Sufficiently engaged? How smart metering systems help local authorities become smart cities

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Abstract

A significant cultural shift occurred recently with the majority of the world's population now living in cities and contributing over two thirds of global carbon emissions (UNEP, 2015). If countries like the UK are to meet their challenging carbon reduction targets, 80% by 2050 for the UK, then how our cities are governed and managed to maximise energy efficiency is of vital importance. Faith is increasingly being placed in what are commonly referred to as 'smart cities' to meet these targets. Most visions of these smart cities though revolve around increased ICT efficiency through what has become known as the 'digital economy.' Smart meters are an example of this and offer clear potential for automated meter readings and innovative displays to help energy managers as well as facilitate better engagement of building users. Evidence is limited on the impact and challenges of ICT tools that genuinely attempt to engage building users across all levels of the organisation.

This paper contributes to that evidence base by presenting findings from the H2020 EU-funded project EDI-Net (Energy Data Innovation Network). The project has designed three energy focused ICT tools with specific functionalities: 1) to track energy performance and communicate this performance in a user-friendly way (energy data dashboard and league tables), 2) to facilitate communication between stakeholders (online discussion forum), and 3) to manage intervention plans for energy efficiency (energy efficiency benchmarking tool). Do these tools come anywhere near fulfilling the potential of smart cities?

The paper presents results of feedback from interviews with selected building users about the individual, social and institutional changes prompted by the EDI-Net ICT services in the three participating public authorities during the operation of EDI-Net: Leicester, Catalonia and Nuremberg.

Introduction

If EU countries like the UK are to meet their challenging carbon reduction targets, 80 % by 2050 for example in the UK, then how our cities are governed and managed to maximise energy efficiency is of vital importance. Smart cities seemingly offer a utopian vision of urban integration, efficiency and [subsequent] carbon reductions yet urbanisation presents real challenges, as noted by the fact that Smart Cities now features as a Sustainable Development Goal. Smart Cities and Communities is Sustainable Development Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable. Carbon reductions and environmental considerations are just one challenge for future cities. These densely populated urban centres pose significant resource challenges for energy, water and food; transport, planning and infrastructure.

In response to these challenges technology giants such as Schneider, Cisco and Siemens and policy makers believe that the opportunities afforded by integrated data platforms to connect energy, water and transport can transform our cities. But is 'smart' purely seeking maximum technical efficiencies or does smart need to incorporate citizens as well? Cities, we argue (in borrowing a well cited phrase from Katy Janda (2011), like any building development or infrastructure, don't use energy, people do. Concerns have been raised by academics (Cowley &

Caprotti 2018, Martin et al 2018) that such interpretations of smart cities are lacking a democratic mandate and also perpetuate a consumerist growth agenda that will fail to resolve the underlying problems facing cities.

A concrete example of smartness is the smart meter. Here a smart meter is defined as a utility meter (i.e. a measuring device and related hardware) capable of generating, storing and communicating digital data about the utility usage it is measuring. Smart meters are a new source of data that are being introduced at a mass scale. The EU directive 2009/72/EC for example has an aspiration that by 2020 at least 80 % of consumers should have such 'intelligent metering' systems (Azzenoud et al 2017). This represents a very large volume of data being generated and stored, much of which will relate to cities.

In a smart city, utility data will be integrated into urban management processes. Salient information will be extracted and communicated seamlessly to those individuals who can use them. The information will be presented in a format in which they can most readily be used. Smart meters become part of an integrated service to support decisions which help to optimize energy efficiency of the urban infrastructure. This paper considers the practical realities and experiences of implementing a smart city ICT platform to help public authorities manage their energy, gas and water. The H2020 EU-funded project EDI-Net (Energy Data Innovation Network) implemented the platform across public authorities in Europe. This paper first critically explores the concept of Smart Cities before presenting the EDI-Net, the research methodology and key findings.

Smart Cities – an evolving concept?

The phrase 'smart city' has emerged during the last decade and has been used, since then, by different companies but notably the IT sector and companies such as IBM, Cisco and Siemens. Definitions of smart cities vary according to the sector in which they are used, and it is immediately evident from the range of definitions that there is little consensus. The range of industrial definitions were chronicled by Bull & Azzenoud (2016) and can be seen in Table 1.

This table reflects the first stage of what the Future Cities Catapult refer to as the 'marketeer's' vision of smart cities, which they felt dominated in the 1990s. The focus was on capitalizing on the potential of ICT solutions to connect energy, water and transport. At this stage the term 'smart city' would have been interchangeable with the 'information' or 'digital' city. From here commentators note a second stage with visions and definitions expanding to included citizen engagement in various forms – be it face-to-face participatory processes or on-line engagement through digital tools. Future Cities Catapult note a third emerging trend though as citizenship is being traded for consumerism. Open data and digital platforms are enabling new business models which blur the lines between citizens and consumers. Airbnb and Uber being two examples of technology enabled transformative business models that are transforming people's daily lives and habits.

Businesses like IBM, Schneider Electric, CISCO and Siemens have used the concept of a smart city to market their vision for the cities of tomorrow through the 'application of complex information systems to integrate the operation of urban infrastructure and services such as buildings, transportation, electrical and water distribution, and public safety' (Paroutis et al., 2013, p. 2). The Future Cities Catapult agree that *global technology companies saw an opportunity to sell digital transformation and new technology into big city systems (water, energy, transport). 'Smart City' caught the imagination as smart phones and digital transformation spread across the world at a phenomenal rate (Future Cities Catapult 2017)*. However, according to Harrison and Donnelly (2011), this concept is not new; its origins go back to the Smart Growth Movement in the late 1990's. Definitions of smart cities vary according to the sector in which they are used and it is immediately evident from the range of definitions that there is little consensus.

Policy makers have been swift to react to this emerging and evolving smart city agenda. Both at the local, national and European/International level there is no shortage of guidance, local action and policy directives. Caprotti et al (2016) recently found examples of nearly a third of UK's towns and cities developing plans for activities that could be labelled 'smart'.

Smart cities are now a major policy initiative of the European Union. In their Strategic Implementation Plan for 'Smart Cities and Communities' (2013) smart cities are defined as

> … systems of people interacting with and using flows of energy, materials, services and financing to catalyse sustainable economic development, resilience, and high quality of life; these flows and interactions become smart through making strategic use of information and communication infrastructure and services in a process of transparent urban planning and management that is responsive to the social and economic needs of society.

In this document they describe areas of focus around sustainable urban mobility, energy efficient buildings and integrated Infrastructures and processes across energy, ICT and transport. Space is given to the need for increased citizen engagement and the benefits that brings. The areas of focus are (1) developing a common European framework for cities, (2) removing barriers from experimental initiatives that innovate and increase knowledge, and support co-creation, and (3) establishing local citizens committees to work with local public authorities, SMEs and larger industry in order to set the targets for developments.

In the UK the Department for Business, Innovation, & Skills (BIS) has defined the process by which cities turn into smart ones. It refers to the process as one in which cities become more 'liveable and resilient'. For BIS a smart city should enable every citizen to engage with all the services on offer, public as well as private, in a way best suited to his or her needs and incorporates 'hard infrastructure, social capital including local skills and community institutions, and (digital) technologies to fuel sustainable economic development and provide an attractive environment for all' (BIS 2013, p.7). Here they note five key features that should underpin a smart City.

1. a modern digital infrastructure
2. a recognition that service delivery is improved by being citizen centric
3. an intelligent physical infrastructure ("smart" systems or the Internet of Things)

Table 1. Industrial Definitions of Smart Cities (Bull & Azzenoud 2016).

Company	Vision	Key Vision
IBM	Cities can capitalize on new technologies and insights to transform their systems, operations and service delivery. Being smarter can change the way their cities work and help deliver on their potential as never before.	• Big data and analytics for deeper insights • The 'cloud' for collaboration among disparate agencies, mobile to gather data and address problems directly at the source, social technologies for better engagement with citizens.
Schneider Electric	Cities need to become smarter, more efficient, sustainable and livable. This can be done through collaboration with different entities (municipality, council, etc.) to deliver urban efficiency.	• Smart Energy: Energy management System to make end users, renewable energy sources and electric vehicles efficient and smartly connected to the grid. • Smart Water: use of management systems to detect water leaks in the network, to optimize the energy used for supplying water, and to provide solutions to face storms and floods. • Smart Building: use of Building Management Systems to monitor the energy use. • Smart Mobility: Traffic and transit management systems that deliver realtime visibility across the entire transportation network, electric vehicles and efficient and safe recharging infrastructure via tolling and congestion charging solutions. • Smart Public Services: solutions ranging from street lighting to the public safety with a focus on data collection for better management. • Smart Integration: linking different management systems available in the city to increase the efficiency of each one of them and the overall efficiency of the city.
Siemans	Smart Cities should find ways to optimize its infrastructure through intelligent infrastructure solutions – such as smart grids, building automation, security solutions and traffic control systems.	• The use of sensors, communications, computational ability and control in some form to enhance the overall functionality of the electric power delivery system
Cisco	Smart cities should include an integrated urban information and communication technology (ICT) that can overlay on a city that can support delivery of connected urban services and allow for efficient management of those services on a global scale.	• Leveraging the Internet of Everything, cities can integrate people, processes, data and things to create safe and vital places to live, work, learn and play

4. an openness to learn from others and experiment with new approaches and new business models; and
5. transparency of outcomes/performance, for example, city service dashboards to enable citizens to compare and challenge performance, establishment by establishment, and borough by borough.

These are further described in the recent BSI Standard for Smart Cities "Smart city framework – guide to establishing strategies for smart cities and communities" (2014). In this document they note that a smart city is/should be visionary, citizen-centric, digital and open and collaborative. It is clear then that, on paper at least, a purely techno-centric view of smart cities is dissipating. Policy makers and practitioners are starting to see the citizen is an essential stakeholder, even if there is a blurring over the boundaries between citizens and consumers. It is also unclear what these policymakers actually refer to when they talk about citizen engagement.

The shifting definitions of smart cities have been captured well in the academic literature. For example, a comprehensive review by De Jong et al., (2015) highlighted twelve different categories of cities in the literature for the period running from 1996 to 2013: 'sustainable city', 'eco city', 'low carbon city', 'liveable city', 'green city', 'smart city', 'digital city', ubiquitous city', intelligent city', 'information city', 'knowledge city', and 'resilient city'. They found 'sustainable city' had the highest number of occurrences followed by 'smart city'. However, the importance of this study resides in defining the links between these different types depending on their number of occurrences in the selected range of academic literature:

Huber and Mayer (2015) noted that there is no clear definition or conceptual content of smart cities unlike the low carbon and eco cities, and that it is still a fuzzy concept; but there exist many interpretations. They conceptualise this through three perspectives:

1. Instrumental perspective: this consists of using ICT to gather high quality data from different sources of information in shorter times to help improve the work of institutions, like the municipalities, through the processing of these data in

order to produce meaningful information which can help in building the right strategies and making decisions.

2. Administrative perspective: the goal of a smart city is to unify the work of institutions through the establishment of a smart policy. In other words, it is fundamental for all structures/departments belonging to the same municipality, as an example, to interact and unify their efforts to develop a vision to the city; a vision that has as a starting point defining the needs of the citizens and as an endpoint meeting these needs.
3. Governance perspective: citizens should have a great role in defining how their cities should look like, this is why it is essential to overcome the traditional top down governance and transit to a new governance style; a style which enables integration of all stakeholders in the decision making.

This governance perspective gets to the core issue of how citizens are engaged in decision making, be it for the design of a new building, infrastructure project or city-level planning such as a new transport policy or carbon management strategy. What does it mean to actually engage the citizens of a particular area or city? Recent policy documents such as the BSI Standard for Smart Cities do have a strong emphasis on the need for citizen engagement, be it by actual face-to-face stakeholder engagement or through the use of digital platforms such as EDI-Net

Other perspectives though have raised concerns around some of the underlying assumptions around smart cities. Notably for example Martin et al. (2018) who fear that these visions of smart cities are ultimately underpinned by capitalist or consumer understandings of cities. Undertaking a review European and North American interpretations they conclude that "smart city initiatives in practice reinforce the focus on delivering unsustainable forms of economic growth and consumerist cultures, while neglecting social equity and environmental protection" (2018:18). On a more positive note they also note that these new models of smart city offer greater potential for new models of urban governance, particularly through data platforms and citizen engagement and empowerment. In that regard the shift towards more participatory definitions of smart cities are welcomed as is the need to ensure a critical voice against the techno-centric views by the technology firms who do appear be finding problems to solutions they have. What is lacking in these definitions though is concrete examples of what is actually feasible. Our EU project EDI-Net offers insights into this challenge.

Methodology: introducing EDI-Net

EDI-Net consists of an energy focused ICT digital platform designed with three specific user requirements in mind: 1) to allow stakeholders to track energy performance and communicate this performance in a user-friendly way (energy data dashboard and league tables), 2) to facilitate communication between stakeholders (online discussion forum), and 3) to manage intervention plans for energy efficiency (energy efficiency benchmarking tool) – see Figure 1 for screenshots[1].

1. The EDI-Net system (Stuart et al 2017) is a development of the Leicester pilot of the Smartspaces EU project. The initial design of the platform is described in Stuart et al. 2013. A detailed technical overview is provided in Stuart and Fleming (2014) and a discussion of the initial indications for community-wide behaviour change are discussed in Stuart et al 2016.

The EDI-Net system automatically analyses thousands of datasets continuously and provides users with the results of these analysis via a series of tools: dashboard, forum and energy efficiency benchmarking tool. The EDI-Net dashboard presents energy and water usage data in a simplified format showing each building as a 'smiley face'. This format enables users to gain a very quick overview of current performance across their entire building portfolio and draws attention to poor performing buildings (those where consumption is higher than the its baseline of the previous year). This monitoring functionality is augmented by the ability to 'publish' simplified results in 'league tables' which encourage friendly competition and provide links to detailed insight into why a building is considered to have good or bad performance. The EDI-Net community uses an online forum. The forum allows participants to share their experiences, promote their successes and discuss their challenges. The EDI-Net benchmarking tool allows the review of the energy consumed over time in the building's portfolio at a range of time scales from 15 min data to monthly data. Its main purpose is to support strategic decision making based on the analysis of the building energy usage behaviour and compared against different characteristics, and the evaluation of the impact of implemented Energy Efficient Measures (EEM). These tools can be used by both technical and non-technical stakeholders with the purpose of eliciting evidence of the continuity of the monitoring process (energy and behaviour change) and informing the progress of the public authorities.

This paper presents findings from the project mid-term evaluation in order to understand how the EDI-Net services may have an influential impact on the participating public authorities (PAs): Leicester City Council (LCC), Generalitat de Catalonia (GENCAT) and Nuremberg City Council (NUR).

The mid-term evaluation took place using focus groups and interviews (semi-structured format) in order to obtain in depth insights of the participants' thoughts, viewpoints, attitudes and actions. The themes investigated were related to the role of participants related to energy management in their organisations, the use of EDI-Net in their public authority or organisation, the impact of the use of the tools at the institutional level, and their perception on how the EDI-Net tools communicate with users. Questions also sought to understand whether participants perceive that levels of awareness and knowledge of energy use were influenced at the individual or collective level as a result of viewing or interacting with the tools. In addition to the interviews, the researchers had the opportunity to attend a schools' meeting in Leicester in July 2018 to gather further feedback about the EDI-Net tools.

A total of 31 participants were interviewed face-to-face, in a focus group or virtually via video conference between February and July 2018. Three participants responded to a mid-term online questionnaire following the schools' meeting in Leicester and four interviews took place. In Generalitat de Catalonia two focus occurred, an initial one in February 2018 with 12 energy/sustainability professionals (central managers) responsible for various buildings in their Departments across the region. The second meeting was conducted by the delivery managers in Generalitat de Catalonia on May 2018 for training and to follow up issues that emerged in the focus group held in February. This time twenty-two participants attended this meeting (including the original 12) from the same Departments. Two

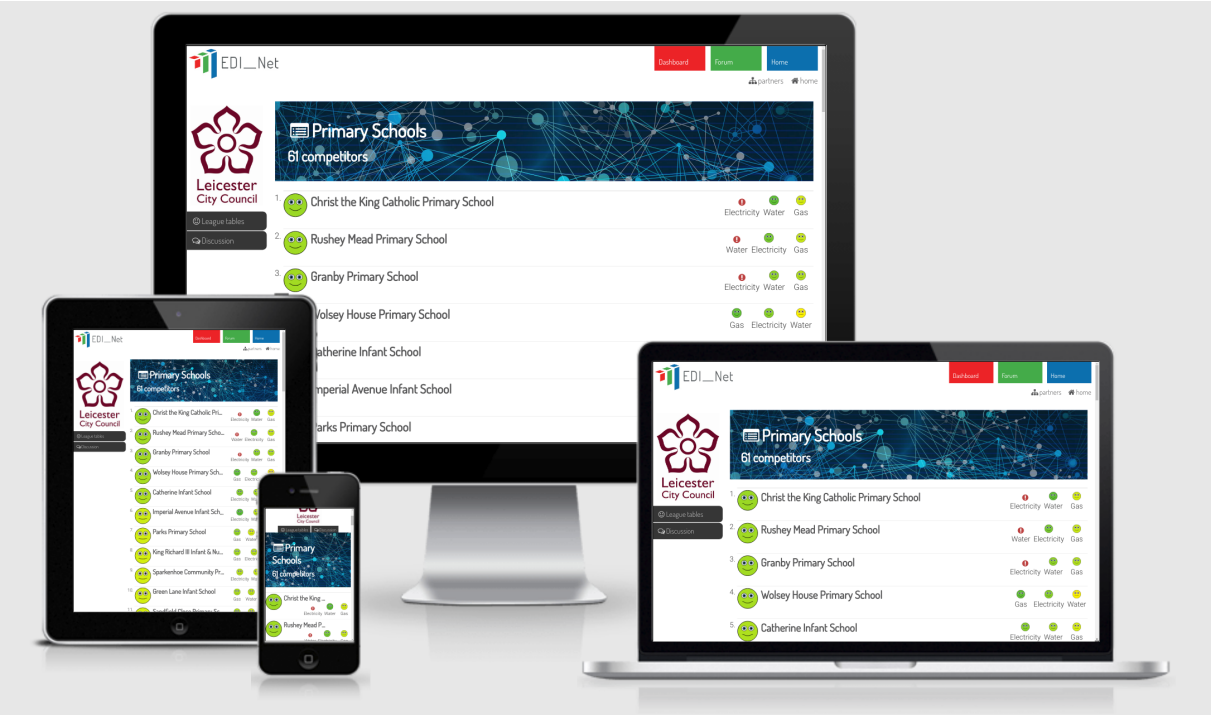

Figure 1. Screenshots of the EDI_Net tool.

interviews were also held in Nuremberg. The role of interviewees and focus groups' participants has been essential in the implementation and communication of the services in their respective public authorities. Central and local energy managers can influence horizontally to their colleagues as well as downwards to the building users. Some of these managers also support the decision-making on energy efficiency investments. Energy coaches and energy champions also have an important role as mentors among their peers and other users (e.g. pupils and students). Table 2 summarises the relevant information about the participants.

The focus group sessions and all interviews with staff of partner public authorities in Leicester (LE1-LE7), Catalonia (CAT-FG1, CAT-FG2) and Nuremberg (NUR1-NUR2) were transcribed verbatim. Transcripts were initially coded (using NVivo software version 11) according to the extent to which they aligned with the pre-identified themes of the EDI-Net evaluation framework. In this initial coding stage, known as open coding, interviews are broken down into tentative labels. Subsequently, commonalities among the coded data are sought and connections between categories emerge within and between public authorities. This subsequent coding stage (known as axial coding) attempts to bring coherence to the coded data. Responses of the schools' meeting questionnaire were also included in the analysis. Descriptive statistics (means) and excerpts of responses to the open questions are presented. Initial findings were presented to representatives of the public authorities to validate results or add further information.

Findings from EDI-Net

This section explores the use of the EDI-Net tools (dashboard, forum and benchmarking tool) by the partner public authorities and how they use the tools in their operations, for example, energy management, awareness campaigns and communication with users, planning of energy efficiency investments, and reporting among other uses.

DASHBOARD

The dashboard is the main tool used in Leicester and in Nuremberg. The main uses of the dashboard identified in the interviews were for energy management and for communication with internal stakeholders (colleagues and pupils in schools) on a periodic basis or in mobilisation campaigns. The dashboard is considered in terms of energy management, mobilising campaigns.

Energy management

Most interviewees mentioned that they have recently started using and testing this tool [NUR1, LE1] and use the tool once or twice a month [LE2, LE4] or less that once a month [LE5Q, LE7Q].

Energy and sustainability managers find the dashboard very useful to have a "quick overview of the energy consumption in each building" [NUR1] and an understanding on "how the buildings are performing" [LE3]. Even for non-technical users, the tool is found easy to use and to understand [NUR2, LE3]. One teacher commented that she uses the tool to show how much energy is consumed in the school and to tell colleagues and students to "switch off lights" or "do not use the heater if you do not need it" [NUR2].

One of the main features mentioned by various interviewees was the ability to detect energy or water abnormal consumption in a timely manner. For example, three cases of water wastage were found in the past 3 months in Nuremberg [NUR1]. As soon as the red faces are discovered by central energy managers in the city, they communicate with the staff in the buildings to initiate countermeasures. Similar cases were reported in

Table 2. Summary of participants in partner public authorities.

Interviewees codes	Participants	Building types	Roles/responsibilities
		Catalonia	
CAT-FG1 (February 2018)	12	Various	Central energy/sustainability managers responsible for various buildings in their Departments across the region (mainly office buildings, but can also include museums, fire/police stations). Representatives of the following departments attended this focus group: Culture, Justice, Governance (3), Agriculture (2), Interior, Work, Presidency, and the EDI-Net delivery manager. Central energy managers may also have energy-related finance responsibilities.
CAT-FG2 (May 2018)	22	Various	Including the 12 participants of the first focus group. Selected local energy managers from departments across the region.
		Leicester	
LE1	1	School	Local site manager Energy champion, responsible to coordinate pupils in the Eco-Schools initiative
LE2	1	School	Local business manager Energy champion, responsible to coordinate pupils in the Eco-Schools initiative Financial responsibility on energy efficiency investments
LE3	1	University	Energy and sustainability officer Energy champion, responsible of staff and student engagement
LE4	1	University	Energy manager Financial responsibility on energy efficiency investments
LE5(Q)	1	School	Local energy management responsibilities, including financial decisions on energy efficiency investments Coordinating pupils in the Eco-Schools initiative
LE6(Q)	1	School	Energy champion, responsible to coordinate pupils in the Eco-Schools initiative
LE7(Q)	1	School	Local energy management responsibilities, including financial decisions on energy efficiency investments
		Nuremberg	
NUR1	1	Several	Head of Municipal Energy Management Responsible of a portfolio of around 800 buildings Financial responsibility on energy efficiency investments
NUR2	1	School	Eco-teacher, responsible to teach energy in the curriculum (various ages) Energy champion, engaging staff and students

schools in Leicester. One participant of a school commented that the water wastage was resolved extremely quickly. The overall cost of the extra water was about £15, but if the anomaly would have continued for 200 days, the cost would have been easily around £1,400 [LE2].

Based on the training received from the LCC Environmental education coordinator, who can be seen as an energy coach, local managers are able to understand better the energy performance in their buildings and conduct actions to improve it. One interviewee commented that looking at the graphs, they observed that the electricity and water use reduced during the Easter holidays, but the gas consumption did not [LE1]. They discovered that the heating was running over Easter. The interviewee is now planning to shut down the heating over the summer holidays, but this event also prompted him to request training for the school's building management system (BMS), so this can be done automatically in future holiday periods [LE1].

Participants responding to the questionnaire tended to agree that the tool is useful to track energy performance of the building at a glance (mean=4) and to improve energy management in the school (mean=4).

Mobilisation campaigns

Awareness raising and engagement campaigns are run in several ways across the PAs. For example, primary and secondary schools can have eco-warriors teams or an eco-ambassador as part of the Eco-Schools programme in Leicester [LE1, LE2], "Green Impact" teams comprised of environmental champions among staff in different departments of the university [LE3, LE4] and teachers embedding energy awareness in the curriculum of schools in the city of Nuremberg [NUR2].

Several interviewees perceived that the dashboard communicates energy performance in a user-friendly manner and also facilitates communication among users. Some interviewees referred to the simplicity and clarity of the smiley faces: "Anybody can understand a red unhappy face and a green smiley face" [LE3], "the smiley faces is probably one of the best graphic things, I have seen … because it is very straight away" [LE4].

In one primary school in Leicester, the interviewee considered that for four or five years old children the "smiley and sad faces communicate better than words" [LE1]. The interviewee explained that when he asks pupils about the faces, the children can easily interpret that a sad face means that the school is not performing well. Similarly, the teacher in a school in Nurem-

berg mentioned that they can use the smiley faces with young children, while they can use the detailed graphs for higher classes [older age], which teachers can ask them to evaluate them [NUR2]. In combination with other monitoring system, the teacher would like to show the renewable energy generation from their solar PVs and use the dashboard to highlight how the school uses heat and electricity [NUR2]. Responses from the schools' questionnaire in Leicester showed that while respondents agreed that the tool is useful to communicate with internal stakeholders (mean=4), they did not completely agree that it is useful to communicate with non-technical users (mean=3.5). Nevertheless, one questionnaire respondent agreed that the information provided by the dashboard was clear, engaging and useful, but neither agreed or disagreed that it was credible and reliable.

League tables

One interviewee found the comparison with other schools and buildings in the league table useful [LE1]. The interviewee thought that comparing with the school "across the park" will be very useful as the buildings are identical in terms of number of pupils, number of classrooms and the energy usage should be very similar. The manager considers that through the comparison of energy use with this school, he can understand if they are conducting appropriate actions or if something is wrong. The interviewee believes that showing the comparison of smiley faces to the pupils can help to discuss with them "if they are doing better than us, we can think, well where we are going wrong? … we should have a smiley face" [LE1]. He considers that competing with this school would be very useful with the pupils.

In contrast, one interviewee disagrees with the comparison of schools in the current league tables available [LE2]. The business manager considers that buildings should be compared on the basis of similar sizes (gross internal area), similar number of students, similar age and similar building type. The interviewee considers that the comparison with primary schools or secondary schools smaller in size is not adequate as these schools use less energy due to fewer students. At the time of the interview (July 2018), the interviewee's school was at the bottom of the league table. From an educational viewpoint, he suggested that a more "like-for-like" comparison could better incentivise the students: "when they see those smiley faces is not always about what colour they are, but it is also about what ranking they are … they want to be top of the league" [LE2]. The questionnaire respondents agreed that the tool is useful to compare local energy performance with other schools (mean=4).

FORUM

None of the interviewees and focus groups participants in the 3 PAs reported using the forum on a frequent basis. In the University, one of the interviewees tried to engage with the environmental champions in the "Green Impact" teams using the forum in the previous academic year 2017–2018 [LE3]. The interviewee asked teams to post messages about energy savings within their buildings and try to run few competitions, and sometimes even offered a small prize (e.g. free fair trade bar of chocolate). However, he considers that *"people are really busy"* and asking them to get used to another system is complicated, but once they understand how it works, they can understand how useful it is [LE3].

In some cases, the forum has been used to communicate with energy management teams. One interviewee in Nuremberg commented that she has used the forum 2 or 3 times to ask questions, such as the heating insulation in the school, to experts (energy management in the city of Nuremberg) [NUR2]. She found the responses very helpful to understand how the energy systems work in the school. Similarly, in the University, some people flag up issues in the forum requesting information from the energy management team or prompting an investigation [LE4]. However, the interviewee, who checks the forum every couple of weeks, considered that there is little activity and "not many other groups come through there" [LE4]. With regards to communicating among peers (energy teams, schools), some of the main barriers to use the forum by a wider audience are a lack of time [LE1, LE2, LE3, NUR1] and the little activity in the forum [LE2, LE4, NUR1]. Interviewees considered that to become interesting, the forum needs a "critical mass" [NUR1] as a "self-pushing system, the more people use it, the more people will start using it" [NUR2].

ENERGY EFFICIENCY BENCHMARKING TOOL

The energy efficiency (EE) benchmarking tool (Figure 2) is the main tool used in Catalonia [CAT-FG1, CAT-FG2]. The ED benchmarking tool is a strategic decision-making tool that enables building managers to quickly obtain all relevant data for a specific building or building group, to analyse actual consumption in comparison to predicted consumption and to evaluate the effect of different energy efficiency measures. It can also review the profitability of investments improving decision making about the most appropriate energy efficiency measure for other buildings.

Few interviewees in other PAs have experience in the use of this tool [LE4, NUR1]. The delivery manager in the Generalitat explained that the tool is deployed mainly among departmental energy managers, who are responsible for energy and sustainability aspects in their departments and for their associated buildings. These managers are responsible to input the energy efficiency measures (EEM) in the tool. At the Generalitat level, the delivery manager can visualise the 1,200 buildings and 2,000 EEM.

Energy management and EE measures documentation

Two participants of the focus groups commented that the tool is useful to monitor energy performance in the buildings and see if the energy systems are working properly. One participant mentioned that "having this feedback is very good" [CAT-FG1]. Another participant explained that the tool allows them to focus on the buildings with the worst performance, so when they see a "red face" (also available in the benchmarking tool), they can plan actions to tackle the problems. Another participant mentioned that some of the features she liked the most from the tools were the comparison with the baseline, presentation of the energy savings and the weather correction. The participant considered that the provision of actual annual savings despite weather changes is very good.

For some of the buildings with available hourly electricity data, a participant commented that the monitoring of data has been useful to detect "buildings operating during the weekend

Figure 2. The benchmarking tool.

as weekdays rather than as festive days" [CAT-FG1]. However, the visualisation in the EDI-Net tool was not fully used in her department yet due to the data problems. The delivery manager in Generalitat found the comparison with buildings very useful. She explained that the tool has been useful to conduct a general analysis at the PA level, to know the energy consumption by different building types and also by departments, to follow up the EE measures that have been implemented as well as the cost of those measures [CAT-FG1]. This approach has been further explored after the first focus group [CAT-FG2].

Although the benchmarking tool has not been widely used in De Montfort University, one interviewee commented that several energy efficiency measures have been implemented in the buildings over the last year and the documentation of these measures can help to develop good case studies and be replicated in other buildings [LE4]. He also considered that in theory, the tool could help to develop business cases for the interventions that are planned for the next five years in the revised carbon management plan in order to secure some funding for those projects.

In contrast, one person in Nuremberg considered the use of this tool is not feasible in their PA [NUR1]. The interviewee argued that it is not possible to standardise energy reductions to single measures, as there are too many factors influencing the success of the measures which differ from measure to measure, building to building, and community to community. It was emphasised that not only the different effects or different implementations have to be considered, but also the human judgement of the effects of the measures. These effects cannot be easily standardised or even accurately calculated on the basis of calculating numbers on a data server.

Manage and intervention plan for energy efficiency

As previously mentioned, several focus group participants and one interviewee found it useful to be able to document and monitor EE measures in the benchmarking tool to understand their economic and energy impacts, and to plan the potential implementation of some measures [CAT-FG1, LE4]. Similar to comments related to the content in the forum, one participant suggested that the tool requires a large amount of information to be more reliable: "the more information is in the system, the more reliable it becomes, and the results could be more useful" [CAT-FG1]. However, she also pointed out that filling out the data in the system requires time due to the great diversity of energy saving actions and the diversity of building typologies.

In Nuremberg, the interviewee considered that the tool could be simplified and estimate the energy savings in terms of kilowatt-hours only, but not in monetary values. Firstly, because it is sometimes difficult to assign the associated cost to the energy efficiency measure. The interviewee explained that using the whole cost does not make sense, as some measures would have been conducted anyway as part of refurbishment or renovation works: "is it only the additional cost for the energetically better solution, or is it the whole cost that is assigned?" [NUR1]. Secondly, because despite it being a tool targeting financial decision-makers, the selection of EE measures should be conducted side-by-side with an energy management expert, who can judge and recommend "what kind of measures or what combination of measures could be the most efficient" to reduce energy consumption [NUR1]. The interviewee concluded that the simplification of the tool would have a two-fold effect: "have less effort in feeding the system and have a good result, seeing the evaluations but not money based" [NUR1].

Communicating with stakeholders

Participants in Catalonia commented that they conduct periodic campaigns to prompt staff to switch off lights, IT equipment, etc. One participant considered that having a system "where you can document these, see the impact and be able to communicate it" is very useful [CAT-FG1]. Another participant agreed that communicating the efforts with users can help to make them more committed with the performance of the building: "they can see that even a small thing (change), you can have some savings" [CAT-FG1]. Another participant mentioned that the tool can also be useful to seek cooperation among users, for example, when they have done all that they

can within the building controls, but people disagree with their thermal comfort.

One participant mentioned that in her department's intranet, her team provides information of the annual energy consumption of each building within the region for the last 4–5 years accompanied with indicators, such as kWh per square meter or kWh per person, and then people can compare their building with the rest of the offices. The participant explained that the team makes these tables and graphs manually for the annual training sessions with their local energy management teams, but she can see a great potential in the tool if this can be done in an automated manner. The participant considered that if the information can be easily prepared using the tool, the communication with the users could be done more frequently [CAT-FG1].

Conclusion

So, has EDI-Net enabled the local authorities become smarter? The software is designed to support the capacity building and coordination of EU public authorities to more effectively use smart metering and related building use data to reduce electricity, gas and water consumption in buildings but, as noted earlier, by 'smart' we're referring to better use of technology underpinned by engagement of citizens and building users.

Based on the feedback received in interviews, focus group and online surveys the following key changes were identified as a result of using the EDI-Net tools at both the individual, social and institutional level. At the individual level the most notable impact was on the energy and financial managers. Notably the tool enabled clearer representation of energy budgets to financial managers to help motivate people to save energy in Catalonia. It also saw an increase in the speed of identifying energy saving opportunities in their buildings (e.g. water leakages, changes in heating settings over holidays) (Leicester, Nuremberg). The most significant impact though was in the increased social interactions between users, managers and senior leaders, Energy managers shared of best practice between performance of their buildings (Leicester, Catalonia) and there was more effective engagement of building users/managers to promote sustainable energy (Leicester, Catalonia, Nuremberg]. Exchange of information about energy and water use in buildings and share best practice is facilitated through the on-line forum (Leicester, Nuremberg). More time beyond the duration of the project is needed to clearly define the institutional change and the long-term effects. However, in Leicester, the EDI-Net tools have been embraced by the schools' pupils who used the dashboard and league tables to compare energy and water use data with previously years as part of the monitoring and evaluation activity of the Eco-Schools initiative. Recently (November–December 2018), Leicester launched a city-wide league table competition involving around 100 schools. In Nuremberg it was explained that the municipality has already implemented several technical energy efficiency measures. Hence, engagement with users is becoming more important in the future and "pushing information" to people that have not been previously engaged is extremely important. Therefore, the Energy Department in this municipality is starting to show the EDI-Net dashboard in public screens in the short-term and planning to incorporate in the medium-term the most energy-intensive buildings (around 150) of their portfolio in the dashboard.In Generalitat of Catalonia, the benchmarking tool was used to analyse EE measures particularly in 34 buildings and is enabling more sophisticated planning of the implementation of electricity and thermal energy related EE measures in these 34 buildings and their associated costs and savings.

Challenges remain though, notably around increasing user-engagement and technical difficulties According to our review of the definitions of smart cities, citizen engagement is fundamental and EDI-Net had limited success in engaging building users more widely in the forum and in the buildings' information in the benchmarking tool. It is also required that energy managers familiarise more with the benchmarking tool to document best practices for replication or develop business cases to seek/ensure investments in energy efficiency measures. The implementation of further mobilisation campaigns is also recommended to strengthen engagement strategies within the PA's energy policies. Initial technical software problems within the EDI-Net tools related to data acquisition, data loggers and data transfer or missing data affected the earlier and wider deployment of the tools across the partner PAs in the first 18 months of the project. Hence, the use of the tools has been limited in the departments and organisations of these PAs by the time of the focus group and interviews. However, plans of using the tools more widely are envisaged.

Smart cities then can be a very vague notion. This paper locates though broad definitions into a tangible example of how technology, underpinned by engagement can improve the energy performance of municipalities. In these public authorities technology has enabled better engagement, both internally and externally, with the data which is facilitating better decision making, and resource efficiencies. There is undoubtedly a long way to go to cities like these three to be truly 'smart' – but concrete steps have been taken as a result of EDI-Net.

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