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## **Energy use in the context of behaviour and practice: the interdisciplinary challenge in modelling flexible electricity demand**

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Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

**Energy use in the context of behaviour and practice:  
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**Abstract**

Moving towards a low carbon energy system in line with energy policy requires that we more fully appreciate the relationship between people and the technology they use. Specifically, in a future electricity grid dominated by renewables we may need to consider our response to an intermittent electricity supply. This has significant implications for energy practices. Traditionally engineering approaches have focused on technology, whilst sociological approaches have people as their main object of study. A practice based approach has the relationship between the two at its core and so there is the potential to combine their methodologies in new interdisciplinary ways. This paper proposes that analysing household practices can better represent domestic energy consumption in context and that this may therefore be used to build more representative models.

## **1. Introduction**

The challenge of greening the grid by integrating a high percentage of renewable generation capacity is usually considered to be a technical one. This paper will argue that both purely technical and purely social approaches are limited and so we shall propose a socio-technical approach. Specifically, we shall focus on the interdisciplinary challenge of using Practice Theory to inform an engineering model of flexible demand; flexible demand being an essential aspect of balancing the grid in the context of intermittent renewables.

To discuss this challenge we will introduce the reader to the concepts of domestic flexible demand modelling and Practice Theory and explain their advantages over current approaches before proposing an interdisciplinary way forwards. We believe this is a useful endeavour because it opens up the normally technical analysis of flexibility and allows us to explore new data collection methods and innovative socio-technical solutions to an important sustainability issue.

## **2. The Interdisciplinary Challenge in the Modelling of Flexible Demand**

### **2.1 Flexible Demand**

One of the challenges in maintaining the electricity grid is the need to continuously balance supply and demand. At present in the UK, householders can use electricity whenever they wish because we have a flexible electricity supply, achieved through the “scheduling, dispatch and response of relatively flexible fossil fuelled plant” (McKenna, E. Ghosh, K. & Thomson, M. (forthcoming) ). Renewables, however, do not offer this flexibility because, simply put, we cannot switch them on at will.

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

Given a future grid dominated by inflexible nuclear generation and intermittent renewable generation would have less supply flexibility, the ability to shift the time of domestic electricity demand from periods of low to high generation output would be helpful. In other words, it could become necessary to consider not only *how much* electricity people use, but *when* they use it. Shifting the time of electricity demand in this way is known as flexible demand.

The extent to which flexible demand has the potential to contribute towards the greening of the grid, therefore, is largely dependent upon how *and when* people use electricity in the home, which we currently understand only partially. Gaining a detailed insight into domestic electricity use commonly involves constructing and validating models or simulations and so we shall examine these next.

## **2.2 Limitations of Existing Domestic Demand Models**

Electricity demand models enable the simulation of electricity use in the home over a period of time. Typically, these models are based upon measured energy use and, in some cases, data that describes how people spend their time in the home, commonly known as time-use data. There is considerable literature on domestic demand modelling: a useful discussion of the different approaches is described by Swan and Ismet Ugursal (Swan, L. & Ismet Ugursal, V. 2009). The functional scope of detailed electricity demand models are also discussed elsewhere (Richardson, I. 2010).

A common approach to modelling domestic electricity demand is to use stochastic methods to simulate the appliance switch-on events that take place throughout the

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

day. Occupancy data (Richardson, I., Thomson, M., Infield, D. 2008) represents when occupants are active within a household, as well as the likelihood of particular domestic activities taking place at different times. We would expect, for example, that cooking appliances be used in occupied households around mealtimes. Probability distributions derived from time-use data have been shown to be effective in modelling this time variation resulting in the realistic simulation of domestic electricity demand profiles ((Ian Richardson 2010) and (J. Widén 2010)).

In order to achieve this, models typically infer a loose relationship between domestic activities (derived from time use data) and the appliances involved. However, whilst there is a close relationship between certain activities and appliances (television watching requires a television), other relationships are more obscure (ironing may also involve a television, for example). Where the relationship between activities and appliance end-use is only an approximation, therefore, the resultant model is necessarily limited.

Whilst time-use data tells us what people do, it generally contains no information on the use of specific appliances in the context of an activity (e.g. using a vacuum as part of cleaning the house, which will use electricity, as opposed to a duster, which will not). Neither does it detail the correlated use of appliances (e.g. using the vacuum while the television is on), important in representing the realistic (and sometimes unexpected) diversity of appliances used when undertaking different practices simultaneously. Finally the shared use of appliances (e.g. two occupants watching the same television) is also not taken into account.

## **2.3 Flexible Domestic Demand Models**

Adding the concept of flexibility to a demand model requires firstly that individual appliances are represented because they use the energy that must be shifted: this is a technical consideration. Secondly, practices in the home must be taken into account because it is these that determine the extent to which shifting is possible: this is a socio-technical consideration, as we shall explain later.

Perhaps most significantly for this work, however, whilst models that utilise time-use data are capable of effectively modelling *existing* demand, they do not permit exploration of the ‘what-if’ scenarios necessary for considering *flexible* demand. For this the interaction between appliances and the practices that co-opt them must be investigated and then modelled somehow. Essentially, activity data without context is insufficient to model flexible demand because we know nothing about its impact on practices.

## **3. Understanding the Context for Flexible Demand**

### **3.1 Three Approaches to Understanding Energy Use**

There are three main approaches to investigating domestic energy. First, the technological approach favoured by engineers. This approach defines the problem, such as comfort (Hinton 2010, Cole 2008, Gram-Hanssen 2010a, Wilhite 2009, Shove 2008) and solves it technologically. Users are expected to conform to particular parameters or are seen as ‘problems’ that disrupt the smooth operation of the technological system. Tools for change in a domestic energy context include smartness, automation, efficiency, design, information and feedback. Although it is not

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

always recognised by the implementers of this approach, agency lies with the technology, though users typically wrest control back from the system.

Next there is the social but individualised approach centred on the agent or individual as either an economically rational being (Shaw, Attree et al. August 2009, Rad 2008, Owen, Ward 2006) with access to all the necessary information to make the 'right' decision or a psychologically coherent being (Devine-Wright 2005, Devine-Wright , Devine-Wright 2009a, Macey, Brown 1983, Nisbet 2008, Abrahamse 2005) with an identifiable (and alterable) set of values and attitudes who will behave consistently by applying these to their decisions which, again, are based on fully accessible (and accessed) information (Desmedt 2009). Wider societal or systemic change according to these models results from the accumulated choices of individual consumers acting on the basis of behaviour change 'tools' like information, awareness raising and pricing.

The third approach is also social but locates agency in culture or society. It is variously known as the cultural (Gram-Hanssen 2010b), contextual (Hargreaves 2008) or structural (Shove 2010) approach. Sociological and anthropological theories focus on the collective structures of consumer behaviour, identifying how identity, status and associativeness are all created and sustained through this behaviour. In these models society has more deterministic agency than individual choices.

Tools for change tend to focus on the macro level: legislation, policy making, international agreements and design standards; the broader social level: social/segmented marketing (DEFRA & DTI 2003); (DEFRA 2008); or community-based,

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

peer group or social networking approaches (Payne, P.R. & Williams, K.R. 2008, Payne, P.R. & Williams, K.R. 2008, Devine-Wright 2009b, Middlemiss 2006, Georg 1999, Wall 2007). This approach has been critiqued for focusing on 'conspicuous' consumption at the expense of the more 'inconspicuous' consumption usually indicated by energy usage (Gronow, J. and Warde, A. 2001).

### **3.2 A Socio-technical Approach to Agency in Energy Use**

Each of the above approaches has strengths and it is not the contention of this work that they are invalid, merely limited. While it is possible to manipulate some behaviour using the tools and strategies outlined above, there remains an unbridgeable gap to achieving sustainable practices using these methods (Devine-Wright 2005, Fidrmuc, Gërxhani 2008, Maiteny 2002, Schatzki 1986, Moloney, Maller et al. )

Precisely because energy is invisible (Whilhite 2005, Jelsma 2003), energy use is ubiquitous, energy prices are low (relative to other household budget items) and the problems of trying to tackle the impacts of our energy use are so great (climate change and biodiversity depletion) and so urgent, each of these approaches runs aground. Many writers on energy now acknowledge that we need to combine these approaches and adopt a socio-technical approach to understanding energy usage (Jelsma 2003, Shove 2003, Wilhite, Shove et al. 2000).

They recognise that both living and non-living things: people, technology and their surroundings, are active and therefore share agency<sup>1</sup>. As there is a spectrum of

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<sup>1</sup> Agency is almost synonymous with instrumentality and is defined as the ability to influence or change something or to take action. It is generally considered to be an active concept though

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

agency, interventions are possible at multiple levels. Agency moves back and forth within this socio-technical system, so the elements of the system co-evolve over time. Within this context the 'user' is seen as a practitioner or agent with a local, contextualised knowledge of his/her own socio-technical environment.

We will now go on to discuss Practice Theory, consistent with a socio-technical approach, and explain its usefulness in understanding domestic electricity usage.

### **3.3 Practice Theory**

In practical terms, Practice Theory moves us beyond either an individualised analysis of values, attitudes and beliefs or an analysis of the various contextual barriers to change. Instead, it is recognised that unsustainable consumption is embedded within and occurs as part of social practices and so these become the focus of our analysis; the place where agency (or the capacity to influence change) is understood to lie.

Practice Theory is complex but we intend to keep our description and use of it as simple as possible for the purposes of this paper. Practices are routinized behaviours (Reckwitz 2002) which consist of interconnected elements that interact with each other. They involve the body and mind; things and structures in the world around us and their uses; and different forms of knowledge. Practice theorists therefore focus on the interactions between skilled carriers of practices (usually human); the technology, infrastructures and institutions that frame those practices and the 'rules of the game'

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the status quo may also be thought of as having agency. Finally, it may be the property of an agent or may be located outside the thing which is being changed. The search for agency is important because it makes sense to focus our interventions wherever we believe the potential for change exists.

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

within which those interactions occur (Hargreaves 2008, Bourdieu 1984). In order to be considered practices they must be recognisable “coordinated entities” (Schatzki, 1966: 89, in (Gram-Hanssen 2010a): 154) recognisable by others who could in turn replicate it across time and space (Hinton 2010).

Gram-Hanssen (Gram-Hanssen 2010b) proposes that it comprises four elements: know how/ embodied habits, institutional knowledge, engagements and technologies and these provide a key focus for us in this paper. We can interpret this as follows: local knowledge (‘how we do things around here’); officially sanctioned knowledge (the way things are ‘supposed’ to be done); meanings (culturally and individually determined); and technology – what Shove calls ‘stuff’ (the material components such as the space and fabric of the home and the things we use). We shall use the example of laundry throughout the paper to illustrate what we mean.

### **3.4 Looking at Laundry Differently**

We might usefully, for example, link Gram-Hanssen’s four elements to laundry practice. Local knowledge in one home might demand that laundry is done when the wash basket is full or on Saturday mornings. Officially sanctioned knowledge, on the other hand, might prefer that washing is only done when a full load can be put into the machine because that is most efficient. Meanwhile culturally determined meanings might require that laundry be washed after every wear to be considered adequately clean in Western work cultures. The technology involved in laundry is most obviously a washing machine (in a Western context) but would also include detergent, softener and the fact the house has piped water and is grid connected, for example. It is clear these elements have implications for energy consumption.

Practice Theory therefore moves us from a behavioural or structural analysis of the factors that drive an individual's decision to use a washing machine and select particular settings (resulting in a particular amount of energy being used) to an analysis of how 'carriers' (Reckwitz 2002) of laundry practices are recruited into performing washing in a particular way in the course of their 'normal' lives (Shove 2004 in Hargreaves 2011) because the practice (or cluster of practices) demands to be done. In the first case the individual decides to do the washing and might be imposed on to think about their electricity use whilst doing so and so the unit of analysis would either be the machine or the individual. In the second case it is recognised that electricity use is actually invisible (Burgess 2008); the washing needs to be done as part of a number of intersecting practices (such as football on Saturday, entertaining on Sunday afternoon and work on Monday), and the practice becomes the unit of analysis.

Practice theory, then, extends our analysis of electricity use in two important ways. Firstly, our attention is allowed to broaden beyond a narrow 'rationalisation' framing' (Hargreaves 2011) to include both types of knowledge identified by Gram-Hanssen (know-how and institutional knowledge) and encompass technology. Agency is located in numerous places, opening the analysis and implying that the opportunities for change are similarly diverse. Secondly, because practices must be repeatedly performed to be sustained (Shove & Pantzar 2005), our interest is also drawn from the merely cognitive to consider 'doings' (Schatzki 2000), the 'bodily activities' referred to by Reckwitz (Reckwitz 2002). Again this means that we must look at what people do, not just what they say, and at the ways they interact with the world around them.

### 3.5 Practice Theory applied to Domestic Electricity Consumption

In **Table 1** below we link Gram-Hanssen’s elements to examples of common British domestic laundry practices to both understand the theory more clearly and start untangling the energy implications. Attempting to use Practice Theory in the context of an engineering model is awkward but this is the interdisciplinary challenge.

	<b>Elements of Practice Theory</b>			
	<b>Know-how and embodied habits</b> <i>(Local skills and knowledge)</i>	<b>Institutional knowledge</b> <i>(Officially sanctioned knowledge)</i>	<b>Engagements</b> <i>(Individual and cultural meaning)</i>	<b>Technology</b> <i>(Technological specification/ physical characteristics)</i>
<b>(A)</b> <b>Illustrative examples of when and why the practice demands to be done</b>	<p>“I do it like this because I always have/ my family does it this way.”</p> <p>“I wash every Friday/ when the wash basket is full/ when the sun is shining.”</p>	<p>“The rule book/ instruction manual/ expert/ person in authority told me to do it like this.</p> <p>Economy 7 users may decide to wash at cheaper times</p>	<p>“I think this is the best/ right way to do it. This is the way we do it in the UK.”</p> <p>“Laundry must be washed every time it is worn, must smell fresh, be ironed and not have any marks or stains.</p> <p>“House should not have laundry hanging in it when guests arrive.”</p>	<p>Includes, for example, the electricity grid, mains water supply, domestic appliances and separate houses.</p> <p>Likelihood of having different settings for big/ small loads, delay button, etc.</p> <p>A washer drier may allow more flexibility in selecting time of day.</p>
<b>(B)</b> <b>Illustrative examples of how practice demands to be done in a certain way</b>	<p>“This is the only way I know/ my system works best this way.”</p> <p>“This is the setting I always use/ the only setting I know.”</p>	<p>“This is the recommended setting for this wash.</p> <p>“Someone told me to do it this way.”</p> <p>“Certain items may require a particular type of wash.”</p>	<p>“Only hot washes clean whites properly.”</p> <p>“Cold washes are more environmentally friendly.”</p>	<p>Depends what settings are on the appliance and how these are ‘advocated’ to the user.</p> <p>Spin speed and temperature.</p>

**Table 1 – Deconstructing Laundry Practice**

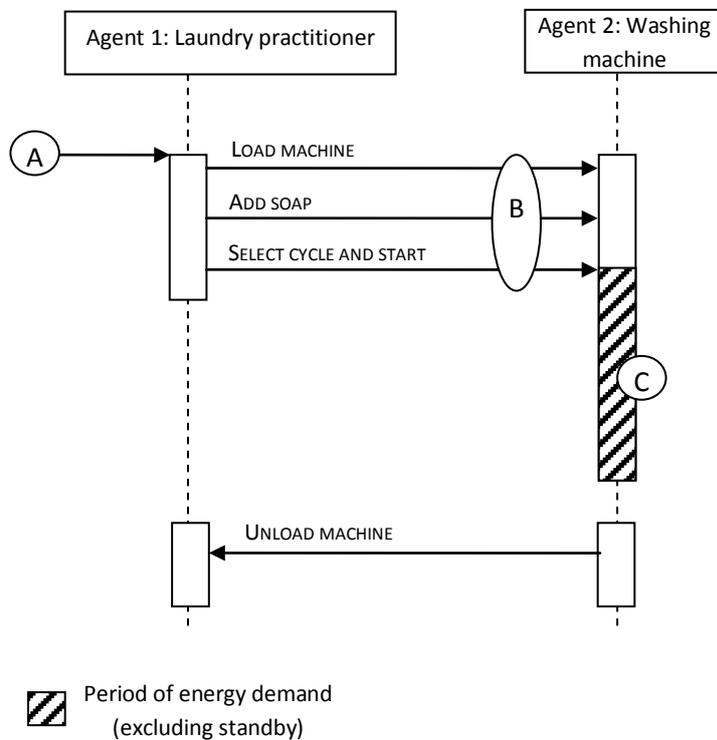
### 3.6 Practice Theory in a Modelling Context

Our objective then is to take a socio-technical approach to enable the modelling of flexible demand because a purely technical or purely social approach will not adequately represent the context of energy use. We therefore wish to map our four elements of practice onto a dynamic system model as shown in **Fig. 1**. The figure shows a Unified Modelling Language (UML) sequence diagram<sup>2</sup> also representing laundry practice.

The important aspects of this systems model can be described in terms of practice theory. Firstly, there are two agents involved (though notice that it is not only they who have agency): the laundry practitioner and the washing machine. The two vertical dotted “swim” lanes that stretch downwards represent time. The boxes superimposed on the lines represent the timeline of practices that take place and the horizontal arrows represent the interrelationships between the agents’ roles. The letters (not part of UML) are for annotation purposes and their significance is discussed above (**Table 1**) and below.

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<sup>2</sup> Unified Modelling Language, Object Management Group, <http://www.uml.org/> (Consulted 17<sup>th</sup> August, 2011).



**Fig. 1. Illustrative UML sequence diagram for the washing practice**

In **Fig. 1**, 'A' represents the moment when the practice demands to be done (laundry in this case) and any number of the four practice elements shown in Table 1 may contribute to why this happens. They are not driving factors but they are elements of the practice which make resisting it more or less difficult.

'B' represents the detail of how the practice is 'carried' or how it demands to be done. In **Table 1**, this relates to the practice demanding that the technology perform in specific ways, and again, all four elements may be relevant. For example, if it is important for white washing to be boiled (engagements demanding that this is what cleanliness requires) a high temperature will be selected. Relating back to Practice

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

Theory then, we notice that agency is located in the mind and actions of the practice carrier, as well as in the technology being used and the actual practice itself.

Finally, 'C' represents the operation of the technology (the washing machine and appliance where energy is going to be consumed). Once the washing machine is started the agency of the machine is clear. The hashed area in **Fig. 1**, 'C', represents the period of energy use by the machine. The energy demand during this period is dependent upon the choices made during A and B but also relies on the efficiency of the machine in performing the washing as set by its cycle.

#### **4. Discussion**

So far we have managed to relate Practice Theory to appliance use using the example of laundry practices. This has allowed us to recognise some of the implications for energy use. Over and above contextualising electricity usage, using Practice Theory has an interesting secondary impact on our analysis in that it shifts attention from the merely technical characteristics of the appliances or, indeed, the wider systems of provision involved, to include the social aspects of practice. By adopting Practice Theory we have opened up both the analysis and innovative space for new interventions.

We have taken this further by exploring how an energy use model relates to a practice based approach. The great advantage in doing so is to enable us to simulate flexible demand. At the start of the paper we said the model was limited because it couldn't predict the use of specific appliances in the context of an activity. We have started to

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

address this limitation even though we have only focused on one appliance within the context of one practice.

It is also fairly straightforward to see how a practice approach might increase our insight into both the time coincident and the shared use of appliances (i.e. when several appliances are being used simultaneously and when one appliance is being used by several people). In addition we've shifted the unit of analysis from appliances to practices. PhD work is currently observing practices in the home over a 24 hour period whilst measuring electricity demand to increase this understanding.

We have not learned how to shift things yet but the practice and energy timelines produced by our observations will help us more fully appreciate the importance of when practices happen and, again, how practices intersect with each other will be of key importance. We may anticipate, for example, that the timing of laundry practices on Saturday morning is not so much determined by the desire to do laundry but by the fact that working practices resume on Monday and entertainment practices happen on Sunday afternoon.

We can see how the space between these practices both allows the time for the laundry practice to be done but also determines the fact that the practice must be carried out. In terms of flexible demand it is worth noticing here that for some practices to shift, others need to make way for them, a process not too dissimilar to the concept of 'fossilisation' (Shove & Pantzar 2006).

Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

However, there is the problem of the considerable complexity of practices and whether it is possible to turn the qualitative insights we gain into quantitative representations in a model. Even if this is possible, we still need to deal with the variation between households and the need to generalise so valued by engineering, without making our models deterministic and losing some of the main insights from Practice Theory. The authors will deal with this in future work.

We've established that measured demand or activity data on its own is not useful but data gathering about practices is difficult and time consuming. Gaining access to households to carry out 24 hour observations is delicate, for example. People are private and reluctant to open themselves and their intimate practices to academic scrutiny. Even when this is achieved we are unlikely to be able to observe a 'normal' day, despite our best efforts. Quite aside from influencing the data just by being in the house, our findings so far are that there is 'no such thing as normal' in many households.

Using the data previously described to construct a model is currently work in progress by the authors. In particular, modelling a practice such as laundry in the context of other practices could become very complex. The challenge is to find a way of representing practices without having to attempt to model entire lifestyles.

Nevertheless, despite the complexity and data difficulties we have faced, by taking a more holistic socio-technical approach we believe we can better understand the opportunities for flexible demand.

## **5. Conclusions**

In this paper we have brought together Practice Theory and the engineering modelling world and have discussed how they can work together. This is a difficult task. However, the process has opened up new ways of collecting data and we can also anticipate new solutions that are not only technical. Overall, therefore, this has been a useful exercise, promoting dynamic conversations between two distinct disciplines.

In short, we recognise the difficulties of the task. However, models have to be built without undue speculation so must be based on empirical data even if that is constrained by the difficulty of getting it. We believe that we have taken the first promising steps towards that goal. Analysing household practices can better represent domestic energy consumption in context and this can be used to build more representative models better able to assess the flexibility needed to cope with intermittent electricity supply, despite the interdisciplinary challenges we have faced.

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The interdisciplinary challenge in modelling flexible electricity demand

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Energy use in the context of behaviour and practice:  
The interdisciplinary challenge in modelling flexible electricity demand

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