At Home with Agents: Exploring Attitudes Towards Future Smart Energy Infrastructures[1]

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Abstract

This paper[1] considers how consumers might relate to future smart energy grids. We used animated sketches to convey the nature of a future energy infrastructure based on software agents. Users showed a considerable lack of trust in energy companies raising a dilemma of design. While users might welcome software agents to help in engaging with complex energy infrastructures, they had little faith in those that might provide them. This suggests the need to design agents to enhance trust in these socio-economic settings.

1 Introduction

Energy has emerged as a major societal challenge resulting in a raft of sustainability initiatives across a broad range of countries. Political responses have focused on the issues of energy policy and security seeking to address the uncomfortable question of how to manage with less [MacKay, 2009]. Research endeavours have explored the development of new energy technologies often focusing on smart grids. Responding to the challenge of sustainability has motivated a focus within HCI on providing feedback on consumption to raise awareness and promote behaviour change [DiSalvo and Sengers, 2010].

There is a growing call within HCI to be sensitive to the broader social context [Shove, 2010] and more aware of existing energy research, and to be more connected to emerging energy systems such as smart grids [Pierce and Paulos, 2012]. This paper provides an exploration of UK energy users' attitudes towards future smart energy infrastructures that combine the widespread use of smart meters with embedded autonomous software agents to manage demand on energy networks. Our exploration demonstrates the effectiveness of whiteboard animations to expose the nature of a future infrastructure in such a manner that we can solicit views from users about both the elements that are visible to them, as well as a host of critical behind-the-scenes issues.

Our findings highlight the critical influence of the lack of trust between consumers and energy providers. This is further amplified by the fact that energy infrastructures are as much the product of cultural, political and economic drivers as the technologies that realise them. We suggest that designers need to understand and mitigate for this in how they develop agent-based systems. We propose a focus on trust enhancing approaches to design and suggest a number of design principles for embedded agent systems.

2 Future Energy Systems

Current power grids are largely centralised and distribute power from generators to consumers. *Peak demand,* periods of strong consumer demand, presents a critical problem, and handling them makes power production and distribution inefficient. The mismatch between demand and response is likely to be exacerbated as future grids obtain an increasing proportion of supply from renewable energy which can fluctuate strongly as a result of environmental conditions [cf., MacKay, 2009]. Peak demand and intermittent supply are expensive both economically and ecologically.

Smart grid technologies enable *demand response* (DR) [DECC, 2011], allowing a closer coupling between energy use and generation. Research has shown that small shifts in peak demand could have large effects on savings for consumers [Spees, 2008]. Demand-side management techniques such as *dynamic pricing* seek to reduce peak demand by encouraging *shifting* of demand to off-peak periods through higher prices at peak times. This load shifting offers benefits in the overall efficiency of the grid by optimizing the use of generated energy.

2.1 Agent-Based Energy Grids

Our particular interest focuses on understanding users' views of future smart grid energy infrastructures that exploit machine learning techniques [Scott *et al*., 2011] and embedded autonomous software agents [Ramchurn *et al*., 2012]. These techniques are often suggested as a way to gain insights from energy information collected via metering systems and to exploit this information to act on behalf of the user or the energy provider. The dynamic

[1] The paper on which this extended abstract is based was the recipient of the best paper award at CHI 2013 [Rodden *et al.,* 2013].

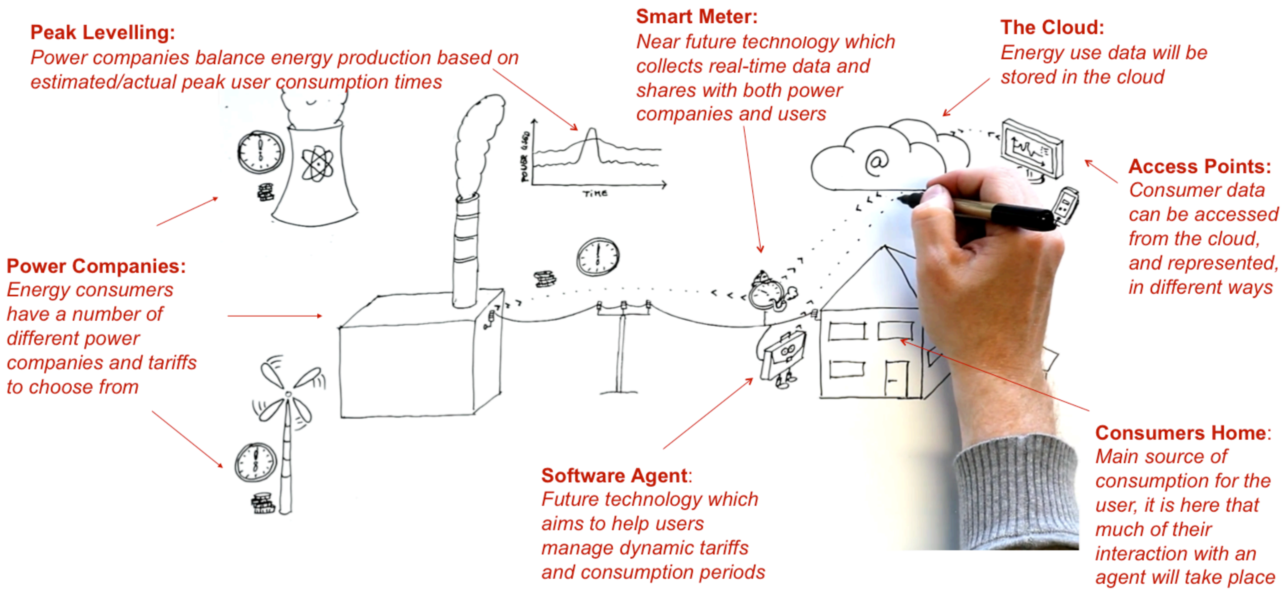

Figure 1: Key behind-the-scenes concepts introduced through the animation.

nature of agent-based infrastructures makes it possible to realise a broad range of services. These might include passive personalised energy guides or much more active interventions including automatic appliance control [Ramchurn *et al*., 2011] and automated home heating based on occupancy [Scott *et al.*, 2011]. Rather than advocate either a passive or active role for agents, our work aims to understand the various arrangements of people and agents. We are interested in the extent to which users might understand and engage with an active infrastructure that is likely to expose complexities that are currently hidden. We were particularly interested in three key research questions surrounding the use of agents in a smart grid.

- How do people respond to the issues of ***autonomy and control*** within the infrastructure and the extent to which they may accept energy agents?
- How much do people ***trust an active infrastructure*** given the need to rely upon it for a crucial utility?
- How do people feel about ***the monitoring of energy use*** and the ways this might impinge on their privacy?

3 Exploring Future Smart Infrastructures

Gathering feedback on the acceptability of a future active infrastructure poses two significant challenges. Firstly, how do you reveal the behind-the-scenes complexity of an infrastructure that is yet to be realised? Secondly, how do you allow users to comment on the broader socio-economic issues shaping the infrastructure?

To convey the infrastructure, we developed an approach based on animating sketches. The substantive part of our engagement with users was centred on an ***animated future infrastructure*** sketch, which conveyed the nature of a future agent-based energy infrastructure. Bill Buxton has described sketching as "the archetypal activity of design" [Buxton, 2007] used in the early stages of ideation and design exploration [Tohidi *et al.*, 2006]. By comparison with more sophisticated techniques such as physical or even video prototyping, sketches are quick to make and inexpensive.

We chose whiteboard animations to animate our sketches of future technologies. Essentially, the animation illustrates a concept or idea through an oral presentation by a narrator while a hand draws a single or multiple drawings that illustrate the spoken words. This allows us to convey the nature of the overall energy systems bringing together the key technologies, the underlying concepts, key stakeholders and the nature of the end-to-end system.

The animation sketch was designed in three parts. *Part 1* explained the current state of the world. *Part 2* described the near future, with forecasts based on current policy, trends and anticipated technologies. *Part 3* went further into the future describing a world where software agents become integrated into home electricity management. Figure 1 shows an overview of the key concepts introduced in the video[2].

4 Focus Group Sessions

Structured focus groups were used to help users move from current experiences of energy infrastructure to commenting on the future energy infrastructure presented in the video. We recruited 17 participants for the focus groups. Ten were enlisted from the general public via a specialised recruitment agency and seven were drawn from one of our previous studies. They were between 25 and 77 years of age and were of mixed socio-economic background. The only

[2] Full video available at http://youtu.be/UePV6Wazz40

requirement we asked was that they regularly dealt with the energy bill of their household. We ran four sessions, each involving between three and five participants. Each session lasted for 60-75 minutes and consisted of three key stages

Stage 1: Grounding in the present - Participants were initially given a brief demonstration of an online service that helps people compare energy providers and their tariffs and switch between providers. This was followed by Part 1 of the video. The intention was to first ground participants' understanding in existing energy technologies and to begin building a picture of current infrastructures. Afterwards, discussion was held focusing on people's perspectives on current energy systems.

Stage 2: Exploring the Near Future - Participants were then introduced to a *grounded agent demonstration* in the form of a web service that would interrogate energy data collected using IHDs and draw upon on-line services to recommend the most appropriate tariff to users. The aim of this service was not in itself to implement a demand side management approach but to demonstrate how software agents might be used in practice and provide a practical example of how agents and data analysis might be manifest. The aim was to help support, and enhance their grasp of the increasingly complex picture being constructed and presented in Part 2 of the video. This was followed by a second discussion focusing on these emerging trends.

Stage 3: Envisioning the Future - Finally, participants were presented with Part 3 of the video, an envisagement of future energy systems focusing on autonomous software agents. Participant groups were shown one of two alternate, fictional views of the future. This was designed to elicit different perceptions of future scenarios during discussion.

5 Findings

Participants views were strongly grounded in the current infrastructure. By and large users expressed little motivation or interest in engaging with the infrastructure, seeing this as a low priority. Users felt that they should be more interested in energy use and appeared to be torn between the desire to "do the right thing" and simply getting on with life. They recognised the need to be more proactive in their energy engagement but are not interested enough to do anything about it. This would appear to identify an ideal role for autonomous software agents. However, the appeal of having software agents absorbing this overhead was balanced with concerns about control, trust and privacy.

5.1 Autonomy and Control

When presented with autonomous agents, users expressed a strong initial reaction about the loss of autonomy and control within their own home.

> *"… **I think if a machine tried to tell me when to put the washing machine on I'd probably break it**… I can see the benefit but I think it might be a step too far."*

This negative reaction was also linked with a more particular concern about the viability of time shifting. Users felt it was that unlikely they had the space to time-shift activities. The concern was amplified by a suspicion about the motivation for smart energy grids. Participants felt that the energy companies sought to maximize profits and that the infrastructure was really about the identification of peak time to charge more.

> "*I do have a problem though with making peak time that expensive."*

This suspicion was amplified by the sense that energy companies had established a complex set of tariffs in order to minimize consumers' ability to exercise choice and change. Users felt that agents could allow them to exercise greater economic autonomy from their energy provider. However, users wished to maintain some involvement in the process such that they exercised bottom line choice. They also wanted to be able to inspect the rationales for the agents' interaction.

Much of these desires reflected unease about the extent to which users would trust the overall energy systems to emerge from these smart grids.

5.2 Trust and Complexity

The users felt very strongly that the energy system as a whole needed to be trustworthy. One issue for the users was a concern about introducing more complexity. This was manifested both in terms of the technology and the complexity of the dynamic energy model being introduced.

Users did not view energy companies as particularly trustworthy and felt that these companies were exploitative. This was often expressed as a desire for agents to be involved in holding these companies to account. The role then for an agent for these users was as an advocate who would look after their interests. However, this hung very much on whom the users perceived the owners of the agent to be and whom the agent was acting for.

> *"Who's going to own the agent? That's going to be us as an individual is it, or a power company?"*

This issue of ownership also applied to the data collected and analysed by agents, with users feeling that it was important it was open and available to them.

5.3 Monitoring and Privacy

Although smart energy systems require considerable monitoring of the energy data, users expressed less concern about the nature of this data. The issue of privacy for users centred much more on how companies might exploit this data. In particular, they were concerned about the ways in which energy companies may seek to make commercial advantage from this either through the use of advertising or selling on of the data.

> *"There are positive stuff that you can do with that data but I suspect the principal goal being for large power companies to make large profit."*

These concerns were also tied up with a practical understanding of consent and the need to be informed about the use of the data by these agents.

6 Discussion

The design of future smart infrastructures needs to take seriously that the endeavour has a socio-political dimension rather than factor off the design of the technology and user interfaces. Many parts of an energy infrastructure result from policy decisions that cannot be designed away or ignored. For example, countries might politically choose not to allow a particular form of energy generation or to only allow its use in particular settings for sound political reasons irrespective of the nature of the technology.

Understanding this broader context is essential in assessing the overall benefit of any intervention. Obviously, these different contexts will play out in a myriad of ways depending on the technical intervention and the nature of the system. It is critical that designers attend to these differences and recognise the particular impacts of a given socio-political context and elaborate designs that are sensitive to these contexts.

6.1 Addressing "The Trust Dilemma"

We suggest that users' views of energy companies presents an intriguing ***dilemma of trust***. Consumers fundamentally don't trust those who provide the infrastructure [Chetty *et al.*, 2007]. To tackle this dilemma we need to recognise the suspicion users have of commercial and government influences in energy. We suggest the need to design future embedded agent systems in a manner that they actively promote and enhance trust. To aid developers of these systems we offer a number of key design guidelines.

Principle 1: Articulate to users the ownership, intent and permitted activities of embedded agents. Participants' trust was often undermined by an uncertainty surrounding whom an embedded agent was acting for and what the permitted actions of this agent might be. Making explicit who owns and controls an embedded agent and the stated aims and limits of the agent is essential. Is an agent acting on behalf of an energy supplier, and are actions limited to monitoring, analysing and reporting behaviour? Is an agent acting on behalf of a user to monitor the activities of the infrastructure and alert them of significant changes? There is an opportunity for the agent to be perceived as a mediator between the energy company and the activities within the home. The challenge is developing the appropriate means of articulating these relationships and the permissible activities of the agents. This articulation may eventually require standardisation and regulation. An approach that is increasingly the norm is financial agreements and contracts.

Principle 2: Promote and support an open infrastructure. An inherent feature of the distrust among users was a feeling of not knowing what energy companies were doing with their data. Closed and proprietary approaches to the design and development of smart grid infrastructures are likely to amplify these concerns. Mirroring calls by other initiatives (e.g., greenbuttondata.org and data.gov), a commitment to open energy data is essential. Users should be empowered by allowing them to apply alternative analysis and understandings of monitored data. In addition, an agent infrastructure needs to allow an easy interchange of agents. Thus, if consumers do not trust an agent's actions they should be able to easily replace this with an alternative.

Principle 3: Design accountability of action into the agent. Participants' lack of trust was also manifest in a concern that software agents in the infrastructure would do things that a user would not understand. This suggests that autonomous agents need to be designed from the outset to provide users with understandable accounts of their actions. They should be able to provide information about what triggered a particular action or drove a given strategy. This is particularly challenging given that many of these agent-based systems exploit machine learning techniques where inference is driven by a balance of probabilities.

Principle 4: Provide an on-going mechanism of consent and withdrawal. Participants demonstrated little trust in how energy companies would handle information. Current models of consent with their focus on a single moment of approval do not align with the continual monitoring of users. The process is unwieldy and users seldom feel that they have sufficient information to make a genuinely informed choice. This suggests the need to provide a strong dialog-based approach to consent where it is an on-going process and users will maintain the right to withdraw.

The provision of these principles as a feature of future systems will require an alignment between technologies and policies. Conseqently technology developers will need to engage in a dialog with the various agencies involved in setting policies to ensure that they adopt a trusted position.

7 Conclusions

We have presented our experiences in soliciting views about a future smart energy infrastructure using animated sketches. Participants' engagement with future energy infrastructure was fundamentally socio-technical. It is critical that we develop approaches to the design of infrastructures that reflect these. Moreover, this is a domain that is fundamentally political in nature and design needs to understand and reflect these critical drivers.

Studying and understanding an infrastructure also presents significant challenges in conveying the complexity and nature of something that seldom becomes visible [Star, 1999]. An issue compounded when the infrastructure is not yet built. Our sketching approach allowed us to explore these issues by articulating the broad socio-technical nature of these future infrastructures and conveying their core concepts to our participants. As well as promoting a reaction to the technical infrastructure, our animation approach also provided the space of expression to allow users to articulate broader concerns centered on a lack of trust of the commercial entities involved in energy provision. These concerns critically frame the infrastructure and need to be systematically addressed by designers.

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