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Interreg France (Channel Manche) England
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ICE PROJECT OUTPUTS DESCRIPTION

OUTPUT 1: SMART HEATING RETROFIT

MARCH 2020

ICE report OUTPUT 1:

SMART HEATING RETROFIT (UEA)

Background information

UEA was an early adopter of the low energy/carbon agenda, with its low carbon campus journey beginning in the early 1990s. Currently, the UEA is investing more than £6.5million to reduce its carbon footprint from 23,000 tonnes to 12,800 and become increasingly autonomous. Inter alia, there have been significant investments in: (a) campus-wide energy saving initiatives, (b) renewable technologies, (c) the upgrade of UEA's Combined Heat and Power (CHP) engines that produce energy significantly greener from that imported from the National Grid, and (d) in the development of highly energy efficient buildings and accommodation blocks.

In spite of major infrastructural changes, significant amounts of energy continue to be wasted in the residential buildings of the UEA campus (>20%), whilst occupant thermal comfort remains problematic. The "invisibility" of energy use and the lack of occupant control over heating temperatures in UEA's dormitories[1], continue to prevent energy-efficient behaviours and undermine experienced levels of comfort.

Through the development of a smart heating system and through the provision of relevant energy use feedback, we aim to: (a) increase people's awareness of their energy consumption, (b) maximise efficiency and reduce costs by using the Internet of Things (IoT), and (c) optimise – and automate where possible – control of heating to maximize indoor comfort and even predict, in the near future, building behaviour and energy consumption.

SYSTEM/TECHNOLOCY SPECIFICATIONS

The smart heating system designed and developed within residential buildings on the UEA campus includes 7 key components, including hardware, software and network components (see Fig.1 for a simplified schematic representation of the system):

1. A ***zoning control system*** that enables the independent operation of radiators in individual student room (previously managed centrally at the flat level).
2. ***Programmable Thermostatic Radiator Valves (PTRVs)*** installed in individual rooms/radiators. These are battery-operated and have motorised valves and temperature sensors to control the flow of hot water to the radiators according to a target temperature schedule assigned for the room where the radiator is located. (NB – In contrast to conventional TRVs that are only adjustable to 5-6 different levels and, thus, leave householders without a clear understanding of what temperature each level is representing, exact temperatures can be adjusted using these PTRVs).
3. A ***central controller*** which communicates wirelessly with the PTRVs and through which the schedules for the target temperatures can be set remotely. (NB – Temperature settings can be manually overridden by the occupants if/when needed).
4. ***Sensors*** for monitoring the outdoor conditions and indoor (ambient) temperature – connected, through ***actuators***, to the heating units/system to control their operation based on instructions received by the control algorithm. These enable on/off automatic control of heating units based on: (a) the outdoor weather conditions, (b) indoor temperature, and/or (c) whether windows are open (i.e. auto-window function that closes the radiator valve when ventilating the room).
5. A ***wireless user interface*** (mobile/tablet app and online platform) allowing users to set up and plan the heating profiles/ set-point temperatures and receive feedback about outdoor and indoor conditions and energy consumption. Up to six set points per day and three different set point temperatures can be set, and users can also choose from three pre-set operation modes – namely 'Eco', 'Holiday' and 'Day-Off' modes depending on their occupancy and specific needs.
6. Auxiliary clamp-on ***energy (gas) meters*** recording energy use data accessible through a dedicated online interface.

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[1] Heating is centrally managed at the flat level (i.e. clusters of individual student bedrooms sharing a kitchen) rather that at the level of semi-independent rooms occupied by individual students.

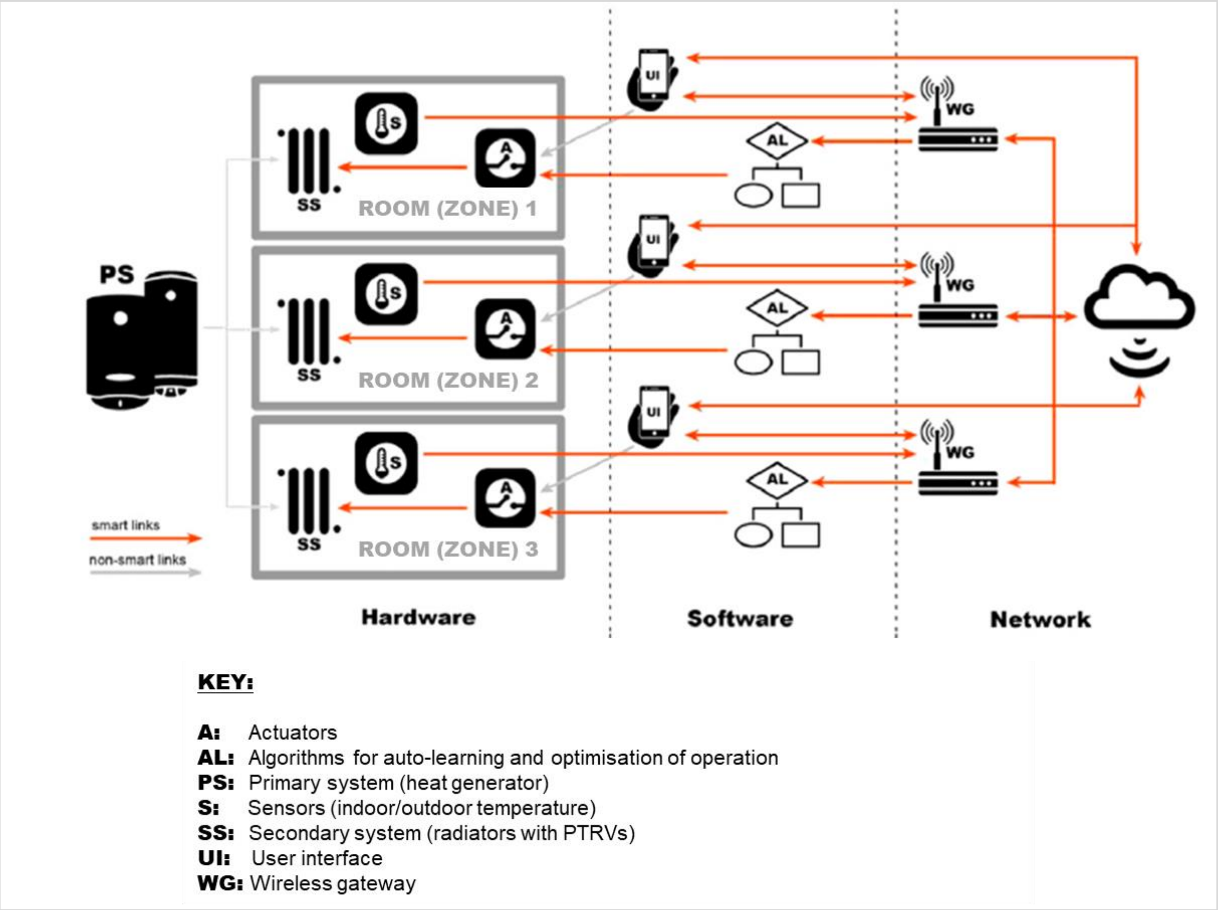

Figure 1: Schematic representation of all the components and connections of the smart heating system designed and delivered in multi-zonal residential units on the UEA campus. (NB – Whilst student flats at the UEA typically comprise of 8-10 individual rooms, the diagram includes only 3 rooms/zones in the interest of simplicity.)

ANTICIPATED AND/OR RECORDED IMPACTS/ BENEFITS

Smart heating systems – and smart energy technologies in general – are widely celebrated as easy technological fixes for sustainable energy transitions. The specific system designed and introduced at the UEA is expected to deliver many of these benefits. Moreover, a number of additional benefits are expected to arise because this otherwise simple retrofit radically reconceptualises heating in student dormitories. Specifically:

1. This system offers a very cost-effective way of attaining the optimal control of heating. A retrofit intervention with such a smart system does not require the replacement of the primary system itself, as its individual components are designed to be easily connected to existing systems wirelessly.
2. Extrapolating from research on similar systems, we expect that the small initial investment costs can be overcome, through energy cost savings, in less than 5-6 years.
3. The system allows for the partitioning of residential buildings into independent heating zones. By enabling control of heating in each zone (room) following specific user needs and habits in place of depending on central heating control, occupant comfort and convenience are expected to improve.
4. In its real-time optimization, the system considers information regarding outdoor conditions, the occupant presence, the current indoor temperature and the desired comfort temperature to enable efficient energy use without compromising comfort.
5. User interfaces provide an effective and simple way of managing the system according to personalised comfort preferences while being aware of the effect that occupant actions cause to the system performance.

6. User interfaces enable the comparison of a single user profile with that of other similar users and, thus, offer an opportunity to develop a well-rounded understanding of energy-related needs and practices on the UEA campus.
7. As similar smart retrofits have resulted in energy savings of 5-22% in other settings, significant energy savings are also expected at the UEA campus.

ANTICIPATED AND/OR RECORDED CHALLENGES

The system's ability to deliver on its key aims (namely to increase people's awareness of energy consumption, maximise efficiency, reduce costs, and optimise control of heating) might, ultimately, be undermined by 4 key technological and social challenges:

1. Given that residential buildings on the UEA campus are centrally metered, reliance on clamp-on meters recording energy use (gas flow meters) at the room (in place of the flat or building) level means that data quality is questionable.
   - The distribution of flow velocity becomes irregular due to bends in the piping or changes in the pipe diameter. Drifting occurs when the centre of the distribution of flow velocity shifts away from the centre of the pipe. Swirl flow occurs when the fluid rotates around a centre axis, parallel to the direction of flow. Both swirling and drifting cause irregular distributions of flow velocity. Performing flow measurements in these conditions may lead to large measurement errors.

2. Similarly, proximity of indoor temperature sensors to heat sources might result in imprecise temperature measurements and, consequently, in suboptimal control.

3. With the battery-powered PTRVs requiring a battery change on a yearly basis (on average), management/maintenance of a large-scale rollout of the technologies across university campuses might prove challenging.

4. Most importantly, the effectiveness of the system in reducing energy consumption whilst improving occupant comfort ultimately depends on the use of the system by the occupants. If occupants reject or misuse the system, the UEA will not be able to realise all of the benefits associated with more efficient energy use.
   - In spite of important automations (e.g. auto-window off function), occupants might: (a) choose to re-set the set-point temperatures to higher points – thus consuming more energy, (b) disable functions, and/or (c) fail to activate energy saving modes when they are off-campus.
   - Given that students living on the UEA campus do not pay for their energy bills, there are no real economic incentives for them to put the technologies to good use by better managing/reducing their energy use.