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D4.2 Trial Specifications (short version)

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ABBREVIATIONS

A/C	Air Conditioning
BLE	Bluetooth Low Energy
CT	Current Transformers
D	Deliverable
EU	European Union
HR	Human Resources
IT	Information Technology
kWh	Kilo Watt Hours
M	Month
MNHA	Musée National d'Histoire et d'Art
MOA	Motivation-Opportunity-Ability
NFC	Near-Field Communication
PC	Personal Computer
RES	Renewable Energy Sources
TIPI	Ten-Item Personality Index
UTAUT	Unified Theory of Acceptance and Use of Technology
WP	Work Package

EXECUTIVE SUMMARY

The investigation of user and system requirements in WP2 and WP3, as well as the definition of game challenges designed in D3.7 to incentivize and engage the building users, helped draw the deployment topology of the pilot site environments in which the successive versions of the ChArGED solutions will be deployed and tested.

This deliverable provides, first of all, a comprehensive survey of the public building floor plans made available at DAEM in Athens, ICAEN in Spain and MNHA in Luxemburg, as well as a methodology to follow for running similar survey in future pilot sites. Using this information, a very detailed monitoring setup for each site is suggested, based on specificities such as electrical installation wiring, staff location and electrical devices, as well as flexibility actions available. Details given include the nature and number of metering devices deployed (smart meters, smart plug and gateways), as well as sensors (contact switch and 4-in-1 temperature/humidity, luminance and motion sensors) and systems for capturing users' movement and control actions within the environment (NFC stickers and BLE beacons).

The reasoning and methodology employed to specify the monitoring system at each pilot site can serve as basis for future monitoring system specification. An effort was made to specify a monitoring set up that balances the needs of the ChArGED application while maintaining the capital expenditure within budget, which is of utter importance for the commercial success of the application. We opted for an approach based on the monitoring of electrical circuits feeding equipment on the floor plan, as opposed to a dedicated monitoring of every piece of equipment. The approach taken means that the energy readings collected by the platform must be disaggregated to identify and validate the control actions taken by the users, and to measure the savings achieved. This is achieved thanks to the combination of power measurements with NFC swipes and location information processed by the analytics engine, described in Deliverable D3.3. A solar panel installation was also specified for the DAEM pilot site, as a way to demonstrate that microgeneration can be a trigger for impactful game challenges.

The document finally describes the questionnaires that will be given to game players before and after ChArGED. Given that ChArGED is developing a rich set of tools for engaging end-users to proactively achieve energy savings, this ensures that all the developed tools will be tested at least in one pilot site, and that comprehensive feedback will be gathered for the evaluation report.

1. Introduction

1.1 Purpose and Scope

This report defines the deployment topology of the environments in which the successive versions of the ChArGED solutions will be deployed and tested. The report follows a methodology by which a clear understanding of the floor plan in which the application will be tested is gathered first, uncovering what can be achieved in each site, in terms of who will play the application, what appliances are used and how we can monitor the users' actions over such appliances and the savings generated.

The result of this work is the specification of the monitoring equipment necessary to operate the application, i.e. which monitoring device will be used for which purpose, and where that equipment will be deployed to guarantee a full coverage for operation of the game. The document aims to be the building stone for the configuration of the pilot sites before the evaluation phase, and to serve as reference for the methodology to follow for any future environment.

1.2 Intended Audience

This document targets various stakeholders of the project, starting from the pilot site managers who must implement the recommendations and utilise the monitoring equipment as requested. The precise guidelines given in the report will allow them to order equipment and install it as per the needs of the game application.

This document will also serve as reference for future deployments of the application in other sites, and will showcase the type of analysis that must be conducted before implementation. While we aim to make the setup of the application as seamless as possible, it is important to follow some guidelines in order to provide a monitoring infrastructure complete enough for the needs of the application.

1.3 Document Overview

The document is organised as follows:

- Section 2 provides a comprehensive overview of the three pilot sites, focusing on the layout, usage patterns, equipment inventory and electrical installations;
- Section 3 proposes the deployment topology, reviewing first the flexibility actions available at each site, the game challenges and associated data requirements;
- Section 4 describes the onboarding and post-ChArGED evaluation questionnaires;
- Finally, Section 5 concludes.

2. PILOT SITES SURVEY

This deliverable explores the usage patterns and installations of the sites where the ChArGED application will be piloted, in order to specify what the game play conditions will be and what the monitoring and game setup requirements are. We review first the topology of each pilot site, to highlight the way each floor plan is divided among teams and areas, and to put each electrical appliance, electrical circuit and controller on the map. Furthermore, we describe the way the various building spaces are used, in order to specify what aspects should be monitored to capture the usage patterns during the game execution.

2.1 DAEM, ATHENS, GREECE

2.1.1 LAYOUT

DAEM's offices are clustered in 8 main areas that correspond to different teams of employees, with different duties and use of electrical energy:

- The **IT department**, a shared room with 11 employees.
- The **Helpdesk**, in the same room as the IT department, with 5 employees.
- The **E.U. Projects** office, a shared room with 5 employees.
- The **Sales & Marketing** office, a shared room with 7 employees.
- The **Supporting Supplies Services** office, a shared room with 8 employees.
- The **Administration and Management** cubicle of offices, with 7 employees. This cubicle includes 5 rooms, used by employees with similar characteristics, including a meeting room.
- The **Technical Support** office, a shared room with 9 employees present (many are usually absent, on on-site calls, as already noted).
- The **W.C. & Kitchenette**, two rooms that are commonly used by all employees.

Table 1 sums up key DAEM pilot site characteristics, indicating some coverage requirements for the gaming application.

TABLE 1: DAEM PILOT SITE LAYOUT CHARACTERISTICS

Number of rooms	8	The game app must target electrical equipment affecting each room
Number of employees	51	The game app must target electrical equipment that each of the 51 users can impact on
Game participation	100%. All departments to play the game, including staff that is on/off site	The game app must scale to run with at least 51 users in parallel
Internal staff movement	Scarce, with few workstations re-assignment	Automated re-assignment of people and electrical equipment within the application is not a major requirement
Entrance/Exit	Two, the "visitor's entrance" and the "employee entrance". Both are used by staff.	The game app must manage users entering/leaving the game area via multiple doors.

2.1.2 EQUIPMENT INVENTORY

As a way to illustrate better the availability of electrical equipment and associated control actions, a full inventory is made to count and spatially locate electrical equipment within the various areas, such as the air conditioning units, lighting, PCs and printers. The position of windows and blinders is also given.

LIGHTING FIXTURES

The floor plan has a total of 40 lighting groups, with controllers positioned at the door or within the office space.

A/C UNITS

Each room is equipped with more than one fan coil unit, providing energy saving opportunities for all teams within the office floor. Because fan coil units are fed directly from the electrical panel, they must be monitored with sub-meters as opposed to smart plugs. As a way to reduce monitoring costs, it is important to monitor at least one unit in each area of the floor plan, to provide an opportunity for all staff members to win points as part of the game.

The fan coil units within the offices are fed by independent central air-conditioning units that are electrically powered. The latter units are installed in an external area at the basement level of the building. The temperature in each fan coil unit is centrally configured to a setpoint that cannot be changed by staff, while the fan speed can be modified.

COMPUTERS AND PRINTERS

Workstations (14 printers/scanners and 75 PC units) are positioned throughout the office floor in various offices.

Computers and printers are supplied from wall sockets, so they can be monitored from either the electrical cabinet or with smart plugs. The advantage of electrical measurement at the electrical panel is that a group of computers can be monitored at once, if a given circuit feeds all the plugs within the room, allowing insights to be collected at a lower capital cost.

WINDOWS

Staff can open many windows during the day, however not all windows can be opened. This provides an opportunity for the users to influence the internal conditions within the office based on specific weather conditions, and the game app can therefore incentivise the end users not to open the windows to let air come in while the air conditioner is on, towards a specific goal on air conditioning energy use.

2.1.3 OFFICE USE

Table 2 provides information on the way the office space is used, providing useful time boundaries for the game backend to analyse patterns of inefficient energy use outside of business hours.

TABLE 2: USAGE PATTERNS OF THE DAEM OFFICE

Work days	Monday - Friday (all) Saturday - Sunday (Tech staff if emergency)	Zero consumption at week-end cannot be assumed. Week-end energy use should be confined to specific areas.
Work hours	08:00 - 16:00 or 09:00 - 17:00 Overtime if deadlines or emergency (Sales and Marketing, Tech Department)	Overnight and early morning energy use from PCs should not be expected. After hours consumption expected.
Lunch-break	13:00 - 15:00 Most eat at desk or outside No kitchen or common area with tables	Few opportunities to save energy at lunch time.
Cleaning Staff	07:00 - 09:00 Monday - Friday	Lighting and socket energy use expected early morning.

2.1.4 ELECTRICAL INSTALLATIONS

Electrical lines originate from the utility meters and ascend towards the building's floors, where they are distributed to electrical panels.

The electrical panel available on the first floor of the building provides power to DAEM offices (half of the floor), as well as adjoining services. All floor equipment is fed from this panel. The electrical wiring runs under the floors, and is easily accessible by raising floor tiles. There was no electrical wiring diagram available at the start of the project.

A comprehensive survey and labeling of the pilot site's electrical installation allowed the mapping of electrical circuits to the floor plan electrical equipment, as well as to users of such electrical equipment. Table 3,

Table 4 and Table 5 present such mapping for plug load devices, lighting and fan coil units, showing the link between electrical circuits, devices and users.

TABLE 3: TABLE SHOWING THE MAPPING BETWEEN ELECTRICAL CIRCUITS, PLUG LOAD DEVICES AND USERS

Electric circuit	Equipment monitored	Team name	Users
I13A	1 PC Common equipment: 1 Printer, 1 Paper shredder & 1 TV Screen	ADMINISTRATION	1
I17A	1 PC	ADMINISTRATION	2
I15A	2 PC	ADMINISTRATION	3,4
I7	2 PC	ADMINISTRATION	5,6
I6A	4P & 1 Laptop Common equipment: 1 Scanner	SALES & MARKETING DEPARTMENT	7,8
I11A	3 PC Common equipment: 1 Printer, 1 Scanner, 1 Multimachine/fax, 1 Paper shredder & 1 Water dispenser	SALES & MARKETING DEPARTMENT	9,10,11
I16A	3 PC	SUPPORTING SUPPLIES SERVICES DEPARTMENT	12,13,17,18,19
I2A	3 PC Common equipment: 1 Printer, 1 Fax & 1 Paper shredder	SUPPORTING SUPPLIES SERVICES DEPARTMENT	14,15,16
I14A	2 PC Common equipment: 1 Water Dispenser	SUPPORTING SUPPLIES SERVICES DEPARTMENT	20,21
I3A	4 PC Common equipment: 2 Printers & 1 Scanner	EU PROJECTS DEPARTMENT	22,28,31
I18A	3 PC Common equipment: 1 Printer/Scanner	EU PROJECTS DEPARTMENT	23,24,25
I4A	4 PC Common equipment: 1 Paper shredder & 1 Water dispenser	HELP DESK	27,29,30

I12A	4 PC	IT DEPARTMENT	32,34
I7B	1 PC	IT DEPARTMENT	34
I6B	4 PC	IT DEPARTMENT	35,36
I1B	2 PC	IT DEPARTMENT	37
I9A	5 PC	IT DEPARTMENT	40,42,43
I10A	2 PC Common equipment: 1 Refrigerator, 1 Microwave oven, 1 Coffee maker & 1 Water dispenser	IT DEPARTMENT	41
I10B	3 PC Common equipment: 1 Printer/scanner	TECHNICAL SUPPORT DEPARTMENT	43,46
I17C	2 PC	TECHNICAL SUPPORT DEPARTMENT	44
I12B	1 PC	TECHNICAL SUPPORT DEPARTMENT	47
I5B	1 PC Common equipment: 1 Printer, 1 Refrigerator & 1 Water dispenser	TECHNICAL SUPPORT DEPARTMENT	48
I14C	1 PC	TECHNICAL SUPPORT DEPARTMENT	49
I13B	Common equipment: 1 Printer/multimachine, 1 Paper shreder	ADMINISTRATION	All team
I5A	Common equipment: 1 Printer, 1 Refrigator & 1 Water dispenser	SUPPORTING SUPPLIES SERVICES DEPARTMENT	All team
I11	Camera control	CAMERA CONTROL	

TABLE 4: TABLE SHOWING THE MAPPING BETWEEN ELECTRICAL CIRCUITS, LIGHTING UNITS AND USERS

Electric circuit	Equipment monitored	Team name	Users
I2C	Lighting	ADMINISTRATION	All team
I3C	Lighting	ADMINISTRATION	All team
I6C	Lighting	HELP DESK	All team
I8C	Lighting	HELP DESK	All team
I16B	Lighting	IT DEPARTMENT	All team
I9C	Lighting	IT DEPARTMENT	All team
I13C	Lighting	IT DEPARTMENT	All team
I10C	Lighting	SALES & MARKETING DEPARTMENT	All team
I5C	Lighting	SUPPORTING SUPPLIES SERVICES DEPARTMENT	All team
I16C	Lighting	TECHNICAL SUPPORT DEPARTMENT	All team

TABLE 5: TABLE SHOWING THE MAPPING BETWEEN ELECTRICAL CIRCUITS, FAN COIL UNITS AND USERS

Electric circuit	Equipment monitored	Team name	Users
I12C	Air condition (1 unit)	ADMINISTRATION	All team
I15C	Air condition (1 unit)	ADMINISTRATION	All team
I11C	Air condition (3 units)	EU PROJECTS DEPARTMENT & SALES & MARKETING DEPARTMENT	All team
I17	Air Condition (4 units)	IT & HELP DESK DEPARTMENT	All team
I18C	Air Condition (2 units)	SUPPORTING SUPPLIES SERVICES DEPARTMENT	All team
I8B	Air Condition (6 units)	TECHNICAL SUPPORT DEPARTMENT	All team

2.2 ICAEN, BARCELONA, SPAIN

2.2.1 LAYOUT

The ICAEN floor plan consists of 1 open-space office area, 8 individual offices, 5 meeting rooms, 1 waiting room, 1 kitchen and restrooms.

Both technical and administrative staff occupy the open-space office area, while the individual offices are for director and managerial staff. There are 49 employees working in the 3rd floor in total in various roles (administration, energy efficiency and RES, project management, communications, economics, regulator consultants, and more).

Table 6 sums up key ICAEN pilot site characteristics, indicating some coverage requirements for the gaming application.

TABLE 6: ICAEN PILOT SITE LAYOUT CHARACTERISTICS

Number of rooms	17 (1 open-space office area, 8 individual offices (1 unused), 5 meeting rooms, 1 waiting room, 1 kitchen, and restrooms)	The game app must target electrical equipment affecting each room
Number of employees	49	The game app must target electrical equipment that each of the 49 users can impact on
Game participation	100%. All departments to play the game, including staff that is on/off site	The game app must scale to run with at least 50 users in parallel
Internal staff movement	Moderate	The game app must manage relocation of people and electrical equipment
Entrance/Exit	Four, accessible via 4 elevators and stairways	The game app must manage users entering/leaving the game area via multiple doors.

2.2.2 EQUIPMENT INVENTORY

As a way to illustrate better the availability of electrical equipment and associated control actions, a full inventory is made to count and spatially locate electrical equipment within the various areas, such as the air conditioning units, lighting, PCs and printers. The position of windows and blinders is also given.

LIGHTING FIXTURES

The lighting in ICAEN is divided in 3 areas. Each area has 6 lines of fluorescents and 3 switches, each controlling 2 lines of fluorescents, see Figure 1.

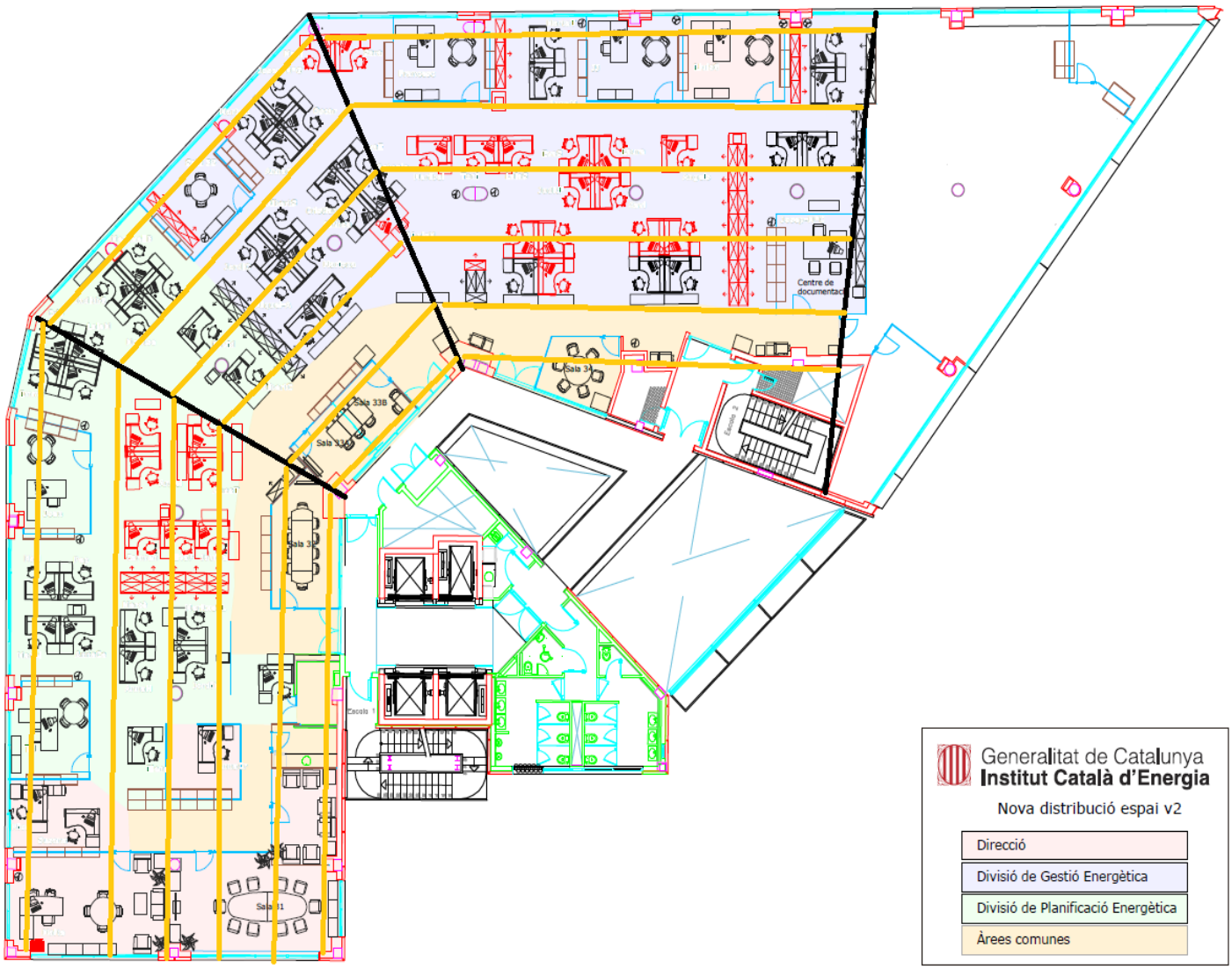

FIGURE 1: SPATIAL LOCATION OF LIGHTING FIXTURES WITHIN THE ICAEN OFFICE PLAN

Each individual room has its own switch; however the light of the individual rooms is also controlled by one of the 3 general switches of each area, meaning that if the general switch is off, then you cannot switch on the light of the separated room. Some individual rooms have additional light (compact fluorescents) besides the linear fluorescents.

A/C UNITS

The floor is divided in 4 thermal areas, with 3 thermals areas under ICAEN areas (ZT12, ZT13 and ZT14), which fall under the coverage of the game app. There is a total of 16 fan coils across the three areas, yet they can only be operated by maintenance staff, not by building users, meaning that the game challenges cannot directly target energy savings on such units, and only recommend best practice when inappropriate use of windows is detected.

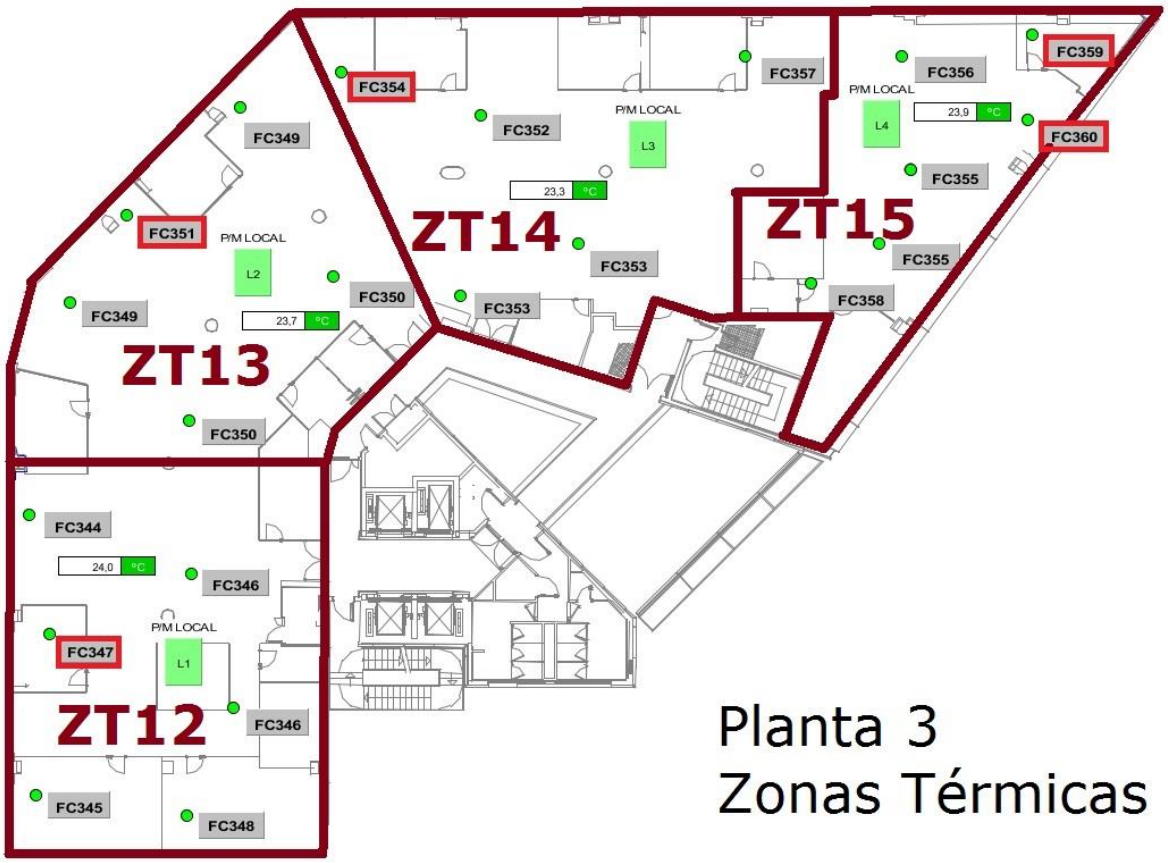

FIGURE 2: SPATIAL LOCATION OF AIR CONDITIONING UNITS WITHIN THE ICAEN OFFICE PLAN

COMPUTERS AND PRINTERS

The green squares in **Error! Reference source not found.** show the PCs currently used by ICAEN staff. The 3 PCs in blue belong to staff not working for ICAEN, which won't participate to the pilot. 2 PCs marked in red are not currently used but should be used within months. Finally, the PC marked in black is the PC running the pre-existing monitoring system which is always on, in stand-by.

Two main printers are used throughout the office floor, with one smaller printer available for the director.

WINDOWS

Error! Reference source not found. shows that staff can open many windows during the day. While the air conditioning system is controlled centrally, this provides an opportunity for the users to influence the internal conditions within the office, and as a result get the automated air conditioning system regulate the delivery of cool/hot air accordingly.

2.2.3 OFFICE USE

Table 7 provides information on the way the office space is used, providing time boundaries for the game backend to analyse patterns of inefficient energy use outside of business hours.

TABLE 7: USAGE PATTERNS OF THE ICAEN OFFICE

Work days	Monday - Friday (all) Most staff have summer vacation in August	Zero consumption at week-end can be assumed Near zero activity in August can be

		assumed
Work hours	Must work from 09:00 (09:30 if child under 12) until 14:00 from Oct-May and 09:00 (09:30 if child under 12) until 14:30 from Jun-Sep. Must work 2 afternoons between 16:00 and17:30 from Oct-May. Flexible hours from 7:30 - 19:30 from Oct-May to make total of 37.5 hours, and 7:30 - 16:00 from Jun-Sep to make total of 35.5 hours. Friday afternoon is off for all staff. Overtime if deadlines or emergency	The working schedule is flexible. The floor is empty before 07:30. Winter Schedule (Oct - May) • The floor is quiet between 07:30 - 08:30. • The floor is at full activity between 09:00 - 14:00. • The floor is quiet after 15:30 (half staff is at work). • The floor is empty after 19:30. • The floor is empty at 16:00 on Friday afternoon. • Summer Schedule (Jun - Sep) • The floor is at full activity between 09:00 - 15:00. • The floor is quiet after 15:00 but not empty (some staff still run the winter schedule). • The floor is empty after 19:30. • The floor is empty at 16:00 on Friday afternoon.
Lunch-break	People go out for lunch or at the 4th floor canteen during winter schedule, and have lunch outside after they leave the office (15:00 - 16:00) during summer schedule.	Staff do not have lunch in the 3rd floor office, opportunity to challenge them on switching off workstations as they go out
Cleaning Staff	05:00 – 08:00 Monday - Friday	Lighting and socket energy use expected during early morning hours.

2.2.4 ELECTRICAL INSTALLATIONS

The main power switch for the whole building is located at the 2nd basement of the building. The electrical switching is split among different floors, different rooms, lighting, humidification and A/C. At the 3rd floor of the building, within the ICAEN premises, there are three electrical panels supplying individual circuits within the three areas of the office plan. These panels are fed from the main switchboard circuit to the 3rd floor. Each panel feeds one of three zones, including lighting, the fan coils and electrical appliances connected to the white plugs. Computers and other power sensitive devices can be connected to the red plugs, fed from the central UPS system.

FIGURE 3: ELECTRICAL PANEL WITHIN THE 3RD FLOOR OFFICE, WITH CIRCUITS FEEDING FLOOR EQUIPMENT

The 3 panels feeding ICAEN's office have a similar layout, so the description in the following focuses on the area fed by panel 1. Similar wiring organisation exists for the other two panels. The following shows how equipment at various locations is supplied with power, which allows us to specify how to measure their load demand and in turn the savings achieved for the various challenges.

PLUG-LOAD EQUIPMENT

Non-critical white plugs are fed from 4 monophase circuits at the electrical panel 1 (circuits F1-F4). Critical red plugs (fed from UPS) are also fed from 4 monophase circuits at the electrical panel 1 (circuits S1-S4).

PCs and monitors are powered from either red or white plugs. Theoretically, a PC should be connected to a red plug and a monitor to a white plug, but in reality this is not always the case. In the area covered by panel 1, all PCs and monitors are fed from red plugs only. In the other two areas the wiring varies more between white and red plugs.

Table 8 shows that only 11 plugs out of the 26 locations fed with plugs are permanently occupied by computers used by staff. In addition one LCD screen is located in the area covered by panel 1, fed from the S1 circuit. This means that by monitoring the four S1-S4 circuits we can monitor user workstations with rather good granularity.

TABLE 8: MAPPING SHOWING WHICH PLUGS ARE CONNECTED TO ELECTRICAL EQUIPMENT WITHIN ICAEN AREA 1

Plug circuit	Locations with PCs and monitors
F1/S1	U1
	U5
F2/S2	U7
	U8
	U9
F3/S3	U11
	U13
	U14
	U16
	U17
F4/S4	U18

LIGHTING FIXTURES

Lighting units in Area 1 of the ICAEN office are fed from 3 monophase circuits (A1-A3). Figure 4 shows the position of the 3 lighting circuits A1-A3, each made of two vertical lighting fixtures.

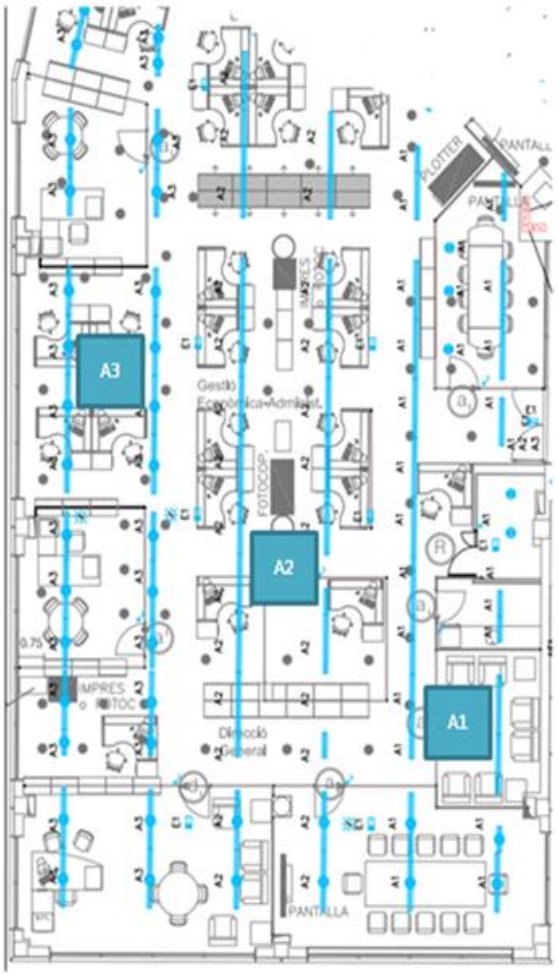

FIGURE 4: POSITION OF THE THREE LIGHTING UNITS WITHIN ICAEN'S AREA 1

Table 9 describes which locations are covered by each lighting circuit. This table is useful to assign lighting consumption to various locations (and users within these locations), and to understand what users can impact lighting at various locations. Some locations are impacted by lighting fed from two different circuits, hence the reason why they appear twice in the table.

TABLE 9: MAPPING OF LIGHTING AREAS TO ELECTRICAL CIRCUITS WITHIN ICAEN AREA 1

Lighting circuit	Locations covered by circuit
A1	PT23
	PT24
	PT15
	PT20
	PT21
	PT10
	PT123
	PT8
	PT3
	PT4
A2	PT120
	PT18
	PT19
	PT15
	PT20
	PT11
	PT12
	PT10
	PT123
	PT122
	PT7
	PT8
	PT2
	PT3
A3	PT18
	PT19
	PT16
	PT17
	PT13
	PT14
	PT11
	PT12
	PT122
	PT9
	PT7
	PT6
	PT
	PT1
	PT2

A/C UNITS

All fan coil units are fed from one three-phase circuit (L11). Figure 5 shows the six fan coils in the area covered by electrical panel 1.

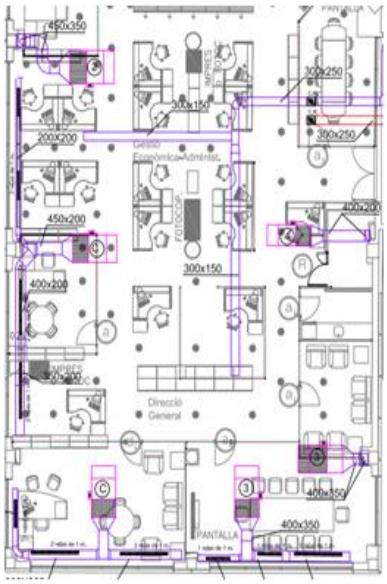

FIGURE 5: POSITION OF THE FAN COIL UNITS WITHIN ICAEN'S AREA 1

Table 10 describes the locations covered by the A/C circuit. This table shows that all locations are cooled/heated by fan coils fed from the same circuit.

TABLE 10: MAPPING OF A/C AREAS TO ELECTRICAL CIRCUITS WITHIN ICAEN AREA 1

A/C circuit	Locations covered by circuit
L11	All

2.2.5 LEGACY MONITORING SYSTEM

ICAEN have a pre-existing energy monitoring system from Circutor[1], which provides them with floor-level and consumer-type information on energy use. The system can provide 15mn readings, as well as historical data sets, which will be valuable at evaluation time for establishing a solid baseline to measure the effective savings achieved by the introduction of the game.

The Circutor system includes smart meters for the total building consumption, per floor consumption (i.e., lighting, fan coils, electrical plugs), for A/C (chillers and pumps), for each individual chiller, for the central humidifiers on the roof, and for the UPS. The electricity consumptions of lifts, corridors and bathrooms are grouped together in the "Rest of Common Services" box. The next table presents the list of smart meters of the building.

2.3 MNHA, LUXEMBURG

2.3.1 LAYOUT AND EQUIPMENT INVENTORY

The museum welcomes about 65K visitors per year. One constraint is that the public and employees cannot and should not act on the climate in order to protect the exhibits. For that reason, a different set of game challenges are to be piloted in the public area and admin offices (elevator's challenge and full ChArGED challenges, respectively).

The exhibition rooms' space is 4300 m^2 and there are 25 administrative offices. The new central building contains the reception with a shop and a cafeteria on the ground floor, an auditorium and a projection room

[1] http://circutor.com/en

on the first floor, and a room for temporary exhibitions on the top floor. There are 5 floors and 4 underground levels where the museum's archaeological collections are exhibited to the visitors.

There are about 100 employees in the museum and 40 of them belong to administrative staff. Admin staff offices are distributed over 4 floors. **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.** depict the user location and devices within each office.

2.3.2 Office use

Table 11 provides key information on the way the admin offices are used, providing useful time boundaries for the game backend to analyse patterns of inefficient energy use outside of business hours.

TABLE 11: MNHA PILOT SITE LAYOUT CHARACTERISTICS

Opening days	Tuesday - Sunday (exhibition area) Monday - Sunday (staff) Monday (schools visits)	Lower consumption on Mondays can be assumed
Work hours	Exhibition area Tuesday - Sunday (10:00 - 18:00) Thursday (10:00 - 20:00) Offices 7:00-9:00 to 16:00-19:30 depending on role	The exhibition floor is empty before 10:00 and after 18:00. The office is empty before 7:00 and after 19:30.
Lunch-break	11:30 to 14:30, one hour minimum	Possibility to get staff to switch off equipment when they take their break
Cleaning Staff	Exhibition area 5:30 to 10:00 Offices 6:00 to 12:00	Both spaces are used before work hours, expected low consumption

2.3.3 Electrical installations

A utility room in the basement hosts the electrical supply feeds for the various areas of the museum. The electrical feeds are wired and organised with the hierarchy depicted below, with each entry being an electrical panel located within the building.

```
Main power switch
    Visitor Zone 1
    Visitor Zone 2
        Floor -1
        Floor +1
        Floor +3
        Floor +5
    Offices + Monitoring Room
    UPS
    HVAC BA-1
    HVAC BA+3
    Lifts
    Water Cooling System for HVAC
    Wing Wiltheim
```

FIGURE 6: OVERVIEW OF THE ELECTRICAL INSTALLATION AT MNHA'S MAIN DISTRIBUTION BOARD

The evaluation of the game targets two main areas within the MNHA pilot site:

- Lifts
- Admin offices

Three main elevators are used at MNHA:

- Panorama elevator for visitors, which will be the focus for the stairs game challenge for visitors
- Freight elevator
- Small elevator for physically disabled persons and also used by staf

3. DEPLOYMENT TOPOLOGY

This section specifies the monitoring infrastructure deployed for each pilot site, allowing the ChArGED game challenges to run according to the flexibility available. The pilot survey analysis described in section 2 is used to infer where and how monitoring equipment should be deployed. A discussion is also given to assess whether the monitoring coverage can support the challenges we plan to run for each pilot site.

3.1 DAEM, ATHENS, GREECE

3.1.1 ELECTRICITY MONITORING

The in-depth surveying and labeling work conducted at DAEM allowed metering equipment to be deployed within the one electrical panel in September 2016, to monitor a total of 40 electrical circuits, powering up the circuits highlighted in section 2.1.4. That setup covers a total of 49 users' workstations, common equipment, lighting zones in 6 departments and A/C units in 7 departments.

Power meters, current sensors and gateway were used for that installation:

- 1 x Bosch gateway
- 3 x 18-channel Accuenergy AcuREV Modbus meters
- 48 x Current transformers (CTs)
- 5 x Fibaro smart wall plugs

Priority was given to the monitoring of individual user's computer stations, so all staff can participate to the game. As shown in Table 12, we have reduced metering needs by monitoring at the electrical panel, hence reducing the number of smart plugs. That way we managed to monitor one circuit feeding power to more than one computer (or workstation), and run advanced analytics on the measurements to identify the on/off pattern of the computers connected to that circuit.

TABLE 12: MAPPING OF USERS' WORKSTATIONS TO ELECTRICAL CIRCUITS, SHOWNIG THAT MORE THAN ONE WORKSTATIONS ARE FED FROM THE SAME CIRCUIT

Administrative Team	
USER 1	I13A
USER 2	I17A
USER 3	I15A
USER 4	I15A
USER 5	I7A
USER 6	I7A

Sales & Marketing Team	
USER 7	I6A
USER 8	I6A
USER 9	I11A
USER 10	I11A
USER 11	I11A
USER 12	I16A
USER 13	I16A

Eu Projects Team	
USER 22	I3A
USER 23	I17A
USER 24	I17A
USER 25	I17A
USER 26	I5A

Help Desk Team	
USER 27	I4A
USER 28	I3A
USER 29	I4A
USER 30	I4A
USER 31	I3A

Technical support Team	
USER 42	I14B
USER 43	I10B
USER 44	I17C
USER 45	I14B
USER 46	I10B
USER 47	I12B
USER 48	I5B
USER 49	I14C
USER 50	I4B

IT Team	
USER 32	I12A
USER 33	I12A
USER 34	I7B
USER 35	I6B
USER 36	I6B
USER 37	I1B
USER 38	I8A
USER 39	I8A
USER 40	I9A
USER 41	I10A

Supporting Supplies ServicesTeam	
USER 14	I2A
USER 15	I2A
USER 16	I2A
USER 17	I16A
USER 18	I16A
USER 19	I16A
USER 20	I14A
USER 21	I14A

In addition to computer equipment, lighting circuits are also monitored at the electrical panel.

While not all lighting fixtures are monitored, at least one lighting fixture is monitored in each area, allowing all teams to compete on lighting challenges.

Five fan coil circuits are also monitored at the electrical panel. The A/C wiring setup is more complicated as the same circuit can feed A/C units in more than one room. An effort was made to monitor circuits feeding as many fan coil units as possible in various areas, and the final setup covers 16 units.

As a matter of illustration of the overall monitoring coverage achieved by metering equipment at the electrical panel, we focus on the Sales & Marketing office. Table 133 is an extract showing the circuits monitored in that office, and **Error! Reference source not found.** shows the office on the map.

TABLE 13: CIRCUITS MONITORED WHICH FEED ELECTRICAL EQUIPMENT WITHIN THE SALES & MARKETING DEPARTMENT AT DAEM

Area Name	Circuit monitored	Meter	Meter input	Users

SALES & MARKETING DEPARTMENT	Lighting	A	I1	All
SALES & MARKETING DEPARTMENT	4 PC & 1 Laptop Common equipment: 1 Scanner	A	I6	2 users (n.7,8)
SALES & MARKETING DEPARTMENT	3 PC Common equipment: 1 Printer, 1 Scanner, 1 Multi machine/fax, 1 Paper shredder & 1 Water dispenser	A	I11	3 users (n.9,10,11)
SALES & MARKETING DEPARTMENT	Lighting	C	I10	All
EU PROJECTS DEPARTMENT & SALES & MARKETING DEPARTMENT	Air condition (3 units)	C	I11	All

Table 13 shows that two lighting circuits are monitored. This means that when a user switches off either the yellow or purple lighting switch, then he/she will swipe either controller with the mobile phone, and the analytics engine within the ChArGED platform will identify it has to process the energy readings coming from circuit I1A to measure a drop and notify the gaming engine that the action is real and points can be given. More details about the analytics engine operation are given in Deliverable D3.3.

Looking at the PCs, five users use a total of 7 PCs and 1 laptop, due to the nature of their work. The ChArGED platform will have access to the computers' readings via two circuit measurements (I6A and I11A), on which analytics will allow monitoring of their control actions and savings.

Finally, two air conditioning units near the window are monitored by circuit I11C. This means that we can run a challenge on the fan coil units near the window by attaching a NFC sticker next to them; however, no challenge can be conducted that could be focused specifically on the other A/C units in the room since they are not monitored.

3.1.2 SENSOR MONITORING

In addition to the monitoring of electrical energy from field devices, it is important to monitor the activity of the users on the floor plan, to link control actions to power variations, validation of game challenges and energy savings.

User interaction with equipment is achieved via NFC stickers. Movement of users within the floor plan is provided through BLE beacons, and contact switch sensors provide the status of windows for evaluation of air conditioning efficiency.

The analysis of the game challenges requirements and DAEM's floor plan led to the following hardware requirements and specifications.

- 1 NFC per workstation
- 1 NFC per lighting switch
- 1 NFC per A/C controller
- 1 NFC per printer
- 1 beacon per room or 1 beacon per set of desks grouped together
- 1 beacon per elevator
- 7 4-in-1 sensor to provide the temperature/humidity, luminance and presence for each room of the floor plan
- 13 contact switch sensors to monitor the 13 windows near AC units monitored by the system.

3.1.3 SOLAR ENERGY MONITORING

As a way to demonstrate that micro-generation can be an integral component of the ChArGED application and associated game challenges, DAEM have installed a photovoltaic system in August 2017. The system has a maximum power of 4,88 kWp and is located on the roof of the building. Following a technical analysis, a total of 25 solar panels have been deployed with a 30º and a north orientation, see Figure 7.

FIGURE 7: PART OF THE SOLAR PANELS INSTALLATION

The electrical connection within the installation includes 6mm solar wires. The complete installation includes:

- generators interconnected sequentially
- a DC electrical panel
- a Kaco powador 10.0 TL3 inverter

3.1.4 VALIDATION ROOM MONITORING

As a way to evaluate and illustrate the impact of fine-grained monitoring (one power meter for each electrical device) against lightweight monitoring (power meters on electrical circuits) on the evolution and impact of the game, the R&D office in DAEM was equipped with additional monitoring equipment:

- 4 x Fibaro smart plugs to monitor all workstations individually,
- 2 x 4-in-1 sensors at each corner of the room to provide temperature/humidity, luminance and motion in the room, and
- 1 x contact switch sensor for the window that can be opened

3.2 ICAEN, BARCELONA, SPAIN

3.2.1 ELECTRICITY MONITORING

The in-depth surveying and labeling work conducted at ICAEN allowed the planning of a metering equipment installation to happen in September 2017, to monitor a total of 47 individual circuits. That's a total of 47 users' workstations, 9 lighting zones, 2 printers, 1 LCD and 3 A/C units monitored with the hardware below:

- 1 x Bosch gateway
- 3 x 18-channel Accuenergy AcuREV Modbus meters
- 37 x Current transformers (CTs)
- 6 x Fibaro smart plugs

Priority was given to the monitoring of individual user's computer stations, so all staff can participate to the game. We have reduced metering needs by monitoring at the electrical panel, hence reducing the number of smart plugs. That way we can monitor one circuit feeding power to more than one computer,

and run advanced analytics to identify the on/off pattern of the computers connected to that circuit.

The following describes the monitoring setup specified for each of the three areas of the ICAEN floor plan.

AREA PANEL 1

Electrical panel 1 will be equipped to monitor the four red plug circuits (S1-S4), supplying power to 11 users and 1 LCD screen.

TABLE 14: LINK BETWEEN USERS' PC AND MONITOR AND ELECTRICAL CIRCUITS FEEDING THEM IN ICAEN AREA 1

Area Panel 1		
	PC	**Monitor**
USER 1	S1	S1
USER 2		
USER 3	S2	S2
USER 4		
USER 5		
USER 6	S3	S3
USER 7		
USER 8		
USER 9		
USER 10		
USER 11	S4	S4

In addition, the 3 lighting circuits feeding the 3 lighting zones as well as the three-phase circuit feeding the fan coil units have been monitored.

Below is the final metering setup installed at the electrical panel 1 to allow measurement of savings achieved on workstations and lighting, LCD, and to some extent on A/C:

- 1 x Bosch gateway
- 1 x Accuenergy AcuREV meter
- 10 x 60A 0.4" CTs

AREA PANEL 2

Electrical panel 2 was equipped to monitor the four white (F1-F4) and the four red (S1-S4) plug circuits, supplying power to 21 users in that area, as well as 1 printer and 1 LCD screen (both fed from circuit F1).

TABLE 15: LINK BETWEEN USERS' PC AND MONITOR AND ELECTRICAL CIRCUITS FEEDING THEM IN ICAEN AREA 2

Area Panel 2		
	PC	**Monitor**
USER 1	S1	
USER 2		
USER 3	F1	
USER 4	S2	
USER 5		
USER 6		
USER 7		
USER 8		
USER 9		
USER 10		
USER 11	S3	
USER 23		
USER 12	F3	
USER 13		
USER 14	F3	S3
USER 15	S4	
USER 16		
USER 17		
USER 22		
USER 18	F4	
USER 19		
USER 20		
USER 21		

Figure 8 shows on the floor plan map where the 21 users are located and which circuits their workstation is fed from.

FIGURE 8: LOCATION OF USERS MONITORED IN AREA 2 ALSO SHOWING THE CIRCUITS FEEDING EACH GROUP OF USERS

In addition, the 3 lighting circuits feeding the 3 lighting zones as well as the three-phase circuit feeding the A/C unit have been monitored.

Below is the final metering setup installed at the electrical panel 2, to allow measurement of savings achieved on workstations and lighting, printer, LCD, and to some extent on A/C:

- 1 x Bosch gateway
- 1 x Accuenergy AcuREV meter
- 14 x 60A 0.4" CTs

AREA PANEL 3

Electrical panel 3 was equipped to monitor the four white (F1-F4) and the four red (S1-S4) plug circuits, supplying power to 15 users in that area, as well as 1 printer fed from circuit F3.

TABLE 16: LINK BETWEEN USERS' PC AND MONITOR AND ELECTRICAL CIRCUITS FEEDING THEM IN ICAEN AREA 3

Area Panel 3		
	PC	**Monitor**
USER 1	S1	
USER 2		
USER 3	S1	F1
USER 4	F1	S1
USER 5	F2	
USER 6	S2	
USER 7	S2	F2
USER 8	S4	
USER 9		
USER 10		
USER 11	S4	F4
USER 12		
USER 13	S2	F2
USER 14	S1	
USER 15	S3	

Figure 9 shows on the floor plan map where the 21 users are located and which circuits their workstation is fed from.

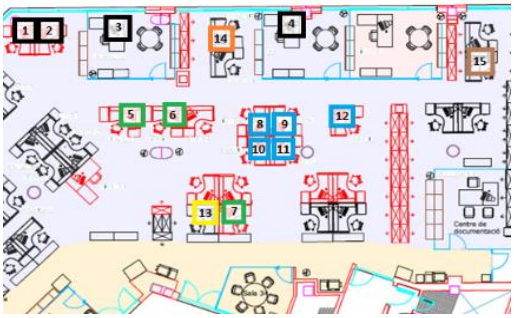

FIGURE 9: LOCATION OF USERS MONITORED IN AREA 2 ALSO SHOWING THE CIRCUITS FEEDING EACH GROUP OF USERS

Below is the final metering setup installed at the electrical panel 3, to allow measurement of savings achieved on workstations and lighting, printer, LCD, and to some extent on A/C.

- 1 x Bosch gateway
- 1 x Accuenergy AcuREV meter
- 13 x 60A 0.4" CTs

3.2.2 Sensor monitoring

In addition to the monitoring of energy use from field devices, it is important to monitor the activity of the users on the floor plan, to link control actions to power variations, validation of game challenges and energy savings.

The analysis of the ICAEN's floor plan led to the following hardware requirements and specifications:

- 1 NFC per workstation
- 1 NFC per lighting switch
- 1 NFC per A/C controller
- 1 NFC per printer
- 1 beacon per room or 1 beacon per set of desks grouped together
- 1 beacon per elevator
- 3 4-in-1 sensor to provide the temperature/humidity, luminance for each of the three areas of the floor plan
- 9 contact switch sensors to monitor 3 windows near AC units in each area of the floor plan.

Windows are also monitored despite the fact that the building occupants have no control over the air conditioning controls. The reason is that we believe that the overall A/C consumption will be affected by windows being open, and we want to address the associated savings/wastage. The specific challenge associated will be to keep the windows shut while the air conditioner is on.

3.3 MHNA, Luxemburg

3.3.1 Electricity monitoring

The in-depth surveying work conducted at MNHA allowed metering equipment to be deployed in June 2017 to monitor a total of 14 three-phase circuits, powering up various areas of the building, as highlighted in section 2.3.3.

This deployment provides an overview of the energy use consumed in the exhibition areas as well as admin offices and lifts which we are most interested with for the project. **Error! Reference source not found.** and **Error! Reference source not found.** show the installation of the meters and current sensors on the electrical boards.

Part of the monitoring equipment will be redeployed shortly to the electrical panels feeding the Admin offices and visitor lifts in order to produce finer-grained readings for the evaluation of the game challenges.

Because major works have been conducted in the Admin offices with changes to the electrical installation and movement of people between offices, the labeling process proves complicated and the final survey is not available yet for redeployment of the meters. The redeployment will therefore happen once the information is updated, and will be summarised in Deliverable D4.3 when analyzing the first results of the ChArGED application in MNHA. Smart plugs will also be deployed in parallel to the metering installation to capture known major energy offenders that cannot be monitored from the electrical panel, as a way to facilitate targeted energy actions through the gamified app.

3.3.3.2 Sensor monitoring

In addition to the monitoring of energy use from field devices, it is important to monitor the activity of the users on the floor plan, to link control actions to power variations, validation of game challenges and energy savings. The analysis of the MNHA's floor plan led to the following hardware requirements and specifications:

- 1 NFC per workstation
- 1 NFC per lighting switch
- 1 NFC per A/C controller
- 1 NFC per printer

- 1 beacon per room or 1 beacon per set of desks grouped together
- 1 beacon per elevator

Indoor temperature and windows are not monitored because the offices do not have air conditioning equipment and therefore no such savings opportunities exist in this pilot site., and the related game challenges cannot be applicable.

4. EVALUATION METHODOLOGY FOR PILOT TESTS - PRE AND POST IMPLEMENTATION QUESTIONNAIRE

In deliverable D4.1, we provided the questionnaires that shall be used during the first validation periods (period 1 & period 2) of the project (M18-M20 & M20-M22). In this chapter of the present deliverable, the questionnaire instrument that shall be used for the assessment purposes of the ChArGED product during validation period 3: M24-M36 (M24-M30, M31-M35) is outlined and explained in this section of the document.

As outlined in Deliverable D4.1, the output of Deliverable D3.5 (the integrated ChArGED system for real life evaluation), that includes the demonstration of the gamified mobile app and its interoperability with the backend system, will be assessed by taking under consideration direct feedback from the users. The objective will be to:

- Assess the usability and acceptance of the 'real life' integrated ChArGED system.
- Obtain feedback from end users regarding their impressions from using the mobile app in real life tests.
- Use the feedback collected through the application usage to improve the ChArGED system that will be delivered at the end of the project.

This validation process also applies for the web dashboard that will be used by the building managers. Furthermore, at this stage the validation will be complete and also include qualitative and quantitative aspects, against the validation metrics set during the project. Therefore, taking into consideration direct feedback from the end-users, we will also be assessing the systems':

- Effectiveness in Behavioural Change – in the form of energy conservation at the workplace
- Perceived quality and effectiveness as a gamified product

The ChArGED app will be tested in each pilot site, where the deployed and fully customized system will be used. In each pilot site all employees (~50 on each site expected to use the app) will be invited to download and use the ChArGED app, as well as those persons from the building management that will use the ChArGED dashboard. The users at each site will operate the Mobile App for a year. During that time period, there will be two evaluation sessions, one at M30 and another at M35. In each session the test participants will fill in specific questionnaires that will be related to the following aspects:

- Energy related measures
- Users' feedback
- Behavioural change results

The usage of the mobile App will also be monitored using Mobile App usage analytics tools (automated usage results). In the end of each session both questionnaires and electronic usability results will be combined and studied to provide additional and/or pending recommendations to WP3 for developing the final updates on the ChArGED system that will be delivered at M36. The results of the evaluation at M30 could also be used to update specific bugs/faults on features of the ChArGED system (without changing the key aspects of the Mobile App and the ChArGED dashboard). Finally, during that assessment phase the actual energy consumption will be monitored and recorded, in order to be compared with the previously recorded baseline measurements. The questionnaires that will be deployed to the participants, in order for them to evaluate these parameters, are delineated below.

To assess the characteristics of the ChArGED product, as well as its effectiveness in behavioural change – in the form of energy conservation by the participants in their workplace – we have designed a composite questionnaire instrument, which includes mainly 7-point Likert scale questions. The questionnaire features two distinct versions: a pre-experimentation and a post-experimentation version. We would like to also

note that a sub-set of the questionnaire items we shall be using have already been introduced in deliverable D2.1, as part of the requirements analysis process, where the relevant anonymously collected insight was used to calibrate the characteristics of the resulting mobile apps and implementation. In this case, we shall be utilizing them to record the behavioural effect of the application on each user (questions shall be answered and matched with the users' username), as well as groups of the users and our whole user base. A comparison between the answers before and after using the ChArGED solution shall be made and conclusions shall be drawn accordingly.

The pre-experimentation version of the questionnaire is to be completed by all participants, as part of the on-boarding process. The items included are aimed at recording the personal characteristics of the participants, as well as their current energy consumption behavior at the workplace. This data will be used for two important purposes. First of all, to assess the personal profile of the individual participants, so as to be in a position to explain their upcoming behavior and preferences within the gamified app. Secondly, to record a baseline self-reported behavior, with regards to energy consumption at the workplace, prior to using the ChArGED product. The sections included in this version of the questionnaire include:

- An assessment of the employees' personality profile, to aid in the explanation of the behavior of the participants both before and after using the ChArGED app, based on their individual personal characteristics.
- An assessment of the employees' work engagement levels – before using ChArGED (to be used in assessing the effect of the ChArGED app on employee engagement, as well as screen for the overall effect of the employees' engagement level on the adoption, usage and effectiveness of the app after its usage).
- An assessment of the employees' energy conservation behavior prior to using the ChArGED app, comprising of the following sub-sections:
    - Self-reported appraisal of the frequency in which a set of energy consumption behaviours are performed by the participants at their workspace.
    - Levels of the participant's intentions towards conserving energy at the workplace.
    - The strength of the pro-environmental worldviews, with regards to energy consumption, held by the participants.
    - Degree to which the participants identify with a set of personal norms related to energy conservation at the workplace.
    - Level of awareness of the means through which they can conserve energy at the workplace.
    - Direction of the participants' locus of control, with regards to energy conservation at the workplace – whether it is internal (their own obligation), or external (other peoples' obligation).
    - Possible behavioural spill-over effect from the participants' energy conservation behavior at home.
    - Intention to use a serious game/gamified app for energy conservation at the workplace, prior to its deployment.
    - Degree to which energy conservation is already a habit to the participants.
    - Degree to which the existing self-reported energy conservation behavior of the participants is consciously performed.
    - Demographic characteristics of the participants, namely their role in the organisation, age, gender and whether they have children.

The post-experimentation version of the questionnaire is to be completed by all participants, at the end of the experimentation period. The items included are aimed at recording the resulting behavioural profile of the users with regards to energy consumption at the workplace, after interacting with the ChArGED product

for an ample amount of time. The purpose of the sections included in this composite instrument is again two-fold: First of all, we will use the data from the collected answers, in order to compare the self-reported behavior of the participants before and after the intervention and derive the self-assessed behavioral effectiveness of the app in energy conservation at the workplace. In other words, we will be in a position to record the perceived effect that ChArGED has had on the participants with regards to their energy conservation behavior. Secondly, we will record the participants' assessment of the effectiveness of the ChArGED product as a gamified app with the specific aim of reducing energy consumption at the workplace. This will be a complete documented report on how the actual users of the system perceived its utility towards the set purpose of energy conservation at the workplace and will be useful in ascertaining the parameters of the system that may need fine-tuning or improvement. Since this part of the questionnaire is meant to be administered after a completed interaction phase with the ChArGED offering, it will be administered at the end of the two testing sub-periods (M30 & M35), as outlined in D4.1. The sections included in this version of the questionnaire include:

- An assessment of the employees' work engagement levels – after using ChArGED – to assess the effect of the ChArGED app on employee engagement, as well as screen for the overall effect of the employees' engagement level on the adoption, usage and effectiveness of the app.

- An assessment of the employees' energy conservation behavior after using the ChArGED app, comprising of the same sub-sections as in the pre-implementation version of the questionnaire:

    - Self-reported appraisal of the frequency in which a set of energy consumption behaviours are performed by the participants at their workspace. By comparing the pre- and post- answers we will assess the perceived effect of ChArGED on the participants' actual behavior.

    - Levels of the participant's intentions towards conserving energy at the workplace. By comparing the pre- and post- answers we will assess the effect of ChArGED on the participants' behavioral intentions.

    - The strength of the pro-environmental worldviews, with regards to energy consumption, held by the participants. By comparing the pre- and post- answers we will assess the effect of ChArGED on affecting the participants' worldviews.

    - Degree in which the participants identify with a set of personal norms related to energy conservation at the workplace. By comparing the pre- and post- answers we will assess the effect of ChArGED on the participants' norms.

    - Level of awareness of the means through which they can conserve energy at the workplace. By comparing the pre- and post- answers we will assess the perceived effect of ChArGED on educating the participants' in ways to conserve energy at the workplace.

    - Direction of the participants' locus of control, with regards to energy conservation at the workplace – whether it is internal (their own obligation), or external (other peoples' obligation). By comparing the pre- and post- answers we will assess the perceived effect of ChArGED on altering the direction of the participants' locus of control with regards to energy conservation at the workplace.

    - Possible behavioural spill-over effect from the participants' energy conservation behavior at home. By comparing the pre- and post- answers we will assess the perceived effect of ChArGED on the participants' actual behavior at home – spillover effect from the work environment to the home environment.

- Intention to use a serious game/gamified app for energy conservation at the workplace, after its deployment. By comparing the pre- and post- answers we will assess the attractiveness of ChArGED to the participants – if intention rises, then it will be an indication of attractiveness.

- Degree in which energy conservation is a habit to the participants. By comparing the pre- and post- answers we will assess the effect of ChArGED in altering the participants' energy behavior in the degree that they have become a habit and will continue to be performed regardless of using the app.

- Degree in which the existing self-reported energy conservation behavior of the participants is consciously performed. By comparing the pre- and post- answers we will assess the effect of ChArGED on the participants' consciousness in energy consumption at the workplace.

- An assessment of the perceived effectiveness of the CHARGED app in reducing energy consumption through various parameters. The sub-sections include:

    - Attitude towards using the ChArGED app – General perception of the ChArGED offering by the participants as a product and/or service.

    - Continued use intention – Measurement of the respondents' perceived intentions of continuing to exercise the desired behavior after the intervention period.

    - Hedonic motivation – Enjoyment – Overall perceived enjoyment and contentment with using the service.

    - Ease of use – Effort expectancy – The degree of belief that using a system would be free of effort.

    - Playfulness while using ChArGED – A situation-specific characteristic of a person – a trait of playfulness emerging when the person is interacting with the system.

    - Usefulness for its set purpose – Performance Expectancy – The degree of belief that using a system would enhance the performance of the task the system is designed for.

    - Social Influence – The degree to which the participants' peers are perceived to endorse the usage of ChArGED.

    - Effect of ChArGED on instilling energy consumption habits to the participants.

    - Personal Innovativeness – a measure we shall be using to assess the adoption behavior of the participants with regards to the ChArGED app.

The questions employed within the questionnaire instrument delineated above have been carefully selected from well-respected references and have in many cases found application in field applications. As per work engagement, as it was already administered in the requirements analysis phase of project ChArGED, we shall be employing the Utrecht Work Engagement Scale (UWES-9) (Schaufelli et al, 2006), an instrument that measures the level of engagement, amongst employees based on three pillars – vigor, dedication and absorption. It is widely regarded as one of the most valid instruments for this purpose, as it can be used in studies on positive organizational behavior (Schaufelli et al, 2006). We want to measure work engagement because the engaged employees are prone to contribute towards the organization, within which they are employed, "drive innovation and move the organization forward" (Prakash & Rao, 2015). Furthermore, they are expected to devote their efforts towards contributing to the overall good of their work environments, as well as their co-workers, as well as to adopt energy responsible behaviours and the ChArGED gamified apps more willingly than their disengaged counterparts. More information on the rationale behind assessing employee engagement, as well as supporting references and information can

be found in deliverable D2.1. The same stands for most of the questions included in the part regarding the participants' energy conservation behavior. As per the specific energy-conservation behaviours assessed, we try to capture the existing habits of employees regarding energy-consumption behaviour in their work space and assess the participants' individual energy consumption profile. This part of the questionnaire is necessary to collect specific info on the energy usage habits pre- and post- ChArGED. Environmental personal norms and environmental worldviews concerning employee energy use have been mainly adapted from Scherbaum et al (Scherbaum et al., 2008), while some additional questions were added to the original questionnaire, in order to account for and explain the desired behavior more accurately. As per the employees' personality profile, we will be assessing it to aid in the explanation of the behavior of the participants both before and after using the ChArGED app, based on their individual personal characteristics. The measure selected is the Ten-Item Personality Index (TIPI) (Gosling et al., 2003), which assesses the participants with regards to five characteristics: Openness to experience, conscientiousness, extraversion, agreeableness and emotional stability (neuroticism). It has been used in a wide variety of applications, while the big-five characteristics have been connected to a large number of individual behaviors, including the behavior within games, as well as pro-environmental behavior, environmental concern, as well as environmental engagement, that are connected to electricity conservation behavior (Hirsh, 2010; Milfont & Sibley, 2012). Moreover, we capture the problem awareness of public-building employees regarding the energy sustainability, and their knowledge and attitude regarding energy conservation. The knowledge and problem awareness is an important psychological factor that affects energy-consumption behaviour, while knowledge is part of the ability dimension in the MOA (Motivation-Opportunity-Ability) behavioural model (Ölander, F. and Thøgersen, J. 1995). Attitude is also part of the motivation dimension in the MOA behavioural model. Moreover, personal responsibility is part of the perceived cost/benefit ratio (which is part of the motivation dimension in MOA model), which is another important psychological factor.

Locus of control reflects a person's perception of whether they have the capability to enact change and/or control events that impact them. Individuals with a strong internal locus of control believe that they can exercise personal control over their own decisions, life circumstances and outcomes (i.e., belief that events arise primarily from internal factors, such as one's own motivation and actions), whereas those with a strong external locus of control believe that decisions, life circumstances and outcomes are controlled by environmental factors outside their influence (i.e., belief that events arise primarily from external factors, such as other people, the government, socio-economic influences, etc.). Knowledge and problem awareness are assessed, because understanding the multi-dimensional problem of energy sustainability and knowledge on how to conserve energy generally enable more sustainable energy-consumption behaviours. However, the absence of a direct link between knowledge and action is often referred to as "knowledge-action gap".

As per the items regarding the assessment of the perceived effectiveness of the CHARGED app in reducing energy consumption, the items regarding the users' attitude towards using the ChArGED app, they were adapted from a questionnaire instrument suggested by (Hamari & Koivisto, 2015), that was employed towards a gamified application, based on the Theory of Planned Behavior, to depict the general attitude of the users towards the ChArGED system. The general trait of playfulness depicts a multifaceted construct encompassing five distinct factors (Webster & Martocchio, 1992): cognitive spontaneity, social spontaneity, physical spontaneity, manifest joy, and sense of humour while cognitive spontaneity represents the most relevant playfulness factor in the context of human-computer interactions. We have employed a questionnaire subsection adapted from Webster & Martocchio (1992). As per the measurement of Habitual attachment to conserving energy at the workplace and using the ChArGED system, we have adapted the questionnaire instrument suggested by (Pavlou, P. A., & Fygenson, M., 2006). The personal innovativeness of the participants shall be measured by employing a scale by (Agarwal & Prasad, 1998), whereby personal innovativeness is defined as "the willingness of an individual to try out any new information technology" – in our case the ChArGED solution. The rest of the items that we use to assess the perceived effectiveness of the CHARGED app in reducing energy consumption were adapted by the respective construct proposed as

part of the Unified Theory of Acceptance and Use of Technology (UTAUT), as revised and delineated by (Venkatesh et al., 2012). The actual questionnaire instrument we will be using can be found in the following section of the document.

5. CONCLUSIONS

The present document describes in detail the trials specifications pertaining to the validation and evaluation process of the ChArGED platform in three pilot sites in Greece, Spain and Luxemburg. Detailed specifications of each test-bed facility have been gathered based on floor plan information, including user mapping, equipment inventory, usage patterns and labeling of electrical installations.

The information collected made it possible to specify the monitoring equipment to be installed in each pilot site and to conclude which game challenges can be performed in the real life pilots. A monitoring infrastructure based on multi-channel power meters, smart plugs, NFC stickers, BLE beacons and a variety of sensors was identified for the needs of the project. More specifically, a solution where individual assets are not monitored with a dedicated monitoring device is proposed; instead we opted for a middle ground approach with monitoring at electrical circuit and room level that balances the granularity of the readings with the equipment capital cost. The methodology followed for surveying the pilot sites and for specifying the monitoring infrastructure have been described so as to be repeated in any future site where the ChArGED system is deployed.

In order to validate the ChArGED solution, two questionnaires were defined in this deliverable. They will be used in conjunction with the evaluation plan described in Deliverable D4.1. The ChArGED platform and application will be assessed with field trials starting from March 2018 and concluding a year later by the end of February 2019. Upcoming deliverables *D4.3 Intermediary end-users evaluation report* and *D4.4 Final end-users evaluation report* will report the results of each pilot site.

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