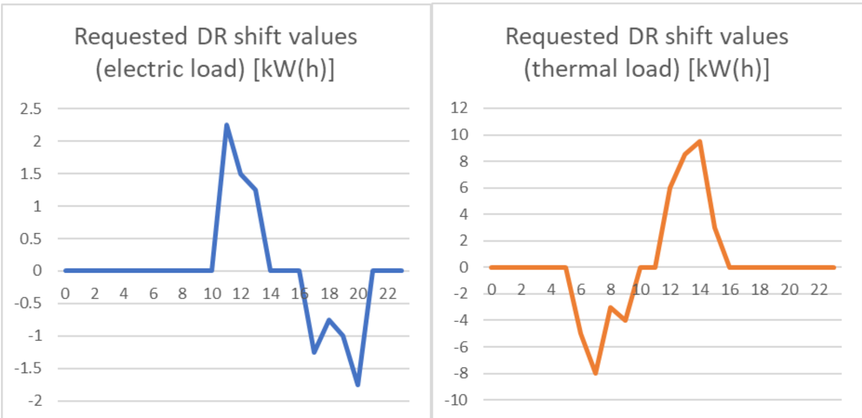

Figure 3 - An example of indicator-based explicit DR

Since, as previously mentioned, the RESPOND consortium does not include a DR aggregator, there was no stakeholder that would be directly responsible for defining these messages. Therefore, they were constructed in line with general project goals such is maximization of local production. For example, in Aarhus, based on the forecasted production profile, a DR event is formulated before each optimization that modifies the load so that as much energy as possible is consumed during the period of time with the highest production. On the other hand, for Madrid, the events are created to supplement the variable price scheme and guide users to utilize this as much as possible. However, the implementation allows for even more detailed controls to be suggested with respect to load modifications, but these would require additional research to be conducted in order to determine the optimal way to define DR events.

A consistent methodology for defining DR messages should be enforced when deploying a large-scale system in order to ensure fairness and ease of interpretation of the output results. If there is no independent body that would govern the definition of the goals that are to be achieved by DR implementation, all relevant stakeholders within the consortium should define a strategy for the formulization of DR events as the main load adjustment influences.

2.2 RESULT INTERPRETABILITY AND APPLICABILITY

As it is originally conceived, the DR optimization services is supposed to work only with timeseries data. Namely, its main inputs (day-ahead energy demand forecast, day-ahead energy production forecast and planned DR events) are all formulated as hourly timeseries. As such, the optimization utilizes the assumed flexibility of the demand as well as the crucial peak or valley periods denoted by the DR events and outputs a timeseries that correspond to the optimal power consumption curve with all previous factors taken into account. As a byproduct of this optimization, all variables within the model are also optimized. For example, the input power curves (see figure) can be acted upon very easily by programming the corresponding controllers to, if possible, adhere to the optimal energy import/export profile.

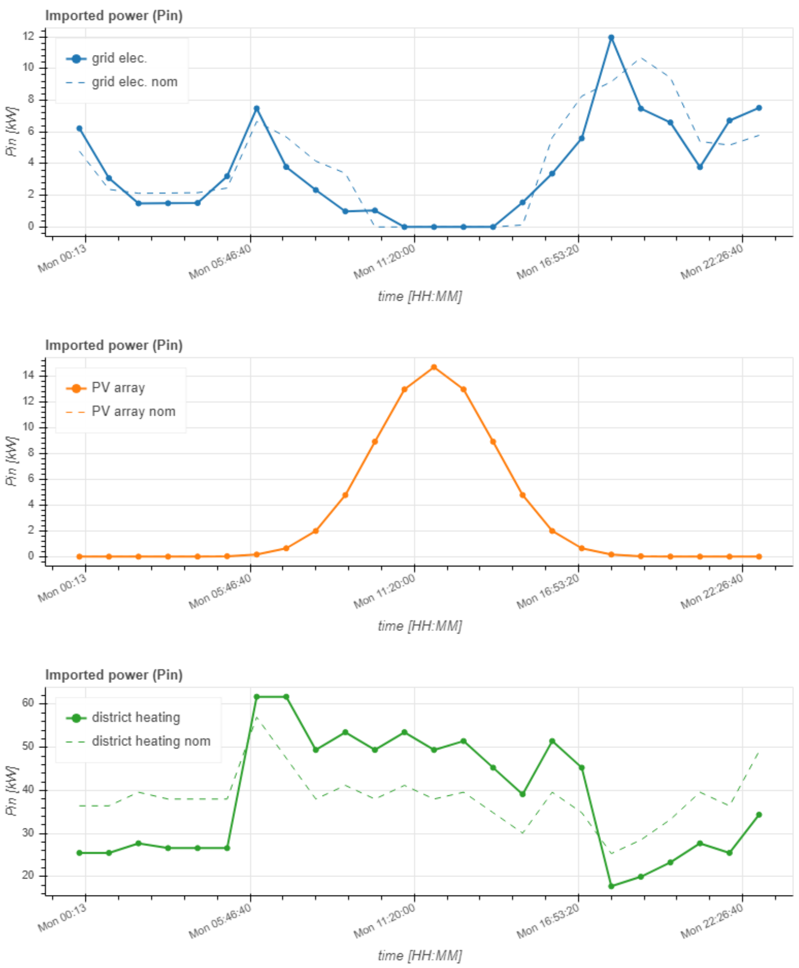

Figure 4 - An example of optimal curves for energy imports

However, the situation is somewhat different for the optimal energy consumption profiles. Namely, since not all of the devices that contribute to the total consumption can be acted upon automatically by the system (which is also considered undesirable since it would severely impact user comfort which is a major factor and a notable adoption barrier), the optimal demand profile (see figure) has to be realized using both direct controls and indirect influences towards end users. While batteries, inverters, some A/C equipment and some heaters can be automatically managed in a reasonable manner, special types of controls have to be implemented for all of these appliances to be included in the DR loop.

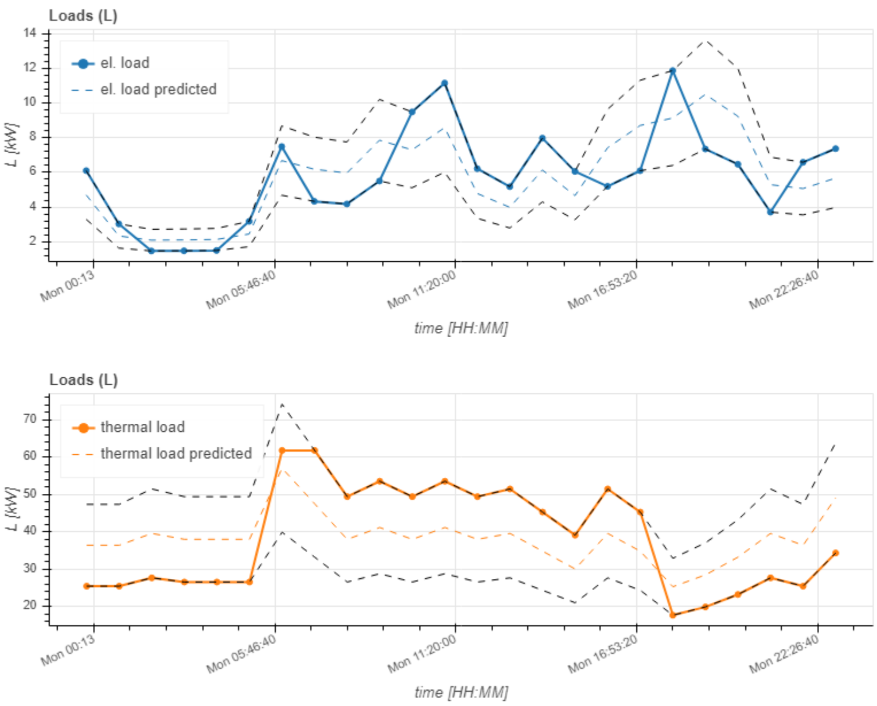

Figure 5 - An example of optimal demand curves

In order to do so, the optimal profile has to be converted into actionable suggestions, first for those aforementioned appliances which can be actuated upon automatically and then for other appliances that are controlled directly by end users. Since there are different types of loads, each one of them has to be addressed separately. Therefore, the conversion from the optimal profile to actionable suggestions and automatic actions has to be carried out by an intermediately adapter/service. In this process, there are significant ambiguities that have to be resolved since the conversion is not an exact process and there is no universally agreed upon methodology to perform this conversion. To complicate things even further, in order to execute this procedure formally in its entirety, inverse building models must be employed for the thermal domain in order for the power consumption curve to be converted into setpoint temperatures. Developing one model for this procedure is a relatively complex procedure and, doing it in exact form for all participating apartments, can be regarded as highly demanding. Therefore, certain generalizations and approximations have to be implemented for this type of load curve to be converted into an applicable format.

As for the electric demand, the three curves (predicted/forecasted demand, optimal demand and measured demand) can be utilized in order to deduce what are the most adequate load modifications at a given time. For example, based on the differences between the forecasted and optimal profile, general broad notifications can be drafted as soon as the optimization procedure is finalized. When a noticeable difference is foreseen between the two profiles, the users with can be sent general instructions on how to behave. However, since individual measurements are available, and thus the information about which appliance is active can be inferred, the measured power can also be included in this analysis. If, for example, the total consumed power is to be reduced, the system can, in real-time, look at what large consumer are currently turned on and target those specifically.

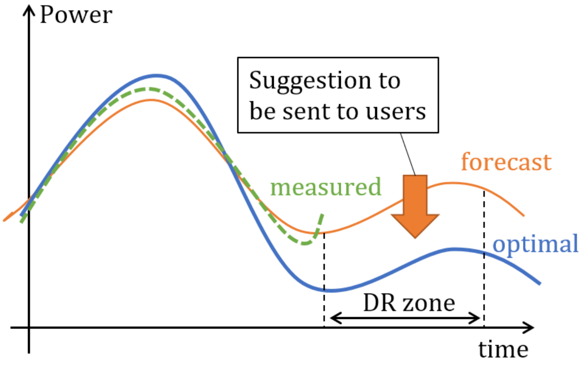

Figure 6 - An example of reasoning over different demand curves

Another alternative for generating user suggestions is to bypass the optimization service altogether and utilize the forecasted production and send users the information regarding at what time they can expect the local generation to be at its peak, and hence when they should strive to consume the most. Although this approach is relatively simplistic, it cannot be utilized for precise load management, but is however easily understood by end users. In conclusion, the adoption for any of these methodologies for converting the optimal profile into actions is highly dependent on end user adoption and it, by itself, is a highly complex issue that warrants further research and testing in order to determine what approach is the best for obtaining the desired final effect.

Interpreting the optimization results and converting them into control actions is a complex process that warrants the development of a separate adapter service that would perform this task. However, in order for this process to be undertaken, the consortium must agree on a concrete strategy for exploiting these results since there are many levels at which the optimizer can be utilized. Again, a consistent approach is needed since interpreting different levels of utilization can be ambiguous and achieve similar goals in multiple ways.

2.3 RESPOND PLATFORM

The activities related to the deployment of the RESPOND platform were mainly focused on the deployment of open-source software components, their configuration as well as development of custom software for functions specific to RESPOND. As has been already described in previous reports, RESPOND platform consists of the following components:

- Middleware: the central components used to enable seamless integration of information coming from different sources. It comprises two components. On the one hand, there is the MQTT broker for implementing the communication between different components of the architecture. On the other, the Historical Data module to collect, process and store in adequate repositories all the data obtained from the field level devices and other related system components.

- External services: such as aggregators or weather forecasting services provide relevant information that can be valuable for other components, such as the Analytic Services. In order to integrate data provided by these services, it is necessary to develop an adapter.
- The Analytic Services. Since historical data may not be enough at times, an analytical services module in charge of generating advanced analytics is also necessary. This module is composed of a set of analytic services that transform historical data into valuable information that contributes to an optimal decision making. Among the components of this module, there will be a semantic repository to store metadata based on an ontology.

In the next sub sections, it will be presented learning from the three platforms already described, and additionally, the semantic model.

2.3.1 MIDDLEWARE

RESPOND platform middleware has been implemented by using the following software components

- Mosquitto MQTT broker: MQTT broker represents the main connection point from the field level devices towards the rest of RESPOND cloud platform. We have chosen Eclipse Mosquitto, which is an open source (EPL/EDL licensed) message broker that implements the MQTT protocol versions 5.0, 3.1.1 and 3.1. Mosquitto is lightweight and is suitable for use on all devices from low power single board computers to full servers, as it is case in RESPOND project.
- TICK stack: represents the combination of standalone components (Telegraf, InfluxDB, Chronograf, Kapacitor) that can be used individually and jointly to form a central data repository, analysis and visualization tools for Internet of Things (IoT) systems. It is open source, widely used software for systems where large amount of time stamped data have to be stored, retrieved in a scalable manner.

Since Mosquitto is already a mature and stable product, no significant issues were experienced during its configuration. Although it is quite stable, at the beginning of RESPOND project, an important TICK stack component Telegraf was not that stable and customizable as it is at this moment (September 2020). Telegraf is an open source server agent aimed at collecting and sending metrics from a wide array of inputs and writing them into a wide array of outputs. It is plugin-driven for both collection and output of data, making it easily extendable with additional data sources.

Chronograf represents the user interface and administrative component of the InfluxDB platform. It allows a user to quickly visualize the data stored in InfluxDB and rapidly create interactive dashboards with real-time visualizations. In RESPOND project, Chronograf is used for basic inspection of collected data.

Since the main purpose of Telegraf within RESPOND was to take the data published on Mosquitto broker and to store then in InfluxDB, it was decided to swap it with a custom developed Python script with same functionality, until a more stable version is released. Due to notable performance of custom-built component, which works correctly for more than two years, it has been left in operation until now.

There exists more advanced visualization tool, that provide more granular user management and different databases, such as Grafana. Grafana can be easily integrated with TICK stack and should be considered for future development.

2.3.2 EXTERNAL SERVICES

External service interface allows integration of RESPOND platform with various external data providers such as weather forecast service. After reviewing a couple of free and paid options for weather data, weatherbit.io service has been chosen. Initially, the free plan suited well the needs of RESPOND platform, since it permitted access to 48h weather forecast.

app_temp	city_name	clouds	country_code	datetime	dewpt	dhi	dni	elev_angle	ghi	h_angle	lat	lon	ob_time	pod	precip	
9.20	Kilronan	41	IE	2019-03-27 16:00:00	4.9	73.010	640.710	32.460	261.040	25.700	53.13000000	-9.72000000	2019-03-27 16:05:00	d	0.00	103
8.90	Ã…rhus	99	DK	2019-03-27 16:00:00	6.8	80.940	697.450	21.700	332.100	75.000	56.19000000	10.20000000	2019-03-27 15:52:00	d	0.00	101
15.00	ChamartÃn	0	ES	2019-03-27 16:00:00	-8.5	102.960	848.770	37.980	618.890	60.000	40.46000000	-3.67000000	2019-03-27 15:55:00	d	0.00	929
9.30	Kilronan	73	IE	2019-03-27 17:00:00	4.8	50.110	448.780	25.720	112.020	38.600	53.13000000	-9.72000000	2019-03-27 17:05:00	d	0.00	103
8.90	Ã…rhus	100	DK	2019-03-27 16:00:00	6.8	64.400	573.730	14.040	195.840	75.000	56.19000000	10.20000000	2019-03-27 16:37:00	d	0.00	101
17.80	ChamartÃn	0	ES	2019-03-27 16:00:00	-5.5	90.210	773.800	27.980	446.990	60.000	40.46000000	-3.67000000	2019-03-27 16:42:00	d	0.00	940
9.20	Kilronan	90	IE	2019-03-27 18:00:00	4.5	5.820	10.450	17.740	1.320	51.400	53.13000000	-9.72000000	2019-03-27 18:05:00	d	0.00	103
8.90	Ã…rhus	0	DK	2019-03-27 17:00:00	6.8	38.330	332.120	5.830	62.810	90.000	56.19000000	10.20000000	2019-03-27 17:40:00	d	NULL	101
18.40	ChamartÃn	0	ES	2019-03-27 17:00:00	-5.0	70.690	638.300	17.050	250.790	75.000	40.46000000	-3.67000000	2019-03-27 17:42:00	d	0.00	940
9.10	Kilronan	98	IE	2019-03-27 19:00:00	4.6	0.000	0.000	9.050	0.000	64.300	53.13000000	-9.72000000	2019-03-27 19:05:00	n	0.00	103
8.90	Ã…rhus	0	DK	2019-03-27 18:00:00	7.0	0.000	0.000	-2.480	0.000	-90.000	56.19000000	10.20000000	2019-03-27 18:43:00	n	NULL	101
17.30	ChamartÃn	0	ES	2019-03-27 18:00:00	-6.0	37.620	335.190	5.710	61.800	90.000	40.46000000	-3.67000000	2019-03-27 18:42:00	d	0.00	940
9.20	Kilronan	86	IE	2019-03-27 20:00:00	4.5	0.000	0.000	0.120	0.000	77.100	53.13000000	-9.72000000	2019-03-27 20:05:00	n	0.00	103
4.20	Ã…rhus	0	DK	2019-03-27 20:00:00	6.0	0.000	0.000	-10.500	0.000	-90.000	56.19000000	10.20000000	2019-03-27 19:46:00	n	NULL	101
16.70	ChamartÃn	0	ES	2019-03-27 20:00:00	-5.3	0.000	0.000	-5.660	0.000	-90.000	40.46000000	-3.67000000	2019-03-27 19:52:00	n	0.00	941
9.20	Kilronan	87	IE	2019-03-27 21:00:00	4.6	0.000	0.000	-8.650	0.000	-90.000	53.13000000	-9.72000000	2019-03-27 21:05:00	n	0.00	103
7.80	Ã…rhus	0	DK	2019-03-27 20:00:00	6.4	0.000	0.000	-17.810	0.000	-90.000	56.19000000	10.20000000	2019-03-27 20:40:00	n	NULL	101
15.60	ChamartÃn	0	ES	2019-03-27 20:00:00	-3.8	0.000	0.000	-16.730	0.000	-90.000	40.46000000	-3.67000000	2019-03-27 20:42:00	n	0.00	941
Console	Kilronan	81	IE	2019-03-27 22:00:00	4.6	0.000	0.000	-16.850	0.000	-90.000	53.13000000	-9.72000000	2019-03-27 22:05:00	n	0.00	103

Figure 7 - Weather data stored in relational database

However, at the beginning of 2020, weather bit changed their pricing schema, where free account is not providing hourly forecast anymore. After reviewing other weather service options in terms of forecasted data (e.g. solar irradiation availability), it was decided that weatherbit.io is still the optimal.

Pupin, as the partner in charge of developing weather service adapter, has subscribed to starter plan at weatherbit.io which provides 48h hourly forecast.

2.3.3 OPENWHISK/ DOCKER

Serverless frameworks are very good for short real-time or near-real-time processes. For long duration operations, however, a special care is needed. OpenWhisk allows five minutes to execute an action (task) and if it takes longer, another action needs to be called. OpenWhisk is installed via helm, works properly immediately after installation with all pods coming up properly. However, after a reboot or restart of Docker, things sometimes no longer work: Running any basic wsk command e.g.: wsk action list unexpectedly fails. Also, debugging of services running on OpenWhisk can initially be quite troublesome.

Another issue, OpenWhisk supports creating actions from archive files containing source files and project dependencies. However, the maximum code size for the action is 48MB. Applications with lots of third-party modules, native libraries or external tools can easily run into this limit. Machine Learning libraries often use numerous shared libraries and compile native dependencies for performance. This can lead to hundreds of megabytes of dependencies.

The following should be observed when considering OpenWhisk framework:

- Special care should be taken about the duration execution of OpenWhisk actions.
- OpenWhisk should be carefully deployed.
- Additional modules need to be included to ease the development process.
- Size of the OpenWhisk actions should be taken into account at deployment time.
- Services implemented as OpenWhisk actions should use action sequences where possible, if there is a possibility to exceed execution time limit.
- When installed and prior to the deployment of production environment OpenWhisk framework should be thoroughly tested to avoid any unexpected behaviour.
- The OpenWhisk Debugger tool (wskdb) could be used. It supports debugging OpenWhisk actions written in NodeJS, Python, and Swift. The debugger will arrange things so that the actions needed to be debugged will be offloaded from the main OpenWhisk servers and instead run on the local machine.
- OpenWhisk supports creating actions from an archive file and a custom Docker image. If a custom Docker runtime is built, which includes shared libraries, those dependencies don't need including in the archive file. Private source files will still be bundled in the archive and injected at runtime.

2.3.4 SEMANTIC MODEL

Performance of simple queries in semantic repositories are lower than other types of repositories like relational or time series databases, and this performance impacts on the user experience. Since the devices were planned to be installed one single time and the replacement of these devices was not foreseen, no mechanism for updating the semantic model was defined.

There are some configuration parameters that have an important impact on the semantic repository performance and adjusting these parameters is very important. Topological information update is also very important and impacts on data management and user credibility.

Validation of semantic repository performance should be done in a more ambitious pilot with a higher number of users and computation capacities. Additionally, a clear procedure defining the people in charge of updating the pilot site topological information, the means and the times for update must be defined in the early deployment plan.

2.4 PREDICTION MODELS

2.4.1 DEMAND PREDICTION

The reliability of monitoring devices must be very high. Data loss impacts on the accuracy and therefore, in the reliability of the demand predictions. In this aspect, network communications should be included. Wireless communications as Zigbee, Wi-fi or GPRS are very convenient in general, but they have more failure possibilities. Moreover, social aspects could impact on the demand forecasting because could induce changes in the consumption behaviour. These changes impact negatively in the reliability of the demand predictions. The example is the COVID-19 pandemic.

It is very important to test the reliability of the monitoring devices in the field and specially network communications. Demand predictions based on machine learning algorithms must be retrained to adapt the prediction to the latest consumption behaviour.

Manual retraining of demand predictions should be always available. Automatic retraining is a very promising research field. The ideal approach would be to retrain the models when a change in the distribution of the data appears, and consequently, a significant loss of accuracy happens. But how to detect this data distribution changes or measure this accuracy loss and how to retrain and make the decision to update the model, are complicated areas.

Monitoring the status of the measurements and setup alarms to know as soon as possible when data is being lost and to be able to react is recommended. Moreover, the use of wired communications whenever it is possible is suggested, because they are more reliable, and they have less probability of failure. Setup procedures shall be considered to fix any problem with the connectivity of devices.

2.4.2 PRODUCTION FORECAST VALUES OUTPUT EXPLOITATION

There are various approaches and methodologies present nowadays for steering end users to decrease their energy consumption, or to, at least, balance it with the production of the renewable sources. This crucial alignment could be carried out in many different ways, such as by exploiting optimization results, but also by sending notifications to end users in which time interval of the next day they should expect to have peak production. Nonetheless, in order not to bother users too much with frequent notification, one of the approaches would be to send them the notifications only when the maximum of the estimated production is above a certain threshold.

By analyzing the production data from the Aarhus pilot, it was noticed that maximum of the PV production during the same week variates significantly. Namely, as shown in the figure below, a difference in the maximal daily production within one week in June 2020, could variate more than 200 kW, which almost 50% of the maximum value, and more than 100% of the minimum value. Therefore, it was concluded that setting the threshold for the PV production for sending notification to the end user is not appropriate, especially taking seasonality into account.

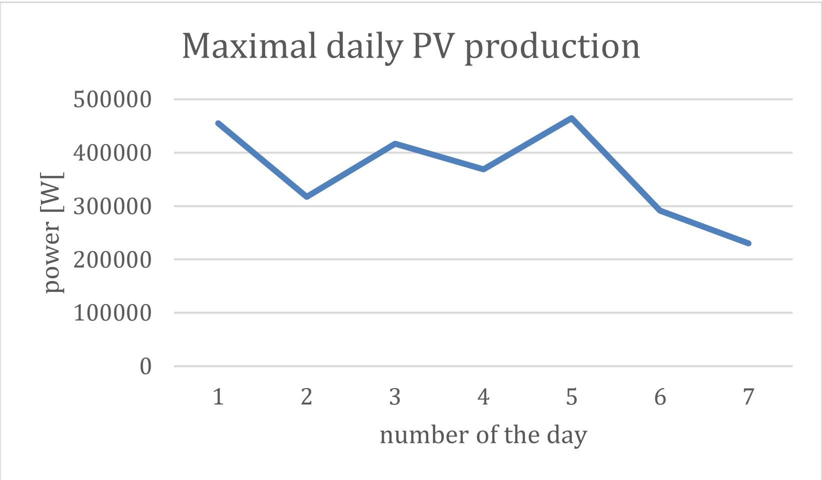

Figure 8 - Maximal daily PV production

Taking all previous into account, it can be concluded that, even though PV panels have a predefined capacity their maximum production highly depends on the weather conditions, and therefore, if needed, should be exploited carefully.

2.4.2.1 COMPARISON OF DIFFERENT PRODUCTION FORECAST METHODOLOGIES

Due to differences between the pilots in the RESPOND project, mostly in the context of the available data, it was necessary to develop different approaches depending on the pilot site, which resulted in the possibility of comparing different methodologies. Namely, it was originally intended to provide data-driven models for all three pilot sites. Nonetheless, due to the lack of data required for the training purposes of forecasting models from the Aran pilot site, a physical model has been chosen. Therefore, a comparison between relevant characteristics of the PV forecasting methodologies (data driven in Aarhus and physical in Aran island) have been carried out.

Expectedly, data driven model achieved higher performances in comparison with the physical one, as it can be seen in figures below. Nonetheless, it required a much more extensive amount of data and competent hardware configuration due to numerically complex and demanding training process, in return. On the contrary, the selected physical model required only well-known parameters which are available in the data sheets, which enables wide potential utilization in real world practice. In the end, both of these methodologies are depended on the precision and availability of an accurate weather forecast.

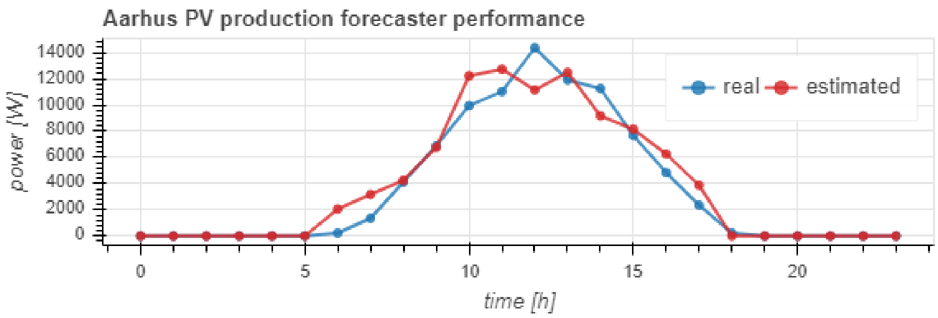

Figure 9 - Aarhus PV production forecast performance

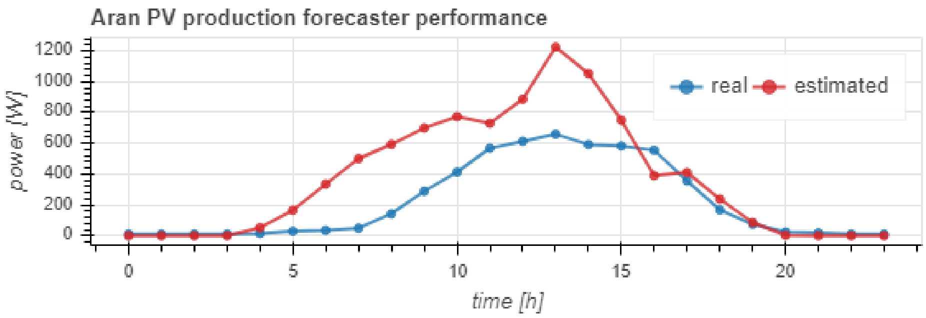

Figure 10 - Aarhus PV production forecast performance

At the end of the day, it could be concluded that data-driven models should be utilized as much as possible, due to their high performances. Nonetheless, in cases when required amount of data for training purposes is not available, physical models could be taken as acceptable replacement.

2.4.3 PREDICTIVE MAINTENANCE

Driven by the performance prediction of different component and assets, early anomalous performances are expected to be identified, in order to suggest the corresponding maintenance tasks. Figure 11 shows the different scenarios identified in predictive maintenance tasks regarding the performance of different components and systems.

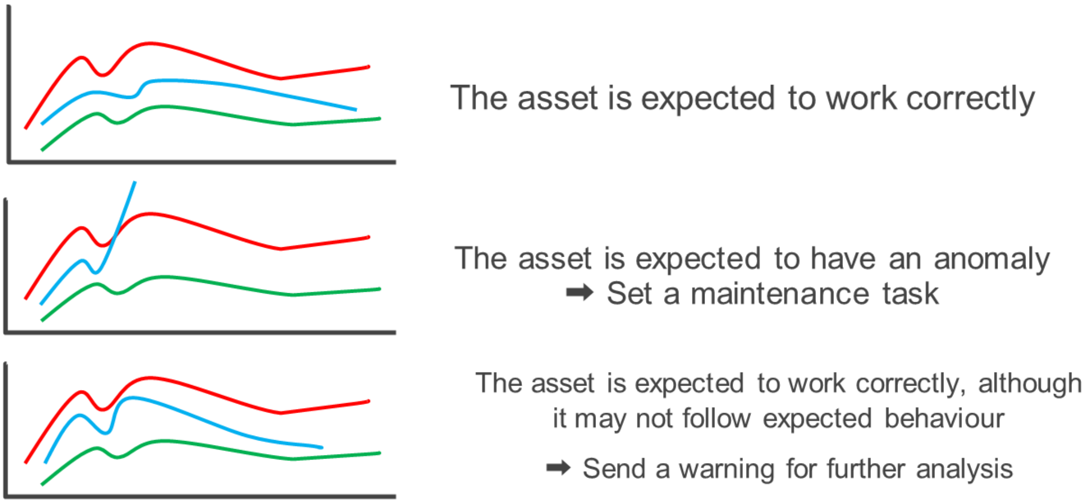

Figure 11: Potential Performance of Different Systems and Components

The assets that could be analysed are:

- Aran PV panels
- Aran heat pumps
- Aarhus PV panels
- Madrid solar thermal collectors

Due to the problems with the monitoring equipment, the period of data available related to performance from the previous assets is less than two years and, in some cases, less than one year. The collected data is not complete and there are several missing values periods. This data quality problem does not allow the setup of a normal profile for a year. If this normal profile is not available, then there is no possibility to know if there is any loss of performance and therefore, if there is a need of a maintenance task.

Thanks to the data provided by the Evishine webpage (https://evishine.dk/ALBOA) we could download the data related to the electricity production of the PV panels of Aarhus from 2016 to 2020. Likewise, Solcast (https://solcast.com/) enabled the download of solar radiation data for Aarhus for the same period. The next figures show the correlation of these two variables:

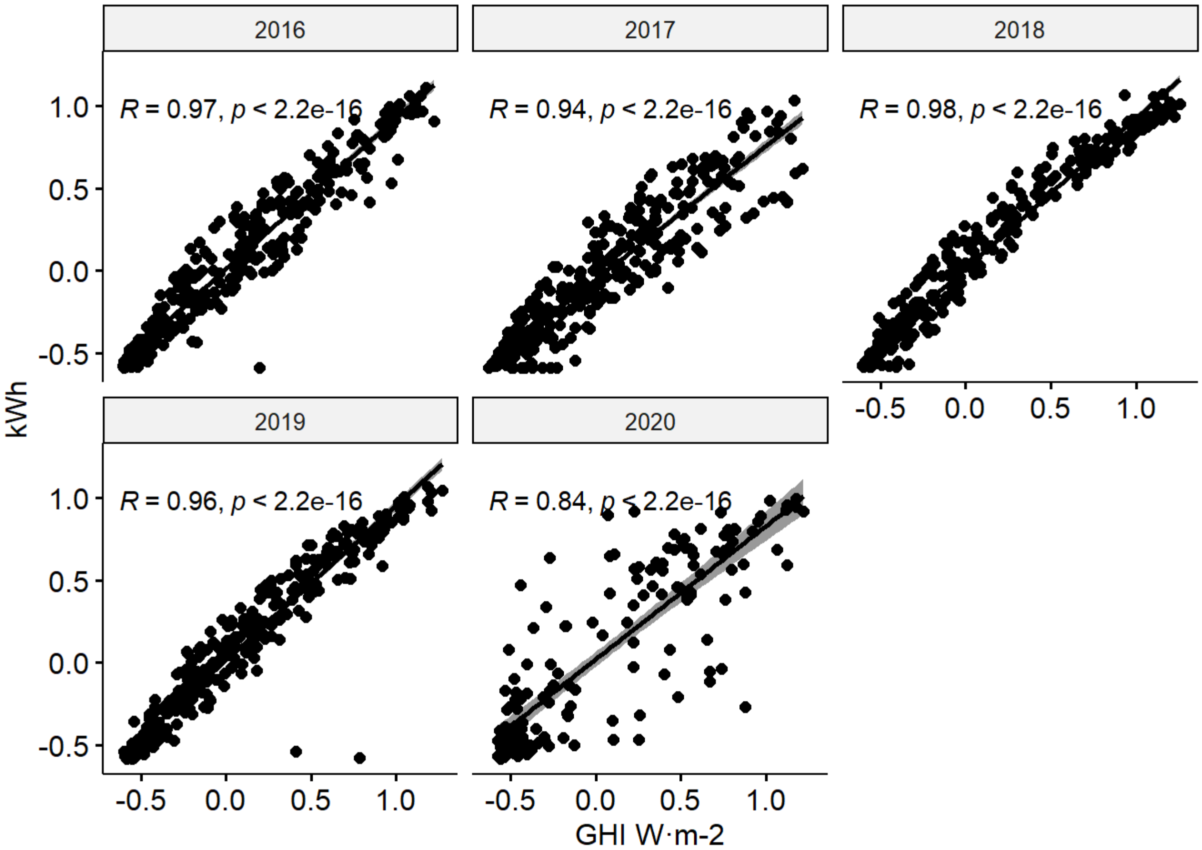

Figure 12: Correlation of Aarhus PV panels production and solar radiation

The analysis has shown that the irradiance (GHI) and the productivity of the panels are highly correlated. This fact makes it possible to model or estimate the productivity of the panels based on the irradiation parameter and machine learning algorithms.

We can see that the correlation is worse in 2017 compared with 2016. The correlation improves in 2018 and 2019. Finally, the correlation is significatively worse in 2020. A possible explanation could be that the accumulated dirt of the PV panels' surface was cleaned between 2017 and 2018, and that they need to be cleaned again this year to ensure the optimal performance of the panels.

In turn, these estimates can be used to obtain early alarms of solar panel malfunctions. If the model is robust and is developed with representative historical data, the deviation between the actual production and the estimate made by the machine learning model could be an indicator of a malfunctioning of the solar panel. And it would be possible to generate early alarms to identify and correct this fact.

Starting from the previous data set, we have taken the data for the years 2016, 2017, 2018 and 2019 to develop a machine learning model (using a regression algorithm), which estimates the productivity of Evishine based on radiation parameter (obtained from Solcast). Once the model was developed, we have used it to identify anomalous production values and generate malfunction alarms during 2020. However, as shown in the next figure, the production of the solar panels is similar to that estimated by the model, and it is within the confidence limits. Therefore, it can be assumed that the panels are producing within the normal range (although the correlation has been lower for this year, R=84).

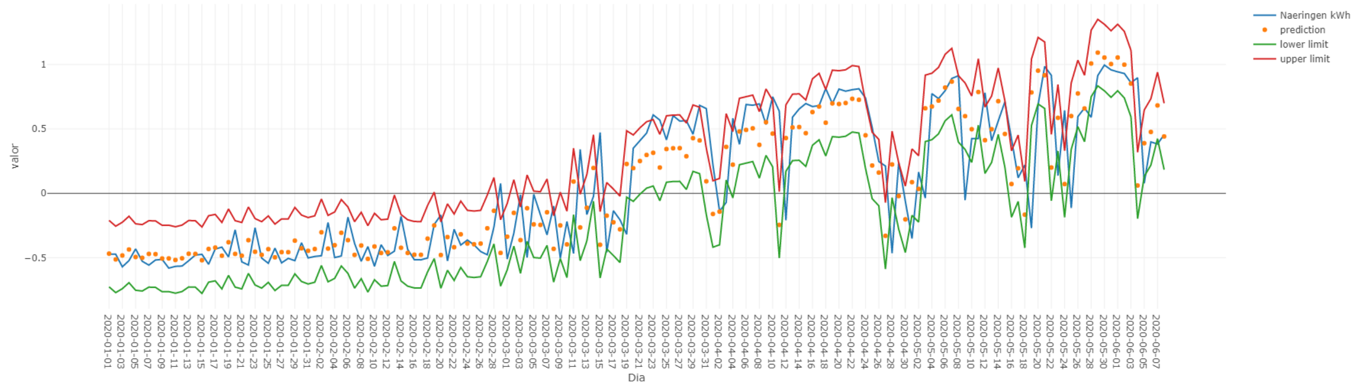

Figure 13: Production estimated for Evishine by machine learning model vs the real one (year 2020)

This model could be used with data for the next few years. If the solar panels begin to degrade in the coming years, and consequently their production begins to decrease, the deviation between the prediction made by the machine learning model and the reality will start to increase. Being the real production less and less in relation to that estimated by the model.

The conclusion is that we need data from several years to be able to make predictions for predictive maintenance due the slow degradation of this type of components, and specially, PV panels.

The recommendation for other R&D projects is to have historical data related to the equipment performance previous to the beginning of the project, because the data acquired during the life of the project is not enough to develop a machine learning model for predictive maintenance. The existence of historical data allows developing predictive maintenance models early in the project, and therefore, to have the possibility to verify the outcomes during the project execution.

2.5 RESPOND APP

Over the users' interviews presented in deliverable 6.3 [3] some issues were detected regarding RESPOND APP, as described below:

Issue 1: Mobile app for demand response and energy feedback is in most cases only downloaded and used by one person in a household. This is a challenge as energy consumption is often related to the everyday activities of several household members. Thus, it is not given that relevant information is disseminated to all household members, which limits the impact of mobile apps.

Lessons learnt and Recommendations: It is important to make designs of mobile app – or related communication activities – that promote that more household members use the app. Communicate to households that the app should be downloaded by all (adult) household members. Design apps that make it possible for the user to easily share data or recommendations with other household members.

Issue 2: If an app is difficult to navigate, pages load slowly or errors and breakdowns are experienced, this makes many users abandon the app after a few times of use.

Lessons learnt and Recommendations: Ensuring intelligibility, speed and reliability are important for design of apps. Involve prospective users early in the design of mobile apps in order to get their feedback on first versions of mobile apps. Especially in relation to intelligibility. Speed and reliability are basic requirements, which should be ensured by the technical design.

Issue 3: Comparing one's own energy consumption and DR performance with that of the neighbours appears to be an attractive feature of mobile apps.

Lessons learnt and Recommendations: Utilize the users' interest in comparing oneself to others in the design of apps. Include data and charts comparing level and time pattern of energy consumption of the user's household with the averaged energy consumption and pattern of neighbourhood.

Issue 4: App notifications with recommendations on demand response actions can be a helpful feature, especially as a reminder and learning tool for households that have not already established such DR practices.

Lessons learnt and Recommendations: Encourage auto-consumption (self-sufficiency) through mobile app notifications. Offer app notifications for optimizing auto-consumption to households with local RE power generation, and who have not already established DR actions as part of their daily routines.

2.6 EQUIPMENT

This section presents the main findings related to equipment, explaining the main issues found in the three pilot sites and providing recommendations to solve them. It is composed by the content also presented in deliverable 6.4 [4](replication plan - development of practical information section), with additional information about the issues and also new topics.

2.6.1 GATEWAY (AARHUS)

Gateway Connectivity issue 1 – Develco Products found out in March 2019 that no data was coming at Develco Products platform from the deployed devices. The reason was that ALBOA's administration switched to a new phone subscription with Telia. Telia said that it was necessary to restart the gateway for Develco Products to be able to receive data again, which caused many problems for the families. Gateway restart was difficult due to battery backup.
In relation to the families, they had to turn off the gateway for a minimum of 6 hours to ensure that the gateway's battery backup was drains. Successfully restarted approx. ½ of the gateways, but unfortunately this maneuver did not prove to be sufficient in the remaining families. Some gateways fluctuated between being on/off and some families tried several times to turn on and off without success.
ALBOA's caretaker tried to help the families. Then, AURA and Develco visited the remaining families to resolve the issue. After the visits, all gateways were online from April 4, 2019.

Gateway Connectivity issue 2 – Connection was interrupted because the maximum data limit was exceeded on the sim card subscription. Historical data was lost and could not be recovered during that period. In 2019 October/November all the families got a new SIM card provided by Develco Products which rectified the problem and simplified the situation.

Gateway Connectivity recommendation –The problem for the above two issues was caused in part because of such division of labour: ALBOA oversaw the sim card and Develco Products was in charge of the installation and managing of energy monitoring platform. Apart from the necessary and valuable teamwork in wide tasks, where each partner cooperates in their specialty field, in these kinds of very specialized tasks that require compatibilities between technologies, it is easier if work is not split between many partners. The future recommendation to avoid similar circumstances is that one partner should oversee related tasks like the ones mentioned to the extent possible, e.g. administering the Gateways and SIM-card. With this it is not implied that teamwork is not necessary; on the contrary it is absolutely needed and key for most projects' success, as it has been constantly being learned and proved along this one.

Additional recommendations:

- Gateways must be installed out of reach of small children and house pets to avoid downtimes including the wiring to the gateway.
- Plan should be set in case of family relocation, dismantling of gateway/devices.

2.6.2 Thermostat Solution (Aarhus)

Thermostat Compatibility issue 1 – Finding a ZigBee based thermostat compatible with the gateway platform was a challenge during the installation stage. The first choice, Spirit ZigBee thermostats worked very well electronically regarding the connection with the gateway and wireless platform. On the contrary the device did not work mechanically to control Danish radiator valves. In the beginning of the test period at the two test-households, all thermostats were working as expected. Then after a very cold night the It was not possible to control the thermostat and turn the heat down again.

Tests have shown that 9 out of 11 thermostats did not work with the old valves. The reason for this is unknown. It could be because of the old valves or because the weather changed very quickly from warm to cold in Denmark that night, when the 9 thermostats stop working. We contacted the manufacturer (Spirit) to learn about the problem but we could not find the cause of the problem.

Thermostat Compatibility issue 2 – The challenge with the second choice, Danfoss ECO2 Bluetooth thermostats was signal range for the gateway. Our test showed that the signal cannot penetrate the concrete wall up to the 1st floor or down into the basement.

The Danfoss thermostats did not work electronically due to signal range, but very well mechanically. The thermostats have a short signal length, meaning that there must be a least 3 gateways (one on each floor). If the doors to the individual rooms are closed, more gateways are needed to be used.

Table 4 shows an overview of the thermostat solutions test of two products, including their advantages and disadvantages.

Table 4 - Thermostat comparison.

	Spirit ZigBee, Art. Nr. 700045	**Danfoss ECO2 Bluetooth, Best.nr. 014G1100**
Manufacturer	Eurotronic Technology GmbH, Germany	Danfoss A/S, Denmark
Picture		
What do we know	Spirit ZigBee is at new product from Autumn 2018. There is no experience with the product or the firm in Denmark. The firm do not answer mails with our questions. We can only buy the product online and we don't know if it is possible to get products in time	Danfoss ECO2 Bluetooth is from Sommer 2017. In Denmark it is a well-known product. Danfoss A/S answers our questions and want to help us. We can buy the product in Danish constructions market, through plumbing installers or online. Delivered from day to day.
Test	We have testes 11 thermostats and did also replaced the canister in one whole house for one week.	Danfoss thermostats have a well- known problem with signal range in houses built of concrete. The test should show if the signal range to the gateway would be good enough from each radiator. We tested one day.
Resuls of test	The spirit thermostats didn't work mechanically, but very well electronic. The mechanically problem Tests have shown that 9 out of 11 thermostats do not work with the old valves. The reason for this is unknown. It could because of the old valves or because the weather changed very quickly from warm to cold in Denmark that night the 9 thermostats stop working. We also don't know why 2 thermostats	The Danfoss thermostats didn't work electronic, but very well mechanically. The electronic problem The gateway is placed in ground floor. Our test shows that the signal cannot penetrate the concrete wall up to the 1st floor or down into the basement. The gateway has to be near the radiator. The thermostats have a short signal length, with means that there must be a least 3 gateways (one on each floor). If the doors to

	were going on working. They were not placed at the same floor.	the individual rooms are closed, more gateways are likely to be used. Danfoss has stated that the thermostats work together with the old valves if the stuffing box is replaced.
What is needed for the thermostats to be used in RESPOND?	We assumed that the thermostats will work with new radiator valves, but this has not been tested. Replacing the valves. AURA does not have the authority to do this work. It must be made by a plumber. 3 offers must be obtained and funds granted for the work.	Thermostats will work with a gateway nearby. It means at least 3 gateways in one house. AURA can set up the products Several gateways will affect data collection and the further handling of data in the project. More electronic equipment gives more risk of errors for example the risk that the families accidentally turn off one gateway when they are using their vacuum cleaner. How will the families handle it for example accept of occupies more sockets, perhaps even one in each room?
Economy*	Replacement of thermostats valves must be carried out by the plumbing installer. This requires approval from the project management and 3 offers must be obtained. Estimated additional cost per. House: Assembly of 11 pcs. Thermostats valves 1.075 EUR 5 working hours for AURA It could be done “all-in” for fewer houses	Setup can be done by AURA and Develco. Estimated additional cost per House: Minimum 2 stk. gateways 300 EUR 11 stk. packing boxes 80 EUR. 10 working hours for AURA Extra expenses for the development of data collection and data management cost is unknown. It could be done “all-in” for fewer houses or the RESPOND test area could be limited to ground floor in each house.
Options for RESPOND	It could be done “all-in” for fewer houses.	It could be done “all-in” for all houses or fewer houses The test area is limited to ground floor (living room, kitchen) in each house. All thermostats are near by the gateway. We installed thermostats where we are quite sure it will work. It could be installed for all the families or selected families – it depends of how many hours/moneys we are allowed to use. This solution is the lightest solution with least cost and problems. Individual solution for each house

		(we know from the workshop, that some families only regulate/use the radiators in the basement)
Influence on time schedule	Installation period is unknown	Installation period can be within a few months. Extra work on developing data collection and data management is unknown

Thermostat Compatibility recommendation – for the implementation of other future platforms but with similar objectives and approaches, thermostat in Danish pilot sites needed to live up to the following criteria:

- Should work with very old Danish valves
- The wireless solution should cover ranges on all floors in the house
- Two-way communication with back end system and the thermostats must be able to control the temperature setup point remotely.

There was a challenge of choosing a thermostat solution and none of the tested products were to be recommendation for RESPOND project and there were no more time/resources for testing.
The consortium had to decide what to choose and based on dialogue with Danfoss, it was decided to use Danfoss ECO2 Zigbee (Thermostat compatibility issue 3) as Solution for RESPOND project.

Thermostat Compatibility issue 3 – Danfoss ECO2 ZigBee thermostat, Solution for RESPOND project.

The final choice for the integration, Danfoss ECO2 ZigBee thermostat solved the range issue, but the Danfoss ZigBee version was not officially released for the market and was a beta version. There was no other ZigBee thermostat on the market that was compliant with Danish valves during this time.

Thermostat Problem: The radiator sometimes works and sometimes not.

All 10 families got new thermostats in the periodic from October – December 2019 (the cold time in Denmark were started) and several families were having difficulties controlling the thermostats. Hence the thermostat was beta version, the performance was unstable.

The radiator sometimes works and sometimes not. Several families (Aarhus 01, 06,15,17) have experienced that some of the radiators become very hot and that they were difficult to control. The family in Aarhus_17 describes it like this: “The radiator is very unstable; it starts to knock and blows out with heat. It does not stop until the temperature is set to 13 degrees. This happened many times after we got the new thermostats turned on”.

At first, we thought that the thermostats were installed incorrectly or that the families could not figure out how to use them or get used to a new type of thermostat. We were in contact with Danfoss development department discussing the problem. The Thermostats was incorrectly configured to horizontal. New firmware (version 1) was push out in February 2020 making it possible to change the configuration remotely. New issues were found in March and Danfoss release new firmware (version 2). End of march all the thermostats was updated and functioning correctly.

It turned out to be a software issue due to the immaturity of the version. Danfoss was able to release a new firmware for the thermostat and all thermostats worked correctly afterwards. Unfortunately, it was almost at the same time as the UC05 were ended.

Conclusion

On March 31th 2020 we can say with 100% certainty that all the thermostats run with the correct configuration – vertical setting.

Unfortunately, we do not know how many and which thermostats have been running with the wrong configuration. The thermostats that have run with the wrong setting will sporadically turn the temperature all the way up and down. We also know that these fluctuations were worst in the run-in phase.

2.6.3 GENERAL EQUIPMENT (ARAN)

Lack of local installation support - Develco Products was responsible for the installation of the pilot site at Aran Islands. Performing the design and installation stages were extremely difficult since there was no partner to provide technical installation support near the pilot sites. The problems made it very difficult to perform activities related to Design and Installation stage. For example, finding device incompatibility issues regarding country specific power rating took time. The Irish system is based on single phase 20A while the Danish system is designed for three phase 13A. Most of the devices from Develco Products were not designed for the Irish power rating. Energomonitor had to finally perform the installation of their equipment at the Aran pilot site.

Recommendation - Any deployment activity must be preceded by deep analysis of the pilot sites on target. The building analysis at the Design and Engineering stage shall include the study of the location and climate, constructive features and typology, all the related energy systems (inputs from energy grids, building-integrated energy generation and storage, HVAC equipment appliances, etc.), any potential already existing monitoring and building automation systems, and available communications infrastructure. The Design and Engineering process often require site visits. Develco Products recommends future implementation of such projects to have a local installation team from same area as the pilot sites to better coordinate the site visit and exchange feedbacks with the technology provider to accelerate the process.

As it has been mentioned, Energomonitor took up after these issues.

2.6.4 GATEWAY (ARAN)

Gateway issue: defective HW - We found that one gateway on the pilot site did not record or send data. After testing the basic troubleshooting, we came to the conclusion that it was a faulty HW. Energomonitor therefore sent a replacement gateway, which was installed and operated without further problems.

Gateway connectivity issue 1 - After the installation, we detected that some Gateways could not connect to the provisioning server. They received data from sensors that are visible on the display. The LEDs on the Ethernet connector blinked. On the device security server, "Last Boot" and "Update Request" are either "never" or very far in the past. In this case, it was necessary to check whether the user's network settings were correct.

The first step to solve this was to check if the DHCP server was functioning. Some networks need static IP address, which means that the Gateway will work only after a manual modification of the network setting. Unfortunately, this cannot be done remotely yet. Also, some networks need to have the MAC address of the device allowed in DHCP. It is necessary to send the user the MAC address which starts with 00:08:dc:XX:XX:XX and where XX is the first part of the device serial number. Some networks have a forbidden communication on port 80 and require communication through proxy server. In this case, the Gateway will not work. Other networks have a strict firewall and forbidden ports 80 (HTTP protocol) and1883 (MQTT protocol). These ports must be allowed in order to allow the Gateway to work properly.

Gateway connectivity issue 2 - Another problem we experienced on this pilot site during the installation was that the gateway was unable to connect to the network. We only experience this problem with corporate networks with certain types of switches and routers.

To resolve this issue, the network administrator must first check that the Gateway (its MAC address) is not visible in the network. There are no visible ARP packets coming from the Gateway and it does not request an IP address via DHCP and does not communicate in any other way. It is necessary to check the active elements in the network. For example, we know from experience that Cisco Catalyst Switches do not cooperate with Gateway EWG6. The solution in this case is to connect the Gateway to another active element in the network from another manufacturer.

Recommendation

Although this is not a common problem, we recommend to point out the type of elements that do not work with the gateway before future installation. Their replacement will then allow a smoother installation. In addition, in the case of development projects, it will help with planning and save costs for unnecessary equipment.

Gateway connectivity issue 3 - The third Gateway connectivity issue we experienced on the Aran pilot was that Gateway was not sending data but according to provisioning data it kept restarting itself.

To fix this issue we had to check first in the provisioning server that “last boot” is smaller than several previous minutes and that “upgrade request” is either “never” or far in the past. Next step was to check if any firmware update was planned.

If an update is planned, then provisioning attempts to update the Gateway, but the bootloader cannot download it. This is a relatively rare problem for the EWG6 and has occurred in the past with firmware version 15.1 in combination with the VDSL router. There are two possible solutions. A user can connect a Gateway on another network with another router. Then turn it on, check in provisioning that a firmware update has been performed. In the case of the Aran Island site, this step helped, and the Gateway was then placed back on the original network and worked.

If the user cannot connect to Homebase in the network using another router, it is necessary to replace the Gateway with a new one, which has to be first checked for a firmware version higher than 20.0.

2.6.5 GENERAL UC8 EQUIPMENT (MADRID)

Over the deployment of UC8, in the Madrid pilot site, the following issues described below were found, so it was not possible to get measurements from the individual water meters and from the boiler meter. As a result, data quality was not sufficient for a quantitative validation of the use case, hence a qualitative validation approach through the interviews with households was made.

Individual water meters:

- The first issue found is that the meters did not have free pulse LEDs or the water meter company did not allow the installation of pulse monitors as in the electrical meters.
- FEN contacted the water meter reading company to make an API / webservice or similar.
- The meter reading company refused to provide us with the requested data.
- FEN made an application that automatically entered to the meter reading company website and extracted the data.
- The meter reading company provided a temporary password that was valid for all users, but in August 2019 there was a change of the company website and they informed that they could no longer provide a similar password that was valid for all users. So, the access to the data was stopped. At that time, there were two difficulties:
    - We would have to reprogram the application
    - We would have to ask each of the participants for their individual passwords.
- All the process afore mentioned took long time, hence it was too late to make baselines or similar and it was decided to focus on doing what we could with the general meter of the boiler.

Boiler meter:

- The readings were working until April 2020 and suddenly they stopped working.
- In Madrid population was confined due to COVID-19, so when FEN was allowed to visit the pilot with the installation company to restart the equipment, it was discovered that the records that were being sent before did not coincide with the real readings of the meters. The graphs of the APP showed a much lower record than there really was. The reading was done by pulses and not all the pulses were being properly read.
- An attempt was made to rescue the controller programming files but they were on a PC of an employee that no longer works in Feníe Energía, so the files were deleted.
- Programming files process was done all over again and FEN visited the pilot to reprogram the equipment and to check if it worked correctly.
- After a week, measurements were lost again, and FEN had to visit the pilot to restart the PC again.
- Measurements were only recorded for one minute and the connection got lost again.
- FEN had to pick up the PC and repair it: changing the battery and cleaning the fans, because it said it was failing due to excess of temperature.
- FEN reinstalled the PC and it stayed working but it was already the end of July 2020. Furthermore, the measures were still not working properly.

Working with external companies may be difficult, as they have their own process that may slow down the reaction times if some issue technical issue happens, such as communication lost. This situation is also aggravated due to unprecedented situations such as COVID-19. It is also important to keep backup of the scrips and programming files, to avoid re-doing the task.

3. USERS AND COMMUNITY

Deliverable 6.3 [3] presents lessons learnt about the Community behaviour for all the three pilots, with all the analysis already presented and described. For the Madrid pilot, some additional information will be included to this report, to better describe the recommendations from the pilot.

Descriptions from Madrid pilot about the results of Use Cases 07 and 08

Almost all participants are collaborative and willing to interact with the RESPOND solution, with very few exceptions. There is a difference, though, between retired people and young adults still working, as technology is easier to understand and manage for the second group. Besides, young adults seem more optimistic and flexible with the idea of changing patterns and routines. Anyhow, retired people are also quite open-minded towards the project, even if they state that they could have some limitations regarding the use of technology.

Generally, participants prefer recommendations rather than automated actions. They can follow price recommendations to consume or not at certain hours, others to switch-on/off certain appliances. Extreme prices notifications are also interesting as a motivation to time-shift consumption.

Two happy hours in different time frames (15-16h and 22-23h) are not convenient for most participants, as one hour is not enough in general to move the functioning of the washing machine or the dishwasher. Therefore, after the first set of interviews, other time frames were proposed: 15 to 17h and 22 to 24h. Participants were much more committed and made use of these happy hours, unlike previously.

Regarding DHW, some participants are flexible in regard to its consumption and willing to try to change habits, mostly children showering routines. However, many others cannot commit to changing showering hours due to their working routine. Solar thermal panels do not bring noticeable benefits for consumers, at least in the case of Madrid.

Young participants enjoy the most the RESPOND app and use it almost daily, as they feel it is something that can help them change habits. The notifications they receive through it are useful for them to be aware of events like happy hours. There is a significant difference regarding the age of the participants: the older they are, the less motivated and less prepared to interact with technology and the more resistant to change habits.

Focus groups resulted to be an essential tool to present, explain, inform, educate the community participants about DR. Due to Covid-19, they were substituted by interviews (by phone) and they resulted to be a useful alternative tool that also provided interesting feedback about participant behaviour, their acceptance before the DR actions proposed and a way to maintain a fluent interaction with the community.

Simple schemes maintained for a period of time seem more practical for the users. Some extreme actions can be interesting, e.g. a game, to check the engagement level the participants can reach.

Users are aware about the benefits of having a renewable resource, so RESPOND solution can take advantage to create interactions with them.

If happy hours were to be offered, they should last, at least two hours.

In general, changing DHW consumption habits is not so easy for the participants, thus it might not be interesting to thoroughly focus in this measure.

For the older participants it would be interesting to focus in reaching them through other media rather than the APP, as, in general, they do not feel comfortable with technology. Focus could be set on phone calls, or text messages. Same thing happens to home appliances for the incentive-based models: they should be as simple to use as possible.

A fluent channel of communication with the community is recommended. The information that the user receives has to arrive clear and it's important that they are able to clarify their doubts and ask raising questions at any time. To gain customer's trust is clue in a very competitive market.

4. STAKEHOLDERS

The main stakeholders identified as possible investors in RESPOND (non-public entities) were:

- Energy utilities
- Independent aggregators
- Active customers
- Citizen energy communities
- Energy service companies or ESCOs
- Equipment manufacturers
- Municipalities

Each of them is described in D6.4 [4] and D7.3 [5]. In this last deliverable, it was also analysed how the identified stakeholders would include RESPOND in their value chain: the benefits it would bring, the risks, their possibilities, the needs, etc. After an individual study, supported by SWOT analyses, three of them were selected: energy utilities, independent aggregators and ESCOs.

A comparison SWOT analysis for these three players is presented in Table 5. In black, the common elements for ESCOs and utilities, whose business models are similar in a way. In orange the points for ESCOs; in green, for utilities; in blue, for independent aggregators.

Table 5. Comparison SWOT analysis for the three main stakeholders identified

STRENGTHS	WEAKNESSES
- Cost reduction for customers - Customer affiliation and loyalty - Need for improvement and continuous development - Rising investment in renewable energy and environmental matters - Good electric market position - Newly formed, just for the purpose of demand response - Not enough software yet: willingness to evolve - Open to change and innovation - Agility and speed	- Big companies: difficulty to introduce changes - Unwillingness to innovate - Need to enter the electric markets - Lack of infrastructure (SW and HW) - Fragility - Cash balance - Not big enough to achieve good results
OPPORTUNITIES	**THREATS**
- Innovation changes being introduced among other SHs - Overall environmental concern - Need to increase market share - Need to be made known	- Regulation and compliance requirements - New regulation, may not be defined

A business canvas model for each of them, and a financial analysis were then developed. Benefits and costs both for final users and for the stakeholders were estimated.

Benefits were calculated for final users in terms of the electricity bill reductions they would achieve with each model. The Spanish Electric market was used as an example to obtain specific numbers, though these numbers will certainly vary from one country to another. As each country has different electricity prices and different incentives and legislations, a great effort should be made to estimate benefits in each of them. It is left as an open task for each responsible partner in the countries were RESPOND will be finally implemented.

For stakeholders, the benefits were estimated in terms of the equipment selling and the fee charged to final users for the RESPOND subscription. A non-direct, but very important benefit for utilities and ESCOs, would be the attraction of new customers due to the integration of demand response programs in their value chain.

Costs were also estimated from two point of views: utilities/ESCOs/independent aggregators, and final users.

From the point of view of the stakeholders, the costs include:

- Software acquisition
- Product integration, integration of the app to reach the final customer, call center
- Home automation devices and general equipment
- Devices deployment, installation, and maintenance
- Personnel costs, R&D
- Marketing and other expenses

From the point of view of final users, the main costs are:

- Monthly subscription to the service
- Initial investment for home automation devices and general equipment
- Installation of the equipment

As mentioned before, after the stakeholders' analysis, three final ones in which to focus were chosen: utilities, independent aggregators and ESCOs. They are the ones with more resources to include RESPOND in their value chain, and the ones that more potential benefits may obtain. A business canvas model was developed for the three of them to study the comparison between their value chain with and without RESPOND.

Utilities and ESCOs should have a clear interest in integrating RESPOND in their value offer, due to the increasing environmental concern as well as the increasing demand response presence in the world. Demand response, eventually, is expected to be implemented in all developed countries to increase renewables integration, improve grid's stability, and give more space to innovation, among many other reasons.

For its part, it is not unreasonable to assume that independent aggregators will represent a key role in electric markets, thanks to the new EU legislations (944/2019), as well as the new legislations in certain countries. For example, in Spain, country that was lagging behind in demand response programs compared to others such as UK, France or Belgium, the independent aggregator figure has already been considered in several laws (RDL 23/2020 - Law 24/2013).

When developing the financial analysis, however, the final benefits, both for end users and for stakeholders, were not very optimistic.

The best case was found out to be Time of Use Rates models, and other programs combined with it. In the best cases (price-based models), and without even charging final consumers a monthly fee, they would start collecting benefits around year 14. This is due, among other expenses, to the initial investment in equipment. A solution to this would be that utilities could access the electricity meters; thus, it would not be necessary that users bought the information-collecting equipment. This way, the equipment cost for the price-based scenarios would be reduced to zero. In this case, a monthly fee could be charged to domestic users by utilities/ESCOs/independent aggregators, calculated of 1,5€/month (18€/year). *The revenues for stakeholders will depend on the final exploitation model chosen for RESPOND (joint, individual…), which would define its selling/renting price (D7.6).*

Equipment for incentive-based models would necessarily have to be installed, but with incentives, the investment could be significatively reduced.

For demand response programs to be significant in the domestic user environment, new legislations in many countries that give them an important role in the electricity markets through stakeholders are needed. Public incentives would be very positive as well.

The importance of the role of independent aggregators (or demand aggregators) is increasing rapidly and should be endorsed and promoted by Governments of every country. Barriers for the operation of demand response programs in the domestic environment by utilities and ESCOs should be eliminated, in order to facilitate its integration. As it has been present throughout the whole project, this would entail many benefits for society.

CONCLUSION

As a result of this document, it is possible to identify the technical and social aspects where RESPOND project can evolve, which can also be used as a reference for new demand response projects. Overall, the results found were promising, even considering the challenges and impacts faced during the deployment and baseline period. The outcomes per pilot site can be found below:

Ireland – Aran Islands

It was possible to analyze customers being involved in manual action, achieving more than 10% of energy savings in all use cases. There is a possibility for automated actions in the pilot in UC2, UC3 and UC4, that can bring additional savings and load shifting. The individual ownership of PV panels resulted in higher engagement in the DR actions.

Denmark - Aarhus

The Danish demonstrators allowed to see results for both manual and automated actions. The results of UC05 (automated) show that for up to three hours there was only moderate negative impacts on the user's comfort. The manual actions expected in Use Case 06 were realized, and the app notifications with recommendations on DR actions can be a helpful tool.

Spain - Madrid

In Spain is possible to see the outcomes of the price incentive being applied as an efficient tool for rescheduling the electricity load. The participants of the project effectively changed the demand during the specified hours, especially when they received some contact informing about the DR event.

Regarding technology, some of the issues presented are unavoidable, but they have an impact on the customer experience. Therefore, monitoring the project performance and assets in terms of hardware and software is essential to keep the user's engagement, especially when the issues have a potential possibility of affect their comfort. Moreover, ensuring data gathering helps to enhance the prediction models, thus allowing a better optimization process.

Finally, automated DR actions have proven to be very effective in terms of energy savings and rescheduled demand, as presented in UC05 and also simulated in UC03. With the user's consent, this model could be extended to the other use cases. The user's comfort has to be respected, as situations such as indoor overheating may let the user afraid of automated actions. On the other hand, with the right incentive, manual actions can make the participant adapt their daily activities to achieve savings.

REFERENCES

RESPOND DOCUMENTS

[1] F. Seri and P. Lissa, “D6.1 RESPOND validation methodology,” no. 768619, 2020.

[2] NUIG, “D6. 2 Validation analysis of operation scenarios,” 2020.

[3] AAU, “D6.3 - Qualitative evaluation of user of user experiences and recommendation,” 2020.

[4] FEN, “D6.4 - REPLICATION PLAN DEVELOPMENT.”

[5] FEN, “D7.3 - RESPOND business model.”

Annex 1 - Risk Management Summary

Risk Management Summary – D6.4 [4] *(Adapted)*

#	Description of the risk	Proposed risk-mitigation measures
		Technical risks
1	Firmware and HW issues	Some of these issues are unavoidable, but they have an impact on the customer experience, the negative side of which we can mitigate. It is good to point out these possibilities at the beginning of the project and during the installation. Another option is to offer a longer warranty or free replacement at an increased selling price. Providing increased support is taken into account as well.
2	Lack of connection quality, outages, environment influence	To mitigate the influence of this risk, a clear explanation during the installation and manual for customers with basic scenarios for solving common problems is crucial.
3	New technologies issues	Consortium briefings will take a place once there is a new technology to be used. This should mitigate any risks connected to its implementation and possible delays caused by insufficient knowledge and in inter-partner communication.
4	SW issues	Due to the set internal monitoring, this has an immediate response and quick correction. SW issues data will be collected during WP4 and WP5 to prevent its repetition. Once occurred, assess their severity and impact on the other parts of the project
		Social risks
5	User's reluctance, lack of cooperation	Summary and notation of indications that could lead to a future possibility of user's reluctance within WP3. Special attention for high-risk users within T3.3 WP3.
6	Dissatisfaction with the product or support	Detailed introductory procedure in WP3 should mitigate the dissatisfaction risk caused by existing deficiencies. Regular consortium briefings mentioned in Risk n.3 will mitigate lack of development.
7	Insufficient continuity, lack of internal communication	Setting up communication channels and project management tools is the most effective way to mitigate this risk.
8	Wrong target group	As with risk n.5, WP3, D3.1 will help mitigate this risk. Within this, it is possible to collect valuable feedback, which can be used for possible further development of the platform.
9	Change of legislation	This risk cannot be mitigated or influenced. By setting the price range for individual parts of the project, we can increase the likelihood of a faster and smoother response to change.