Project FLEXUM, D1: Flexibility characterization, baseline calculation and demo definition

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About OneNet

OneNet will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

The project OneNet (One Network for Europe) is funded through the EU's eighth Framework Programme Horizon 2020. It is titled "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

While the electrical grid is moving from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. For this reason, the two major associations of grid operators in Europe, ENTSO-E and EDSO, have activated their members to put together a unique consortium.

OneNet will see the participation of a consortium of over 70 partners. Key partners in the consortium include: already mentioned ENTSO-E and EDSO, Elering, E-REDES, RWTH Aachen University, University of Comillas, VITO, European Dynamics, Ubitech, Engineering, and the EUI's Florence School of Regulation (Energy).

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
CDD	Cooling Degree Days
DRE	Demand Response Event
DSO	Distribution System Operator
EAEVE	European Association of Establishment for Veterinary Education
EV	Electric Vehicle
FATCC	Free-Access and/or Teaching Computer Classroom (rooms for teaching and/or free-access with computers)
FIWARE	Open-source technology/platform used for implementing Smart solutions
FSP	Flexibility Service Provider
HP	Heat Pump (a Heat Pump can provide heating and/or cooling)
HVAC	Heating, Ventilation and Air Conditioning
IoT	Internet of Things
JSON	JavaScript Object Notation
kW	Kilowatt (power)
kWh	Kilowatt per hour (energy)
MQTT	Message Queueing Telemetry Transport
NGSI-LD	Next Generation Service Interface – Linked Data
OMIE	Operador del Mercado Ibérico de Energía (Iberian Peninsula energy market operator)
SCADA	Supervisory Control And Data Acquisition
VRF	Variable Refrigerant Flow

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Executive Summary

Throughout the document it is described how the preliminary evaluation of the flexibility capacity of the University of Murcia has been carried out with certain buildings, being these the following ones: Chemistry Faculty, Pleiades building, Veterinary Faculty, Psychology Faculty, General Lecture Room and Mathematics Faculty, Work Sciences Faculty, General Library and Documentation Faculty. In each of the tests carried out, the schedules with the process of performance, the baseline used as a reference for the results obtained and the results are described. The first 3 buildings mentioned above already had monitored Variable Refrigerant Flow (VRF) consoles while in the remaining the direct control of the Heating, Ventilation and Air Conditioning (HVAC) equipment has been extended in order to be able to run the tests on it.

The results of the power reduction obtained in each test (the flexibility capacities) are shown throughout the deliverable as well as the control systems used and how they are executed. Based on the tests performed, it can be seen that a reduction above 0.5 MW can be achieved, enough to reach the expected outcomes and therefore showing how Flexibility Services can help alleviate network congestion as stated in the proposal.

During the tests an additional question has been detected and will have to be analysed, namely, the need for Distribution System Operators (DSOs) and Flexibility Service Providers (FSPs) to agree on a common way to calculate baselines in order to guarantee that both parts can validate whether the flexibility requests have been properly fulfilled. This is relevant as payments/penalties depend on the result of flexibility actuations.

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1 Introduction

This deliverable reports the actions that have been carried out for what would correspond to Task 1 of FLEXUM's proposal about flexibility characterization by means of different tests that have been executed. In addition, another objective of this document is to define the baseline on which the results of power flexibility capacity have been obtained and the definition of the demo that is performed in cooperation with the University of Murcia as FSP together with ODINS to ensure pre-qualification and preparation processes.

2 Resource description

The University of Murcia counts with 5 campuses all over the Region of Murcia. Buildings from one of them have been selected to be the participants in the demo, more specifically from the Campus of Espinardo, where there are more than 30 buildings.

Some of the buildings that have been pre-selected to carry out the Demand Response Event (DRE) have a significant maximum power peak and general consumption throughout the year in the entire campus in both summer and winter.

Figure 1 – Buildings in the Campus of Espinardo

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Table 1 – Maximum power peaks of the preselected buildings

ID	Building name	Maximum power peak of January 2021 (kW)	Maximum power peak of July 2021 (kW)
1	Chemistry Faculty	417	375
2	Pleiades building	122	137
3	Veterinary Faculty	421	618
4	Psychology Faculty	230	228
5	General Lecture Room and Mathematics Faculty	179	523
6	Work Sciences Faculty	223	312
7	General Library and Documentation Faculty	251	277

2.1 Resources

2.1.1 Chemistry Faculty

The predecessor of the current Chemistry Faculty was built to replace the old Science Faculty, which was created when the University of Murcia was born in 1915.

Sixty years later, with the implementation of the Bachelor's Degree in Biological Sciences and Bachelor's Degree in Exact Sciences, the old Chemistry Faculty was divided into two other faculties, Mathematics and Biology. The same thing happened with the Diploma in Optics and Optometry.

Nowadays the faculty is focused on 4 study branches, namely Chemistry, Biochemistry, Chemical and Physics Engineering.

The Chemistry Faculty consists of 6 floors and the roof, where the main front building consisted of big vitrines.

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Figure 2 – Chemistry Faculty

2.1.2 Pleiades Building

Pleiades, with 8 floors, contains a Centre of multidisciplinary research. Its name is an acronym derived from Interdisciplinary Experimentation Platform in Earth and Life Sciences. This building is also the headquarters of University of Murcia Editions (Editum), the Publications Service of the University of Murcia. In addition, it hosts a Learning and Research Resource Centre Library.

Figure 3 – Pleiades Building

2.1.3 Veterinary Faculty

The Veterinary Faculty is one of the first Veterinary faculties to join the European Association of Establishment for Veterinary Education (EAEVE). The 7th floor not only contains classrooms, but also laboratories where the temperatures of the rooms are crucial for the progress of the works carried out there.

Figure 4 – Veterinary Faculty

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2.1.4 Psychology Faculty

Psychology studies have passed through four different faculties during the last 40 years. The last one, where is currently based, is the Psychology Faculty. In the 5 floors that form the faculty, there are PhD's, Master's and bachelor's degrees and laboratories for researching as in other faculties.

Figure 5 – Psychology Faculty

2.1.5 General Lecture Room and Mathematics Faculty

A single building hosts the General Lecture Room, where different studies from other faculties are taught (from Mathematics, Chemistry, Communication and Documentation faculties), and the Mathematics Faculty.

Figure 6 – General Lecture Room and Mathematics Faculty

2.1.6 Work Sciences Faculty

The Work Sciences Faculty was founded at the end of the 20^{th} century. At the beginning, teaching and administration sectors were shared with other faculties. Currently it offers Labour Relations and Human Resources as well as masters in Law, Risk Prevention, etc. in the 5 floors that make up the building.

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Figure 7 – Work Sciences Faculty

2.1.7 General Library and Documentation Faculty

Space for studying, learning and accessing old archives is available in the library, while in other degrees related to communication and information are studied in the Documentation Faculty (abbreviation from Communication and Documentation Faculty). Both buildings are internally connected.

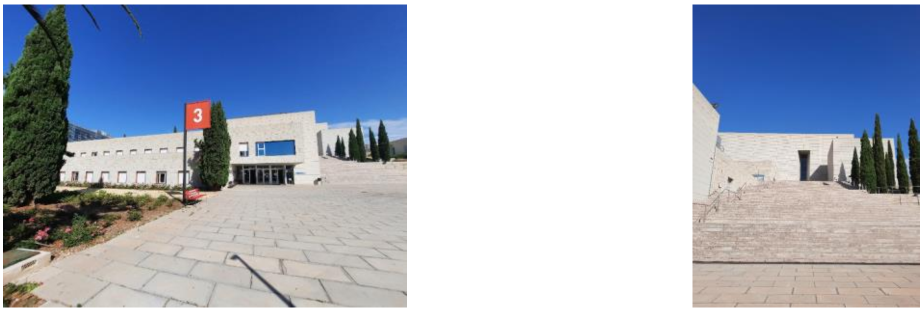

Figure 8 – General Library and Documentation Faculty

2.1.8 Electric Vehicle Chargers

There are several electric vehicle (EV) chargers which will not be taken into account in the actions to be carried out for providing flexibility since they are not currently active (year 2022). However, in the future they could be considered for the implementation of flexibility services. The Computer Science Faculty EV charger can provide a power of 44 kW, with two 22 kW sockets. This means the maximum power that can be consumed is 44 kW if 2 EV are charging at the same time, or 22 kW if just one EV is charging.

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Figure 9 - Characteristic sheet of EV charger from Computer Science Faculty

2.2 Assessment of the original situation of the pre-selected buildings

To carry out the remote actions and to monitor the air conditioning and heat pumps machines to reduce the power peaks in these buildings, an evaluation of the original situation of these installations in each of the buildings was carried out.

Pleiades Building, Chemistry and Veterinary Faculties are already monitored and controlled remotely, by turning off/on completely VRF devices or reducing/increasing the set point of the VRF devices.

Table 2 – Summary of installations

ID	Building name	Original installations (Type of machine to be monitored)	Total nominal power to be monitored (kW) Cooling / Heating	What needs to be monitored
1	Chemistry Faculty*	Consumption data (239 consoles of Toshiba VRF)	733 / 833	[monitoring in place]
2	Pleiades Building*	Consumption data (88 consoles of Toshiba VRF)	352 / 440	[monitoring in place]
3	Veterinary Faculty*	Consumption data (154 consoles of Toshiba VRF)	462 / 525	[monitoring in place]
4	Psychology Faculty	Consumption data (HVAC)	≈ 300 / 200	1 controller / actuator
5	General Lecture Room and	Consumption data (HVAC)	810	1 controller / actuator

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	Mathematics Faculty			
6	Work Sciences Faculty	Consumption data (HVAC)	≈ 350 / 250	2 controllers / actuators
7	General Library and Documentation Faculty	Consumption data (HVAC)	345	2 controllers / actuators for each building (General Library and Documentation Faculty)
** In the case of the laboratories of Chemistry and Veterinary Faculties where the work performed depends on the room temperature, no shutdown or setpoint modification will be performed. It also happens in Pleiades Building, where there are some splits which need to be always active.*				

In terms of power consumption, all the values of the tests have been extracted from a SCADA server used by UMU to monitor the consumption of the Campus at a building level. Therefore, the reductions calculated in each building are directly related to the HVAC equipment and the remaining consumption belongs to other systems such as lighting, computers, etc.

On the other hand, the only available peak consumption reference for the buildings is based on the information shown in Table 1 which includes the peaks recorded in past readings. The only way to get a real value of the power peak of a building is by switching all the systems on at the same time and this cannot be done. However, it's relevant to analyse the results of the tests in the period of the year when they are executed as the machinery involved differs depending on whether heating or cooling support must be provided.

Every faculty has a machinery room where the heat pumps for cooling and/or heating are installed. The 4+1 buildings, which count with HVAC systems that could be controlled, are:

1. Psychology Faculty

   HP1, HP2 and HP3. Out of these 3 heat pumps (HPs), two of them are for cooling and heating, while the other one is just for cooling. This last one is therefore only used during summer, providing a nominal power of 300 kW.

2. General Lecture Room and Mathematics Faculty

   There are 3 HPs with a nominal power of 270 kW each.

3. Work Sciences Faculty

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HP1 and HP2. HP1 is just for cooling while HP2 is for cooling and heating, which means the last one is used during both summer and winter, with a nominal power of 350 kW.

4. General Library and Documentation Faculty

   There is a separate machinery room for each building. In the General Library, HP1 and HP2 are installed, each one with a nominal power of 100 kW, while in the Documentation Faculty there are three heat pumps with nominal powers of 100 kW for HP2 and HP3, and 45 kW for HP1.

Table 3 – Description of Buildings

ID	Building name	Classrooms	FATCC	Assembly hall, degrees hall, seminaries, etc.	Laboratories	Other rooms
1	**Chemistry Faculty**					
	Total number of rooms	-	3	4	16	2
	Total capacity	-	127	204	2320	28
2	**Pleiades building**					
	Total number of rooms	-	-	-	60	2
	Total capacity	-	-	-	300	80
3	**Veterinary Faculty**					
	Total number of rooms	10	3	4	36	-
	Total capacity	1238	84	74	777	-
4	**Psychology Faculty**					
	Total number of rooms	7	2	2	-	-
	Total capacity	319	40	42		
5	**General Lecture Room and Mathematics Faculty**					
	Total number of rooms	24	4	1	-	-
	Total capacity	663	845	102	-	-
6	**Work Sciences Faculty**					
	Total number of rooms	8	1	3	-	-
	Total capacity	513	26	198		
7	**General Library and Documentation Faculty**					
	Total number of rooms	7	6	1	1	*reading posts
	Total capacity	525	133	60	33	

3 Flexibility characterization

To evaluate the flexibility capacity of the resources, tests have been carried out in some of the faculties mentioned in the previous point.

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3.1 Actuation equipment

The equipment to carry out the tests depends on the faculty. In the case of the Pleiades Building and Veterinary and Chemistry Faculties, actuations are performed over units that are integrated in Supervisory Control and Data Acquisition (SCADA) systems which offer remote management support. With this, both switching them ON/OFF and updating their setpoint can be done in an automated way.

Figure 10 – Console for individual control in the room (remotely monitored to control the set-point)

For the other buildings, an actuator clock was installed in their machinery rooms where the HVAC equipment is located. The configuration of these clocks was done manually, selecting the hours at which the HVAC equipment was going to be online/offline.

Figure 11 – Manually-programmable clock for direct actuation on HVAC equipment

These preliminary tests were used to evaluate the flexibility potential of the buildings, and in the case of those that are not controlled remotely (not integrated in SCADAs), the installation done for the tests will be used as a starting point for the installation of the final actuators which are IPex04 Dataloggers/actuators (ODINS equipment with embedded hardware). The communication will be based on the MQTT protocol and the FIWARE topic format will be used for both sending data to the platform and receiving commands (ON/OFF) from the platform.

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3.2 Prequalification tests and baseline

Different tests were executed to evaluate the capacity of selected faculties for flexibility services. Each test is divided in three parts, namely, methodology, baseline and results.

3.2.1 Test of Tuesday, February 1st, 2022

On February 1st, the first test was run in the Pleiades Building by actuating over the VRF consoles.

1. ACTUATION METHODOLOGY

The VRF consoles of the rooms were turned on and off remotely following a predefined sequence. There were 2 starts and 2 shutdowns:

- 1st Switch On: 09:00 - 12:00
- 1st Switch Off: 12:00 - 13:30
- 2nd Switch On: 13:30 - 17:00
- 2nd Switch Off: 17:00 - end of the day.

2. BASELINE

Using the monitoring equipment installed in the building, it was possible to represent separately the power consumption of the machines and the total consumption of the building in order to measure the reduction obtained as a result of these ON/OFF sequences.

3. RESULTS

Each graph represents the shutdowns executed on the VRF consoles (black vertical dashed lines) and a comparison of the power consumption of the VRF involved compressors (orange curve) and the total power consumption of the building (blue curve).

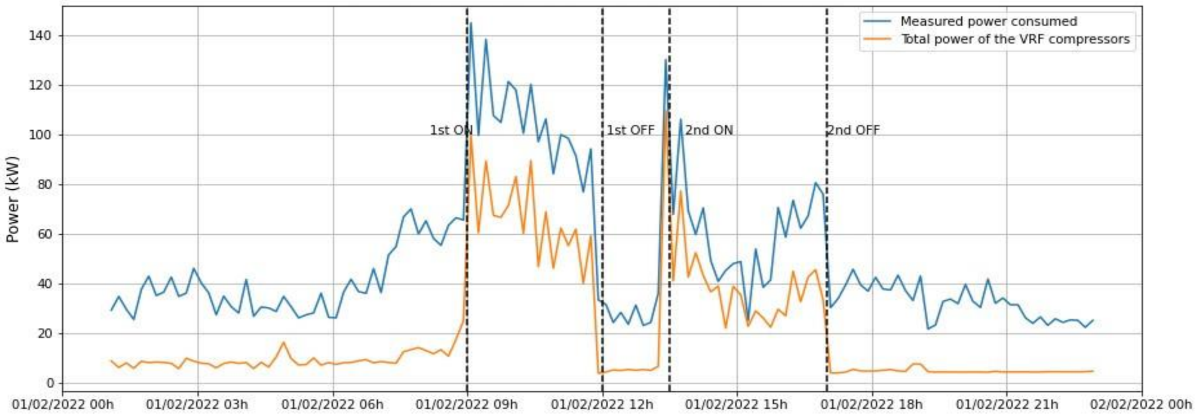

Figure 12 – Test of February 1st, 2022

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The maximum power peak of the February 1st test was 144kW (Figure 12), and the maximum historical peak reached in the month of July 2021 is about 137kW, so it can be considered that this study has moved in the ranges that would be expected in summer with an air conditioning operation that has not been forced on.

Figure 13 – Test of February 1st, 2022 (extended)

Considering the power consumption of the VRF equipment is well known and having detected that during both shutdowns the drops of VRF compressors power consumption match the global reduction of the total power consumption of the building, it can be seen as a confirmation that this reduction actually comes from the VRF compressors and not from other systems of the building.

The power reduction is obtained by calculating the difference between the total consumption of the building (blue line) just before each shutdown and the value it was executed (this is when the orange and blue lines are practically flat after having had a significant drop in power consumption). A reduction of approximately 60% in the building with 58 kW was achieved in the first shutdown (dashed red horizontal lines) and 48 kW (dashed green horizontal lines) in the second shutdown.

3.2.2 Test of Monday, March 7th, 2022

The test was performed on March 7th by acting on the VRF consoles of the Chemistry Faculty remotely.

1. ACTUATION METHODOLOGY

There were carried out 3 switching off:

- 1st Switch Off: 11:02
- 2nd Switch Off: 14:02
- 3rd Switch Off: 20:33

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2. BASELINE

On the one hand, in order to calculate the power reduction, the power consumption of the day after (March 8th) was used as a reference. On the other hand, knowing that in March the power consumed by the heating system is far from reaching the yearly maximum value, which is detected usually in January and then the drop of power consumption at the beginning of each shutdown was transferred to that maximum peak.

3. RESULTS

The test was carried out on March 7th, where the maximum peak is lower than the maximum of this building. Due to the shutdowns, the power reductions were between 10% and 15%. The 3rd shutdown corresponds to the consumption stretch where the demand decreases to reach its residual value (night-time begins once daily work finishes).

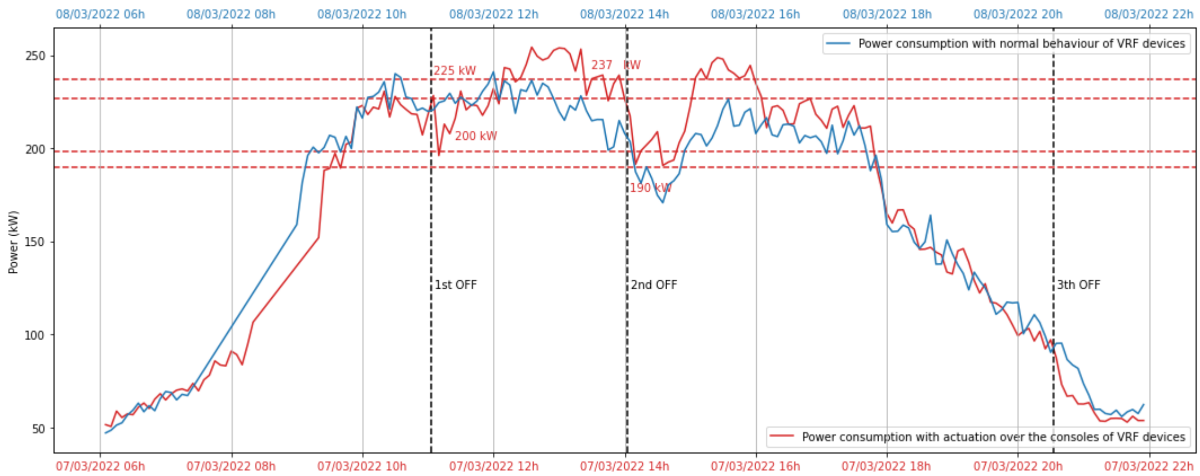

Figure 14 – Test of March 7th vs March 8th with normal behaviour of VRF consoles

It was possible to reduce the maximum power by 25 kW only with the first shutdown. This can be seen in the red line at 11:00. The 14:00 shutdown shows a sudden reduction of 35 kW by considering the peak just before the shutdown of 237 kW. It should be noted that in the graph of the following day (blue one), the power consumed during the first hourly periods is similar to the day of the test and that after 12:30, due to different aspects such as the activities carried out internally in the building or a reduction in the need of air conditioning, the power consumption is lower with respect to the day of the test (red line). The third outage, although masked by the building shutdown, also shows a jump close to 25kW.

Since the test was carried out in March, when the heating load is far from its maximum peak (which is 330 kW, reached on January 24th), and that there is data on the power on the day when this peak is reached, it has been possible to verify the jump and the reduction in power by transferring these values to the day indicated. If

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we consider that it was reached 200kW with the first shutdown, the power reduction would be 35% (in comparison with the peak of that day) and the immediate jump would be 75kW.

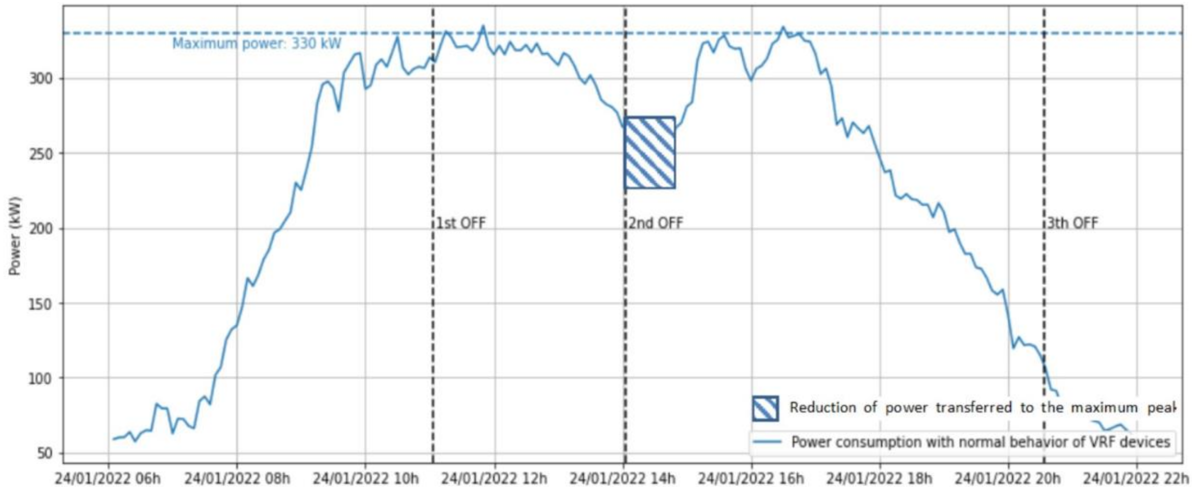

Figure 15 – Maximum peak power of the Chemistry Faculty in winter season of 2022 (normal behaviour)

In both Figure 14 and Figure 15 there is a coincident power drop on the 2nd shutdown, although it has not been carried out. This could be due to the habits of both the users of the machines and the janitors. In any case, these drops at 14:00 have been seen to be lower when there is no shutdown sweep than when there is one.

On the other hand, the shutdown process of the air conditioning systems began on March 22nd. In Figure 16 it appears that in this building the machines were turned off on March 25th, which makes it possible to see an overall reduction in power consumption from those days onwards. This is shown in the same figure, where you can see the periods of low consumption that coincide with Saturday and Sunday. In the case of April 15th to 24th, 2022, the power was reduced because this period is within the Easter Week.

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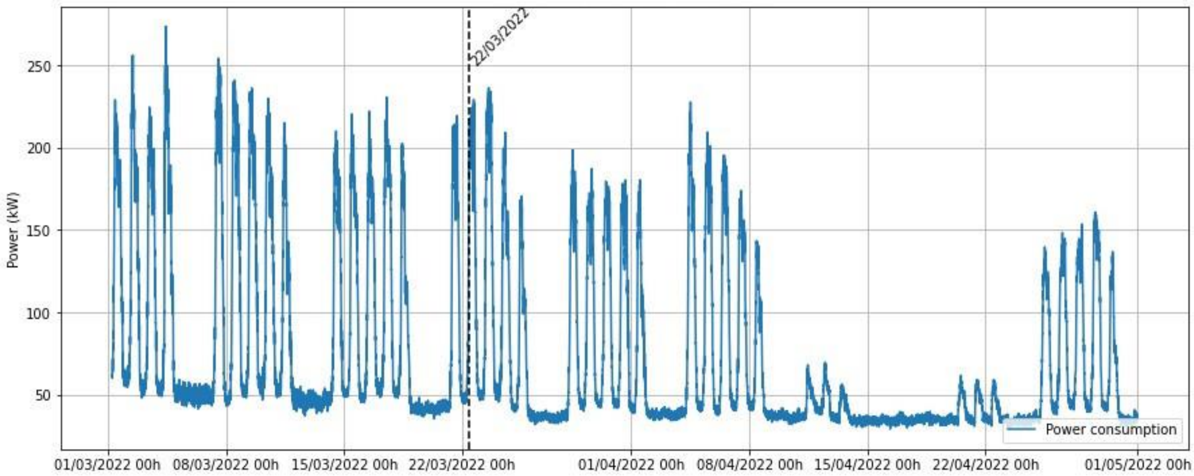

Figure 16 – Power consumption of Chemistry Faculty from March 1st to May 1st, 2022

3.2.3 Test of Tuesday, June 14th, 2022

On June 14th, two shutdowns of HVAC systems were carried out in the following buildings:

- Psychology Faculty.
- General Lecture Room and Mathematics Faculty.
- General Library and Documentation Faculty.
- Work Sciences Faculty.

1. ACTUATION METHODOLOGY

Each shutdown was carried out with the programming of the manual clocks (Figure 11) and each actuation of the 4 faculties was programmed to be synchronized with the duration of the shutdowns being 2 approximately 30-minute intervals:

- 1st Shutdown: 08:45 – 09:15 (+/- 5 or 10 minutes)
- 2nd Shutdown: 12:00- 12:30 (+/- 5 or 10 minutes)

2. BASELINE

The baseline was calculated using ISO 5001 to normalize the power consumption respect to the weather. This means weather data is used to perform the normalization. In this case, as explained below, cooling degree days are used, which relate the average daytime temperature to a certain comfort temperature for cooling from June 7th, the same day of week from the week before the shutdowns took place.

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For the baseline it was considered the Cooling Degree Days (CDD) to describe the need of the building to be cooled. A factor ($Factor_{CDD}$) to be applied on the power consumption of June 7th was calculated based on CDD:

$$Factor_{CDD} = \frac{CDD_{June\ 14th}}{CDD_{June\ 7th}}$$

$CDD_{June\ 14th}$: cooling degree days of June 14th, when both shutdowns were carried out.

$CDD_{June\ 7th}$: cooling degree days of June 7th, which is the day with normal power consumption and not shutdowns actuations over HPs.

CDD data was obtained from Degree Days [1] which calculates it based on the temperatures of many weather stations located in different parts of the world. For the given case, a Murcia weather station has been selected and used as the reference temperature for CDD calculations, 21ºC, same as IEA used for their annual CDD calculations [2].

Once the $Factor_{CDD}$ is calculated, it is applied to the power consumption of June 7th ($(kW)_{June7th}$), obtaining its normalization respect to the weather:

$$P_{normalized\ respect\ to\ the\ weathe}(kW) = Factor_{CDD} \cdot P(kW)_{June\ 7th}$$

Furthermore, it was used a correction factor about the difference between the maximum peak of the power consumption at the same moment of the shutdown (first one) for June 7th and June 14th, divided by the maximum power peak mentioned above.

At the end, the power consumption normalized is:

$$P_{normalize}(kW) = P(kW)_{June\ 7th} \cdot Factor_{CDD} \cdot Correction\ Factor$$

In the figures shown in the next section of 'RESULTS', 3 types of lines are included:

- In green: the normalization of the power consumed with respect to the weather, taking the CDD to show what would correspond to the air conditioning for the Tuesday, June 7th, which is the Tuesday of the week prior to the shutdown of June 14th.
- In red: the total consumed power of the building corresponding to the performance of the 2 shutdowns on June 14th.
- In blue: the total power consumption in the corresponding building on June 7th with the marked intervals of when the shutdowns occurred on June 14th.

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3. RESULTS

Each of the % reduction of the actuations was calculated by:

$$P(\%)_{reduction} = \frac{P(kW)_{reduction}}{Pmax_{June\ 7th}(kW)} \cdot 100$$

$(kW)_{reduction}$: difference between the maximum peak normalized power with respect to the weather on June 7th and the power on June 14th, both at the off-peak intervals.

$Pmax_{June\ 7th}(kW)$: maximum peak power during shutdown intervals of normal behaviour on June 7th.

i) Psychology Faculty

The power reduction with respect to the maximum power peak during the first shutdown and the second one is about 71 kW and 33 kW, respectively.

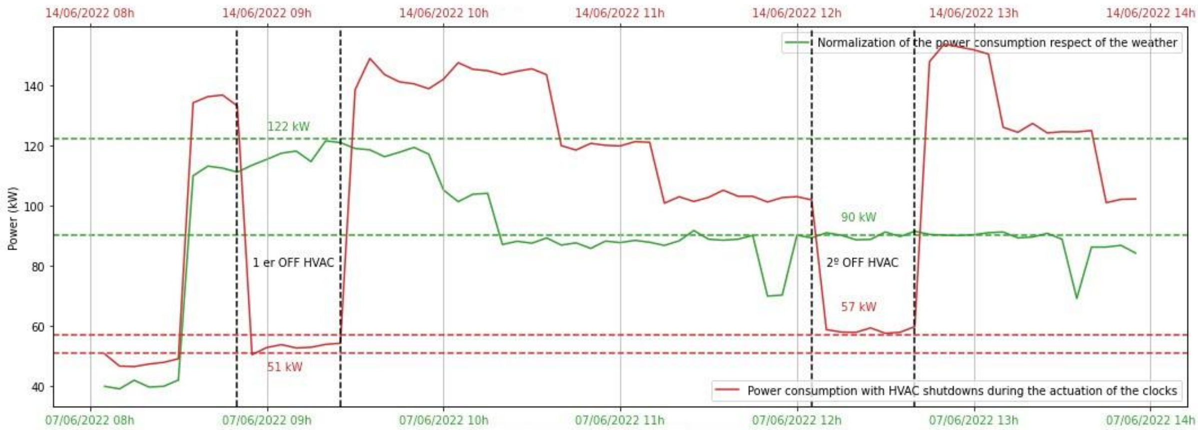

Figure 17 – Test of June 14th / Psychology Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Normalized consumption power respect of the weather

Previous power reduction with respect to the total power consumption is 48% for the first shutdown and is close to 30% for the second.

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Figure 18 – Test of June 14th / Psychology Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Power consumption with normal behaviour of HVAC

ii) General Lecture Room and Mathematics Faculty

Due to 1st shutdown of HVAC equipment, the power reduction based on the normalized power of June 7th is 418 kW while on the 2nd shutdown it is reduced by more than half of the first one, 288 kW.

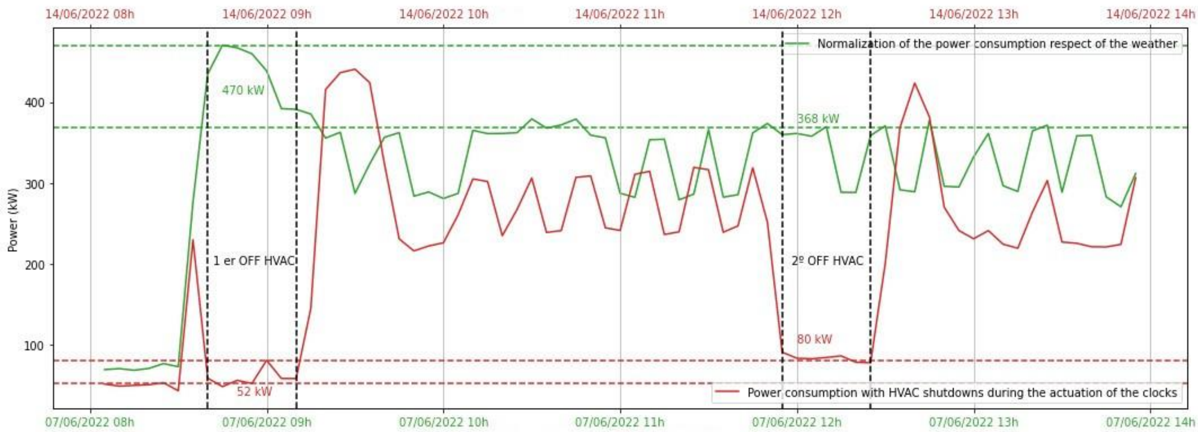

Figure 19 – Test of June 14th / General Lecture Room and Mathematics Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Normalized consumption power respect of the weather

During the 30 minutes of each shutdown, the reduction was about 92% and 82% respectively.

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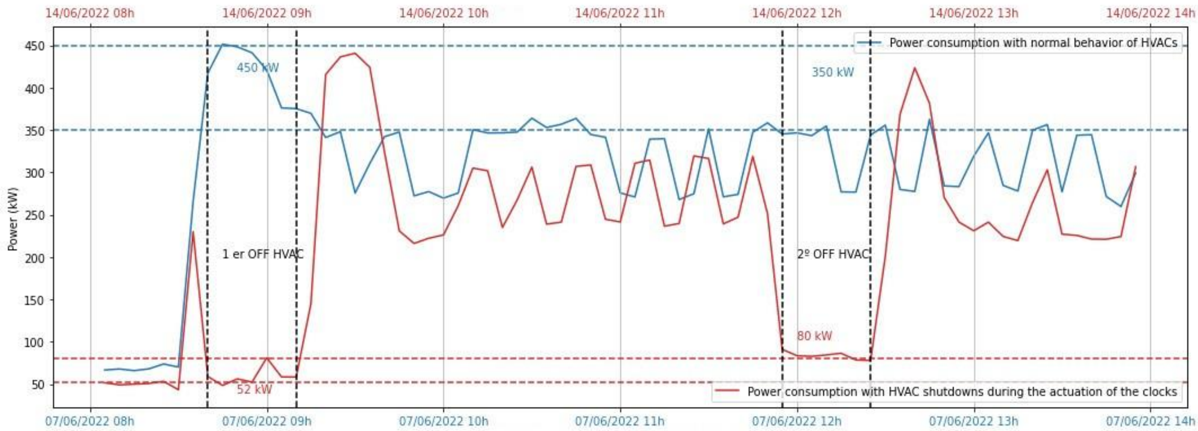

Figure 20 – Test of June 14th / General Lecture Room and Mathematics Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Power consumption with normal behaviour of HVAC

iii) General Library and Documentation Faculty

Reduction of the power consumption on June 14th with respect to what would correspond to the normalization of the power with the weather (green line of Figure 21) of the previous Tuesday, June 7th, of 30 kW and 50 kW for the 1st shutdown and the 2nd one.

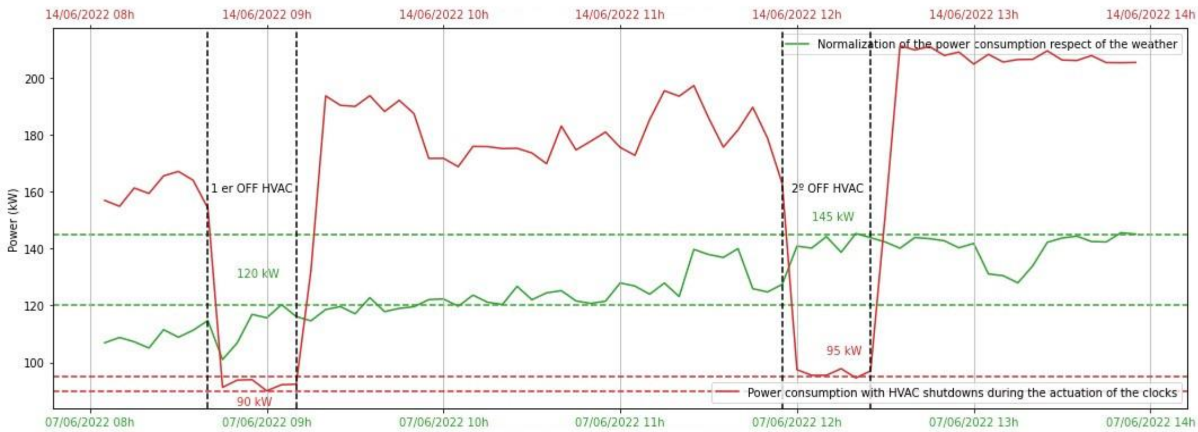

Figure 21 – Test of June 14th / General Library and Documentation Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Normalized consumption power respect of the weather

Comparing the 30 and 50 kW with respect to the total consumption on Tuesday, June 7th, which is the power with normal HVAC behaviour, reductions of 17 and 23% are obtained during the thirty minutes that each of the shutdowns lasts (Figure 22).

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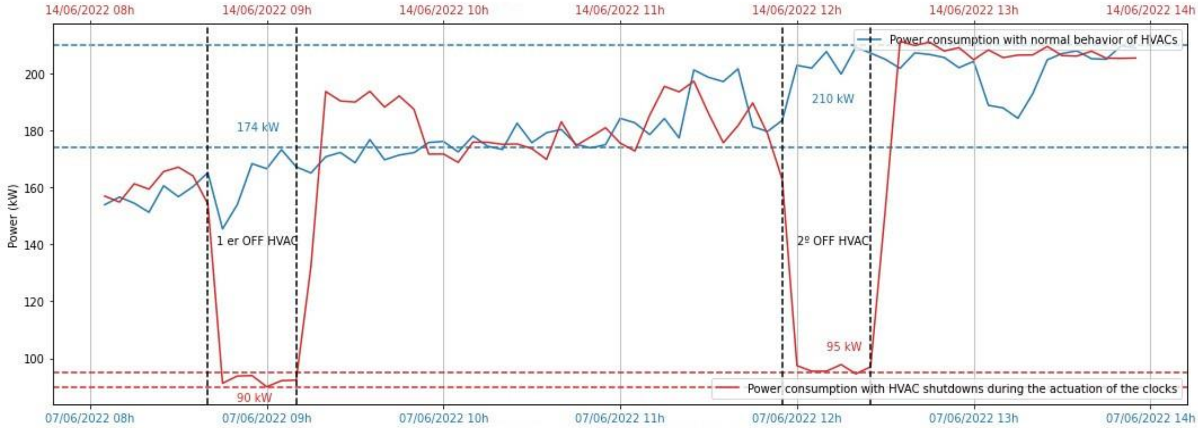

Figure 22 – Test of June 14th / General Library and Documentation Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Power consumption with normal behaviour of HVAC

iv) Work Sciences Faculty

The shutdown of the clocks on the HVAC systems in the actual test for both the 1st and the 2nd Shutdowns produced power drops corresponding to the air conditioning (Figure 23) of 112 and 100 kW respectively.

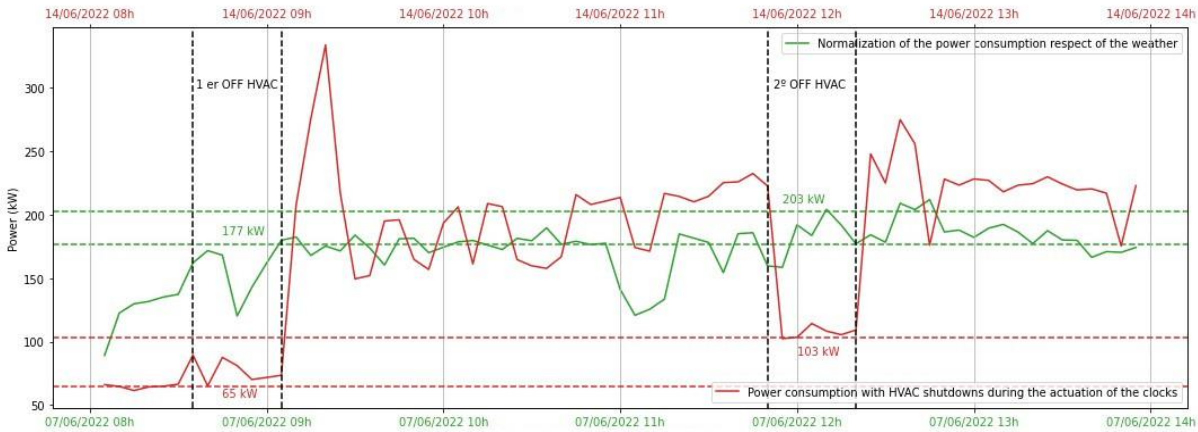

Figure 23 – Test of June 14th / Work Sciences Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Normalized consumption power respect of the weather

Those power reductions due to both shutdowns correspond to a 48% and 38% respectively with respect to the total power consumption with normal behaviour of HVACs in Figure 24.

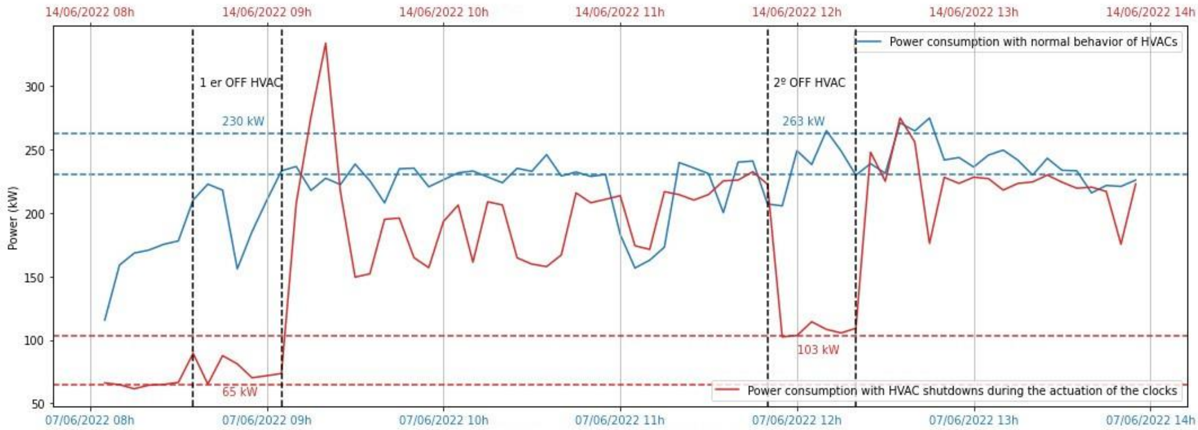

Figure 24 – Test of June 14th / Work Sciences Faculty - Power consumption with HVAC shutdowns during the actuations with the clocks vs Power consumption with normal behaviour of HVAC

3.3 Flexibility test prequalification results

After the tests shown in the previous sections, the following table summarizes the results of the power reductions obtained with each actuation that was carried out.

Table 4 – Prequalification results

Building name	Maximum demand (1) (kW)	Maximum flexibility (2) (kW)
February 1st, 2022		
Pleiades Building	90	58
March 7th, 2022		
Chemistry Faculty	237	25
June 14th, 2022		
Psychology Faculty	147	71
General Lecture Room and Mathematics Faculty	450	418
General Library and Documentation Faculty	174	30
Work Sciences Faculty	230	112

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Total Power (3) (kW)	1001	631
(1) During the shutdowns tests of each building when the maximum power value has occurred. **(2) Power reduction obtained from the shutdowns by executing them when there is the maximum power value.** **(3) Total power in tests of June 14th, 2022**		

4 Communication between the different actors

The integration between ODINS/UMU facility as a FSP with the Iberian Peninsula energy market operator (OMIE) is shown in the following figure.

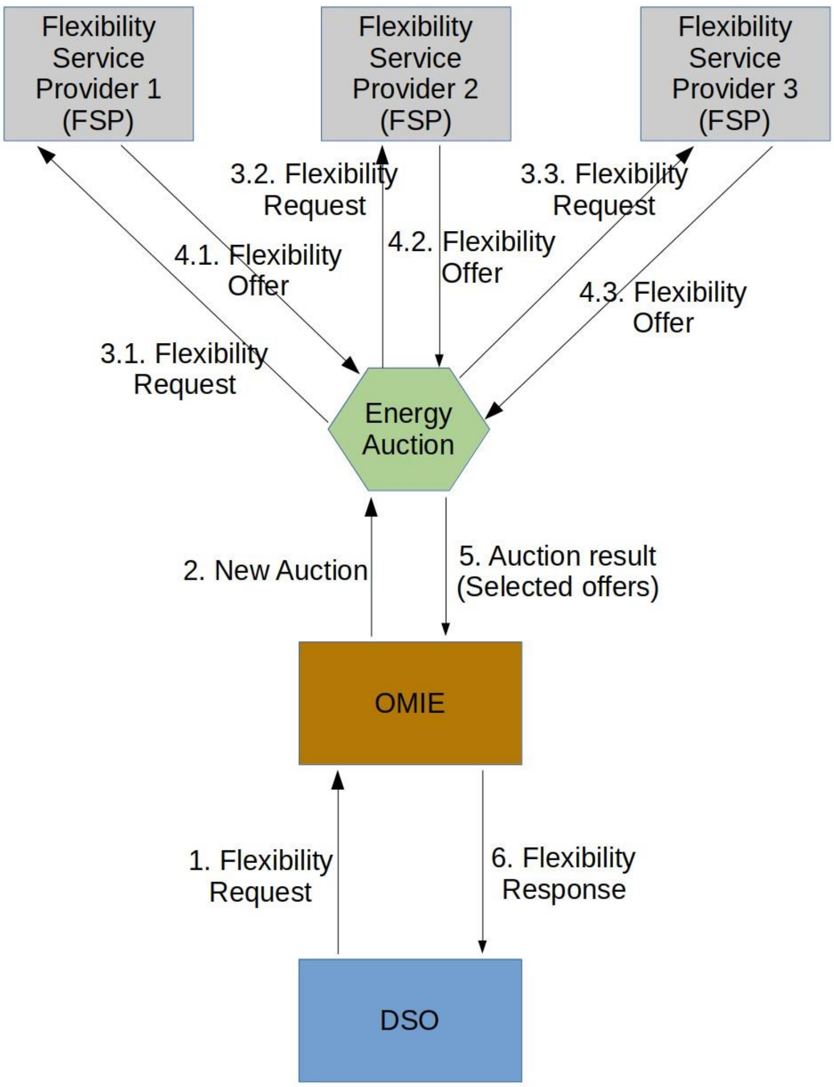

Figure 25 – Integration of FSPs in the Spanish energy market

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One of the possible scenarios in which Flexibility Services can explode their potential involves DSOs. When a DSO detects a potential or already-active network overload, it can send a request to the energy broker (OMIE) asking for a reduction of consumption to the registered FSPs.

When the broker receives a request, a new Energy Auction will be started and the registered FSPs will be notified. Once the auction is over, the broker will choose the cheapest combination of offers that are compatible with the request received. As a result, the selected FSPs will be informed that their offers have been accepted and the DSO will receive the response.

Knowing that a perfect matching between the received Flexibility offers and the request might not be possible, the broker always has the possibility to accept offers partially. This means each selected FSP will be informed about how much of their offer has been accepted.

5 KPIs evaluation

FLEXUM has several specific objectives defined, KPIs, that will be offered in three deliverables, being for this Deliverable 1 the following ones:

KPI1.1: Develop a comprehensive list of technical and non-technical requirements for the implementation of a FSP on the communication ecosystem of the energy market platforms.

Technical requirements:

- Platform
- Context Broker
- Agents
- IoT Gateways (Dataloggers/Actuators)
- Services

Non-technical requirements:

- Legal procedures: communication to senior management, to the technicians of the equipment that are going to be used on the tests and to requests for permission to perform the tests, as well as the evaluation and management of the economic capacity to be able to adapt, if necessary, the control facilities of the equipment installed to perform the final tests.
- Feedback: flexibility service should not affect the comfort level of the people in each building. The evaluation of this will be obtained through feedback obtained during and after making tests.
- Analysis of installed air conditioning equipment and building infrastructure: the knowledge of the equipment installed in each of the faculties, not only the engine but also consoles of air conditioning

systems inside rooms, which can be controlled in order to be able to perform the tests for giving flexibility services.

- Building infrastructure: analysis of the thermal inertia of each building and its thermal response to the tests performed (the capacity and speed to retain heat/cold and to dissipate it).
- Internal use of faculties: the power consumption of the buildings varies according to the activities carried out in each of them. Therefore, having a certain flexibility capacity will depend on this consumption. On weekends and holidays the use of the faculties is practically null and consequently the consumption is minimal, so the flexibility service is active during weekdays.

KPI1.2: Specify the features and services that ODINS has to offer to be considered a FSP in terms of flexibility.

- Platform. A backend platform will be deployed where all the communication and processing modules will be hosted. It will be based on Linux and the modules will run as containers on top of a Docker instance.
- Context Broker. Orion-LD will be used as Context Broker. It will provide NGSI-LD and FIWARE compatibility.
- Agents: The standard JSON MQTT IoT-Agent will be deployed to interconnect the Context Broker and the IoT (Internet of Things) Gateways.
- IoT Gateways. ODINS will install a number of IPex04 IoT Gateways to provide remote access to the HVAC systems that need to be integrated.
- Services. This section is divided in two main blocks:
    - Flexibility services.
    - Interconnection with OMIE.

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6 Baseline calculation

One of the topics that must be discussed in the future is the definition of the mechanism that should be used to calculate the baselines. This is a wide and complex topic as it involves not only metering devices, which have to be trusted by both sides, but also the variability in the consumption pattern of the infrastructure of each FSP.

The first point opens the door to the creation of third-party entities which would be in charge of guaranteeing a reliable power consumption monitoring.

For the second one, it is up to the FSPs to guarantee that it has fulfilled its part of the deal. However, different results can be obtained under different circumstances (changes in weather conditions for FSPs that rely on solar plants, different energy consumption for FSPs that answer to flexibility requests by switching HVAC units off and depend on the temperature of the moment when the actuation must be done, etc.), and this has to be taken into account.

All this considered, it makes sense to offer multiple criteria for the FSPs to choose. There are mainly two types of criteria:

- Based on setting a limit to the power peak. The FSP has to keep the power consumption below a certain point during the designated period.
- Based on previous measurements. Different ways to define the baseline are described in the following examples:
    - Use as reference the average power peak of the last 7 days during the same period of the day.
    - Use as reference the average power peak of the last 4 Mondays (today is also Monday) also during the same period of the day.

7 Conclusions

The University of Murcia will have available for the final flexibility tests all the buildings commented throughout the deliverable, being these: Chemistry Faculty, Pleiades Building, Veterinary Faculty, Psychology Faculty, General Lecture Room, Mathematics Faculty, Work Sciences Faculty, General Library and Documentation Faculty.

Flexibility capacity through the tests that have been described varies between 0.6 and 1 MW just including Psychology Faculty, General Lecture Room, Mathematics Faculty, Work Sciences Faculty, General Library and Documentation Faculty. If the remaining 3 buildings were also considered, this flexibility would have increased. In addition to this, the thermal inertia of the buildings has a direct relation to their infrastructure and hence there are differences in the amount of time it takes for the building to heat up or cool down. Consequently, the

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corresponding machines (HVAC engines and VRF compressors) will have to work at higher or lower powers with the impact it has on the total power consumption of each building. Furthermore, from the point of view of the individuals, it should be considered for future tests that the duration of the tests shall be established so that the comfort of the people working in these the faculties was not affected.

As stated in the previous section, it is necessary to reach an agreement when it comes to define the baseline for power reduction in order to be able to make proper power flexibility comparisons for future tests. And this is not only required in the context of the University, but also when analysing data of the DSOs so that the defined baseline can be extrapolated to other companies, institutions, etc. which in the future might use/offer flexibility services.

The next efforts will be focused on the development of a flexibility engine and flexibility services that can handle flexibility requests using the interface offered by the IoT PHOENIX platform.

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8 References

[1] Degree Days - https://www.degreedays.net/

[2] Cooling Degree Days in Spain 2000-2020 (IEA) - https://www.iea.org/data-and-statistics/charts/cooling-degree-days-in-spain-2000-2020