



eTEACHER

D4.1 Evaluation Methodology and preliminary pilots descriptions

WP4 Demonstration and Evaluation of Behavioural Change through eTEACHER solutions

T4.1 Evaluation Methodology

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D4.1: Evaluation Methodology and preliminary pilots descriptions

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D4.1: Evaluation Methodology and preliminary pilots descriptions

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0 Executive Summary

The eTEACHER project aims to encourage and enable energy behaviour change of building users by means of an ICT tool-box that displays continuous interventions to save energy and improve indoor environment quality (IEQ). As part of the project, behavioural changes must be demonstrated in twelve real buildings. A deep knowledge of the pilot buildings and a consolidated evaluation methodology are crucial to plan a successful demonstration. This report presents a characterization of the pilot buildings and a description of the evaluation methodology that will be used in eTEACHER. The content of this deliverable are results from *T4.1 Evaluation Methodology* and *T4.2 Initial monitoring and data collection before eTEACHER. Pilots characterization* to date.

Table 0.1 and Table 0.2 summarize the target behaviours and potential energy-related and IEQ-related improvements (use cases) that want to be demonstrated in every pilot building.

Table 0.1 Summary of target behaviours

Energy-related behaviours	Engagement behaviours
Lighting behaviours <ul style="list-style-type: none">• Turning off lights when leaving a room or at end of day• Checking lighting levels and needs during day – reducing use of unneeded lights• Making use of natural light more	<ul style="list-style-type: none">• Self-reporting energy-related behaviours in response to in-app activities and challenges• Reporting comfort levels to app in response to prompts• Viewing energy consumption of whole building• Viewing energy consumption of own room/apartment• Using eTEACHER tool to report any building issues (e.g. overheating, too cold, equipment failures etc.) with Facility Management• Using eTEACHER tool for Facility Management to report back to users the status of any issues in building• Viewing energy data for specific appliance use• Discussing energy-related issues, such as sharing tips and suggestions with other building users
Appliance use behaviours: <ul style="list-style-type: none">• Ensuring appliances are not left on standby overnight• Changing default settings or manually using sleep/hibernate modes and 'screen off' when computer is not in use• Turning off computer if away from desk for any length of time• Turning off own computer at end of the day• Changing power mode to be more efficient• Choosing more efficient hardware and default settings• Turning off chargers once fully charged• Turning off TVs/screens at end of the day• Turning off projectors when not in use• Turning off medical equipment if possible	
HVAC and comfort related behaviours <ul style="list-style-type: none">• Reducing thermostat temperature for heating• Managing temperature via clothing or activity rather than heating/cooling whole space• Increasing air-conditioning temperature set for cooling• Ensuring that air-conditioning and heating not on at the same time• Ensuring that if heating is on, windows and doors are kept closed (if possible) to keep the heat from escaping• Choosing more efficient systems or better use of system settings• Reducing use of personal fans/heaters within the building	

D4.1: Evaluation Methodology and preliminary pilots descriptions

Table 0.2 Pre-selection of use cases to be demonstrated in every pilot building

Type	Building name (location)	USE CASES
Office	OAR - Organismo Autónomo de Recaudación (Spain)	ECM1, ECM2, ECM3, BP1, IEQ1
	NCR - Nottingham Council House (UK)	ECM2, ECM3, ECM4, BP1, IEQ1
Residential	Apartment Block Badajoz (Spain)	ECM1, ECM2, ECM3, ECM4, IEQ1
	InCity (Romania)	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1
School	IES Torrente Ballester - High School (Spain)	ECM2, ECM3, IEQ1
	CEI Arco Iris – Kindergarten (Spain)	ECM1, ECM2, ECM3, ECM4, IEQ1
	Djanogly City Academy (UK)	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1
Health Care Centre	Guareña (Spain)	ECM1, ECM2, ECM3, ECM4, IEQ1
	Villafranca de los Barros (Spain)	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1

ECM1 - Save cooling energy using HVAC control, windows and blinds; **ECM2** - Save heating energy using HVAC control, windows and blinds; **ECM3** - Save lighting energy using natural lighting or power-off when there are not people using it; **ECM4**- Save electric energy power-off unnecessary appliances, devices or equipment; **BP1** - Detection of building underperformance conditions; **IEQ1**- Monitoring and advisor of indoor environmental quality to improve the wellness and productivity

The **pilot buildings characterization** is focused on buildings envelope (windows, fabric, facades), energy systems (lighting, heating, cooling, ventilating, appliances), monitoring and control systems, building use (schedule, activity, etc.) and occupants' behaviour (users' profile, interaction with energy systems and building components, etc). The identification of potential eTEACHER users and energy savings is also part of pilot buildings characterization.

The procedure to do pilot buildings characterization consists of following steps:

- Step 0: Definition of a generic template to collect information from the building, energy systems, monitoring and control system and occupants' behaviour.
- Step 1: Visit the building with the support of some technical manager to collect the information.
- Step 2: Evaluation of information to describe the energy behaviour of occupants.
- Step 3: Evaluation of technical details to integrate eTEACHER BACS add-ons and deploy the engagement solutions to change occupants' behaviour

The **evaluation methodology** of eTEACHER uses measured and self-reported evidences and is based on three methods: *monitoring*, *eTEACHER app* and *feedback forum & surveys*. Besides, *key performance indicators* (KPIs) that represent project impact and success; the *experimental design* to know how to apply the three methods and the *evaluation plan* have been detailed in this report.

Figure 0.1 shows the high-level **monitoring plan** for building pilots. This general approach has been customised for every pilot building.



D4.1: Evaluation Methodology and preliminary pilots descriptions

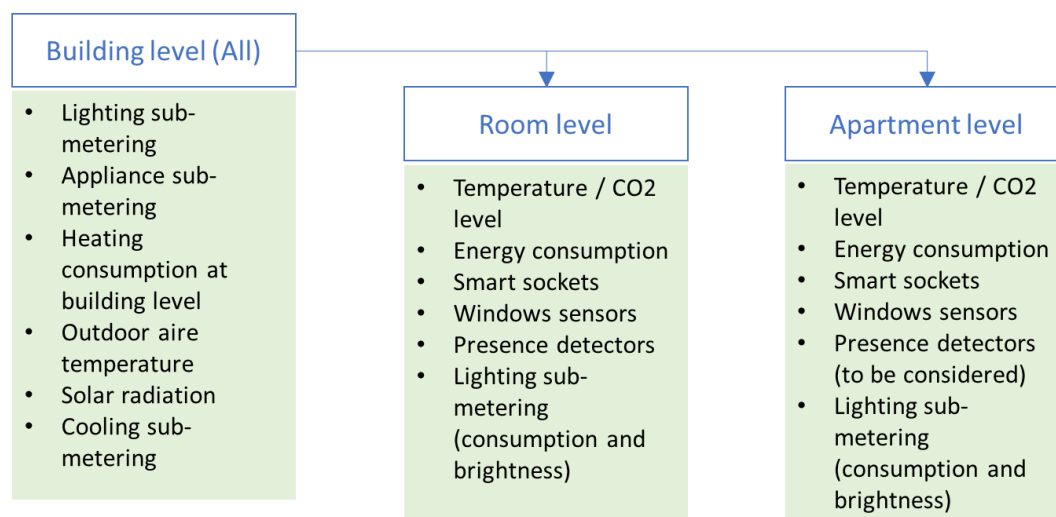


Figure 0.1 High-level monitoring plan for building pilots

Following data must be collected by **eTEACHER app** to evaluate project results: level of interaction with eTEACHER tool, self-reported energy-related behaviours in response to in-app activities and challenges, self-reporting of issues to the app, self-reporting of issues to the app, use of the app by users to discuss energy-related issues

Two surveys will be used to evaluate the usability of the tool. The first one will determine the baseline and the second one will be used for the evaluation. The surveys contain 10 statements such as “I think that I would like to use eTEACHER frequently” that must be marked from 1 (strongly disagree) to 5 (strongly agree) by building occupants after using eTEACHER tool. On the other hand, **Feedback Forum** which are semi-structured focus group will qualitatively describe their use to date of eTEACHER, share evaluative feedback on eTEACHER’s effectiveness and collaboratively analyse the factors influencing engagement with eTEACHER and its effectiveness.

Table 0.3 summarises the **KPIs** that have been defined to measure the effectiveness of eTEACHER to increase the energy efficiency and environmental indoor quality (IEQ):

Table 0.3 Key Performance Indicators to measure project effectiveness

Code	Description	KPI	Target(s)
IM1	Energy Savings and reduction of CO2 emissions	Energy savings vs. number of interactions with eTEACHER’s app	6-10%
IM2	Fast deployment	Monitoring deploying time during the project Development of deploying plan and installation procedures	<1 month during the project <1 week after the project
IM3	Fast adoption	eTEACHER acceptance surveys	15-30% users’ satisfaction
IM4	Number of users changing behaviour	App feedback	30% (952 users)



D4.1: Evaluation Methodology and preliminary pilots descriptions

OIM1	RoI based on energy savings and investments	Cost savings vs. Monitoring investments (tenders)	< 3 years
OIM2	Economic growth	To be defined	Qualitative
OIM3	Indirect economic growth	To be defined	Qualitative
OIM4	Growth of innovative SME	To be defined	Qualitative
OIM5	European leadership on ICT solutions for Energy Efficiency	To be defined	Qualitative
OIM6	Improve occupants' wellbeing	CO ₂ levels and indoor conditions (temperature and humidity ratio)	Better IEQ values from baseline

IM – impact indicator; **OIM**- other impact indicator

The **experimental design** of the project is based on eeMeasure Methodology (Woodall, 2011) and consists of comparing control environments (environments without eTEACHER) with study environments (environments with eTEACHER) before and after the deployment of eTEACHER to draw conclusions regarding behaviour change caused by eTEACHER interventions. This comparison is done using data collected by means of the three methods (monitoring, eTEACHER app and feedback forum & surveys) in both kind of environments as well as calculating corresponding KPIs.



Table of Contents

0	Executive Summary.....	4
1	Introduction.....	12
2	Context: Pilot Building Characterization.....	13
2.1	Technical Description	14
2.2	Office Buildings.....	14
2.3	Residential Buildings	18
2.4	Academic Buildings	21
2.5	Health Care Centres	27
3	Target Behaviours	30
3.1	Theory of Change	30
3.2	Energy-related behaviours.....	31
3.3	Engagement behaviours.....	34
4	Evaluation Methodology	36
4.1	Application of eeMeasure on eTEACHER.....	42
4.2	Monitoring	45
4.3	eTeacher App	65
4.4	Feedback Forums and Surveys.....	66
5	Conclusions.....	71
	References	74
	Annex A. Templates to Collect Pilot Information	76
1	BUILDING NAME	76
1.1	General Information	76
1.2	Geometry	76
1.3	Construction Materials.....	77
1.4	Building components	78
1.5	Energy Systems	79
1.6	Monitoring system.....	86
1.7	Control system: BACS / BEMS	87
1.8	Historical monitoring & energy consumption data	88
1.9	Energy Audits	88
1.10	Summary of building problems related to energy efficiency according to users.....	88
1.11	Additional information	88
	Annex B. Behaviour Change Evaluation	89



D4.1: Evaluation Methodology and preliminary pilots descriptions

List of Figures

Figure 0.1 High-level monitoring plan for building pilots	6
Figure 3.1 COM-B Model (Michie, 2011)	31
Figure 4.1 Evaluation Methodology	37
Figure 4.2 Evaluation Plan	41
Figure 4.3 Evaluation approach using one environment before and after	42
Figure 4.4 Evaluation approach using control groups.....	43
Figure 4.5 Demand Units and control groups. Monitoring system and eTEACHER tool-box	45
Figure 4.6 Monitoring devices for building pilots (Dresden, May 2018).....	46
Figure 4.7 Monitoring devices for building pilots (September 2018)	46
Figure 4.8 Ajzen's Theory of Planned Behaviour (Figure from Ajzen, 1991).....	49
Figure 4.9 Survey design for baseline and evaluation with consideration of control and monitored groups.....	67
Figure 4.10 SUS score with grade and adjective rankings (Bangor, Kortum and Miller, 2009)	69

List of Tables

Table 0.1 Summary of target behaviours	4
Table 0.2 Pre-selection of use cases to be demonstrated in every pilot building	5
Table 0.3 Key Performance Indicators to measure project effectiveness	6
Table 1.1 Summary of eTEACHER building pilots.....	12
Table 3.1 Energy related behaviours currently exhibited in eTEACHER pilot buildings	32
Table 3.2 Target behaviours and relevant users eTEACHER should focus on	33
Table 3.3 Engagement behaviours and related building users	35
Table 4.1 Key Performance Indicators for Impact Assessment	38
Table 4.2 Evaluation procedure to calculate KPI based on data collection.....	40
Table 4.3 Comparison of experimental design approaches.....	44
Table 4.4 Preselection of use cases to be tested in each eTEACHER building pilots.....	50
Table 4.5 Existing monitoring level in building demos	52
Table 4.6 Monitoring system in OAR.....	53
Table 4.7 Monitoring system in Nottingham Council House	55
Table 4.8 Monitoring system in InCity	56
Table 4.9 Monitoring system in Apartment Block Badajoz.....	57
Table 4.10 Monitoring system for Torrente Ballester	59



D4.1: Evaluation Methodology and preliminary pilots descriptions

Table 4.11 Monitoring system for Djanogly City Academy.....	60
Table 4.12 Monitoring system for Arco Iris	62
Table 4.13 Monitoring system for Villafranca de los Barros	63
Table 4.14 Monitoring system for Guareña	64
Table 4.15 SUS for calculating eTEACHER tool usability.....	67
Table 4.16 Feedback Forums suggested from D1.4 and relevant evaluation	69



D4.1: Evaluation Methodology and preliminary pilots descriptions

Abbreviation and Acronyms

AHU	Air Handling Unit
App	Application
BACS	Building Automation and Control System
BEMS	Building Energy Management System
BP	Building Performance
DHW	Domestic Hot Water
ECM	Energy Conservation Measure
ESCO	Energy Service Company
HVAC	Heating, Ventilating and Air-Conditioning
ICT	Information and Communication Technology
IEQ	Indoor Environmental Quality
KPI	Key Performance Indicator
LED	Lighting Emitting Diode
NCH	Nottingham Council House
OAR	Organismo Autónomo de Recaudación
Rol	Return of Investment
VRF	Variable Refrigerant Flow
WP	Work Packages



1 Introduction

The overall goal of eTEACHER is to empower building energy users to achieve energy savings and to improve comfort and health conditions by **enabling behaviour change** with the tool-box developed in the project. To achieve this goal, the project has been structured in different work-packages (WP): WP1 is focused on the analysis of building energy users, WP2 and WP3 are focused on the development of the tools and WP4 aims at **demonstrating energy behaviour change** through eTEACHER tool-box. Therefore, eTEACHER tool-box will be installed in 12 real buildings located in 3 different climate conditions. Table 1.1 summarises the pilot buildings where eTEACHER will be demonstrated:

Table 1.1 Summary of eTEACHER building pilots

Type	Building name	Location
Office	OAR - Organismo Autónomo de Recaudación	Spain
	NCR - Nottingham Council House	UK
Residential	Apartment Block Badajoz	Spain
	InCity Residence (4 buildings)	Romania
School	IES Torrente Ballester (High School)	Spain
	CEI Arco Iris (Kindergarten)	Spain
	Djanogly City Academy	UK
Health Care Centre	Guareña	Spain
	Villafranca de los Barros	Spain

Specifically, the current document “D4.1 Evaluation Methodology and preliminary pilot description” aims at:

- 1- **Characterizing pilot buildings** and their energy systems
- 2- Defining a **Monitoring and Evaluation Plan** to ensure that the main objectives of the projects will be proved and evaluated appropriately in the pilot buildings.

For those purposes, the characterization of building energy users and the target behaviours identified in WP1 have been used as inputs.

The content of D4.1 are the results of tasks *T4.1 Evaluation Methodology* and *T4.2 Initial monitoring and data collection before eTEACHER. Pilots characterization to date.*

This report is structured in 5 sections. First section is the introduction and explains the objective of the report within eTEACHER context and its content. Second section describes the pilot buildings including general information, envelope, energy related systems (HVAC, lighting, BACS), main



D4.1: Evaluation Methodology and preliminary pilots descriptions

appliances, energy related use and behaviour. Third section is focused on target behaviours. It explains theory of change and summarises energy-related behaviours identify in the pilot buildings as well as engagement behaviours linked to building energy users. Section 4 addresses the evaluation methodology based on monitoring, eTEACHER app and feedback forum & surveys. It defines what, how and when eTEACHER will be demonstrated. It also specifies the monitoring plan in every pilot building. The last section summarises the conclusions of the report.

2 Context: Pilot Buildings Characterization

The aim of building characterization is to know and understand all the aspects regarding the building environment of eTEACHER pilots: building performance, energy systems, existing monitoring and control systems, how it is operated and how the behaviour of building occupants and their profiles are. Building characterization has required the definition of several steps to make the data collection procedure efficient during the project and after the project as input or preliminary steps for the potential eTEACHER solution. These are the steps followed to perform the building characterization:

- Step 0: Definition of a generic template to collect information from the building, energy systems, monitoring and control system and occupants' behaviour. This template is included in Annex A.
- Step 1: Visit the building with the support of some technical manager (manager, owner, facility manager, etc.) to know in detail the different aspects and collect the information requested by the template. Visits should not interrupt the normal operation of the building.
- Step 2: Evaluation of information to describe the energy behaviour of occupants. This entails the description of interactions between energy/control systems with building occupants (see deliverables (Morton A. R., 2018) and (Reeves, 2018))
- Step 3: Evaluation of technical details to integrate eTEACHER BACS add-ons and deploy the engagement solutions to change occupants' behaviour (see deliverable (Peralta, 2018)). In this step is necessary to check the available monitoring data and control systems to plan the necessary developments and actions to deploy the platform solutions.

As general recommendation, building characterization must be performed in an early stage because several visits and iterations may be needed because so often technical managers cannot access all the necessary information, or they have never thought about the reasons behind standard procedures that have been implemented. Given this and to harmonise building description, a specific template to collect building information was designed, which is complemented with pictures and comments from the technical staff.

From the technical point of view, the characterization of building energy depends on describing building envelope (windows, fabric, facades...), energy systems (lighting, devices, appliances, heating, cooling and ventilating), monitoring and control system (measures and algorithms) and the occupants' behaviour, which is the main target of eTEACHER research.

Data collection and visits were performed in January, February and July 2018 in Spain, UK and Romania demo respectively. After visits, it was highlighted that any building has the minimum monitoring level to evaluate the impact of eTEACHER, thus an additional monitoring system was prepared for all the demos with two clear objectives: compare before and after interventions and feed the software and BACS add-ons with the required information to work. Evidently, in a final version (commercial product), less monitoring requirements will be needed.



2.1 Technical Description

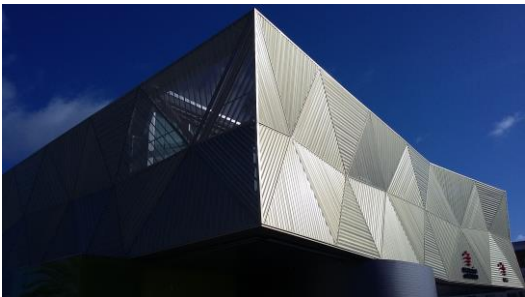
This section provides a summary of the technical description of project building pilots. Although some information has been presented in previous deliverables (see (Morton A. R., 2018) and (Peralta, 2018)), this chapter provides the keys to understand the complexity and challenges of different buildings regarding energy systems, operation and occupants' behaviour. The building type (Delzendeh, 2017) leads the main type of activity that determines the metabolic heat and the clothing and, together with social and personal factors (awareness of energy issues, gender, age, employment, family size and socio-cultural belonging), characterise the occupants' energy behaviour. This main activity will be considered the focus for each building in such a way that although different activities can occur in the same space at the same time, this is considered the main feature to define the building indeed. Thus, when we refer to office buildings, residential academic, etc. we mean a specific activity. Other factors, like climate, socio-cultural, etc. are considered to allow comparing same type of buildings under different situations.

2.2 Office Buildings

Office buildings in Europe account for approximately 6% of the total stock (Building Performance Institute Europe, 2011). There are two office pilot buildings available to deploy the eTEACHER solutions and the methodology for behavioural change in two different countries (Spain and UK), climates and building ages (classical and modern), covering a wide scope of office buildings. Technical details of these buildings are described as follows.

Organismo Autónomo de Recaudación (OAR) – Badajoz (Spain)

The OAR (Organismo Autónomo de Recaudación – Autonomous Collection Agency) is an autonomous non-profit administrative body dependent on the County Council of Badajoz. It is an entity of public law whose function is the executive collection of economic rights of the Autonomous Community of Extremadura and tax management and collection of economic rights delegated through agreements signed with municipalities and other public entities. The building of Badajoz City, with its modern architecture, is the headquarters of the Agency.

OAR Building  (Picture: January 2017)	Location	Badajoz (Spain)
	Year of construction	2011
	Estimated number of users	130
	Description of envelope (fabric and glazing)	Rectangular shape. Glazed building with metallic solar protection (steel panels), 3 floors (ground floor plus 2) and underfloor.
Total surface	3210.97 m ²	

D4.1: Evaluation Methodology and preliminary pilots descriptions

External shadows/barriers	Deciduous trees
Schedule	Monday-Friday 8:00-15:00 (Tuesday and Thursday extra time 16:00-20:00)
Energy sources	Electricity
HVAC System	Heating and cooling based on VRF heat pump and compact AHU with distribution system by ductworks and lines of vents. Individual offices present specific split systems with individual control for set-point.
Lighting system	Fluorescent lamps
Electric devices	Computers, printers, beamers and electric radiators.
BEMS/BACS	<ul style="list-style-type: none">• HVAC controls system (used only for set-up) – Not used• Monitoring system for energy consumption (general and HVAC)
Potential target users	Managers, staff, cleaning crew and security team
Behaviour description	<ul style="list-style-type: none">• Operable windows• Electric radiators working together with heating system on (comfort problems)• HVAC manual controls (thermostats) with tamperproof systems• Security team switch on/off lights• The Corporate Social Responsibility (CSR) system implemented keeps the awareness of staff and people about energy efficiency with specific campaigns
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows• Use of electric/electronic devices• Use of lighting• Use of elevator• Temperature set-points

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the three most prominent behaviours reported by users and observed during the visit are:

- Additional heat sources being used (93% of users)
- Computers being left on when not in use (57% of users)
- Additional cooling sources being used (57% of users)

Additional heat sources are used because heating flow goes through vents located in ceilings, what entails a non-desirable effect for people that work seated. Warm air tends to stay stratified and this effect drives that people's feet remain cold, what produces a discomfort situation. This issue should be addressed carefully when alternatives and suggestions are recommended with engagement



D4.1: Evaluation Methodology and preliminary pilots descriptions

methods because the comfort level has a higher priority than efficiency. Therefore, the monitoring of electric heaters and the appropriate use of them is addressed.

Computers and electronic devices in general are one of the most extended sources related to energy behaviour. Screens, computers, printers and other small office electronic devices are left on or in stand-by mode when they are not used. In order to identify and correct this behaviour, it would be necessary to overcome an intensive monitoring device by device, what is expensive and unfeasible. Therefore, in this case, a number of devices are selected randomly by type to extend the conclusions to the whole building.

Finally, additional cooling sources have been also identified as potential issues. However, given that the building is glazed, and the solar radiation effect is predominant, the use of these additional cooling sources is justified to keep comfort levels in individual offices and meeting rooms. In this case, eTEACHER interventions (advice) are focused on the sensible use of cooling sources like adjusting the temperature set-up above 24° C or switch-off when leaving the room.

Nottingham Council House (NCH) – Nottingham (UK)

This building is the Nottingham City Council. This emblematic building is an important part of the city's heritage, and poses a big challenge regarding energy efficiency improvements, monitoring energy parameters and integrating ICT solutions. The main function of this building is providing administrative services for citizens, weddings and other kind of official events.

NCH Building



(Picture: Provided by NCC)

Location	Nottingham (UK)
Year of construction	1927
Estimated number of users	40 regular users
Description of envelope (fabric and glazing)	Rectangular shape. Classic building construction (stone and single-glazed windows). 7 floors including basement and roof areas.
Total surface	5826 m2
External shadows/barriers	No
Schedule	Cleaning 7 a.m. (first staff), 8:30 (opening), 18:00 (close if there are no events). If there is some events even until 1:00 a.m. approx.
Energy sources	Electricity and District Heating



D4.1: Evaluation Methodology and preliminary pilots descriptions

HVAC System	Heating from the District Heating (hot water) and distributed to radiators, convectors (local control) and some AHUs for meeting rooms. Some electric radiators in offices. No cooling systems. It is only regulated with outdoor air through AHUs in meeting rooms.
Lighting system	The building is gradually undergoing a total LED lighting upgrade; these are replacing a mixture of types of fitting including fluorescent and halogen.
Electric devices	Computers, printers and electric radiators.
BEMS/BACS	<ul style="list-style-type: none">• Central control of hot water distribution by floor for radiators, convectors, AHUs and DHW.• Whole electric consumption monitored by local energy supplier.
Potential target users	Energy managers, staff, cleaning crew and security team
Behaviour description	<ul style="list-style-type: none">• Operable windows• Electric radiators working together with heating system on (comfort problems)• HVAC with central control (facility manager)• Lighting controlled through circuit breakers (manual)
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows• Use of electric/electronic devices• Use of lighting• Use of elevator• Temperature set-points

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the five most prominent behaviours reported by users and observed during the visit are:

- Lights being left on in empty rooms (100% of users)
- Heating being left on when not needed (91% of users)
- Computers being left on stand-by overnight (82% of users)
- Additional heat sources being used (91% of users)
- Computers left on when not in use (82% of users)

Lights have been perceived as one of the main problems about energy behaviour. Some rooms with manual switches are left on when they are empty, provoking useless energy consumption. This is the main issue to fix with the project interventions. However, during the visit it was noted that there is a process to install LED lights, what would reduce the improvement expectations in energy savings since LED lights consumes up to 47% less than fluorescent lamps (Avella Ruiz, 2015).

Regarding heating and electronic devices like computers, the main detected issue is related to leaving them working when not needed. It was noted that the solution can be found arising the



D4.1: Evaluation Methodology and preliminary pilots descriptions


awareness of the implications of such behaviours, thus it is addressed in the strategy definitions for this case.

2.3 Residential Buildings

Residential buildings in Europe account for approximately 75% of the total stock (Building Performance Institute Europe, 2011). There are five apartment blocks pilots available to deploy the eTEACHER solutions and the methodology for behavioural change in two different countries (Spain and Romania), climates and building ages (80's and modern), covering a wide scope of residential building facilities and construction technologies. Indeed, facilities of the four apartment blocks in Bucharest (Romania) has been built according to actual trends in facility management and the heating system of the building block in Spain is managed by an ESCO. Technical details of these buildings are described as follows.

Residential Building Block (Badajoz) – Badajoz (Spain)

The Spanish residential building is located in Av. Godofredo Ortega y Muñoz – Badajoz, built in 1984. The building represents a typical condominium in the City. The average of apartment size is 119m². The heating system has been changed, recently, from oil to natural gas by an ESCO.

Residential building block  (Picture: January 2017)	Location	Badajoz (Spain)
	Year of construction	1984
	Estimated number of users	95
	Description of envelope (fabric and glazing)	Rectangular shape. Standard brick-based facade building with balconies and solar protection, aluminium frames and 5 floors and underfloor for the facility room.
Total surface	4540 m ²	
External shadows/barriers	No	
Schedule	N/A	
Energy sources	Electricity and Natural Gas	
HVAC System	Heating based on natural gas 4 central boilers supplying all the apartments through radiators (controlled and monitored). Individual cooling splits in some apartments.	
Lighting system	Mostly Fluorescent lamps	
Electric devices	Home appliances	



D4.1: Evaluation Methodology and preliminary pilots descriptions

BEMS/BACS	<ul style="list-style-type: none">• Heating system centralised, controlled and monitored (accounting system)• Electric consumption by smart-meters (energy provider company)
Potential target users	Manager and householders
Behaviour description	<ul style="list-style-type: none">• Operable windows and blinds• Heating working on empty rooms• Cooling: splits with manual controls (thermostats)• Home appliances (computers, TV, washing machines...)• Lighting in empty rooms
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows/blinds• Use of home appliances• Use of lighting• Temperature set-points (cooling)• Avoid heating in empty rooms (heating)

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the three most prominent behaviours reported by users and observed during the visit are:

- Lights being left on in empty rooms (100% of users)
- Chargers left plugged in but not being used (100% of users)
- Heating on in areas not being used (100% of users)


The results of this analysis show that all the behaviours observed are key targets of the project. Average energy consumption of lights in residential buildings in Spain accounts for 4.1% (IDAE & Eurostat (European Commission), 2011) whilst standby (chargers left) and heating accounts for 2.3% and 47% of total energy consumption respectively, hence the project demonstration addresses 53.4% of total energy consumption. However, the combination of lighting/heating and occupancy at room level cannot be addressed without high investments of monitoring systems (room by room), thus this issue is addressed with energy literacy and through the control of energy demand with windows, blinds and thermostats.

InCity Residence (InCity) – Bucharest (Romania)

InCity Residence is a residential complex of new apartments located in the Vitan area on Dudești Street, in Bucharest, Romania. The residential complex InCity Residences, was opened in 2009 and is currently home to more than 360 families. The residential complex has 4 new and modern apartment blocks, each with 13 types of apartments distributed on 17 floors. The apartments in the residential complex InCity Residences combine generous spaces and decoration features with a complete finishing solution, all in a modern and minimalist decor. Within the residential complex InCity Residences, the residents have more than 5,000 square meters of green spaces, 24 hour security 24 hours, 530 underground parking spaces, a fitness center, a playground for the children and a beauty salon.



D4.1: Evaluation Methodology and preliminary pilots descriptions

Residential building blocks 	Location	Bucharest (Romania)
	Year of construction	2009
	Estimated number of users	1500
	Description of envelope (fabric and glazing)	4 Building blocks with different configuration of apartments (up to three floor levels) and double layer aluminium frame.
Total surface	67900 m2	
External shadows/barriers	No	
Schedule	N/A	
Energy sources	Electricity and District Heating (Natural Gas as backup)	
HVAC System	Heating and DHW provided by the central district heating system through radiators (all rooms). Apartments present split systems for cooling.	
Lighting system	LED	
Electric devices	Systems and equipment's at building level Home appliances at apartment level	
BEMS/BACS	<ul style="list-style-type: none"> • Heating: thermostats controlled manually by householders and production controlled by a BEMS system for the four buildings (supply/return temperatures). • Ventilation: controlled and monitored by the central system. 	
Potential target users	Energy/Facility managers and householders	
Behaviour description	<ul style="list-style-type: none"> • Operable windows and blinds • Heating working on empty rooms • Cooling: splits with manual controls (thermostats) • Home appliances (computers, TV, washing machines...) • Lighting in empty rooms 	



D4.1: Evaluation Methodology and preliminary pilots descriptions

Potential energy saving targets	<ul style="list-style-type: none">• Use of windows/blinds• Use of home appliances• Use of lighting• Temperature set-points (cooling)• Avoid heating in empty rooms (heating)
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The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the five most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (100% of users)
- Heating being left on when not needed (85% of users)
- Computers being left on stand-by overnight (69% of users)
- TVs being left on (74% of users)
- Air-conditioning on when not needed (72% of users)

Results in this case show a very similar behaviour regarding the Spanish building: lighting, heating and home appliances being left on when not needed. Therefore, the aim for these buildings is focused on raise the awareness about not useful energy (energy literacy), monitoring home appliances and recommending a rationale use of the heating energy. On the other hand, as apartments have multiple rooms; appliances must be selected according the most frequent use like computers and TVs.

2.4 Academic Buildings

Academic buildings in Europe account for approximately 4% of the total stock (Building Performance Institute Europe, 2011). There are three pilot buildings available to deploy the eTEACHER solutions and the methodology for behavioural change in two different countries (Spain and UK), climates and building ages (from 60's to 21st Century), covering a wide scope of academic buildings, facilities and construction technologies. Technical details of these buildings are described as follows.

Torrente Ballester High School (Torrente) – Miajadas (Spain)

The State Secondary School “Torrente Ballester” in Miajadas, Spain, shelters students in the 2nd phase of National Obligatory Education from the town and surroundings. The building was built in 1965 and it is symmetric with rectangular shape that guarantees natural lightning in all classrooms. The big challenge of this building is that it presents a low level of monitoring and old facilities, which requires more effort for integrating eTEACHER solutions.

Torrente Ballester	Location	Miajadas (Spain)
	Year of construction	1965
	Estimated number of users	120



D4.1: Evaluation Methodology and preliminary pilots descriptions



(Picture: January 2017)

Description of envelope (fabric and glazing)

Rectangular shape. Standard brick-based facade building, aluminium frames with blinds, 3 floors and additional building for the sport hall.

Total surface	5307 m2
External shadows/barriers	No
Schedule	Sep-June: 8:00-14:00 & 15:00-19:00 (cleaning staff) July: 9:00 – 15:00 (teachers) August: closed.
Energy sources	Electricity & fuel-oil
HVAC System	Heating based on fuel-oil boiler that distributes how water to classrooms through radiators. Cooling based on splits in administrative area and teachers' offices.
Lighting system	Fluorescent lamps
Electric devices	Computers, printers and beamers
BEMS/BACS	No any existing BEMS/BACS.
Potential target users	Managers, staff, teachers & students
Behaviour description	<ul style="list-style-type: none"> • Operable windows/blinds • Switch on/off computers, beamers and smartboards. • Switch on/off lighting • HVAC manual controls with valves in radiators. • Switch on/off splits



D4.1: Evaluation Methodology and preliminary pilots descriptions

Potential energy saving targets	<ul style="list-style-type: none">• Use of windows/blinds• Use of electric/electronic devices• Use of lighting• Temperature set-points
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The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the four most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (100% of users)
- Computers being left on stand-by overnight (75% of users)
- Additional heat sources being used (75% of users)
- Computers left on when not in use (75% of users)

In this case, again the lighting is the main issue identify by users, who confirm that lights are being left on in empty rooms, for example, when students change the classroom or during breaks. This effect can be monitored and the behavioural change motivated in specific classrooms through monitoring devices like lighting consumption and presence detectors. On the other hand, devices like computers could be corrected through energy literacy and monitoring the energy consumption of classrooms too.

The heating system have not got any kind of central control and accounting system for energy. Energy is consumed through all the radiators in classrooms and corridors and the control is manual using the output valve. In this case, the access and manipulation of this valve is the responsibility of managers, who will decide the input heating level in each classroom. Recommendations in this regard will be generated by the eTEACHER app.

Arco Iris Kindergarten (ArcoIris) – Miajadas (Spain)

The Nursery School “Arco Iris” in Miajadas, Spain, was built in 1976 and is surrounded by an extensive garden. The nursery is for children from 0 to 3 years old. The kindergarten is a small school without existing BEMS or monitoring systems. Thanks to the building size, most of school rooms can be monitored to evaluate project interventions.

Kindergarten (SP)



(Picture: January 2017)

Location	Miajadas (Spain)
Year of construction	1976
Estimated number of users	120
Description of envelope (fabric and glazing)	Octagonal shape of 1 floor. Standard brick-based facade building, aluminium frames with double glass windows.



D4.1: Evaluation Methodology and preliminary pilots descriptions

Total surface	905 m2
External shadows/barriers	Deciduous trees
Schedule	Sep-June: 8:00-15:00 July: 9:00 – 15:00 (teachers) August: closed
Energy sources	Electricity & fuel-oil
HVAC System	Heating based on fuel-oil boiler that distributes hot water to classrooms and corridors through radiators. Cooling based on individual splits.
Lighting system	Fluorescent lamps
Electric devices	Computers, printers and beamers. Additional home appliances (washing machine) and kitchen equipment.
BEMS/BACS	No any existing BEMS/BACS.
Potential target users	Staff (managers and teachers)
Behaviour description	<ul style="list-style-type: none">• Operable windows/blinds• Switch on/off computers and beamers.• Switch on/off lighting• HVAC manual controls with valves in radiators.• Switch on/off splits
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows/blinds• Use of electric/electronic devices• Use of lighting• Temperature set-points for cooling• Valve control for heating.

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the four most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (100% of users)
- Heating being left on when not needed (75% of users)
- Computers left on when not in use (100% of users)
- Air-conditioning on when not needed (75% of users)

In this case, again the lighting is the main issue identify by users, who confirm that lights are being left on in empty rooms, for example, when children leave the classroom or during breaks. This effect can be monitored and the behavioural change motivated in specific classrooms through monitoring devices like lighting consumption and presence detectors. On the other hand, devices like computers



D4.1: Evaluation Methodology and preliminary pilots descriptions

could be corrected through energy literacy and monitoring the energy consumption of classrooms too.

The heating system have not got any kind of central control and accounting system for energy. Energy is consumed through all the radiators in classrooms and corridors and the control is manual using the output valve. In this case, the access and manipulation of this valve is the responsibility of managers, who will decide the input heating level in each classroom. Recommendations in this regard will be generated by the eTEACHER app.

Finally, there is also a potential energy saving in air-conditioning through splits in classrooms. In this case, the energy literacy and a convenient set-point of splits are incorporated as recommendations in the eTEACHER app.

Djanogly City Academy (Djanogly) – UK

The “Djanogly City Academy” is a school with space for over 800 students. Despite the Academy’s inner-city location and close proximity to a major road, the site is dominated by green space. The building is on the edge of Forest Recreation Ground, which once formed part of the ancient Sherwood Forest, and to the rear of the Academy, the former school was demolished to create playing fields. The Academy’s design exploits this natural setting, with full height glazing to draw the landscape into the building and wide terraces, sheltered by a canopy of brisesoleil. A simple rectangle on plan, the teaching spaces extend from a long central atrium, bounded at each end by double-height spaces, containing a restaurant, entrance hall, library and internet café. Breaking down the scale of the Academy into three ‘houses’, the elevated balconies define self-contained units, each with its own resource area and staff room. The theatre and sports facilities are grouped together in the east of the building, away from the teaching areas, to allow easy out-of-hours use by the local community. Classroom doors are glazed and an installation of coloured panels by artist, Sophie Smallhorn runs through the main circulation route, between each structural bay. The steel frame encloses a glass facade and internal walls are non load-bearing, so can be moved in future to suit changing requirements.

This academy is a modern building with monitoring and control technologies. Some underfloor heating, radiators, cool ceiling, automatic windows for ventilation (and which act as smoke vents in an emergency evacuation), etc. are examples of modern HVAC technologies that makes this building very interesting to test energy efficiency interventions.

Djanogly City Academy



(Picture: February 2017)

Location	Nottingham (UK)
Year of construction	2005
Estimated number of users	800
Description of envelope (fabric and glazing)	Rectangular shape of 2 floor. Glazed and steel-based building, with double glass windows and blinds.



D4.1: Evaluation Methodology and preliminary pilots descriptions

Total surface	9163 m2
External shadows/barriers	No
Schedule	Sep-June: 8:30-16:30 (Monday-Thursday) and Fridays until 12:00 (Academy teaching day – building open 06:00-19:00 each week day) January-March (Saturdays): 9:00-12:00 Sundays: 10:00 – 13:00 (Local Church) July: 9:00 – 15:00 (teachers) Summer break: some activity.
Energy sources	Electricity & Natural Gas
HVAC System	Heating systems: gas boilers supplying hot water through underfloor heating in corridors of one zone, radiators in classrooms and common spaces and AHU. Cooling system: electric chillers supplying cold ceilings and AHUs.
Lighting system	Fluorescent lamps
Electric devices	Computers, printers and projectors. Additional equipment in laboratories.
BEMS/BACS	The existing BEMS monitors and control the HVAC production system (set-points) and functioning, although a separate air con system operates in the computer science classrooms
Potential target users	Staff (managers and teachers) and students
Behaviour description	<ul style="list-style-type: none">• Operable windows on North face• Operable blinds on South face• Switch on/off computers and beamers• Switch on/off lighting• Energy manager controls valve opening in radiators.• Energy manager controls set-points for heating and cooling
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows/blinds• Use of electric/electronic devices• Use of lighting• Temperature set-points for cooling• Valve control for heating.



D4.1: Evaluation Methodology and preliminary pilots descriptions

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the four most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (77% of users)
- Chargers being left plugged in but not being used (64% of users)
- Computers left on when not in use (86% of users)
- TVs being left on (64% of users)

The main issue detected is computers and electronic devices that are being left when not used. This behaviour can be corrected with energy literacy and recommendations but requires a low level monitoring to measure the difference. This can be monitored at classroom level, selecting those that present more devices. Regarding lighting, the same strategy can be applied to avoid lights being left on in empty rooms. Finally, although heating and cooling have not been identified as one of the main issues, a better operation of the HVAC system is possible thanks to the eTEACHER BACS add-ons services, able to provide better recommendations for energy managers, for example adjusting set-points according to outdoor and indoor conditions.

2.5 Health Care Centres

Office buildings in Europe account for approximately 2% of the total stock (Building Performance Institute Europe, 2011). There are two health centres pilot buildings available to deploy the eTEACHER solutions and the methodology for behavioural change (both in Spain) with cold winters and hot summers, being an additional challenge to improve energy efficiency and keep comfort conditions. Technical details of these buildings are described as follows.

Villafranca de los Barros Health Care Centre (Villafranca) – Badajoz (Spain)

This health care centre offers a wide list of health services like medical consultation, tests and emergency. The entire building works with electricity, including HVAC facilities based on heat pumps, AHU and fan-coils. A previous monitoring project to measure general consumption, HVAC consumption and indoor conditions was performed, what allows taking advantage of monitoring devices to perform energy efficiency analysis at building level.

Health Care Centre of Villafranca de los Barros



(Picture: January 2017)

Location	Villafranca de los Barros (Spain)
Year of construction	2002
Estimated number of users	915
Description of envelope (fabric and glazing)	2-floor building with H shape. Brick-based facade with double-glazed windows with blinds and aluminium frame.



D4.1: Evaluation Methodology and preliminary pilots descriptions

Total surface	2180 m2
External shadows/barriers	No
Schedule	Monday-Friday: 8:00-15:00 (all services), 15:00-8:00 (emergency services), cleaning staff (until 19:00). Weekends: emergency service (24 h)
Energy sources	Electricity
HVAC System	HVAC system for heating and cooling composed of heat pumps, fan-coils and AHU that supply the entire building.
Lighting system	Fluorescent lamps (80%)
Electric devices	Computers, printers, beamers and electric radiators.
BEMS/BACS	<ul style="list-style-type: none">• Basic temperature control set-point for heating and cooling in production units.• Monitoring system for energy consumption (general and HVAC)
Potential target users	Managers and medical staff
Behaviour description	<ul style="list-style-type: none">• Operable windows• Electric radiators working together with heating system on (comfort problems)• HVAC manual controls (thermostats)• Doors open due to people get in and out during opening hours• Office and medical electronic devices
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows• Use of individual electric heaters• Use of electric/electronic devices• Use of lighting• Use of elevator• Temperature set-points and use of fan-coils

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the six most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (100% of users)
- Heating being left on when not needed (100% of users)
- Computers being left on stand-by overnight (78% of users)
- Additional heat sources being used (78% of users)
- Computers left on when not in use (78% of users)
- Air-conditioning on when not needed (78% of users)




D4.1: Evaluation Methodology and preliminary pilots descriptions

In general, the sources of unnecessary energy consumption are related to carelessness of people that use the facilities, who usually leave on lighting, devices and HVAC. However, the building presents some issues regarding discomfort due to the continuous get in and out of people in the centre, what produces discomfort situations that can be only balanced with additional heat sources like electric radiators.

Guareña Health Care Centre (Guareña) – Guareña (Spain)

The second health care centre also offers a wide list of health services like medical consultation, tests, physiotherapy and emergency. The entire building works with electricity, including HVAC facilities based on heat pumps (roof-tops). A previous monitoring project to measure general consumption, HVAC consumption and indoor conditions was performed, what allows taking advantage of monitoring devices to perform energy efficiency analysis at building level.

Health Care Centre of Guareña  (Picture: January 2017)	Location	Guareña (Spain)
	Year of construction	2000
	Estimated number of users	577
	Description of envelope (fabric and glazing)	2-floor building with rectangular shape. Brick-based facade with double-glazed windows with blinds and aluminium frame.
Total surface	1270 m2	
External shadows/barriers	No	
Schedule	Monday-Friday: 8:00-15:00 (all services) Emergency services: 24h	
Energy sources	Electricity	
HVAC System	HVAC system for heating and cooling composed of heat pumps (roof-tops) and splits	
Lighting system	Fluorescent lamps (85%)	
Electric devices	Computers, printers and medical equipment	
BEMS/BACS	<ul style="list-style-type: none">• HVAC thermostats located in administrative area.• Monitoring system for energy consumption (general and HVAC) and indoor conditions	
Potential target users	Managers and medical staff	



D4.1: Evaluation Methodology and preliminary pilots descriptions

Behaviour description	<ul style="list-style-type: none">• Operable windows and shadings• HVAC manual controls (thermostats) and electric radiators• Doors open due to people get in and out during opening hours• Office and medical electronic devices
Potential energy saving targets	<ul style="list-style-type: none">• Use of windows and shadings• Use of individual electric heaters• Use of electric/electronic devices• Use of lighting• Temperature set-points

The energy behaviour analysis of this building is described in (Morton A. R., 2018) that shows that the three most prominent behaviours reported by users and observed during the visit and survey are:

- Lights being left on in empty rooms (67% of users)
- Computers being left on stand-by overnight (67% of users)
- Additional heat sources being used (78% of users)

Apart from controlling lights, stand-by modes and additional heat sources, at building level temperature set-points can be also recommended to reduce energy consumption.

3 Target Behaviours

Changing energy related behaviours, whether through; conservation, lifestyle changes, increased awareness, energy investment or low-cost actions, has been shown to have the potential to generate significant savings in energy consumption. However, a one-size-fits-all approach is not advised as it is important to carefully select not only the target groups but also the target behaviours in order to make sustainable change. It is also important to fully understand the influential factors involved with these target groups and behaviours as these can have significant impact on the outcome of any intervention.

3.1 Theory of Change

A theory of change is seen as a project roadmap which defines the end goal of the project and what is being worked towards and then uses backwards mapping to illustrate how the project's work and tasks carried out shape the conditions for the possibility of achieving the desired end goal. For eTEACHER a theory of change was presented (Morton A. R., 2018) which utilised the Enabling Change framework to plan work around creating recommendations for the design of the eTEACHER tool following social studies into each pilot building but also how to plan for sustained engagement with the tool after implementation. Underpinning this is the COM-B behavioural framework (Michie, 2011), shown in Figure 3.1, which is a useful heuristic to understand three key influences on human behaviour. Core to the framework is the assumption that users' capability (physical or mental) and



D4.1: Evaluation Methodology and preliminary pilots descriptions

their opportunity (social or physical) relates to their motivation to carry out a specific behaviour and that each of these constructs influences and is influenced by the behaviour itself.

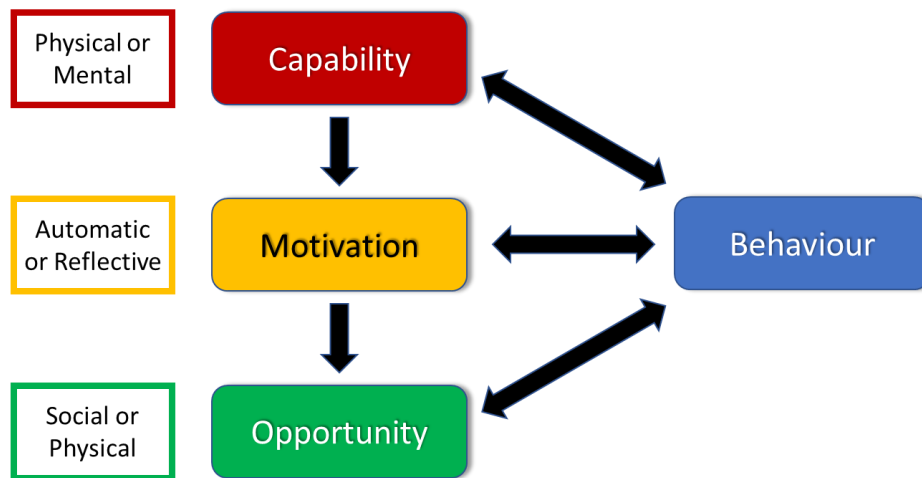


Figure 3.1 COM-B Model (Michie, 2011)

The model firstly shows that for behaviour change, it is important to uncover users' motivations towards energy efficiency and their attitudes towards energy conservation schemes and the importance of improving energy use within each building. However, users' motivations are influenced by their capability and opportunity and therefore this means it is important to understand the capability of users regarding their agency towards specific behaviour changes and interventions. The opportunities for change within each pilot building relate to the wider context for specific behaviour change, taking both the building context into consideration as well as the technical feasibility within the project (technical capabilities, monitoring requirements, budget constraints etc.) Within eTEACHER the social opportunity could play a key part in the success/uptake of the ICT tool as it includes whether social norms and expectations support or hinder the performance of behaviour, so engagement with users is key to ensure that social norms are formed integrating the use of the eTEACHER tool with each building and the users.

The COM-B framework underpins the over-arching Theory of Change for eTEACHER, which is that:

- the design of the tool will motivate sustained use of the eTEACHER app
- use of the tool will trigger and sustain action on a range of energy-related issues such as lighting and appliance use

The design of the tool is shaped significantly by the energy-related behaviours which are to be targeted by eTEACHER and the use of the resulting tool will be influenced by engagement behaviours of users.

3.2 Energy-related behaviours

The current energy behaviours being carried out in all the pilot buildings has previously been presented in (Morton A. R., 2018) and Table 3.1 summarises the key behaviours believed to be the most prominent ones for each of the pilot buildings.

D4.1: Evaluation Methodology and preliminary pilots descriptions

Table 3.1 Energy related behaviours currently exhibited in eTEACHER pilot buildings

eTEACHER building	Current most prominent user behaviours
OAR County Council, Spain	<ul style="list-style-type: none">–Additional heat sources being used (93% of users)–Computers being left on when not in use (57% of users)–Additional cooling sources being used (57% of users)
Council House, UK	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Heating being left on when not needed (91% of users)–Computers being left on stand-by overnight (82% of users)–Additional heat sources being used (91% of users)–Computers left on when not in use (82% of users)
Badajoz apartments, Spain	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Chargers left plugged in but not being used (100% of users)–Heating on in areas not being used (100% of users)
InCity apartments, Romania	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Heating being left on when not needed (85% of users)–Computers being left on stand-by overnight (69% of users)–TVs being left on (74% of users)–Air-conditioning on when not needed (72% of users)
Torrente Ballester, Spain	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Computers being left on stand-by overnight (75% of users)–Additional heat sources being used (75% of users)–Computers left on when not in use (75% of users)
Arco Iris, Spain	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Heating being left on when not needed (75% of users)–Computers left on when not in use (100% of users)–Air-conditioning on when not needed (75% of users)
Djanogly City Academy, UK	<ul style="list-style-type: none">–Lights being left on in empty rooms (77% of users)–Chargers being left plugged in but not being used (64% of users)–Computers left on when not in use (86% of users)–TVs being left on (64% of users)
Villafranca HCC, Spain	<ul style="list-style-type: none">–Lights being left on in empty rooms (100% of users)–Heating being left on when not needed (100% of users)–Computers being left on stand-by overnight (78% of users)–Additional heat sources being used (78% of users)



D4.1: Evaluation Methodology and preliminary pilots descriptions

	<ul style="list-style-type: none"> –Heating on in areas not being used (78% of users) –Computers left on when not in use (78% of users) –Air-conditioning on when not needed (78% of users)
Guareña HCC, Spain	<ul style="list-style-type: none"> –Lights being left on in empty rooms (67% of users) –Computers being left on stand-by overnight (67% of users) –Additional heat sources being used (78% of users)

From the analysis of reported behaviours and those reported and observed during site visits the resulting recommendation (Morton A. R., 2018) was for the eTEACHER tool to focus on lighting behaviours, appliance use behaviours and comfort related behaviours across all buildings. However due to the range of building types and therefore variety of user types consideration needs to be taken into which behavioural interventions and advice are targeted to which users and the capability and opportunity available to all users within each of the pilot buildings. Table 3.2 presents the recommended behaviours that eTEACHER should include within the tool design and the relevant users which can influence these behaviours.

Table 3.2 Target behaviours and relevant users eTEACHER should focus on

Target behaviours		User types to be targeted
Lighting Behaviours	Turning off lights when leaving a room or at end of day	All users
	Checking lighting levels and needs during day – reducing use of unneeded lights	Energy/facility managers/staff, building staff, residents
	Replacing bulbs with more energy-efficient ones	Energy/facility managers, residents
	Installing improved lighting and controls	Building managers
	Making use of natural light more	All users
Appliance use Behaviours	Ensuring appliances are not left on standby overnight	All users
	Changing default settings or manually using sleep/hibernate modes and ‘screen off’ when computer is not in use	Energy/facility managers/staff, residents, building staff
	Turning off computer if away from desk for any length of time	Building staff
	Turning off own computer at end of the day	All users (with access to computer)
	Changing power mode to be more efficient	Energy/facility managers/staff, residents, building staff
	Choosing more efficient hardware and default settings	Building managers



D4.1: Evaluation Methodology and preliminary pilots descriptions

Target behaviours		User types to be targeted
	Turning off chargers once fully charged	All users (with access to chargers)
	Turning off TVs/screens at end of the day	All users (with access to TV/screens)
	Turning off projectors when not in use	Energy/facility managers/staff, building staff
	Turning off medical equipment if possible	Building staff (in HCCs)
Comfort related Behaviours	Reducing thermostat temperature for heating	All users (with access to thermostat)
	Managing temperature via clothing or activity rather than heating/cooling whole space	All users
	Increasing air-conditioning temperature set for cooling	Energy/facility managers/staff
	Ensuring that air-conditioning and heating not on at the same time	Energy/facility managers/staff, building staff, residents
	Ensuring that if heating is on, windows and doors are kept closed (if possible) to keep the heat from escaping	All users
	Choosing more efficient systems or better use of system settings	Energy/facility managers/staff
	Reducing use of personal fans/heaters within the building	Energy/facility managers/staff, building staff, residents

3.3 Engagement behaviours

It has been well established that occupant behaviour has a significant impact on energy consumption in buildings. Often differences between the expected energy consumption from design and the real energy consumption of the building are put down to occupant behaviour (Paone, 2018). Research has focused on interventions combining visualisation and quantification of energy, such as feedback, social interaction and gamification, as a means of changing occupant behaviours in order to foster energy efficiency. However, with many of these types of studies the engagement of users may have a steep drop off following the initial implementation, particularly if the intervention includes a “new toy” or novel piece of equipment. Similarly, engagement behaviours may be found to peak around any subsequent interventions or advice roll outs. Therefore, engagement behaviours are increasingly becoming main focal points within energy intervention projects. Understanding engagement behaviours within projects can aid the understanding of energy saving results following interventions. (O'Brien, 2008) identified various attributes in their work which can have an influence on user engagement. Influential attributes could include aesthetics, novelty, motivation, control, feedback and interaction components of the user experience (emotional, sensual and spatiotemporal



D4.1: Evaluation Methodology and preliminary pilots descriptions

aspects). Understanding the different attributes influencing building user engagement is an important part of the monitoring and evaluation plan as various different attributes will influence user engagement with the tool. For eTEACHER understanding as many attributes as possible, given the range of building types and users being targeted with the tool, will allow for a better evaluation of engagement behaviours.

Engagement with the eTEACHER interventions is a vital part of the design of the ICT tool, especially as the quantification of engagement and behaviour change of energy end-users is listed as one of the specific objectives and measurable results for eTEACHER. Engagement refers to the building users' response to the eTEACHER tool, and project overall, and refers to the acceptance and user impressions towards the interventions. Without widespread user engagement with the tool, eTEACHER's success will be limited. Various engagement behaviours were identified in (Morton A. R., 2018) which are relevant to monitor levels of engagement throughout the eTEACHER study, Table 3.3 recaps these engagement behaviours and the relevant building users.

Table 3.3 Engagement behaviours and related building users

Engagement behaviours	Relevant users
Self-reporting energy-related behaviours in response to in-app activities and challenges	All users (with access to app – students may be unable to report their own behaviours due to limited access to smartphones to use eTEACHER app)
Reporting comfort levels to app in response to prompts	All users
Viewing energy consumption of whole building	All users
Viewing energy consumption of own room/apartment	Residents
Using eTEACHER tool to report any building issues (e.g. overheating, too cold, equipment failures etc.) with Facility Management	All users
Using eTEACHER tool for Facility Management to report back to users the status of any issues in building	All users
Viewing energy data for specific appliance use	All users (with access to the specific appliance)
Discussing energy-related issues, such as sharing tips and suggestions with other building users	All users

Engagement can be influenced significantly by the design of the tool and therefore it is important to understand how user's engagement may be influenced by factors such as; the appeal of the eTEACHER tool, ease of understanding, how it complements day to day life, and the relevance of the tool to users. These factors have been discussed in (Preston, 2018) following workshops with building users to aid the design recommendations. However, it must also be noted that there can be multiple influential factors on user engagement out with the control of the project such as; new policies within organisations, staff turnover, parallel campaigns which may impact energy use.



D4.1: Evaluation Methodology and preliminary pilots descriptions

Therefore, it is important to capture as much detail as possible from building users regarding engagement throughout the project, this can be monitored through the use of the app once implemented but also during the app development from use of feedback forums, introduced in (Reeves, 2018).

4 Evaluation Methodology

The aim of eTEACHER is to evaluate the impact and effects of energy-use behaviour change regarding energy savings and improvement of indoor conditions. Effective evaluation of a behaviour change intervention requires input from stakeholders before, during and afterwards, and data to be collected both on what happens (e.g. measured and self-reported behavioural changes) and why (e.g. user's accounts of their experience of eTEACHER). A strong evaluation strategy should explicitly address each aspect of the proposed links articulated through a project's theory of change, which links the interventions to the actions that may result (Robinson, 2018). The over-arching Theory of Change for eTEACHER is that:

- the design of the tool will motivate sustained use of the eTEACHER app
- use of the tool will trigger and sustain action on a range of energy-related issues such as lighting and appliance use

Thus, evaluation plans need to focus on two types of behaviour: *engagement* with eTEACHER and *energy-related* actions.

- **Energy related actions** (section 3.2) are behaviours that may use more energy than needed for the normal operation and occupancy of the building, resulting in wasteful use of energy and often reducing the expected energy efficiency according to theoretical models and designs. Examples of such energy related actions include; appliances being left on, temperatures out with recommended ranges, opening windows (particularly when heating is on) or non-essential devices being left connected or in stand-by modes.
- **Engagement with eTEACHER** (section 3.3) refers to actions carried out by users due to eTEACHER. Examples include; empowering users to report discomfort situations, increase users' knowledge about how to save energy or increase the energy efficiency, increase users' awareness of energy consumption and energy use through focusing on the economic, environmental or social motivation of users. User engagement with eTEACHER also refers to the accessibility, usability and functionality of the final tool meeting users' needs, which will form part of the overall evaluation for the eTEACHER tool.

Two types of evidence can support this evaluation – measured evidence (e.g. before and after electric energy meter readings or data on lighting use from loggers) and self-reported evidence and **three main methods** are used to capture these evidences (see Figure 4.1):

1. Monitoring:
 - a. Building-level data (e.g. total gas/electricity use).
 - b. Behaviour-level (e.g. lighting use in a specific room). This level is classified by three types of demand units or experimental zones that have been defined for technical reasons: control or reference zones (monitored but without eTEACHER interventions), non-monitored study zones (with eTEACHER interventions but without



D4.1: Evaluation Methodology and preliminary pilots descriptions

monitoring system) and monitored study zones (with monitoring system and eTEACHER interventions). Further details about this classification and its rationale are detailed in section 4.1.

2. eTEACHER app
 - a. Via self-reports of behaviour (e.g. days when PC fully shut down at end of work) and measure of engagement (e.g. how often used; which functions used; etc.)
3. Feedback Forum and Surveys
 - a. Data from users on their energy-related behaviours, engagement with eTEACHER and views on influences on these two behaviours

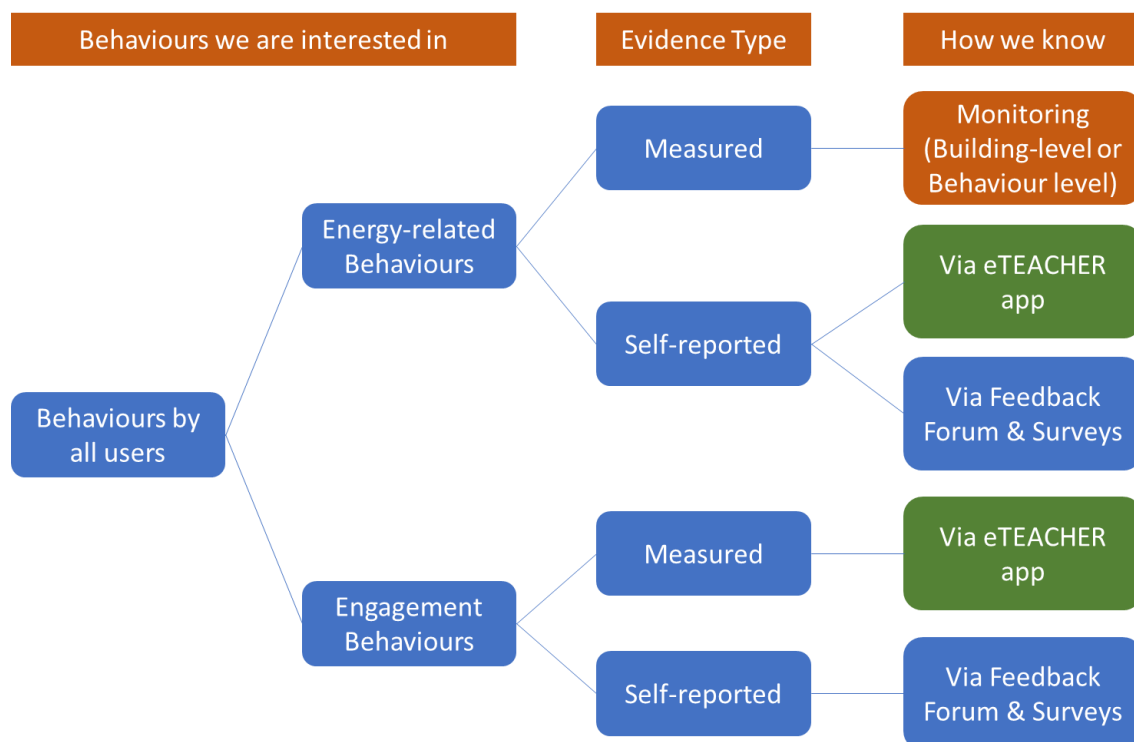


Figure 4.1 Evaluation Methodology

A detailed table can be found in Annex B which outlines the specific data being used to evaluate behaviour change within eTEACHER, separated by the behaviour categories being targeted by the eTEACHER tool.

As stressed earlier on in this report, the engagement of building users within eTEACHER is vital and therefore their input in the evaluation process has already been factored in, through the use of the Enabling Change process and utilization of Feedback Forums. This inclusion of user input throughout not only after the implementation of eTEACHER but also during the development stage allows for a “reality-check” to be carried out on the project progress and plans for the tool. This inclusion was presented in (Reeves, 2018) and the monitoring of behaviours via feedback forums is discussed in further detail in Section 4.4. Given the design for monitoring and evaluating the impact of eTEACHER presented previously, not all users will be influenced by the information, advice and challenges provided through the eTEACHER tool, as the control groups will not have access to the eTEACHER tool itself. However, it must be taken into consideration that users of the building, particularly those in the more detailed monitoring group, are likely to talk about the new “toy” in the workplace for instance. Therefore, some of the behaviour change interventions may still filter through

D4.1: Evaluation Methodology and preliminary pilots descriptions

at a social level to those users within the control groups. Hence why it is important to include user input into the evaluation strategy for eTEACHER through the likes of the feedback forums and the surveys distributed.

On the other hand, to apply the three main methods (monitoring, eTEACHER app and Feedback Forums and Surveys) and assess the project impact, we have defined the **what, how and when** with a list of key performance indicators (KPI), the experimental design and the evaluation plan respectively.

What: Key Performance Indicators (KPI)

Several impact indicators and targets, which are detailed in Table 4.1, have been defined in order to measure the effectiveness of the project interventions and strategies to increase the energy efficiency and environmental indoor quality (IEQ). The indicators have been classified in two groups: **impact indicators** (IM) regarding user experience and energy efficiency and **other impact indicators** (OIM) relating to the potential indirect impact in the economy and SME growth. Whilst key performance indicators (KPI) for project impacts have been defined, other impact indicators must be defined before the final assessment of the project according to market analysis and the exploitation strategies for eTEACHER outcomes (other activity performed in eTEACHER). Besides, these KPIs will be assessed at pilot and project level.

Table 4.1 Key Performance Indicators for Impact Assessment

Code	Description	KPI	Target(s)
IM1	Energy Savings and reduction of CO2 emissions	Energy savings vs. number of interactions with eTEACHER's app	6-10%
IM2	Fast deployment	Monitoring deploying time during the project Development of deploying plan and installation procedures	<1 month during the project <1 week after the project
IM3	Fast adoption	eTEACHER acceptance surveys	15-30% users' satisfaction
IM4	Number of users changing behaviour	App feedback	30% (952 users)
OIM1	RoI based on energy savings and investments	Cost savings vs. Monitoring investments (tenders)	< 3 years
OIM2	Economic growth	To be defined	Qualitative
OIM3	Indirect economic growth	To be defined	Qualitative
OIM4	Growth of innovative SME	To be defined	Qualitative
OIM5	European leadership on ICT solutions for Energy Efficiency	To be defined	Qualitative
OIM6	Improve occupants' wellbeing	CO ₂ levels and indoor conditions (temperature and humidity ratio)	Better IEQ values from baseline



How: Experimental Design

The experimental design is a key issue in the evaluation methodology. It strongly influences the reliability of the evaluation results carried out after the data collection process. It also allows guaranteeing the statistical significance of results and defining the procedure to calculate KPI and impact indicators related to the effect of implementing eTEACHER toolbox in buildings.

The experimental design of eTEACHER is based on eeMeasure Methodology (Woodall, 2011) and consists of comparing control/reference environments with study environments before and after the installation of eTEACHER to draw conclusions regarding behaviour change caused by eTEACHER interventions. This comparison is done using data collected by means of the three methods (monitoring, eTEACHER app and feedback forum & surveys) in both kind of environments/zones as well as calculating corresponding KPIs and impact factors.

A control zone is a room or group of rooms in the pilot buildings where eTEACHER are not installed and are used as reference during the experimental period. A study zone is a room or group of rooms in the pilot buildings where eTEACHER will be deployed. It should be noted that the control zones must have similar conditions as the study zones (orientation, use, schedule, number of people, energy systems, energy appliances...) to allow comparing the evolution of both zones before and after the deployment of eTEACHER toolbox. The control and study zones/environments are defined according to the existing facilities configuration and design. For example, one zone is a group of rooms that are conditioned by the same boiler or a group of rooms whose lighting system is controlled as one zone

The experimental period of eTEACHER has two phases. The first phase is called *baseline period* and has no interventions and no eTEACHER toolbox. The second phase is called *demonstration period* and it is the period where eTEACHER toolbox will be installed and interventions will be carried out in study zones.

The first step to estimate behaviour changes is to calculate the deviation in between control and study zones behaviours with data collected during the baseline period where both behaviours must be similar, comparing the results with external factors like weather conditions in turn. The second step is to compare differences of energy behaviour in control zones and study zones during the demonstration period with the behaviour deviation estimated during baseline period to draw conclusions regarding behaviour change.

Extrapolations of zone levels results will be done to draw conclusions at building level. These extrapolations will use energy use monitored and collected at building level and external weather conditions.

Further explanations and discussions on the application of eeMeasure Methodology on eTEACHER are described in section 4.1.

Once the experimental period before and after eTEACHER tool-box implementation is completed, the list of collected values at building and zone level are used to evaluate project impact indicators. The preliminary framework for evaluating is defined as follows:



D4.1: Evaluation Methodology and preliminary pilots descriptions

Table 4.2 Evaluation procedure to calculate KPI based on data collection

Evaluation of...	Measures	Calculation procedure
IM1. Evaluation of energy Savings and reduction of CO2 emissions	Building level Lighting sub-metering Appliance sub-metering Heating/cooling consumption Outdoor conditions (including solar radiation) Room/apartment level Energy consumptions (lighting, devices, etc.)	<p>Comparison of energy consumption between control and study rooms* (average values, or per month using HDD or CDD). This comparison results in the energy savings indicators in %.</p> <p>Comparison of energy consumption of study rooms with building level. Savings at room level are extrapolated proportionally regarding room consumption and whole building consumption by use (lighting, HVAC and appliances). This comparison results in the energy saving indicators in kWh and applying CO2 factors in reduction of emissions.</p> <p>Complementary analysis comparing energy consumption regarding outdoor conditions, indoor conditions and occupancy will be analysed to detect main sources of energy consumption.</p>
IM2. Fast deployment	Building characterization and database preparation Monitoring system installation and programming eTEACHER deployment (web services and devices integration)	<p>Based on eTEACHER experience:</p> <p>Estimation of time needed for building characterization regarding area (m2) and typology of energy systems. Templates and general protocol provided.</p> <p>Estimation of time needed for additional monitoring system: Time used for installation and commissioning of basic devices** with respect to all the monitoring devices.</p>
IM3. Fast adoption	Use indicators of eTEACHER app	<p>Specific indicators must be defined to characterize the fast adoption as time of use and frequency of users' interaction with the software. Users' feedback can be also considered to evaluate the satisfaction level of recommendations (e.g. user-friendly, effectiveness, etc.)</p>
IM4. Number of users changing behaviour	Energy savings (IM1) Users' interaction with eTEACHER app Changes reported by building users	<p>IM1 will be calculated as it is explained above in this table.</p> <p>eTEACHER app will measure interaction but it is not determined how yet.</p> <p>The % of survey responses from building users who reported a change in previous behaviours/energy use.</p>
OIM1 Rol based on energy savings and investments	Building pilot budgets Whole energy savings (IM1)	<p>Return of investment is evaluated with the ratio between costs savings obtained through the energy savings with regards to the total costs of pilot budget for monitoring and deployment of eTEACHER solutions. This ratio can be easily obtained knowing the energy costs of building</p>



D4.1: Evaluation Methodology and preliminary pilots descriptions

Evaluation of...	Measures	Calculation procedure
		pilots and the final budget allocated for the monitoring system and BACS add-ons solutions.
OIM2-OIM5	To be defined	Socio-economic indicators are assessed together with the exploitation plans at the last stage of the project (to be defined).
OIM6 Improve occupants' wellbeing	Indoor conditions	CO ₂ level, temperature and humidity are key factors to characterize and evaluate the improvement of indoor conditions. Specific sensors for these parameters are installed to evaluate and compare them between control and study zones. Occupancy and external weather conditions are used to compare objectively the results. The evaluation consists of the occupancy time when these parameters are within comfort range (e.g. 24° C, 50% humidity ratio and 360 ppm CO ₂).

(*) Reminder: control zones are monitored but without eTEACHER interventions and study zones those monitored and with eTEACHER interventions.

(**) Basic devices are those needed to run eTEACHER applications. During the project additional devices are installed to perform necessary experiments (technical and social aspects).

When: Evaluation Plan

The evaluation plan is shown in Figure 4.2. First of all, data is collected before eTEACHER by means of feedback forum & surveys with end-users and the initial monitoring to characterize the baseline. Secondly, data is collected after the installation of eTEACHER in the pilot buildings by means of monitoring, feedback forum & surveys and eTEACHER App. Finally, data collected before and after eTEACHER is compared to evaluate the behaviour change.

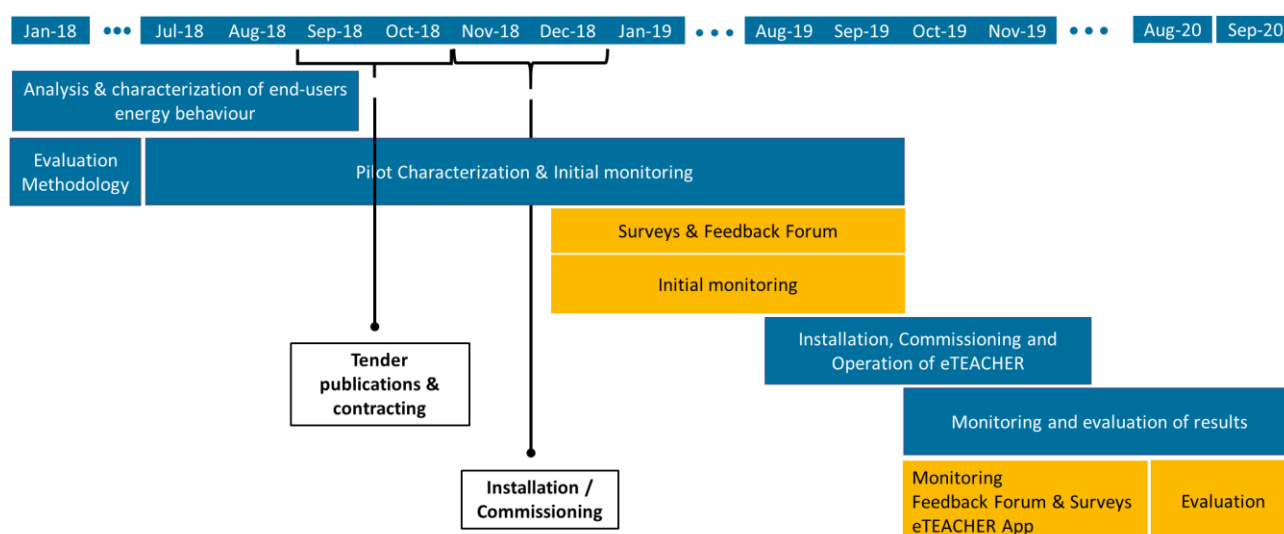


Figure 4.2 Evaluation Plan



4.1 Application of eeMeasure on eTEACHER

The framework provided by the eeMeasure Methodology (Woodall, 2011) establishes three basic conditions:

1. *“Experiments should be replicated”*. This is one of the objectives of the overall evaluation strategy since the methodology must be common for all the building demos. Indeed, at building level sensors and measurements are similar considering the particular conditions of every building.
2. *“Experimental periods should be long enough to include a representative set of conditions that will impact energy consumption”*. The project has established 9 months for monitoring the baseline period and 9 months for demonstration, which is time enough to evaluate winter, summer and soft climate conditions and differences in occupancy and building use.
3. *“It is possible to predict variable consumption patterns by either creating a regression model during a baseline period, using a control group with very similar characteristics to the experimental group or a combination of both”*. This condition has entailed a challenge within eTEACHER context and defines two possible paths. The first one requires modelling and calibrating computational models to capture the building performance and its uncertainties, thus obtained results depend on the accuracy of energy models. In Figure 4.3 is explained the possibilities and limitations this approach offers.

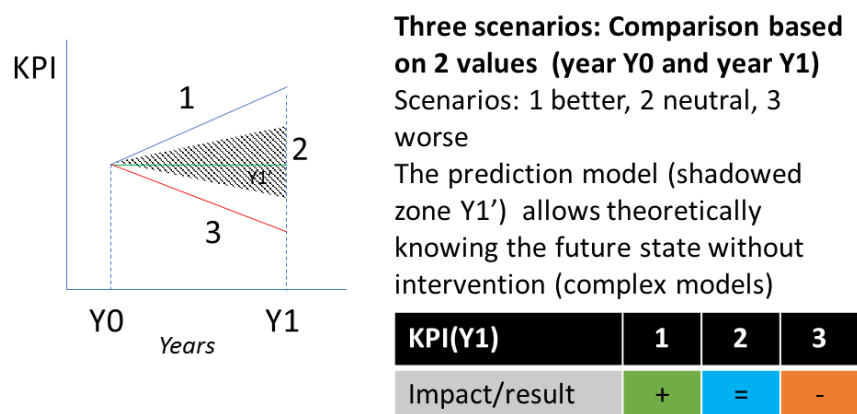


Figure 4.3 Evaluation approach using one environment before and after

Using the same environment allows comparing the results with three scenarios, simplifying the analysis. However, to detect and evaluate the effect of energy behaviour change it is necessary isolating or identifying the effect of variables that participates in the building energy consumption like weather conditions and operation of energy systems. Thus, assuming eTEACHER would be able to make people's energy behaviour becomes better, if weather conditions are worse than the baseline period or the use of the building changes significantly, the real effect of eTEACHER interventions can be spoiled or overestimated.

The second option is based on identifying control environments (control groups) that are monitored without any kind of intervention. This option requires the control zones present similar conditions as the corresponding study zones (orientation, use, schedule, number of people, energy appliances...) to allow comparing the evolution of both zones before and

D4.1: Evaluation Methodology and preliminary pilots descriptions

after. This option offers more combinations than the former and it does not require the development of complex building models (see Figure 4.4). In total, thanks to the control zone, nine scenarios can be compared objectively for any KPI.

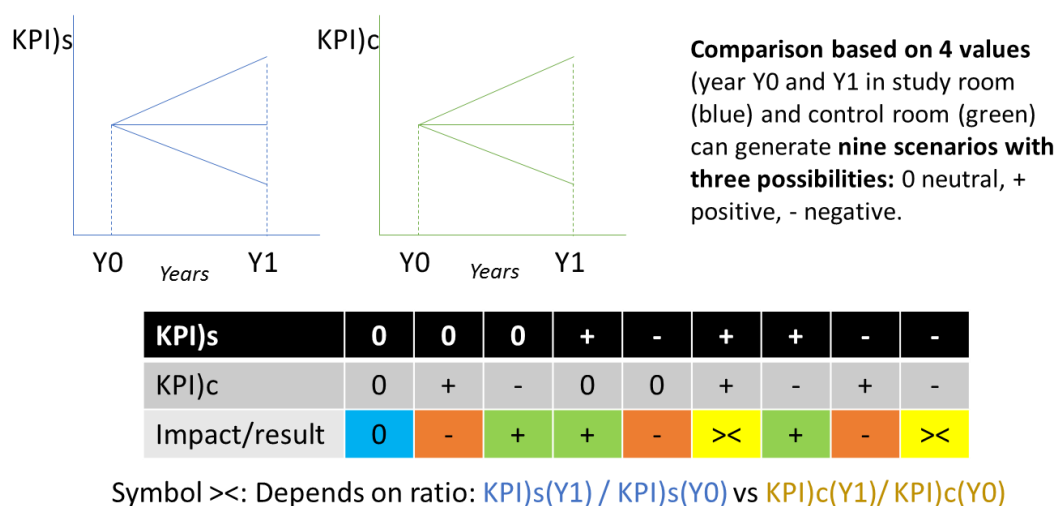


Figure 4.4 Evaluation approach using control groups

In the case of eTEACHER, the baseline and demonstration periods are not scheduled for months with similar climate conditions. Although such difference between different periods may be addressed with the well-known approach of heating/cooling degree days (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2017), additional uncertainties and differences regarding energy behaviour and building use could invalidate results. For example, in academic buildings where the use of classrooms has several uses per day or week or in health care centres and public buildings where the occupants are different daily (and thus the energy-use behaviour), just applying regression models based on thermal building performance do not guarantee the validation of results. On the other hand, performing building modelling to extend theoretically the results of the baseline period is out of the scope of eTEACHER due to the complexity and the effort required to carry out this kind of engineering designs (eTEACHER project was thought to provide a low-cost ICT service and solutions to improve the energy efficiency of building through energy-use behaviour). For these reasons, at **room or apartment level the control zone** option has been adopted as the most suitable approach to allow validating the results.

However, at **building level** is not possible to find a similar building that can work as control group. Using the control zone at room or apartment level and monitoring the main energy sources at building level, extrapolations of results can be applied to estimate global KPI and whole project impact. Besides, this allows comparing results using the approach of heating degree days (HDD) or cooling degree days (CDD) where applicable.

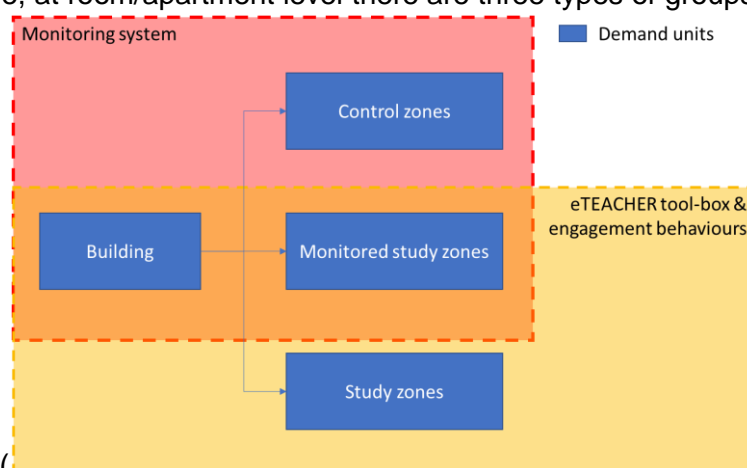
D4.1: Evaluation Methodology and preliminary pilots descriptions

Therefore, we can say that the overall evaluation strategy will be based on a hybrid approach between control zones at room/apartment level and extrapolations at building level, where the effect of study rooms or areas will be extrapolated proportionally for the whole building. The Table 4.3 summarised and compares these two options (prediction model and control group).

Table 4.3 Comparison of experimental design approaches

Using same environment (self-reference)	Using control groups
<p>Single room/zone/building is monitored before and after and compared itself.</p> <p>Boundary conditions (e.g. weather) must be compared before and after to assess results (it requires strict definition and monitoring of boundary conditions and the analysis is complex).</p> <p>It requires prediction models, otherwise we obtain a simple KPI analysis comparing values before and after (risky due to uncertainties in the case that results become worse than expected).</p>	<p>Every room/zone (under study) has a control/reference room with similar conditions (occupancy, schedule, building construction (glazing, walls...), building orientation, facilities and devices/appliances and is monitored before and after.</p> <p>Control/reference room/zone is only monitored (energy and comfort condition) but does not apply any kind of intervention.</p> <p>Similar conditions between similar rooms should be checked frequently to validate the model.</p> <p>It allows comparing study room (before and after), control room (before and after) and obtaining relative KPI (Figure 4.4)</p> <p>Sometimes it is difficult to identify “similar” environment available.</p>

Moreover, due to budget limitations to deploy monitoring devices in pilot buildings, only a representative number of rooms/apartments are selected as monitoring study and control groups. Therefore, at room/apartment level there are three types of groups or demand units



and the building (Figure 4.5):

1. Monitored study zone: those rooms/areas/apartments that will be monitored and where eTEACHER tool-box is running during the second period (intervention time).
2. Monitored control zone: those rooms/areas/apartments that will be only monitored.

D4.1: Evaluation Methodology and preliminary pilots descriptions

3. Non-monitored study zones: those rooms/areas/apartments that are not monitored and where eTEACHER tool-box is running during the second period (intervention time).
4. Building: monitoring of energy consumption and outdoor conditions.

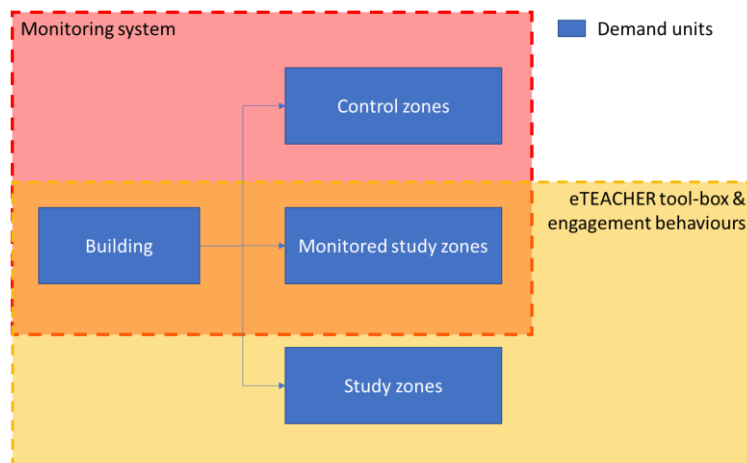


Figure 4.5 Demand Units and control groups. Monitoring system and eTEACHER tool-box

4.2 Monitoring

The monitoring system has two objectives:

1. Evaluate target behaviour changes identified in WP1.
2. Provide inputs to BACS add-ons defined in WP2

The project team drafted a first version of the monitoring plan during the project meeting held on Dresden (May 2018) considering preliminary requirements for BACS add-ons and preliminary specifications from social analysis as well as considering the project impact indicators and those related to identify the effect of energy behaviour change. The Figure 4.6 shows the first version of the monitoring plan where monitoring data/devices to be collected are classified into: a) to be installed, b) still in consideration, c) nice but expensive. Due to the diversity of buildings and use, it was highlighted the need to harmonise monitored values to allow comparing results between similar buildings and countries.

Afterwards (September 2018), the initial draft of the monitoring plan was updated according to: 1) a better knowledge about buildings and their energy systems, 2) a more consolidated list of requirements and eTEACHER system architecture (Peralta, 2018), and 3) a cost-effective analysis of monitoring technologies in the market taking into account project budget. Figure 4.7 shows the second version of the high-level monitoring plan (September 2018).

D4.1: Evaluation Methodology and preliminary pilots descriptions

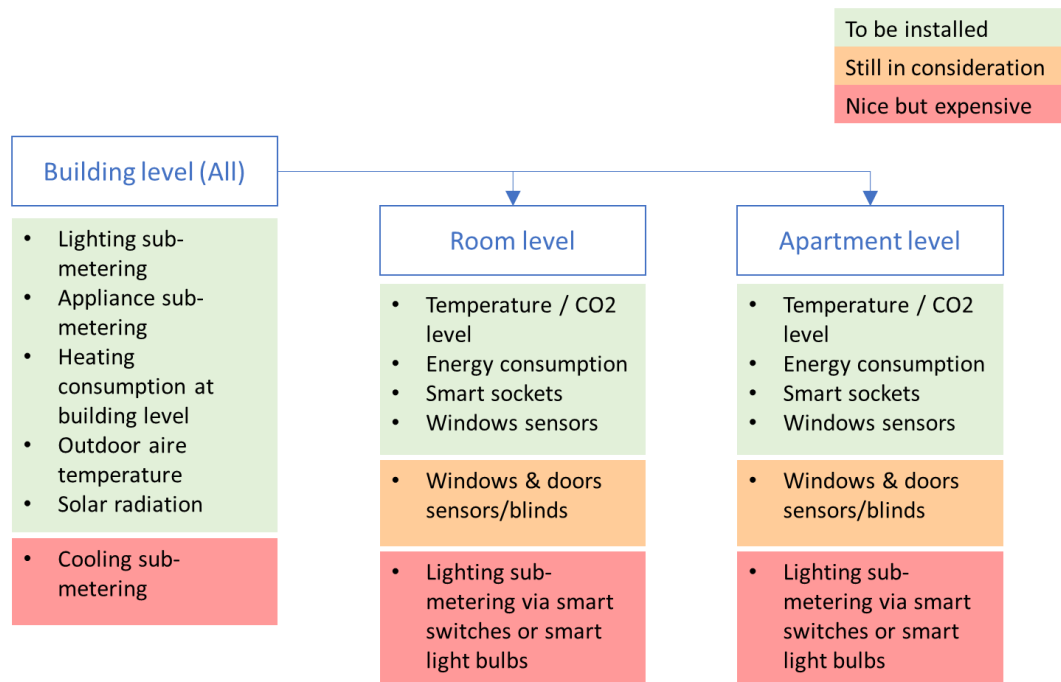


Figure 4.6 Monitoring devices for building pilots (Dresden, May 2018)

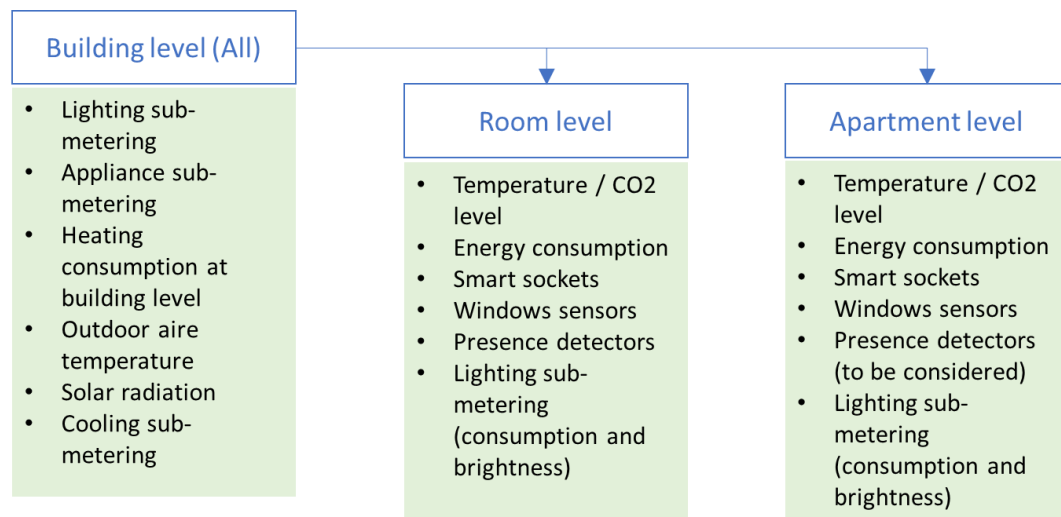


Figure 4.7 Monitoring devices for building pilots (September 2018)

The design of monitoring systems is the cornerstone for implementing ICT solutions in buildings. Number and type of sensors, position, type of connection (wire or wireless), data transfer and frequency, energy supply, cost and communication protocol are questions that must be addressed in detail to satisfy both technical and social requirements, i.e. overall requirements, use cases and social research feedback. In this context the objectives to define the monitoring systems have been the following:

D4.1: Evaluation Methodology and preliminary pilots descriptions

- Fulfil the EVO International Performance Measurement & Verification Protocol¹ (IPMVP), summarised and explained in the Measurement and Verification (M&V) methodology proposed by “eeMeasure” for residential and non-residential buildings (Woodall, 2011).
- Find low disruptive (easy to install) sensors and monitoring devices able to measure data points of use cases and behaviour change requirements and to be integrated in existing BEMS/BACS.
- Balance the monitoring budget between building pilots for each country (Spain, UK, Romania). This objective has entailed seeking and testing low-cost sensors with enough reliability and connectivity (e.g. Sonoff², Z-Wave Alliance³, ad-hoc solutions with Arduino⁴ or Raspberry PI⁵ and Netatmo⁶).
- Design an effective and secure monitoring system architecture and able to be integrated in standard server databases.

The strategy to fulfil with the IPMVP or eeMeasure together with project requirements is explained in section 4.1. To deal with the iterative process for sensor selection and balance the budget allocated for demonstration and research, it was created a template with the following information:

- Building data: name, location, heating and cooling system type, BACS/BEMS level (low, medium, high), availability of Internet connection, users involved and number of building target areas
- Data points: measurements (Figure 4.7), location in the building (windows, doors, roof...), type of monitoring device (power analyser, temperature sensor...), reference device/sensor (link to commercial sensor), number of sensors, unit price and measured variable (energy, temperature, CO2 level, etc.)
- Description and estimation of auxiliary works (e.g. installation)
- Total budget estimation
- Selection of demand units (building areas under research) with blueprints and schemas.

Detailed information of the contents of this template for every building is shown in section 4.2.3.

Following, the BACS addons requirements and the conclusions of the behaviour characterization which have influenced the design of the monitoring system are summarized.

4.2.1 Behaviour characterization conclusions

As previously mentioned, during a project meeting (Dresden, May 2018) project partners decided on the best target behaviours for eTEACHER based upon the behaviours identified within the pilot buildings, the existing data in each building, the monitoring potential (to achieve a uniform picture of measurements across all buildings) and the desired behaviour change evaluation for eTEACHER

¹ <https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp>

² <http://sonoff.itead.cc/en/>

³ <https://products.z-wavealliance.org/regions/1/categories/8/products>

⁴ <https://www.arduino.cc/>

⁵ <https://www.raspberrypi.org/products/raspberry-pi-3-model-b/>

⁶ <https://www.netatmo.com/es-ES/site/>



D4.1: Evaluation Methodology and preliminary pilots descriptions

as stated at the start of the project. Four key behavioural targets were identified and selected to be factored into the design of the eTEACHER tool. The four behaviours were;

- Lighting use behaviours
- Appliance use behaviours
- Comfort related behaviour
- Engagement behaviour

Each of these behaviours has associated monitoring data being collected as part of the monitoring plans produced. Within each of these behavioural categories the behaviours shall be analysed by the whole building level consumption (lighting use, appliance use, heating and cooling use) and also in some cases on a detailed room or apartment level. With the more detailed level the behaviours within the room/apartment will be much more apparent compared to the whole building level. Therefore, self-reported behaviour will also be important to triangulate the behaviours occurring and any resulting behaviour change following eTEACHER implementation.

As behaviour change is a key element of the evaluation of the eTEACHER project's impact and success (positive or negative) it is vital that a common methodology for assessing behaviour change can be applied across all of the different pilot buildings. To allow comparisons of the extent of behaviour change across all buildings the methodology must use a baseline measurement and post-intervention measurement for each building separately. However, consideration also needs to be taken of the fact that behaviours are not static but rather they are often dynamically evolving over time. Many models and studies tend to treat behaviours as a static condition and do not factor in how behaviours may change over the course of a study, or how independent variables may influence changes in behaviours during a study. Similarly, the motivations behind behaviours are often neglected within studies as more emphasis is often put on answering how and why users exhibit particular behaviours. As presented in (Morton A. R., 2018) behaviours can be influenced by the capability, opportunities and motivations of users, therefore an important factor for the evaluation of eTEACHER is to focus on behaviours of individuals as well as the collective energy-use behaviours within each of the pilot buildings.

Therefore, the Theory of Planned Behaviour (TPB) (Ajzen, 1991) will be used within eTEACHER to underpin the evaluation strategy towards behaviour change from implementation of eTEACHER. The theory of planned behaviour, shown in Figure 4.8, can be used to describe a user's behaviour as a function of the individual's attitude towards the behaviour, subjective norms and their perceived behavioural control. Therefore, the use of TPB to underpin the evaluation in eTEACHER allows for key factors and influences on the specific target behaviours to be identified, covering attitudinal factors (social norms, beliefs), contextual forces (persuasion) and the individual's personal capability (knowledge and skill).



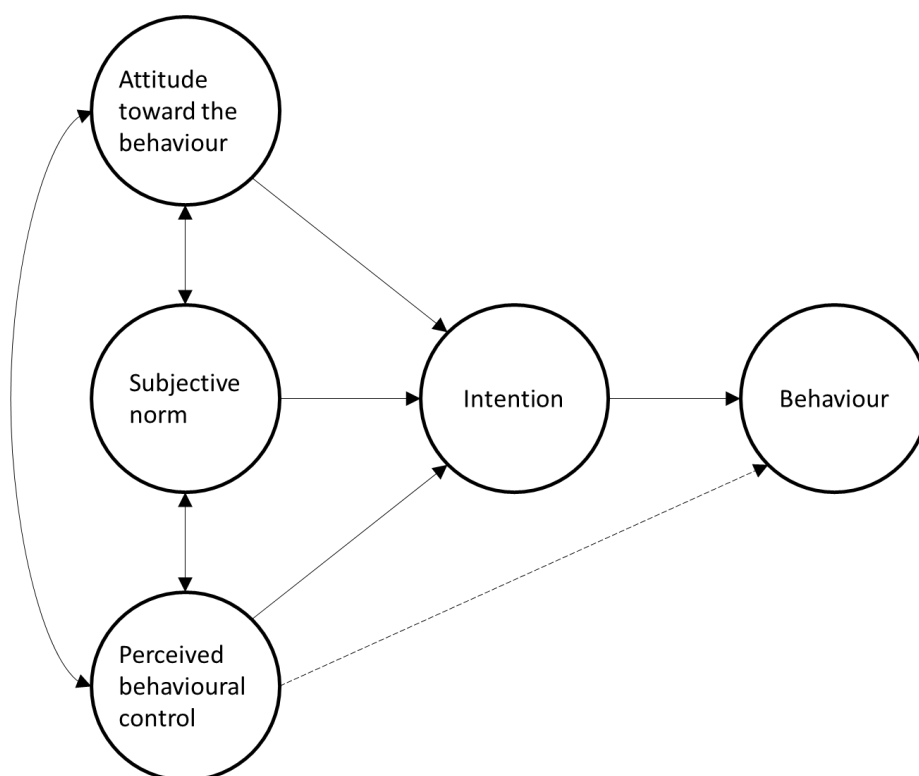


Figure 4.8 Ajzen's Theory of Planned Behaviour (Figure from Ajzen, 1991)

For eTEACHER energy end-users' behaviours can be analysed from physical measurements of energy consumption (at a building level, room/apartment level, appliance level as mentioned previously) but it will also rely heavily on self-reported behaviours from building users due to the budget constraints of the project. Therefore, within the evaluation strategy it is important that behaviour change is assessed pre and post eTEACHER implementation, ideally at an individual user level. However, given the number of building users in each building and the longitudinal aspect of the monitoring period this may not be possible for all building users and as such the behaviours within the experimental groups (both detailed monitored groups and whole building level groups) and within the control groups can be compared to evaluate the impact on specific behaviours. Given the risk of external influences on behaviours within each building, such as if a new energy policy or campaign is launched in one building, it is important to not only rely solely on one pre and post behavioural assessment. Within eTEACHER engagement with building users has been factored into both the development year and implementation year, as presented in (Reeves, 2018), therefore opportunity has been designed into the evaluation strategy to collect additional information and behavioural measurements throughout year 2 and 3 of the project.

4.2.2 BACS add-ons requirements

BACS add-ons are considered the ICT solutions that eTEACHER toolbox integrates in existing BEMS and BACS. These technologies encompass several web services like what-if analysis for energy demand and consumption prediction and control, Metrix and Pulse for energy consumption and indoor air quality conditions, the eTEACHER app and the universal BACS interface, which integrates in turn the collection of add-ons, the building control systems and the monitoring system. These tools have several objectives that were defined in (Peralta, 2018) and classified in overall

D4.1: Evaluation Methodology and preliminary pilots descriptions

requirements and use cases (i.e. energy conservation measures, building performance and indoor environmental quality) as follows:

Overall requirements (OR):

- OR1. Access to available building information
- OR2. Existing ICT infrastructure network
- OR3. Establish communication between add-on services
- OR4. Evaluation of energy, CO₂ and cost savings
- OR5. Evaluation of indoor environmental quality (IEQ)
- OR6. Prioritise energy conservation measures (ECM)
- OR7. Creation of advice based on engagement methods and users' feedback
- OR9. Identification of under-performance conditions

Energy conservation measures (ECM) use cases:

- ECM1. Save cooling energy using HVAC control, windows and blinds
- ECM2. Save heating energy using HVAC control, windows and blinds
- ECM3. Save lighting energy using natural lighting or power-off when there are not people using it
- ECM4. Save electric energy power-off unnecessary appliances, devices or equipment

Building performance (BP) use case:

- BP1. Detection of building underperformance conditions

Indoor Environmental Quality (IEQ) use case:

- IEQ1. Monitoring and advisor of indoor environmental quality to improve the wellness and productivity

Technical requirements of these use cases prioritise data points that must be monitored by eTEACHER toolbox to accomplish the project research objectives (technical and social) and to allow the complete operation and integration of the toolbox. For instance, doors sensors are not considered anymore and cooling and lighting are mandatory. On the other hand, as not all the use cases are tested in building pilots, a preselection of these use cases according to the possibilities of each building pilot was done in (Peralta, 2018) and it is reviewed and updated in section 4.2.3.

Table 4.4 Preselection of use cases to be tested in each eTEACHER building pilots

Building	Type	Pre-selection of use cases
OAR (Spain)	Administrative	ECM1, ECM2, ECM3, BP1, IEQ1
NCC (UK)	Administrative	ECM2, ECM3, ECM4, BP1, IEQ1
Badajoz (Spain)	Residential	ECM1, ECM2, ECM3, ECM4, IEQ1
InCity (Romania)	Residential	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1



D4.1: Evaluation Methodology and preliminary pilots descriptions

Building	Type	Pre-selection of use cases
Torrente high school (Spain)	Academic	ECM2, ECM3, IEQ1
Arco Iris school (Spain)	Academic	ECM1, ECM2, ECM3, ECM4, IEQ1
Djanogly high school (UK)	Academic	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1
Guareña (Spain)	Health Care Centre	ECM1, ECM2, ECM3, ECM4, IEQ1
Villafranca (Spain)	Health Care Centre	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1

4.2.3 Monitoring of Buildings

In this section, the monitoring and evaluation plan is adapted to the characteristics of project pilot buildings in terms of construction, energy systems and occupants' behaviour. This adaptation is driven to satisfy the following experiment design requirements:

- test use cases (Table 4.4) according to BACS add-ons functionalities;
- evaluate key performance and impact indicators (Table 4.2);
- monitoring the necessary parameters to construct robust baseline dataset (section 4.1);
- integration with existing BEMS and building facilities (e.g. protocol specifications);
- low disruptive installation and commissioning (e.g. best location to install monitoring devices);
- and selection of most suitable demand units to take the maximum advantage of available budget and maximise the eTEACHER's effects.

To decide the best solution to satisfy these requirements it is necessary a deep knowledge of target buildings, thus several visits with the support of local partners (demo coordinators) have been indispensable to access buildings and the information thereof. However, one of the goals of eTEACHER project is to harmonise the identification procedure for a future application of proposed solutions. For this reason, templates like the presented in Annex A have been designed to increase the effectiveness of preliminary activities of data collection and characterization.

Selection of demand units / experimental zones is one of the most important points of the experiment design and depends on available resources (e.g. budget) and technical constraints of the building. Demand units at zone level must be selected with homogeneous criteria focusing on surface, HVAC system, equipment, external envelope (facade and windows), number and type of occupants, occupants' behaviour, etc., since the monitoring system (devices and components) must be the same to make results comparable.

In addition, once the demand units were selected, the design of the monitoring plan had to deal with the following challenges:

- Existing monitoring level:** the number and type of existing components and devices monitoring building parameters is the first step to plan the monitoring system. Under some circumstances it is possible to access and connect to existing devices, taking advantage of



D4.1: Evaluation Methodology and preliminary pilots descriptions

current information and saving monitoring costs. However, at other times, it is more effective to install new components since integration require programming effort or additional devices that can be even more expensive than installing parallel systems. The following table shows the level of monitoring level (considering only electronic devices able to send information remotely) found in the building demos:

Table 4.5 Existing monitoring level in building demos

Building demo	Monitoring level	Energy parameters
OAR (Spain)	Average	General electric consumption HVAC electric consumption
NCC (UK)	High	General electric consumption (smart-meter managed by energy supplier) General District Heating consumption (heat meter) Heating and DHW temperatures (inlet/outlet) Temperature of rooms and corridors AHU setpoints (temperature/air flow)
Badajoz (Spain)	High	General electric consumption General district heating consumption Heating consumption per apartment DHW consumption Water consumption
InCity (Romania)	Average	Electric smart meter (managed by energy supplier) DHW consumption Heating consumption
Torrente high school (Spain)	Low	None
Arco Iris school (Spain)	Average	Smart- electric and heating meters (managed by energy supplier) BEMS (heating, DHW and cooling set-points) Local temperatures
Djanogly high school (UK)	Low	Electric smart meter (managed by energy supplier)
Guareña (Spain)	Average	Indoor temperature/humidity Electric consumption (general and HVAC)



D4.1: Evaluation Methodology and preliminary pilots descriptions

Building demo	Monitoring level	Energy parameters
Villafranca (Spain)	Average	Indoor temperature/humidity Electric consumption (general and HVAC)

- **Combination of energy sources and energy system complexity:** the second challenge is to identify which type of device is appropriate to measure energy parameters. While heating systems usually are fed with fuel-based energy sources, in the Mediterranean climate we can find heating system working with electric energy instead. Whilst electric equipment can be easily monitored with smart-meters and power analyser, fuel-based equipment requires advance heat meters (e.g. ultrasonic) that otherwise, it would require the interruption of service to install conventional models. This is even more complex when we find these two technologies combined in the same building. On the other hand, although electric equipment can be easily monitored in some cases electric circuits usually supplies different building uses, what makes impossible separating and identifying the final use of electric energy. For this reason, the monitoring system have been adapted to building singularities, leveraging the available budget and current monitoring technologies.
- **Number of measurement points at zone level:** due to the number of measurement points needed to satisfy the monitoring requirements related to energy-use behaviour at zone level in non-residential and block of buildings is necessary to cover long distances inside and such devices must be supplied with electric energy. For instance, monitoring window opening, appliance consumption or the specific indoor conditions of rooms require may elements that have to be interconnected, labelled and programmed to collect the information.

These challenges have been addressed in the building demos as it is explained in following sections.

4.2.3.1 Office Buildings

OAR demo (section 2.2) is a modern building located in Badajoz (Spain). It was built in 2011 and it has 3 floors. The HVAC system consists of VRF (variant refrigerant flow) heat pumps and compact AHU (air handling units). In addition, there are some splits located in individual offices and in the ground floor. The building has a central lighting system with fluorescent lamps. The main appliances are computers and printers.

Demand units / experimental zones: the first floor is used as control zone except for the toilets and the individual offices located in the main facade (southwest orientation). The rest of the building is used as study zone. In addition to the control zone, the second floor will be monitored except for the toilets and the zone located at the main facade. The selection of the experimental zones is based on the use of the rooms, the boundary conditions and the facilities design. Therefore, control and monitored zones are equivalent from the point of view of the use, HVAC system, lighting system, appliances and most of the boundary conditions (orientation). Another important criterion is that the design of facilities allows measuring the HVAC, lighting and appliance consumption at the level of control and monitored zones.

Monitoring system

Table 4.6 Monitoring system in OAR



D4.1: Evaluation Methodology and preliminary pilots descriptions

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use cases
Building level	Lighting sub-metering	General electric switchboard (facility room)	Power analyser	Energy (kWh)	ECM3
	Appliances sub-metering	Facility room (general consumption)	Connection and integration with existing meter	-	ECM4
	HVAC consumption	Facility room (HVAC consumption)	Connection and integration with existing meter	-	ECM1 ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (°C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside- Roof	Pyranometer	Irradiance level (W/m ²)	ECM3
Zone level	Window opening	Windows	4 magnetic opening sensors by floor	Opening (binary)	ECM1 ECM2
	Motion sensor	Windows	4 sensors per floor	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness sensor	Windows	4 sensors per floor	Brightness (lux)	ECM3
	Appliances	Electric circuit	20 Smart plugs for offices devices	Energy (kWh)	ECM4
	Lighting sub-metering	Electric lighting circuit	2 power analysers	Energy (kWh)	ECM3
	Indoor environmental quality	Two per floor	Multisensor	Temperature (°C) Humidity (%) CO ₂ (ppm)	IEQ1 BP1
	Heating/cooling sub-metering	Electric circuit of VRVs	Power analyzers & current transformers	Energy (kWh)	ECM1 ECM2 BP1



D4.1: Evaluation Methodology and preliminary pilots descriptions

Nottingham Council House demo (section 2.2) is an emblematic and classic building built in 1927. It has 7 floors (including basement and roof areas) and 5892 m². This demo building has mainly offices and meeting rooms. These rooms are conditioned by radiators and convectors with water from a district heating. The building has also AHUs (Air Handling Units) used for ventilating large meeting rooms.

Demand units / experimental zones: Four rooms in 4th floor are used as control rooms and 4 equivalent rooms in 4th floor are monitored. The control rooms are similar to monitoring study rooms in terms of use, size and devices. The other rooms are non-monitoring study rooms.

The *monitoring system* is described in Table 4.7.

Table 4.7 Monitoring system in Nottingham Council House

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use cases
Building level	General electric consumption	General electric switchboard	Power analyser	Energy (kWh)	ECM4
	Lighting sub-metering	General electric switchboard	Power analyser	Energy (kWh)	ECM3
	Heating consumption	District Heating	Heat meter existing in the facility	Energy (kWh)	ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3
Zone level	Window/door opening	Windows	22 magnetic opening sensors	Opening (binary)	ECM2
	Motion sensor	Windows	8 sensors	Presence (binary)	ECM2 ECM3 ECM4
	Brightness sensor	Windows	8 sensors	Brightness (lux)	ECM3
	Appliances	Electric switches of appliances	20 Smart sockets for offices devices	Energy (kWh)	ECM4
	Lighting sub-metering	Light switches	8 electric energy meters embedded in light switches	Energy (kWh)	ECM3



D4.1: Evaluation Methodology and preliminary pilots descriptions

	Indoor environmental quality	Door	8 multi-sensors	Temperature (°C) Humidity (%) CO ₂ (ppm)	IEQ1 BP1
	Heating sub-metering	Radiators/convectors per room	2 temperature sensors per radiator (26 in total)	$T_{\text{radiator}} - T_{\text{room}}$ (Δ°C)	ECM2 BP1

4.2.3.2 Residential Buildings (AGE, ICPE)

InCity (section 2.3) is composed of 4 residential building blocks located in Bucharest (Romania). These buildings were constructed in 2009 with modern facilities and a centralised BEMS that allow obtaining useful information to evaluate heating energy consumption and use. The heating system is supplied with a district heating system (hot water) with a gas boiler as backup when district heating suffers interruptions. The cooling system is based on individual heat pump splits in apartments. All the apartments have Internet connection and the target group are the householders, although the entire buildings present other kinds of facilities like office, sport centres, supermarket, etc.

Demand units / experimental zones: Currently, it is estimated that about 16 apartments (12 study apartments + 4 control apartments) will be part of the experiment although the final number is not decided yet. The selection is based on same orientation, similar number of occupants, similar floor surface, number of windows, number of radiators and number of splits (air-conditioning).

The *monitoring system* is detailed in Table 4.8

Table 4.8 Monitoring system in InCity

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Cases
Building level	Lighting sub-metering	General electric switchboard (common areas)	Power analyser with current transformers	Energy (kWh)	ECM3
	General electric consumption	Main cabinet of each building	Power analyser with current transformers	Energy (kWh)	ECM4
	Heating consumption	Facility room (BACS)	Information already available in BEMS	Energy (kWh)	ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (°C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM1 ECM2



D4.1: Evaluation Methodology and preliminary pilots descriptions

Apartment level	Window opening	Windows	2-4 sensors/apartment	Opening (binary)	ECM1 ECM2
	Motion sensor	Windows	1 sensor per apartment (close to kitchen or living room)	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness sensor	Windows	1 sensor per apartment	Brightness (lux)	ECM3
	Appliances	Switches of appliances	Power switch and meter or smart-sockets (2-4 per apartment)	Energy (kWh)	ECM4
	Indoor environmental quality	Living room	Temperature, humidity and CO2 sensor (1 per apartment)	Temperature (° C) Humidity (%) CO2 (ppm)	IEQ1
	Heating sub-metering	Facility room (BACS)	Information already available in BEMS	Energy (kWh)	ECM2 BP1
	Cooling sub-metering	Splits	Power switch and meter or smart-socket (1 per apartment)	Energy (kWh)	ECM1 BP1
	Electric sub-metering	Apartment Switchboard	Power switch and meter (2-4 per apartment)	Energy (kWh)	ECM3

(*) Door opening at apartment level is not relevant in terms of energy efficiency due to the low frequency of opening.

Apartment Block Badajoz (section 2.3) was built in 1984. It has 4540 m² distributed in 5 floors with apartments and the basement area which is used as facility room. The building has a central heating system that has 4 natural gas boilers. The heating system is already monitored. In addition, the apartments have splits for cooling some rooms. Moreover, apartments have fluorescents lamps and home appliances.

Demand units / experimental zones: Currently, it is estimated that about 10 apartments (8 study apartments + 2 control apartments) will be part of the experiment although the final number of apartments is not decided yet. The selection is based on same orientation, similar number of occupants, similar floor surface, number of windows, number of radiators and number of splits (air-conditioning).

The *monitoring system* is detailed in Table 4.9:

Table 4.9 Monitoring system in Apartment Block Badajoz



D4.1: Evaluation Methodology and preliminary pilots descriptions

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3
Apartment level	Window opening	Window	3 sensor per apartment	Presence (binary) Brightness (lux)	ECM1 ECM2
	Motion	Window	1 sensor per apartment	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per apartment	Brightness (lux)	ECM3
	Appliances	Switches of appliances	Smart-sockets (2 per apartment)	Energy (kWh)	ECM4
	Lighting sub-metering	Lighting switches	Smart switches (1 per apartment)	Energy (kWh)	ECM3 BP1
	Indoor environmental quality	Main room (living room)	Temperature, humidity and CO ₂ sensor	Temperature (° C) Humidity (%) CO ₂ (ppm)	IEQ1 BP1
	Heating submetering	Apartment entrance	Connection & integration with existing meter	Energy (kWh)	ECM2 BP1
	Cooling submetering	Splits apartments	Smart sockets	Energy (kWh)	ECM1 BP1
	Electric submetering	Switchboard	Smart meter	Energy (kWh)	ECM1 ECM2 ECM3 ECM4

4.2.3.3 Academic Buildings

Torrente Ballester High School (section 2.4) was built in 1965. It has 5307 m² distributed in 3 floors. The building has a central heating system that has 1 fuel-oil boiler and radiators in classrooms. The heating system is already monitored. In addition, some administrative and teachers' offices have



D4.1: Evaluation Methodology and preliminary pilots descriptions

splits for cooling. Lighting system has fluorescent lamps and is manually controlled (switch on/off). The main appliances are computers, printer and beamers

Demand units / experimental zones: The control zone is a classroom located in the second floor. Apart from the control zone, three additional classrooms will be monitored. Two of them located in the second floor and one of them in the first floor. The other classrooms are part of the experiment (study zones) but they are not monitored. The monitored and control classrooms are representative classrooms with similar orientation, number of students, schedule, floor surface, number of windows and number of radiators. They have been chosen in the south-east facade to take into account solar radiation effect.

The monitoring system is detailed in Table 4.10:

Table 4.10 Monitoring system for Torrente Ballester

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Lighting sub-metering	General electric switchboard (ground floor)	Power analyser in lighting circuit + current transformer	Energy (kWh)	ECM3 BP1
	Appliance sub-metering	General electric switchboard (ground floor)	Power analyser in general circuit + current transformer	Energy (kWh)	ECM4
	Heating consumption	Primary heating circuit of the boiler	2 contact-temperature sensors	Temperature (°C)	ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (°C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3 BP1
Zone level	Window opening	Window	8 sensors per classroom	Presence (binary)	ECM1 ECM2
	Motion	Window	1 sensor per classroom	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per classroom	Brightness (lux)	ECM3
	Appliances	Switches of appliances	Smart Plug (1 per classroom)	Energy (kWh)	ECM4



D4.1: Evaluation Methodology and preliminary pilots descriptions

Level	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
	Lighting sub-metering	Lighting switches	Smart switch with power analyser (1 per classroom)	Energy (kWh)	ECM3 BP1
	Indoor environmental quality	Classrooms	Multi-sensor	Temperature (° C) Humidity (%) CO2 (ppm)	IEQ1 BP1
	Heating sub-metering	Radiators	2 temperature sensors per radiator	Temperature (° C)	ECM2 BP1

Djanogly City Academy (section 2.4) is a modern building built in 2005. It has 9163 m² distributed in 2 floors. The building is conditioned by gas boilers and electric chillers. Hot water is supplied to AHUs, radiators and heating floor. Cold water is supplied to cooling ceiling and AHUs. The BACS controls and monitors the production of the HVAC system. Lighting system are mainly LED and will all be LED manually controlled (switch on/off). The main appliances are computers, printer and beamers.

Demand units / experimental zones: The control zone are the classrooms located in the central module of the first floor. The rest of the classrooms are study zones. The other classrooms located in the first floor are also monitored. The control and monitoring zones are representative classrooms with similar use, size, HVAC system, appliances, lighting and boundary conditions. A key issue to choose control and monitoring zones is that they have measurable energy consumption.

The monitoring system is explained in Table 4.11:

Table 4.11 Monitoring system for Djanogly City Academy

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Lighting sub-metering	General electric switchboard in lighting circuit	Power analyser in lighting circuit + current transformer	Energy (kWh)	ECM3 BP1
	Appliance sub-metering	General electric switchboard (ground floor)	Power analyser in general circuit + current transformer	Energy (kWh)	ECM4
	Heating consumption	Primary heating circuit of the boilers	2 ultrasonic heat meters in the primary circuits of boilers	Energy (kWh)	ECM2 BP1
	Cooling consumption	Electric circuit of chillers and AHUs	Power analyzers + current transformer	Energy (kWh)	ECM1



D4.1: Evaluation Methodology and preliminary pilots descriptions

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3 BP1
Room level	Window opening	Window (north façade)	3 sensors per classroom	Presence (binary) Brightness (lux)	ECM1 ECM2
	Motion	Window	1 sensor per classroom	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per classroom	Brightness (lux)	ECM3
	Appliances	Sockets of appliances (e.g. smartboard)	Smart Plug (1 per classroom)	Energy (kWh)	ECM4
	Lighting sub-metering	Lighting switches	Smart switch with power analyser (1 per classroom)	Energy (kWh)	ECM3 BP1
	Indoor environmental quality	Classrooms	Multisensor	Temperature (° C) Humidity (%) CO ₂ (ppm)	IEQ1 BP1
	Heating sub-metering	Radiators	2 temperature sensors per radiator	Temperature (° C)	ECM2 BP1

Arco Iris kindergarten (section 2.4) was built in 1976. It has 905 m² distributed in one floor. The building has a central heating system that has 1 fuel-oil boiler and radiators in classrooms. The classrooms are also conditioned by splits for cooling. The lighting in the corridors has a timer but it can be also manually controlled (switch on/off). The lighting in the classrooms is manually controlled. The main appliances are computers, printer and beamers. They also have home appliances like washing machine and other kitchen equipment

Demand units / experimental zones: The control zone is a classroom located in the west facade. Apart from the control zone, three additional classrooms will be monitored. Two of them located in the south facade and one of them in the west facade. The other classrooms are part of the experiment (study zones) but they are not monitored. The monitored and control classrooms are representative classrooms with similar orientation, size, number of students, number of windows and number of radiators and splits.



D4.1: Evaluation Methodology and preliminary pilots descriptions

The *monitoring system* is detailed in Table 4.12:

Table 4.12 Monitoring system for Arco Iris

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Lighting sub-metering	General electric switchboard (facility room)	Power analyser in lighting circuit + current transformer	Energy (kWh)	ECM3 BP1
	Appliance sub-metering	General electric switchboard (facility room)	Power analyser in general circuit + current transformer	Energy (kWh)	ECM4
	Heating consumption	Primary heating circuit of the boiler	2 contact-temperature sensors	Temperature (°C)	ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3 BP1
Room level	Window opening	Window	1 sensor per classroom	Presence (binary)	ECM1 ECM2
	Motion	Window	1 sensor per classroom	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per classroom	Brightness (lux)	ECM3
	Appliances	Switches of appliances	Smart Plug (1 per classroom)	Energy (kWh)	ECM4
	Lighting sub-metering	Lighting switches	Smart switch with power analyser (1 per classroom)	Energy (kWh)	ECM3 BP1
	Indoor environmental quality	Classrooms	Multisensor	Temperature (° C) Humidity (%) CO ₂ (ppm)	IEQ1 BP1
	Heating sub-metering	Radiators	2 temperature sensors per radiator	Temperature (° C)	ECM2 BP1



D4.1: Evaluation Methodology and preliminary pilots descriptions

4.2.3.4 Health Care Centres (AGE)

Villafranca de los Barros Health Care Centre (section 2.5) was built in 2005. It has 2 floors and 905 m². The HVAC system consists of air-water heat pumps that supply water to fan-coils and AHUs. The lighting system has fluorescent lamps and is manually controlled by the users. The main appliances are computer, printers and medical equipment.

Demand units / experimental zones: The control zone is a consulting room located in the South-East façade of the ground floor. The rest of the building are study zones. 3 additional consulting rooms will be monitored. The three monitoring rooms have similar location, size and use to the control room. Both type of zones (control and monitoring zones) are representative consulting rooms.

The monitoring system is detailed in Table 4.13:

Table 4.13 Monitoring system for Villafranca de los Barros

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Lighting appliance & sub-metering	General electric switchboard - facility room (general consumption)	Connection and integration with existing meter	Energy (kWh)	ECM3 ECM4 BP1
	HVAC consumption	Facility room (HVAC consumption)	Connection and integration with existing meter	Energy (kWh)	ECM1 ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3 BP1
Room level	Window opening	Window	1 sensor per consultation room	Presence (binary)	ECM1 ECM2
	Motion	Window	1 sensor per consultation room	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per consultation room	Brightness (lux)	ECM3
	Appliances	Plugs of appliances	Smart Plug (1 per consultation room)	Energy (kWh)	ECM4
	Lighting sub-metering	Lighting switches	Smart switch with power analyser (1	Energy (kWh)	ECM3 BP1



D4.1: Evaluation Methodology and preliminary pilots descriptions

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
			per consultation room)		
	Indoor environmental quality	Consultation rooms	1 Multisensor per room	Temperature (° C) Humidity (%) CO2 (ppm)	IEQ1 BP1
	Heating/cooling sub-metering	Fancoils	2 temperature sensors per fancoil	Temperature (° C)	ECM1 ECM2 BP1

Guareña Health Care Centre (section 2.52.4) was built in 2000. It has 1270 m² and 2 floors. The second floor is used as facility room. The HVAC system consists of air-air heat pumps controlled manually with thermostats by administrative staff. The lighting system has fluorescent lamps and is manually controlled by the users. The main appliances are computer, printers and medical equipment.

Demand units / experimental zones: The control zone are the central west module of consulting rooms and corridor located in the ground floor. All the consultation rooms that are part of the control zone are conditioned by the same heat pump so HVAC consumption can be measured at zone level. The rest of the building are study zones. The east module of consultation rooms and corridor is also monitored. The monitoring zone has similar characteristics to the control zone. Both type of zones (control and monitoring zones) are representative consulting rooms.

The monitoring system is detailed in the Table 4.14:

Table 4.14 Monitoring system for Guareña

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Building level	Lighting appliance & sub-metering	General electric switchboard – administrative area (general consumption)	Connection and integration with existing meter	Energy (kWh)	ECM3 ECM4 BP1
	HVAC consumption	Administrative area (HVAC consumption)	Connection and integration with existing meter	Energy (kWh)	ECM1 ECM2 BP1
	Weather conditions	Outside (roof)	1 Weather station	Temperature (° C) Humidity (%) CO ₂ level (ppm)	ECM1 ECM2
	Solar radiation	Outside (roof)	1 Pyranometer	Irradiance level (W/m ²)	ECM3 BP1



D4.1: Evaluation Methodology and preliminary pilots descriptions

	Measurement	Location	Monitoring device(s)	Monitored variable(s)	Use Case (s)
Room level	Window opening	Window	1 sensor per consultation room	Presence (binary)	ECM1 ECM2
	Motion	Window	1 sensor per consultation room	Presence (binary)	ECM1 ECM2 ECM3 ECM4
	Brightness	Window	1 sensor per consultation room	Brightness (lux)	ECM3
	Appliances	Plugs of appliances	Smart Plug (1 per consultation room)	Energy (kWh)	ECM4
	Lighting sub-metering	Lighting switches	Smart switch with power analyser (1 per consultation room)	Energy (kWh)	ECM3 BP1
	Indoor environmental quality	Consultation rooms	1 Multisensor per room	Temperature (° C) Humidity (%) CO2 (ppm)	IEQ1 BP1
	Heating/cooling sub-metering	Fancoils	2 temperature sensors per fancoil	Temperature (° C)	ECM1 ECM2 BP1

4.3 eTeacher App

As recommended in (Morton A. R., 2018) the eTEACHER tool should be designed in a way that it captures measured data on engagement of users and capture any self-reported data on energy-related behaviour in response to advice/challenges given.

The data which should be measured by the eTEACHER tool includes;

- Level of interaction with the eTEACHER tool – which users are engaging with the tool, how long are they using it for, how often are they using the tool (daily, weekly etc.), what advice are they responding best to
- Self-reported energy-related behaviours in response to in-app activities and challenges – responses including simple yes or no answers to whether they acted upon advice or challenges given in the tool
- Self-reporting of issues to the app – using the app to aid communication between building users
- Self-reporting of issues to the app – did users click to access energy consumption data for whole building, for individual rooms/apartments, for individual appliances



D4.1: Evaluation Methodology and preliminary pilots descriptions

- Use of the app by users to discuss energy-related issues, such as sharing tips and suggestions with other building users

The exact specifications of how the data will be captured and then analysed will not be finalised until the development of the eTEACHER tool has begun and whether compromises are needed as to the level of detail possible for monitoring user engagement.

4.4 Feedback Forums and Surveys

As touched on in earlier sections of this report the use of surveys and feedback forums will be used in eTEACHER to gather self-reported data on energy behaviours; engagement behaviour; influences on these behaviours and will also include evaluation of eTEACHER's effectiveness from the building user's perspective.

Surveys are a common methodological approach for gathering data on user behaviours. As already presented in (Morton, 2018) a user survey has already been implemented with a small subsample of building users within each of the pilot buildings. This survey gathered information on the current energy use behaviours, energy attitudes, user motivations and ICT use to contribute towards the eTEACHER tool design recommendations. Two further surveys will be used to measure behaviour within the eTEACHER buildings and the impact the eTEACHER tool has on successfully changing specific energy related behaviours. A new baseline survey shall be implemented, building on the first building user survey, but focusing on users' attitudes and behaviour relating to the specific target behaviours for eTEACHER. This baseline survey shall be distributed during the development stage (Year 2). A second survey shall be designed which will cover the same questions as the baseline survey (to evaluate any change in attitudes and specific behaviours) but also be aimed at collecting data on users' evaluation of the eTEACHER tool. Due to the range of building user demographics and geographical location (language) the survey shall predominantly focus on questions involving Likert-type scales for answers – this shall also allow for statistical analysis to be carried out.

Due to the design of the monitoring and evaluation strategy for eTEACHER the distribution of the surveys needs to be carried out with specific considerations taken into the monitored groups and control groups. Ideally for the optimum evaluation pre and post eTEACHER surveys will be completed by all users relevant to the monitored rooms/apartments and the control groups. However, a whole building level baseline is important. Therefore, Figure 4.9 represents the likely distribution and specific topics of questions which need to be factored in.



D4.1: Evaluation Methodology and preliminary pilots descriptions

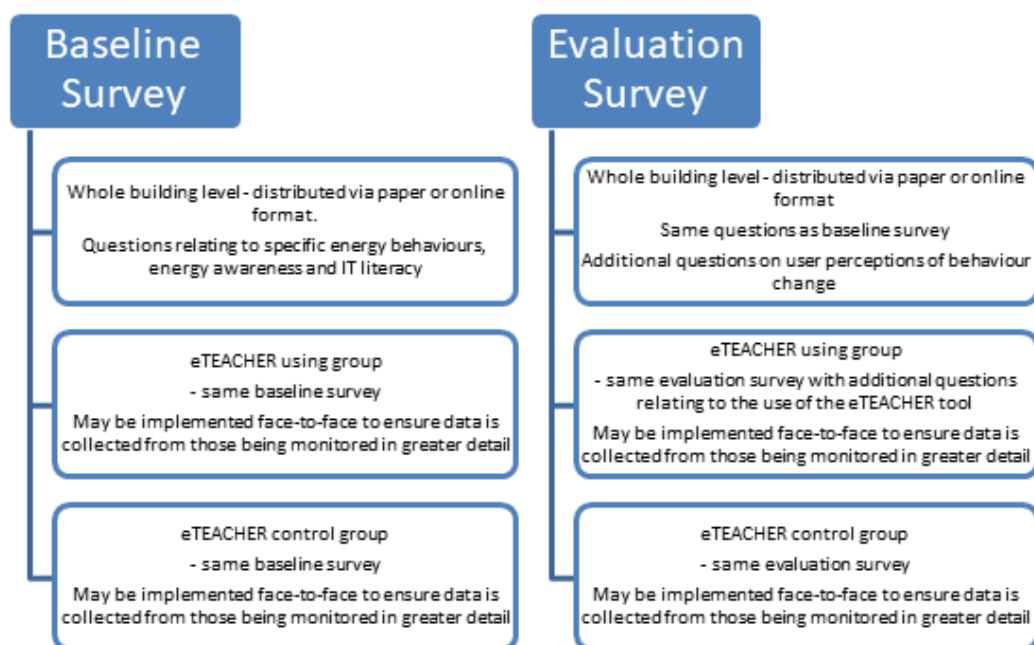


Figure 4.9 Survey design for baseline and evaluation with consideration of control and monitored groups

The second survey will be focused on evaluating the success and impact eTEACHER has had within each of the pilot buildings. The usability of the tool has a large influence on user engagement with the tool and it is therefore advisable that a measure is taken of how users' perceived the usability of the final eTEACHER tool. To do this a ten-item scale called the System Usability Scale (SUS) (Brooke, 1996) can be adapted to eTEACHER and included within the second survey (although this question will not be applicable to those building users within the control groups). This scale will allow for a usability score across all pilot buildings and within the specific building typologies used (Health Care Centres, Schools, Administrative and Residential) to be calculated. This score will give an indication of the overall usability of the final eTEACHER tool. Table 4.15 represents the SUS scale, adapted to eTEACHER, which can be used. To calculate the overall score the total contribution from each question is summed and this overall total is then multiplies by 2.5, giving a score within the range of 0 and 100. To calculate each questions score the following rules apply;

- Questions 1, 3, 5, 7 and 9 – the score is the scale point minus 1
- Questions 2, 4, 6, 8 and 10 – the score is 5 minus the scale point

So if a user marked that they strongly agreed with Q2 (scale point 5) then a contribution of 0 ($5 - 5$) would be made to the overall score. If a user marked that they strongly agreed with Q3 (scale point 5) then a contribution of 4 ($5 - 1$) would go to the overall score.

Table 4.15 SUS for calculating eTEACHER tool usability

	Strongly disagree				Strongly agree
1. I think that I would like to use eTEACHER frequently					
	1	2	3	4	5

D4.1: Evaluation Methodology and preliminary pilots descriptions

2. I found eTEACHER unnecessarily complex					
	1	2	3	4	5
3. I thought eTEACHER was easy to use					
	1	2	3	4	5
4. I think that I would need the support of a technical person to use eTEACHER					
	1	2	3	4	5
5. I found the various functions in eTEACHER were well integrated					
	1	2	3	4	5
6. I thought there was too much inconsistency in eTEACHER					
	1	2	3	4	5
7. I would imagine that most people would learn to use eTEACHER very quickly					
	1	2	3	4	5
8. I found eTEACHER very awkward to use					
	1	2	3	4	5
9. I felt very confident using eTEACHER					
	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with eTEACHER					
	1	2	3	4	5

The overall SUS score gives a measure of the perceived usability of eTEACHER and therefore a good assessment of how people see the tool. A study by Bangor et al (2009) links the SUS scale with evaluations of products in terms of users' ratings, "good", "poor" or "excellent", as shown in Figure 4.10. From this it can be seen that a SUS score of 70 and above is deemed to indicate good usability and user evaluation of the product.



D4.1: Evaluation Methodology and preliminary pilots descriptions

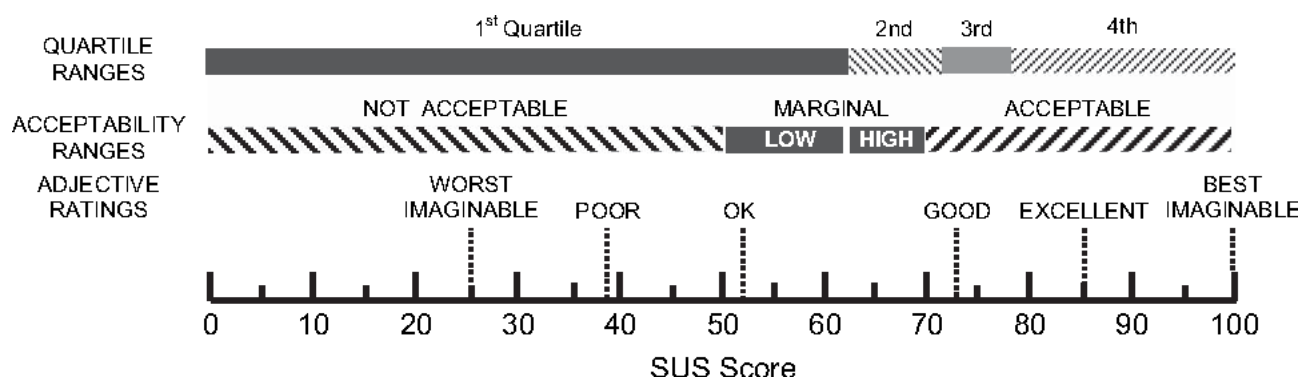


Figure 4.10 SUS score with grade and adjective rankings (Bangor, Kortum and Miller, 2009)

The distribution of surveys is recommended to be undertaken in the spring of concurrent years, so the baseline survey is distributed in spring 2019 and the evaluation survey should be distributed in spring 2020 so to minimise any influence on participants answers due to the time of the year. However, Feedback Forums will be used throughout 2019 and 2020 to collect additional information, which will be able to identify any external influences within each of the pilot buildings as well as to aid the development and analyse the evolution of use for the eTEACHER tool.

The use of Feedback Forums was presented in (Reeves, 2018) and will typically take the format of semi-structured focus group sessions during which users are able to:

- *Qualitatively describe* their use to date of eTEACHER, observed use by others in their building and any changes in energy-related behaviour
- *Share evaluative feedback* on eTEACHER's effectiveness, including strengths and potential improvements
- *Collaboratively analyse* the factors influencing engagement with eTEACHER and its effectiveness in influencing changes in energy-related behaviour

Table 4.7 summarises the Feedback Forums suggested within (Reeves, 2018) highlighting the data of relevance being collected in each one and the associated evaluation from that data. The Feedback Forum structure and any related materials will be circulated to all pilot coordinators to allow for translation and to ensure that there is continuity between all of the pilot sites, ensuring that comparisons can be made from the data collected across all pilot buildings.

Table 4.16 Feedback Forums suggested from D1.4 and relevant evaluation

Action	Description	Suggested timescale	Data collected being	Evaluation planned
Planning phase - Ai: Identify list of users and potential involvement in developing eTEACHER	Pilot site co-ordinators combine a list of existing contacts with further outreach (e.g. via email, posters, word of mouth) to develop a list of contacts who are interested in offering feedback to develop eTEACHER	End of October 2018	Relevant building users to engage with throughout project	N/A
Planning phase - Ai: Maintain list of users and potential involvement in	Pilot site co-ordinators maintain (and add to, as needed) a list of contacts who are interested in offering feedback to develop eTEACHER	Throughout Year 2 & Year 3	Relevant building users to engage with throughout project	N/A

D4.1: Evaluation Methodology and preliminary pilots descriptions

Action	Description	Suggested timescale	Data collected being	Evaluation planned
developing eTEACHER				
Scoping phase - Aii, Aiii & Biv Aii: Identify potential "right inviters" Aiii: Establish feedback forum Biv: Consult with users at each pilot site to pre-test materials	An initial Feedback Forum meeting including: •Introductions and introduction to the role of the Feedback Forum •Summary of the aims and approach of eTEACHER – framed around the benefits to users •Discussion on identifying potential "right inviters" •Sharing of existing plans for feedback in relation to WP2, WP3 and WP4.	December 2018	"Right inviters" for the tool roll-out Feedback on what users think of initial tool scope	N/A
Early prototype phase – Aii & Biv Aiii: Establish feedback forum Biv: Consult with users at each pilot site to pre-test materials	Feedback Forum meeting •Focus on feedback to aid initial tool design – pre-test materials	March 2019	Aid development of tool:	What ideas do users respond best to – how does this compare across building types/users types
Late prototype phase – Aiii & Ciii Aiii: Establish feedback forum Biv: Consult with users at each pilot site to pre-test message	Feedback Forum meeting •Focus on feedback to aid initial tool design – pre-test messages	June 2019	Aid development of tool:	What visualisations do users respond best to – how does this compare across building types/users types
Initial feedback phase – Diii: Consult with users at each pilot site (user feedback)	Feedback Forum meeting involving recorded semi-structured focus group sessions during which users are able to: • Qualitatively describe their use to date of eTEACHER, observed use by others in their building and any changes in energy-related behaviour • Share evaluative feedback on eTEACHER's effectiveness, including strengths and potential improvements • Collaboratively analyse the factors influencing engagement with eTEACHER and its effectiveness in influencing changes in energy-related behaviour	October 2019		<ul style="list-style-type: none"> Use of eTEACHER tool User feedback on tool – what do users like, dislike, think could be improved, what do users think they will use it for predominantly
Heating season feedback phase – Diii: Consult with users at each pilot	Feedback Forum meeting involving recorded semi-structured focus group sessions during which users are able to:	January 2020		<ul style="list-style-type: none"> Use of eTEACHER tool – how this has changed over time



D4.1: Evaluation Methodology and preliminary pilots descriptions

Action	Description	Suggested timescale	Data collected being	Evaluation planned
site (user feedback)	<ul style="list-style-type: none"> • Qualitatively describe their use to date of eTEACHER, observed use by others in their building and any changes in energy-related behaviour • Share evaluative feedback on eTEACHER's effectiveness, including strengths and potential improvements • Collaboratively analyse the factors influencing engagement with eTEACHER and its effectiveness in influencing changes in energy-related behaviour 			<ul style="list-style-type: none"> • User feedback on tool – what do users like, dislike, think could be improved – comparison between initial thoughts from Feedback Forum 4 (Oct '19) and now. Gives an indication of how user engagement and perception of the tool has changed over time.
Final feedback phase - Diii: Consult with users at each pilot site (user feedback)	<p>Feedback Forum meeting involving recorded semi-structured focus group sessions during which users are able to:</p> <ul style="list-style-type: none"> • Qualitatively describe their use to date of eTEACHER, observed use by others in their building and any changes in energy-related behaviour • Share evaluative feedback on eTEACHER's effectiveness, including strengths and potential improvements • Collaboratively analyse the factors influencing engagement with eTEACHER and its effectiveness in influencing changes in energy-related behaviour 	May 2020		<p>Evaluation of self-reported</p> <ul style="list-style-type: none"> • Use of eTEACHER tool – how this has changed over time • User feedback on tool – what did users like, dislike, think could be improved – comparison between initial thoughts from Feedback Forum 4 (Oct '19) and final Feedback Forum. Gives an indication of how user engagement and perception of the tool has changed over time. • Was the use of the tool impacted by a specific factor – e.g. others using it, specific information provided.

5 Conclusions

This report has presented a **characterization of the 12 real buildings** where eTEACHER will be demonstrated and the **evaluation methodology** that will be used to analyse the behavioural change of building users as consequence of eTEACHER.

The characterization of pilot buildings addresses the more relevant building & users features that are necessary for the development of the project. These features are related to **building envelope, energy systems, control and monitoring system and occupants' behaviour**. Within the context of the project, the pilot buildings characterization is used in WP2 to develop BACS Add-ons that are integrable in real buildings and provide valuable energy conservation measures. In addition, pilot buildings characterization is used in WP4 as basis for the whole project demonstration. It should be highlighted that the large variety of pilot buildings covers a broad spectrum of building types so the replicability of eTEACHER in other buildings will be ensured and direct.

The **evaluation methodology** is built upon measurable and self-reported evidences collected by means of **monitoring, eTEACHER app and feedback forum & surveys**. The evaluation



D4.1: Evaluation Methodology and preliminary pilots descriptions

methodology will be used in WP4 to measure behavioural changes and their influence on energy consumption and indoor environmental quality as well as to draw conclusions on the effectiveness of the project and on best practices for behavioural change through ICT solutions.

The first step to design the evaluation methodology was defining objectives and their indicators clearly to create the corresponding baseline to compare results before and after the project experiments. In addition, **selected indicators must be specific, measurable, achievable, relevant and time-bound (SMART)** to make the demonstration feasible and obtain a credible and objective reference to evaluate the performance of project solutions. Moreover, indicators related to energy consumption and environmental factors depend on multiple variables whose monitoring must be synchronized and harmonized carefully to allow a real evaluation of effects and impacts, for instance indoor environmental quality, weather conditions, operation of building facilities, among others. Therefore, objectives and indicators support the definition of the what (measure points), how (technologies) and when (planning).

A key point related to the evaluation methodology is the **experimental design** which strongly influences the reliability of the demonstration and evaluation results. The general approach of the experimental design consists of defining control environments and study environments to compare users' behaviour in both kind of environments before and after eTEACHER interventions. Control environments are used as reference and do not have eTEACHER during the demonstration period, neither during the baseline period (before eTEACHER). Study environments have eTEACHER during the demonstration period but not during the baseline period. **The definition of control and study zones in every pilot building has been a challenging task** since both kind of environments must be similar in terms of use/activity, energy systems, appliances, envelope and boundary conditions. Besides, it is required that energy consumption is measurable not just at building level but also at study and control zone level.

One of the most important issues addressed for the evaluation methodology in eTEACHER has been the **multiple energy sources and technologies found in pilot buildings**. For example, gas boilers, heat pumps and AHU require different monitoring devices (electricity, temperature, flow...) to measure the necessary variable to obtain energy and environmental indicators. While electric systems can be easily monitored with power analyzers or power meters, fuel-based heating system require expensive heat meters and AHU require multiple data points to separate general consumption from HVAC. This issue must be addressed carefully during building visits in an early stage to identify existing energy sources, energy facilities and the possibilities

In the ICT market there are plenty of **technologies to measure data points for energy efficiency evaluation**. Wired and wireless technologies can be installed to provide the necessary information and the decision is usually based on budget and compatibility with existing monitoring system and equipment. Other factors must be considered like the transmission coverage and the energy supply and consumption of these devices. Transmission coverage is especially important in buildings with long distance and thick walls and reinforced concrete structure, which can make impossible to access the device remotely. On the other hand, monitoring devices need specific power supply to work but sometimes it is not possible to connect them to the power system and alternative sources like batteries or transformers are applied. Therefore, it is **recommended that selecting the most appropriate devices regarding coverage and energy supply must be considered in an early stage of the evaluation plan**. In this regard, the eTEACHER monitoring and evaluation plan is focus



D4.1: Evaluation Methodology and preliminary pilots descriptions

on Wifi and Z-wave technologies that provide the necessary coverage and present low consumption to work long time with low power supply sources.

Finally, it should be highlighted that **feedback forum & surveys** are recommendable tools for gathering self-reported data for the evaluation of eTEACHERS success from the point of view of the building users (energy related and engagement behaviours). Major challenges in this case are related to the **recruitment of a significant sample of participants**.



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D4.1: Evaluation Methodology and preliminary pilots descriptions

Annex A. Templates to Collect Pilot Information

1 BUILDING NAME

1.1 General Information

Building Type	[high school, office, etc.]
Surface (m ²)	
Address	
Year of construction	
Refurbishing (year / name / short description)	[Roof insulation (2010): ...] [New boiler (2015): ...]
Number of users	

1.2 Geometry

1.2.1 Summary

Non-Residential

Room Type	Floor 1	Floor 2	...	Floor n
[Room Type 1]	[n° rooms; n° users; m ²]			
[Room Type 2]				
...				
[Room Type n]				

Residential

Flat Type	Description
[Flat Type 1]	[m ² ; orientation; n° users; type/number rooms]
[Flat Type 2]	[150 m ² ; south; n° users; 2 bedrooms, 1 kitchen, 2 toilets, 1 livingroom, corridor]
...	
[Flat Type n]	



D4.1: Evaluation Methodology and preliminary pilots descriptions

Flat Type	Floor 1	Floor 2	...	Floor n
[Flat Type 1]	[n° flats, n° users, m ²]			
[Flat Type 2]	[n° flats, n° users, m ²]			
...				
[Flat Type n]				

1.2.2 Plans

ID	Name	Description
[G.01]	[Distribution Floor 1]	[It includes ... (2013)]

1.3 Construction Materials

Construction Type	Surface (m ²)	Layers ⁷
Exterior wall		[Mortar Cement 1.5cm / Brick 12cm / Mineral Fiber Rock 4cm / Walls Air Gap / Brick 9cm / Gypsum 1.5cm]
Interior wall		
Floor/ceiling		
Roof		
Doors		
Windows		

⁷ If no data about the layers, it is also possible to provide U(W/m²K)



D4.1: Evaluation Methodology and preliminary pilots descriptions

1.4 Building components

1.4.1 Windows

DESCRIPTION

Type/number	Glass	Frame	Shadings	Control	User interaction

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.4.2 Doors

DESCRIPTION

Type/number	Glass	Frame	Shadings	Control	User interaction

OTHER INFORMATION

Problems	
----------	--



D4.1: Evaluation Methodology and preliminary pilots descriptions

Potential eTEACHER interventions	
Comments	

1.5 Energy Systems

1.5.1 HVAC

HEATING

GENERAL DESCRIPTION

Energy source	[Natural gas]
Production system	[3 gas boiler for heating and 1 for DHW]
Distribution (secondary)	[circuits, pipes, pumps, fan, ...]
Terminal units	[Radiators in all the rooms of the building]
Control	[Central control] [Boilers automatically regulated according to $T_{\text{water,return}}$] [Radiators can be manually adjusted]
Interaction (user + how is the interaction)	FM can regulate setpoint for $T_{\text{water,return}}$ Teachers & students can manually regulate radiators
Problems	
Potential eTEACHER interventions	
Comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]
Cold circuit 1	[Chiller 1 connected to pumps 3,4; collector 1, and fancoils 1-4 in floor 1 (corridor & administrative area)]



D4.1: Evaluation Methodology and preliminary pilots descriptions

Design Plans/Blueprint

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes ... (2013)]

COMPONENTS DESCRIPTION

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model ⁸	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID

⁸ If no vendor model, introduce main features: Cooling Capacity, COP, etc.



D4.1: Evaluation Methodology and preliminary pilots descriptions

COOLING

GENERAL DESCRIPTION

Energy source	
Production system	
Distribution (secondary)	
Terminal units	
Control	
Interaction (user + how is the interaction)	
Problems	
Potential eTEACHER interventions	
Other comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]



D4.1: Evaluation Methodology and preliminary pilots descriptions

Design Plans

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes ... (2013)]

COMPONENTS DESCRIPTION

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID



D4.1: Evaluation Methodology and preliminary pilots descriptions

VENTILATION

GENERAL DESCRIPTION

Energy source	
Production system	
Distribution (secondary)	
Terminal units	
Control	
Interaction (user + how is the interaction)	
Problems	
Potential eTEACHER interventions	
Comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]

Design Plans

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes ... (2013)]

COMPONENTS DESCRIPTION



D4.1: Evaluation Methodology and preliminary pilots descriptions

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID

1.5.2 Domestic Hot Water

GENERAL DESCRIPTION

Energy source	
Production type	
Power installed	
Control	



D4.1: Evaluation Methodology and preliminary pilots descriptions

Users interaction	
Problems	
Potential eTEACHER interventions	
Comments	

COMPONENTS DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

1.5.3 Lighting

GENERAL DESCRIPTION

Lighting type	
Power installed	
Control	[central/manual; schedule, etc]
Users interaction	
Problems	
Potential eTEACHER interventions	
Comments	

COMPONENTS DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

1.5.4 Other equipment

[Include computers, washing machines, printers, etc.]



D4.1: Evaluation Methodology and preliminary pilots descriptions

DEVICES DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.5.5 Electric cabinet

CABINETS DESCRIPTION

[Include 1 table per cabinet]

Name / location	
Description	
Picture	
Single Line Diagram	
Main electric meter type	[digital, analogic, smart meter, etc.]

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.6 Monitoring system

Variables (measurements / sample time)	
--	--



D4.1: Evaluation Methodology and preliminary pilots descriptions

Network configuration	[description & diagram/squema]
Sensors type (vendor model)	
Communication protocol(s)	
Monitoring software	
Other components description (pcs, router, modem, gateways, etc.)	
Interoperability / reuse in eTEACHER	
Other comments	

1.7 Control system: BACS / BEMS

Variables (measurements / frequency)	
Controlled variables	
Setpoints	
Network configuration	[description & diagram/squema]
Sensors type (vendor model)	
Actuators type (vendor model)	
Communication protocol	
BEMS/BACS software	
Other components description (pcs, router, modem, gateways, etc.)	
Interoperability / reuse in eTEACHER	
Other comments	



D4.1: Evaluation Methodology and preliminary pilots descriptions

1.8 Historical monitoring & energy consumption data

[Registered data from previous years, invoices, etc.]

Name	File type /format	Data type /frequency

1.9 Energy Audits

Date	Objective	ECMs applied	Report name

1.10 Summary of building problems related to energy efficiency according to users

Building problems	
Potential eTEACHER interventions	

1.11 Additional information



D4.1: Evaluation Methodology and preliminary pilots descriptions

Annex B. Behaviour Change Evaluation

Behaviour Change Evaluation	Whole building level		Monitored rooms/apartments level		Control room/apartment level	
	Self-reported	Monitored	Self-reported	Monitored	Self-reported	Monitored
Lighting behaviours Examples; <ul style="list-style-type: none"> Turning off lights when leaving a room or at end of day Checking lighting levels and needs during day – reducing use of unneeded lights Replacing bulbs with more energy-efficient ones Installing improved lighting and controls Making use of natural light more 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on lighting – e.g. <ul style="list-style-type: none"> Use of lighting in building Awareness of lighting Control of lighting and capability of users Attitudes towards lighting Use of additional light sources – lamps etc. Utilising natural light 	<ul style="list-style-type: none"> Whole building lighting consumption [Monitoring Data] External solar radiation [Monitoring data] vs. lighting consumption (daily) [Monitoring data] 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on lighting – same as whole building level survey 	<ul style="list-style-type: none"> Room/Apartment level total lighting consumption [Monitoring Data] Lighting levels in room/apartment [Monitoring data] Lighting consumption vs. occupancy/presence data [Monitoring data] to assess if lights being left on when room/apartment empty 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on lighting – same as whole building level survey 	<ul style="list-style-type: none"> Room/Apartment level total lighting consumption [Monitoring Data] Lighting levels in room/apartment [Monitoring data] Lighting consumption vs. occupancy/presence data [Monitoring data] to assess if lights being left on when room/apartment empty
Appliance use behaviours Examples; <ul style="list-style-type: none"> Ensuring appliances are not left on standby overnight Changing default settings or manually using sleep/hibernate modes and 'screen off' when computer is not in use Turning off computer if away from desk for any length of time 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on appliance use – e.g. <ul style="list-style-type: none"> Awareness of energy consumption from appliance use Use of appliances (number, frequency, duration) Attitudes towards appliance use Use of personal appliances (mainly focusing on schools, HCC and offices) Capability of users 	<ul style="list-style-type: none"> Whole building level consumption from appliances [Monitoring Data] (Total energy – total lighting consumption – total heating consumption) 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on appliance use – same as whole building level survey Use of ICT, knowledge and skill [Feedback Forums] 	<ul style="list-style-type: none"> Total consumption of appliances being monitored in room/apartment [Monitoring Data] Comparison of average daily consumption [Monitoring Data] and impact when campaigns/information is given out focused on appliance use [App Data] 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on appliance use – same as whole building level survey 	<ul style="list-style-type: none"> Total consumption of appliances being monitored in room/apartment [Monitoring Data] Comparison of average daily consumption [Monitoring Data] and impact when campaigns/information is given out focused on appliance use to see if social influence has an impact on control groups [App Data]



D4.1: Evaluation Methodology and preliminary pilots descriptions

<ul style="list-style-type: none"> Turning off own computer at end of the day Changing power mode to be more efficient Choosing more efficient hardware and default settings Turning off chargers once fully charged Turning off TVs/screens at end of the day Turning off projectors when not in use Turning off medical equipment if possible 	<ul style="list-style-type: none"> to change appliance settings or types If there are any appliances being used which cannot be switched off (particularly important in HCC) IT literacy levels Understanding of ICT 					
<p>Comfort related behaviours</p> <p>Examples;</p> <ul style="list-style-type: none"> Reducing thermostat temperature for heating Managing temperature via clothing or activity rather than heating/cooling whole space Increasing air-conditioning temperature set for cooling Ensuring that air-conditioning and heating not on at the same time Ensuring that if heating is on, windows and doors are kept 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on user comfort in buildings – e.g. <ul style="list-style-type: none"> Satisfaction of thermal environment in building User perceptions of temperatures in building Comfort expectations of users Capability of users in altering temperatures in building Use of air conditioning Use of heating Adaptive comfort behaviours Use of personal fans/heaters to achieve satisfaction 	<ul style="list-style-type: none"> Whole building level heating and cooling consumption [Monitoring Data] Whole building level average temperatures [Monitoring Data] 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on user comfort – same as whole building level survey Self-reported issues around comfort via the app [App Data] 	<ul style="list-style-type: none"> Total consumption of heating/cooling in room/apartment [Monitoring Data] – if possible to sub-meter Comparison of average daily heating consumption [Monitoring Data] and impact when campaigns/information is given out focused on adaptive measures to improve comfort without using HVAC systems [App Data] User's reporting discomfort in building [App Data] Temperatures in room/apartment [Monitoring Data] Window opening occurrence [Monitoring Data] Temperature and presence data 	<ul style="list-style-type: none"> Survey Questions [Survey Data] on user comfort – same as whole building level survey 	<ul style="list-style-type: none"> Total consumption of heating/cooling in room/apartment [Monitoring Data] – if possible to sub-meter Comparison of average daily heating consumption [Monitoring Data] and impact of social influence when campaigns or information is given out focused on adaptive measures to improve comfort without using HVAC systems [App Data] Temperatures in room/apartment [Monitoring Data] Window opening occurrence [Monitoring Data] Temperature and presence data [Monitoring Data] to detect if heating is on



D4.1: Evaluation Methodology and preliminary pilots descriptions

<ul style="list-style-type: none"> closed (if possible) to keep the heat from escaping Choosing more efficient systems or better use of system settings Reducing use of personal fans/heaters within the building 	<ul style="list-style-type: none"> ➤ Attitude towards heating/cooling in building ➤ Knowledge and awareness of energy consumption from heating/cooling 			<ul style="list-style-type: none"> • Temperature and window opening data [Monitoring Date] to detect if windows are open when heating is on 		<ul style="list-style-type: none"> • when not needed • Temperature and window opening data [Monitoring Date] to detect if windows are open when heating is on
<p>Engagement behaviours</p> <p>Examples;</p> <ul style="list-style-type: none"> • Self-reporting energy-related behaviours in response to in-app activities and challenges • Reporting comfort levels to app in response to prompts • Viewing energy consumption of whole building • Viewing energy consumption of own room/apartment • Using eTEACHER tool to report any building issues (e.g. overheating, too cold, equipment failures etc.) with Facility Management • Using eTEACHER tool for Facility Management to report back to users the 	<ul style="list-style-type: none"> • Survey Questions [Survey Data] – on engagement with the eTEACHER tool (questions suited to second survey) e.g. <ul style="list-style-type: none"> ➤ What users like or dislike about the tool ➤ How often users engaged with the tool ➤ What information did users engage with ➤ Was the tool useful to users ➤ Did users utilise the tool to report issues in the building ➤ How did energy managers /facility staff use the tool ➤ Did users share ideas, tips with others 	<ul style="list-style-type: none"> • Number of registered users (if design includes profile creation for users) [App Data] • Number of active users (those who have used the tool) [App Data] • Number of active users over time (how has engagement changed over time) [App data] • Number of users logging reports in building via app [App Data] 	<ul style="list-style-type: none"> • Survey Questions [Survey Data] on engagement with the eTEACHER tool – same as whole building level survey • What users want from the tool [Feedback Forum, Survey] • What users like, dislike, would change in the app [Feedback Forum, Survey] • Usability of tool and influence on engagement [Feedback Forum] 	<ul style="list-style-type: none"> • Number of interactions with app [App Data] 	<ul style="list-style-type: none"> • Survey Questions [Survey Data] - relating to social influence will allow to see if those in the control groups have engaged with eTEACHER e.g. <ul style="list-style-type: none"> ➤ Have you changed your energy use/behaviour over the last X months? ➤ If yes, why? ➤ Are you aware of the eTEACHER tool? ➤ Have you used the eTEACHER tool? 	N/A



D4.1: Evaluation Methodology and preliminary pilots descriptions

<p>status of any issues in building</p> <ul style="list-style-type: none">• Viewing energy data for specific appliance use• Discussing energy-related issues, such as sharing tips and suggestions with other building users						
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