How infrastructures and consumers interact: insights from the interface

Catherine Grandclément
EDF R&D – GRETS
1 avenue du Général de Gaulle
92141 Clamart Cedex
France

Magali Pierre
EDF R&D – GRETS
1 avenue du Général de Gaulle
92141 Clamart Cedex
France

Elizabeth Shove
Sociology Department
Room B09, Bowland North
Lancaster University
Lancaster, LA1 4YT
UK

Keywords

practices, sociology, smart grid, electric vehicles, consumer construction, infrastructures of consumption, markets

Abstract

Despite the fact that the world of the consumer (and of appliances) and the world of engineers/utilities (and of infrastructures) are constituted as separate fields of activity, conceptualised, organised and 'governed' along really very different lines, infrastructures and systems of provision are closely tied to patterns of consumption and demand. Not surprisingly, the points at which these systems, infrastructures on one hand, appliances, on the other hand, come together are fraught with tension. In this paper we explore the infrastructure-consumer interface and the social-material-political configuration of a selection of such junctions. As this exercise shows, material interfaces whether between electric vehicles and the grid, or between meters, display devices and other appliances link, and in a sense also separate, institutional and economic domains, markets, philosophies and systems of provision. In showing how these connections are negotiated and how roles and responsibility are defined and allocated between the consumer, the market and the public interest, we show that arrangements at the interface are contingent and that present solutions 'black box' and provisionally stabilise what are at heart essentially contested relations. Whatever form they take, these technological and institutional responses embody and reproduce a form of energy politics.

Introduction

In most discussions of energy, consumers and infrastructures belong in very different worlds.[1] Infrastructures are the province of engineers and specialists, their design and operation requires complex skills and knowledge and they typically depend on massive investment. They are certainly not part of the world of consumer goods, nor are they topics of individual consumer desire. From the consumers' point of view, infrastructures are routinely invisible meaning that we rely on them without noticing or even sometimes knowing that they are there.

More abstractly, network infrastructures like electricity and gas grids, telecommunications and water networks, produce what are thought of as 'public goods'. According to Graham and Marvin, public goods have a number of distinguishing features. For example, the fact that one consumer uses a phone system or an electricity network doesn't deprive another user of the chance to use that system as well; second, such systems cannot be appropriated for the sole use of a single consumer; third, and in some cases, use is in effect obligatory – to participate in contemporary society people need connections to these systems (Graham and Marvin, 2001: 80). In other words in terms of ownership and regulation, appliances (which consumers choose) and infrastructures (which consumers do not choose) inhabit contrasting regimes – private vs. collective, visible vs. invisible, changing vs. relatively obdurate.

These separate realms are, of course, connected. In daily life, private consumers interact with electricity infrastructures and with the world of public goods each time they plug an appliance in to the grid.[2] In using and selecting appliances, they connect to, and in a sense sustain an infrastructure which exists beyond them, which they did not choose but on which they depend. The extent of this dependence is dramatically

revealed in case of blackout, and more subtly, when people adjust methods and habits of cooking, and perhaps heating, when moving from a home that has a gas supply to one which relies on electricity.

By the same token, infrastructures depend on consumer actions which are, in aggregate, crucial for matters of design, and for the economics and practicalities of operating and managing grids and networks. As others have explained, the early years of building an infrastructure of electric power went hand in hand with efforts to generate demand through marketing and selling appliances which used, and thus created the need for electricity. Relevant examples include the electrification of light or of cooking or heating (Hughes, 1983; Platt, 1991; Rose, 1995; Akrich and Méadel, 1999). Over time, the work involved in constructing markets for infrastructure-related appliances and for electricity itself has receded from view. As appliances like washing machines and fridge-freezers become normal, and as they become embedded in daily life (Graham and Marvin, 2001, Shove, 2003, Shove et. al 2012), so the close connection between consumers, practices and infrastructural provision fades into the background. In other words, infrastructures, markets and people and their practices are often seen as three different and separate dimensions that can be conceived, organised and managed separately, according to different principles (technical, economic, social).

There are, however, occasions on which it is difficult to make a neat division between infrastructures of energy provision, markets and patterns of use. In these instances, the tangled relation between infrastructures, markets and practices comes back into view. For example, although consumers, and the appliances and devices they use, are situated in a world of private action defined by discourses of freedom of choice and of individual aspiration/lifestyle given expression in the market, people are sometimes called upon to act as 'citizen-consumers'. This means that they are invited to act in the public interest by consuming responsibly, or by making 'green' their brand of choice. This call to economic agents to act according to interests other than one's own is in direct contradiction with a founding tenet of liberalism: that the pursuit of private ambitions will result in public virtue. Adam Smith is undoubtedly the most famous proponent of such an idea. His notion of the "invisible hand" of the market. Implies that there is no need to intervene in-between private and public interests other than in letting the market function. And yet, moral and civic calls are repeatedly addressed to market agents such as the consumer.

On other occasions, infrastructure providers seek to manage demand so as to optimise the functioning of the system as a whole. Attempts to persuade individuals to change their daily rhythms and therefore use power at different times of day and night represent attempts to structure a multitude of 'individual' choices to suit the 'needs' of the infrastructures on which these consumers invisibly depend.[3] Other efforts to discipline the consumer involve normative appeals to notions of excess and waste – exemplified by the notion that certain actions, for instance installing and operating air conditioning units in the summer, are uncalled for, or unjustified.

As these few examples demonstrate, infrastructures and systems of provision are closely tied to patterns of consumption and demand. Not surprisingly, the points at which these systems come together are fraught with tension. In this paper we explore the infrastructure-consumer interface and the social-material-political configuration of a selection of such junctions. As this exercise shows, material interfaces whether between electric vehicles and the grid, or between meters, display devices and other appliances link, and in a sense also separate, institutional and economic domains, markets, philosophies and systems of provision. In showing how these connections are negotiated and how roles and responsibility are defined and allocated between the consumer, the market and the public interest, we show that arrangements at the interface are contingent and that present solutions 'black box' and provisionally stabilise what are at heart essentially contested relations. Whatever form they take, these technological and institutional responses embody and reproduce a form of energy politics. This is not the 'big' politics of supply, nor is it the politics of national and international agreements. It is, nonetheless, a politics of public/state and private/market responsibility that becomes inscribed in the hardware involved (the appliances, the infrastructures)[4] and in related systems of provision.

In drawing attention to these features we notice that interfaces are not set in stone: they could be other than they are today. For example, the boundary between the role of the consumer and that of the provider is not in some sense natural: such distinctions are negotiated and repeatedly reconfigured. For example, the range of actions that 'the consumer' is supposed to take can be very different depending on the features of the interface between them and the infrastructure. In addition, "Consumers" are sometimes situated not as customers, but as beneficiaries as in the public service model of energy provision.

We argue that much of this configuration occurs at the points at which the electricity system and end-users meet. Our aim in this paper is to show that infrastructures, markets and "electricity consumers" despite being conceptualised, organised and 'governed' along really very different lines, are in fact essentially entangled. As well as underlining this basic entanglement we also analyse the different forms this takes. This exercise is relevant for studies of energy demand as it shows that demand is not located only in the actions and "choices" of end-users but is also shaped by technical systems and more crucially by the interfaces connecting them[5].

Analysing interfaces

PAPER OUTLINE

This an essentially a conceptual paper. Since this is an incredibly complex field, and since the project of revealing the normally obscure politics of the interface is inherently tricky, we work with just two empirical cases, both relating to the electrical grid. We do not present all aspects of our two case studies, but instead draw out only those features which are relevant to the project of conceptualising and theorising the interfaces involved.

In the next section we consider the relation between smart meters and display devices, using the introduction of these technologies as a means of investigating the figure of the consumer and his/her role in relation to those who operate and optimise the grid, and who regulate the management not only of energy, but of knowledge as well.

The second empirical section concentrates on the electric vehicle and its initially problematic connection to the charging infrastructure. Again this case shows how the infrastructure-consumer interface is configured and contested, and how commercial interests are packaged and bundled within this space.

In the final part of the paper we highlight points of similarity and difference between these two examples and discuss the forms of interface-management that they represent. We conclude by commenting on the significance of interfaces and boundaries like the ones we describe, and on the politics of consumption and supply that these 'marginal' cases reveal.

MATERIAL

The data on which the first empirical section is built comes from the research project "Collener" (socio-technical collective and energy transition) and more specifically on a fieldwork conducted by Catherine Grandclément with Alain Nadaï on the emergence of the French technological policy on smart grids in 2014. The fieldwork consisted in a documentary review ("grey literature", laws and regulatory texts, news articles) and a dozen of interviews with the main actors of this policy in France.

The second empirical part is based on the results of field studies conducted by Magali Pierre in 2012–2013, as part of a demonstration project that has been deployed in eastern France in order to promote the diffusion of electric vehicles. The main goal of these field studies were to grasp the diffusion conditions and the use of electric vehicles and charging infrastructure. Fieldwork consisted on semi-structured interviews with stakeholders to the project (n=6) and with households having acquired an electric vehicle in the course of the previous year (n=27

Smart meters and display devices: which side are they on?

In line with an EU directive which recommends that all member States roll-out a "modern" electricity metering infrastructure by 2020[6], France launched a smart meter programme. In summer 2008, the national grid operator announced that it had developed a universal smart meter called 'Linky'. The plan was to test this meter in real conditions during the year 2010 and then install it in all homes between 2012 and the end of 2017. This programme has been severely criticised for a range of different reasons and by numerous institutions including the energy ombudsman, consumer organisations, the environment agency and local councils.[7]

Here we focus on just one of the many hotly debated issues, this being the question of how information about electricity consumption should be provided to the consumer.

In France, as in other countries, the smart meter was promoted as bringing benefits to a full set of stakeholders, including the consumer and the environment. The smart meter, it was held, would help households to better control their energy consumption through closer monitoring of their real energy usage.[8] However, as the field tests went on, it turned out that the consumer didn't benefit from enhanced information about his/her energy usage. In fact, the Linky meter alone was not able to provide enhanced information. For this to happen, the meter had to be supplemented by a further device, an interface between the meter and the household called an "in-home display".

This was partly because householders found that it was difficult to read the Linky meter as evidenced during field tests and emphasized by the environment agency, consumer organisations and the energy ombudsman. The meter has a rather limited screen for displaying data and the ergonomics are not good. In addition, meters are often located outside the home or deliberately hidden of sight (concealed in a cabinet with the fuse box, for instance). These material properties of the meter and the home meant that consumers were unlikely to regularly check the meter to collect information and modify their electricity usage accordingly.

As the field tests drew to a close in December 2010, the environment agency rated the meter negatively, concluding that it was unable to deliver the promised energy savings and GHG reductions[9]. The consumer association *Que Choisir* was of the same view, also noticing that although the cost of the new meter would be passed on to the consumer, he or she would need to pay for an *additional* display device in order to get accurate and useful information from the 'smart' meter.[10] In other words, the consumer would have to pay for two devices (a meter and a data display) in order to be properly informed (and in a modern way) about his/her energy consumption.

This is the context in which sometimes tense negotiations took place between the grid operator, the energy regulator, energy providers, the energy and environment ministries, the environment agency, the energy ombudsman, and other interest groups about exactly how the smart meter and the data should be provided. At this point the question was not whether the real-time display of energy consumption data was itself of value. This more fundamental question was already side lined by the EU guidelines, and by an established commitment to the project of smart metering. Instead, the question was how to ensure that smart metering could be justified and legitimised as a programme that would provide consumers with the knowledge they need to act rationally, and in the public interest (in terms of emissions reductions). For this to happen, the meter had to be capable of providing frequently updated information about energy use. Unfortunately, this was not something that the meter (alone) was technically able to do.[11] To achieve this result, a further device – an in home display – was required. So who should provide this extra device? Should the in home display be thought of as a 'consumer' product, like a toaster or a TV, or as part of the infrastructure, like the wires or the meter?

The environment agency, the energy ombudsman and consumer associations agreed, although for slightly different reasons, that the in home display should be provided to everyone along with the smart meter, as part of responding to the EU guidelines, as a basic element of providing energy to the public, and for the common good of protecting the environment. Not surprisingly, energy providers lined up on the other side. This was not because they thought the meter-alone was a solution. Rather, they had already formulated business models based on the telco industry in which they expected to offer consumers energy and energy services in new, commercially viable bundles, for example by offering specific tariffs *and* energy displays. The idea that in home displays would be provided to everyone as part of the basic public service and provision of electricity instantly invalidated these business models. If providers were no longer able to compete on elaborate bundled offers of rates and smart displays but only on bare prices, they would soon

enter a rat-race competition to the bottom. From their point of view the future benefits were evaporating fast.

The French energy regulator, a body in charge of the proper operation of energy markets, was also against the universal provision of in-home displays. The energy regulator saw the provision of data about energy usage as a commodifiable service, and thus as something that should be delivered through the market, rather than being viewed as a public good. It further justified this position with reference to an essentially spatial account of where public service ends and market begins (Nadaï and Grandclément, 2014). Interestingly, these zones are divided (and integrated) by the meter. Upstream of the meter is the natural monopoly of the grid operated by a regulated public company. Downstream is the realm of the market, with several companies competing in the field of energy provision. The meter itself is situated in the world of the public good but is also understood as a flat interface between the two domains. From this point of view, anything which is plugged in 'after' the meter must belong in the world of market competition. This spatial/political order would be disturbed if the grid operator or indeed any public service operator were to provide a data display 'beyond the meter' and if it was to do so as a universal or basic service to all homes. Should this happen, the spatial boundary would be fractured: a public good would go downstream, it would enter peoples' homes, it would enter what is 'rightly' the realm of the market and in so doing it would distort competition.

Finally, the grid operator which had initially argued for a public service model of smart meter roll-out in the name of equality (a single type of smart meter was to be installed in all 30 million homes of metropolitan France) might have been prepared to include the 'extra' display device along with the meter, and to see the provision of information and not only electricity as a public good. In practice, this actor was extremely reluctant to add further expense to the towering and initially underestimated costs of Linky or to introduce another layer of complexity and responsibility to an already gigantic project.

In January 2012, proponents of the universal provision of an in-home display along with the smart meter won a provisional victory. A ministerial order laid down specific rules defining smart meters: these included the criteria that smart meters had to provide an interface accessible to the consumer for information display as well as the potential to transmit data so as to enable the remote control of appliances.[12] However, the devil is in the detail. When the smart meter programme was relaunched in November 2012, it turned out that the interface would not be a separate material device (like an in home display) but a website where the customer could log in and retrieve some information about his/her electricity usage.[13]

Although the situation is more complicated in a deregulated market like the UK where the big 6 utility companies are providing different levels of service, it is worth noting that there have been similar arguments about the smart meter's inability to provide 'useful' real time information to the consumer. In response the Department of Energy and Climate Change has decided that consumers should be provided with a stand-alone information display along with the smart meter, free of charge. However as the UK smart meter roll-out has been delayed, this obligation is not yet effective and energy providers still hope to reverse this decision.[14]

Let us now turn back to the question of infrastructures and interfaces. The story of the meter and the in home display outlined above provides telling insight into the 'edges' and boundaries of systems, markets and mentalities. Does the display+meter constitute part of the infrastructure, and if so does this represent an incursion into what is properly the realm of the home, the consumer, and the competitive market for appliances and/or for information? Or is it the reverse? Are smart meters being configured as consumer appliances when they should properly count as infrastructure, and as technologies which enable providers to manage consumer demand and so manage the grid more effectively?

We are not about to say where the line should be drawn. However, it is obvious that drawing it in one place, and not another, has far reaching consequences – not so much for energy demand (however they are positioned and funded, smart meters with or without in home displays are unlikely to make all that much difference) – but for how energy is conceptualised, for how the role of the consumer is imagined and realised, and for where responsibilities for demand management are thought to lie. This case raises further interesting issues regarding the 'market' status of information alongside and sometimes as part of energy provision. We return to these themes in the conclusion, once we have considered the somewhat different boundary issues explored in our second empirical case.

Where does the car end and the infrastructure begin? Electric vehicles and charging systems

Electric vehicles (EV) are marketed as discrete products: they are designed and promoted by car manufacturers and they are positioned in competition with petrol/diesel cars in terms of design, performance, etc. Likewise, consumers compare and evaluate the qualities and drawbacks of EVs with reference to the wider automobile market (Potoglou & Kanaroglou, 2007). The scientific literature about EVs[15] usually deals with concerns such as purchase intentions (Egbue and Long, 2012; Potoglou and Kanaroglou, 2007), adoption practices (Burgess *et al.*, 2013) or barriers to diffusion. But this literature overlooks charging issues, other than those relating to batteries and the limitations of their range. (Revzani *et al.* 2015). Very little attention is given to major objects such as the wall box, or the charging wire. In what follows we suggest that this is a limited and perhaps deliberately partial representation in that it skates over the fact that EVs plug into and are part of a significantly different infrastructure.

Petrol driven cars require fuelling and for this they depend on an existing network of privately owned garages and filling stations, supplied by a handful of global oil companies. By contrast, electric vehicles depend on a new array of interfaces related to the road infrastructure, but also connected to the electricity network. These include a charging box, charger, plugs, electricity billing systems, public charging stations, etc. From this point of view, the electric vehicle represents a new device or appliance which is plugged into the 'shared' grid and which thereby extends the sociotechnical system involved (van Bree *et al.*, 2010; Jarrigeon *et al.*, 2014). In this respect it has more in common with other electrical appliances like electric heaters or fridge-freezers, than with the petrol/diesel powered car.

The difference is that the existing network needs to be augmented if it is to be capable of powering electric vehicles on any scale. This is complicated. As presently constituted, the electric vehicle is situated at intersection of road and electricity networks and of a multitude of current ownership structures, some public, some private. There is consequently no one answer to the question of who should cover the cost of extending the electricity infrastructure in order to establish a regular commercial market for EVs.

Different arrangements co-exist. For example in the French case, on-street charging facilities constitute part of the public infrastructure funded by local authorities who also pay for the cost of the electricity meaning that the 'charge' is free for the user/consumer. If the charging station is located on private property, for example, in an underground parking area, a shopping centre etc. it is the owner/manager of the site who finances both. Where electric vehicles are owned and used by companies or other organisations the infrastructure needed to charge them is often funded and provided by these institutions. In all cases, large grants from local authorities and from EDF have been allocated in the form of subsidies, specific components or professional expertise. Unsurprisingly, the distribution of these costs is not discussed by users[16], who understand that the outcome is generally favourable to them, allowing a potentially unlimited free recharge for their private vehicle – especially for those who do not have a garage but always park their EV on the street.

These are not the only connections required. In order to establish a market for electric vehicles, conventional car manufacturers are having to get involved in making sure charging points are constructed, that they are appropriately situated and distributed, that the cost – to the user – is 'competitive'[17] and that not only the car, but the EV system as a whole is a system that functions. This calls for new partnerships and arrangements. There are, for instance numerous joint demonstration projects, including the one we've based this analysis on, the aim of which is to help energy providers and car manufacturers work together. More immediately, those who make and sell electric vehicles have to assume that at a minimum, any buyer has regular, reliable and easy access to a charging point at home or elsewhere. Providing, shaping or enabling this system is beyond the normal role of a car manufacturer, but as the following example shows, roles are being extended in this direction.

When one of the biggest carmakers launched a fully electric vehicle on the French market in 2013, an industrial alliance with a manufacturer of electrical equipment and a famous electric installer, thus encouraging car buyers to use this consortium to provide their private charging infrastructure. Whilst it is the consumer who pays, and whilst there are other infrastructure-providers to choose from, it is in the manufacturer's interests to promote commercial 'packages' of this kind (linking the car to specific infrastructure providers) to reduce the risk of accidents or problems with the battery and to ensure that EV owners have properly certified domestic electrical installations. A network of "Zero Emission ready" suppliers and installers was established to provide this service, with a Zero Emission Ready label being given by the installer when checking an EV electric installation to ensure that it conformed to the car manufacturer's specifications.

Since electric vehicles are marketed as cars and not as electrical appliances, the promotional material makes little or no mention of these infrastructural implications. To do so would potentially compromise representations of the EV as something that falls into the same cultural, economic and technological category as 'the car', that consequently affords the same possibilities, and reproduces the same libertarian fantasies of independence and freedom to go (Steg, 2005). Positioning the EV as a car like any other is a move that separates it from its infrastructure and pushes the necessary wires and plugs deep into the background. For example, when Renault mentions "the eco-system of the electric vehicle," it does so in a way that situates and externalises the infrastructure as a contextual variable, and that overlooks the extent to which the EV is itself central, indeed integral, to this eco-system.

Similar tactics are used in representations of plug-in hybrid electric vehicles (PHEV). In its advertising to the French market, Toyota claims that PHEVs represent the "best of both driving worlds", suggesting that the point at which the electric and automotive sectors 'meet' is within the engine itself, an image that again marginalises the significance of the charging infrastructure as a whole.

Despite significant behind-the-scenes efforts to promote the additional infrastructures on which EVs depend, car manufacturers work just as hard to make these necessary systems invisible, separating them from 'the car' and treating the EV as a discrete entity in its own right. As we will see, these carefully constructed boundaries of representation and responsibility do not completely tally with the consumer/user's experience of operating EVs. From this perspective, the additional infrastructure is very much in view, as illustrated by the contested status of the 'wall-box' and the charging cord. The following analyses are based on our field study mentioned in the material section of this paper.[18] We now explore how charging related issues are considered by those who purchase Evs.

Data from fieldwork indicates that EV buyers generally underestimate both the cost and the complexity of installing a special 'wall-box' into which the EV is plugged. This additional expense comes as an unwelcome surprise despite the fact that in France the cost is in part covered by public subsidies[19]. Just as charging points in public space are provided for free (to the consumer), some of the users interviewed argue that the entire EV-related network should remain invisible, i.e. if not free, then integrated into the car (and its cost). This might mean that private charging points would be paid for either by the network provider or the car manufacturers, perhaps being integrated into the price of the electric vehicle.[20] In this case, the cost of the charging infrastructure would be embedded into that of the appliance, on the model of other household appliances such as the washing machine. As these observations suggest, private and public cost and benefit are matters of debate.

Similarly, when acquiring their EV, users have paid particular attention to the status of the battery, which is one of the most expensive parts of the vehicle: some have indeed preferred EV models allowing them to be owner of the battery, while others are returning for it a monthly rent to a subsidiary of the car manufacturer – somehow on the model of the subscription to an infrastructure – preferring to shift risk of battery damage on the renter. This again is a way for users to indicate the boundary between the automotive world and the world of electric-

ity, whether they claim or deplore it. In other words, in both examples (private charging infrastructure installation and battery status), some users relate these expenses to the appliance (preferring to pay once and for all at the time of purchase of the vehicle), others consider them as part of the infrastructure (conceding to pay for a rent in exchange for a repeated and transparent maintenance).

Decisions about whether to buy an electric vehicle and which model to go for are typically framed in terms of the same criteria as those that would apply to an 'ordinary' car. Key issues include the size of the car, its boot space, its (battery) range, comfort, aesthetics, etc. With electric vehicles, the details of the charging system are also critical, despite being underplayed in much of the promotional material. At the time of data collection (early 2013), some electric vehicles could only be charged from specific types of outlet, specially designed by specialist electrical equipment manufacturers. For some potential purchasers the idea of being 'tied' to just one wall-box/charging system provider was quite problematic. In effect they would be paying for an arrangement over which they had no 'choice' and that bound them now and in the future to a particular type of car, and to a certain (inflexible) charging regime.

There are other options, and many electric vehicles can be connected to a standard domestic socket, provided that the household proves that the wiring beyond is robust and secure enough to safely deliver the charge. ,The fact that there are now many brands to choose from (Hager, Schneider, Sobemscam, classical plugs, etc.) could itself be considered as an indication of the extent to which EVs are taking hold under 'real' market conditions. In navigating thorough this field, consumers have to arrive at a view about different forms and modes of charging and hence about the kind of infrastructure-interface they require. Whilst some purchasers resist and resent the extra cost of a dedicated wall-box, others value one or more of the additional services that it provides. The qualities that matter differ from case to case depending on how the car-infrastructure complex is conceptualised. So for certain consumer/users, the wall-box is valuable (and maybe worth the extra cost) because it enables energy management from home, or because it gives an enhanced sense of security/electrical safety or because it delivers additional services like accelerated charging modes, or information on the cost of electricity per charge.

Since the wall-box fits into these different regimes, there is no agreement about what it is really 'for' or how it should be designed and standardised. For example, should it be really simple to use – and thus figure in a world in which charging flexibly is prioritised, or should it be situated as a 'smart' tool, enabling more elaborate forms of programming? In general, the lack of harmonization in terms of modes and types of recharging at the time of the field study (corresponding to an early market stage)[21] is indicative of an uncertainty about where the car ends and the electricity system begins. Since the provision of electricity is routinely understood as a matter for the electricity sector, consumers tend to think that this is where the problem lies. However, it is car manufacturers who design and produce these vehicles and the leads they require, within the framework of "trans-domain" standards such as those negotiated in standardization committees.

For all these reasons, the wall box is a controversial interface with competing interests gathering around the cord, the plug itself and the communication system linking it to the electric network and to the car. On the one hand, there is the promise that EVs constitute cars like any other, hence the significance of what is called an 'occasional recharging cord' – i.e. a lead that can be plugged into any socket, and that will 'work' providing the infrastructure beyond is up to the task. On the other hand, this simple cord is not, alone, enough to deliver on many of the other promises: amongst them, flexibility, security and control. As one interviewee put it, electric vehicles come with 'strings' attached!

The EVs also entail various forms of spatial and informational relocation. For example, they bring the fuelling function, previously situated in garage forecourts, into the space of the home. In addition, and like other mobile appliances (phones, laptops) the EV calls for a special kind of monitoring. Battery charging is not quite the same as filling a tank, and the type of information (range, charging duration, electricity cost) gathered and mobilised is of a different order. Again new conjunctions arise: dashboards reveal electricity consumption and provide multiple forms of feedback to which users respond. In 'seeing' the fuel level/battery use, the EV driver 'sees' the present state of what is, in effect, an ongoing relation between infrastructure and appliance.

Over time, some of the contemporary challenges of the charging interface are likely to settle down. Some configurations, and some solutions are likely to dominate, at least for a while. The purpose of this discussion is not to second guess what might transpire but to underline the point that where ever they might be drawn, boundaries between EVs and infrastructures reflect and also reproduce distinctions between sectors (automotive, electricity); actors and spaces (private, public), and technological forms (discrete objects, mobile appliances, embedded networks).

Discussion

Looking across these two cases one conclusion is clear: interfaces are simultaneously revealing and important. In framing the case studies described above we have made use of a working distinction between consumer appliances, on the one hand, and infrastructures on the other. This has allowed us to discuss, and to 'see' how boundaries are made between state and market actors, and between public and private space. In focusing on points of intersection we have highlighted what look like processes of incursion and retreat across these various dividing lines.

Figure 1 provides a graphic illustration of where and how interfaces between consumers/consumer appliances and infrastructures are, and might be configured. It suggests the contested technologies of the interface can be largely situated on one side of this divide or another, with an alternative scenario in which they constitute a new 'segment' that faces in both directions.

To elaborate, current uncertainty and debate about the status – for example, of the wall box can resolve in one of two directions. It may become more firmly and more comprehensively associated with infrastructure, and with a collective systems of provision. Alternatively, it might be more strongly associated with the appliance, and with the realm of market provision and "consumer choice".

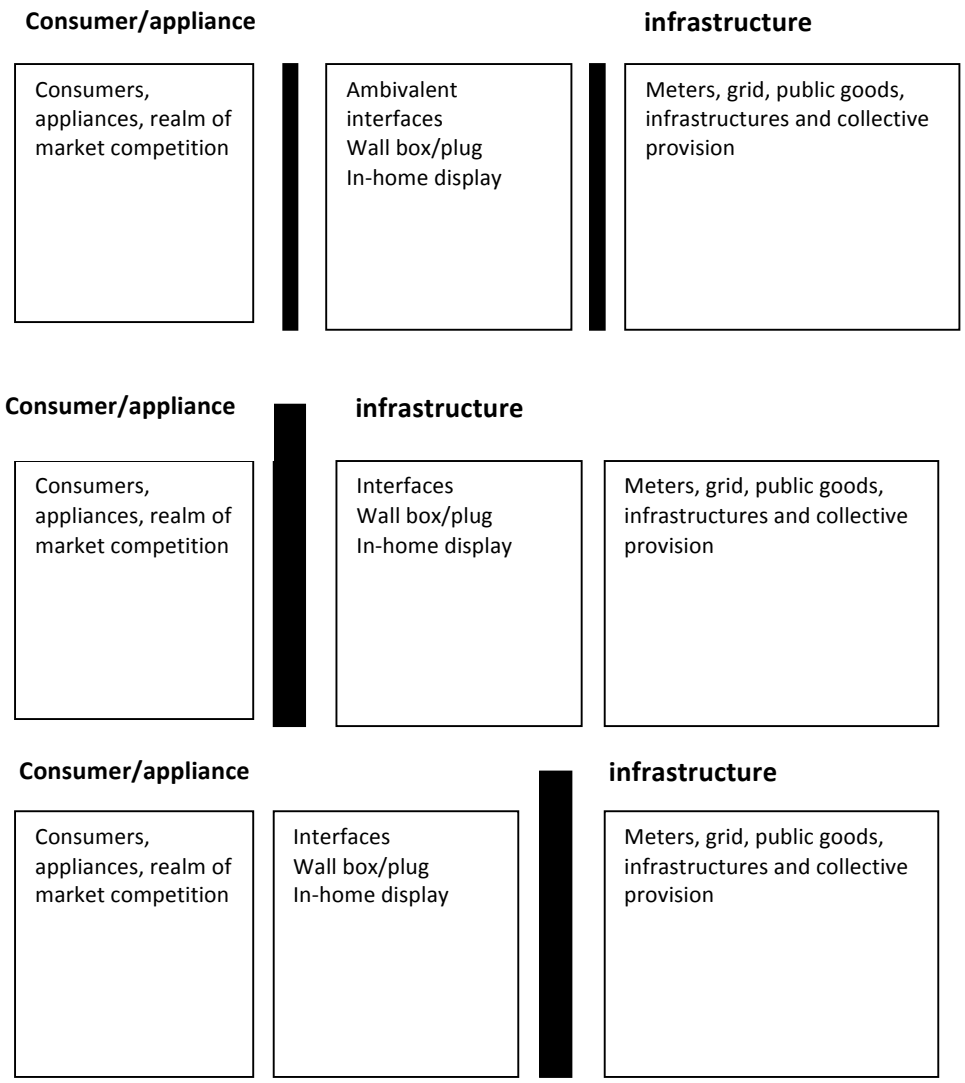

Figure 1. Shifting boundaries between consumers/consumer appliances and infrastructures.

One problem with this simplified analysis is that it overlooks the point that the systems and arrangements about which we have written have multiple edges and that these are not always neatly aligned.

For example, EVs are bought and sold as discrete appliances – that is, as cars. However, this association is not as clear cut as it might at first appear: in motion EVs represent momentarily detachable portions of an infrastructure to which, when charging, they are fully connected. Whilst plans to use EVs as storage systems for the grid make these links even more transparent, the connections involved wind through and around the various and changing roles of car producers, interface designers/manufacturers, network operators and consumers who are increasingly acting as mini-network managers in their own right. More broadly, the ambition of doing what is needed to create a market for EVs forms part of a much bigger, public project which is to decarbonise transport.

As with the meter and the in home display the multiple systems we describe are also in flux. Interestingly, new functions and in a sense new commodities are being introduced in the interstitial 'spaces' that are opening up (or being squeezed in) around the production and management not of electricity, but of data. Again the relations and politics involved are ambivalent and contested. The prospect of empowering consumers and enhancing choice through the provision of more and better information underpins the smart metering vision. In pursuing this project, state and other actors mobilise concepts of markets and rational action with the aim of achieving what are evidently public goals – e.g. demand reduction and reduced emissions of CO_2. Caught in the middle, the in home display does not know which way to face – is it a part of the basic infrastructure, a new device that enables new market actors to offer new services, or an instrument of self-governance and control, or does it represent all three possibilities at once?

These uncertainties are symptomatic of a contemporary layering of discourses of consumption, control and choice on top of networked arrangements and social practices that are basically organised in other ways. Based on our two case studies and on this diagrammatic analysis of the types of connections between interfaces and consumers, we have identified the existence of an 'interstitial' space between infrastructures and consumers (first line of the figure). This interstitial space is often not recognized as such. On the contrary it is often "folded" and considered either part of the infrastructure world or part of the consumer

world (second and third line of the figure). The in-home display and the wall box of the EV are two cases where interfaces do "unfold" and gain a space in their own right in-between the consumer and the infrastructure. Such an expansion of the interface is perhaps a provisional stage, related to the newness of the technology and to the not yet stabilised market context. What matters for this paper is to note the very existence of this interstitial space and how it configures the roles and actions of technical actors, market actors and consumers. In the EV case, car manufacturers do not draw attention to the wall box interface, but they do tend to monopolize it. This strategy creates a captive, locked-in customer. This arrangement has recently changed: as new wall box providers have entered the field, the interface has been redefined, creating new possibilities for the user to act as a consumer. In the case of the in-home display, proponents of the "modernization" of electricity consumption via the "smartisation" of the electricity network discovered that this is a complex process: simply adding a new terminal to the network (a meter in this case) is not enough. The in-home display that some actors wanted to add to the meter re-opens the question of where the "boundaries" lie: where is the frontier between the network infrastructure, on one side, and the market and the home, on the other? The controversy over the in home display shows that there is an ambivalent space between the infrastructure and the consumer and that characteristics of the market and public service depend on features of this interface.

In this paper we have explored some of the tensions that arise around the provision and consumption of electricity. When viewed in these terms, the humble interfaces that we have considered – the in home display and the EV wall box – shed light on a distinctive form of energy politics that has to do with the social and political organisation of state and market action. More grandly, we might go so far as to conclude that these interfaces provide a distinctly, perhaps uniquely revealing 'window' into social and political processes which exist beyond the electricity system, but which also make it what it is today. The definitions they embody organise and enable certain actions and prevent others: in this role they facilitate and foster specific innovations, simultaneously shaping forms of technological change and in the same move structuring the positioning and the contribution of "consumers" and "providers" and their respective roles in co-configuring the practicalities of energy demand. This is important not for the "take up" of pre-defined technologies, or for "individual" behaviour but for much more significant questions about the manner in which infrastructures and practices (whether of consumer or provider) interact.

References

Akrich, Madeleine, et Cécile Méadel. 1999. "Histoire des usages modernes. Énergies, usages et usagers". In *Énergie, l'heure des choix*, 75-103. Paris: Les Éditions du Cercle d'Art.

Bühler F., Cocron P., Neumann I., Franke T. and Krems JF., 2014, "Is EV experience related to EV acceptance? Results from a German field study", *Transportation research* Part F, 25, p. 34–49.

Burgess M., King N., Harris M. and Lewis E., 2013, "Electric vehicle drivers' reported interactions with the public: Driving stereotype change?", *Transportation Research* Part F 17, p. 33–44.

Cihuelo, Jérôme, Arthur Jobert, and Catherine Grandclément, (eds). 2015. *Energie et transformations sociales. Enquêtes aux interfaces*. Paris: Editions Lavoisier.

Egbue O. and Long S., 2012, "Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions", *Energy Policy*, 78, p. 717–729.

Graham, Stephen and Simon Marvin. 2001. *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*. London: Routledge.

Hughes, Thomas P. 1983. *Networks of power: electrification in Western Society, 1880–1930*. Baltimore et Londres: Johns Hopkins University Press.

Jarrigeon Anne, Massot Marie-Hélène, Pierre Magali et Pradel Benjamin, 2014, "Les routines du quotidien à l'épreuve de la mobilité électrique", Communication lors des 13èmes journées MSFS de l'AISLF, 26–27 mars 2014, Lille.

Marres, Noortje. 2012. *Material Participation: Technology, the Environment and Everyday Publics*. Palgrave Macmillan.

Nadaï, Alain, and Catherine Grandclément. 2014. "Smart Grids Demonstration and the Responsive Electricity Consumer". *Paper presented at the 3rd Interdisciplinary Market Studies Workshop (ISMW)*, Saint-Maximin la Sainte Beaume (France), 2–4 June 2014.

Platt, Harold L. 1991. *The Electric City: Energy and the Growth of the Chicago Area, 1880–1930*. Chicago: University of Chicago Press.

Potoglou, Dimitris and PS. Kanaroglou. 2007. "Household demand and willingness to pay for clean vehicles". *Transportation Research Part D: Transport and Environment* 12, 264–274.

Rezvani Z., Jansson J. et Bodin J., 2015, "Advances in consumer electric vehicle adoption research: a review and research agenda", *Transportation Research Part D.*, 34, p. 122–136.

Rose, Mark H. 1995. *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America*. University Park, Pa: Pennsylvania State University Press.

Shove, Elizabeth. 2003. *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. Oxford: Berg.

Shove, Elizabeth, Mika Pantzar and Matt Watson. 2012. *The Dynamics of Social Practice: Everyday Life and How It Changes*. London: SAGE.

Steg, Linda. 2005. "Car use: lust and must. Instrumental, symbolic and affective motives for car use". *Transportation Research Part A: Policy and Practice* 39, 147–162.

Ryghaug M. and Toftaker M., 2014, "A Transformative Practice? Meaning, Competence, and Material Aspects of Driving Electric Cars in Norway", in *Nature+Culture* vol. 9, number 2, Summer 2014.

van Bree, Bas, Geert PJ. Verbong and Geert Jan Kramer. 2010. "A MLP on the intro of hydrogen and battery-electric vehicles". *Technological Forecasting and Social change*, 77, 529–540.

Endnotes

1 The views expressed in this document and the related communication are those of the authors only and not those of EDF which has no responsibility for such content.

2 They also buy and choose things like train tickets which give them the right to use 'appliances' (i.e. trains) that are owned by others.
3 For an example of such a scheme see the "Ecowatt" programme in Brittany in which users are called upon their "civic" sense to moderate their energy usage on certain peak days of which they are warned by text message (users voluntarily subscribe to the SMS feed).
4 See literature on material politics: Marres (2012).
5 Sociotechnical approaches are wary of big categories such "the social" and "the technical". Instead detailed empirical case studies show that "hybrids" proliferate. This is with this tradition that we sympathise in this paper. It is not surprising then that a recent collection of case studies of social studies of energy has pointed also to the importance of "interfaces" (Cihuelo et al. 2015).
6 Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.
7 For a review of these contestations, see the work currently undertaken by Aude Danieli in her PhD work.
8 This represents a techno-economic and managerial view of consumption, and positions the consumer as someone who needs data as much as they need energy.
9 Press release of the Environment Agency, ADEME, December 2010. http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=73790&ref=23980&p1=B, accessed 13/01.2014.
10 Bazot, Alain. 2010. "Les usagers court-circuités", Que Choisir, no 487 (décembre 2010), p. 65.
11 For a fuller inquiry into the smart meter controversy and political consequences of the thick materiality of the meter as an interface between the market and the non-market, see Nadaï and Grandclément (2014).
12 Arrêté du 4 janvier 2012 pris en application de l'article 4 du décret n° 2010–1022 du 31 août 2010 relatif aux dispositifs de comptage sur les réseaux publics d'électricité.
13 To date, that web interface is still not in place (the smart meter roll-out has not yet started). We consequently don't know what type of data and visualization tools will be available. Meanwhile, energy providers are currently developing other interfaces and displays.
14 Gosden, Emily. "Energy bill-payers face hundreds of millions of pound charges for 'pointless' smart meter displays", 26 December 2013. http://www.telegraph.co.uk/finance/newsbysector/energy/10526915/Energy-bill-payers-face-hundreds-of-millions-of-pound-charges-for-pointless-smart-meter-displays.html.
15 We can mention three remarkable exceptions: Bühler et al. (2014), Ryghaug and Toftaker (2014) and Jarrigeon et al. (2015).
16 Even if it puts them in the position of consulmer but not client.
17 Competitive with what? That is another question!
18 We interviewed 27 users households 4 to 12 months after their purchase of an EV. The aim of the interview was to get an overall vision of users' travel and charging practices. The interviews generally took place in the work place or at home, which offered an opportunity to see the car, the electric installation, and sometimes to observe the users' behaviour with their EV. They related to various models of EVs and of charging infrastructures, an aim of the demonstration project being to assess the challenge of interoperability. These vehicles have been used for all types of trips, both private and professional. Moreover, we carried out a few interviews with experts and professionals involved in the demonstration project under study: a customer relationship manager in a charging infrastructure specialist company, a manager of underground parking lots, an urbanist of the metropolitan area, the manager of the Transportation department of the regional council, a representative of a local car-sharing company. These interviews, that we mention here to underline some specific points, aimed to understand some elements that were structuring for use: the infrastructure locating criteria, the conditions of access to public charging points, etc.
19 More precisely, there was a national subsidy for acquiring an EV at the moment of the demonstration project. In addition to this, the local authorities (the Region) allocated a conditional subsidy on the global amount of the car for households attesting that they had gotten a specific charging installation for their EV.
20 This would, in effect, bundle part of the infrastructure with the car – thereby complicating any simple comparison with petrol/diesel powered cars.
21 In other countries, this uncertainty also took the form of a proliferation of market alliances and technological lock-ins. In the UK, if you buy a Nissan or Renault electric car you'll be offered a British Gas unit while Peugeot and Citroen have teamed up with EDF Energy. However, other reputable companies such as Chargemaster, Pod Point and APT Technologies can also install a dedicated home or office charging point. http://www.thechargingpoint.com/knowledge-hub/hot-topics/hot-topics-charging.html.