From calculated to real energy savings performance evaluation: how ICT-innovation and Do-It-yourself user-generated data monitoring can enable to improve real performance evaluation of energy-efficiency initiatives

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Abstract

A recent in-depth policy review, carried out under International Energy Agency (IEA) demand side management implementing agreement Task 24 (Behaviour Change), highlighted how policy programmes aimed to introduce energy-efficient behaviour change often have their impact evaluated based on theoretical data. The study identifies a need to incorporate a real data collection process as part of evaluation.

This paper starts with exploring reasons behind the lack of real data monitoring and evaluation of energy interventions using behavioural change, and discusses the mismatch between the cost of collecting the data and their political value after implementation of the policy, and the political risk of uncovering poor performance results.

Potential benefits are identified for facilitating user-centred data delivery instead of centralised data monitoring and evaluation. We examine how advances in communication technology enable user-centred data delivery, allowing users to collectively input, monitor and evaluate data. DIY monitoring and evaluation creates several advantages in analysis of the influence of behaviour and individual choices on energy use.

However, this potential carries with it significant risks to privacy and security. The processes of collecting and sharing of personal activity data must be carefully controlled to prevent exploitation of users by commercial organisations performing the processes. We outline a flexible methodology for creating user profiles and how this can allow energy data to be analysed 'horizontally' across peer systems as users move between different energy nodes (building & transport), instead of 'vertically' aggregating data within each building or system. Crucially, users retain control over their data: who can access it, when and how it is presented. Drawing on emerging collaborative business models, value is shared between users analysis but no permanent rights are given up.

Introduction on the IEA study

Evaluating the effectiveness of policy implementation requires real impact data. Energy-efficiency programmes base their impact assessment on predicted performance , understandably, to know what a programme will deliver before deciding to go ahead. However, post-intervention evaluation often does not include an attempt to compare predicted savings impacts with achieved savings. In many cases implementation is structured around calculated savings, using. economic payback times, which are then not realized. This causes the policy to fail in its long-term aim of energy-efficiency, even though its short term aims (customer uptake, investment in saving measures) were achieved. The case-studies investigated in this paper identified political and economic reasons behind these problems but also practical limitations in collecting real data on a large-scale. Advances in social networking, connecting large numbers of people and their information together, offer a route to a solution, but one with implications and risks attached. This paper explores these themes through analysis of results produced by an in-depth policy review carried out as part of implementing agreement Task 24 (Behaviour Change).of the International Energy Agency (IEA) demand side management (DSM) programme.

This multi-themed work is a result of an open collaborative – or social – approach to analysis and evaluation. Beyond the initial work-plan and targets, project involvement was on a voluntary basis, and both the input and output were determined by each participant themselves. It presents an alternative view of research, outlined in (Batey, Decorme & Bull, 2013), where different actors bring particular perspectives and project findings together to generate a collaborative analysis. The findings are immediately applied and developed in the specific real world situations of the individual projects. As such this paper reflects a snapshot of intertwining aims, objectives and results, where findings depend on the context in which each participant evaluates/applies them.

A key aim of the IEA study was to uncover aspects of successful behaviour change approaches that could be applied in future programmes with equal success (Mourik & Rotman, 2013). The scope of 'behaviour change' covered by the study was left open to interpretation, incorporating both one-time investment decisions in technical improvements (e.g. fitting insulation) as well as adaption of lifestyle behaviour patterns to be more energy efficient. A key finding is the critical role played by context in a programme's success. The best approaches are tailored to the specific context in which they are applied. The nature of policy, particularly 'short-termism' towards gaining positive, easily measurable results (Shove, 2010, Broennum & Moller, 2013), makes a long-term, tailored approach less suitable. But there is a need to strike a balance between the top-down aims of the policy-makers and bottom-up aims and needs of those energy end-users for whom the programme is intended (Bull et al, 2011).

These issues and the combined study fields of the authors led to the focus of this paper: the use of Information and Communication Technology(ICT) tools to collect, process and deliver to users their own data - automatically - enabling end-users to decide how to assess, act upon and share the information.

The "policy implementation deficit " and participatory approaches

Headline figures proclaiming the success of energy-saving programmes can hide a more complex truth and ambivalent impact. Potential reduction in carbon emissions by demand-side behaviour changes, brought on by installing interactive smarter meters in the UK, was estimated at 2.5–3.5 million tonnes per year (DTI, 2006). The subsequent policy measure outlined a planned roll-out of smart meters within 5-10 years, without taking into account advances in communication infrastructure, necessary for successful implementation (Burgess & Nye, 2008). The policy will be deemed a success if all meters are installed, irrespective of whether a single unit of energy is saved, highlighting a key distinction between the outcome [meters installed] and impact [savings, or not]. The predicted impact is used to justify support for delivering the outcome, but actual impact is not measured. In the Netherlands a similar expectation is placed on the top-down specified smart meters to generate behaviour change, but little attention paid to the specific business and lifestyle changes also required to deliver actual reduction in energy demand (Breukers et al, 2013).

Shove (2010) provocatively suggests that this scenario is a conscious choice of policy makers, interested in preserving the status quo with some added efficiency. They try to persuade the individual to make limited changes in purchasing behaviour, rather than tackling how policy itself needs restructuring in order to shape "transformation in the fabric of daily life on the scale and at the rate required." The focus is on the manageable areas where marginal but measurable impact can be achieved and positively evaluated (idem). This creates a policy context where the headline objective of tackling climate change is not specifically implemented and thus need not be evaluated.

More recently, on-bill financing (OBF) models have become a favoured route to achieving deep renovation energy-efficiencies. Financing is done by a third-party, usually an energy services company, which charges the customer a monthly energy fee, paid back through resulting energy savings (Weiss & Francia, 2013). An example is the Green Deal programme in the UK, which has run into problems of low uptake due to predicted savings not being realised (Collinson, 2014). The predictions are based on theoretical building performance modelling, not accounting for individual behaviour and hence being unreliable. This is one of the key reasons identified to explain why consumers do not take up energy-efficiency measures with apparently short payback periods (Weber, 1997, Jaffe & Stavins, 1994). Certainly a need to increase trust in political institutions, their true motives and aims, has been identified as an argument for a more participatory process (e.g. Bloomfield et al, 2001).

Is there also a fear factor, that the results of actual performance will not meet predictions, particularly in the case of programmes aimed at achieving behaviour change? Policy responses to failed behaviour change programmes generally consist of more of the same – information, financial incentives and standards – instead of accepting that the limitations of these approaches in tackling behaviour causes failure (Ek & Söderholm, 2010). Lorenzini, Nicholson-Cole et al (2007) support this view that the "top-down" information-deficit approach prevalent in UK climate change mitigation policy rarely achieves any measurable change in behaviour, which might justify a 'fear' of real impact data.

However, the lack of collecting and evaluating real savings data might simply be an issue of cost and practical limitations. It is often impractical for national policy programmes to study each specific implementation context (location, culture, organisation), In such cases, a bottom-up approach, incorporating some user-involvement, may be appropriate. Making a case for Living Labs (for a definition, see Følstad, 2008) as a policy implementation tool, Broennum & Møller (2013) highlight that political interest in a policy programme is highest at the outset. Interest falls dramatically as the programme follows its course and political cycles move on, in direct contrast to results and data available for evaluation, which rise as the project continues. Bull et al (2011) remark on a necessary move away from the technocratic approach of policy, simply telling us the right and only way, to more deliberative processes where stakeholder involvement forms part of the policy process and implementation.

It is claimed that participatory policy processes do lead to better results (Fioriono, 1990, Pianosi, Bull & Reiser, 2012), in terms of actual energy impact. Policies adaptable to the specific application context of, as part of deliberative approach to implementation, are prepared for negative initial results or feedback. This is opposed to the one-size-fits-all approaches which can, by design, only succeed or fail. Stringer (1996: in Pianosi, Bull & Reiser, 2012) outlines such an approach in a 'look, think, act' routine to action research, which is replicated in spiral activity, wherein each stage of implementation is performed, reviewed and redone if required. Darby (2006) showed that persistent energy savings are more likely where feedback has generated intrinsic behaviour changes, i.e. new habits. Recent research has shown that user-involvement in the how, why and what of the feedback can help engender intrinsic changes, more than the information itself (e.g. Batey, Decorme & Bull, 2013, Bull et al, 2012).

Involvement of users through DIY User-generated data

This paper in the context of the IEA policy review asks whether access to actual impact data can be improved by connecting the feeling of empowerment, created by a participatory implementation process, to the capability, enabled by ICT, to share personal or collective pride in achievements. Is this a route towards a solution to the practical problem of collecting diverse data from a widespread group? Also, could it open up avenues to specific behaviour change actions through social learning (Darby, 2006) and peer-to-peer evaluation (e.g. Opower, see also Bauwens, 2013)?

Significant risks and potential negative impacts are attached to inviting all this personal data into the public domain, or even only within an organisation. Activity monitoring is a sensitive issue both at home (Darby, 2010, Hargreaves, Nye & Burgess, 2010), in the workplace and when travelling (location data). and Protections are required to ensure data isn't used for purposes other than energy management (Coleman et al, 2012). Where the intention is to use data to create tailored personal energy solutions, this requires a lot of sensitive data on activity use and personal behaviours, which individuals will be reluctant to give up on demand (Breukers and Mourik, 2013).

The success of Opower's peer-to-peer comparison model (figure. 1) suggests users are happy to share data presented the right way with other users. Breukers & Mourik (2013) propose a decentralised data collection and management system, where the role of the active end-user becomes critical but the personal data itself remains solely in their hands. In the case of the methodology outlined in this study, data sharing becomes a Do-It-Yourself (DIY) process where end-users present only the data they choose to and in whatever abstracted form they decide.

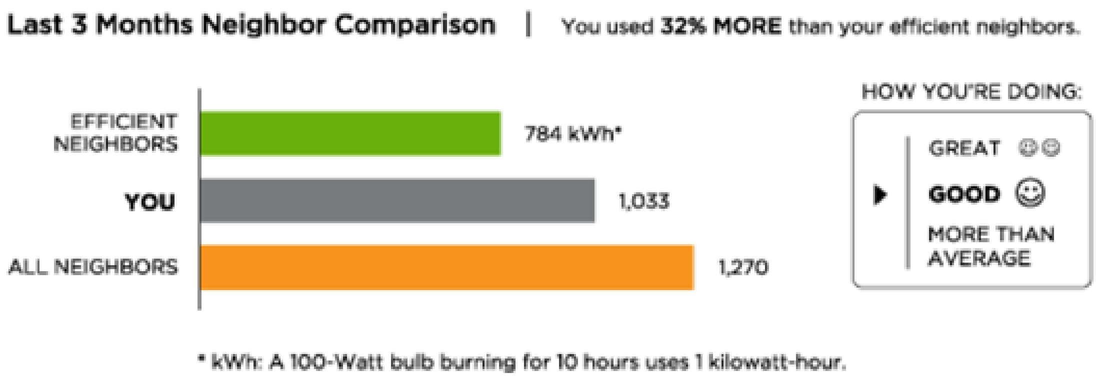

Figure 1. Comparitive billing example (Opower in: Dooley, 2011)

IEA DSM Task 24 Behaviour Change – Closing the Loop: from Theory to Practice

IEA Task 24 is a collaborative project, supported by 8 national governments on 3 continents. The main objective of this project is to create a global expert network and design a framework to allow policymakers, funders of DSM programmes, researchers and DSM implementers to:

I. Create and enable an international expert network interacting with countries' expert networks
II. Provide a helicopter overview of behaviour change models, frameworks, disciplines, contexts, monitoring and evaluation metrics
III. Provide detailed assessments of successful applications focusing on participating/sponsoring countries' needs (e.g. smart meters, SMEs, transport or refurbishment and/or renovations)
IV. Create an internationally validated monitoring and evaluation template
V. Break down silos and enable mutual learning on how to turn good theory into best practice

The project is broken down into three Subtasks, the findings of Subtask 1 being the focus of this study.

Research Method

The analysis was conducted through a series of expert workshops, detailed mixed methods case-studies conducted by the relevant national expert and follow-up interviews. Moreover, all reports and workshop outputs were published on a project Ning (online social network) for comment and discussion.

The full findings are found in a project report to be published by the IEA shortly . This paper analyses key findings related to evaluation of real impacts and the (potential) role for ICT in improving this process, by enabling widespread DIY evaluation.

Review of case-studies and findings

The 12 case-studies cover a variety of schemes in the fields of housing renovation, transport, smart-metering and small to medium enterprises (SMEs). For this study the projects are grouped by whether (Y) or not (N) they assessed real energy impact in evaluating the project. There were three anomalies where impact evaluation has either not yet been carried out or was only partial (see last column in Table 1).

Table 1. Summary of relevant case-studies reviewed in this paper

Country	Programme	Type	Theory	Evaluation of real impact?
NL	Blok4blok	Renovation	Economics	N
NZ	Warm Up NZ	Renovation	Social marketing; Theory of Planned Behaviour (TPB)	N
NO	Demo Steinkjer	Smart meter	TPB	N*
SE	Clockwise	Smart meter	Design with Intent	Y
AT	Energy Neighbourhoods 2	Smart meter	Participatory approach	Y
PT	On Demand	Smart meter	Participatory approach	Y/N
UK	Kirklees Warmzone	Renovation	Economics	N
	CHARM	Smart meter	Social norms	Y
USA	Opower	Smart meter	Social norms	Y
BE	Build4Good	SME	Nudge	Y/N
ES	Verdiem	SME	Economics	Y
IT	Time of Use	Smart meter	Economics	Y

In the three renovation programmes included above (and others reviewed under the IEA Task) impact evaluation consisted mainly of quantifying the percentage of the target group that took part in the programme. Carbon emission reduction or energy savings were estimated based on modelled building performance impact rather than actual savings. In the WarmUp NZ programme, the health benefits, including reduced demand for healthcare were so predominant in the evaluation that the energy-savings – which were not on target due to increases in heating technology and its use to maximize comfort and health benefits – were deemed irrelevant to its success.

The general reason for not assessing real savings was to keep the evaluation simple and low cost. Also, it avoids the need for pre-intervention metering and benchmarking, which is rarely carried out, and would delay any political point scoring from a 'successfully' implemented programme. Perhaps more importantly, predicted performance impacts take no account of any behavioural changes after implementing the measure, which may result in actual impact lower than predicted impact. E.g. increased comfort levels encourage more rooms in the house to be occupied, or increased ventilation activities after installing insulation (Mourik & Rotman , 2013). Both Blok4Blok and Kirklees Warmzone were reported to be great successes in terms of energy-saving impact, based on pre-calculated savings due to retrofitting insulation In the latter case, 50% of the potential energy-savings were assumed to have been taken in comfort rather than actual use reduction (Edrich et al, 2011).

Some of the case-studies highlighted the difficulty of instigating a bottom-up approach (consumer behavior) to achieving a top-down aim (energy-savings). If users are immediately asked to work (e.g. collecting data, filling in forms for renovating their homes) before receiving benefits (subsidies, cost savings) this can cause many not to go ahead (Blok4blok, Kirklees).

Technological acceptance = positive impact?

The smart-meter case-studies all collected real data, even though one - Energy Neighbourhoods 2 (EN2) in Austria - didn't actually employ smart meters. Generally a level of energy-saving was reported, except in the trial of 28000 homes under the Italian Time of Use project. The Norwegian project, Demo Steinkjer, has not yet included any real impact data in the evaluation, as the provisional findings deal mainly with technical issues in installing and setting-up functional smart meters in the homes. However the expected savings are based on the assumption that energy-savings will result after installations. This is based on the information and financial incentives provided through the smart meter, despite evidence referred to in previous sections suggesting otherwise.

A critical issue for both user-centred data generation and technological acceptance is the users' capability to access and operate the necessary ICT equipment. This was emphasised by the Portuguese On Demand project in an area of low technological readiness – e.g. internet penetration – of its target public. The project was evaluated by acceptance rates and the automatic load shift changes performed by the installed equipment. However, considering the project attempted to compare social (intrinsic) against extrinsic (financial) incentives (Owens, 2000, Brafman & Brafman, 2008) some qualitative evaluation of behavioural impacts would have added value. However, budget restrictions led to a typical front-loaded policy evaluation, assessing only the extent to which expected outcomes were attained.

The Swedish Clockwise project approached the issue of technological acceptance and adopted a strong visualisation element. Energy feedback was provided in an aesthetically attractive graphic form on an Energy Aware Clock, an example of emotional design (Norman, 2004) The trial demonstrated savings of 10% compared to houses not fitted with the clock, along with behavioural learning as the clock adjusts its data representation to reflect measured behaviour in each household. However the sample size of only 20, and questionable validity of the energy data, cast doubt on the positive evaluation.

Real impact data: qualitative or quantitative?

In the analysis of the cases key distinctions were highlighted between the precise type of impact data collected. While smart meters were able to collect post-intervention energy-use data, few projects collected metered data prior to installing the smart-meter. Though consumption data could be found on bills, prior to the smart meter installation, this data is not disaggregated per activity. Hence behaviour change was only measurable through self-reported change of the users themselves (e.g. via survey forms or interviews). Self-reported behaviour change also differs from actual (observed) behaviour change, because duration and frequency of practices (e.g. running the tumble dryer) are often different to what people think when recounting them (Mourik and Rotman, 2013).

Metered data is also limited in its research value, because it cannot attribute any reduction to a particular trigger, financial incentives, increased awareness or social triggers. Even the efficiency programme Opower, a long-running (7 years), large-scale and embedded in social science theory (Cialdini's Social Norms, Cialdini, 1988) cannot accurately attach reported savings to a specific reason. In fact, though Opower reports an average saving of 2% per household customer, Schultz et al (2007) describe a 'boomerang effect' where social norms cause high efficiency users in comparison with their peers to actually increase energy use. So although energy impact data was metered in all smart-meter case studies, in many it was not possible to evaluate the impact in terms of behaviour change, which, as the aim of the project, represents a lack of real impact data.

Conversely, in the Belgian SME case-study, real impact data was measured in annual carbon-footprint assessments which are built up from the impact of each individual activity, allowing specific behaviour change impacts to be measured.

Measuring behaviour change and its energy impact was certainly carried out in the Austrian EN 2 project, but on a manual basis by highly engaged residents supporting each other's collective and comparative efforts. Competing groups of 5-12 households were led in their energy saving and 'auto-evaluation' by trained Energy Masters, acting in place of the smart meter as human engagement tools. This highly participatory approach was rewarded by substantial coverage on social media, local press, TV and radio. Thus all savings were achieved in a bottom-up approach by engaged participants. It provided empirical evidence in support of the argument that individuals will happily share 'data' if it is entirely their choice of what data and how to present it, even though in this case it was wrapped up in a qualitative form of personal experiences.

The case-studies of Opower and EN2 sit on opposite sides of a debate between decentralized (DIY) and centralized data management, analysis and reporting (e.g. Weiss, Loock et al, 2010). Opower does not openly share specific user data, presenting it to others only in abstract forms. It presents neighbour averages and predicted savings due to a certain efficiency measure based on experiences in comparable households (Mourik & Rotman, 2013). However the process is systematically managed, while on the EN2 project, each participant controls their data, its sharing or not, and the sharing via which medium. Savings by Opower customers range between 1,5 and 3,5%, while on EN2 – admittedly a substantially smaller dataset - the average topped the target 9% up to a best saving of 26%.The latter is an example of the increased impact of the participatory or DIY approach. The benefits to the participants are intrinsic, including social relatedness, new skills (autonomy) and a sense of achievement (competence or mastery) (Baard, Deci, & Ryan, 2003), while the energy savings are merely a positive consequence of this engagement (Batey, Decorme & Bull, 2013).

Finally, the Verdiem case-study of Barcelona City Council managed energy-using equipment (Pc's) according to existing user behaviour. This function mimicked that of a smart meter in learning user behaviour profiles and adjusting equipment "on-time" to precise utilisation profiles. Although the system was only applied to PC's in this case, it can be connected to energy management systems to control lighting and HVAC, or employeed as a system of sensors to rationalise office space use according to specific demand profiles (Batey & Garcia, 2014).

Though this was an individual commercial action rather than a policy programme, by focusing on the interaction between users and equipment that drives energy consumption, rather than trying to connect users to energy use, the software tool collected highly specific and precise real impact data on an individual user basis. By mapping recorded energy consumption to specific user activity, detailed evaluation of behaviour change impacts becomes feasible. Disaggregating data down to the level of each user, the further possibility is created to build user profiles based on packets of disaggregated data from multiple locations. The Verdiem approach to disaggregation, based on device activity monitoring, is suitable for allocating workplace energy use, but less appropriate for domestic use. The home smart meter examples described in this review will provide equipment level data that can potentially be allocated per user, but in a different form, highlighting the need for user profile methodology to incorporate various types of data.

The findings are summarized in Table 2. Impact data refers to energy-use impacts. Measured energy-saving impacts are given in a project specific context, and not directly comparable. In all three cases where the User evaluation is given as 'mixed' this relates to lower than expected adoption rates.

Table 2. Specific findings for the case studies

Programme	Type	Evaluation of real impact?	User-involvement in collecting impact data	User involvement in evaluation	Measured energy-saving impact	User evaluation of programme
Blok4blok	Renovation	N	N	Y	N	Mixed
Warm Up NZ	Renovation	Y	N	Y	+/-	+ve
Demo Steinkjer	Smart meter	N	N/A	N/A	N/A	N/A
Clockwise	Smart meter	Y	Y	Y	10%	+ve
EN2	Smart meter	Y	Y	Y	9%	+ve
On Demand	Smart meter	Y/N	Y	Y	9-10%	Mixed
Kirklees Warmzone	Renovation	N	N	N	N	Mixed
CHARM	Smart meter	Y	Y	Y	UR*	+ve
Opower	Smart meter	Y	N	Y/N	1-3,5%	+ve
Build4Good	SME	Y/N	N	Y	Y	+ve
Verdiem	SME	Y	N**	N	Y	+ve
Time of Use	Smart meter	Y	N	N	N	N/A

* Users were involved by having PC use monitored individually, but they were not contacted directly
** UR = Unquantified Reduction effect

Methodology for Calculating User-Profiles

Based on these initial findings, the methodology for user profiles comprises four key elements:

- Real-time energy consumption disaggregated to an individual user level.
- Flexibility to allow collation of data in different forms
- User management & control of personal data
- Central platform on which to share & compare data.

Disaggregation follows the basic formulae:

If energy-use is measured per user,

$$E_{U1} = EM_{U1t}$$

(where E_{U1} refers to energy per user number 1 per location, EM_{U1t} r refers to specific metered energy use over the period of occupancy). If energy-use is measured only on an aggregated level,

$$E_{U1} = \frac{EM_{Utot} * t_{U1} / t_{tot}}{nt_{U1}}$$

(where EMU_{tot} refers to total measured energy over time period t_{tot}; t_{U1} refers to occupancy time period of user_1; and nt_{U1} refers to the number of occupants over the occupancy period of user_1)

It is accepted that significant potential for inaccuracy exists in the calculation as energy-use and occupancy are not uniform over time. The longer the measuring period, the greater this potential becomes. However, the ongoing rollout of smart metering in the EU (Directive 2012/27/EU) suggests this problem should be reduced over time. The primary aim is to enable users to act and interact on their energy use data and its reporting. At this stage it is assumed that by doing so, users themselves will mobilise to improve the accuracy of their data, particularly if the inaccuracy is a cause of poor recorded performance, under continuous peer-to-peer evaluation, analogous to the Wikipedia approach (Malone, 2004). This assumption requires further testing and investigation of its validity.

Finally, a user daily energy profile is given by,

$$E_{U1}(\text{day}) = E_{U1}(\text{loc}\mathit{1}) + E_{U1}(\text{loc}\mathit{2}) + \ldots + E_{U1}(\text{loc}\mathit{n})$$

(where (locx) refers to each location or activity (e.g. travel) the user is involved with during the day.)

The above is flexible enough to allow even manual input of data, e.g. an annual energy bill, the number of hours in occupancy and the number of other occupants. Based on current state-of-the-art, the user interface is imagined to be a smartphone app or web portal. It is assumed that technological development will enable increasing electronic data collection, even on transport systems through electronic control (private vehicles) and ticketing systems (public) – e.g. London’s Oyster Card. Energy usage of transport could be measured directly or employ reference figures for the given mode and model.

The protocol for exchanging data collected by transport or building systems to the user interface is critical. It needs to recognize that individual usage data, even that collected at system level, is the property of the user, not the system. The exchange should occur while the end-user is still in contact with the system and requires permission to be given by the end-user for data to be collected. However, the legal issues surrounding the control of access described are substantial.

Once the end-user has collected the data, it is entirely their choice whether and how to analyse and present it. Referring back to the Opower example, personal performance data could be similarly summarised, presented and shared via a social platform, allowing peer-to-peer comparison. Alternatively, evidenced by the EN2 case-study, end-users can create their own local community group to exchange ideas through word-of-mouth or other preferred media. This exchange of information is analogous with emerging social business models (e.g. Gansky, 2010, van den Hoff, 2013), where users volunteer personal data across a peer network, enabling others to benefit, while they benefit from others' data.

While this doesn't immediately improve access to real data to analyse policy effectiveness centrally, the users will potentially self-analyse and their communications reflect the success or otherwise of a policy measure. Not only are data collection costs reduced, but also central data analysis costs, replaced by social data analysis. Models for ensuring this process generates scientifically valid analysis are a key area for future research.

The wider advantage and value of the user profile approach is the new analytical perspectives it offers. The user and their precise needs and preferences are now central to the analysis. Energy-use systems (buildings, modes of transport) are measured according to utilization rates across multiple end-user behaviour profiles, creating the ability to assess potential energy-reduction impacts through end-users autonomously changing their usage patterns, rather than – often costly – technical improvements.

Observations on possible routes for further research

Of the case-studies under the IEA behaviour change task listed, Charm, Opower, EN2, Clockwise and On Demand task produced empirical data, in terms of successful user engagement, satisfaction and resulting energy savings, in support of a DIY user-generated data model, decentralised control and peer-to-peer evaluation,. However, even in these successful examples, the barrier to sustaining low energy behaviours, once the project has finished, remains.

The analysis also demonstrated the practical and political limitations to participatory approaches and their evaluation. They are labour-intensive and often neither the political interest or budget allows for a detailed qualitative evaluation. These limitations can be offset by bottom-up evaluations through a participatory, collaborative structure, but getting people involved at the outset in taking the lead on a project is a drain on resources and reliant on individual motivation. Social media can aid this process but more detailed analysis is required to demonstrate how it can be implemented on a wider scale.

Further investigation is required to develop and test a widely applicable methodology for a comparative data tool, based on self-reported behaviours and impacts. The enthusiasm shown in participatory and social norm case-studies suggests the ability to create personal energy profiles across peer systems would increase willingness to actively collect and share data, in turn increasing the availability of real impact data for evaluation. The Verdiem case-study demonstrated the beginnings of a protocol for collecting building energy use disaggregated to user level. A methodology for constructing user profiles across all activities and their locations needs to include flexibility to allow data to be measured and presented in different forms.

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