

# Summative behaviour change evaluation of up-to-date metered energy feedback in European public buildings

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## Abstract

Energy consumption practices and behaviour are increasingly an important focus of attention, for energy efficiency measures. Such is the demand caused by behaviour at the level of the individual, it may cancel out the benefits of engineering solutions, such as more energy efficient appliances (Adua, 2010).

This paper focuses on an evaluation of the SMARTSPACES project and its effect on energy-related behaviour change. The project provided two services: an energy management service (EMS) and an energy decision support service (EDSS). These services were implemented in over 450 public buildings across 11 European cities in 8 European countries (Serbia, France, Germany, Italy, The Netherlands, Spain, Turkey and United Kingdom). Building professionals (energy managers) primarily used the EMS and building staff used the EDSS. These services intended to inform, support and enable target audiences to use up-to-date metered feedback to reduce energy use in public buildings. The theory of change that underpins the evaluation framework is based in the Elaboration Likelihood Model which aims to understand how communication can influence attitudes and the Theory of Planned Behaviour that examines which attitudes are more likely to predict intentions and behaviours (Wilson, 2014).

The paper presents results of ex-ante and ex-post surveys to building staff about their levels of awareness, attitudes, perceived control behaviour and intentions in three selected cities: Bristol, Leicester and Venlo. Outcomes varied across the examined cities depending upon the type of information presented, the level of engagement of users with the energy saving campaigns and the amount of previous energy management work undertaken by buildings' facilities and energy management professionals.

**Keywords:** theory-based evaluation, energy efficiency in public buildings, behaviour change

## Introduction

There is no well-established definition of what features a communication-based energy efficiency intervention must have, but such interventions are underpinned by the idea that more and better information will encourage consumers to conserve energy use (Delmas, et al., 2013). Such interventions can involve awareness campaigns, education and training programmes, labelling schemes, smart metering and pricing information (Mikkonen & Gynther, 2010). Interventions based on communication would be classified as a behavioural intervention, which focusses on awareness, motivation, knowledge and intention (Dougherty, n.d.). The potential from such initiatives is sizeable but frequently not realised, varying between little or no effect, to up to 30% savings (Delmas, et al., 2013; Darby, 2006;

Hargreaves, et al., 2010; Carrico & Riemer, 2011; Dixon, et al., 2015). It is frequently agreed that communication interventions will continue to be an important feature of attempts to encourage energy-related behaviour change, even when acknowledging the failure of some communication-based interventions to make big impacts on energy use (Kennedy, et al., 2009; Lorenzoni, et al., 2007; Stern, 2011).

The aim of the three-year (2012-2014) EU-funded SMARTSPACES<sup>1</sup> project was to enable sustained energy reductions in public buildings in 11 cities across 8 European countries. The energy services consisted of an energy management service (EMS) targeted mostly to building professionals (central and/or local energy/facilities teams) for directly controlling building equipment and an energy decision support service (EDSS) to inform and motivate behavioural change in the building staff towards a more efficient energy use in their buildings.

Each city designed the content and style of their services independently based on their local context. Energy feedback (measured consumption vs. baseline, historic consumption or daily consumption) was presented in a variety of forms across the cities through simple and easy to understand views ranging from bar graphs, smiley faces, tachometers (green/amber/red gauge system to indicate high energy consumption), and playful animation for children, as shown in Figure 1. Some cities also included information about energy costs (Bristol, Lleida, Murcia, Venlo), energy savings or CO<sub>2</sub> reductions (Venlo), indoor and/or outdoor temperatures (Istanbul, Murcia, Milan, Moulins), a league table dashboard comparing energy use across participating buildings (Leicester), indoor air quality (Moulins), thermal comfort situation (Lleida), more detailed information about half-hourly consumption profiles on graphs (Leicester) or hourly-slotted coloured matrices to compare energy consumption with occupancy (Bristol).

Each city developed the key messages to present in their energy visualisation tools. For example, the team in Leicester conducted a formative evaluation for the selection of content material and stylistic features. Wilson and Stuart (2014) conducted focus groups' discussions and questionnaires to gather background information of potential users, develop the early prototype versions of the message content and learn about the audience predispositions. Focus groups with a sample of building staff provided insights into aspects that would motivate or fail to motivate users to save energy. Subsequently, the early prototype versions of the message concepts were refined. Quantitative results from the questionnaires showed that staff perceived the information credible and associated with increased intentions.

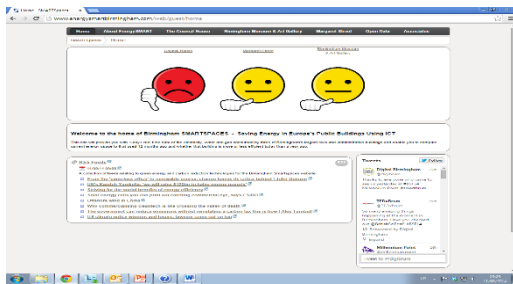
In addition, the researchers conducted a process evaluation of the project to understand the impacts of the SMARTSPACES services in the 11 cities. Qualitative data were gathered through a set of interviews with 36 building professionals at the central or building level. These interviews identified vital differences in how the energy-efficiency communication-based campaigns were implemented at each site, such as further engagement tools that supported the energy feedback information (Ozawa, et al., 2015). Insights from this research were shared with cities' representatives in the project to foster campaign improvement.

This paper describes the summative evaluation of the SMARTSPACES services using ex-ante and ex-post surveys to building staff to assess individual responses in terms of the levels of awareness, attitudes, and intentions to reduce energy use in public buildings. The next sections discuss the theoretical framework underlying the evaluation, the methods used, the results and the conclusions.

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<sup>1</sup> Information about the SMARTSPACES project is available at: <http://www.smartspaces.eu/>

## Birmingham



## Bristol



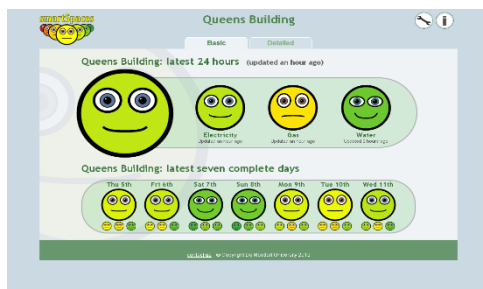
## Hagen



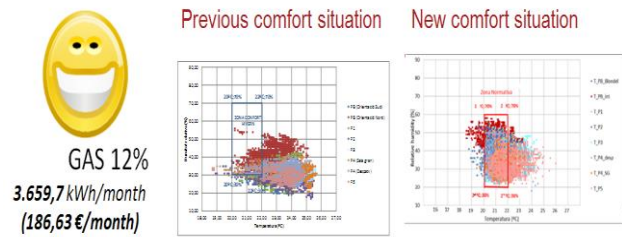
## Istanbul



## Leicester



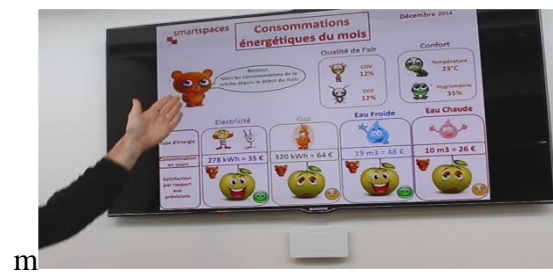
## Lleida



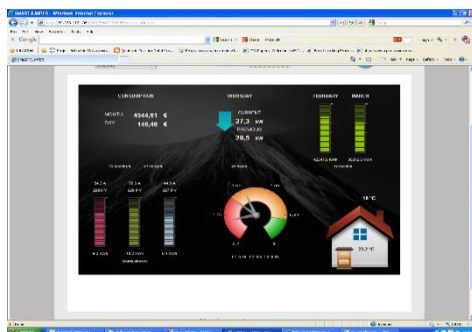
## Milan



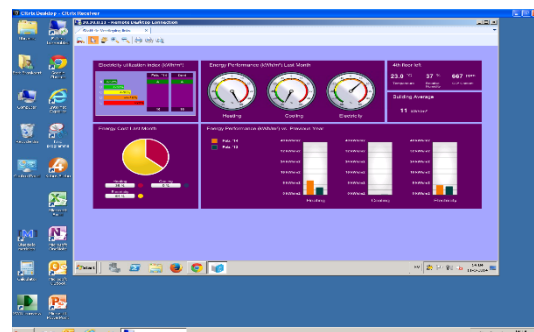
## Moulins



## Murcia



## Venlo



Source: <http://guide.smartspaces.eu/2121/>

Figure 1: Screenshots of selected features in the EDSS of different cities

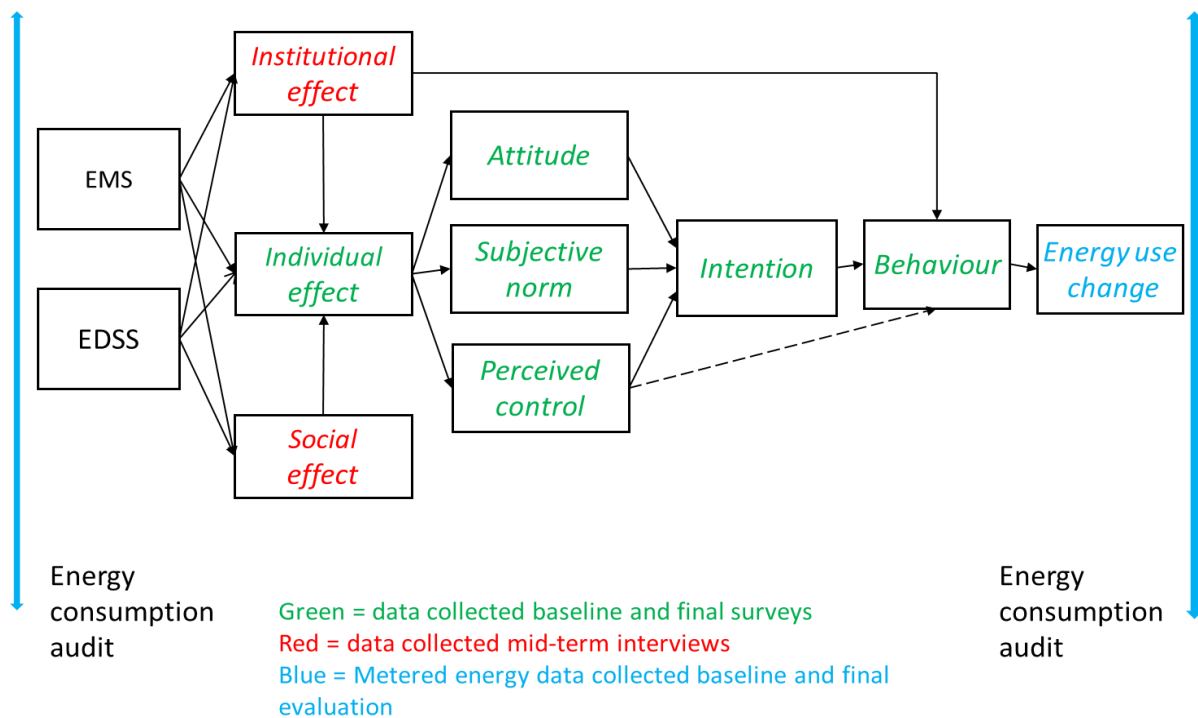
## Theoretical Framework

The energy-related behaviour change evaluation framework focused on assessing responses to the SMARTSPACES services on the extent of engagement or thoughtful behavioural choices as these are more likely to lead to an enduring change (Bator & Cialdini, 2000). To measure the behaviour change impact due to the communication of the EDSS, the Elaboration Likelihood Model (ELM) was used to understand how communication can influence attitudes (Petty & Cacioppo, 1986a; Petty & Cacioppo, 1986b) and the Theory of Planned Behaviour (TPB) to examine which attitudes (such as towards energy reduction in the work place) are most likely to predict intentions and behaviour (Ajzen, 1991; Ajzen, 2011). (This theoretical framework is fully described in Wilson, 2014).

The combination of these theories allows the measured ELM variables to explain how users' perception and understanding are changed and the measured TPB variables to explain when or in what conditions behaviour is changed (Wilson, 2014). The theoretical underpinning the evaluation reflects current dominant behavioural approaches based on the idea that there is an information deficit which, once resolved, will change behaviour. Previous research in organisational settings identified that employees are not typically motivated to save energy when they do not have to pay the energy bills (Carrico & Riemer, 2011; Christina, et al., 2014), due to the invisibility of energy consumption as far as the space is comfortable and the equipment is working (Stuart, et al., 2013; Goulden & Spence, 2015), and when appliances are often used by multiple employees, which may diminish the degree to which staff perceive they can individually control their energy consumption (Dixon, et al., 2015). More participative approaches to tackling barriers to behaviour change around energy consumption were possible within the intervention and are documented elsewhere (Wilson & Stuart, 2014).

Figure 2 illustrates the SMARTSPACES evaluation framework and the data collected at each stage during the entire project. The individual effects were the focus of the baseline and final surveys (green), while the mid-term interviews concentrated on the institutional and social effects (red). Changes in energy use were also assessed to produce a measure of impact on energy consumption at each city (blue arrows and box). Further details on the methods used to evaluate the energy use changes can be found in Ozawa et al. (2015).

While the examination of change at the level of the individual is the most commonly assessed factor in the evaluation of many communication campaigns, some researchers note that impacts can be missed if changes above the level of the individual are not examined (Hornik & Yanovitzky, 2003). Interviews conducted in the process evaluation were used to investigate changes at the institutional and social level as well as other potential external factors (confounding variables) that could offer alternative explanations for the surveys' results (e.g. staff exposure to the communication-based campaigns, descriptive or injunctive norms, sense of ownership of energy savings) as well as changes in the metered energy consumption (e.g. space use change), thus offering triangulation of evidence (Ozawa, et al., 2015).



Based on Hornik & Yanovitzky (2003)

**Figure 2: SMARTSPACES Evaluation Framework**

## Methods and Materials

To assess the individual-level behaviour change, the researchers conducted a pre-post comparison of attitudes and behaviours of building staff. A control (or comparison) group (e.g. participating and non-participating buildings) was not used in this evaluation. Such a control would have given greater credence to an argument that the observed change resulted from the intervention and not to other external factors. While such control are considered to offer the gold standard for evaluation (Evans, 2008), they were not possible to arrange in the project. In several cases this was because it was not possible to isolate a control group when communication was aimed to the entire organisation (e.g. Bristol City Council). In such circumstances it was unlikely that staff in non-participating (comparison) buildings were not aware of the SMARTSPACES services to be able to isolate their impact, and the attempt to deliberately inhibit communication risked constraining the project (Hornik, 2002). A further difficulty is that for a control group to have true validity, participants need to be randomly allocated to one group or another, and the physical building requirements of the project made this impossible. However it is acknowledged that this would have been a desirable feature of the evaluation.

To strengthen the evaluation without a control group, this research conducted an experimental design using repeated measures meaning that the same participants took part in the ‘panel’ ex-ante and ex-post surveys. The ‘panel’ (or paired sample) analysis allows the evaluation to measure the influence of each respondents’ past behaviour (Valente, 2001). A minimum number of 50 responses per city in each survey was sought for the statistical analysis of the ‘panel’ data to control for and measure the influence of each respondent’s past behaviour.

## Instrument

The researchers drafted two questionnaires for the baseline and final surveys evaluation. Using a 5-point Likert-type agreement scale (1=strongly disagree, 5 = strongly agree), both surveys measured levels of awareness and knowledge (antecedents of beliefs), attitude, subjective norms, perceived behavioural control, and intentions to reduce energy use in public buildings (based on TPB factors) (Ajzen, 1991; Ajzen, 2005). To strengthen the validity of the responses, multi-item scales per variable were used. Cronbach Alpha scores ( $\alpha$ ) measure variance within individual questions and between other questions proposed to be used alongside them to represent variables. Such scores offer guidance on the internal consistency or reliability of items, or the extent to which questions 'hang together'. The usually accepted cut-off is that alpha should be 0.7 or higher. The variables measured in the surveys are described below, with the Cronbach alpha scores based on surveys' responses in parenthesis.

- Awareness: Two-item scale that measured the extent that the respondent believes that energy use causes serious environmental problems, such as climate change (Cronbach  $\alpha_{T1}$  = 0.734, Cronbach  $\alpha_{T2}$  = 0.811, n = 116).
- Knowledge: Two-item scale that measured to what extent the respondent knew how to reduce energy use in the workplace by minimising use of electrical equipment or adjusting control settings to use less energy (Cronbach  $\alpha_{T1}$  = 0.748, Cronbach  $\alpha_{T2}$  = 0.618, n = 116).
- Attitude: Four-item scale that measured respondent's belief that reducing energy is not only worthwhile, but also effective and convenient for them (Cronbach  $\alpha_{T1}$  = 0.660, Cronbach  $\alpha_{T2}$  = 0.763, n = 116)
- Subjective norms: One-item scale that measured the extent that the respondent believed that people important to them are taking action to reduce energy use.
- Perceived behavioural control: Two-item scale that measured to the extent that respondents perceived that reducing energy use is easy or difficult (Cronbach  $\alpha_{T1}$  = 0.577, Cronbach  $\alpha_{T2}$  = 0.653, n = 116)
- Involvement: Four-item scale that measured the relevance perceived by respondents of reducing energy use in public buildings. It was considered that this ELM variable mediates between the attitudes and behaviour and the message (Cronbach  $\alpha_{T1}$  = 0.863, Cronbach  $\alpha_{T2}$  = 0.913, n = 112)
- Intention to reduce energy: Five-item scale that asked respondents about their intent to reduce energy use over the next six weeks. These were related to 1) minimising the frequency of use of electrical equipment, 2) turning off equipment when not in use, 3) adjusting controls so equipment use less energy, 4) replacing equipment with more efficient alternatives, and 5) making existing equipment more efficient (Cronbach  $\alpha_{T1}$  = 0.836, Cronbach  $\alpha_{T2}$  = 0.854, n = 114).

The final surveys (T2) also explored respondents' views about the usefulness of the information provided by the SMARTSPACES services based on the ELM variables (Petty & Cacioppo, 1986a; Petty & Cacioppo, 1986b) as follows:

- Argument quality: Five-item scale that measured to what extent the respondent perceived that the information provided in the services was not only understandable and clear, but also memorable (Cronbach  $\alpha_{T2}$  = 0.860, n<sub>T2</sub> = 113)
- Ability to process: Six-item scale measure of the message utility perceived by the receiver, not only if the user found the information engaging and attractive, but also useful and reliable (Cronbach  $\alpha_{T2}$  = 0.935, n<sub>T2</sub> = 113)

- Source credibility: Six-item scale that measured the degree in which the respondent considered that the institution providing the information was credible, expert and competent (Cronbach  $\alpha_{T2} = 0.945$ ,  $n_{T2} = 113$ )
- Intention to elaborate (based on TPB factor): Five-item scale that asked respondents the likelihood (1=very unlikely, 5=very likely) in which respondents would engage in thoughtful elaboration as a result of the information provided in the SMARTSPACES services. These level of thoughtfulness was assessed through a range of actions, such as 1) thinking more about energy use in the building, 2) changing activities in the workplace, 3) talking positively about the visualisation tool to friends and colleague, 4) becoming more interested in the topic when it is discussed by others, and 5) seeking further information on how to reduce energy use (Cronbach  $\alpha_{T2} = 0.890$ ,  $n_{T2} = 113$ ).

As most of the TPB and ELM variables met the Cronbach alpha threshold ( $\alpha \geq 0.7$ ) either in the baseline or final survey, composite variables using the average of items for each variable were calculated.

## Procedures

All questions in both surveys were translated to the local language (if needed), and depending on the individual city's preferred method of data collection, the surveys were entered into an online tool or provided with a paper-based survey template. Ethical approval for the conduct of the survey was provided by De Montfort University, who led the evaluation. This included ensuring participation was voluntary and participants were assured of anonymity.

For the baseline surveys, cities' representatives contacted members of staff in the participating buildings and requested them to complete the survey online or on paper between September and November 2013. For the final surveys, De Montfort University (DMU) invited the baseline survey respondents to complete the final survey between June and September 2014. Although senior staff of cities' representatives endorsed the invitation to participants of the baseline survey to respond to the final survey and in some cases supported by an "energy-saving appliance" prize draw or tokens (e.g. mugs and pens), a very low response was received by the end of August 2014. Under the rationale that participants may have been more responsive if their own representatives have contacted them, researchers requested cities' representatives to contact staff to complete the surveys.

A total of 732 responses from staff in participating buildings were received in the baseline survey, whereas 342 responses were received in the final survey. From the final survey, only 176 responses were from participants of both surveys (see Table 1).

Despite a large number of staff responses being received in the baseline survey and the efforts conducted by DMU and the cities' representatives for the data collection in the final survey, none of the cities achieved the minimum target of 50 responses for the panel data analysis. This was due not only to movement of staff to other buildings and staff redundancies (due to councils' budget cuts particularly in the UK), but also thought to be a reflection of the time pressures on staff, who were not formally part of the project and thus had no special reason to voluntarily participate in its evaluation.

Surveys responses in Belgrade were disregarded as several participants of the baseline survey declined to fully complete the final survey and requested the data collectors (city representatives) use the same responses of the baseline survey. Due to the low number of paired responses in Birmingham, Hagen, Istanbul, Milan, Moulins and Murcia, panel data analysis in these sites was not conducted. In Lleida, two services were offered: a simple solution for the participating municipalities to manage energy consumption based on energy

utilities' billing and a more comprehensive solution for buildings in the city of Lleida that allowed energy management teams to analyse energy efficiency of the facilities based on metered energy consumption. Energy-savings campaigns differed significantly according to the offered solution. Due to the low number of paired responses received for each solution in Lleida, these responses were not considered for analysis in this paper. Quantitative results presented in the following sections therefore focus only on Bristol, Leicester and Venlo.

**Table 1: Survey responses per city**

City, Country	Participating buildings	Baseline T1 survey	Final T2 survey	Panel data (T1=T2 respondents)
Belgrade	2	60	60	-
Birmingham	3	34	11	6
Bristol	400	205	46	29
Hagen	2	34	25	9
Istanbul	1	54	9	6
Leicester	20	99	40	27
Lleida	22	109	44	12
Milan	3	49	25	7
Moulins	1	21	20	0
Murcia	6	37	37	7
Venlo	1	30	25	13
TOTAL responses	461	732	342	116

Despite the low responses in the selected cities, a pooled analysis for the entire programme was not able to be conducted as each city designed the content of their messages and engagement activities independently. A key aspect of the project evaluation was to identify differences between cities as well as effective messages and activities that had a larger impact on energy consumption and staff behaviour.

## Results and Discussion

In the attempt to explain the results, it is important to understand the differences in the implemented energy services in the analysed cities as well as how communication and engagement activities were deployed specifically in each city.

### Implementation of Services in the Examined Cities

Online access to the EDSS was available through public web portals in Bristol and Leicester, and through a password protected staff web portal in Venlo. Information was also communicated through building-specific monthly reports via email and staff newsletters (Bristol); display screens (Leicester and Venlo), internal emails (Leicester) and monthly meetings with the energy coach (Venlo).

**Bristol** had the largest portfolio of participating buildings including council offices, children's homes, schools, nurseries, depots, museums, cemeteries, libraries, youth centres, hostels and community centres. As part of the programme, automated meter readers (AMRs) were installed in buildings that previously recorded and analysed energy data manually or through energy bills. As the EMS and EDSS were able to analyse the energy consumption and present the data in different formats, building professionals perceived the quality of data



improved and became more reliable, while the energy data visualisation became more accessible to non-specialist audiences (e.g. schools) (Ozawa, et al., 2015).

In **Leicester**, AMRs and building energy management systems were already in place in most of the participating buildings, however, they were not automatically accessed by the SMARTSPACES services. Most of the buildings of the university and city council are centrally managed with the exception of schools. In this particular case, both services were presented in the same web portal: a simple and user friendly ‘smiley faces’ view targeted for non-specialist audiences (EDSS) (see Figure 1) and detailed graphs for interested users (energy teams and staff) who were interested to know more about the energy consumption profiles as well as the predictions of the consumption model (EMS). The main mechanisms where the services could influence automated control settings were to provide the visualisation of energy data directly to facilities’ managers. These managers have access to control settings and by providing staff with the capability to engage in discussions about the performance of their building through an online forum, these settings could be changed.

In **Venlo**, the EMS was mainly used by the energy management team, but staff could also change locally the settings of heating and cooling through thermostats. Both services (EMS and EDSS) presented disaggregated energy use data for different end uses (e.g. heat pumps, elevator, lighting, etc.) or spaces areas (e.g. heating in the entrance area, offices). Communication with building users was conducted specifically through the energy coach and the operational management of the building. Staff could ask questions about the energy consumption of the building in monthly training meetings and the energy coach instructed the users on how to interpret the energy data and provided some advice on how energy use could be reduced.

### **How Services Communicated with Building Staff**

The Elaboration Likelihood Model was used to investigate factors that might increase or decrease the likelihood of thoughtful consideration on reducing energy use in public buildings and understand how the communication in the campaigns exerted any influence on attitudes. Internal factors to the receiver, such as motivation and ability to process the information provided by the services, as well as external factors, such as the perceived quality of the argument and rating of the source of the information, were only explored in the final questionnaire.

Table 2 illustrates that respondents in Venlo agreed that energy use in public buildings is a relevant issue for them (*involvement*), while they tended to agree that the information provided in the services were credible, understandable and clear (*argument quality*). Respondents tended to agree that the information provided by the tool was reliable, useful and engaging (*ability to process*). As a result of viewing or using the services, staff responded that they were more likely to think further about energy use in the buildings or change activities in their work or personal life (*intention to elaborate*).

Particularly in Leicester, respondents tended to agree that information sources were credible, competent, knowledgeable and reliable (*source credibility*). In the process evaluation, interviewees considered that the smiley faces were simple, easy to understand, attractive and a clear way to inform staff about the performance of their buildings (Ozawa, et al., 2015), which is reflected in the tendency of survey respondents to agree about the clarity (*argument quality*) and usefulness of the information (*ability to process*).

Respondents in Bristol tended to agree on the perceived quality of the message (*argument quality*) and the rating of the source of information (*source credibility*). This was also found in the process evaluation, where interviewees referred to the reports and dashboard as “very visual and user friendly” tools that helped them to understand the energy profile of the buildings, while they pointed out that communication with the energy coach played an

essential role in enhancing the credibility of the information (Ozawa, et al., 2015). However, the perceived message utility (*ability to process*) tended to be neutral for the respondents.

**Table 2: Descriptive statistics on ELM variables**

Variable	City	N	Mean	95% confidence interval for mean		Std. deviation	Std. error
				Lower bound	Upper bound		
Involvement	Bristol	29	4.121	3.813	4.428	0.809	0.150
	Leicester	27	3.994	3.770	4.428	0.566	0.109
	Venlo	13	4.231	3.996	4.465	0.388	0.108
Argument quality	Bristol	30	3.507	3.302	3.711	0.548	0.100
	Leicester	25	3.522	3.226	3.878	0.790	0.158
	Venlo	13	3.646	3.270	4.022	0.623	0.173
Source credibility	Bristol	30	3.578	3.356	3.800	0.595	0.109
	Leicester	25	3.740	3.435	4.045	0.739	0.148
	Venlo	13	3.615	3.256	3.975	0.595	0.165
Ability to process	Bristol	30	3.233	3.056	3.411	0.475	0.087
	Leicester	25	3.600	3.326	3.874	0.663	0.133
	Venlo	13	3.795	3.344	4.246	0.746	0.207
Intention to elaborate	Bristol	30	3.373	3.082	3.665	0.780	0.142
	Leicester	25	3.656	3.358	3.954	0.722	0.144
	Venlo	13	3.862	3.408	4.315	0.750	0.208

Results indicated that the key aspect for staff to consider changing their behaviour to reduce energy use in their buildings is that the information provided by the energy service is perceived as reliable, useful and engaging.

### **Did Attitudes and Intentions Change as a Result of the Energy Services?**

Individual-level changes as a result of the implementation of the SMARTSPACES services were assessed by analysing differences in levels of awareness, knowledge, attitudes, subjective norms, perceived control, and behaviour intentions between the baseline (T1) and final (T2) surveys.

Mean scores of baseline survey showed in Table 3 indicates that staff respondents were aware of environmental impacts associated with energy use and they also perceived that they had knowledge on how to save energy. Respondents also had relatively positive attitudes towards saving energy. However, particularly in Venlo respondents indicated that they did not feel able to reduce their energy use although they knew how to.

The Wilcoxon Signed Ranks non-parametric T-Test was used to examined if there were significant differences between the means in Table 3. The difference in responses was statistically significant ( $p < .05$ ) and with a large effect size change in Venlo for two variables indicating that energy data visualisation tool and surrounding engagement activities (e.g. monthly training meetings with the energy coach) increased staff's knowledge and perceived behavioural control on how to reduce energy in their building.

In Bristol, the difference was statistically significant and with a moderate effect size change regarding a more positive attitude towards energy savings in their workplace. With a large number of buildings in Bristol, communication and engagement activities were particularly challenging. Training sessions and interactive workshops on how to interpret the energy data of the EDSS were concentrated in particular directorates and in staff discussions

with similar positions or departments. Staff that received the training were responsible to disseminate the information in their buildings. Similar to Venlo, the presence of an energy coach played an essential role in the training and learning processes and increasing the staff's technical knowledge on the energy performance of the buildings (although the trend of change was not statistically significant). Regarding attitudes and intentions, it is important to differentiate between facilities managed centrally by Bristol City Council and medium or small locally managed single-team buildings (such as libraries and schools). In the centrally managed facilities, staff have little or no control over their buildings' energy use for heating and little engagement and ownership of energy savings as the bills are centrally paid. In locally managed buildings, facility managers usually have the ability to adjust thermostats, timers etc. and can exercise greater control over the energy consumption; in addition, staff are also typically more motivated to reduce energy consumption to decrease their energy bills (Ozawa, et al., 2015). Unfortunately, within the surveys, it was not possible to identify respondents who received the training or by building type (centrally or locally managed). The main significant change observed in the panel data was that respondents had a more positive attitude regarding energy savings in their workplace perhaps as a result of more accessible and meaningful data (for example, hourly energy usage that helps them to identify when the energy is being used, what the building is doing, and the ability to locate high energy usage at a particular time).

**Table 3: Descriptive statistics and results of Wilcoxon Signed Ranks T-test**

Variable	City	Mean T1	Mean T2	Mean Difference (T2-T1)	Z score	Sig. <sup>1</sup>	Effect size <sup>2</sup>
Awareness	Bristol	3.963	3.593	-0.357	-2.296	0.011	-0.434
	Leicester	4.111	3.889	-0.222	-1.667	0.056	-0.318
	Venlo	3.654	3.885	0.231	-0.674	0.264	-0.187
Knowledge	Bristol	4.036	4.250	0.185	-1.335	0.096	-0.252
	Leicester	4.389	4.222	-0.167	-0.165	0.063	-0.318
	Venlo	4.154	4.577	0.423	-1.781	0.043	-0.494
Attitude	Bristol	3.472	3.676	0.204	-2.080	0.019	-0.393
	Leicester	3.833	3.796	-0.037	-0.259	0.402	-0.050
	Venlo	3.769	4.019	0.250	-1.222	0.124	-0.339
Subjective norm	Bristol	3.071	3.000	-0.071	-0.577	0.387	-0.109
	Leicester	3.741	3.556	-0.185	-1.147	0.181	-0.221
	Venlo	3.461	3.385	-0.077	-0.632	0.383	-0.175
Perceived control	Bristol	3.222	3.107	-0.143	-0.809	0.223	-0.153
	Leicester	3.481	3.370	-0.111	-0.720	0.253	-0.139
	Venlo	2.923	3.577	0.654	-2.399	0.010	-0.665
Intention to reduce energy	Bristol	3.207	3.156	-0.052	-0.186	0.430	-0.031
	Leicester	3.437	3.185	-0.252	-1.555	0.062	-0.299
	Venlo	3.215	3.400	0.185	-0.490	0.327	-0.136

<sup>1</sup> Exact significance (1-tailed)

<sup>2</sup> Effect size (r) is calculated by the dividing the z-score of each variable by the square root of the number of total observations in T1 and T2. The effect size can be interpreted using Cohen's benchmark. If effect size is above 0.5, it means there is a large change, if it is between 0.3 and 0.5, it is a medium to large change.

In Leicester, difference s in responses between the baseline and final surveys were not statistically significant. Although there is some indication that the energy data visualisation and online forum encouraged staff to have more thoughtful consideration to reduce their

energy use (*intention to elaborate*) (Table 2), there were not significant changes in the attitudes and intentions of the respondents despite a clear ‘participatory’ call to action.

It is important to mention that the analysed cities achieved actual energy savings during the programme (further details are provided in Ozawa et al. 2015). Bristol reduced the gas consumption in their participating buildings by 8.1%, while they decreased their electricity consumption by 0.8%. In Leicester, the gas consumption decreased by 4.1%, while the electricity consumption reduced by 1.5%. Venlo achieved the largest energy savings in their building: 57.8% of its gas/heat consumption and 28.8% of its electricity consumption. In Venlo’s building, the energy services were effectively utilised by the local energy team to improve the energy efficiency of equipment, react quickly to faults or consumption anomalies and test energy- and cost-effective innovative control strategies. In Bristol, the gas savings were attributed to schools and the small locally managed buildings, because facilities’ managers had an increased ability to adjust timers and settings of the heating systems. In Leicester, the visual check of the energy visualisation tool by energy management teams aimed to respond quicker to consumption anomalies and to achieve actual savings through adjustments in heating schedules or temperatures.

Overall, it appears that the SMARTSPACES services benefited in great extent to building professionals to improve the energy management of their buildings, but an actual change of attitudes and intentions to reduce energy use by normal staff was limited. Potential external factors to the users that may have influenced their response to energy services could have been a limited exposure to the EDSS: for example, some cities reported that in their councils employees used slow speed web browsers that did not allow energy consumption graphs to be adequately displayed. Internal factors may be attributed not only to limited ability to control energy use and limited sense of ownership of energy savings in centrally managed buildings, but also to lack of time and conflicting work priorities in times of council’s budget cuts, economic recessions and increased workloads in the public sector which reduces the importance of energy management tasks in normal employees’ minds.

## Conclusions

The purpose of this paper was to assess the extent that the energy services implemented in the research had an impact on the levels of awareness, attitudes and intentions of individuals’ responses to reduce energy use in public buildings.

Better impacts were observed in cities with relatively low numbers of buildings (such as Venlo). This was because city representatives could concentrate on engaging with building users more effectively than cities with large numbers of buildings, such as Bristol, or deployed by two different institutions, such as Leicester. Levels of knowledge and local practices were considerably different in large cities. In Leicester, automated meter readings, building energy management systems and monthly energy reports to users were already in place before the research started. However, in Bristol some buildings had AMRs installed as part of the project. In these cases, the energy services made energy consumption more ‘visible’ and accessible to a larger number of users (Stuart, et al., 2013; Hargreaves, et al., 2010) and the nearly up-to-date energy feedback allowed a quicker local response to energy use anomalies.

It was clear that energy feedback alone as an information provision tool to provide building users an appropriate frame of reference to determine whether their energy consumption is excessive is not enough to motivate them to reduce energy wastage in their buildings. To achieve more enduring and effective change in attitudes and intentions to reduce energy use, further engagement activities need to complement the energy feedback, such as monthly training meetings to engage with users on how to interpret data and provide

advice on actions that can reduce energy consumption in the workplace. Direct communication with central energy management teams (through energy coaches or an online forum) is needed. Finally, specific energy saving campaigns related to heating, minimisation of electricity use and air conditioning, at critical points in the calendar when the audience is more likely to be attentive or active in seeking information to maintain their thermal comfort, but decreasing the energy consumption (Atkins & Rice, 2013) should be undertaken.

Results of this study suggest smart meter data on its own will only deliver smaller savings compared to efforts where metered data are integrated with coaching and engaging with building users. In future research, the use of gamified incentivisation models (e.g. competitive approaches) could be explored in order to intensify knowledge exchange and participation among the users (Vine & Jones, 2015).

The use of ex-ante and ex-post surveys to assess levels of awareness, attitudes and behaviour encountered real difficulties with accessing survey data and with ensuring adequate sample sizes across all the partners. Ideally larger samples of paired responses were sought, but it was not possible due to changes in staff, changes in building use and time pressures of staff responding to other workplaces demands. Attrition is a major methodological problem for longitudinal studies, and was experienced in this evaluation. Attrition affects evaluators being able to generalise findings. Participants who continue to participate may differ from those who drop out. Analysis of socio demographic data provided by participants to attempt to assess any attrition bias was insufficiently detailed to make any estimate of such bias beyond the scope of this evaluation. Other weakness in the evaluation design was the lack of a control group, which, as explained earlier, was not able to be achieved by any of the participating partners due to lack of an early definition of a set of non-participating buildings where participants could be randomly allocated. Due to the low response rates and lack of strong quantitative findings from the surveys, it was not possible to determine to what extent the actual energy savings can be attributed to upgrades in equipment and infrastructure, to the better control and energy management conducted by building professionals and to the behavioural change of staff. These limitations should be considered and addressed in future evaluation through a stronger design.

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