
eTEACHER

# D4.5: Evaluation of eTEACHER results. First release

## *WP4*, *T4.4* Monitoring, data collection and end-users' feedback after eTEACHER deployment and evaluation of results

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eTEACHER

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**Disclaimer**

*The information reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.*

**Technical References**

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# 1 Introduction

The project eTEACHER aims to develop a set of ICT tools to empower building users (building owner, occupants and facility managers) to save energy and optimise indoor environmental quality. The mission of these tools is to encourage building users to change their behaviour towards energy efficiency. For that purpose, eTEACHER tools process information from buildings and users, integrate behavioural change techniques and provide tailored advice.

The project lasts three and a half years. During the first year, social studies were carried out to identify key aspects of behavioural change and to translate the findings into recommendations for the design of empowering ICT tools. The second year and a half focused on the development of the tools, including the communication interfaces (UBCI), the data processing services (What-if Analysis, Metrix, Pulse) and the user interfaces (eTEACHER mobile App and dashboard). The last year is the demonstration phase. The buildings´ users are provided with the project´s tools and the impact of the tools in terms of behavioural change, energy savings and indoor environmental quality is evaluated.

The work presented in this deliverable is part of Task 4.4 Monitoring, data collection and end-users´feedback after eTEACHER deployment and evaluation of results which aims at:

- Analysing energy consumption and indoor climatic conditions after eTEACHER deployment
- Quantifying how frequently the tools are used as well as carrying out surveys, questionnaires and interviews to analyse the users acceptance and engagement
- Comparing the analysis after eTEACHER with the analysis before eTEACHER to evaluate the behavioural change and its impact on energy savings and indoor environmental quality
- Finding out conclusions, best practises and suggestions to incentive behavioural change.

The report explains a preliminary evaluation of the project results in terms of behavioural change towards energy efficiency, energy savings and enhancement of indoor environmental quality. For that purpose, the analysis of the buildings and their users after receiving eTEACHER tools is compared with the analysis of the buildings and their users before eTEACHER. The analysis is based on monitoring data and users feedback collected by means of surveys or interviews. Specifically, the tools were massively provided to the building users by mid of October 2020 and the data analysed correspond until mid January 2021, so this report presents the analysis of the impact of the tools during these three months. It should be noted that this document is a first release of the project results and there will be a second release by the end of the project (June 2021) with the data of three more months.

The deliverable is structured in 6 main sections: Introduction, Background, Demonstration activities, Demonstration Results, Lessons learned and Conclusions. Introduction presents the context of the deliverable; Background summarises previous works of the project that are key for this deliverable; Demonstration activities describes all the actions carried out during the demontration phase; Demonstration results explains the users feedback, surveys and statistics and the evaluation of the monitoring data in terms of energy savings, enhancement of indoor environmental quality and behavioural change; Lessons learned summarizes the highlighted knowledge gained according to the experience of the pilot coordinators and tools developers; Conclusions draws main findings and next steps.

# 2 Background

The eTEACHER project is demonstrated in **12 pilot buildings** which include 1 office building, 2 schools, 1 residential building and 2 health care centres in Spain; 1 office building and 1 school in UK, and 4 residential buildings in Romanian. Table 2.1 shows an overview of the pilot buildings which were characterized in T4.2 Initial monitoring and data collection before eTEACHER using existing documentation about the pilot buildings as well as data collected during pilot visits, monitoring devices and surveys (see (Jiménez- Redondo, 2018) and (Calleja-Rodriguez, 2019)).

**Table 2.1 Overview on pilot buildings**

| Type | Building name (location) | Potential target users | Technical Systems | USE CASES |
|---|---|---|---|---|
| **Office** | OAR - Organismo Autónomo de Recaudación (Spain)<br>2011, 3210.97 $m^2$ (3 floors) | 130 users: Managers, staff, cleaning crew and security team | HVAC - Heating and cooling based on VRF heat pump and compact AHU. Individual offices present specific split systems.<br>Appliances - Computers, printers, beamers and electric radiators<br>Lighting – Fluorescent lamp | ECM1, ECM2, ECM3, BP1, IEQ1 |
| | NCR - Nottingham Council House (UK)<br>1927, 5826 $m^2$ (7floors) | 40 regular users: energy managers, staff, cleaning crew and security team | HVAC – District heating and radiators/convectors. Some AHUs for meeting rooms. Some electric radiators in offices<br>Appliances - Computers, printers and electric radiators<br>Lighting – upgrading with LED | ECM2, ECM3, ECM4, BP1, IEQ1 |
| **Residential** | Apartment Block Badajoz (Spain)<br>1984, 4540 $m^2$, 5 floors | 95 users: manager and householders | HVAC – 4 boilers (natural gas) and radiators. Individial cooling splits in some apartments<br>Appliances – home appliances<br>Lighting – fluorescent lamps | ECM1, ECM2, ECM3, ECM4, IEQ1 |
| | InCity (Romania)<br>2009, 67900 $m^2$,<br>4 buildings | 1500 users: Energy/Facility managers and householders | HVAC – District heating and radiators. Splits for cooling<br>Appliances – home appliances<br>Lighting – LED | ECM1, ECM2, ECM3, ECM4, BP1, IEQ1 |
| **School** | IES Torrente Ballester - High School (Spain)<br>1965, 5307 $m^2$<br>3 floors | 120 users: Managers, staff, teachers & students | HVAC – Boiler (fuel-oil) and radiators. Splits for cooling in teachers and administrative offices<br>Appliances – computers, printers and beamers<br>Lighting – Fluorescent lamps | ECM2, ECM3, IEQ1 |

| Type | Building name (location) | Potential target users | Technical Systems | USE CASES |
|---|---|---|---|---|
| | CEI Arco Iris – Kindergarten (Spain)<br>1976, 905 m2, 1 floor | 20 users: Managers and teachers | HVAC – Boiler (fuel-oil) and radiators. Splits for cooling<br>Appliances – computers, printers, beamers and home appliances<br>Lighting – Fluorescent lamps | ECM1, ECM2, ECM3, ECM4, IEQ1 |
| | Djanogly City Academy (UK)<br>2005, 9163 m2, 2 floors | 800 users: Staff (managers and teachers) and students | HVAC – Boiler (gas) and underfloor heating, radiators. AHUs. Electric chillers and cold ceilings<br>Appliances – computers, printers, beamers and lab equipment<br>Lighting – Fluorescent lamps | ECM1, ECM2, ECM3, ECM4, BP1, IEQ1 |
| **Health Care Centre** | Guareña (Spain)<br>2000, 1270 $m^2$, 2 floors | 577 users: Managers and medical staff | HVAC – heatpumps and splits<br>Appliances – Computers, printers and medical equipment<br>Lighting – Fluorescent lamps | ECM1, ECM2, ECM3, ECM4, IEQ1 |
| | Villafranca de los Barros (Spain)<br>2002, 2180 $m^2$, 2 floors | 915 users: Managers and medical staff | HVAC – heatpumps, fancoils, AHUs<br>Appliances – Computers, printers and medical equipment<br>Lighting – Fluorescent lamps | 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

## 2.1 Evaluation methodology

The evaluation methodology of eTEACHER was defined in (Jiménez- Redondo, 2018). It uses measured and self-reported evidences and is based on three methods: *monitoring, eTEACHER app and feedback forum &surveys*.

The ***monitoring*** collects following data at building level and apartment/room level:

- Outdoor conditions: Temperature (ºC), CO2 (ppm), Relative Humidity (%), Solar radiation (W/m2)
- Indoor conditions: Temperature (ºC) , CO2 (ppm), Relative Humidity (%), lighting level (lux)
- Energy consumption(kWh): lighting, HVAC, appliances
- Others: Presence & windows opening

The ***eTEACHER app*** collects users statistics such as:

- Number of users registered
- Number of active users per specific building
- Number of users per specific route/functionality

- Number of accepted recommendations

The ***Feedback Forum*** are used to generate discussions with pilot building users and collect their feedback on eTEACHER tools (what do users like, dislike, identify things that could be improved, what do users use predominantly, etc).

The ***surveys*** are carried out pre and post eTEACHER and aim at collecting information about comfort, energy behaviour and awareness and use of lighting, appliances, heating and cooling.

Besides, ***key performance indicators*** **(**KPIs) were defined in (Jiménez- Redondo, 2018) for impact assessment. Table 2.2 and Table 2.3 summarize the KPIs that will be used to measure project impact and how they will be calculated.

**Table 2.2 Evaluation procedure to calculate KPI based on data collection (Jiménez- Redondo, 2018)**

| Evaluation of… | Measures | Calculation procedure |
|---|---|---|
| **IM1. Evaluation of energy Savings and reduction of CO2 emissions** | **Building level**<br>Lighting sub-metering<br>Appliance sub-metering<br>Heating/cooling consumption<br>Outdoor conditions (including solar radiation)<br>**Room/apartment level**<br>Energy consumptions (lighting, devices, etc.) | 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 %.<br>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.<br>Complementary analysis comparing energy consumption regarding outdoor conditions, indoor conditions and occupancy will be analysed to detect main sources of energy consumption.<br>Energy indicators: $ESR_b$, $GHG_s$ |
| **IM2. Fast deployment** | Building characterization and database preparation<br>Monitoring system installation and programming<br>eTEACHER deployment (web services and devices integration) | Based on eTEACHER experience: Estimation of time needed for building characterization regarding area (m2) and typology of energy systems. Templates and general protocol provided. This information is provided by pilot and project coordinators according to the experience. Characterization time: $t_c$ (weeks).<br>Estimation of time needed for additional monitoring system: Time used for installation and commissioning of basic devices** with regard to all the monitoring devices. This information is provided by pilot coordinators after monitoring commissioning. Deployment time: $t_d$ (weeks).<br>$t_{cd} = t_c + t_d$ |
| **IM3. Fast adoption** | | To estimate the fast adoption of the app's functionalities, it is necessary to know the |

| Evaluation of… | Measures | Calculation procedure |
|---|---|---|
| | Average time of use (all users) per week.<br>Feedback (survey): number of users willing to user the app after demonstration. | number of total users and the average active users over the demonstration period. The ratio of both indicators allows estimating the percentage of users that keep using the app and, thus the ratio of users that has accepted the app as usual tool to change the energy behaviour. This indicator is defined as follows:<br>**IM3 = $A_V N_U$ / $N_U$ x 100 (%)**<br>According to the eTEACHER objectives, a successful ratio should be between 15-30% of users.<br>On the other hand, IM3 will be assessed through direct survey, requesting the end-user's willingness to use the tool after the project and their experience with the gamification aspects.<br>Both numbers will be compared as double-check to determine the real acceptance with the real user's feedback. |
| **IM4. Number of users changing behaviour** | Energy savings (IM1)<br>Users' interaction with eTEACHER app<br>Changes reported by building users | Number of users changing energy behaviour can be measured according to 3 aspects: (1) energy savings motivated by eTEACHER toolbox and collected through the monitoring system; (2) user's acceptance of the app; (3) target behaviours and the direct feedback of end-users through surveys.<br>(1) IM1 will be calculated as it is explained above in this table. Energy savings is the indicator that leads and validates the effectiveness of changing behaviour. In addition, the indicator $TB_{energy}$ allows quantifying the real energy used when a target behaviour is not carried out and detect the sources of energy inefficiencies.<br>(2) The user's acceptance is calculated with the average number of users accepting at least one recommendation per week ($N_{U,A}$).<br>(3) Target behaviours indicators allow calculating the number of hours, the amount of energy and energy costs related to the end user behaviour ($TB_h$, $TB_{energy}$, $TB_{cost}$). On the other hand, IM4 will be assessed through direct survey, requesting the end-user's opinion about their behaviour change regarding energy, comfort and IEQ aspects. |
| **OIM1 RoI based on energy savings and investments** | Building pilot budgets<br>Whole energy savings (IM1) | 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 |

| Evaluation of… | Measures | Calculation procedure |
|---|---|---|
| | | pilots and the final budget allocated for the monitoring system and BACS add-ons solutions, a.k.a. payback time (PBT).<br>**PBT = $(C_i+C_s)$ / $(C_e – 12 \times N_u \times C_f)$** |
| **OIM2. Direct economic growth due to a new type of ICT product** | Building pilot budgets<br>Whole energy savings (IM1)<br>Monthly subscription fee for eT online services (assumption)<br>Number of app users | Direct economic growth can be defined as the turnovers motivated by the installation of eT solution in target buildings. Therefore, this value comprises the installation costs, monitoring costs, energy savings costs and subscription fees, which determine the related incomes, investments and profits.<br>To perform this calculation, it is assumed that eT consortium will target mainly the EU building stock of main developers and building pilots, i.e. Spain, UK, Romania, Finland and Germany. Besides, to increase the accuracy and credibility of calculation, using the information from the European Building Observatory, we will differentiate between countries and building types, considering the type of buildings as reference regarding number of buildings and surface.<br>The general assumption is to achieve the 1% of EU building stock in 10 years with 10 000 initial projects, what means 505.703 buildings addressed with 47.6 Mm2 of surface.<br>Equation: **Direct Economic Growth in 10 years (€) = $C_i + C_s + C_e + 12 \times N_{u\_acu} \times C_f$,** where:<br>Nu_acu = cumulative number of users in 10 years. |
| **OIM3. Indirect Economic Growth** | Installation time<br>Design and preparation time for eT solution | Indirect economic growth is related with the number of employees generated by the eT solutions, which comprises installers, ICT developers, ICT providers and related administrative and logistics.<br>To perform this calculation, it is assumed that eT consortium will target mainly the EU building stock of main developers and building pilots, i.e. Spain, UK, Romania, Finland and Germany. Besides, to increase the accuracy and credibility of calculation, using the information from the European Building Observatory, we will differentiate between countries and building types, considering the type of buildings as reference regarding number of buildings and surface.<br>The general assumption is to achieve the 1% of EU building stock in 10 years with 10000 initial |

| Evaluation of… | Measures | Calculation procedure |
|---|---|---|
| | | projects, what means 505.703 buildings (projects) addressed with 47.6 Mm2 of surface.<br>In addition, it is assumed that a technical team will be composed of 1 designer (engineer), 2 installers, 5 ICT providers and an additional 20% of people supporting administrative and logistics. In total 10 people per team.<br>To calculate the number of projects (buildings) that can perform a working team in one year, it is considered 48 weeks/year regarding the time to deploy the entire solution:<br>Equation: $\mathbf{P_n = 48 / t_{cd}}$ where:<br>$P_n$ is the number of projects per year per team<br>$t_{cd}$ is the deployment time in weeks<br>The maximum number of workers over 10 years will be considered as the Indirect Economic Growth of eTEACHER. |
| **OIM4. Growth of innovative SME** | Installation time<br>Design and preparation time for eT solution | Using the same approach as OIM3, we assume the creation of a new SME every 40 new workers. Therefore, the formula of this indicator is: $\mathbf{N_{SME} = OIM3 / 4}$ where $N_{sme}$ is the number of new SME triggered by eTEACHER. |
| **OIM5. European leadership on ICT solutions for Energy Efficiency** | Contribution to smart home market in EU-28 | The last report of "Smart Home and Home Automation" magazine shows (see **Error! Reference source not found.**) the following projections, demonstrating that EU will be leading the smart market on 2021 (see figure below). Considering the 1% of residential buildings addressed in ten years in eT target countries, that means: 4880 multi-family dwellings with more than 4 homes, thus 24404 average homes, **what constitutes the 0.03%** of the expected smart home market in EU28+2, according to assumptions. |
| **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. 24º C, 50% humidity ratio and 360 ppm $CO_2$). |

**Table 2.3 Demonstration indicators (measured and calculated) (Jiménez- Redondo, 2018)**

| Symbol | Indicator (*) | Comment / Equation |
|---|---|---|
| $E_b$ | Building energy consumption | Recommended in monthly basis. HVAC consumption, lighting and appliances. |
| $E_{cr}$ | Control room energy consumption | Recommended in monthly basis. HVAC consumption, lighting and appliances. |
| $E_{ms}$ | Monitoring and Study room energy consumption | Recommended in monthly basis. HVAC consumption, lighting and appliances. |
| $E_{sr}$ | Study rooms energy consumption | $E_{sr} = E_b - E_{ms} - E_{cr}$ |
| $F_{es}$ | Energy saving factor (> 1) | Ratio of energy savings comparing the control room with a monitored and study room. In case of several monitored and study rooms, it will be considered the average value. $F_{es} = E_{cr} / E_{ms}$ |
| $ES_b$ | Building energy saving | Estimated energy saving at building level with the energy saving factor. This factor is applied to study rooms to increase virtually their consumption values. $ES_b = (E_{ms} + E_{sr}) \times F_{es} + E_{cr} - E_b = (E_b - E_{cr}) \times (1- F_{es})$ |
| $ESR_b$ | Building energy saving ratio (%) | Estimated energy saving ratio. $ESR_b = E_b / (E_b - E_{cr}) / (1- F_{es})$ |
| $GHG_s$ | CO2 savings through energy savings | kg of CO2 obtained by energy savings. This value will be calculated with the official CO2 conversion factor (CF) by country and energy sources (gas, electricity and fuel) $GHG_s = CF \times ES_b$ |
| $C_i$ | Installation costs | Costs related to working people deploying the monitoring system, including assembly material and configuration tasks. |
| $C_s$ | Monitoring costs | Costs related to the sensors to acquire the necessary information for the BACS add-ons. It is assumed that the 50% of project monitoring costs will be necessary to undertake the future commercial solution. |
| $C_e$ | Annual energy saving costs | This cost is calculated with the average energy cost ($C_a$) and the monthly building energy saving ($E_{bs}$) as follows: $Ce = C_a \times \sum E_{bs}(t)$ |
| $N_u$ | Number of users | Number of user's app licenses |
| $N_{U,A}$ | Number of users per week accepting at least one recommendation | This indicator is collected through the server analytic tools |

| | | |
|---|---|---|
| $C_f$ | Monthly subscription fee | Monthly subscription fee per user. This value will be provided and agreed by ICT developers at the end of the project. |
| $IEQ_T$ | Percentage of occupied hours with temperature out of standard comfort parameters | Indoor Comfort Temperature range 21-26º C<br>$IEQ_T$ = (Number of hours in 21 ≤ Indoor temperature (º C) ≤ 26) / (Number of occupied hours) x 100 |
| $IEQ_H$ | Percentage of occupied hours with relative humidity out of standard comfort parameters | Indoor Comfort Relative Humidity 40-60%<br>$IEQ_H$ = (Number of hours in 40 ≤ Relative humidity (%) ≤ 60) / (Number of occupied hours) x 100 |
| $IEQ_{CO2}$ | Percentage of occupied hours with CO2 level out of the standard healthy levels | Indoor healthy (productivity) CO2 level: ≤ 800 ppm<br>$IEQ_{CO2}$ = (Number of hours in CO2 ≤ 800 ppm) / (Number of occupied hours) x 100 |
| $IEQ_L$ | Percentage of occupied hours with luminance out of the recommended lighting levels | Indoor Luminance ≥500 lux (≥150 lux in residential buildings)<br>Non-residential building:<br>$IEQ_L$ = (Number of hours in Luminance ≥ 500 lux) / (Number of occupied hours) x 100<br>Residential building:<br>$IEQ_L$ = (Number of hours in Luminance ≥ 150 lux) / (Number of occupied hours) x 100 |
| $TB_h$ | Number of hours that a target behaviour is not carried out by the users of the building | These values are calculated with the data acquired from the monitoring system: Turning off lights when leaving a room or at the end of the day; TB2: Reduce use of unneeded lights checking lighting levels and needs during the day; TB3: Turn off appliances at the end of the day; TB4: Appliances off when away from room for 1 hour or more; TB5: Reducing thermostat temperature for heating when overheating; TB6: Increasing thermostat temperature for cooling when undercooling; TB7: Ensuring that if heating/cooling is on, windows and doors are kept closed (if possible); TB8: Turn off HVAC system if room/building is not in use for more than one hour; TB9: Ensuring that air-conditioning and heating are not working at the same time. |
| $TB_{energy}$ | Energy used/wasted during the hours that a target behaviour is not carried out by the users of the building (kWh) | |
| $TB_{cost}$ | The cost of the energy used/wasted during the hours that a target behaviour is not carried out by the users of the building (€) | |

The ***experimental design*** of the project was also defined (Jiménez- Redondo, 2018). It is based on eeMeasure Methodology (Woodall, 2011) and consists of comparing control environments (environments that will never get eTEACHER) with study environments (environments that will get eTEACHER tools during the demonstration phase) 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. It should be noted that the control zones/environments must have similar conditions as the study zones/environments (orientation, use, schedule, number of people, energy

systems, energy appliances…) to compare the evolution of both zones before and after the deployment of eTEACHER toolbox. 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.

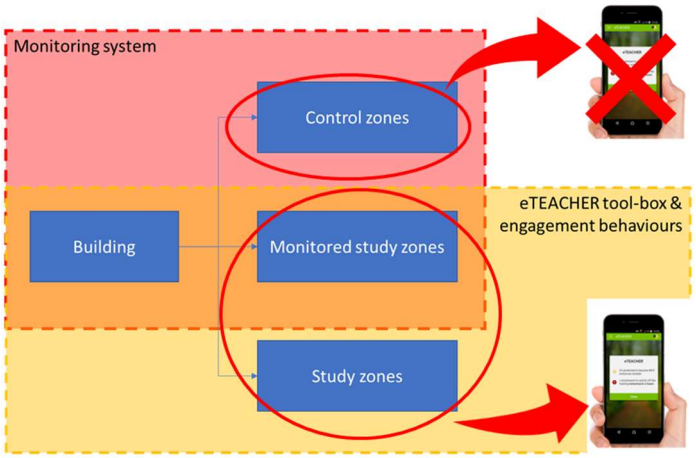



**Figure 2.1 Control and study environments used in the experimental design (Jiménez- Redondo, 2018)**

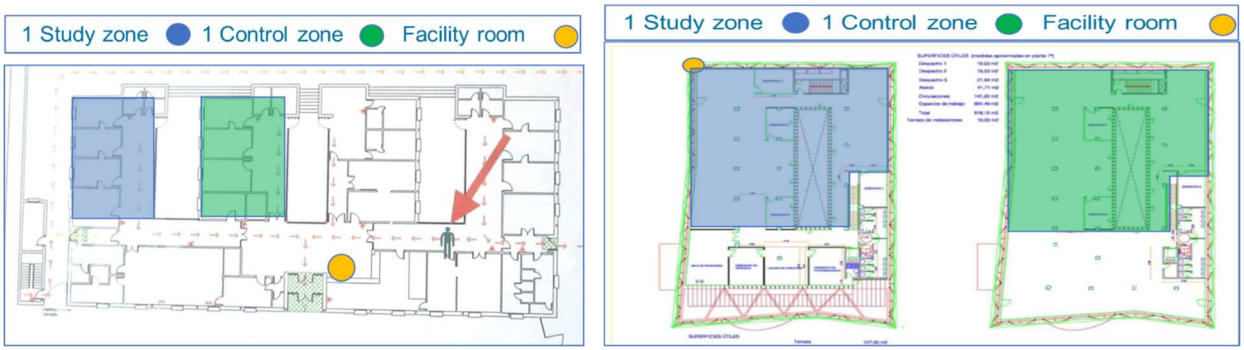



**Figure 2.2 Control and study environments used in 2 pilot buildings (Calleja-Rodriguez, 2019)**

## 2.2 Demonstration baseline

In Task 4.2 “Initial monitoring and data collection before eTEACHER. Pilots characterization” (Calleja-Rodriguez, 2019), the pilot buildings were analysed before eTEACHER using monitoring data and users feedback to define the baseline for energy and indoor environmental quality of the pilots. This first analysis was planned to be compared, at the end of the project with the data collected during the demonstration phase in order to see the impacts of the project.

In order to provide an overview of the energy consumption in every pilot building, the energy consumption (kWh) monitored every 10 mins was aggregated into daily and monthly consumption.

Specifically, the energy consumption in every building was analysed per type of use and in total not just at building level but also at room/zone level. Three main energy uses have been identified in the pilot buildings: lighting, HVAC and appliances.

To characterize the IEQ in every building, the monitoring temperature, relative humidity, luminance and $CO_2$ level were analysed every hour to quantify the number of hours where the rooms/zones are occupied and these variables are out of the thresholds where IEQ is guaranteed:

- Indoor Temperature: 21-26 ºC
- Indoor Relative Humidity: 40-60%
- Indoor Luminance: ≥500 luxes (≥150 luxes in residential buildings)
- Indoor $CO_2$ level: ≤ 800 ppm

In addition, the target behaviours were characterized for every building based on the monitoring rooms/zones (study and control rooms/zones). Such characterization consisted of quantifying the number of hours that these target behaviours are not carried out by the users of the buildings before eTEACHER is deployed, the energy (kWh) wasted during those hours and the cost of the energy wasted during those hours (€).

The pre-eTEACHER survey on users´ behaviours was also elaborated and distributed to buildings users addressing the following topics: comfort & you, energy & you, lighting & you, appliances & you.

The main conclusions of the demonstration baseline analysis were:

Regarding the users´ energy awareness, it was concluded according to the users behaviour surveys that there was an existing energy awareness in the users of the pilots that could be increased by eTEACHER project. Specifically, more than 55% of respondents said they currently took daily actions to reduce energy consumption. For example, 38 respondents (75%) stating that they turn off lights in empty rooms on a daily basis and the use of natural light is also reported as being a daily behaviour by 31 respondents (61%). On the other hand, there are still examples of inefficient behaviours regarding lighting use. It has been also identified that 65% of the respondents cannot access heating and/or cooling settings while ability to control different appliances is much greater.

In addition, it was identified that there was a potential to improve indoor environmental quality in all the pilot buildings analysed. The highest potential seemed to be by improving the luminance conditions. And the buildings with higher potential to improve IEQ are Torrente High School and Residential building in Badajoz.

Finally, the most promising target behaviours for eTEACHER were those ones related to the use of the cooling system: (TB6) Increasing thermostat if undercooling, (TB7) Close windows if HVAC is on, (TB8) Turn off HVAC if none. It should be noted that the data analysed corresponded to Spring and Summer so conclusions related to Winter season such as those ones related to the use of the heating systems couldnt be drawn.

It is important to remark that the data collected during the baseline period (Calleja-Rodriguez, 2019) belongs from January 2018 until September 2018 while the data collected during the demonstration period included in this report belongs from October 2020 until January 2021. This means that the baseline period and the demonstration period include different seasons and so that weather conditions and energy consumption profiles are quite different and cannot be compared. For that reason, in this report data from October 2019-January 2020 will be used as baseline period and data from October 2020-January 2021 will be used as demonstration period.

## 2.3 Action plan for validation

An action plan for validation was created in T4.3 eTEACHER installation, commissioning, operation, maintenance and final tuning and included in (Florian Frank, 2020). The action plan described the activities to be implemented during the demonstration phase by individual partners and detailed the roles and specific responsabilities.

It should be noted that this action plan is being followed with following modifications:

- The initial schedule has been changed due to the delay in the implementation of the tools and the delays caused by the project suspension due to COVID impact.
- Some additional activities (highlighted in red colour in Figure 2.4) have been added addressed the inconveniences caused by the project suspension and COVID

Following, the action plan for validation with the updated scheduled and activities is explained.

The validation has been divided into 3 phases (Figure 2.3):

- The **Kick-off phase** takes place during the first months (November 2019 until May 2020). It's the preparation of the demonstration and it aims to produce the planning and procedures for users training and engagement as well as for the supervision of the tools and monitoring data/sytems.
- The **Core phase** is from October 2020 till May 2021. It is the time when the building users are using eTEACHER tools. The keys of this phase are: the supervision of the monitoring and the tools to ensure good performance as well as supervision and enhance of the users´ engagement.
- The **Closure phase** lasts 1 month (June 2020) and is focused on evaluating results to draw main conclusions, best practises and suggestions.

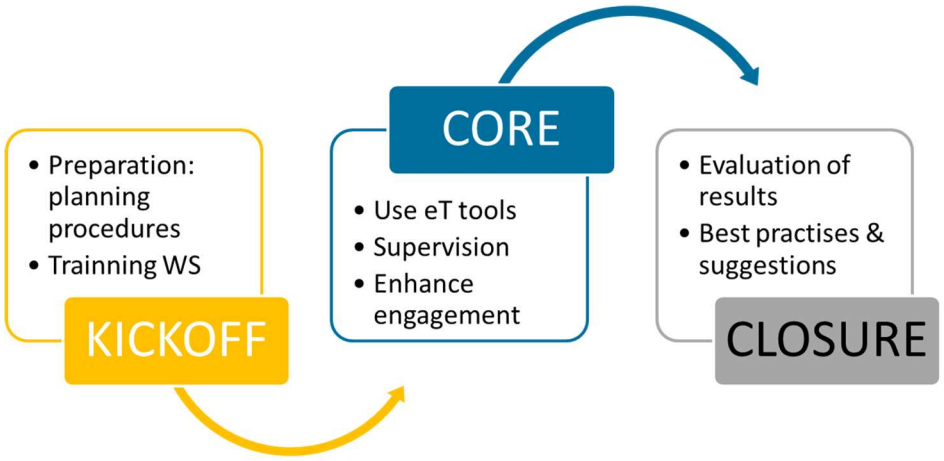
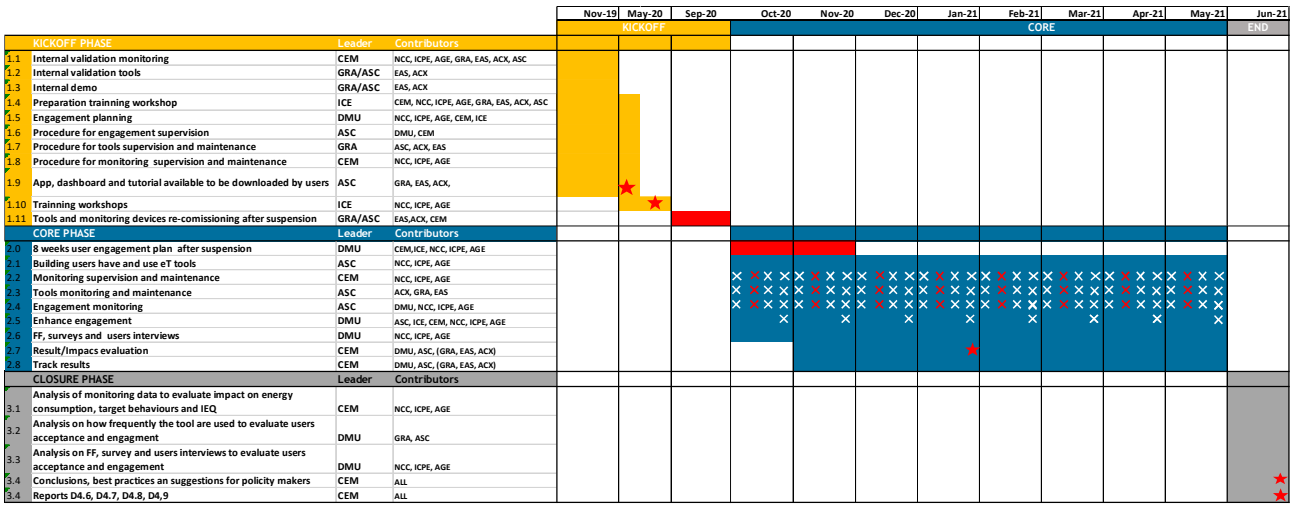



**Figure 2.3 Three Validation Phases: Kickoff, Core and Closure**

Figure 2.4 shows the updated overall action plan for validation with 11 activities foreseen for the first phase, 9 activities for the second phase and 4 activities for the last phase, the leader and contributors of every activity are defined as well as the timing. Further descriptions of the validation activities can be found in (Elina Neugebauer, 2019).




| | KICKOFF PHASE | Leader | Contributors |
|---|---|---|---|
| 1.1 | Internal validation monitoring | CEM | NCC, ICPE, AGE, GRA, EAS, ACX, ASC |
| 1.2 | Internal validation tools | GRA/ASC | EAS, ACX |
| 1.3 | Internal demo | GRA/ASC | EAS, ACX |
| 1.4 | Preparation trainning workshop | ICE | CEM, NCC, ICPE, AGE, GRA, EAS, ACX, ASC |
| 1.5 | Engagement planning | DMU | NCC, ICPE, AGE, CEM, ICE |
| 1.6 | Procedure for engagement supervision | ASC | DMU, CEM |
| 1.7 | Procedure for tools supervision and maintenance | GRA | ASC, ACX, EAS |
| 1.8 | Procedure for monitoring supervision and maintenance | CEM | NCC, ICPE, AGE |
| 1.9 | App, dashboard and tutorial available to be downloaded by users | ASC | GRA, EAS, ACX, |
| 1.10 | Trainning workshops | ICE | NCC, ICPE, AGE |
| 1.11 | Tools and monitoring devices re-comissioning after suspension | GRA/ASC | EAS,ACX, CEM |
| | **CORE PHASE** | **Leader** | **Contributors** |
| 2.0 | 8 weeks user engagement plan after suspension | DMU | CEM,ICE, NCC, ICPE, AGE |
| 2.1 | Building users have and use eT tools | ASC | NCC, ICPE, AGE |
| 2.2 | Monitoring supervision and maintenance | CEM | NCC, ICPE, AGE |
| 2.3 | Tools monitoring and maintenance | ASC | ACX, GRA, EAS |
| 2.4 | Engagement monitoring | ASC | DMU, NCC, ICPE, AGE |
| 2.5 | Enhance engagement | DMU | ASC, ICE, CEM, NCC, ICPE, AGE |
| 2.6 | FF, surveys and users interviews | DMU | NCC, ICPE, AGE |
| 2.7 | Result/Impacs evaluation | CEM | DMU, ASC, (GRA, EAS, ACX) |
| 2.8 | Track results | CEM | DMU, ASC, (GRA, EAS, ACX) |
| | **CLOSURE PHASE** | **Leader** | **Contributors** |
| 3.1 | Analysis of monitoring data to evaluate impact on energy consumption, target behaviours and IEQ | CEM | NCC, ICPE, AGE |
| 3.2 | Analysis on how frequently the tool are used to evaluate users acceptance and engagment | DMU | GRA, ASC |
| 3.3 | Analysis on FF, survey and users interviews to evaluate users acceptance and engagement | DMU | NCC, ICPE, AGE |
| 3.4 | Conclusions, best practices an suggestions for policity makers | CEM | ALL |
| 3.4 | Reports D4.6, D4.7, D4.8, D4,9 | CEM | ALL |

**Figure 2.4 Overall Action Plan for Validation (updated)**

# 3 Demonstration activities

Following, the different steps related to eTEACHER demonstration are summarised in order to understand the context:

1. In November 2019, ***a first release*** of the eTEACHER tools was delivered to a selected number of building users in every pilot to test them and collect their feedback.
2. ***Several tools releases*** were produced from November 2019 until May 2020 based on feedback of selected users and internal validation within the consortium. These enhancements included the development of new data validation algorithms, more detailed recommendations, better data processing, addition features in the App to make it more user friendly, new features for the virtual building, etc.
3. The ***tools were massively delivered*** first in Romanian pilots (January 2020) through training sessions with dedicated material developed for that purpose (videos, presentations and manuals). Then, the tools were provided to UK (April 2020) also using specific training sessions and material. Finally, the tools were delivered in the Spanish pilots (May 2020) sending the training material via email since COVID didn't allow face to face meetings at that time.
4. The ***project was suspended*** during 3 months (June 2020-August 2020) due to COVID impact. Many of the buildings were not used because of the lockdown and we didn't have access to the buildings to maintain the monitoring devices and ensure data quality for the tools.
5. The project was resumed in September 2020 and a ***recommissioning*** of the monitoring devices and tools was carried out until mid-October 2020 to ensure the right performance of eTEACHER tools.
6. The ***tools were massively delivered again*** for the second time in the Spanish and Romanian pilots by mid of October 2020 by means of an **engagement plan** that consisted of an 8 week plan to introduce one functionality of eTEACHER tools and one topic related to energy efficiency and indoor environmental quality using emails and appealing videos.
7. Continuous **supervision and maintenance of the *monitoring devices*** since mid-October 2020 to date to guarantee data quality
8. Continuous ***supervision and maintenance of the tools*** since mid-October to date to guarantee the right performance
9. Continuous ***supervision of users interactions*** with eTEACHER tools since mid October to date to evaluate the level of user engagement and develop contingency plans to increase user engagement if it is necessary.
10. **Collecting and analysis of monitoring data** from mid October 2020 to date to evaluate project results in terms of behavioural change and its impact on energy savings and indoor environmental quality enhancement (see section 4.2). In general, the demonstration period considered in this report includes 3 months from mid-October 2020 until mid January 2021 with some exceptions in some of the pilot buildings that will be explained along the document.
11. **Additional engagement activities** in December 2020:
    - Pilot coordinators contacted building users in the beginning of December 2020 by phone to support them with the tools, collect their feedback and encourage them to use eTEACHER app.

- An additional email was sent in December 2020 with a short survey to collect users feedback and circulate a new video to increase the use of eTEACHER tools.

12. Development and delivery of **feedback forum 5** in January/February 2021 for increasing user engagement and analyse users acceptance on eTEACHER tools (see section 4.1)

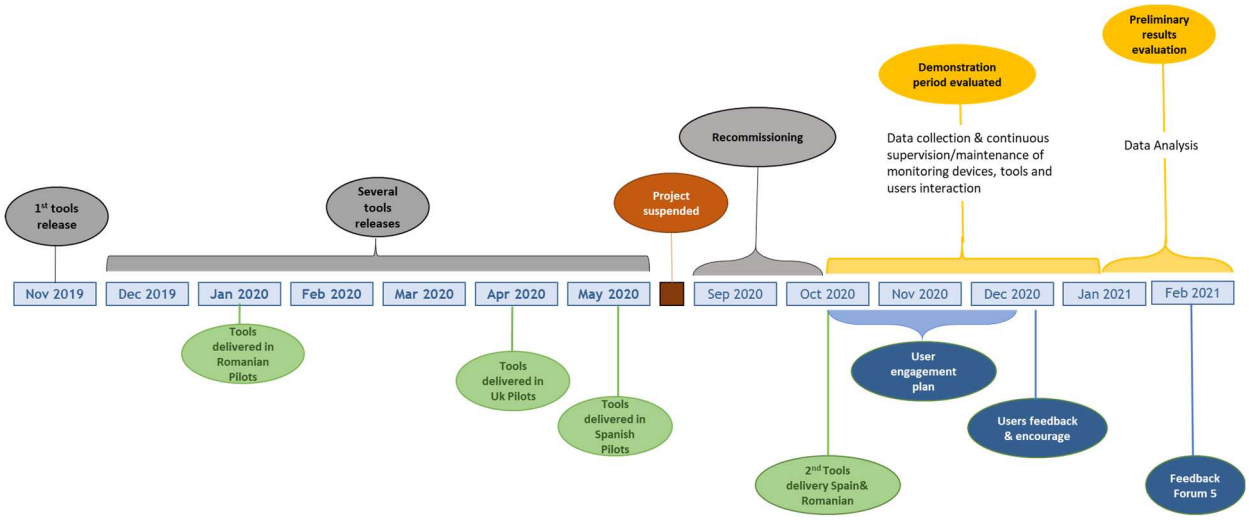



**Figure 3.1 Demonstration activities**

Following, some of the above-mentioned activities are further explained.

## Sessions and material for the first tools delivery

Training sessions were prepared for the first delivery of the tools (January 2020 – May 2020). This training sessions were planned to be physic meetings. Finally, only Romanian could have physic meetings. Spanish and UK pilots need to send the material developed via email and provide support via calls.

The material prepared consisted of:

- One presentation (Figure 3.2)
- Several videos introducing all the tools functionalities (Figure 3.3)
- User manual (Elina Neugebauer, 2019)


**Figure 3.2 Presentation for training sessions (summary)**

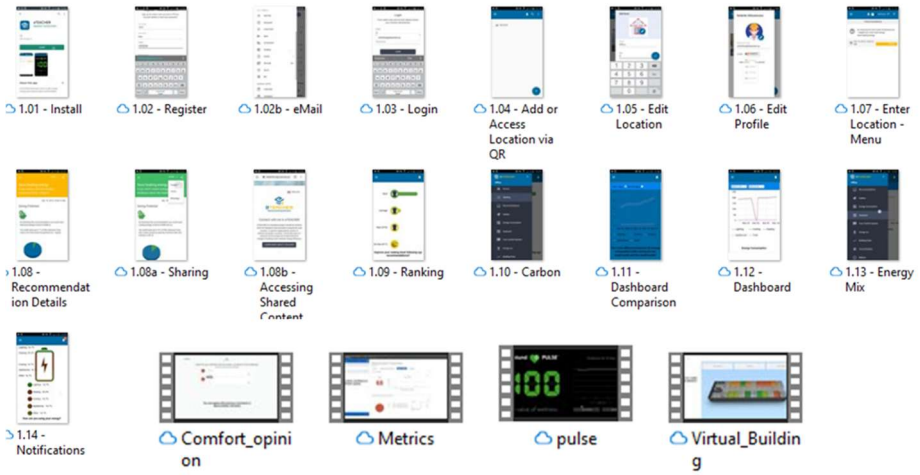



**Figure 3.3 Videos for training sessions (overview)**

## 8 weeks user engagement plan for the second tools delivery

Engagement from building users with the eTEACHER tool is a vital part for the successful demonstration of the tool and for evaluating the impact from the tool on energy consumption, health and wellbeing.

Following an initial meeting between project management, pilot coordinators, social experts and the projects dissemination and communication experts, the need for a clear engagement plan was obvious. This was further emphasised following a short suspension of the project due to COVID meaning no project activity has occurred in the pilot buildings during this period and therefore users' also need to be refamiliarized with the project.

Following, some details for the proposed engagement activities undertaken within the eTEACHER pilot buildings are explained. The engagement plan (October – November 2020) aimed to improve building users' acceptance and engagement with the eTEACHER tool.

The action plan consisted of sending weekly emails with a specific focus or purpose (remind eTEACHER project and app, appliances & recommendations function, gamification & ranking function, etc). The idea was to combine the tips provided by #eTEACHERatHOME campaign with one of the functionalities of eTEACHER App. At the end of the 8 weeks, the users should have received all the key messages of the project and should have understood the main functionalities and advantages of the App. The flow chart shown in Figure 3.4 depicts the different engagement points with the building users, with the subsequent sections describing each engagement point in more detail and the required impact monitoring for that point.

The content of the emails, including appealing text and videos, and the design of the emails were defined to maximized the impact on building users (Figure 3.5)

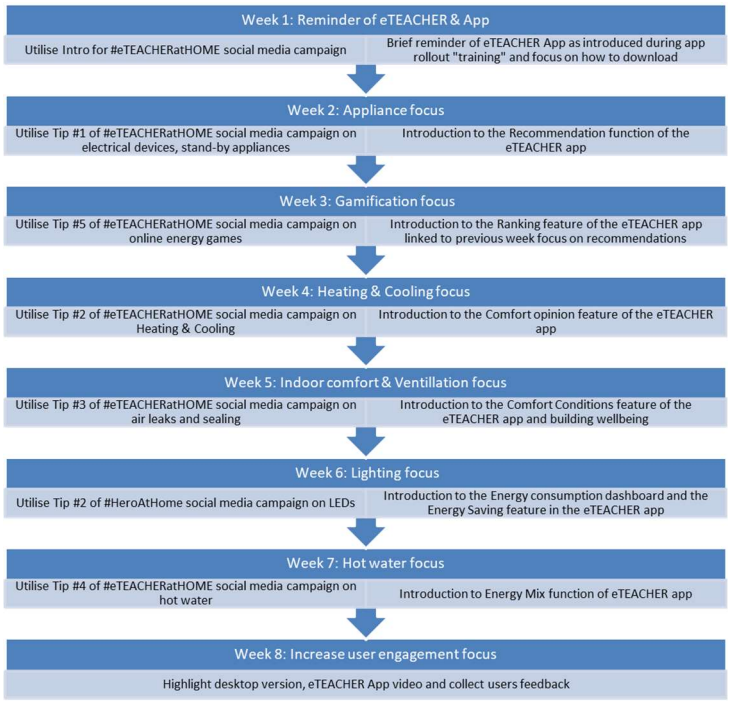



**Figure 3.4 Engagement activity communication plan detailing general topic and specific app function focus for weekly email**

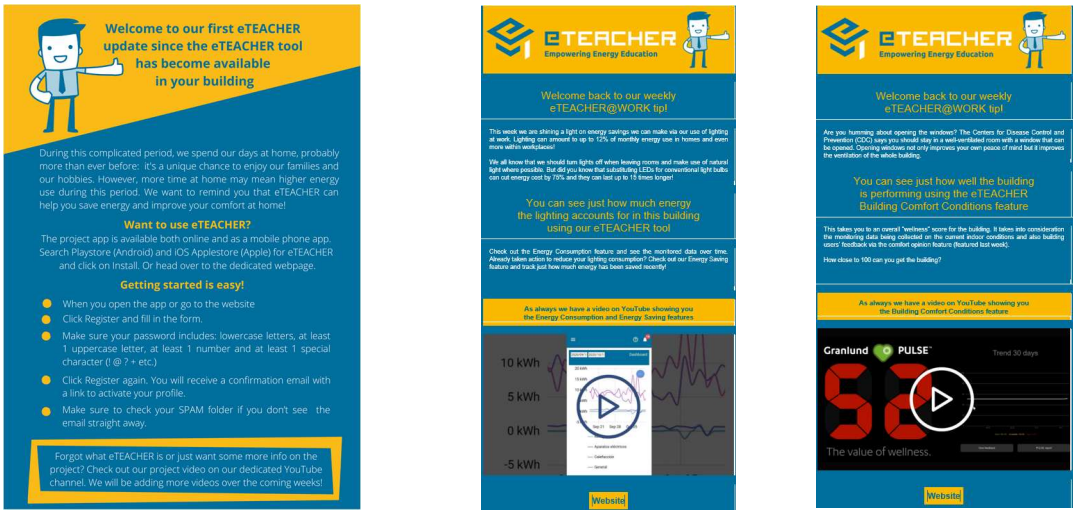



**Figure 3.5 Examples of weekly emails**

## Continuous supervision on monitoring devices, tools and users

For the continuous supervision and maintenance of the monitoring devices, pilot coordinators (ICPE, NCC, AGE) check the sensors and data every week. If any issue is identified they report and solve as soon as possible remotely or in a pilot visit. CEM as demo coordinator reviews the monitoring data and report on data quality issues every month. CEM has developed scripts in Python to connect to the databases and represent the monitoring data into graphs. In addition, the graphs in eTEACHER App are used by CEM to check the data provided by the sensors in every pilot. Tools

developers (GRA, EAS, ACX, ASC) report on monitoring issues identified during the implementation or supervision of their tools

For the **continuous supervision and maintenance of the tool´s** performance, every developer (ASC, GRA, EAS, ACX) uses their own methods, tools and indicators to track the performance of their tools. In addition, pilot coordinators (ICPE, NCC, AGE) report on bugs identified by building users and project coordinator (CEM) carried out periodic tests of the App to ensure the high performance of the tools. After identifying a bug, the developers must find a solution and update their tools as soon as possible.

Continuous supervision of **users´ statistics**. ASC has developed some users statistics (number of users registered, number of users active, number of interactions per functionality, etc) based on DMU and CEM specifications to track the interactions of the users with eTEACHER App and continuously supervise the user engagement in order to develop contingency plans if the participation is too low. The figures of the users statistics are reviewed every 2 weeks. Continuous contingency engagement plans are developed if it is necessary according to the figures.

# 4 Demonstration results

## 4.1 Users feedback, surveys and statistics

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). Engagement with the eTEACHER interventions is a vital part of the project, 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 et al., 2018) which are relevant to monitor levels of engagement throughout the eTEACHER study, **Table 4.1** recaps these engagement behaviours and the relevant building users.

**Table 4.1 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 |

For evaluating the user acceptance and engagement of the eTEACHER tool it was recognised that the following data was required: 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 use of app. As indicated in (Jimenez-Redondo et al., 2018), the evaluation methodology for eTEACHER utilises both measured and self-reported evidences via monitoring, eTEACHER app engagement, Feedback Forums and Surveys.

As indicated at the start of this section, input is required before, during and after a behaviour change intervention for effective evaluation. The input before can be found summarised by the demonstration

baseline presented in (Calleja-Rodriguez, 2019). This report summarises user engagement during the demonstration phase of the eTEACHER project. Therefore, input from end-users was gathered via a number of different means which included Feedback Forums, monitored data, Surveys and non-structured feedback collection. Continued monitoring of engagement and user input will be collected going forward until the end of the demonstration phase to evaluate the overall impact of the eTEACHER tool, ensuring that user input was a key part of the project monitoring and evaluation before, during and after.

### 4.1.1 Feedback Forum

eTEACHER sought to develop and propose effective ideas for a behaviour change intervention, based upon research evidence, consultation with key users of the buildings where eTEACHER will be piloted, and a pre-chosen structured framework for designing behavioural change initiatives, *Enabling Change*. A tailored approach to the *Enabling Change* framework was developed for eTEACHER, presented in (Reeves, Morton & Bull, 2018). The tailored approach developed included the use of “Feedback Forums”. For eTEACHER the use of Feedback Forums addresses the need for a project “brains trust” within the Enabling Change framework, here a group of key building stakeholders and actors which could provide feedback on key ideas and concepts for the development of eTEACHER. The use of Feedback Forums was recommended throughout both Year 2 and Year 3 of the eTEACHER project as a means to encourage and enhance user engagement with the project and the resulting ICT based tool. The continued use of Feedback Forums during Year 3 was seen as an opportunity to gather user feedback on the tool during the demonstration phase. Therefore, two Feedback Forums were designed to focus on this aspect of evaluating the tool in use, Feedback Forum 4 to capture users’ impressions and initial use of the eTEACHER tool shortly following the initial tool rollout, and then Feedback Forum 5 to capture users’ impressions of the tool following roughly 6 months of use.

The aim of Feedback Forum 4 was to collect building user impressions and use of the eTEACHER tool following the initial rollout across all pilot buildings. Unfortunately, FF4 was hampered by a number of reasons which resulted in only 2 sessions being held in Romania, covering 4 of the residential pilot buildings. Unfortunately delays with the app being ready to implement meant the FF4 sessions were postponed in both the UK and Spain until issues with the app were resolved. Unfortunately, this delay then meant that the remaining Feedback Forums were also impacted due to the COVID-19 pandemic, with restricted access to the buildings and local lockdowns enforced. The eTEACHER project was then suspended for 3 months, June-August 2020. Once the project resumed in September 2020 the decision was taken to incorporate relevant elements of FF4 into FF5 as many of the remaining buildings had had the tool rolled out via email before the project suspension and therefore the building users had access to the tool for a number of months compared to a number of weeks, so it was not possible to collect the initial impressions of the tool. Across the two FF4 sessions held feedback was gathered from 11 participants, covering both occupants of the building and staff of the buildings.

The findings from Feedback Forum 4 indicate that building users are generally impressed with the eTEACHER tool and have experienced using the tool for themselves. All features of the app were spoken of positively, however some features were reported as being of less interest or not relevant to the participants of the FF sessions. Functions such as the ranking feature or the ability to share recommendations via social network channels were examples of this. This echoes previous findings from earlier FFs.

The Feedback Forum 4 sessions gave further insight into end-user engagement with the eTEACHER tool, with some indicating that the tool itself, although appreciated and relevant focus, was not deemed to be a priority in their day to day lives. Another factor which highlighted possible barriers to the end-user's engagement with the tool was issues that participants had experienced trying to assign their profile details and needed additional guidance from pilot coordinators. This suggests that the tool might not stand-alone without some additional instruction as to how users can overcome some of the initial set-up issues.

It is obviously worth noting that the findings detailed in this report only cover 4 of the 12 pilot buildings, all of which were residential buildings and located in Romania so not a true representation of the overall end-user impressions across the varied eTEACHER pilot building sample.

Due to the issues experienced with facilitating FF4 following the initial app rollout across all pilot buildings, elements of the session will be incorporated into Feedback Forum 5 to ensure that the impressions of all building user groups across all 3 European pilot locations are recorded and analysed as part of the project evaluation. Feedback Forum 5 was due to take place in February 2021, however some of the sessions have not been feasible due to ongoing access issues and local restrictions in place. Therefore, some of these sessions are due to take place in March 2021. However, FF5 will capture data on end-users use of eTEACHER to date, as well as observed use of other building users, evaluate eTEACHER's effectiveness through identified strengths, weaknesses, and potential improvements, and analyse factors influencing engagement with the eTEACHER tool.

### 4.1.2 Survey results

The initial monitoring and evaluation methodology for eTEACHER proposed two surveys which were to be distributed to all building users, one which would collect baseline pre-eTEACHER and a second survey which would collect comparison data post-eTEACHER. Both the pre- and post-eTEACHER surveys would focus on gathering information on current energy use behaviours, energy attitudes and comfort levels. The post-eTEACHER survey will also focus on evaluation aspects, including use and opinions around the effectiveness of the eTEACHER solution in each building. Due to the range of building user demographics and geographical location (language) the survey predominantly focused on questions involving Likert-type scales for answers –allowing for statistical analysis to be carried out for evaluating change. The survey could be available both online and via a paper format (if requested by building users), in the relevant local language for pilot buildings and was circulated to pilot buildings via email links from pilot coordinators.

The pre-eTEACHER survey results have been presented within (Calleja-Rodriguez, 2019) based on 51 responses across 11 of the pilot buildings. The post-eTEACHER survey will be distributed at the end of the demonstration phase but given the project delays and limitations for in-person engagement impacting FF5 it was felt beneficial to distribute an interim survey to all building users to better evaluate the users impressions of the eTEACHER tool, which can then be compared against the final survey responses, allowing for evaluation of changes in user impressions following longer engagement with the tool. Since the final survey was designed to focus on evaluation aspects of the eTEACHER tool, the interim survey was developed to use the same evaluation questions already planned for the final survey, hence this will allow for comparisons of user impressions and use of the tool at the interim and final stage, whilst users' energy use behaviours, attitudes and comfort levels will be compared against the baseline and final survey results. The interim survey can be found within Appendix section.

As with the previous baseline survey, to encourage participation with the interim survey, information on the survey has been included within Feedback Forum 5. However due to planning logistics many of the FF5 sessions are being held following the submission of this report, therefore the survey link was distributed to end-users via email links from pilot coordinators, and the survey will remain live until all FF5 sessions have taken place. As such the results below, Table 4.2, present a snapshot from some initial interim survey responses across three of the eTEACHER pilot buildings.

Table 4.2 Respondent characteristics from initial interim survey responses

| Pilot Building | Number of initial interim survey responses | End-user type |
|---|---|---|
| | 1 | Staff |
| | 1 | Staff |
| | 6 | Staff |

As can be seen from Table 4.2, all responses came from staff users of the buildings. This indicates that many of these end-users may not be influenced as strongly by financial savings possible from use of eTEACHER's recommendations surrounding energy efficiency, as residents or even energy facility managers. 88% of respondents indicated that they were aware of the eTEACHER tool being used in the buildings, with only 1 respondent from Arco Iris indicating that they were unaware. Although awareness amongst the respondents was high, only 38% indicated having actually used the eTEACHER tool. Of those indicating having used the tool, this included at least 1 respondent from each of the 3 pilot buildings. Therefore, highlighting issues with aligning awareness with interaction with the eTEACHER tool. When analysing the responses from participants as to why they had not used the tool – the key reason behind the lack of engagement appears to be related to difficulties in creating a user profile for the tool (60% of those not using the tool), followed by issues relating to successfully login into the tool (40% of those not using the tool). Of those indicating difficulty in creating a user profile, 1 of those respondents indicated that they did not have a mobile phone. Only 1 respondent not using the tool indicated that they were too busy as their reasoning for not engaging with the tool more. Other reasons selected as to a lack of engagement included: finding it difficult to navigate (1 response), lack of understanding how to add specific rooms (1 response) and the tool not containing the information wanted (1 response). From the initial responses from end-users who completed the interim survey it can be seen that the lack of engagement with the tool could be down to difficulties that users are experiencing trying to create a profile and then login successfully. Further attention needs to be given to ensure users can register for the tool successfully or have access to means of problem solving these issues.

Of those indicating active use of the eTEACHER tool, the staff member from InCity reported using the tool on a daily basis. Whereas weekly use of the eTEACHER tool was reported in Torrente Ballester and Arco Iris. When asked whether those using the eTEACHER tool believed the tool had increased their awareness of energy use within the building an overall positive impact was found. The active users within Torrente Ballester and InCity replied that yes the eTEACHER tool had increased their awareness, whilst the active user within Arco Iris indicated that it might have increased their overall awareness. Although they indicated that the tool might have increased their awareness of energy use within the building, the active user within Arco Iris did say the tool had not changed their use of energy within the building. Within Torrente Ballester the eTEACHER tool was

indicated to have influenced a change in energy use within the building, whilst InCity indicated it might have had an influence on energy use. All active users of the tool indicated that they would recommend the eTEACHER tool to others showing an observed benefit from using the tool. The interim survey allowed respondents to provide further detail on the impact of the tool and these responses indicated that the tool now means one user no longer leaves lights on in rooms they previously did and another simply stated it to be a “success”. Another active user did highlight some issue which was impacting their use and that was that they found the application to crash a lot but hoped to use it more when more stable.

As part of the eTEACHER tool evaluation, understanding users’ impressions of the tool are extremely important but so is understanding the usability of the tool for end-users. The usability of the tool has a large influence on sustained 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) was adapted to eTEACHER and proposed within D4.1 as being part of the final survey. This scale allows 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 4.3 represents the SUS scale, adapted to eTEACHER. To calculate the overall score the total contribution from each question is summed and this overall total is then multiplied by 2.5, giving a score within the range of 0 and 100. To calculate each question’s 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

**Table 4.3 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 |
| 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 4.1. 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.

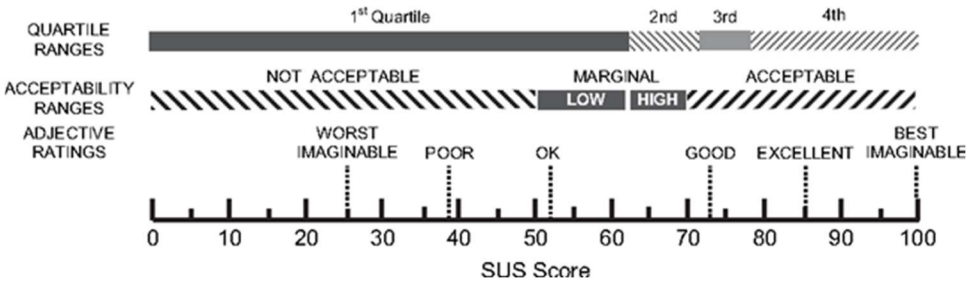



**Figure 4.1: SUS score with grade and adjective rankings (Bangor, Kortum and Miller, 2009)**

The SUS eTEACHER scale questions were included within the interim survey to get a better indication as to users' perceptions on the usability of the tool. From the active user response received a usability score was calculated based on the average SUS score as well as an individual score for Torrente Ballester, Arco Iris and InCity A. An average score from all active users was calculated to be 60, with Torrente Ballester scoring 52.5, Arco Iris scoring 65 and InCity scoring 60. These SUS scores show the usability of the eTEACHER tool to be rated as "OK" but with obvious areas for improvement. A better understanding of the overall usability of the tool can be calculated once more survey responses are received. However, initial responses do indicate areas for improving overall tool usability with improved profile creation and a more stable application. End-user impressions of the tool are positive, with responses indicating the tool is deemed to be interesting and useful, so improved usability should increase overall use of the tool and sustained interaction.

### 4.1.3 Non-structured feedback collection

Engagement from building users with the eTEACHER tool is a vital part for the successful demonstration of the tool and for evaluating the impact from the tool on energy consumption, health and wellbeing. As already indicated the project unfortunately came up against a number of issues which impacted the original timeframe for evaluating the impact of the eTEACHER tool during the demonstration phase. As such a number of non-structured feedback collection events took place to ensure the project could adapt to such unforeseen delays and impacts out with the project's control.

One of these non-structured feedback collections occurred due to the delays with the rollout of the eTEACHER tool within the UK pilots in February 2020. The delay occurred due to issues with the app preventing a whole-building uptake. Within the Council House, an initial five users attempted to register for the app but struggled to do so, with three receiving "invalid email address" message. Feedback from users indicated that many building users would feel uneasy having the tool on their personal mobile phones and would prefer the use of the web-based tool. However, it was unclear how users could add rooms via the QR codes if using the web-version. Users stated that in the

current state of the tool (before major improvements were made) “people will lose the will to live” trying to use the tool. Other feedback from building users during this informal session included that the tool was not very user friendly with a lack of explanation behind some feature, e.g., unclear what the magnifying glass meant; “what would we be searching for?”, “you’d have to be very geeky to use that”. Overall, the end-users’ felt the current state of the tool at the time was confusing and trying to do too much, “it looks like you’ve thrown the kitchen sink at it”. As such the whole-building rollout was postponed in UK pilots, and similarly in Spanish pilots, until improvements could be implemented in the tool. Unfortunately, this delay was them impacted from the COVID-19 pandemic. Therefore, once the app was ready, it was rolled out to a number of pilot buildings via email instead of face-to-face.

Following the eTEACHER tool rollout and subsequent suspension of the project, an user engagement plan based on weekly emails was carried out to refresh building user's awareness of the project (see section 3). Half-way through the email campaign it was seen via the app usage statistics that the initial email communication was not resulting in a noticeable increase in the app interactions of building users. Therefore, pilot coordinators were asked to contact key building stakeholders/users to gather some additional feedback relating to the current situation in each building. Table 4.4 presents the feedback collected from this activity.

**Table 4.4: Informal feedback collected via pilot coordinators during email campaign**

| Building | Feedback |
|---|---|
| Torrente Ballester and Arco Iris, Spain | Both very busy since the beginning of the school period. COVID-19 crisis has also introduced a work overload. So, they are now time-limited to participate in the eTECAHER project.<br>Pilot coordinators also assisted some users to access the APP (creating profiles and adding rooms via QR code). |
| Villafranca de los Barros and Guarena HCC, Spain | Unable to contact the Building Managers, who are also doctors within the HCC’s therefore extremely busy with the current COVID-19 situation. Participation in the project will be very very limited. |
| Apartment Block Badajoz, Spain | Most residents started using APP in May 2020 following email rollout however "because the APP had several errors and lack of information" use stopped during the project suspension period. Pilot coordinator reported to users that the tool had been updated and improved as well as the sensor maintenance. |
| OAR office building, Spain | Some staff are currently using the APP. However, they cannot give an exact number of people because the APP is not mandatory as it should be installed in the personal smartphone. Need for further information on web-based availability of tool. |
| Incity, Romanian | Positive feedback from both staff and from the users. The app was installed on both mobile phones and tablets. One user would like to |

| | |
|---|---|
| | receive fewer messages, eventually 2-3 groups / sets per day. The app is not fully functional, but the users understand that it is used now to test different aspects related to apartments occupancy and that their involvement and feedback us very important. |

Given the feedback collected it was decided that the final email communication of the campaign would focus on the tool's availability via the online platform over the mobile phone application. The final email was also seen as an opportunity to test whether email communications were effective at engaging with the building users in the current environment. As such a survey link was included within the email which took recipients to a short survey which asked whether or not users would recommend the eTEACHER tool and depending on the response, either reasons why they liked the tool or reasons why they would not recommend the tool.

Unfortunately, the survey contained within the final email only received 2 responses, 1 from the OAR Spanish office pilot building and 1 response from the Spanish residential building. The respondent from the Spanish office building indicated that they would recommend the eTEACHER tool to others, showing a positive impression of the tool. The respondent indicated that they liked the simplicity of the tool. However, the residential building respondent indicated that they would not recommend the eTEACHER tool to others. Reasons behind why they would not recommend the eTEACHER tool included: that they found it too complicated, struggled to log-in and did not think relevant information to them was included. This is a stark contrast to the office building respondent; however, given the low response rate across all buildings it is difficult to generalise either of the outcomes. Therefore, it is vital that both the interim and final survey gather a significant number of respondents across all pilots to all for a more thorough evaluation of whether the tool suits specific building types, or user types, better than others.

## 4.2 Monitoring results on energy, indoor environmental quality and target behaviours

In this section, an analysis of monitoring data collected before and after giving eTEACHER tools to the buildings is carried out in order to evaluate energy savings, enhancement of indoor environmental quality and behavioural change based on the enhancement of target behaviours encouraged by eTEACHER. The energy savings, IEQ enhancement and target behaviours enhancement have been evaluated taking into account the difference between the control and study environments before and after eTEACHER. For example, if the energy consumption is lower after eTEACHER in both kind of environments but it has decreased more in the study environments, it is assumed an energy saving encouraged by eTEACHER.

The monitoring data used for the period before eTEACHER (baseline period) belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER (demonstration period) belongs from 1.10.2020-13.01.2021.

Ten pilot buildings have been analysed:

- 2 health care centres, 2 schools, 1 residential building and 1 office building in Spain
- 4 residential buildings in Romanian.

It should be noted that UK pilots have not been analysed because the tools were not really delivered in the pilots after project suspension due to communication problems with the building managers and continuous lockdown in UK because of COVID.

The analysis has been performed with PyCharm (JetBrains, 2018). Following libraries have been used: pandas, numpy, matplotlib.pyplot. Specifically, missing data has been filled in with two methods: Ffill and Fillna.median (McKinney & PyData Development Team, 2019)

### 4.2.1 Energy savings evaluation

This section aims to provide an overview of the energy saving encouraged by eTEACHER tools in every pilot building. For that purpose, monitoring data on energy consumption (kWh) recorded before providing the tools to the building users and after will be compared. The energy consumption in every building will be analysed per type of use (HVAC, lighting, appliances) and in total. The study will be focused at room/apartment level due to the change of use of the buildings related to COVID pandemic. The energy saving will be estimated taking into account the relation between the energy consumption of the study and control rooms before and after they got the eTEACHER tools and assuming that weather conditions and COVID pandemic have had the same impact in both kind of rooms in terms of use (occupancy, ventilation, etc.). As reminder, the control rooms do not get eTEACHER tools while the study rooms are those rooms that get eTEACHER tools during the demonstration phase:

$$Energy_{saving}(\%) = \left(\left(\frac{E_{consump,study-room}(kWh)}{E_{consump,control-room}(kWh)}\right)_{before} - \left(\frac{E_{consump,study-room}(kWh)}{E_{consump,control-room}(kWh)}\right)_{after}\right) x\ 100$$

#### OAR, office building, Spain

Following, a preliminary evaluation of the energy saving encouraged by eTEACHER in OAR building is shown. To understand the results is important to take into account following **information**:

- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
  - The building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
  - The buildings users were encouraged to use the tools again by mid of October 2020 after project resumption and a recommissioning of the monitoring devices and eTEACHER tools.
- The building monitoring is described in (Calleja-Rodriguez, 2019). In this building Floor 1 is considered as control room/space while Floor 2 is considered study room/space. Therefore, only floor 2 gets the eTEACHER App.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020
- The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact:

- The building is less occupied. About 50% of the staff is doing home office (alternatively)
- The ventilation is higher than before.

Figure 4.2 shows the daily energy consumption (total, HVAC, equipment, lighting) in floor 1 and floor 2 before and after eTEACHER while Figure 4.3 shows the monthly energy consumption in floor 1 and 2 before and after eTEACHER. Figure 4.4 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control zones before and after eTEACHER.

- The total energy consumption was reduced in both floors in October and November after eTEACHER, with a higher reduction in floor 2 which turned into an energy saving of 27% in October and about 10% in November. However, the situation changed in December 2019 with a higher consumption (-20% energy saving)
- The energy consumption on appliances in floor 2 after eTEACHER was reduced increasingly from October until December resulting in energy savings of 13% in October and more than 100% in December.
- The lighting consumption is very similar before and after eTEACHER.
- The HVAC consumption was lower in floor 2 after eTEACHER with regard to floor 1 which turned into energy savings about 76% in November.

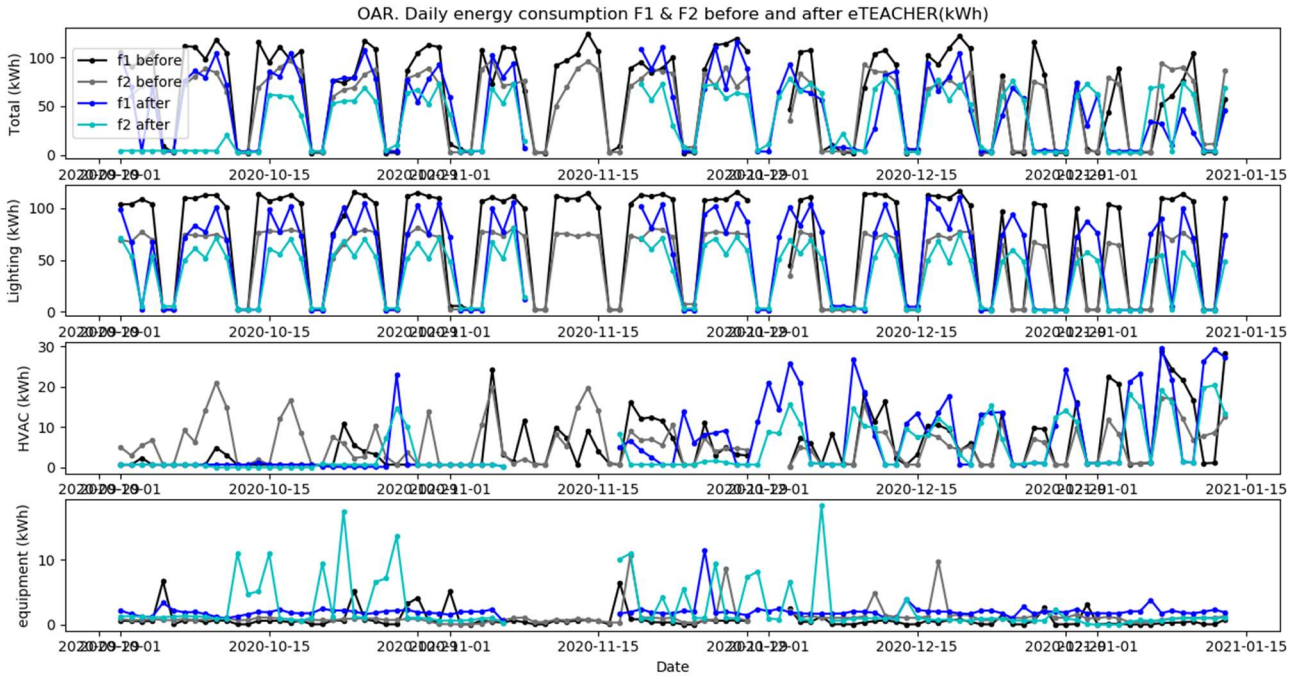



**Figure 4.2 OAR building: Daily energy consumption in floor 1 and floor 2 before and after eTEACHER (kWh).**

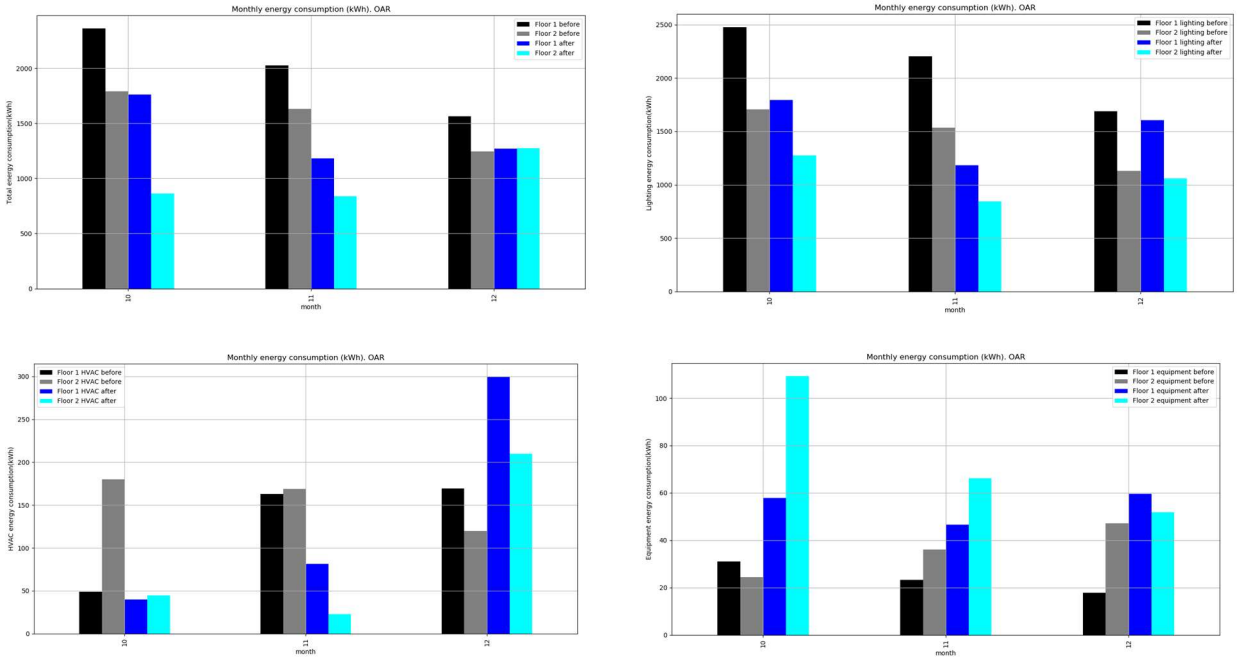



**Figure 4.3 OAR building: Monthly energy consumption in floor 1 and floor 2 before and after eTEACHER (kWh).**

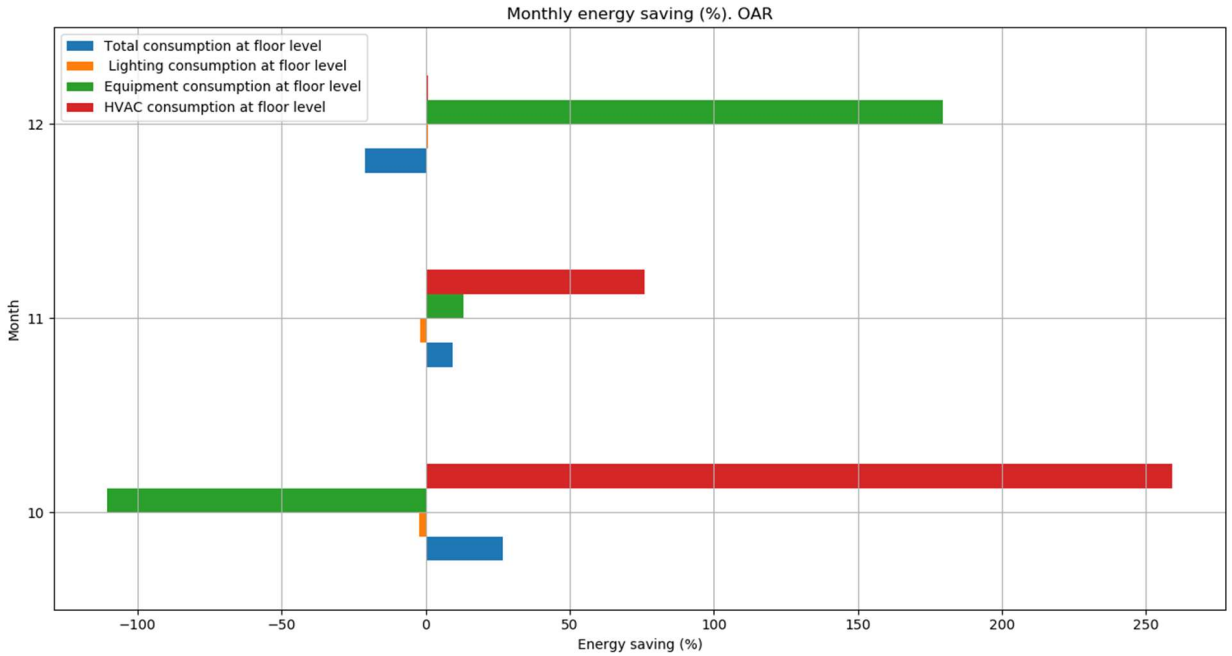



**Figure 4.4 OAR building: Monthly energy saving in floor 1 and floor 2 encouraged by eTEACHER (kWh).**

In conclusion, the figures show some energy savings in the use of appliances (27%) and HVAC (100%) while the energy consumption in lighting is very similar. A larger sample is necessary to see the real trend of the energy savings.

### Guareña, health care centre, Spain

Following, a preliminary evaluation of the energy saving encouraged by eTEACHER in Guareña health care centre is shown. To understand the results is important to take into account following **information**:

- All the energy consumption in this building are electric consumption.
- At room/zone level, 7 rooms divided into 2 monitoring zones have been analysed. Zone 4 is the control zone and zone 6 is the study zone.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
  - The building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
  - The buildings users were encouraged to use the tools again by mid of October 2020 after project resumption and a recommissioning of the monitoring devices and eTEACHER tools.
- The building monitoring is described in (Calleja-Rodriguez, 2019). In this building Zone 6 is considered as study room/space while Zone 4 is considered control room/space. Therefore, only Zone 6 gets the eTEACHER App.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- We only evaluate energy savings related to HVAC and lighting due to a lack of data on equipment consumption in Zone 4.
- The energy savings encouraged by eTEACHER is the reduction of energy consumption in the study zone with regard to the control zone after eTEACHER.
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact:
  - The building is less occupied. Many doctor visits are solved by phone, the number of people waiting in the corridor has been reduced
  - The ventilation is higher than before.

Figure 4.5 shows the daily energy consumption (total, HVAC, equipment, lighting) in control and study zones before and after eTEACHER while Figure 4.6 shows the monthly energy consumption in control and study zones before and after eTEACHER. Figure 4.4 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control zones before and after eTEACHER.

- The lighting consumption increased in the study room after eTEACHER while decreased in the control room. Therefore, we cannot identify energy savings encouraged by eTEACHER in the use of lighting
- The energy consumption on heating decreased in October and November after eTEACHER and increased in December after eTEACHER. The decrease is higher in the study zone and the increasement is lower in the study zone, therefore we can assume some energy savings on the use of heating encouraged by eTEACHER (>100%)

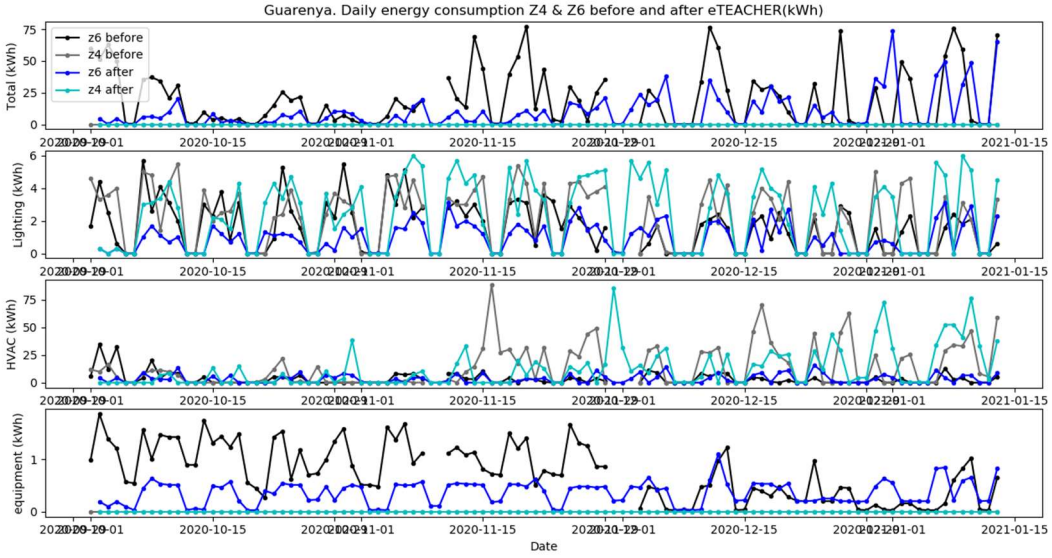



**Figure 4.5 Guareña: Daily energy consumption in zone 4 and 6 before and after eTEACHER (kWh).**

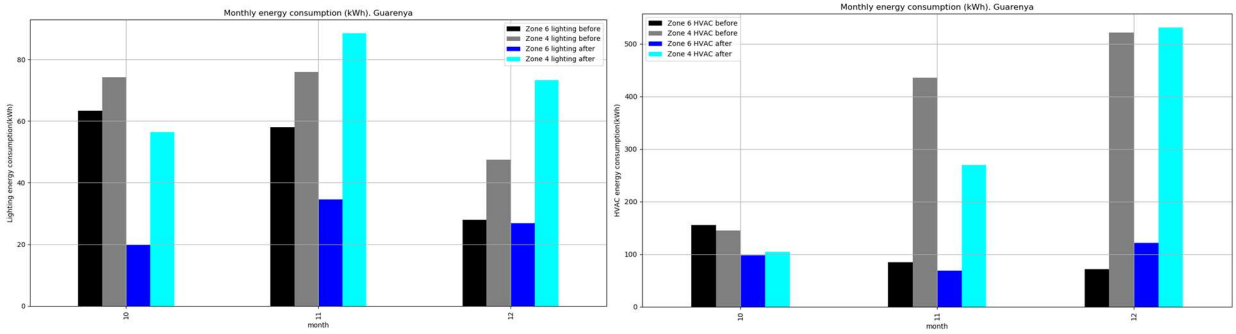



**Figure 4.6 Guareña: Monthly energy consumption (lighting and HVAC) in zone 4 and 6 before and after eTEACHER (kWh).**

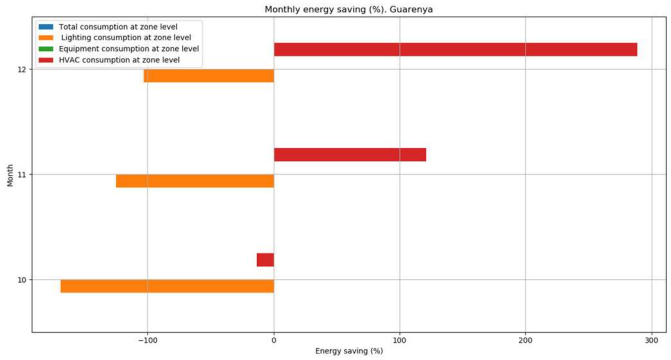



**Figure 4.7 Guareña: Energy saving encouraged by eTEACHER (kWh).**

In conclusion, the figures show some energy savings in the use of heating (>100%) but not in the use of lighting. A larger sample is necessary to see the real trend of the energy savings.

### Villafranca, health care centre, Spain

Following some **relevant information about the monitoring data** used for the energy saving analysis encouraged by eTEACHER to understand the results

- Data used for the analysis belongs from 13.10.2019-13.01.2020 and from 13.10.2020-13.01.2021 because there is a lack of data from 20.09.2020-13.10.2020.
- Consultation 4 (C4) is the control room while consultations 2,3 and 5 are study rooms so only C2, C3, C5 will use eTEACHER during the demonstration phase.
- We assume a COP of 2 to translate the thermal energy (kWh) provided by the fancoils into electricity consumption.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
    - The building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
    - The buildings users were encouraged to use the tools again by mid of October 2020 after project resumption and a recommissioning of the monitoring devices and eTEACHER tools.
- The building monitoring is described in (Calleja-Rodriguez, 2019)
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact:
    - The building is less occupied. Many doctor visits are solved by phone, the number of people waiting in the corridor has been reduced
    - The ventilation is higher than before.

Figure 4.8 shows the monthly energy consumption in control and study rooms before and after eTEACHER. Figure 4.9 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control rooms before and after eTEACHER.

– Two consultation rooms (C2 and C5) show energy savings in lighting (50-75%) and heating (>100%) that can be assumed to be encouraged by eTEACHER

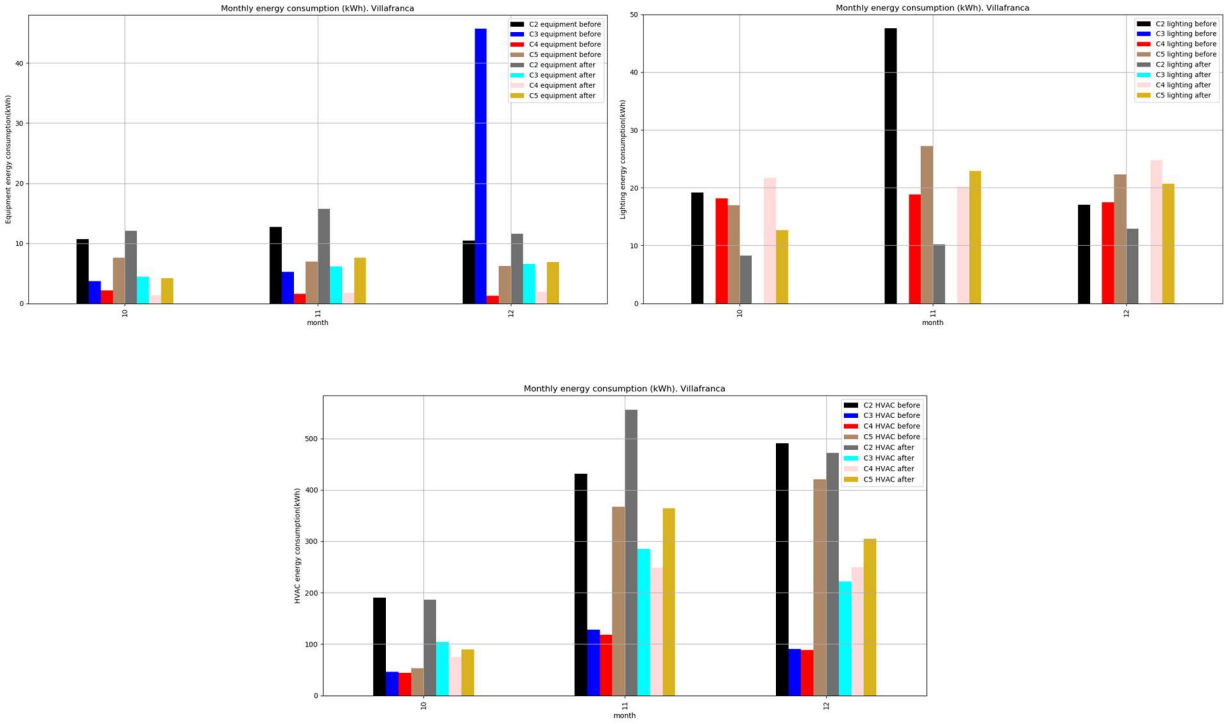



**Figure 4.8 Villafranca: Monthly energy consumption (lighting, equipment and HVAC) in the monitoring consultations before and after eTEACHER (kWh).**

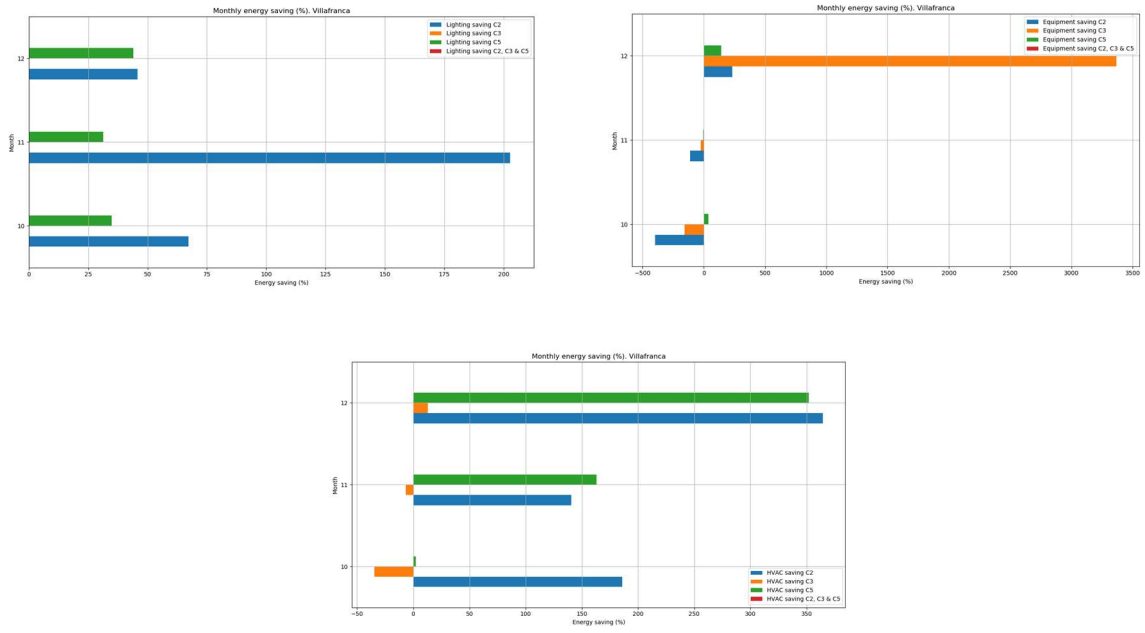



**Figure 4.9 Villafranca: Monthly energy saving encouraged by eTEACHER (kWh).**

In conclusion, the figures show some energy savings in two consultation rooms (C2 and C5) related to the use of lighting (50-75%) and heating (>100%) that can be assumed to be encouraged by eTEACHER

### Torrente Ballester, high school, Spain

Following some **relevant information about the monitoring data** used for the analysis to understand the results:

- Data used for the analysis belongs from 13.10.2019-13.01.2020 and from 13.10.2020-13.01.2021.
- The school has been closed after Christmas until 31.01.2021 due to COVID impact.
- Classrooms 14 and 16 are the study rooms while Classroom 17 is the control room. The building monitoring is described in (Calleja-Rodriguez, 2019).
- Lighting consumption cannot be evaluated at room level because of the circuits and monitoring devices installed.
- Energy savings at building level are not shown because the baseline and demonstration period are too differents due to COVID impact. However, conclusions on consumption at building level can be extrapolated from the room level analysis.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
    - The building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
    - The buildings users were encouraged to use the tools again by mid of October 2020 after project resumption and a recommissioning of the monitoring devices and eTEACHER tools.
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact:
    - The building is much more ventilated

Figure 4.10 shows the daily energy consumption (HVAC and equipment in classrooms 14, 16 and 17 before and after eTEACHER while Figure 4.11 shows the monthly energy consumption in classrooms 14, 16 and 17 before and after eTEACHER. Figure 4.12 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control classrooms before and after eTEACHER:

- There is not identified energy savings in heating consumption encouraged by eTEACHER. The heating consumption in classroom 14 is lower after eTEACHER but the reduction is higher in the control room. The energy consumption in classroom 16 is higher after eTEACHER.
- There is an energy saving on appliances consumption that might be encouraged by eTEACHER in classroom 14 (about 40%). The appliances consumption is higher after eTEACHER but the increasement is higher in the control classroom so it can be concluded that there is an energy saving encouraged by eTEACHER.

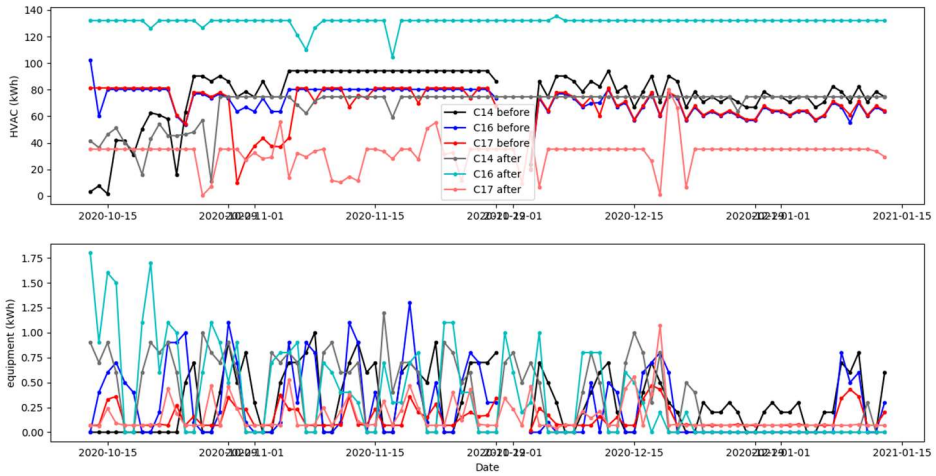



**Figure 4.10 Torrente: Daily energy consumption in classrooms 14, 16 and 17 before and after eTEACHER (kWh).**

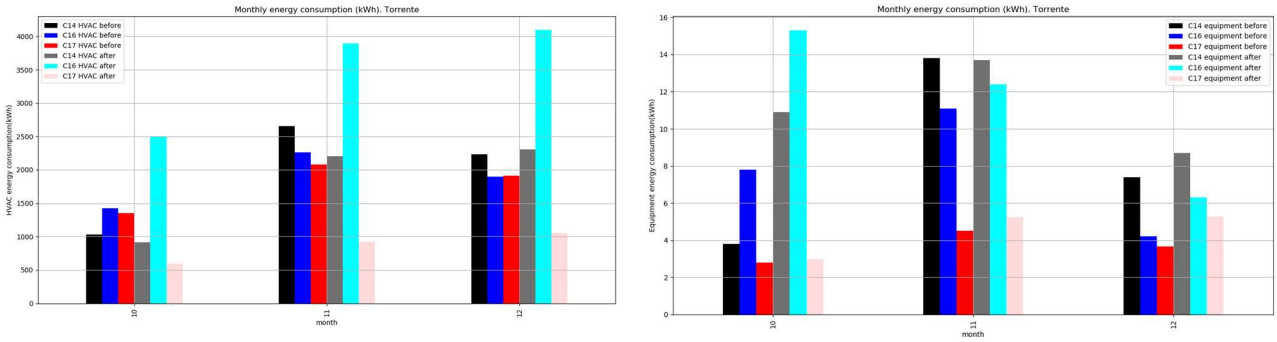



**Figure 4.11 Torrente: Monthly energy consumption (HVAC and equipment) in classrooms 14, 16 and 17 before and after eTEACHER (kWh).**

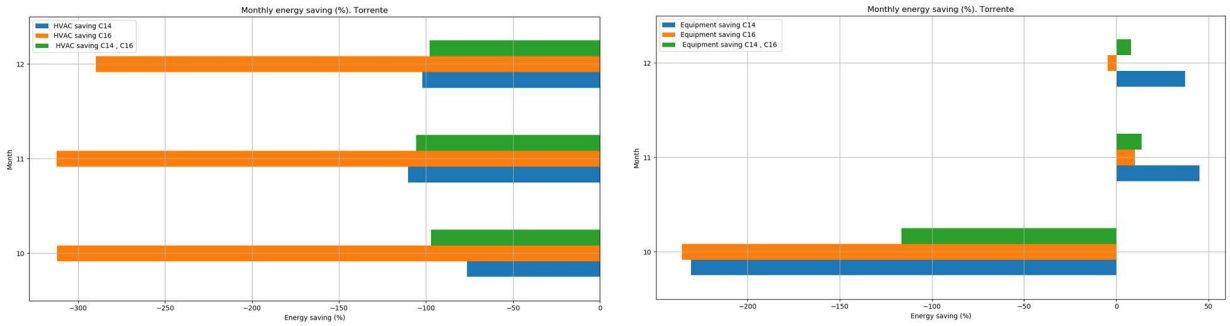



**Figure 4.12 Torrente: Energy savings (HVAC and equipment) in classrooms 14, 16 and 17 after eTEACHER (%). Torrente Ballester, high school, Spain**

In conclusion, the figures show some energy savings in the use of appliances (10-15%) but higher consumption in heating consumption. A larger sample is necessary to see the real trend of the energy savings.

### Arcoiris, Kindergarten, Spain

An energy consumption analysis has been carried out before and after providing builiding users with eTEACHER tools to identify the energy consumption reduction encouraged by eTEACHER. Following information is important to understand the results:

- Energy savings are evaluated taking into account the difference between the control and study rooms before and after eTEACHER. For example, if the energy consumption is lower after eTEACHER in both kind of rooms but it has decreased more in the study rooms it is assumed an energy saving encouraged by eTEACHER. If the energy consumption is higher after eTEACHER in both kind of rooms but has increased more in the control room than in the study rooms, it is also assumed an energy saving encouraged by eTEACHER.
- The building users received eTEACHER tools by mid of October 2020. In this building, only the teachers use the tools since the children are very young. It should be noted that the building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
- The data used for the analysis corresponds from 1.10.2019-13.01.2020 for the period before eTEACHER and from 1.10.2020-13.01.2021 for the period after eTEACHER.
- Dolfphins room is the study room while Cats room is the control room. The building monitoring is described in (Calleja-Rodriguez, 2019)
- Energy savings at building level are not shown because the baseline and demonstration period are too different due to COVID impact. However, conclusions on consumption at building level can be extrapolated from the room level analysis.
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact. Specially, the building is much more ventilated

Figure 4.13 shows the daily energy consumption (kWh) - heating, cooling, equipment and lighting - before and after eTEACHER in the monitoring rooms while Figure 4.14 shows the monthly energy consumption in Dolfphins and Cats room before and after eTEACHER. Figure 4.15 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control classrooms before and after eTEACHER:

- There is identified a reduction in heating consumption that might be encouraged by eTEACHER (50% in December). The heating consumption is higher in both rooms after eTEACHER. This is probably because of the higher ventilation due to COVID. However, the increasement in Dolphins rooms is lower than in Cats rooms.
- There is an energy saving on appliances consumption that might be encouraged by eTEACHER in Dolphins room with regard to Cats room in October and November but not in December (about 50%). The appliances consumption is higher after eTEACHER but the increasement is higher in the control classroom so it can be concluded that there is an energy saving encouraged by eTEACHER.
- There is an enegy saving on lighting consumption that might be encouraged by eTEACHER in Dolphins room with regard to Cats room (20%). The lighting consumption is lower after eTEACHER in both rooms but the reduction is higher in the study room so it can be concluded that there is an energy saving encouraged by eTEACHER.

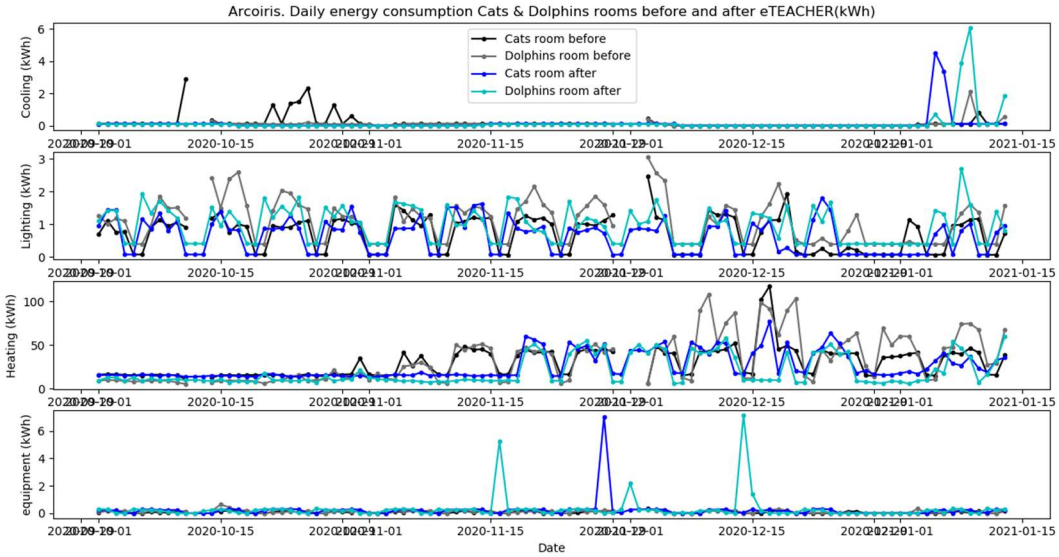



**Figure 4.13 Arcoiris: Daily energy consumption in Dolphins and Cats room before and after eTEACHER (kWh).**

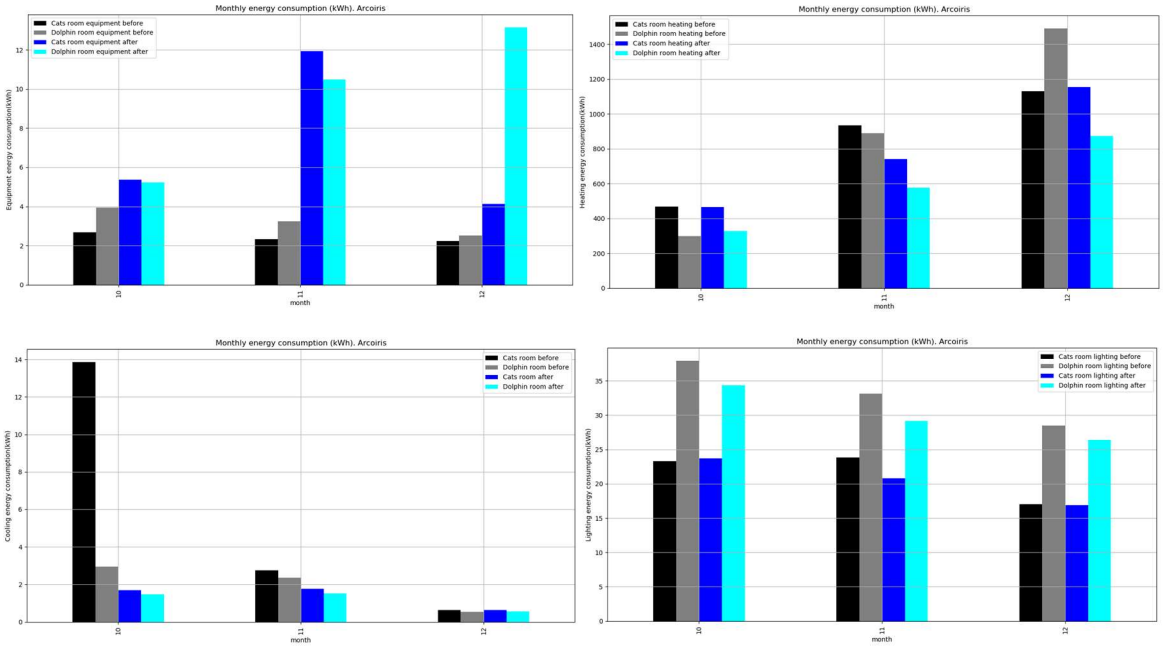



**Figure 4.14 Arcoiris: Monthly energy consumption in Dolphins and Cats room before and after eTEACHER (kWh).**

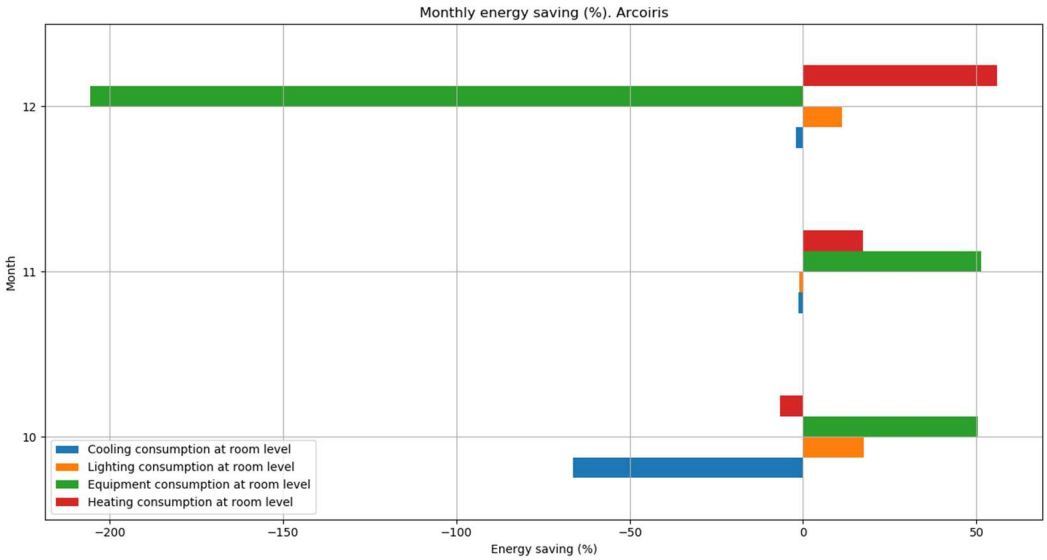



**Figure 4.15 Arcoiris: Monthly energy saving after eTEACHER (%).**

In conclusion, the figures show some energy savings in the use of appliances (27%) and HVAC (100%) while the energy consumption in lighting is very similar. A larger sample is necessary to see the real trend of the energy savings.

### Residential Badajoz, building block, Spain

An energy consumption analysis has been carried out before and after providing builiding users with eTEACHER tools to identify the energy consumption reduction encouraged by eTEACHER. Following information is important to understand the results:

- Energy savings are evaluated taking into account the difference between the control and study apartments before and after eTEACHER. For example, if the energy consumption is lower after eTEACHER in both kind of apartments but it has decreased more in the study apartments, it is assumed an energy saving encouraged by eTEACHER. If the energy consumption is higher after eTEACHER in both kind of apartments but it has increased more in the control apartments than in the study apartments, it is also assumed an energy saving encouraged by eTEACHER.
- The building users received eTEACHER tools by mid of October 2020. It should be noted that the building users got a first introduction of eTEACHER tools in April 2020 through online training material but then the project was stopped in June 2020 due to COVID impact (no access to buildings, no maintenance of monitoring devices, low data quality, very low occupancy, etc.).
- The maintenance of the monitoring devices to guarantee data quality has been quite challenging in the apartments since the owners do not want other people to come inside their apartments due to COVID pandemic. This may have caused some problems with data quality.

- The data used for the analysis corresponds from 1.10.2019-13.01.2020 for the period before eTEACHER and from 1.10.2020-13.01.2021 for the period after eTEACHER.
- Apartment 5B is the control apartment, aparments 5C and 5D are the study apartments. Apartment 5D refused to continue in the project. The building monitoring details are described in (Calleja-Rodriguez, 2019)
- Energy savings at building level are not shown because the baseline and demonstration period are too different due to COVID impact. However, conclusions on consumption at building level can be extrapolated from the apartment level analysis.

Figure 4.16 shows the daily energy consumption (kWh) – heating and equipment - before and after eTEACHER in the monitoring apartments while Figure 4.17 shows the monthly energy consumption in control and study apartments before and after eTEACHER. Figure 4.18 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control apartments before and after eTEACHER:

– The appliances consumption is higher after eTEACHER in all the monitoring apartments. This might be because people are more at home due to COVID. In general, it can be concluded that there is some energy savings in apartment 5C encouraged by eTEACHER because even if the energy consumption has increased, this increasement is lower than in the control apartment. However, there is not energy savings encouraged by eTEACHER in apartment 5D
– The heating consumption was higher in some apartments and lower in other apartments with regard to previous October and November. In December, the heating consumption was lower during the demonstation phase. It cannot be identified energy savings encouraged by eTEACHER.

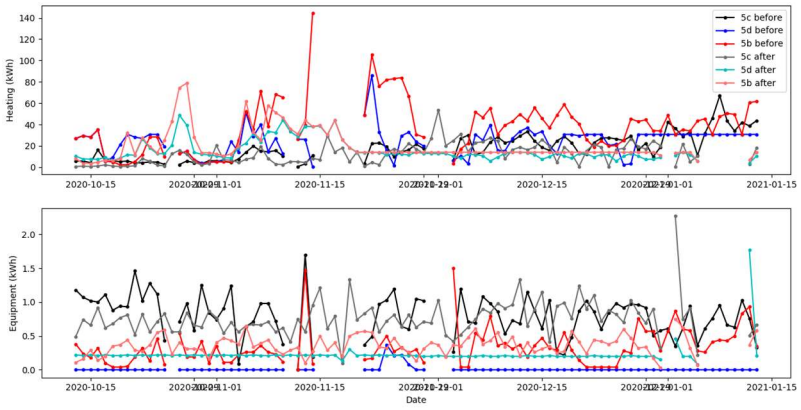



**Figure 4.16 Residential building Badajoz: Daily energy consumption in control and study apartments before and after eTEACHER (kWh).**

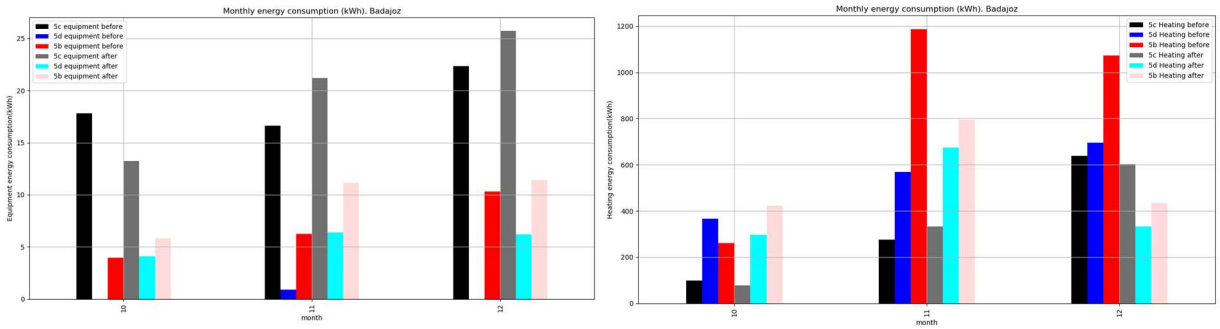



**Figure 4.17 Residential building Badajoz: Monthly equipment and heating consumption in control and study apartments before and after eTEACHER (kWh).**

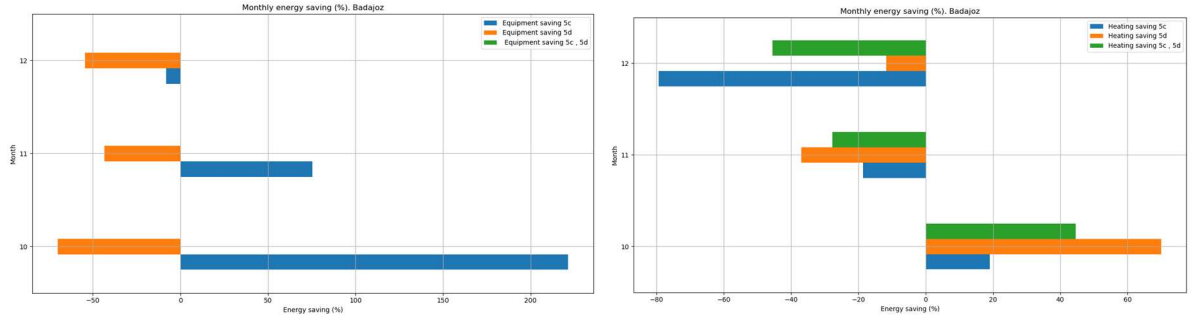



**Figure 4.18 Residential building Badajoz: Monthly energy savings encouraged by eTEACHER (%).**

In conclusion, the figures show some energy savings in the use of appliances (27%) in one of the apartments and no energy savings in the use of heating encouraged by eTEACHER. A larger sample is necessary to see the real trend of the energy savings.

### InCity, residential building, Romanian

An energy consumption analysis has been carried out before and after providing builiding users with eTEACHER tools to identify the energy consumption reduction encouraged by eTEACHER. Following information is important to understand the results:

- The monitoring data collected is from 1.10.2019 till 31.12.2019 for the baseline period and for 1.10.2020 till 31.12.2020. Therefore, data corresponds to Winter and Autumn seasons.
- 10 apartments have been analysed: U16, U22, U38, U127, U133, U181, U255, U273, U416, U466. The control apartments are U466, U133, U16, U273 and U255.
- Total electricity consumption, lighting, cooling and some appliances consumption (oven, washing machine and fridge) have been measured and analysed at apartment level
- Some devices are not sending data on lighting and equipment consumption.
- Electricity consumption at building level cannot be measured since ENEL (energy supplier) didn't allow to install our monitoring devices
- The users got a first introduction of the tools in January 2019. eTEACHER tools very well accepted in this pilot building. They were using the tools until the project was stopped due to COVID impact. They were encouraged to use eTEACHER tools again after all the

monitoring devices and eTEACHER tools were recommissioned after project resumption (mid October 2020). The users engagement in this pilot is the highest.

Figure 4.19 shows the daily energy consumption (kWh) – heating, lighting and equipment - before and after eTEACHER in the monitoring apartments (control and study apartments) while Figure 4.20 shows the monthly energy consumption in control and study apartments before and after eTEACHER. Figure 4.21 shows the energy saving encouraged by eTEACHER taking into account the comparison between the study and control apartments before and after eTEACHER:

- The appliances and lighting consumption before eTEACHER (2019) is very low in all the apartments compared to consumption after eTEACHER (2020). There might be two reasons: gaps of data and lower occupancy before eTEACHER. The increasement of lighting consumption is higher in the control apartments than in the study apartments so we can say that eTEACHER has encouraged some energy savings on the use of lighting.
- The heating consumption is higher after eTEACHER (2020) than before eTEACHER (2019). This is probably because due to COVID the occupancy of the flats is higher in 2020. The heating consumption has increased more in the study apartments than in the control apartments so we cannot say that eTEACHER has encouraged energy saving on heating consumption.

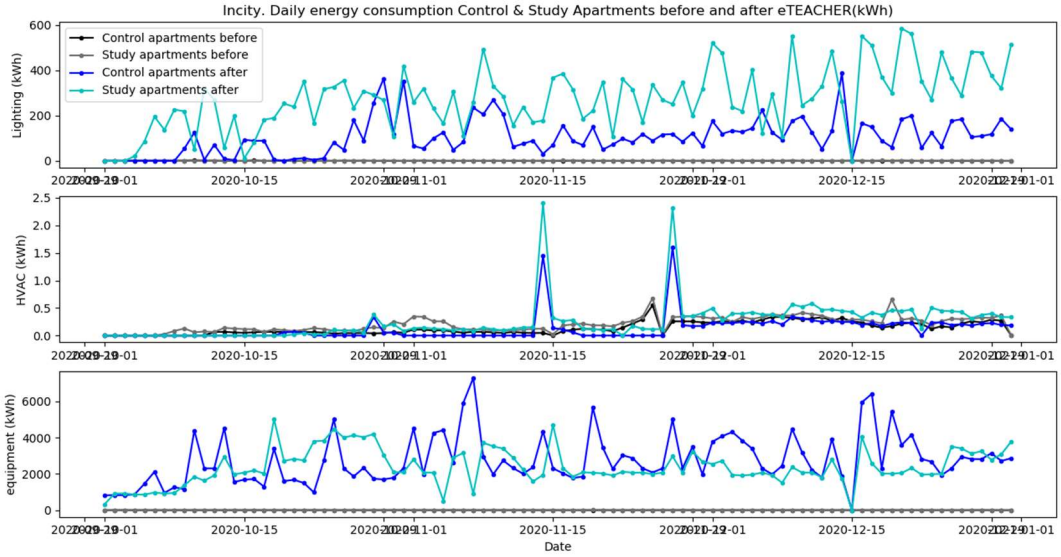



**Figure 4.19 Incity: Daily energy consumption in control and study apartments before and after eTEACHER (kWh).**

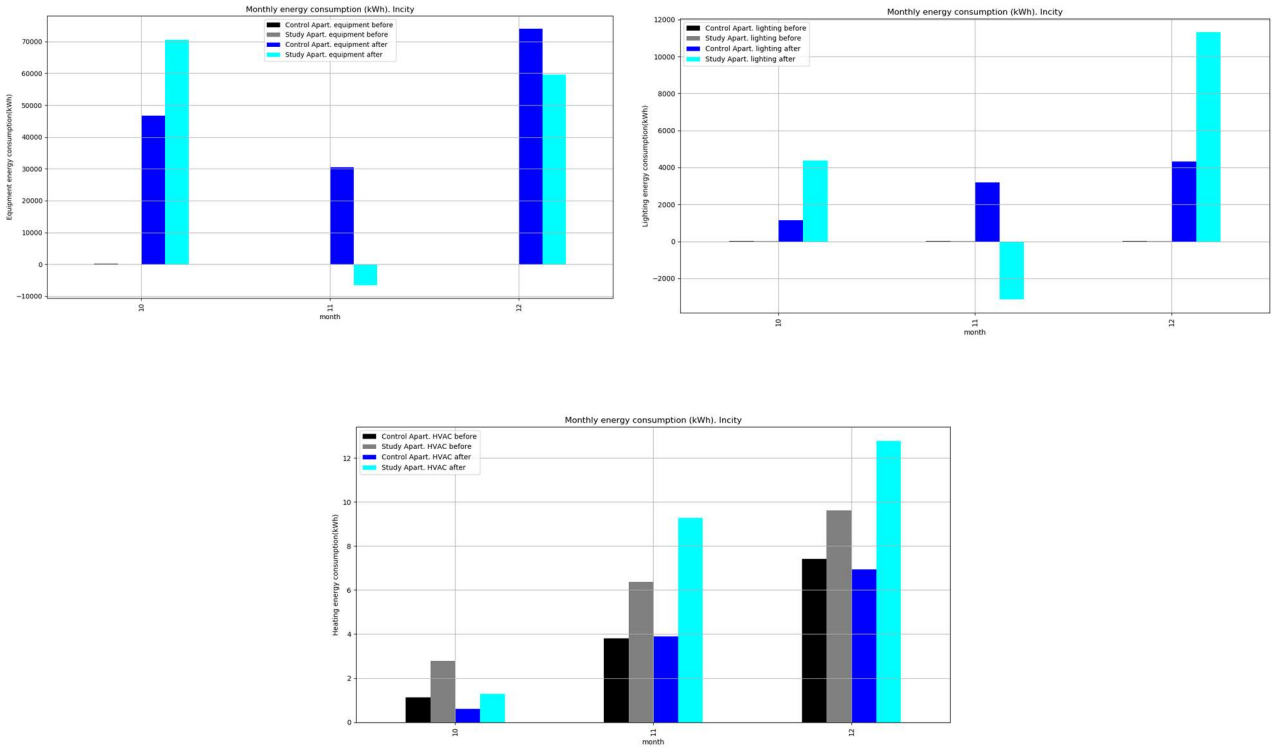



**Figure 4.20 Incity: Monthly energy consumption in control and study apartments before and after eTEACHER (kWh).**

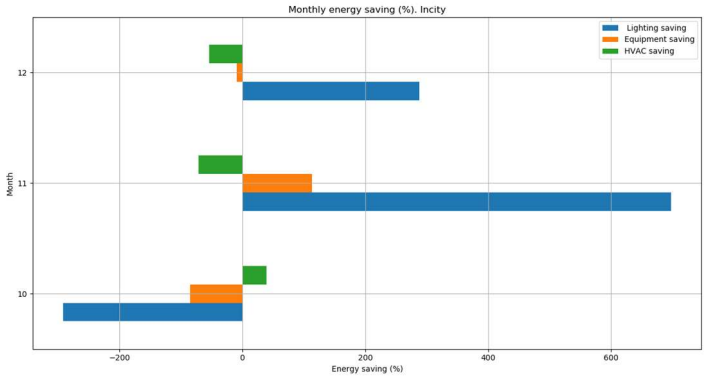



**Figure 4.21 Incity: Monthly energy saving encouraged by eTEACHER (%).**

In conclusion, the figures show some energy savings in the use of appliances (>100%) that can be encouraged by eTEACHER and no energy savings in the use of heating and equipment. A larger sample is necessary to see the real trend of the energy savings.

### 4.2.2 Enhancement of indoor environmental quality

Indoor environmental quality (IEQ) refers to the quality of a building´s environment in relation to the health and wellbeing of those who occupy the building. IEQ is determined by many factors including lighting, air quality, etc. This section is focused on 4 factors or variables related to the IEQ:

temperature, relative humidity, luminance and $CO_2$ level. The thresholds of these variables where IEQ is guaranteed have been defined according to the standards (ASHRAE, ASHRAE Fundamentals Handbook, 1997), (ASHRAE, ANSI/ASHRAE Standard 65-2001, Ventilation fo Acceptable Indoor Air Quality, 2001) (ASHRAE, Standard 55-2017 - Thermal Environmental conditions for Human Occupancy, 2017) (ISO, 2005):

- Indoor Temperature: 21-26 ºC
- Indoor Relative Humidity: 40-60%
- Indoor Luminance: ≥500 luxes (≥150 luxes in residential buildings)
- Indoor CO2 level: ≤ 800 ppm

To evaluate the enhancement of indoor environmental quality encouraged by eTEACHER, the following steps have been followed:

– Quantify the number of hours before and after eTEACHER where the rooms/zones are occupied and these variables (temperature, relative humidity, luminance and $CO_2$) are out of the thresholds where IEQ is guaranteed
– Compare the number of hours (or % of occupied hours) with no IEQ in the study and control rooms before and after eTEACHER and evaluate how much the IEQ have improved in the study room with regard to the control room after eTEACHER.

$$IEQ_{enhancemen}\ (\%) = \left(\left(\frac{No\_IEQ_{\ study\ room}(h)}{No\_IEQ_{\ control\ room}(h)}\right)_{before} - \left(\frac{No\_IEQ_{\ study\ room}(h)}{No\_IEQ_{control\ room}(h)}\right)_{after}\right) x\ 100$$

### OAR, office building, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in OAR building is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in floor 1 and floor 2 before and after eTEACHER. The reduction of hours with no IEQ of Floor 2 with regard to Floor 1 after eTEACHER will be the enhancement.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Floor 1 is considered as control room/space while Floor 2 is considered study room/space. Therefore, only floor 2 gets the eTEACHER App.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the building is less occupied and the ventilation is higher due to COVID impact.
- There is a lack of data regarding CO2 levels after eTEACHER so enhancement regarding CO2 cannot be evaluated.

**Figure 4.22** shows the percentage of occupied hours where IEQ is not achieved in floor 1 and floor 2 before and after eTEACHER (during 3.5 months). **Figure 4.23** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is worst after eTEACHER in both floors. The reason might be the higher ventilation due to COVID. However, the situation is better in floor 2 with regard to floor 1 after eTEACHER which turns into an IEQ enhancement about 400%.
- The IEQ due to relative humidity is worst in floor 1 and better in floor 2 after eTEACHER. The enhancement is about 100%
- The IEQ due to CO2 levels cannot be evaluated due to a lack of data after eTEACHER
- The IEQ due to luminance levels is worst in floor 1 and floor 2 after eTEACHER but the difference is higher in floor 2 so there have been a slight IEQ deterioration

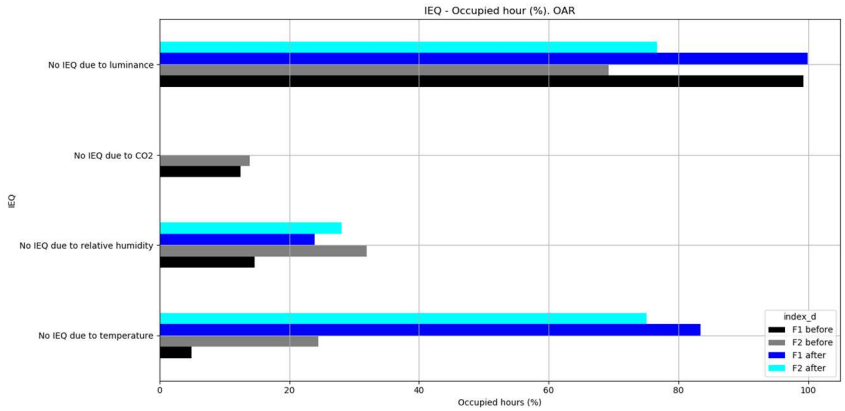



**Figure 4.22 OAR building. Percentage of occupied hours with no IEQ in floor 1 and floor 2 before and after eTEACHER (kWh).**

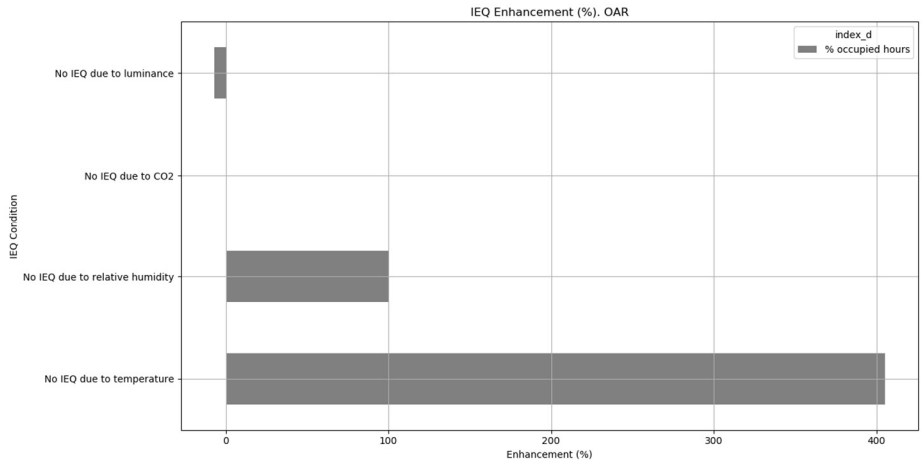



**Figure 4.23 OAR building. IEQ enhancement after eTEACHER (%).**

In conclusion, the figures show IEQ enhancement related to temperature and relative humidity. The IEQ due to luminance is slightly lower and the IEQ due to $CO_2$ level cannot be evaluated due to a lack of data. A larger sample is necessary to see the real trend of the energy savings.

### Guareña, health care centre, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in Guareña building is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in monitoring zones before and after eTEACHER. The reduction of hours with no IEQ of zone 6 with regard to zone 4 after eTEACHER will be the enhancement.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- At room/zone level, 7 rooms divided into 2 monitoring zones have been analysed. Zone 4 is the control zone and zone 6 is the study zone.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the building is less occupied and the ventilation is higher due to COVID impact.

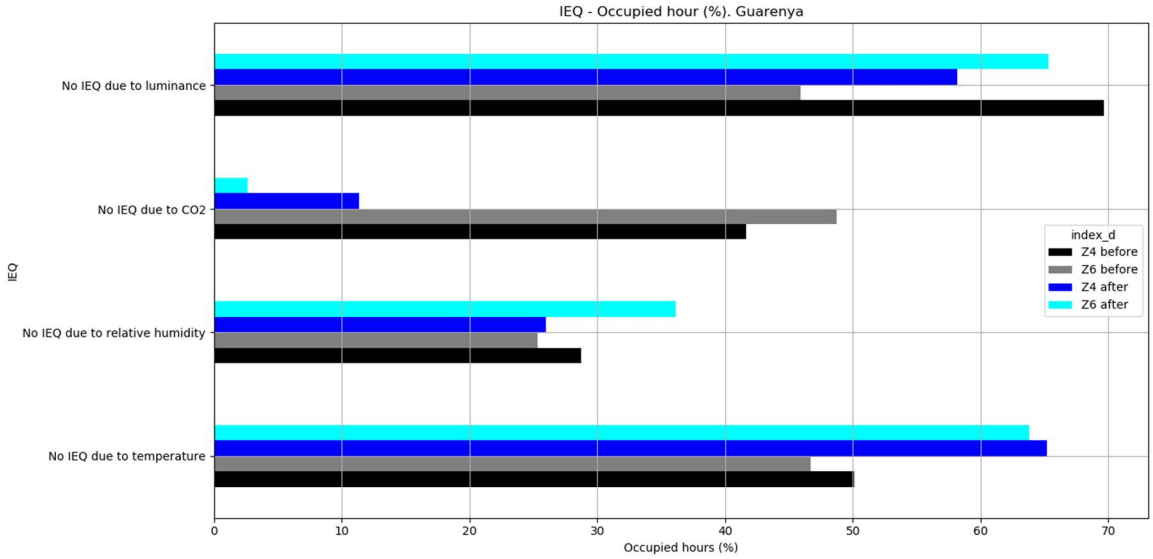



**Figure 4.24** shows the percentage of occupied hours where IEQ is not achieved in zone 4 and 6 before and after eTEACHER (during 3.5 months). **Figure 4.25** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is better after eTEACHER in both zones. However, this enhancement is slightly better in the control zone. So, there is not identified an enhancement encouraged by eTEACHER in this regard.
- The IEQ due to relative humidity is better in the control zone and worst in the study zone after eTEACHER. Therefore, there is not identified an enhancement encouraged by eTEACHER in this regard.

- The IEQ due to CO2 levels is better in the control and study zones but the enhancement is better in the study zone. Therefore, there is an IEQ enhancement that can be linked to eTEACHER (>80%).
- The IEQ due to luminance levels is better in the control zone and worst in the study zone after eTEACHER. Therefore, there is not identified any IEQ enhancement encouraged by eTEACHER in this regard.

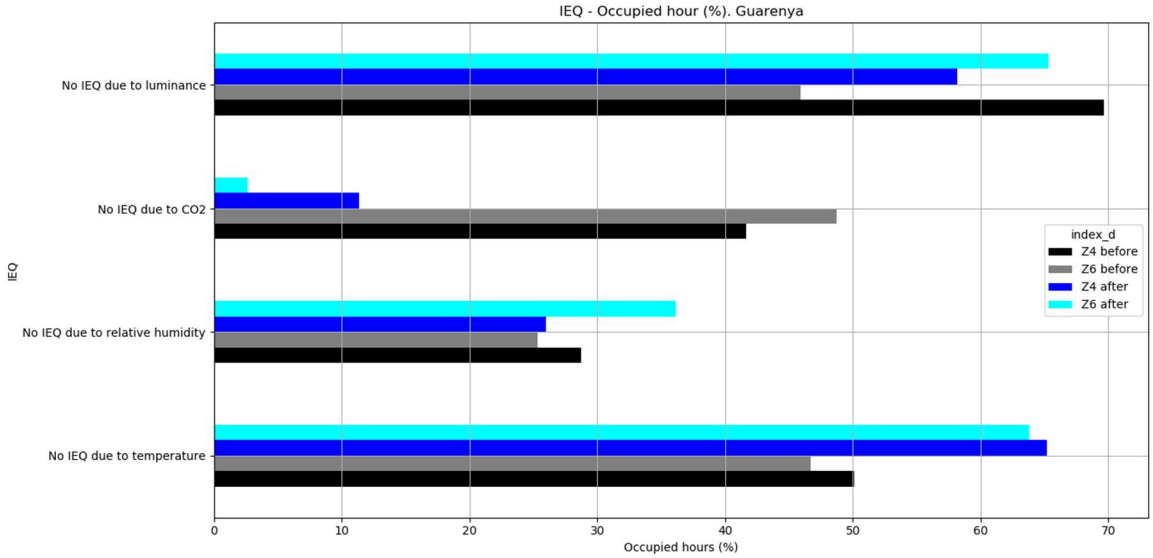



**Figure 4.24** Guareña HCC. Percentage of occupied hours with no IEQ in monitoring zones before and after eTEACHER (kWh).

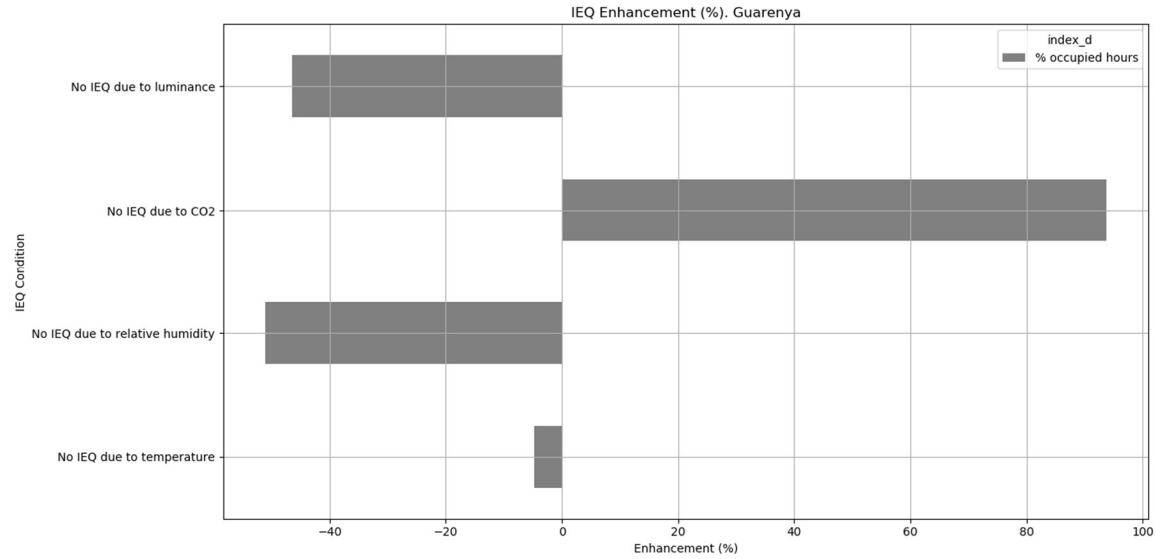


**Figure 4.25 Guareña HCC. IEQ enhancement in study zones encouraged by eTEACHER (kWh).**

In conclusion, the figures show that there is only an IEQ enhancement related to the $CO_2$ levels that can be linked to eTEACHER tools.

### Villafranca, health care centre, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in Villafranca HCC is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in monitoring rooms before and after eTEACHER. The reduction of hours with no IEQ of study consultations with regard to control consultation after eTEACHER will be the enhancement.
- Data used for the analysis belongs from 13.10.2019-13.01.2020 and from 13.10.2020-13.01.2021 because there is a lack of data from 20.09.2020-13.10.2020.
- Consultation 4 (C4) is the control room while Consultations 2,3 and 5 are study rooms so only C2, C3, C5 will use eTEACHER during the demonstration phase.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- It should be noted that there is some lack of data in the demonstration period so the enhancement in some rooms cannot be evaluated.
- There is not data to evaluate IEQ enhancement related to lighting level.
- There has been a change in the use of the building between October 2019 and October 2020 due to COVID impact:
    - The building is less occupied. Many doctor visits are solved by phone, the number of people waiting in the corridor has been reduced
    - The ventilation is higher than before.

Figure 4.26 shows the percentage of occupied hours where IEQ is not achieved in zone 4 and 6 before and after eTEACHER (during 3.5 months). **Figure 4.27** shows the IEQ enhancement (%) encouraged by eTEACHER in terms of number of hours that IEQ is not achieved.

- Regarding the temperature, the IEQ is worst after eTEACHER in all the consultations. However, the situation is worst in the control consultation. So, there is an IEQ enhancement that can be linked to eTEACHER in this regard (20%)
- The IEQ due to relative humidity is worst in all the consultations after eTEACHER. However, the situation is worst in the control room with regard to the study rooms. This results in an IEQ enhancement that can be linked to eTEACHER (60%)
- The IEQ due to $CO_2$ levels is better in all the rooms after eTEACHER. This enhancement is higher in the study rooms. Therefore, we can say there is an IEQ enhancement related to CO2 that might be encouraged by eTEACHER (30%)

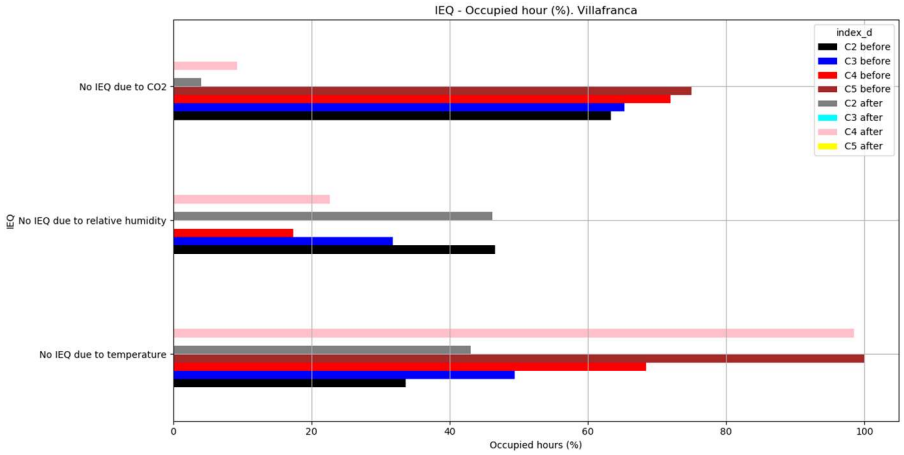



**Figure 4.26 Villafranca HCC. Percentage of occupied hours with no IEQ in monitoring consultations before and after eTEACHER (kWh).**

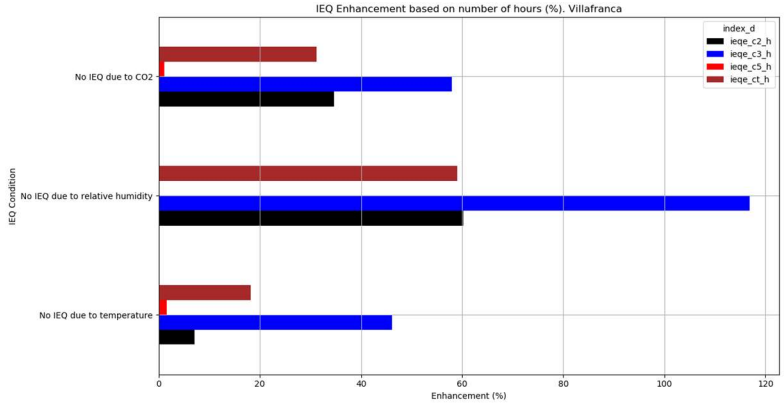



**Figure 4.27 Villafranca HCC. IEQ enhancement in study consultations encouraged by eTEACHER (kWh).**

In conclusion, the figures show that there is an IEQ enhancement that can be assumed it is encouraged by eTEACHER related to temperature (20%), relative humidity (60%) and CO2 levels (30%)

### Torrente Ballester, high school, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in Torrente high school is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in classroom 14 and 16 with regard to classroom 17 (control room) before and after eTEACHER. The reduction of hours with no IEQ of classroom 14/16 with regard to classroom 17 after eTEACHER will be the enhancement.

- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building. Although not many users from this building were registered.
- Classroom 17 is considered as control room/space so they won´t get the App while Classrooms 14 and 16 are considered study room/space.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the ventilation is higher due to COVID impact.

**Figure 4.28** shows the percentage of occupied hours where IEQ is not achieved in the monitored classrooms before and after eTEACHER (during 3.5 months). **Figure 4.29** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is worst after eTEACHER in all the classrooms. The reason might be the higher ventilation due to COVID. However, the comparison of the study classrooms with regard to the control classroom is very similar before and after eTEACHER which means there is not an improvement in this regard.
- The IEQ due to relative humidity is worst in all the classrooms after eTEACHER. However, the situation of the study classrooms with regard to the control classroom is better after eTEACHER which means there is an enhancement in this regard (40%)
- The IEQ due to CO2 levels is better in all the classrooms after eTEACHER. The reason might be the higher ventilation due to COVID. In addition, the CO2 levels are better are better in the study rooms than in the control room after eTEACHER resulting in an enhancement of about 70%
- The IEQ due to luminance levels is better after eTEACHER in all the classrooms but the improvement is higher in the control classroom so we cannot conclude there is an enhancement in this regard encouraged by eTEACHER.

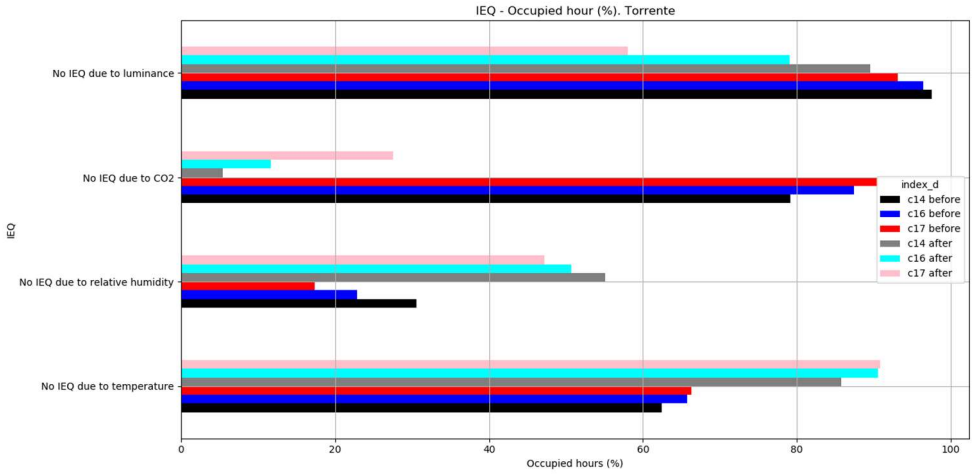



**Figure 4.28 Torrente. Percentage of occupied hours with no IEQ in classrooms 14, 16 and 17 before and after eTEACHER (%)**

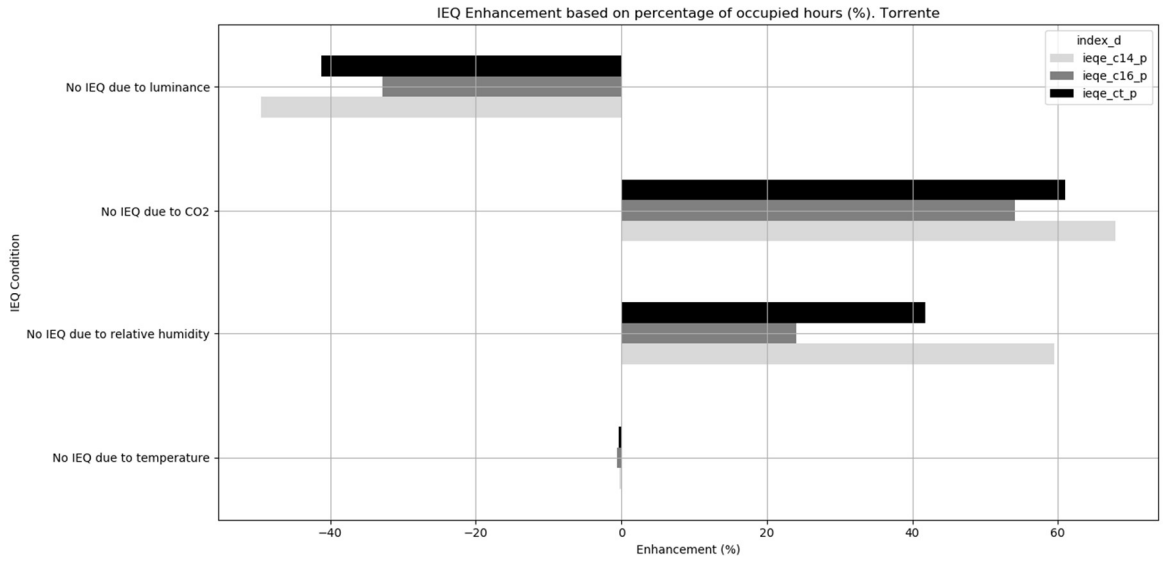



**Figure 4.29 Torrente. IEQ enhancement after eTEACHER (%).**

In conclusion, the figures show IEQ enhancement related to $CO_2$ (60%) and relative humidity (40%). On the other hand, there is not enhancement of IEQ related to the luminance level and the temperature due to eTEACHER. Further data is necessary to evaluate the IEQ enhancement encouraged by eTEACHER

### Arcoiris, Kindergarten, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in Arcoiris is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in control classrooms with regard to study rooms before and after eTEACHER. The reduction of hours with no IEQ of classroom Dolphins room with regard to Cats room after eTEACHER will be the enhancement.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building. Although not many users from this building were registered.
- Cats room is considered as control room/space so they won´t get the App while Dolphins room is considered study room/space.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the ventilation is higher due to COVID impact.

**Figure 4.28** shows the percentage of occupied hours where IEQ is not achieved in the monitored classrooms before and after eTEACHER (during 3.5 months). **Figure 4.29** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is worst after eTEACHER in both classrooms. The reason might be the higher ventilation due to COVID. However, the situation is worst in the control room so it can be assumed a IEQ enhancement encouraged by eTEACHER (40%)
- The IEQ due to relative humidity is worst in all the classrooms after eTEACHER. However, the situation of the study classroom with regard to the control classroom is better after eTEACHER which means there is an enhancement in this regard (70%)
- The IEQ due to CO2 levels is better in all the classrooms after eTEACHER. The reason might be the higher ventilation due to COVID. In addition, the CO2 levels are better in the study room than in the control room after eTEACHER resulting in an enhancement (40%)
- The IEQ due to luminance levels is similar in the control room after eTEACHER and worst in the study room. Therefore, there is no enhancement in this regard.

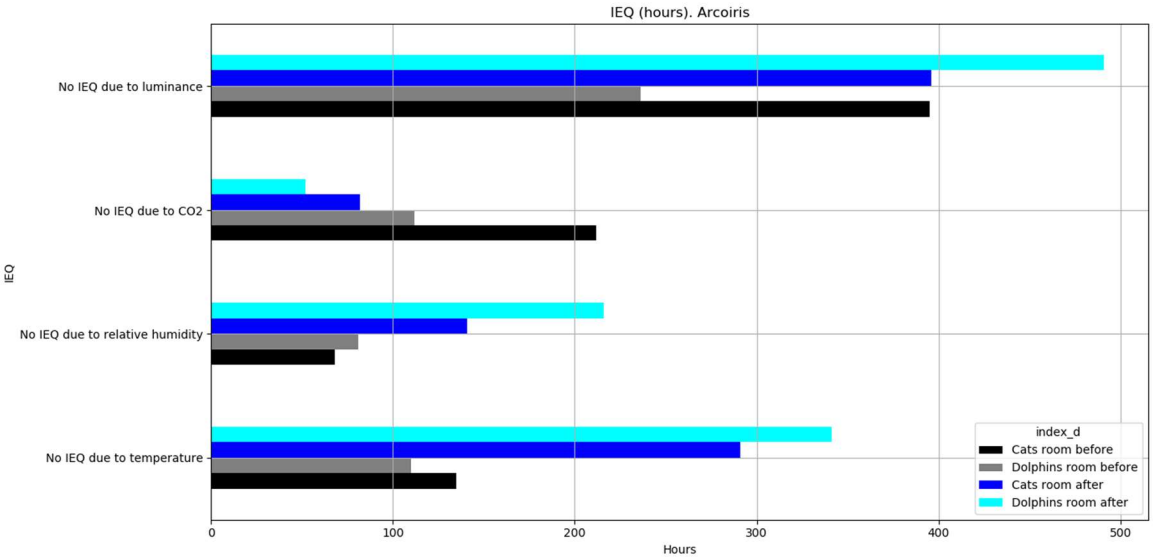



**Figure 4.30 Arcoiris. Percentage of occupied hours with no IEQ in Cats and Dolphins classrooms before and after eTEACHER (hours)**

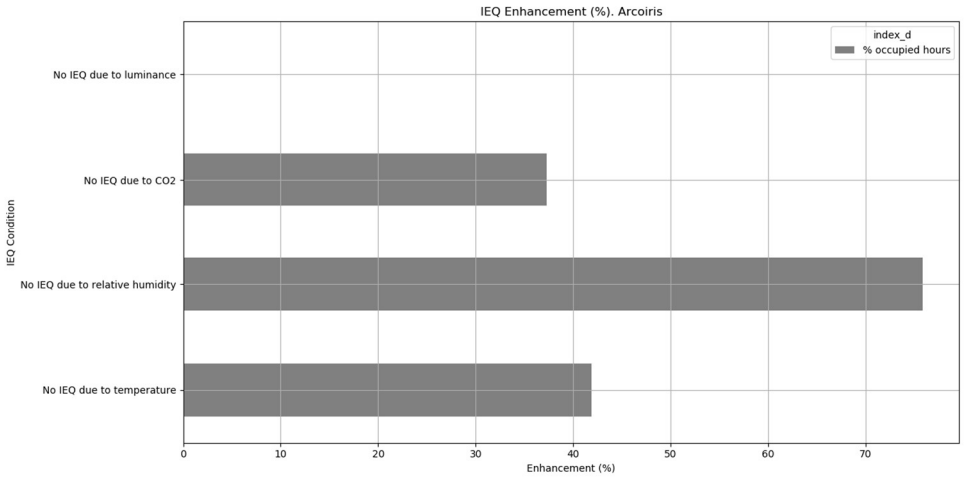



**Figure 4.31 Arcoiris. IEQ enhancement encouraged by eTEACHER (hours)**

In conclusion, the figures show IEQ enhancement that can be linked to the use of eTEACHER tools related to temperature (40%), $CO_2$ (70%) and relative humidity (40%).

### Residential Badajoz, building block, Spain

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in the Spanish residential building is shown. To understand the results, it is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in the study apartments with regard to the control apartment before and after eTEACHER. The reduction of hours with no IEQ of study apartments with regard to control apartment after eTEACHER will be the enhancement.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Apartment 5B is the control apartment, aparyments 5C and 5D are the study apartments. Apartment 5D refused to continue in the project.
- There is a lack of data in apartment 5D during the demonstration period so IEQ enhancement cannot be evaluated.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021. There have been some problems related to the maintenances of the monitoring devices in the apartments since the owners didn't like that people go inside their homes due to COVID. This may result in a lack of data quality.
- There have been some changes in the use of the building before and after eTEACHER: the building is more occupied due to COVID impact.

**Figure 4.32** shows the percentage of occupied hours where IEQ is not achieved in the monitored apartments before and after eTEACHER (during 3.5 months). **Figure 4.33** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is worst after eTEACHER in the control apartment and similar in the study apartment. Therefore, it can be assumed an IEQ enhancement encouraged by eTEACHER (10%)
- The IEQ due to relative humidity is worst in all the apartments after eTEACHER. However, the situation of the study apartment with regard to the control apartment is better after eTEACHER which means there is an enhancement in this regard (90%)
- The IEQ due to CO2 levels cannot be evaluated due to a lack of data during the demonstration phase (after eTEACHER)
- The IEQ due to luminance levels is similar in the control apartment after eTEACHER and worst in the study apartment. Therefore, there is no enhancement in this regard.

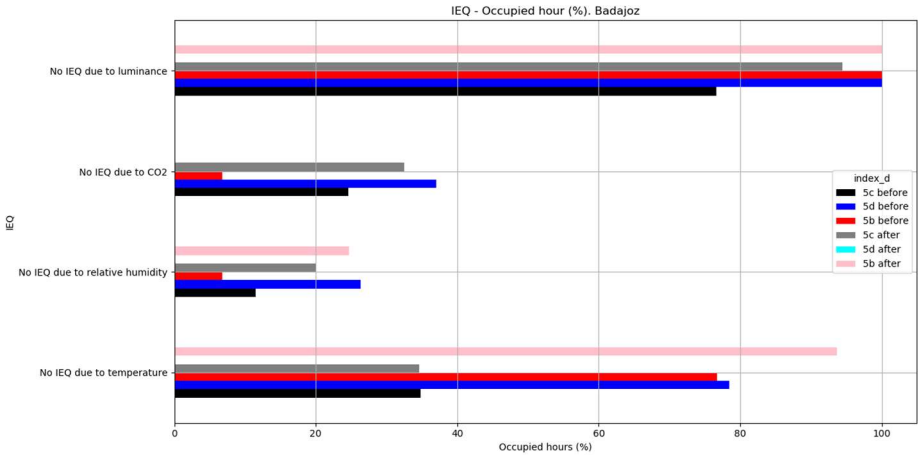



**Figure 4.32 Badajoz. Percentage of occupied hours with no IEQ in monitoring apartments before and after eTEACHER (hours)**

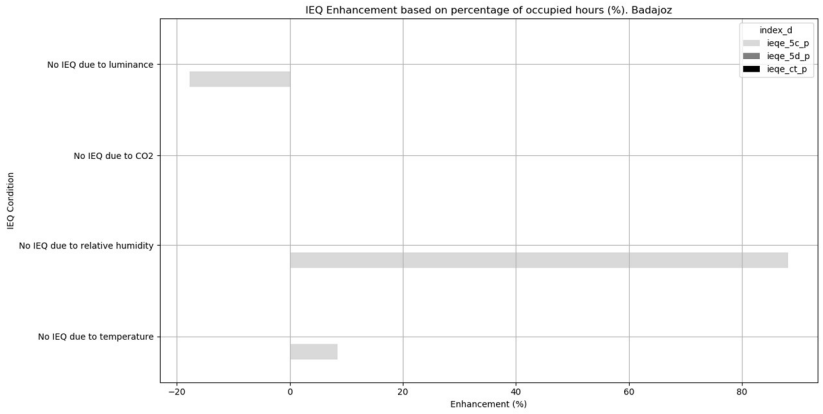



**Figure 4.33 Badajoz. IEQ enhancement encouraged by eTEACHER (%)**

In conclusion, the figures show IEQ enhancement that can be linked to the use of eTEACHER tools related to temperature (10%) and relative humidity (90%). The IEQ related to the CO2 levels cannot be evaluated because there is a lack of data and the IEQ related to luminance levels is worst after eTEACHER.

### InCity, residential building, Romanian

A preliminary evaluation of the indoor environmental quality enhancement encouraged by eTEACHER in InCity building is shown. To understand the results is important to take into account following **information**:

- The IEQ enhancement is evaluated by comparing the total number of occupied hours or percentage of occupied hours that IEQ is not achieved in study apartments with regard to control apartments before and after eTEACHER. The reduction of hours with no IEQ of study apartments with regard to control apartments after eTEACHER will be the enhancement.
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- 10 apartments have been analysed: U16, U22, U38, U127, U133, U181, U255, U273, U416, U466. The control apartments are U466, U133, U16, U273 and U255.
- Some devices are not sending data on lighting and equipment consumption.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-31.12.2019. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-31.12.2020.

**Figure 4.22** shows the percentage of occupied hours where IEQ is not achieved in floor 1 and floor 2 before and after eTEACHER (during 3.5 months). **Figure 4.23** shows the IEQ enhancement encouraged by eTEACHER.

- Regarding the temperature, the IEQ is better after eTEACHER in both type of apartments, control and study apartments. However, the enhancement is better in the control apartment. Therefore, it cannot be assumed an IEQ enhancement encouraged by eTEACHER in this regard.
- The IEQ due to relative humidity is better in control apartments after eTEACHER while it is worst in the study apartments. Therefore, it cannot be assumed an IEQ enhancement encouraged by eTEACHER in this regard.
- The IEQ due to $CO_2$ levels is better in control and study apartments after eTEACHER. This enhancement is higher in the study apartments. Therefore it can be assumed an IEQ enhancement encouraged by eTEACHER in this regard (10%).
- The IEQ due to luminance levels cannot be evaluated in this building.

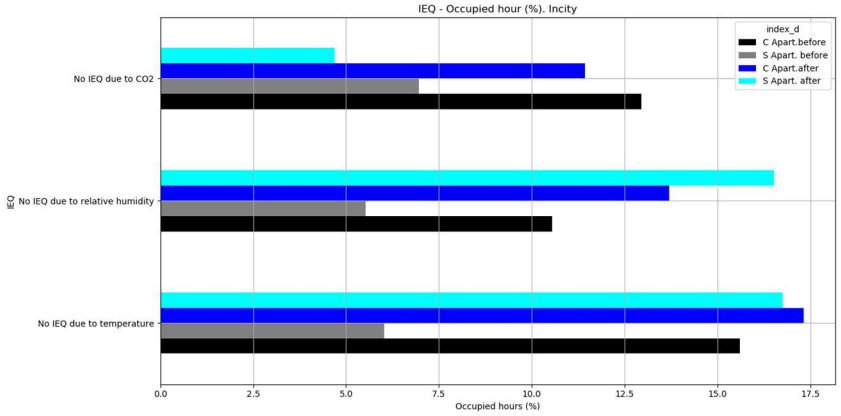



**Figure 4.34 InCity. Percentage of occupied hours with no IEQ in monitoring apartments before and after eTEACHER (%)**

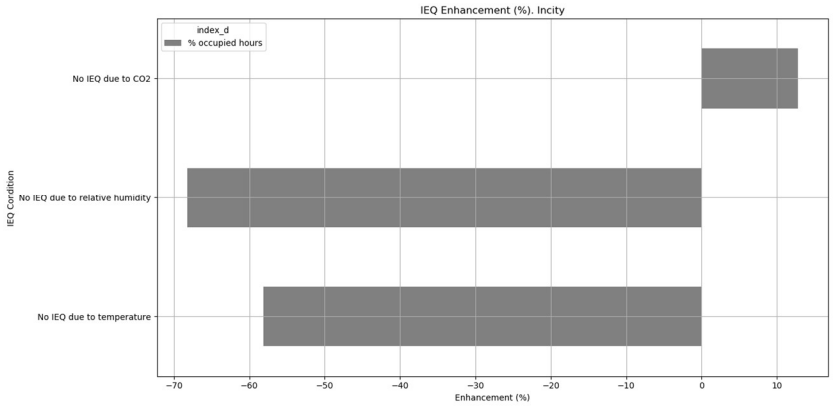



**Figure 4.35 Incity. IEQ enhancement encouraged by eTEACHER (%)**

In conclusion, the figures show an IEQ enhancement that can be linked to the use of eTEACHER tools related to the $CO_2$ levels (10%).The IEQ related to the temperature and relative humidity is worst after eTEACHER while the IEQ related to luminance levels cannot be evaluated.

### 4.2.3 Behavioral change analysis based on target behaviours evaluation

The target behaviours refer to energy related behaviours that the project aims to change. The number of hours that the target behaviours have not been achieved before and after providing the building users with eTEACHER tools have been quantified according to Table 4.5. In addition, the energy (kWh) wasted during those hours and the cost of the energy wasted during those hours (€) have been quantified.

The relation between the number of hours that the target behaviours have not been achieved in the control and study environments are compared before and after eTEACHER to evaluate the behavioural change based on the target behaviours. The control environments are rooms whose users do not receive eTEACHER tools while study environments are rooms whose users get eTEACHER tools during the demonstration phase. The relation between control rooms and study rooms allows to filter the impact of weather conditions or COVID assuming that both environments are exposed to the same changes.

$$TB_{enhancement}(\%\,h) = \left(\left(\frac{No\_TB_{\,study\,room}(h)}{No\_TB_{\,control\,room}(h)}\right)_{before} - \left(\frac{No\_TB_{\,study\,room}(h)}{No\_TB_{control\,room}(h)}\right)_{after}\right) x\ 100$$

In the same way, the relation of energy wasted during those hours where target behaviours are not achieved and the cost of that energy in the study and control room is compared before and after eTEACHER.

$$TB_{enhancemen}\ (\%\,kWh/€) = \left(\left(\frac{No\_TB_{\,study\,room}(kWh/€)}{No\_TB_{\,contr\quad room}(kWh/€)}\right)_{before} - \left(\frac{No\_TB_{\,study\,room}(kWh/€)}{No\_TB_{control\,room}(kWh/€)}\right)_{after}\right) x\ 100$$

**Table 4.5 Description of target behaviours characterization (Calleja-Rodriguez, 2019)**

| Target behaviour | Description |
|---|---|
| TB1: Turning off lights when leaving a room or at the end of the day | Count number of hours in every monitoring room that there is no one and the lights are on (*presence=0 & C_lighting > 0 kWh*)<br>Lighting energy consumed during those hours ($\sum C\_Lighting$(kWh)) and cost of that energy (e.g $\sum C\_Lighting$ kWh x 0.129893 €/kWh ) |
| TB2: Reduce use of unneeded lights checking lighting levels and needs during the day | Count number of hours in every monitoring room that indoor lighting level is enough, outdoor luminance is high and the lights are on (*lum_i > 500 luxes , lum_o >12000 luxes & C_lighting > 0 kWh*)<br>Lighting energy consumed during those hours ($\sum C\_Lighting$(kWh)) and cost of that energy (e.g $\sum C\_Lighting$ kWh x 0.129893 €/kWh ) |
| TB3: Turn off appliances at the end of the day | Count number of hours in every monitoring room that appliances are on, there is no one and it is later that a certain hour when the office/school is close (*C_appliances > 0 kWh, presence =0 & e.g. time>16h*)<br>Appliances energy consumed during those hours ($\sum C\_appliances$(kWh)) and cost of that energy (e.g $\sum C\_appliances$ kWh x 0.129893 €/kWh ) |
| TB4: Appliances off when away from room for 1 hour or more. | Count number of hours in every monitoring room that appliances are on, there is no one (*C_appliances > 0 kWh & presence=0*)<br>Appliances energy consumed during those hours ($\sum C\_Appliances$(kWh)) and cost of that energy (e.g $\sum C\_Appliances$ kWh x 0.129893 €/kWh ) |
| TB5: Reducing thermostat temperature for heating when overheating | Count number of hours in every monitoring room that temperature inside is high and heating is on (*temp_i > 21ºC, C_heating > 0*)<br>Heating energy consumed during those hours ($\sum C\_heating$(kWh)) and cost of that energy (e.g $\sum C\_heating$ kWh x 0.129893 €/kWh ) |
| TB6: Increasing thermostat temperature for cooling when undercooling | Count number of hours in every monitoring room that temperature inside is high and heating is on (temp_i > 21ºC & *C_cooling > 0 kWh*)<br>Cooling energy consumed during those hours ($\sum C\_cooling$(kWh)) and cost of that energy (e.g $\sum C\_cooling$ kWh x 0.129893 €/kWh) |
| TB7: Ensuring that if heating/cooling is on, windows and doors are kept closed (if possible) | Count number of hours in every monitoring room that HVAC system is on and windows/doors are opened (C_HVAC > 0 kWh & Windows > 0)<br>HVAC energy consumed during those hours ($\sum C\_HVAC$(kWh)) and cost of that energy (e.g $\sum C\_HVAC$ kWh x 0.129893 €/kWh) |

| | |
|---|---|
| TB8: Turn off HVAC system if room/building is not in use for more than one hour | Count number of hours in every monitoring room that HVAC system is on and there is no one for more than one hour (C_HVAC > 0 kWh & presence = 0)<br>HVAC energy consumed during those hours ($\sum C\_HVAC$(kWh)) and cost of that energy (e.g $\sum C\_HVAC$ kWh x 0.129893 €/kWh) |
| TB9: Ensuring that air-conditioning and heating are not working at the same time | Count number of hours in every monitoring room that heating is on and cooling is on (*C_Heating > 0 kWh & C_Cooling > 0 kWh*)<br>HVAC energy consumed during those hours ($\sum C\_HVAC$(kWh)) and cost of that energy (e.g $\sum C\_HVAC$ kWh x 0.129893 €/kWh) |

### OAR, office building, Spain

A preliminary evaluation of the behavioural change encouraged by eTEACHER in OAR building based on the analysis of the target behaviour is shown. To understand the results is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in floor 1 and floor 2 before and after eTEACHER. The reduction of hours of Floor 2 with regard to Floor 1 after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (kwh)
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Floor 1 is considered as control room/space while Floor 2 is considered study room/space. Therefore, only floor 2 gets the eTEACHER App.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021

**Figure 4.36** and **Figure 4.37** show the number of hours that target behaviours have not been achieved before and after eTEACHER in floor 1 and floor 2 as well as the energy costs during those hours. Following comments can be made regarding the behavioural change in terms of hours:

- (TB1) Turning off lights when leaving a room or at the end of the day was worst in floor 1 than in floor 2 before eTEACHER (F1b/F2b=1277h/1040h). However, this behaviour is worst in floor 2 after eTEACHER (F1a/F2a=556h/1182h). This shows that eTEACHER was not useful to encourage users to change this behaviour.
- (TB2) Use of unneeded lights is similar in both floors before and after eTEACHER (F1b/F2b=435h/435h; F1a/F2a=340h/340h).
- (TB3) Turn off appliances at the end of the day is worst in floor 2 before and after eTEACHER but the difference is higher before so it seems there has been an improvement due to eTEACHER (F1b/F2b=79h/260h; F1a/F2a=146h/252h)..

- (TB4) Appliances off when away from room for 1 hour or more is worst in floor 2 before and after eTEACHER but the difference is higher before so it seems there has been an improvement due to eTEACHER (F1b/F2b=274h/997h; F1a/F2a=556h/940h)..
- (TB5) Reducing thermostat temperature for heating when overheating. It is better in floor 2 before eTEACHER and worst in floor 2 after eTEACHER. Therefore, this behaviour is worst with eTEACHER (F1b/F2b=1099h/407h; F1a/F2a=93h/105h)..
- (TB6) Increasing thermostat temperature for cooling when undercooling. This behaviour is better in floor 2 before and after eTEACHER but the difference is higher after. Therefore, there has been an improvement (F1b/F2b=253h/249h; F1a/F2a=213h/133h).
- (TB7) Ensuring that if heating/cooling is on, windows and doors are kept closed is worst in floor 2 with regard to floor 1 before while is better after. Therefore, there has been an improvement of this behaviour (F1b/F2b=2220h/2290h; F1a/F2a=1975h/1948h)..
- (TB8) Turn off HVAC system if room/building is not in use for more than one hour. This behaviour is better in floor 2 with regard to floor 1 before and wort after eTEACHER. So there have been a worsening (F1b/F2b=1277h/1040h; F1a/F2a=512h/1001h).

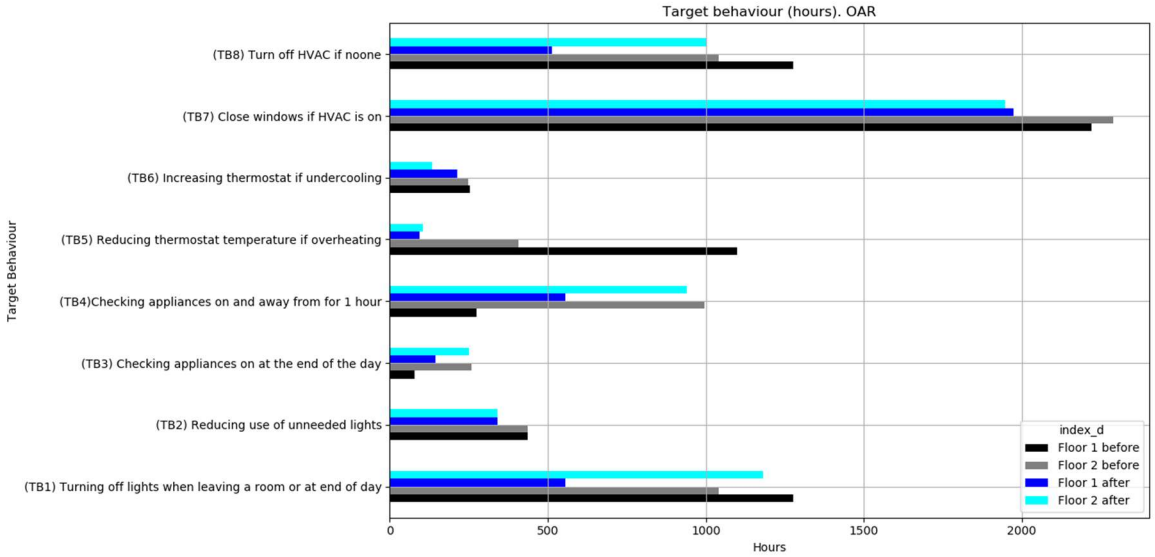



**Figure 4.36 OAR building. Number of hours that a target behaviour is not achieved before and after eTEACHER in floor 1 and 2 (h).**

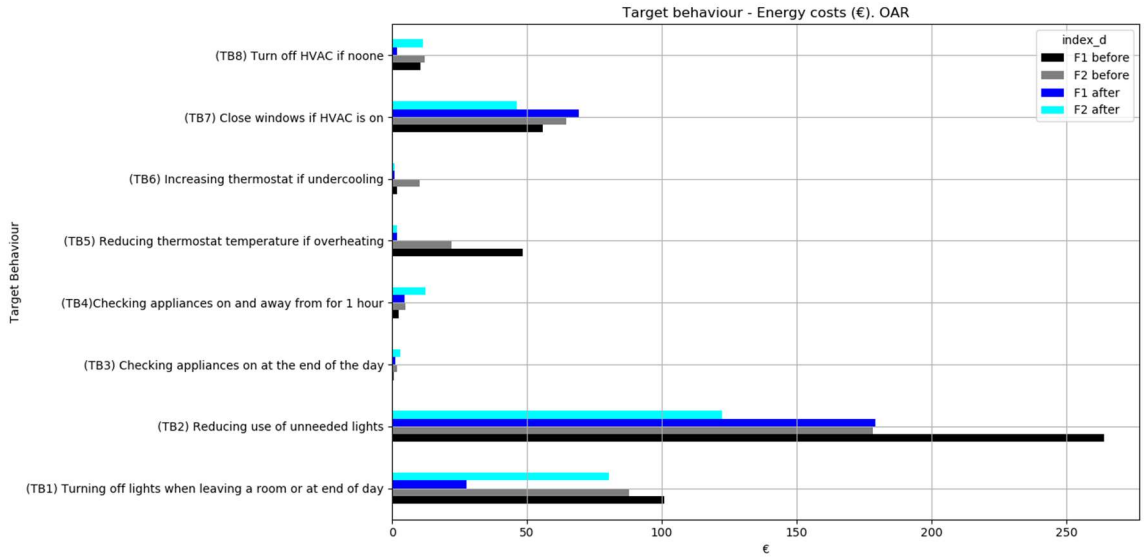



**Figure 4.37 OAR building. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in floor 1 and 2.**

Figure 4.38 shows the target behaviour enhancement (%) in terms of hours and energy costs:

- TB3 Turn off appliances at the end of the day (94%), TB6 Increasing thermostat temperature for cooling when undercooling (474%) and TB7 Ensuring that if heating/cooling is on, windows and doors are kept closed (48%) have been improved in terms of energy costs
- TB1 Turning off lights when leaving a room or at the end of the day, TB4 Appliances off when away from room for 1 hour or more, TB5 Reducing thermostat temperature for heating when overheating, TB8 Turn off HVAC system if room/building is not in use for more than one hour are worst in terms of energy costs
- TB2 Reduce use of unneeded lights checking lighting levels and needs during the day is very similar before and after eTEACHER.

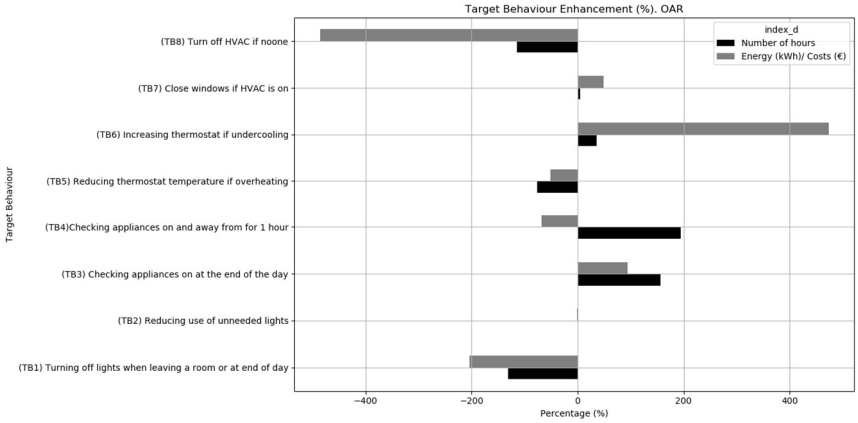



**Figure 4.38 OAR building. Target behaviour enhancement encouraged by eTEACHER in terms of hours and energy costs (%)**

In conclusion, behaviours related to the use of appliances have been improved while behaviours related with the use of lighting are very similar and behaviours related to the use of heating are worst

### Guareña, health care centre, Spain

A preliminary evaluation of the behavioural change encouraged by eTEACHER in Guareña HCC based on the analysis of the target behaviours is shown. To understand the results is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in study zones with regard to control zone before and after eTEACHER. The reduction of hours of study zones with regard to the control zones after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (€)
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- At room/zone level, 7 rooms divided into 2 monitoring zones have been analysed. Zone 4 is the control zone and zone 6 is the study zone.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the building is less occupied and the ventilation is higher due to COVID impact.

**Figure 4.39** and **Figure 4.40** show the number of hours that target behaviours have not been achieved before and after eTEACHER in zone 4 and 6 as well as the energy costs during those hours. **Figure 4.41** summarizes the target behaviour enhancement. Following comments can be made regarding the behavioural change:

- (TB1) Turning off lights when leaving a room or at the end of the day is worst in the control zone after eTEACHER and better in the study zone. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (39 % hours ; 35 % energy costs €)
- (TB2) Use of unneeded lights cannot be evaluated in this building
- (TB3) Turn off appliances at the end of the day has improved in both zones after eTEACHER but the enhancement is higher in the study zone. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (38 % hours ; >100 % energy costs €)
- (TB4) Appliances off when away from room for 1 hour or more is better in the control and study zones after eTEACHER. Since the enhancement is higher in the study zone, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (44 % hours ; >100 % energy costs €).
- (TB5) Reducing thermostat temperature for heating when overheating has improved in the control and study zones after eTEACHER. However, the improvement is higher in the study

zone so it can be assumed an enhancement of this behaviour related to the use of eTEACHER (35 % energy costs €).

- (TB6) Increasing thermostat temperature for cooling when undercooling. It is not evaluated due the season of the data that we are using.
- (TB7) Close windows if HVAC is on is worst after eTEACHER in both zones, control and study. This behaviour is related to the higher ventilation due to COVID.
- (TB8) Turn off HVAC if no one is better in both zones, control and study, after eTEACHER. The enhancement is higher in the study zone so it can be assumed a positive behavioural change encourage by eTEACHER and related to this target behaviour (3,21 % hours ; 60 % energy costs €).

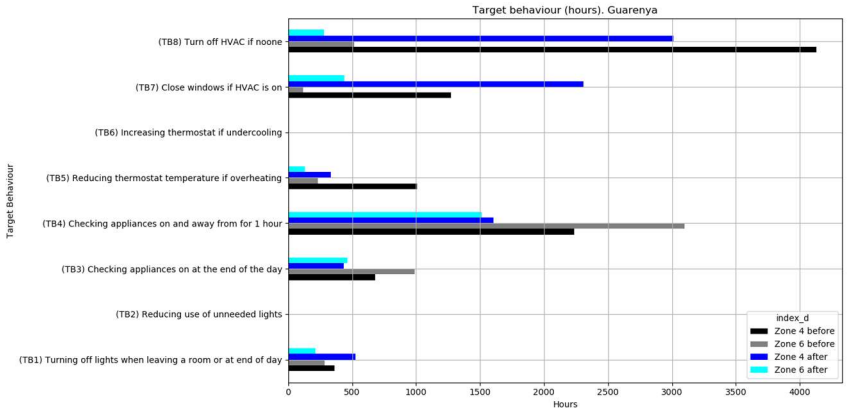



**Figure 4.39 Guareña HCC. Number of hours that a target behaviour is not achieved before and after eTEACHER in zone 4 and 6 (h).**

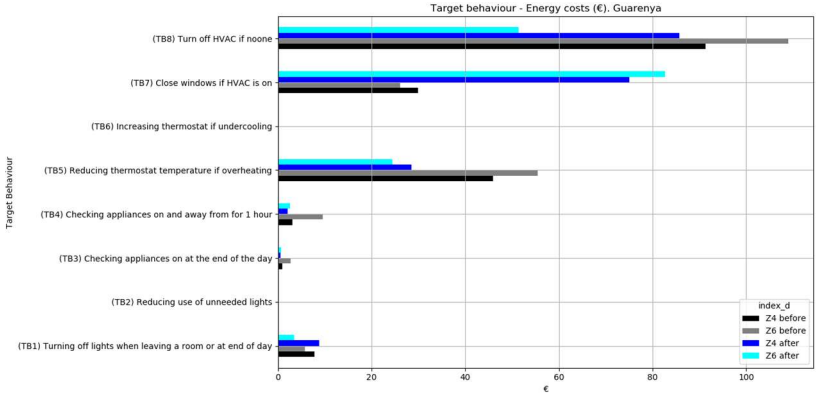



**Figure 4.40 Guareña. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in zone 4 and 6.**

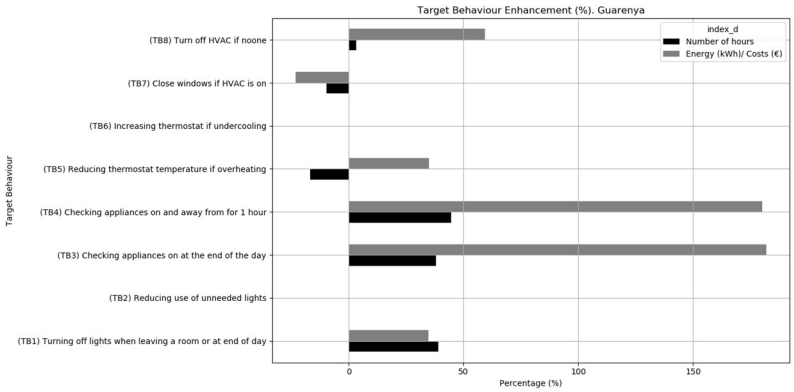



**Figure 4.41 Guareña HCC. Target behaviour enhancement encouraged by eTEACHER in terms of hours and energy costs (%)**

In conclusion, figures show that there have been a positive behavioural change related to most of the target behaviours evaluated: TB1 Turning off lights when leaving a room (39%), TB3 Turn off appliances at the end of the day (38%), TB4 Appliances off when away from room for 1 hour or more (44%), TB5 Reducing thermostat temperature for heating when overheating (35%), TB8 Turn off HVAC if no one (3%)

### Villafranca, health care centre, Spain

A preliminary evaluation of the behavioural change encouraged by eTEACHER in Villafranca HCC based on the analysis of the target behaviours is shown. To understand the results is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in study consultations with regard to control consultation before and after eTEACHER. The reduction of hours of the study consultations with regard to the control consultation after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (€)
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Consultation 4 (C4) is the control room while Consultations 2,3 and 5 are study rooms so only C2, C3, C5 will use eTEACHER during the demonstration phase.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the building is less occupied and the ventilation is higher due to COVID impact.

**Figure 4.42Figure 4.39** and **Figure 4.43Figure 4.40** show the number of hours that target behaviours have not been achieved before and after eTEACHER as well as the energy costs during those hours. **Figure 4.44** summarizes the target behaviour enhancement. Following comments can be made regarding the behavioural change:

- (TB1) Turning off lights when leaving a room or at the end of the day is worst in the control consultation after eTEACHER and better in the study consultation. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % energy costs €)
- (TB2) Use of unneeded lights cannot be evaluated in this building
- (TB3) Turn off appliances at the end of the day is worst in all the consultations after eTEACHER but the situation is worst in the control consultation. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % energy costs €)
- (TB4) Appliances off when away from room for 1 hour or more is worst in the control and study consultations after eTEACHER. Since the situation is better in the study consultations, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % energy costs €).
- (TB5) Reducing thermostat temperature for heating when overheating has improved in the most of the study consultations and in the control consultation after eTEACHER. However, the improvement is higher in the control room so it cannot be assumed an enhancement of this behaviour related to the use of eTEACHER
- (TB7) Close windows if HVAC is on is worst after eTEACHER in all the consultations, control and study. This behaviour is related to the higher ventilation due to COVID.
- (TB8) Turn off HVAC if noone is worst in all the consultation, control and study, after eTEACHER. However, the situation is better in the study consultations with regard to the control room so it can be assumed a positive behavioural change encouraged by eTEACHER and related to this target behaviour (>100 % energy costs €).

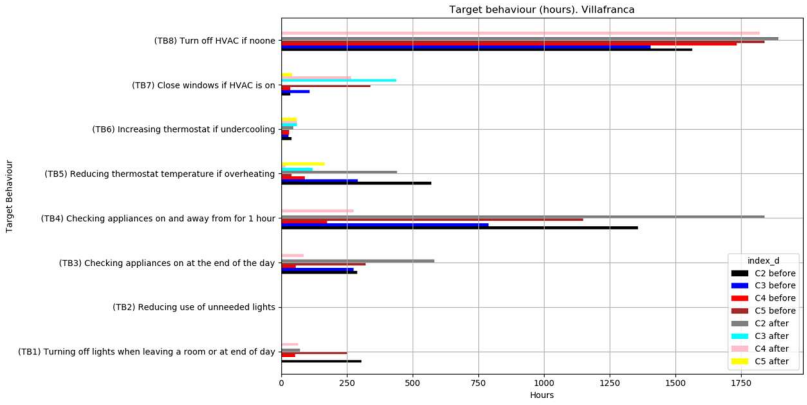



**Figure 4.42 Villafranca HCC. Number of hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations (h).**

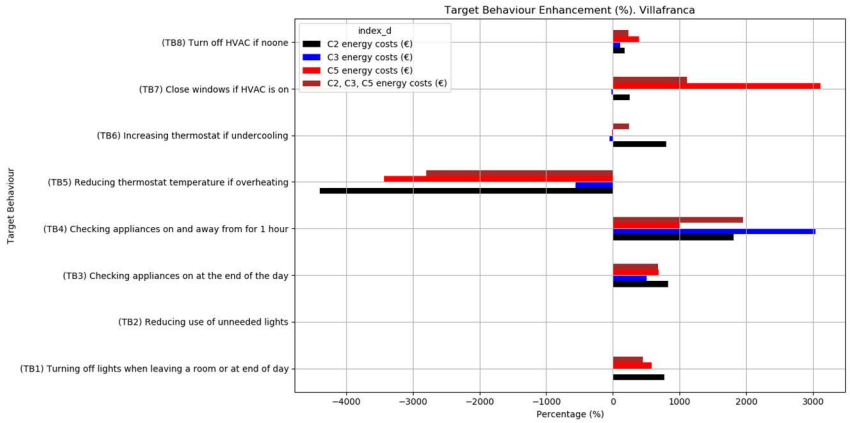



**Figure 4.43 Villafranca HCC. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations.**

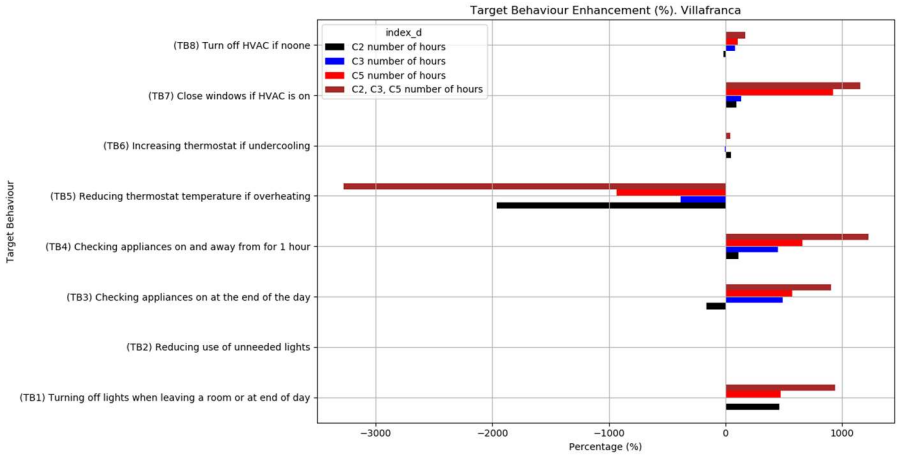



**Figure 4.44 Villafranca HCC. Target behaviour enhancement encouraged by eTEACHER in terms of hours (%)**

In conclusion, it can be appreciated a positive behavioural change in the use of lighting, appliances and HVAC (TB1, TB3, TB4 and TB8) when there is noone in the room that can be assumed it is related with the use of eTEACHER and that have an important impact on energy costs savings (>100%) for the time evaluated.

### Torrente Ballester, high school, Spain

A preliminary evaluation of behavioural change encouraged by eTEACHER has been carried. Following information is important to understand the results:

- The behavioural change is evaluated taking into account the enhancement related to the target behaviours. The target behaviours are evaluated by comparing the number of hours – the energy used in those hours and the cost of that energy - that a target behaviour is not achieved in classroom 14 and 16 with regard to classroom 17 (control room) before and after

eTEACHER. The reduction of hours that a target behaviour is not achieved in classroom 14/16 with regard to classroom 17 after eTEACHER is considered the enhancement.

- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building. Although not many users from this building were registered.
- Classroom 17 is considered as control room/space so they won´t get the App while Classrooms 14 and 16 are considered study room/space.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the ventilation is higher due to COVID impact.

**Figure 4.45** shows the number of hours that a target behaviour is not achieved in the monitoring classrooms before and after eTEACHER. **Figure 4.46** shows the target behaviours enhancement (%) in terms of hours:

- (TB8) Turn off HVAC if no one and (TB7) Close windows if HVAC is on are worst after eTEACHER in all the classrooms, and the worsening in the study classrooms is higher with regard to the control classroom. So, there is no behavioural change encouraged by eTEACHER in this regard. It should be noted that schools must ventilate frequently after eTEACHER due to COVID.
- (TB5) Reducing thermostat temperature if overheating cannot be evaluated because there is a lack of data in the period before eTEACHER.
- (TB4) Checking appliances on and away from for 1 hour is worst in the control room after eTEACHER while it is better in the study rooms after eTEACHER. Therefore, there might be a target behaviour enhancement in this regard encouraged by eTEACHER about 21%

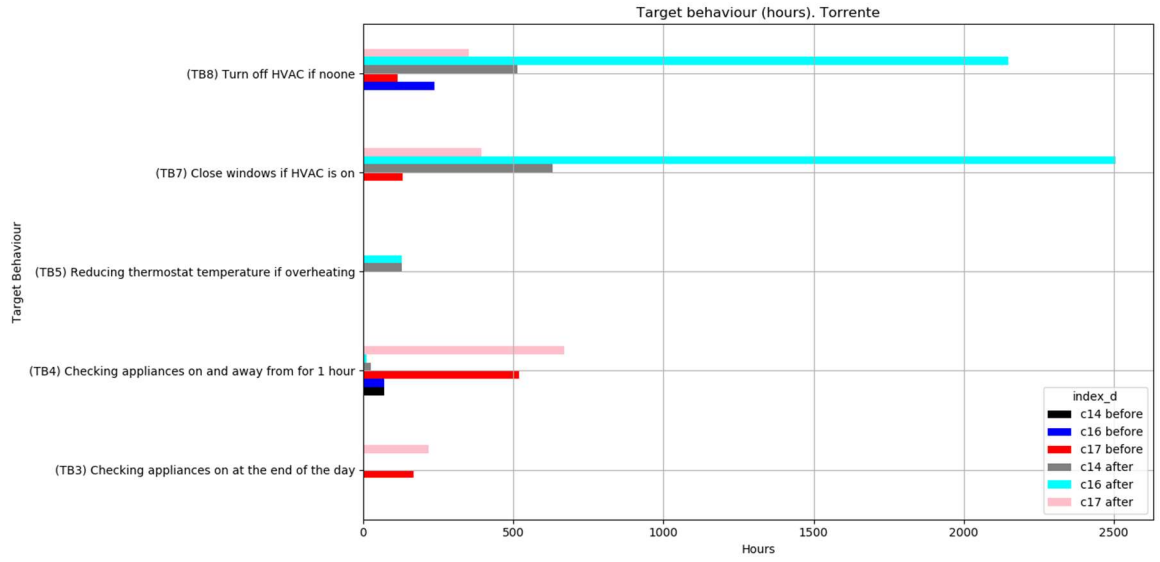



**Figure 4.45 Torrente. Number of hours that a target behaviour is not achieved before and after eTEACHER in classrooms 14, 16 and 17 (h).**

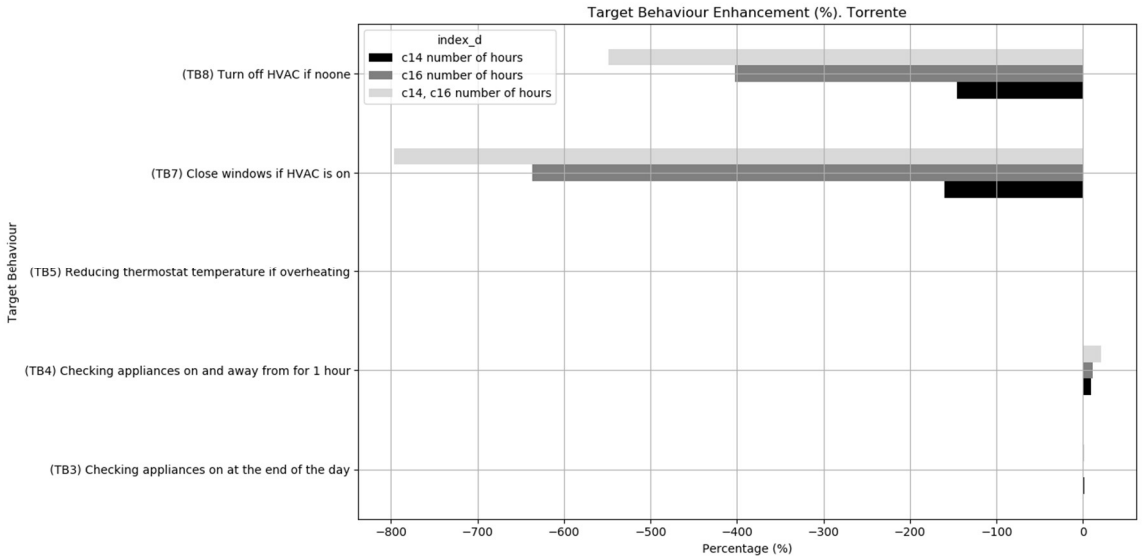



**Figure 4.46 Torrente. Target behaviour enhancement (%) after eTEACHER in classrooms 14, 16 and 17 in terms of hours**

In conclusion, it can be appreciated a behavioural change regarding (TB4) Checking appliances on and away from for 1 hour encouraged by eTEACHER. The enhancement is about 21%. Other target behaviours related to the use of the windows and heating are worst or cannot be evaluated. The reason for this might be the need to increase ventilation due to COVID.

### Arcoiris, Kindergarten, Spain

A preliminary evaluation of the behavioural change encouraged by eTEACHER in Arcoiris based on the analysis of the target behaviours is shown. To understand the results, it is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in study room with regard to control room before and after eTEACHER. The reduction of hours of the study classroom with regard to the control classroom after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (€).
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Cats room is considered as control room/space so they won´t get the App while Dolphins room is considered study room/space
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the ventilation is higher due to COVID impact.

**Figure 4.47** and **Figure 4.48** show the number of hours that target behaviours have not been achieved before and after eTEACHER as well as the energy costs during those hours. **Figure 4.49** summarizes the target behaviour enhancement. Following comments can be made regarding the behavioural change:

- (TB1) Turning off lights when leaving a room or at the end of the day is worst in the control classroom after eTEACHER and better in the study room. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (41% number of hours
- (TB2) Use of unneeded lights cannot be evaluated in this building
- (TB3) Turn off appliances at the end of the day is better in all the classrooms after eTEACHER but the situation is better in the study classroom. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % number of hours
- (TB4) Appliances off when away from room for 1 hour or more is worst in the control classroom and better in the study classroom after eTEACHER. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % number of hours
- (TB5) Reducing thermostat temperature for heating when overheating has improved in control and study classroom after eTEACHER. The improvement is higher in the study room so it can be assumed an enhancement of this behaviour related to the use of eTEACHER (14% number of hours)
- (TB7) Close windows if HVAC is on is worst in the control room and better in the study room after eTEACHER. Therefore, it can be assumed an enhancement of this behaviour related to the use of eTEACHER (16 % number of hours)
- (TB8) Turn off HVAC if no one is better in the control and study room after eTEACHER. The situation is better in the study room with regard to the control room so it can be assumed a positive behavioural change encouraged by eTEACHER and related to this target behaviour (30 % number of hours)
- (TB9) Heating and cooling at the same time is better in the control and study room after eTEACHER. The enhancement is higher in the study room so it can be assumed a positive behavioural change encouraged by eTEACHER and related to this target behaviour (10 % number of hours)

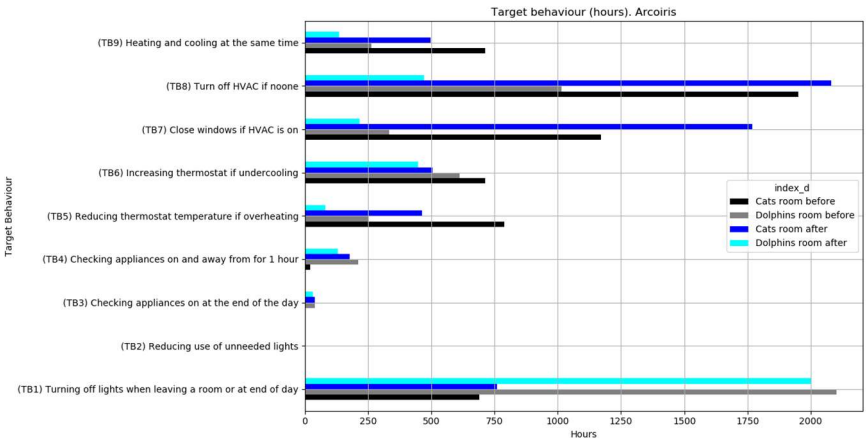


**Figure 4.47 Villafranca HCC. Number of hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations (h).**

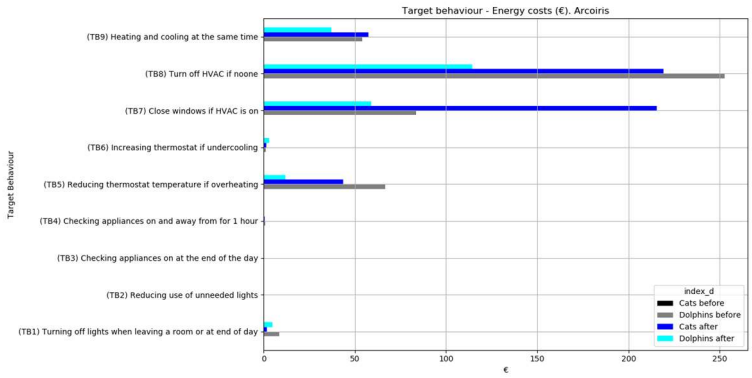



**Figure 4.48 Villafranca HCC. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations.**

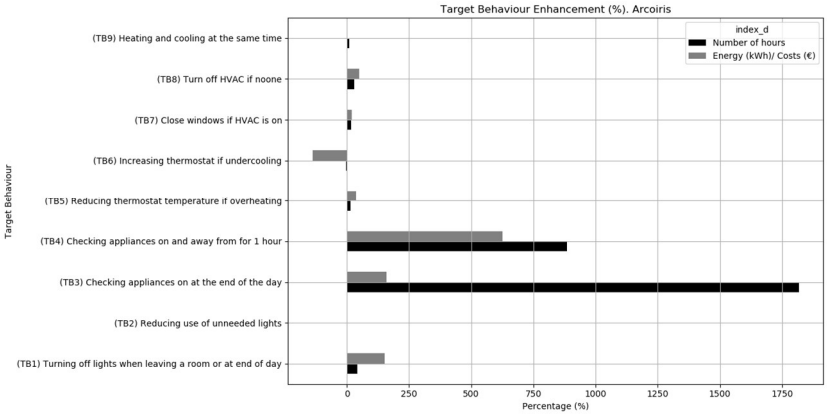



**Figure 4.49 Villafranca HCC. Target behaviour enhancement encouraged by eTEACHER in terms of hours (%)**

In conclusion, figures show that there have been a positive behavioural change related to most of the target behaviours evaluated: TB1 Turning off lights when leaving a room (41%), TB3 Turn off appliances at the end of the day (>100%), TB4 Appliances off when away from room for 1 hour or more (>100%), TB5 Reducing thermostat temperature for heating when overheating (14%), TB7 Close windows if HVAC is on (16%), TB8 Turn off HVAC if no one (30%), TB9 Heating and cooling at the same time (10%)

### Residential Badajoz, building block, Spain

A preliminary evaluation of the behavioural change encouraged by eTEACHER in the Spanish residential building based on the analysis of the target behaviours is shown. To understand the results is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in study apartments with regard to control apartments before and after eTEACHER. The reduction of hours of the study apartments with regard to the control apartments after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (€)
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- Apartment 5B is the control apartment, apartments 5C and 5D are the study apartments. Apartment 5D refused to continue in the project.
- There is a lack of data so only two target behaviours can be evaluated
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-13.01.2020. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-13.01.2021
- There have been some changes in the use of the building before and after eTEACHER: the apartments are more occupied due to COVID impact.

**Figure 4.50** and **Figure 4.51** show the number of hours that target behaviours have not been achieved before and after eTEACHER as well as the energy costs during those hours. **Figure 4.52** summarizes the target behaviour enhancement. Following comments can be made regarding the behavioural change:

- (TB4) Appliances off when away from room for 1 hour or more is worst in the control and study apartments after eTEACHER. The situation is worst in the control apartments with regard to the study apartments. Therefore, it can be assumed an enhancement of this target behaviour related to the use of eTEACHER (>100 % number of hours)
- Although we have data about TB6 increasing thermostat if undercooling, it is not enough to draw conclusions

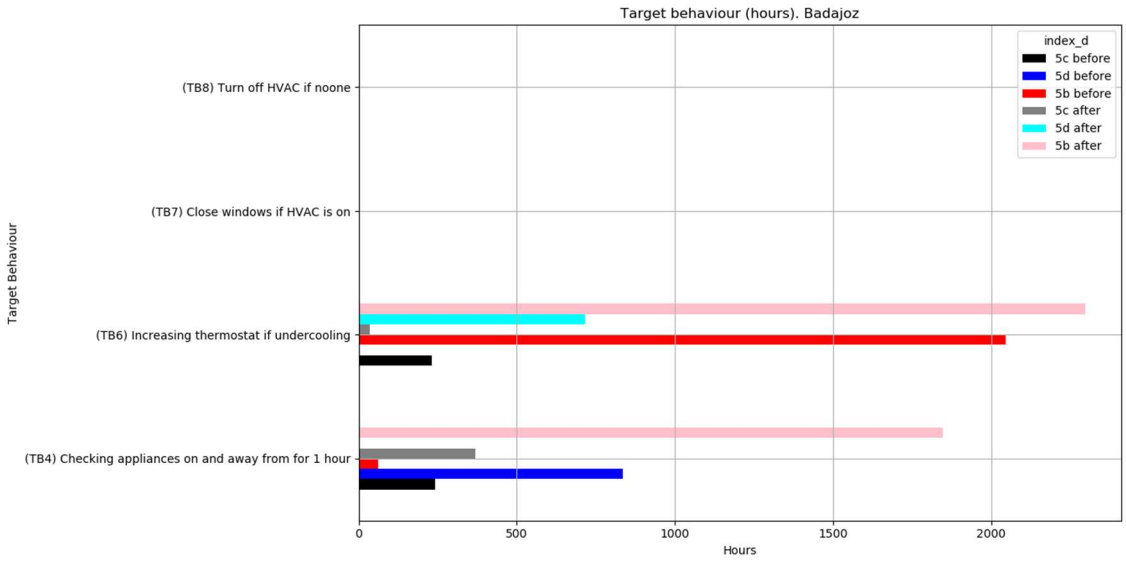



**Figure 4.50 Badajoz. Number of hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations (h).**

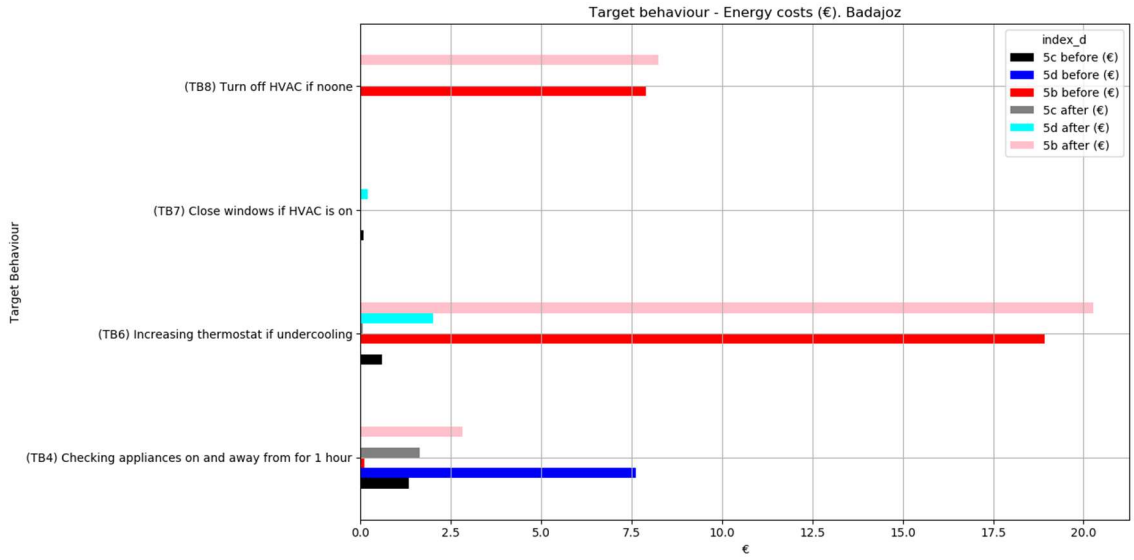



**Figure 4.51 Badajoz. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations.**

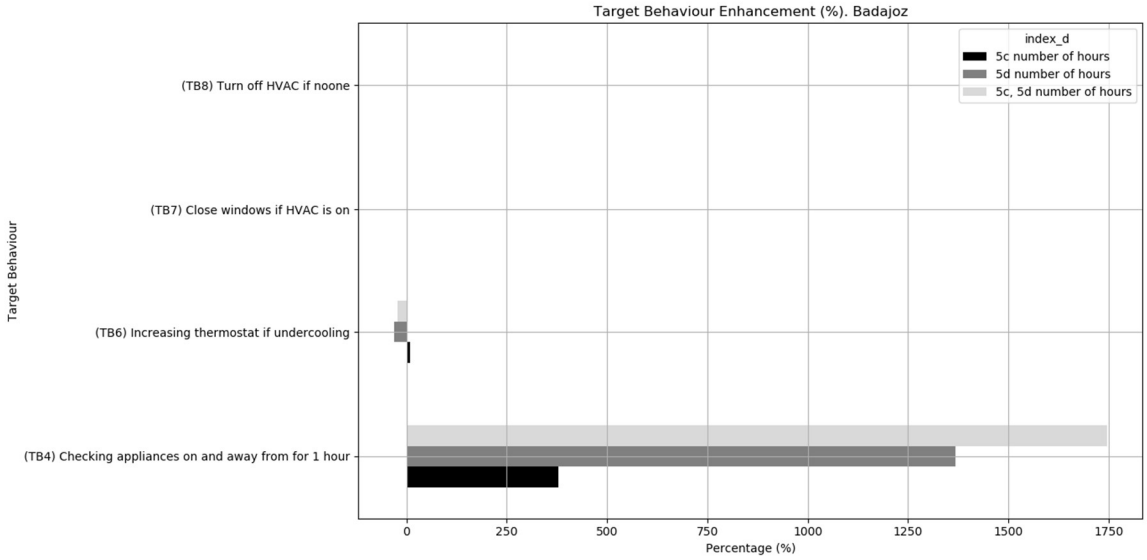



**Figure 4.52 Badajoz. Target behaviour enhancement encouraged by eTEACHER in terms of hours (%)**

In conclusion, there is not enough data to evaluate behavioural change based on target behaviours encouraged by eTEACHER in this building. It is only possible to say that there is an enhancement on the use of appliances (TB4 Appliances off when away from room for 1 hour or more)

### InCity, residential building, Romanian

A preliminary evaluation of the behavioural change encouraged by eTEACHER in InCity based on the analysis of the target behaviours is shown. To understand the results is important to take into account following **information**:

- The behavioural change is evaluated by comparing the number of hours that a target behaviour is not achieved in study apartments with regard to control apartments before and after eTEACHER. The reduction of hours of the study apartments with regard to the control apartments after eTEACHER will be the enhancement. The same calculations are done with the energy wasted during those hours (kWh) and the cost of such energy (€)
- It is assumed that eTEACHER tools were massively delivered by mid of October 2020 in the building.
- 10 apartments have been analysed: U16, U22, U38, U127, U133, U181, U255, U273, U416, U466. The control apartments are U466, U133, U16, U273 and U255.
- Some devices are not sending data on lighting and equipment consumption.
- The monitoring data used for the period before eTEACHER belongs from 1.10.2019-31.12.2019. The monitoring data used for the period after eTEACHER belongs from 1.10.2020-31.12.2020.

**Figure 4.53** and **Figure 4.54** show the number of hours that target behaviours have not been achieved before and after eTEACHER as well as the energy costs during those hours. **Figure 4.55** summarizes the target behaviour enhancement. Following comments can be made regarding the behavioural change:

- (TB1) Turning off lights when leaving a room or at the end of the day is worst in all the apartments after eTEACHER. However, the situation in the study apartments is worst. Therefore, it cannot be assumed an enhancement of this target behaviour related to the use of eTEACHER
- (TB4) Appliances off when away from room for 1 hour or more is worst in control and study apartments after eTEACHER. Since the situation is better in the control apartments, it cannot be assumed an enhancement of this target behaviour related to the use of eTEACHER
- (TB5) Reducing thermostat temperature for heating when overheating has improved in control and study apartments after eTEACHER. However, the improvement is higher in the control apartment so it cannot be assumed an enhancement of this behaviour related to the use of eTEACHER
- (TB7) Close windows if HVAC is on is better in control apartments and better in study apartments after eTEACHER. Therefore, it cannot be assumed an enhancement of this behaviour related to the use of eTEACHER
- (TB8) Turn off HVAC if noone is worst in control apartments and better in study apartments after eTEACHER. Therefore, it can be assumed a positive behavioural change encouraged by eTEACHER and related to this target behaviour (60 % number of hours)

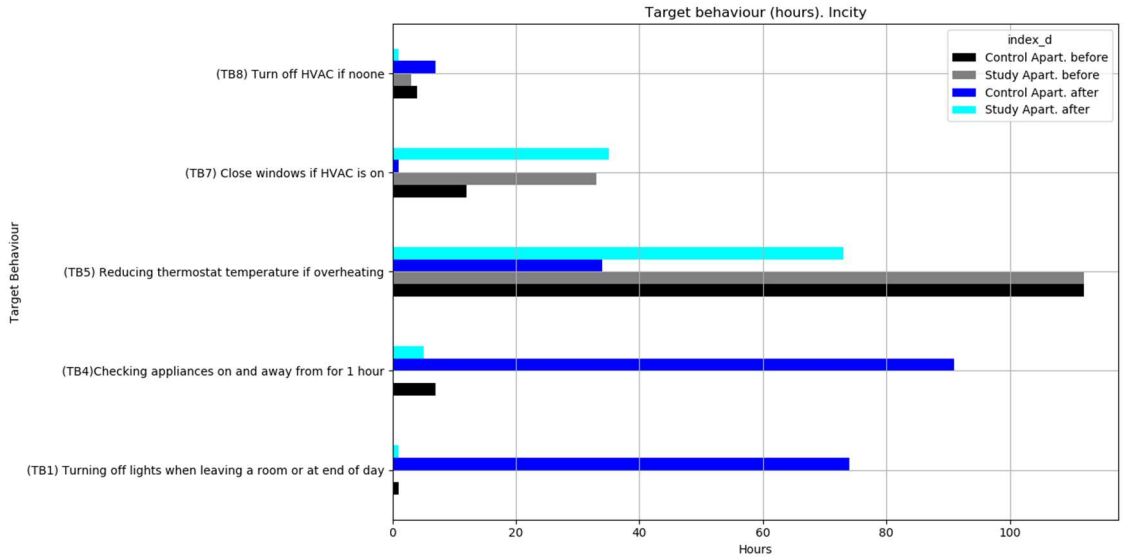



**Figure 4.53 Incity. Number of hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations (h).**

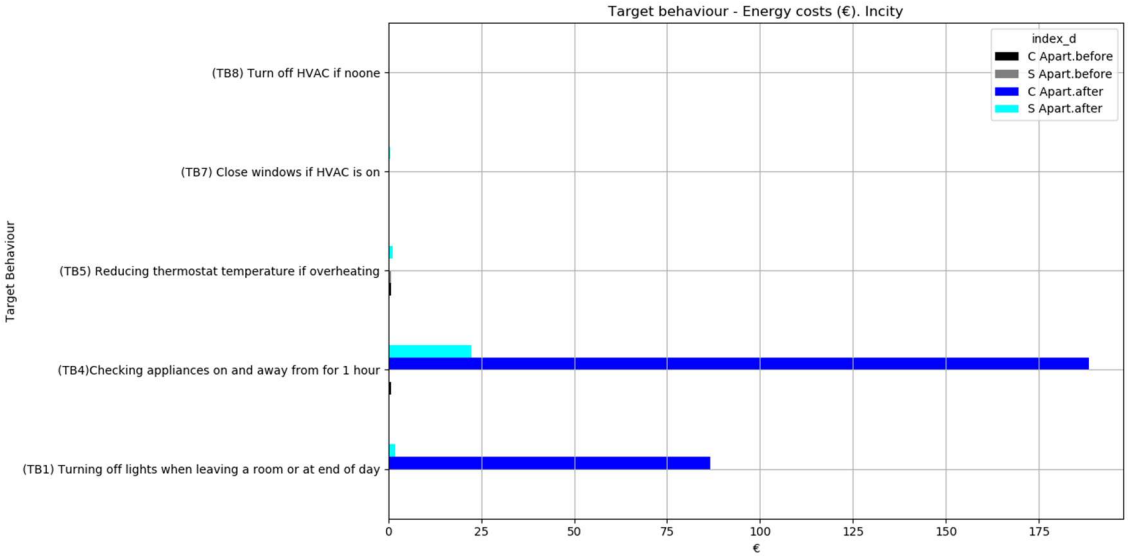



**Figure 4.54 Incity. Cost of the energy (€) wasted during the hours that a target behaviour is not achieved before and after eTEACHER in monitoring consultations.**

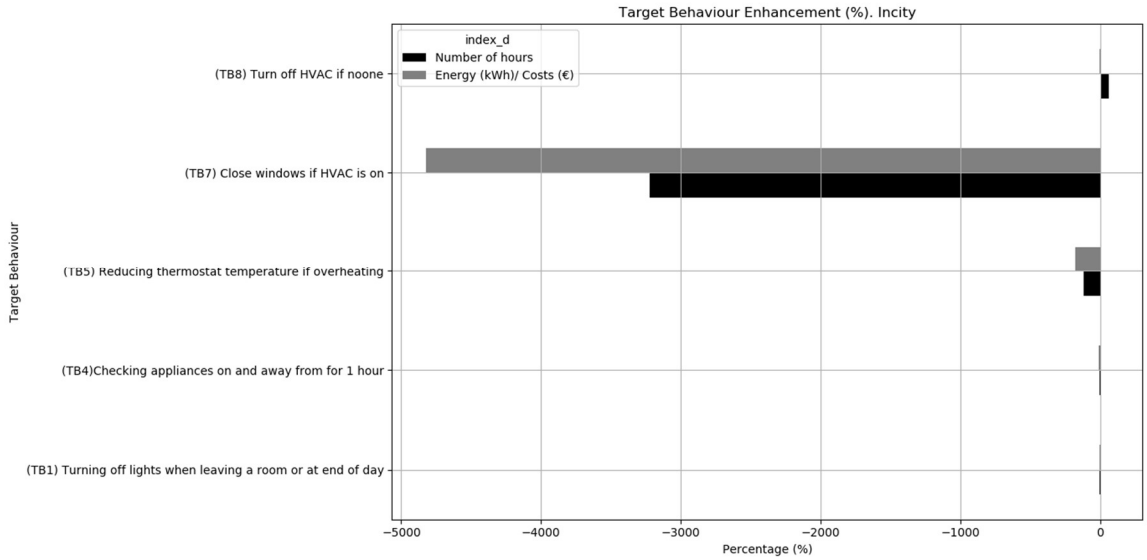



**Figure 4.55 Incity. Target behaviour enhancement encouraged by eTEACHER in terms of hours (%)**

In conclusion, it is only possible to say that there is an enhancement related to TB8 Turn off HVAC if no one (60%) in this building. More data is necessary to evaluate the behavioural change in this building

# 5 Lessons Learned

Following, some lessons learned related to the technical solutions developed and used in the project are explained.

## Lessons learned related to the monitoring of the Spanish pilots

Based on demonstration experience and challenges. Three main problems have been identified:

- Gateway. At first stage, commercial gateways on Z-wave system were selected. However, these gateways were designed to connect their specific commercial server. Additionally, some necessary functions such as to include specific firmware, credentials, etc., are not allowed by the gateways. Then, the solution was created a new gateway based on *Raspberry Pi 3 B+*, adapted to the specification of each building. However, these new gateway from time to time produce a critical error that disconnects the full system. This error is under investigation and a new version of gateways will replace the previous ones.
- Batteries. According to device's commercial specifications the battery duration should be for several months but currently, battery duration is for a few weeks. Probably, this situation is because the sensors sent data each 10 minutes. Currently, some of them have been set to sending data for event (it means when a data modification is made). Thus, battery duration has been enlarged but not enough. Replace batteries is one of the most common maintenance activities and is made as soon as the building is visited by monitoring system installer.
- Number of sensors. Z-wave system has several advantages by which was selected. However, in buildings with a big number of sensors or big distances between sensors, some of them disconnect from the system by themselves. Currently, we have realised that more than 5 sensors connected can make problems. Then, we are trying to solve this issue by a new configuration on the gateways.

Main lessons learned are:

- The maintenance will be critical for the good running of the monitoring system.
- Z-wave system should be used for small buildings (e.g. residential buildings). In big buildings or big distance between sensors, Wi-Fi system works better than Z-wave. Also and thanks to adapted gateways (e.g. *Raspberry Pi 3 B+*), different transmission system such as Z-wave and Wi-Fi can be combined
- Only the most critical parameters should be monitored and the rest of them should be calculated indirectly, even if a lack of precision could be done.

In this way, the eTEACHER tool and system will be more efficient and easier to install.

## Lessons learned from UK pilots

- Data transfer is not 'plug and play' - particularly for the pilots where connection to the centralised database is required, IT experts were required to help setup the automated data transfer from the eedomus gateways to the common database (via an AWS hosted database).
- Overall IT knowledge required – to maintain the sensors an awareness of the eedomus gateway, z-wave system, Amazon web-hosting and centralised SQL database is required –

this is not an 'off the shelf' solution and is not within the skillset of most NCC employees, so significant additional help from other departments was required.

- Reliability of sensors – some of the sensors used in the pilot buildings are not reliable, initial pairing and data logging is successful but after a random period (days/weeks/months) they begin to report erroneous values, with no root cause identified. This applies specifically to the radiator pipe sensors.
- Accessibility of eedomus gateway – script modification and sensor pairing can only be carried out when the user is on the same network as the gateway - i.e. physically present in the pilot building. This means that if there is a problem, diagnostics can only realistically be carried out by going to the building which can add several days delay (particularly in the case of the school). It also means that ad-hoc repairs are often not possible and it is preferable to let issues 'build up' and go to the site less frequently in order to fix multiple issues. The lesson here is that it would have been preferable to use our own office as a pilot building for ease of access (although this data would have been less useful, issues would have been more readily addressed).
- Battery life – this hasn't been properly tested due to the extended lockdown periods in the UK where no building access was possible, however battery replacement (as above) is often not economical to do ad-hoc as units fail, so sensors may remain without battery for a while until a larger replacement is carried out across multiple sensors. The unit cost of the non-standard batteries for the door/window & movement sensors is also very high.
- Damage or loss of sensors

### Lessons Learned from Romanian pilots

- Selection of sensors. On the market there are a multitude of sensors both for monitoring the parameters related to air quality, occupancy or energy for which the technical specifications look very attractive. But in their practical use there have been a number of issues either regarding the correct recording of data, data transmission and, if they are powered by batteries (wireless sensors) their high consumption followed by the need to replace batteries frequently. Lesson learned is that it is recommended that the quality-price ratio be taken into account when selecting the sensors. The NETATMO modules used to monitor air quality in InCity residential buildings have proven to be reliable, with a pleasant design, and easily accepted by building occupants who have agreed to be involved in the eTEACHER project. For monitoring parameters related to the energy consumed in the case of residential type buildings were used HOMEMATIC pluggable switch modules because, in this peculiar case, it was not possible to access the general power panel for direct mounting of the sensors. For these sensors the connection is easy, they have also a pleasant design, they are robust. However, they have quite large overall dimensions, which makes them unusable in areas with limited access, the protections inside them seems that are set quite low and therefore in the case of not too large variations of the supply voltage, they disconnect the devices connected through them. This is a big issue, especially if these HOMEMATIC pluggable switches are mounted on the power supply of refrigerators, disconnecting the refrigerator for a long time (if the owner is not home to reconnect) has resulted in several InCity participants giving up power through these devices.
- Privacy. Privacy is another issue found in the case of residential buildings InCity occupants regarding acceptance of eTEACHER sensors. Some of the potential participants in the project flatly refused, either few initially accepted to participate, because they could not be

convinced that their privacy will be secure. The reluctance was not so much in terms of energy consumption sensors as in relation to IAQ or the presence monitoring sensors placed in their homes, both types of sensors, being able, in their opinion, to disclose data about the dynamics inside the apartments in case of security breaches.

- Battery life. During the project progress it was necessary to replace the batteries for the presence sensors, as well as for the door / window ones. Replacing the batteries for the presence sensor does not present difficulties, their discharges faster or not depending on the intensity of the presence of people or pets in the monitored area. But for door/window sensors batteries replacement is not easy, often occupants preferring to leave them discharged. For further developments, it would be recommended that in the platform that collects the monitored parameters, to exists the possibility to indicate the degree of discharge of batteries, where appropriate, the maintenance of these devices being done much easier in this way on the one hand and on the other hand the information from the sensors would be safe, uninterpretable e.g. the presence of occupants in the monitored area.
- Gateway. It would be better for all sensors, whether they are for energy monitoring, IAQ or presence, to log into the same gateway. The use of several brands for sensors for residential applications, each with its own specific gateway, data transmission, complicates the activity of monitoring, recording and transmitting the targeted parameters to the designed cental platform.

### Lessons Learned from UBCI and common database

- Decentralized database structure. The setup with 3 national databases that are synchronised into a common database requires a lot of maintenance work. The current setup is designed to only transmit the sensor's measurements. However, adding new sensors in the national databases requires manually adding the sensors to the common database, else the synchronisation will fail completely due to the foreign key constraints implemented in the database.
- Interaction with BACS add-ons. The common database is currently mostly a read-only medium other BACS add-ons draw their data from in order to transform that data for calculations and presentation. With a more unified IT infrastructure there could be performance gains by not needing to transmit and transform data.
- Store only data you need. This topic is closely connected to the prior topics. Both decentralized database and common database keep data stored for monitoring the project. However, especially in the common database it was necessary to archive old measurement data in separate tables, as the data collected during the project time amounts to several hundred million datasets. Furthermore, the data collected was consolidated and transformed to provide it for presentation in the eTEACHER App. Adjusting the infrastructure in unity with topics 1 and 2 could lead in a significant reduction of stored data and therefore IT infrastructure needed.

### Lessons Learned from feedback, metrix, pulse and virtual building tools (GRA tools)

- In the coordination of many different systems in one application, changes in the platform of a particular system or authorization practices can cause incompatibilities and inoperability of

a particular functionality. Dependence on application platforms and authorization methods poses a risk that the application will not function as originally intended.

- In addition to the functionality of the application, attention should be paid to the integrity of the data transmission and the division of tasks, which includes data collection hardware, a central database and application software.
- Physical User Feedback Button. COVID situation disables physical user feedback buttons. Physical buttons had been pressed several times in certain buildings. The button is easier to press as you pass, for no better reason, and you can't be sure if the opinion is real. If User Feedback is in the app, barely click it for no reason.
- The Virtual Building is mainly characterized by its different types of data visualization. But having big amounts of data also poses challenges on how to visualize it without obstructing the building model and in the same time delivering useful information. The data display time is also highly important, which is why many optimizations were made to improve it.
- Early prototyping of the tools and use case definition helps to get a better idea about the development requirements for technical developers and end-users to express what they expect from the project. Finding this common agreement will help deliver better solutions.

# 6 Conclusions

The report explains a preliminary evaluation of the project results in terms of behavioural change and its impact on energy consumption and indoor environmental quality. For that purpose, ***monitoring data*** at building and room/apartment level have been analysed including outdoor conditions, indoor conditions, energy consumption and other measurements such as occupancy or windows opening; users statistic on the interaction of the building users with ***eTEACHER App*** have been collected and analysed and ***users feedback*** collected through feedback forums, interviews and surveys have been evaluated in terms of behavioural change towards energy efficiency, energy savings and enhancement of indoor environmental quality. For that purpose, the analysis of the buildings and their users after receiving eTEACHER tools is compared with the analysis of the buildings and their users before eTEACHER. The analysis is based on monitoring data and users feedback collected by means of surveys or interviews.

The analysis of **users feedback and surveys** consisted of collecting end-users' initial impressions of the eTEACHER tool as well as collecting self-reported use of the eTEACHER tool following the rollout and availability of the tool within each building. As previously reported collecting initial impressions and any issues experienced with the tool is a vital part of understanding potential sustained engagement with such a tool. If users' experience a large number of issues or feel that the tool is of no benefit to them, then they are more likely to disengage from interacting with the tool. Therefore, the initial demonstration phase focused predominantly on collecting this data through the use of Feedback Forums and building user surveys. To enrich these findings additional non-structured feedback was collected by the pilot coordinators through informal interviews, calls and visits. It is important to be mindful of not overwhelming, or asking for too much, from end-users as this too can cause disengagement and dissatisfaction with the project. This is a key reason for constant evaluation and adaptation of our user engagement strategies for the project. Unfortunately, this is made ever more challenging with the impact of COVID, particularly with many of the pilot buildings now having reduced occupancy or completely shut. This means that even if users are engaged with the project and keen to use the tool, if they are not using the building then they will gain no benefit from the tool.

According to the **analysis of users feedback and surveys**, we have identified a strong interest in the eTEACHER tool with many users deeming it to be useful. Although a very small response rate currently from our interim survey, it can be seen that users are reporting that the tool is raising their awareness of energy consumption in the buildings and some are even reporting a change in their previous energy-related behaviours. These findings will be investigated further once a larger sample of respondents is available. Although a positive impression has been reported from active users of the tool, there has been a number of issues identified which is impacting the building users from engaging further. A large number of users who are providing feedback are reporting that they are unable to register or log-in using the tool. This can impact the effectiveness of the tool a great deal. Therefore, it is important that users have availability of a problem solver – whether this be through a project contact or additional information made available on the tool for those struggling to register/login. Similarly there was feedback from users that the tool was crashing or not showing any data, hence why it is important for the project to continue with the daily/weekly/monthly checks being made on the tool to ensure it is in a fully operational and stable condition.

The **analysis of monitoring data** includes the evaluation of energy savings encouraged by eTEACHER, the enhancement of indoor environmental quality encouraged by eTEACHER tools and the behavioural change encouraged by eTEACHER which is the enhancement of the target behaviours. The energy savings, IEQ enhancement and target behaviours enhancement have been evaluated taking into account the difference between the control and study environments before and after eTEACHER. For example, if the energy consumption is lower after eTEACHER in both kind of environments but it has decreased more in the study environments, it is assumed an energy saving encouraged by eTEACHER. According to the analysis of monitoring data we can draw following conclusions:

There have been identified ***energy savings in every pilot building analysed*** **that can be linked to the use of eTEACHER tools** although a larger sample of data is necessary to see the real trend of energy savings :

- OAR building: the figures show some energy savings in the use of appliances (27%) and HVAC (100%) while the energy consumption in lighting is very similar
- Guareña HCC, the figures show some energy savings in the use of heating (>100%) but not in the use of lighting.
- Villafranca HCC, the figures show some energy savings in two consultation rooms (C2 and C5) related to the use of lighting (50-75%) and heating (>100%) that can be assumed to be encouraged by eTEACHER
- Torrente high school: the figures show some energy savings in the use of appliances (10-15%) but higher consumption in heating consumption
- Arcoiris, kindergarten: the figures show some energy savings in the use of appliances (27%) and HVAC (100%) while the energy consumption in lighting is very similar
- Badajoz: the figures show some energy savings in the use of appliances (27%) in one of the apartments and no energy savings in the use of heating encouraged by eTEACHER.
- InCity: the figures show some energy savings in the use of appliances (>100%) that can be encouraged by eTEACHER and no energy savings in the use of heating and equipment

There have been identified some kind of ***IEQ enhancement in every pilot building analysed*** **that can be linked to the use of eTEACHER tools**

- OAR building: IEQ enhancement related to temperature and relative humidity. The IEQ due to luminance is slightly lower and the IEQ due to CO2 level cannot be evaluated due to a lack of data.
- Guareña HCC: there is only an IEQ enhancement related to the CO2 levels that can be linked to eTEACHER tools.
- Villafranca HCC: there is an IEQ enhancement that can be assumed it is encouraged by eTEACHER related to temperature (20%), relative humidity (60%) and CO2 levels (30%)
- Torrente high school: there is an IEQ enhancement related to $CO_2$ (60%) and relative humidity (40%). On the other hand, there is not enhancement of IEQ related to the luminance level and the temperature due to eTEACHER.
- Arcoiris kindergarten: IEQ enhancement that can be linked to the use of eTEACHER tools related to temperature (40%), $CO_2$ (70%) and relative humidity (40%).
- Residential Badajoz: IEQ enhancement that can be linked to the use of eTEACHER tools related to temperature (10%) and relative humidity (90%). The IEQ related to the CO2 levels

cannot be evaluated because there is a lack of data and the IEQ related to luminance levels is worst after eTEACHER.

- InCity: IEQ enhancement that can be linked to the use of eTEACHER tools related to the CO2 levels (10%) The IEQ related to the temperature and relative humidity is worst after eTEACHER while the IEQ related to luminance levels cannot be evaluated.

There have been identified some kind of ***positive behavioural change in all the pilot buildings*** analysed that can be linked to the use of eTEACHER:

- OAR building: behaviours related to the use of appliances have been improved with eTEACHER tools while behaviours related with the use of lighting are very similar and behaviours related to the use of heating are worst
- Guareña HCC: there have been a positive behavioural change related to most of the target behaviours evaluated: TB1 Turning off lights when leaving a room (39%), TB3 Turn off appliances at the end of the day (38%), TB4 Appliances off when away from room for 1 hour or more (44%), TB5 Reducing thermostat temperature for heating when overheating (35%), TB8 Turn off HVAC if noone (3%)
- Villafranca HCC: it can be appreciated a positive behavioural change in the use of lighting, appliances and HVAC (TB1, TB3, TB4 and TB8) when there is noone in the room that can be assumed it is related with the use of eTEACHER and that have an important impact on energy costs savings (>100%) for the time evaluated.
- Torrente high school: it can be appreciated a behavioural change regarding (TB4) Checking appliances on and away from for 1 hour encouraged by eTEACHER. The enhancement is about 21%. Other target behaviours related to the use of the windows and heating are worst or cannot be evaluated
- Arcoiris kindergarden: there have been a positive behavioural change related to most of the target behaviours evaluated: TB1 Turning off lights when leaving a room (41%), TB3 Turn off appliances at the end of the day (>100%), TB4 Appliances off when away from room for 1 hour or more (>100%), TB5 Reducing thermostat temperature for heating when overheating (14%), TB7 Close windows if HVAC is on (16%), TB8 Turn off HVAC if noone (30%), TB9 Heating and cooling at the same time (10%)
- Badajoz residential: there is not enough data to evaluate behavioural change based on target behaviours encouraged by eTEACHER in this building. It is only possible to say that there is an enhancement on the use of appliances (TB4 Appliances off when away from room for 1 hour or more)
- Incity: there is not enough data to evaluate behavioural change based on target behaviours encouraged by eTEACHER in this building. It is only possible to say that there is an enhancement related to TB8 Turno off HVAC if noone (60%)

In addition, we have collected a number of lessons learned related to the technology used and developed by the project:

- The maintenance is critical for the good running of the monitoring system.
- There are problems with the reliability of the sensors used and the data quality.
- Sensors battery is an important problem.
- IT knowledge is required for sensors installation and maintenance.
- Privacy is an issue regarding the acceptance of eTECHER sensors

- The setup with 3 national databases that are synchronised into a common database requires a lot of maintenance work.
- With a more unified IT infrastructure there could be performance gains by not needing to transmit and transform data.
- It is important to store only data you need.
- Coordination of many different systems in one application can cause incompatibilities and inoperability of a particular functionality
- Attention should be paid to the integrity of the data transmission and the division of tasks, which includes data collection hardware, a central database and application software
- Having big amounts of data also poses challenges on how to visualize it without obstructing the building model and in the same time delivering useful information. The data display time is also highly important, which is why many optimizations were made to improve it.

In the next release of this deliverable, it will be included:

- A larger analysis of users feedback, surveys and statistics with information collected till the end of the project
- A larger analysis of monitoring data with a larger sample data until the end of the project.
- The impact assessment using the results of the above-mentioned analysis and calculation project indicators to measure the impact
- Further conclusions on users acceptance and engagement as well as an extension of the lessons learned and the best practices of behavioural change through ICT solutions

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# 8 Appendices

## 8.1 Interim end-user online survey

# Energy, Comfort, the building & you!

## Building User Survey

The purpose of this questionnaire is to learn more about you as a building user, and what you think of the eTEACHER tool; did you use it, what you liked or didn't like, whether you think it has improved your awareness of energy and personal comfort etc. These responses will be used to help the evaluation of the eTEACHER tool's impact in this building, therefore you may recognize some of the questions asked. All data collected and processed from this questionnaire will be anonymized and stored in a secure location.

Completing this questionnaire should take around 5-10 minutes of your time.

## All about you

**Please select the relevant building which you use.** ***(Specific country pilots listed in relevant versions – English = UK pilots, Romanian = InCity pilots, Spanish = Spain pilots)***

| | | | | |
|---|---|---|---|---|
| **Djanogly City Academy, UK** | **Torrente Ballester, Spain** | **Arco Iris, Spain** | **OAR, Spain** | **Council House, UK** |
| **Badajoz Apartment block, Spain** | **Guarena Health Care Centre, Spain** | **Villafranca Health Care Centre, Spain** | **InCity A, Romania** | **InCity B, Romania** |
| **InCity C, Romania** | **InCity D, Romania** | | | |

**Please select the best category which best describes the type of building user you are.**

| | | | | |
|---|---|---|---|---|
| **Staff*** | **Energy/Facility staff/manager** | **Student** | **Visitor** | **Tenant/owner** |

**Age bracket (tick the appropriate range):**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11-18 | | 30-39 | | 50-59 | | 70-79 | | 90-99 | |
| 19-29 | | 40-49 | | 60-69 | | 80-89 | | 100+ | |

# eTEACHER & you

1. **Are you aware of the eTEACHER tool being used in this building?**

| | | | |
|---|---|---|---|
| Yes | | No | |

2. **Have you used the eTEACHER tool?**

| | | | |
|---|---|---|---|
| Yes | | No | *If no then skip to Q12* |

3. **How often have you used the eTEACHER tool?**

| | | | | |
|---|---|---|---|---|
| Numerous times each day | Daily | Weekly | Monthly | Rarely |

4. **Please rank the extent to which you agree to the following statements relating to your use of the eTEACHER tool.**

| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| 1. I think that I would like to use the eTEACHER tool frequently | 1 | 2 | 3 | 4 | 5 |
| 2. I found the eTEACHER tool unnecessarily complex | 1 | 2 | 3 | 4 | 5 |
| 3. I thought the eTEACHER tool was easy to use | 1 | 2 | 3 | 4 | 5 |
| 4. I think that I would need the support of a technical person to use the eTEACHER tool | 1 | 2 | 3 | 4 | 5 |
| 5. I found the various functions in the eTEACHER tool were well integrated | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| 6. I thought that there was too much inconsistency in the eTEACHER tool | 1 | 2 | 3 | 4 | 5 |
| 7. I would imagine that most people would learn to use the eTEACHER tool very quickly | 1 | 2 | 3 | 4 | 5 |
| 8. I found the eTEACHER tool very awkward to use | 1 | 2 | 3 | 4 | 5 |
| 9. I felt very confident using the eTEACHER tool | 1 | 2 | 3 | 4 | 5 |
| 10. I needed to learn a lot of things before I could get going with the eTEACHER tool | 1 | 2 | 3 | 4 | 5 |

5. **What did you like about the eTEACHER tool specifically?**

***[open text box for response]***

6. **What do you not like and/or how do you think the eTEACHER tool could be improved?**

***[open text box for response]***

7. **Do you think the eTEACHER tool has increased your awareness of energy use within this building?**

| | | | | | |
|---|---|---|---|---|---|
| **Yes** | | **No** | | **Maybe** | |

8. **Do you think the eTEACHER tool has changed your energy use within this building?**

| | | | | | |
|---|---|---|---|---|---|
| **Yes** | | **No** | | **Maybe** | |

9. **Would you recommend the eTEACHER tool?**

| | | | |
|---|---|---|---|
| **Yes** | | **No** | |

10. **Please can you expand on this?**

***[open text box for response]***

11. **Do you have any other comments or feedback about the eTEACHER tool?**

*[open text box for response]*

**12. Please could you tell us why not?**

| |
|---|
| **I am too busy** |
| **I find it too complicated** |
| **I couldn't create a profile** |
| **I struggle to log-in** |
| **I do not think it is relevant to me** |
| **I am not interested in it** |
| **I find it difficult to navigate** |
| **It does not give me the information I want** |
| **I don't understand how to add rooms** |
| **Other *free text answer*** |

**Thank you for completing this questionnaire, your responses are extremely valuable to the project.**