2.2.2. Achieving change with customers

Results of semi-structured Interviews with project engineers and housing professionals involved in housing development

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September 2015

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1. Introduction

In today's societies where more and more electricity is being consumed every day, electrical overloads are an imminent problem. In the 'last-mile' power delivery, the issue is *not* thermal limits, *but* voltage limits. One possible solution devised by Top and Tail project engineers to this problem is a relaxation of voltage regulation. Many electronic products can operate across a wide range, such as from 90V to 250V; and physical remedies such as digging up the roads and laying new cables, which would be expensive and disruptive, could be avoided. From an engineering point of view, this is, *technically*, a feasible solution.

Yet, in answering whether the relaxation of voltage definitions is going to 'work' in our societies as a solution to electricity overloads (and increasing carbon emissions), one has to consider users' reactions to it. For example, does it matter to users if voltage is lower than present? Do users have any comprehension of electrical overloads and voltage regulation at all? Research conducted by another team of the Top and Tail project suggests that consumers have little knowledge about voltage/power quality, although they are aware of the nominal voltage and risks associated with voltage extremes. Our work package, therefore, sought to examine how commercial users, who would deal with energy infrastructures in their work (as opposed to the general public), understand the relaxation of voltage definitions. We investigated how professional actors in the housing development sector perceived such a new energy service, in relation to their work routines and practices of designing and developing housing estates. How do these users approach electrical loads as part of their daily work? What impacts would engineers' solutions have on their current everyday practices?

Our research aimed:

1) To identify approaches to voltage relaxation developed by the Top and Tail project engineers, and related issues;

2) To explore how users comprehend voltage relaxation in relation to their existing working practices, by presenting those identified approaches and issues to housing professionals.

2. Methodology

Our study involved two strands of research enquiry. The first strand of the study comprised semi-structured interviews with ten project engineers involved in the innovations in the last mile. Our objective here was to identify approaches to the relaxation of voltage and issues related to voltage quality and regulation. We then used these identified approaches and issues to inform our interview questions for housing professionals.

The second strand of the study was ten semi-structured interviews with housing professionals. Interviewees came from a diverse range of backgrounds: an architect, electrical and mechanical engineers, housing development managers, a construction manager, employer's contractors, a chartered building surveyor, and a private and social housing developer (Table 1). All were involved in the development of large-scale housing schemes that ranged from 200-1000 housing units. A detailed information sheet was provided to each participant before the interview explaining the aims of the project, that the interview was voluntary and anonymous, and that they could withdraw from the project at any time.

All interviews took between 30 and 60 minutes, and were recorded and fully transcribed. The interviews were coded openly and analysed thematically to capture emerging issues (Thomas, 2006). These themes form the basis of our analysis presented in this report.

Table 1. Table of Housing Professional Interviewees

Job Title	Job Role
Head of Construction Project Management, Social Housing Association	Leads a construction and project management team.
Surveyor and Employer's Agent	Administrator of building contracts between clients and contractors for new developments.
Director of Architect Practice	Architect of social and private development schemes.
Mechanical Engineer	Manages the integration of sustainable technologies (e.g. CHP) into new building developments.
Private Developer	Commissions design of new building developments, with a reputation for achieving high levels of environmentally sustainable housing design.

Electrical Engineer	Calculates electrical loads for new developments.
Managing Director – Employer's Agent	Administrator of building contracts between clients and contractors for new developments.
Development and Performance Manager, Social Housing Association	Provides construction specifications for new developments.
Council Programme Manager	Manages the delivery of new build social housing programmes for a local council
Director of Architect Practice	Architect of social and private development schemes.

Photos 1 and 2. A large-scale housing development in south London

3. Findings

3.1. Project Engineer Interviews

We identified, from the interviews with project engineers, four key themes as possible approaches to voltage relaxation and regulation and related issues:

1) The use of Direct Current (DC) instead of Alternating Current (AC): Engineers are examining the efficiency of point of use voltage regulation – i.e. the use of DC in the electrical connection into people's homes. The uptake of electrical vehicles and heat pumps, and equipment such as mobile phones and laptops, will increase the electricity loads, and there will be less energy wasted if they are run directly on DC.

2) The capacity of existing infrastructure (e.g. cables) on how electrical loads are approached: Engineers are exploring the capacity of cables to handle different voltages: the stress would be greater with DC than AC. When building a new estate cables are laid with a certain electrical load in mind. This assumes an understanding about how electricity is both consumed and provided.

3) Power quality: Issues of power quality emerge from the discussions of voltage relaxation, as power quality can directly affect users' experience of electricity provision. Engineers are examining power quality in the distribution system before it gets to the 'end user': for instance, developing soft-open points in the distribution system to correct the power flow between the transformer and the consumer premises. This aims to 'clean up' the harmonics in the power system caused by an increase in the use of power electronics. This also tries to regulate the voltage, which drops, as the electrical load gets bigger.

4) Future electrical demand: Engineers can create an 'electrical demand profile' by examining future electrical demand, including the use of new technologies such as Photovoltaics (PVs), and Combined Heat and Power (CHP). They hope to use demand profiles to get a better understanding of how a voltage network may operate in the future.

Using these themes we devised questions for the housing professionals, so as to explore and understand how they 'perceived' the approaches to and issues around voltage relaxation in terms of their existing working practices. Table 2 presents: (a) what we found from the interviews with engineers and (b) questions for housing professionals, translated from those findings.

Table 2. Top and Tail Engineer Interviews: (a) A summary of approaches to voltage relaxation and related issues, and (b) Questions for housing professionals

(a) Approaches to voltage relaxation and related issues	**(b) Questions for housing professionals**
Looking at the efficiency of point of use voltage regulation – the use of DC in the last section of the electrical connection into people's homes. This is important, as there will be changes to the electricity loads generated by the take up of electrical vehicles and equipment such as laptops that use DC.	1. What are their existing approaches to voltage regulation in housing development practices? 2. How do they consider future changes in electricity loads as part of their housing development? 3. How have they, or intend to, adapt their building and design practices to manage the challenges posed by voltage supply and regulation? 4. How would changing to DC affect their work/practices?
Issues of power quality are closely tied to voltage regulation, and directly affect consumers' experience of electricity provision. Looking at demand modelling of electricity in domestic contexts (i.e. modelling use of appliances to determine peak times for electricity use). There are two options for greater voltage regulation: 1. Relax the voltage so both high and low voltages are allowed. This may require replacement of equipment in the home. 2. Change from AC to DC current – this would create a new standard for the housing association, i.e. their design principles may change.	5. How would (a) relaxing voltage, and (b) changing from AC to DC, affect the design of existing housing developments?
Examining future electrical demand and heating (i.e. use of new technologies such as PVs and CHP) to create an 'electrical demand profile'. This will feed into an understanding of how a voltage network may operate in the future.	6. How have they considered electrical demand and the use of renewable technologies as part of their building and design practices?
One package examines the changing ways in which voltage is distributed through a building	7. How would DC impact on housing design

using DC. Specifically, looking at voltage regulation close to the appliance. The second package is looking at what happens if one relaxes the voltage in the last mile to generate more power and current. Interested in the effects on electrical equipment by allowing the voltage to wander as the cable gets close to its thermal limits.	(e.g. choice and installation of appliances)?
Looking at voltage regulation in the last mile with anticipated additional electrical loads. Intervention at sub-station level to introduce better control.	
Looking at the capacity of cables to handle different voltages – stress would be greater with a DC than an AC. When building a new estate one lays cables with a certain electrical load in mind. This assumes an understanding about how electricity is both consumed and also provided.	8. How are electrical loads considered when cables are installed to supply electricity to a housing estate? 9. If pre-existing cables are used, how does their capacity effect how they build and design housing? Would this change using DC, and if so, how? 10. With these questions in mind, how do you consider and manage electrical loads?
Looking at power quality in the distribution system before it gets to the ‘end-user’. Developing soft-open points in the distribution system to correct the power flow between the transformer and the consumer premises. This should clean up the harmonics in the power system caused by an increase in the use of power electronics. This also tries to regulate the voltage, which drops, as the electricity load gets bigger.	Should not impact on the housing association – should be invisible to the ‘end-user’. 11. Do you experience power quality issues, and if so, how are these managed? 12. What power quality issues do you anticipate having in the future, and how do envisage dealing with these? 13. How are power quality issues affected by existing infrastructures and providers (e.g. utility suppliers/network operators)?
Looking at effects of voltage deregulation on typical consumer loads.	
Working on a multi-level converter and looking at conversion form DC to AC to give good output power quality with a low voltage DC network.	See question 7.
Concentrating on keeping equipment and system safe with possibility of high current. With DC voltage you can transfer more power and have higher voltage. Buildings would need to have a separate DC unit with DC protection.	14. How would the introduction of a separate DC unit affect existing housing development practices?

3.2 Findings from housing professional interviews

Most interviewees did not comprehend the notions of voltage relaxation and regulation. In the findings outlined below, we present the *interviewees' understandings* of electricity overloads and voltage relaxation in relation to their daily working practices, according to the four themes we identified. Discussion includes issues not directly related to voltage relaxation, for they emerged as part of the user responses to our questions.

(1) The use of DC in place of AC: Engineers are examining the efficiency of point of use voltage regulation by using of DC in the electrical connection into people's homes.

A large proportion of the interviewees were not able to comment on the issues around DC and AC, as these do not feature in their work or expertise. Those who were able to comment showed concerns over cost, space and safety:

a) Using DC would require additional space within the housing development, adding a premium to already tight profit margins for developers.

One interviewee thought that the use of DC would be beneficial in, for instance, data centres, where there is a large cooling load because of the air-conditioning required to keep the vast number of computers cool. Using DC in this context would be useful because the computers already run using DC, therefore reducing the cooling load. In the domestic context, however, the issue with DC is the distribution losses. The interviewee anticipated that existing infrastructure would have to be upgraded because DC cannot travel the distances that AC can without a voltage drop. Furthermore, additional rooms would be needed to be built to house the AC-DC transformers:

> *"From an AC point of view… say if you've got a suburban greenfield housing estate, in AC your house tends to have to be 300 to 500 metres from the nearest high voltage transformer. Then anything beyond that you've got… voltage problems because you want 220 at least when you have a house and the transformer kicks out at 220/230. By the time it gets to your house it's 220. Any further then you start to get that to 210 or 200 and your stuff wouldn't work. In DC, because your voltage is much less, DC could be 24 or 12 volts,*

which is 10 per cent of that, so you'd have to be 30 to 50 metres away from every transformer. So all of a sudden you need… 5 metre by 5 metre rooms everywhere to house additional DC transformers" (Electrical Engineer).

b) Safety concerns over the use of DC in place of AC.

Safety concerns about the use of Direct Current are prevalent amongst interviewees:

"I'd say there are obvious dangers with the use of DC rather than AC current. Alternating current is a lot safer than direct current because if you were to come into contract you are more likely to be thrown away from the current" (Mechanical Engineer).

c) Developers do not consider the issues surrounding the use of AC and DC because of their focus on reducing carbon emissions.

For many of our interviewees, the issue of DC and AC was seen as irrelevant to their priorities and work of developing housing estates and infrastructures. Instead, interviewees placed attention on reducing carbon emissions and thus their 'carbon footprint', which is emphasised in the planning requirements devised by local planning authorities for gaining building permission:

"They [Developers] are completely carbon focused. They don't consider the difference between AC and DC… There is new research into delivering direct current … I think traditionally it couldn't be delivered well over long distances… and now they've come up with a new technology that can deliver DC over long distances… So when you have PV on the roof we'll end up with a magic box which converts it from DC to AC and then back to the grid. But clients [developers] wouldn't look at that and consider that… they don't think about the advantages of that… There has been a big change to reduce electrical loads, so we have been using a lot of LEDs in communal areas in flats… so they are thinking about reducing the use of electricity, but again, it's mainly drawn out of their reducing their carbon footprint and that's where that kind of mentality comes from" (Chartered Building Surveyor).

Commentary:
The interviewees' perceptions about the use of DC in the residential sector are rather negative, as it would require additional work and costs for them. They also have a concern over safety in using DC. Developers want to focus on, and deal with, reducing carbon emissions and electrical demand, rather than provide for an increase in electrical loads.

(2) The capacity of existing infrastructure (e.g. cables) on how electrical loads are approached: Engineers are exploring the capacity of cables to handle different voltages (e.g. stress tolerance).

Cost is again the issue for our housing professionals:

a) Upgrading existing infrastructure is a negotiation between the network provider and developer over cost.

A majority of interviewees described the effect of existing infrastructure on their working practices as an issue of cost. For example:

> *"They [the cables] have a certain capacity that's already in the ground [and]… you know that the level of capacity required in that neighbourhood is going to be much higher. And it is largely controlled through the local substation and delivery to the substation… And if that supply to the substation is inadequate and they need to upgrade it, it comes at a hell of a cost… A payment will be made to the energy company to provide that facility. It's just about getting your cheque book out… You know, either you've got to pay less for the land… or you've got to build a few more flats or houses on that land to pay for it… So you know, it's just a simple financial evaluation really" (Head of Construction for Projects and Management, Social Housing Association).*

Commentary:
Although this theme is about exploring the potential of cables to handle different voltages, the interviewees interpret the improvement of existing infrastructures to handle larger electrical loads as a concern with 'how much it might cost'.

(3) Power quality: Engineers are examining power quality in the distribution system before it gets to the end user, as relaxing voltage could affect power quality.

Power quality is not a concept which the housing professionals are familiar with or concerned about:

a) In domestic settings one does not need quality power.

Many interviewees did not understand what the term 'power quality' referred to, because it was seen as irrelevant to their routine working practices of housing development and design. Interviewees who did make a comment said that in domestic settings they had not experienced power quality issues because the power required does not need to be of a high standard:

> *"I don't think that electrical demands from residential housing is [are] always that sensitive, so obviously if you are working in a commercial application then there is often large machinery… and stuff like that which has different kinds of loads and requirements and there's just a larger variance of issues surrounding voltage supply and voltage… In a residential application there is not a lot… There is kind of a view that residential use is reasonably conservative with a small 'c'. It's kind of 240 volt… It's kind of low brow, so it's not really an issue that comes to the surface" (Chartered Building Surveyor).*

Similarly:

> *"We haven't really ever experienced quality issues. In a domestic setting a lot of our equipment we use is quite robust, so it doesn't need fine, good quality power… The loads are much smaller; we don't have lots of computers, lots of motors… The things we use at home… they don't need such good quality power" (Electrical Engineer).*

b) With the improvement to building regulations, a future increase in electrical loads, and power quality, are not seen as an issue.

Interviewees' focus is primarily on the reduction of carbon emissions, as stressed by local authorities' planning requirement for new builds. Improvements to building regulations are seen as the main driver to achieve this:

"I would hope that we are moving towards a scenario that's decreasing [electrical loads] with building regulations changing all the time. So I don't anticipate that [power quality issues] being an issue. I doubt the networks are either" (Electrical Engineer).

Commentary:
Power quality is an unfamiliar topic for the interviewees, except for the electrical engineer, and they found it difficult to respond to and comment on our questions. They work to comply with building regulations. For most, this is where their thinking about electrical provision and demand ends, as they have had limited experience of bad power supply issues in developing residential housing.

(4) Future electrical loads: Engineers can create an 'electrical demand profile' by examining future electrical demand (including the use of new technologies such as PVs and CHP) to get a better understanding of how a voltage network may operate in the future.

The issue of future electrical loads generated diverse responses as to how the interviewees perceive and understand it. It is, in general, regarded as irrelevant to their work:

a) Electrical loads in relation to renewable technologies are considered in new housing developments, but use of energy-saving construction materials and techniques are more popular.

Our interviewees described how, when developing housing schemes, they consider electrical loads in terms of the integration of renewable technologies, such as PVs, into the buildings:

"You end up with complicated M & E [Mechanical and Engineering] systems like combined heat and power, plant rooms, photovoltaics, air source heat pumps, you know, you name it they've [clients] have got some of it." (Chartered Surveyor)

Local authority planning requires a high level of renewable energy from these technologies. Yet, there are a number of problems identified with the installation and use of these technologies and their ability to generate substantial and useful electrical loads. For instance, in large housing blocks, PV cannot provide electricity to every home because of the high costs required to build the necessary infrastructure. Often, PV is used to generate enough electricity for ‘landlord loads’ that serve the costs of running communal lighting and lifts. Also, there does not exist the necessary network infrastructure to export large electrical loads back to the grid, nor the export tariffs that make it financially beneficial for the developers. There are other difficulties faced by developers in installing energy-generating technologies: for example, developers cannot supply residents directly with electricity because of the need for third party competition in the market. Finally, renewable technologies such as CHP and PV are perceived as unreliable and the network providers have concerns about safety issues:

> *“We have to inform the network that we’re generating power on-site… they make us go through a few safety precautions so that if there is a power cut those energy-generating devices also shut down as well… You can’t ever go off grid and solely supply your site… because in the event of a network fault they want all our energy-generating devices to turn off” (Electrical Engineer).*

Because of these difficulties, the integration of sustainable technologies to specifically manage electrical loads is not a priority for developers when designing a new housing development. Instead, developers turn to construction methods such as ‘Fabric First’ approaches, which focus on the construction materials to offer good thermal insulation standards and air tightness, which aim to save electricity:

> *“We would go along with the building regulations… largely though thermal insulation standards. They don’t state how many kilowatts or the energy that you would use, but it’s controlled through the thermal value of the building… One would start with the ‘fabric first’ approach, so using the fabric of the building… to provide the easiest route to meeting those standards” (Head of Construction for Projects and Management, Social Housing Association).*

b) The maximum load anticipated is not calculated, but future electrical capacity is already ‘built into’ existing infrastructure.

Calculating electrical loads for new developments involves obtaining data from the network provider about electrical demand, which then enables electrical engineers to determine the average and maximum electrical loads they will be requiring. This calculation often does not reflect the maximum load anticipated, as electrical demand rarely reaches the maximum (due to the effect of building regulations that promotes, for example, low energy lighting).

> *"The networks that run and manage the infrastructure… they've got quite a lot of data, and they can feed in quite a lot of information on how much electrical loads… they give an indication on the average demand and the maximum demand of a property… So when we size, say a block of flats, when we give the load we say 1.8 kilowatts per flat times 100, which is 180 kilowatts… but everyone has the ability to technically draw 60 kilowatts but we know it never happens. So, we don't design to the maximum because otherwise you'd have a power station on every corner… The 1.8, it rarely gets used… [It] is a really healthy allowance and people aren't using it as they did. Where building regulations have improved over time, low-energy lighting's being introduced… peoples' homes have [changed]" (Electrical Engineer).*

Instead, some future capacity is built into the equipment that they use, such as fuses and cables:

> *"Our infrastructure… it's a few sized steps up… So, if you have a load of say 800 kilowatts, you have to put in a 1000-kilowatt transformer because you can't buy a[n] 800 [transformer]. So that 20% infrastructure is installed… and it's the same with fuses… so we determine our load and go the next size up. The way fuses work and the way cables work is we always go one size up. So, sometimes that future capacity is built in, is inherent to the design of the equipment that's available on the market… Even though we declare to the network that we need say 200 kilowatts… but they'll have to put in the infrastructure above that to serve us anyway" (Electrical Engineer).*

c) Future electrical loads are not a priority.

Most of our interviewees said that considering future electrical loads is not a priority for them. Their main priority was building to current building regulations, and consequently obtaining the necessary planning permission to construct their developments:

> *"Our general policy would be to build to building regulation standards… We wouldn't bother with that [future electrical loads] really. It would largely be the building regulations and local*

authority requirements to get planning permission [that is considered]" (Head of Construction for Projects and Management, Social Housing Association).

d) Future electrical loads are primarily considered in terms of planning standards and requirements.

Indeed, developers are concerned with reaching the environmental planning standards imposed by local authorities. Previously, this would have been the Code for Sustainable Homes, which is currently being incorporated into, and replaced by, building regulations. 'Code 4' is a standard that incorporates certain levels of water and energy efficiency, waste, pollution, and use of materials in building construction, for instance:

"In my experience in the residential sector, I think if they [developers] are satisfied the construction of a [housing] unit to be a Code 4 unit, that's kind of like a line in the sand then. Once that building goes over to people to live in they kind of say 'Well, that's a sustainable building. That person is living in it and that's' it'. It's as simple as that for them" (Chartered Building Surveyor).

e) Housing professionals cannot account for the pace of emerging technologies and therefore cannot consider future electrical loads.

In considering the design of large-scale housing estates, 'future proofing' for future electrical loads is difficult due to the difficulties faced in providing the infrastructure for emerging technologies and ways of delivering and storing electricity:

"In Ealing we allowed for a number of electric car charging points… but when we gained planning permission… we didn't know what the demand would be and to provide that. So, there was kind of runs and ductwork installed to allow that provision to be provided as and when that sort of technology became more prevalent… It seems to change constantly about the role of PVs for instance – how to move away from feed-in tariffs and just build big battery stores that you charge and keep your own electricity… I think it's really hard with a project of this scale, you know, it will be 15 years of construction before the first spade goes in the ground, before the final bits are finished. How do you kind of future proof something and allow for all of these changing and emerging technologies to be incorporated?" (Architect).

Commentary:

For the housing professionals, understanding and calculating *future* electrical loads into housing design is not part of their work. They think that future loads are unpredictable because of rapidly developing new technologies; they are more concerned about complying with current building regulations.

4. Conclusion: Discussion and Implications

In this study we firstly identified approaches to voltage relaxation and related issues, and then presented them to housing professionals so as to explore how these professional actors comprehended and perceived electricity overloads and voltage relaxation in relation to their existing working practices.

4.1. Discussion

We found that only a select few of the housing professionals interviewed felt confident to comment on the issues and approaches identified by the project engineers. Predominantly, these were professional actors who had a background in either mechanical or electrical engineering. Presenting the approaches and issues identified by engineers thus demanded of the interviewees a similar expertise, i.e. knowledge about the highly technical issues of voltage relaxation and quality, to be able to respond. Those housing professionals, however, have diverse expertise and jurisdiction and are instrumental to the design and development of energy infrastructures. The conclusions below, therefore, reflect both the limitations outlined above and the respondents' diverse understandings of electrical loads and responses to the themes identified in the project engineer interviews.

Those who did feel able to comment directly on voltage relaxation, regulation and quality , stated that in domestic settings one does not need quality power and that quality issues were therefore irrelevant to their daily concerns. Similarly, they envisaged that using DC would require additional space within the housing development. This was not welcomed by housing developers, as it would create further costs for them. There also exist concerns over the safety of DC. Furthermore, most of the developers we spoke to, and those working for developers, do not acknowledge the issues related to using DC, because for them a central focus is on the reduction of carbon emissions, rather than electrical overloads.

The emphasis on reducing carbon emissions is reflected in local authority planning criteria for housing development. Indeed, current building regulations, which inform the environmental standards for housing development, provide the benchmark from which most of our interviewees think about issues of electrical loads in general. For example, future electrical loads and power quality are not seen as an issue for one interviewee, as he has already seen improvements in a reduction in electrical loads with the requirement for LED lighting in new builds. Furthermore, our interviewees commented that they tend not to consider the future electrical demand and loads, as their focus is on a present concern of developing for the minimum cost. For social housing associations, however, there tends to be a greater engagement for future energy use and demand, primarily because they will be involved in the future maintenance and management of the buildings as landlords. Nevertheless, with the current economic climate resulting in severe cuts to their funding for installing, for instance, sustainable technologies, both private and social housing developers tend to adopt the approach of doing the minimum required by building regulations to reduce carbon emissions and achieve planning permissions. There exists, therefore, a limited engagement with concerns for the future electricity (over)loads and related issues, such as voltage relaxation.

Despite renewable technologies being incorporated into housing developments, developers treat these technologies with caution because of the poor levels of existing infrastructure (both physical and financial) provided by the networks, which do not support the export of large quantities of electricity. As a result, construction methods that aid insulation and air tightness are more popular than more complex approaches such as AC-DC conversion and voltage relaxation.

4.2. Implications

The biggest issue here is lack of familiarity with, and lack of importance placed on, the subject among potential commercial users. Indeed, many are unaware of related issues to relaxing voltage. Whether or not their understanding of AC-DC conversion, the tolerance of existing cables, or power quality is correct, our research indicates that those potential users do not regard electrical overloads and voltage relaxation as relevant to them and that they are often not interested in new technological developments (e.g. DC can now be delivered over long distance) and possibilities (e.g. use of existing cables for DC). The question for us is, then, how to communicate with potential adopters of the last-mile innovations a need to cope with the rapidly growing electrical consumption and the potential solutions.

A few implications can be drawn from the research findings:

First, engineers in the last-mile power delivery need to engage with potential users and communicate the needs and advantages of the solutions they are offering. Because innovations in power delivery cannot usually provide visible benefits for the user, information about possible electrical overloads and how to tackle such a problem should be made widely available. Lack of knowledge is a barrier to adoption and diffusion (Bhate and Lawler, 1997; Rogers, 2003; Salmela and Varho, 2006), and one approach is to direct relevant information to potential users (Ozaki, 2011). Public seminars, consultations, and articles in trade magazines, could provide users with familiarity and awareness regarding what engineers do, why they do it, how they do it, and what are the envisaged benefits for both the adopters of their proposed solutions and society in general (and the costs). This approach can increase understanding among users. At present, the conversion to DC, for example, is *perceived* as an extra work and additional cost for developers. To judge whether potential engineering solutions are better than the current system for users, providing information about the benefits of engineering innovations is essential. Voltage relaxation is still at a very early stage of the development, and therefore it needs promoting more strongly.

The second is the role of the government and local authorities. As our interviewees are anxious to comply with building regulations and requirements of local planning agencies, policy makers could incorporate the element regarding future electrical loads into building regulations. If voltage relaxation is *the* way to cope with electrical overloads, the government and local authorities need to create a strong message to make users aware of issues of future electrical loads and convince them that energy efficiency measures alone might not be enough to cope with increasing electrical consumption in the future.

Lastly, there is also a need for engineers who wish to transform current electricity systems to consider potential users' practices and contexts. Such consideration is necessary in order to better understand how issues concerning electrical provision and demand are approached by those users. This way, engineering solutions to highly technical issues, or the 'last-mile' innovations, could incorporate a good understanding of varied knowledge and working practices of potential users (Shaw and Ozaki, 2013 and 2015); and consequently, the solutions and innovations will not simply be based on technological knowledge relating to solely engineering expertise, but also reflecting user practices, making the solutions more acceptable to their potential adopters.

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