CAN PRACTICE MAKE PERFECT (MODELS)? Incorporating Social Practice Theory into Quantitative Energy Demand Models

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ABSTRACT
Demand response could be increasingly valuable in coping with the intermittency of a future renewables-dominated electricity grid. There is a growing body of work being done specifically on understanding demand response from a people and practices point of view. This paper will start by introducing some of the recent research in this area and will present social practice theory (SPT) as a useful way of looking at the flexibility and timing of energy-use practices.

However, for the insights gained from SPT to have value for the electricity supply industry it is important to be able to represent this flexibility in quantitative energy demand models. This requires an interdisciplinary conversation that allows SPT and modelling concepts to be mapped together. This paper presents an initial step in trying to achieve this. Drawing on empirical data from a recent SPT study into flexible energy-use practices, it will experiment with modelling flexible demand in such a way as to take account of the complexity of practices; not just their 'stuff' but also some of the images and skills involved in their competent performance.

There are several reasons this is a useful enterprise. It encourages interdisciplinary insights which are valuable both to social practice theory and to energy demand modelling, it highlights new ways of intervening in flexible demand and it establishes a research agenda for social practice theorists and modellers which will eventually result in a set of requirements that can be used to build an energy demand model based on practice theory. This area of research is in its early stages and so the conceptual mapping is necessarily speculative but, hopefully, also stimulating.

Introduction

This paper will begin by explaining its current research context: the timing of energy demand. It will then need to explain a number of concepts before settling down to its main objective. Demand response, or shifting the timing of energy use, is important for meeting the government's carbon targets and has previously been considered an engineering challenge but is increasingly recognised as social too. Social Practice Theory (SPT) will be introduced and offered as a useful way of looking at demand response. The paper will then consider how to incorporate the sorts of insights gained from SPT into the quantitative energy demand models used by electrical engineers to help them think about the future development of the electricity grid. The point of doing this is to help create energy demand models that offer a more realistic assessment of the flexibility of energy demand than is currently the case. The main focus of the paper then is to draw an energy demand model of practice, using simple stock and flow concepts, that describes energy demand from a practice point of view, taking into account the intrinsic and extrinsic demands of practices. This conceptual work will be supplemented by insights and quotes from previous empirical research by the principal author (Higginson 2014).

Literature Review

Current Sociological Research into the Timing of Energy Demand

The timing of energy use, an issue of concern for some time in engineering circles (Darby, McKenna 2010), is rightly increasingly recognised as important by sociologists as well, as demonstrated by the budding research in this area. The International Energy Agency is conducting a significant study into demand side management (DSM) projects globally, though many of their case studies focus on reducing rather than shifting energy use (Mourik, Rotmann 2013). Yolande Strengers, Co-leader of the Beyond Behaviour Change research program at RMIT university in Australia, has been conducting research on the flexibility of energy demand practices in an Australian context for some time. Her work has centred on the importance of understanding energy demand from a practice point of view and has highlighted the role of energy infrastructures in determining these practices (for example, Strengers, 2010, 2011, 2012, 2013).

In the UK, new insights in this area are emerging from a number of project-based sources. The Transforming Energy Demand through Digital Innovation (TEDDI) programme has funded numerous projects, amongst them the Low effort energy demand reduction (LEEDR) project, an interdisciplinary four year research project that sought to understand domestic energy consumption and how it relates to everyday activities. This project was interested in energy demand reduction rather than shifting and is still analysing its final results but does offer increased insights into when, how and why domestic energy is used. Based on how participants already use digital technologies and energy resources, the project has started to design products that produce comfort in ways that fit in with participants' existing practices and their sensory experience of 'place' in their homes (Pink, et al. 2013).

Meanwhile, the Low Carbon Network Fund (LCN) funded by Ofgem (the Office for Gas and Electricity Markets) in August 2009 provided up to £500 million over five years to help drive innovation and new technology to deliver the electricity networks of the future, with substantial discretionary awards available for projects which were particularly valuable in helping the networks adapt to climate change whilst also providing security of supply and value for money to consumers. The objective of the fund was to encourage Distribution Network Operators (DNOs) to try out new technology, operating and commercial arrangements.

The most significant of these projects in the context of this discussion is the Customer-Led Network Revolution (CLNR) project, an interdisciplinary study taking a socio-technical approach and using SPT as its theoretical perspective. Learning from this project is just starting to be disseminated but this has been the UK's biggest smart grid project, worth £54 million and is a collaboration between academia and business, led by Northern Powergrid, the DNO for the North East and Yorkshire.

One of its learning outcomes evaluates the extent to which customers are flexible in their load and generation and the cost of this flexibility. There was some evidence that time-of-use tariffs (where energy is charged at a variable rate depending on the time of day) were able to reshape energy-use practices more generally, as the longitudinal study revealed overall reductions in energy use, as well as shifting out of peak, but this finding had not been fully understood yet. Where practices do not respond to the time of use tariff, this appears to relate to: practices needing to be carried out in a conventional way, the rhythms of daily life (such as leisure time at home in the evening) and activities that connect householders to external structures or social groups, such as work, school and social activities. This finding suggests that tariffs need to take into account other schedules and structures if they want to maximise flexibility (Cardwell 2012).

More recently, the DEMAND centre at Lancaster University received major funding in 2013 to run a five year programme focusing on the nature of energy demand, using an SPT approach. Gordon Walker, co-director of the centre has written an important paper outlining the research landscape and highlighting the relevance of the timing of electricity consumption. He points out that temporal patterns are embedded in the social world and, therefore, in energy demand. He discusses three categories of underlying temporal social dynamic – change, rhythm and synchronicity – and how each provides a different way of approaching the relation between time, social practice and energy demand (Walker, 2014). Demand response also forms part of the research agenda for the Realising Transition Pathways project, which has published both on both the technical and social aspects of DSM (Torriti et al. 2010, Higginson, Richardson 2011) and supported the empirical research upon which this paper is partly based. This work suggests that DSM is not being fully exploited as a resource and that energy-use practices can be flexible (Higginson et al. 2013, Higginson 2014).

While the work described tries to establish the amount of flexibility available, the acceptability of flexibility as a concept and how to motivate flexibility, much remains to be done to incorporate these insights into energy demand models. This paper will introduce some of the main concepts and then will take the first steps in trying to accomplish this.

Demand Response

Demand and supply need to be continuously balanced in order for electrical networks to operate. This is currently achieved through flexible supply (dispatch of fossil fuel-based generation to meet the demand). However, in order to meet its carbon targets, the grid will increasingly make use of renewable generation, which is intermittent, or dependent on the weather, and so uncontrollable and therefore less flexible. In order to balance the grid, therefore, flexible demand will become an increasingly useful resource. Demand management has previously focused mainly on reducing energy use but here the interest is on shifting energy use in time. Although there are other ways to shift energy use – it can also be shifted in space, by substituting different practices, by shifting the type of energy associated with the practice or by ceasing the practice (Powells et al. 2014, Higginson et al. 2013) – these will not be dealt with in this paper.

Social Practice Theory (SPT)

A high proportion of the work referenced above takes a Social Practice Theory (SPT) approach. This approach has been well described elsewhere (for example, Shove, 2012), is now accepted as a helpful way to understand energy demand and has increasing policy relevance, as evidenced by its growing prominence, outlined above. It seeks to go beyond more established behaviour change approaches in recognition that energy is not used for its own sake but as part of the accomplishment of socially and materially shared practices in the service of normal everyday life. Rather than focusing on energy efficient appliances, buildings or people, this approach takes practices as its focus of analysis, attempting to understand how trends take hold and so helping to explain the underlying dynamics that comprise energy demand.

SPT is particularly useful for a discussion of demand response because it deals with the time and space within which energy consumption occurs. This is highlighted by Schatzki's definition of practices as "co-ordinated entities that are temporarily unfolded and constitute spatially dispersed nexus of doings and sayings" (Schatzki 1996: 89). In other words, practices have a particular relationship with time and space and acknowledging this relationship is part of their competent performance. Practices are subject to timing, sequencing and duration and if these are not correctly observed through the performance, the fundamental nature of the practice may be compromised, which may mean its demands are unsatisfied and its rewards undelivered. Similarly, practices are subject to space, both in that they take up space and in that they should normally be performed in a certain space[1]. However, this paper will not deal with the spatial nature of practices per se.

There are three main insights into SPT that are necessary to follow the arguments in this paper. The first is that practices are made up of elements. The number and composition of those elements is debated but the most frequently cited is the Shove-Pantzar three element model comprising material artefacts, conventions and competences (sometimes called 'stuff', 'image' and 'skill') Shove (2008: 9). Here 'stuff' "includes technologies, artefacts, spaces, bodies, structures, formats, compositions and ingredients. 'Image' represents the social and personal meaning attempted or achieved through practices, including emotion, aspiration, belief, identity and aesthetics. 'Skill' includes understanding, taste, competence, know-how or 'procedures' for accomplishment of a practice as learned socially and through performance" (Scott 2012: 4). This paper will attempt to map these three elements, stuff, image and skill.

The second is that, although practices exist and can be recognised as entities, they do not live as practices unless they are performed. It is these performances that drive everyday life and, therefore, energy use. There is therefore an important distinction between "practices-as-entities (idealised and abstract forms that are historically and collectively formed) and practices-as-performances (the grounded enactment of practices conducted amid everyday contingencies)" (Hargreaves et al. 2011: 7). While the analysis of practices-as-entities focuses on the elements and the ways they are linked, the analysis of practices-as-performances is interested in the moments of integration that occur when practices are in action (Røpke 2009). In

[1] It is also argued that practices actually 'create' time and space (or, at least, the way these are experienced) but this will not be discussed here either as there is already more than enough to deal with

other words, it is possible to recognise that there is such a thing as the laundry (the practice as entity) but unless it is performed, the practice does not exist in any meaningful sense. This distinct analytical difference allows an examination of how combinations of elements are enacted and reproduced (Shove et al. 2012). This paper will concern itself with modelling the everyday performance of laundry, taking into account the three interacting elements.

This leads to the third important insight into practices for the purposes of this paper; namely that practices are demanding. The human role in practice theory is considered to be that of a practitioner or a 'carrier' of practices. The implication of this is that practices remain the focus of the analysis, not the human individuals or groups that carry them. So, for example, the embodied habits and engagements brought to the performance of a practice are not the attributes of the practitioner, but rather of the practice. While people are not passive or powerless, neither are they autonomous (Wilhite 2012). Rather, they are recruited into performing practices in particular ways because those practices or clusters of practices demand to be done. There are three particular ways in which practices can be said to be demanding (Higginson 2014). Practices are demanding on their own account in that they demand to be performed, practices demand the performance of other practices and the elements within practices were demanding. The competent performance of a practice by a human practitioner or carrier, results in the satisfaction of these demands and may yield rewards which keep recruits loyal to the practice and involves them in 'careers' of practice (Shove 2012). The various demands of practices will be discussed in more detail as the paper progresses and will be evident in the model maps that will follow.

The consumption of energy then, according to SPT, depends on the competent performances of demanding practices in particular times and spaces, during which the elements of that practice are integrated in various combinations. As the practical focus of this paper is mainly on demand response, the theoretical focus will be on the way practices exert their demands and whether it is possible to represent this in a model.

Demand-side Modelling

Quantitative models of energy demand are used to evaluate the impacts of potential future changes in technologies and behaviour. These can range from 'top down' models, which take a whole system, typically national, view of energy demand, to 'bottom up' models that provide a disaggregated view of energy demand, typically at the scale of the individual or building (Swan, Ugursal 2009). The time resolution of the output of such models can range from seconds to years. The 2050 Pathways model (DECC 2013) is an example of a top-down model used by the UK government to explore energy supply and demand scenarios for transitioning to a low-carbon economy over the coming decades. The high-resolution model of domestic electricity demand by Richardson and Thomson (Richardson et al. 2010) is an example of a bottom-up model which has been used within academia and industry to explore the impacts of low-carbon technologies on low-voltage distribution networks (Collinson 2014, EA Technology 2012, Navarro et al. 2013). Quantitative energy demand models can have considerable impacts on the energy landscape, for example by influencing energy policy or being incorporated into industrial design practices.

However, these models currently have limited (or no) representation of the relationship between models of human behaviour and energy demand and, as a result, are limited in their ability to inform studies of flexible demand. Hence the overall aim of this paper to take an initial step in correcting this deficiency. Specifically, the focus of this paper is on incorporating SPT into a bottom-up, practice-based model of energy demand.

A feature of quantitative models is that they have a defined structure which describes what is included in the model and how it works. Drawing out a potential structure for a model is a useful step in its development. It informs constructive criticism and feedback, provides a template for how the model should be built, indicates assumptions that should be tested and starts to suggest the data that would be required to calibrate the model. As an initial step in development, therefore, this paper presents a potential structure for a practice model.

To address this challenge the researchers focused on two questions. The first related to the output of the model and the second related to its structure. Firstly, it was important to clarify what output an SPT energy demand model should produce as this, ultimately, is the purpose of creating it. For comparison, the output of the bottom-up electricity demand model mentioned above was high resolution stochastic electricity demand for an individual building, which is relevant for low-voltage distribution network modelling. The hope is that creating an SPT energy demand model will enhance an understanding of the nature and dynamics of electricity demand, in particular, its flexibility, both in terms of understanding how much flexibility there might be in the system but also in determining where in the system it might exist. This question started to be addressed by asking people to describe the rewards of practices through a mixture of face-to-face and telephone surveys. The results of this will be described in a forthcoming paper.

Secondly, and the subject of this paper, SPT concepts were used to inform a potential structure for an SPT energy demand model. The ambition behind this exercise was to map a practice as a complex system. This was done as a collaborative effort between the authors, who are from different backgrounds: engineering on the one hand and social science on the other. To facilitate this interdisciplinary task, relatively simple modelling concepts were used to build up a picture of the model structure, which will be described next.

Results and Discussion

Starting with System Dynamics

To start with, modelling concepts have been adopted from the field of ‘system dynamics’. System dynamics was created by Jay Forrester in the 1950s as a means to explain the complex behaviour of commercial and industrial systems (Forrester 1958), and later popularised by the book *Limits To Growth* (Meadows et al. 1972) which used system dynamics to describe the (sometimes disastrous) consequences of economic and population growth in a world of finite resources. For the purposes of this paper, the important concept of system dynamics is the characterisation of complex systems in terms of a few simple components, notably stocks, flows and feedback loops.

To illustrate the concepts and symbols, the following runs through a simple example of washing clothes. Figure 1 shows a stock and flow diagram. Two stocks are shown: dirty clothes, and clean clothes, represented by receptacles whose levels can vary. The stocks are linked by flows, the arrows linking the various components of the figure. Washing clothes reduces the stock of dirty clothes and increases the stock of clean clothes. Wearing clothes does the reverse. In this case, the stocks and flows are physical variables (clothes) that vary over time – the system is dynamic. Of course, the flow can be varied. The levels of the stocks influence the flow rate – the more dirty clothes there are, the more clothes are washed.

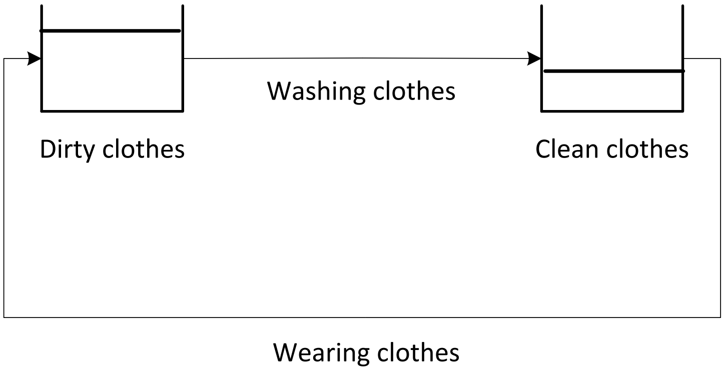

Figure 1

Adding Practices to the Model starting with 'Stuff'

Figure 2 adds more detail to the diagram. Firstly, the wearing clothes flow has been removed. Instead dirty clothes and clean clothes are shown coming from and going to cloud symbols. These are symbols for 'outside the system' and are used to simplify diagrams – the dirty clothes come from somewhere and the clean clothes go somewhere else – that is not of interest here but will be dealt with later. For the moment the interest is focused on the 'washing clothes' part of the previous loop. The second change is that the stocks now have physical receptacles – a laundry basket for dirty clothes and a wardrobe for clean clothes. Another new symbol in the diagram is the 'convertor' in the centre. This is a 'washing, drying (and maybe) ironing clothes' convertor and it converts input variables (dirty clothes) into different output variables (clean dry clothes) but is otherwise not detailed at this stage. Note that the convertor is not a conventional symbol used in system dynamics but has been adopted from electrical engineering instead.

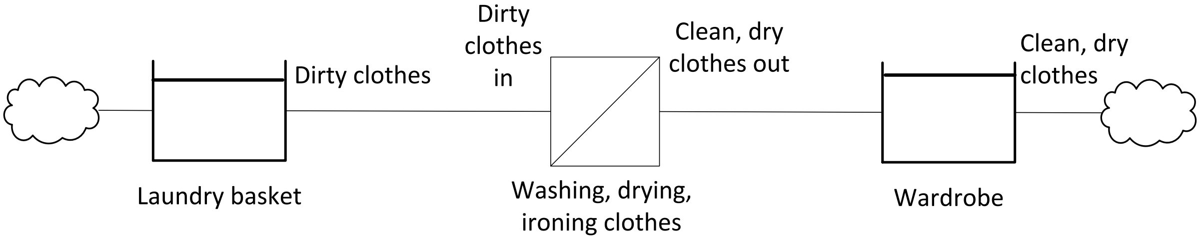

Figure 2

Having introduced the main modelling concepts that will be used in this paper, it is now possible to start mapping these onto some ideas from STP, using the example of laundry, whose temporal phases include soiling, collecting, washing, drying, maybe ironing and putting away, each of which may influence the volume and timing of laundry (Shove 2002, Higginson 2013). Figure 2 shows a part of this sequential arrangement by tracing a particular performance of laundry practice. At this stage, it focuses just on one element, namely the ‘stuff’ of laundry and even this is necessarily reduced for the sake of simplicity. In terms of which ‘stuff’ has been selected, the reader is reminded that the focus of this model is on demand response, so that the components of laundry of interest are those that will most influence its flexibility.

The attempt, therefore, is to try and highlight the demand for laundry where it occurs most strongly within the practice. This means that the stocks, the laundry basket and wardrobe, are of most interest. These were selected based on empirical research, from whence all the quotes in this paper derive (Higginson 2014), in which both were implicated in the flexibility of the laundry: “Everything’s now falling out the laundry basket. It’s time to do a wash load” (Interview 10.3) and “I realised that I didn’t have any short sleeved shirts in my wardrobe and I like short sleeved shirts for work... So, that’s it. They had to be washed” (Interview 5.5). Here the demand for the practice is coming from this particular element – the stuff – in that the levels of the stocks require that the laundry is done: if the laundry basket is full or the wardrobe is empty, the ability to delay the laundry will be significantly constrained.

Introducing the Other Practice Elements: Image and Skill

Figure 2 serves to map some modelling and SPT concepts together and provides some insight into the laundry but it is still too abstracted. Figure 3 does two main things: it adds the other two elements of practice, image and skill, to the ‘stuff’ already outlined, showing these as inputs to the model, and it provides more detail by zooming in on the convertor from Figure 2. Acknowledging that the laundry is comprised of three elements highlights the fact that the use of energy in the service of washing clothes is not merely determined by the washing machine, tumble drier and iron (or whatever other means are used to wash, dry and flatten clothes) but depends on much else, such as the meaning of clean, the way the different schedules in the household come together, how laundry is organised and done in the household and so on (in other words, the images and skills that are part of the practice of laundry). That level of complexity is not the current focus, however, and so the elements are represented by clouds, as before, showing that they come from outside the bit of the system currently being examined (though it is possible to trace this back to Figure 2 for the ‘stuff’ cloud). The three elements are also given different colours to make the difference between them clearer: red is stuff, yellow is image and blue is skill.

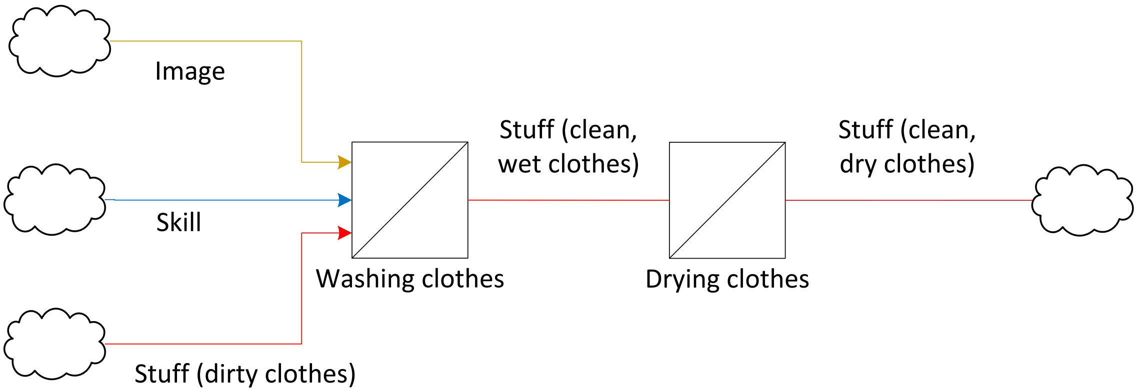

Figure 3

Although it shows three elements as inputs, the figure only shows the stuff of laundry passing through the system. However, images and skills would circulate in a similar way as will be seen later. It is also worth noting that dirty clothes are not the only physical 'stuff' flowing through this system. The 'stuff' of laundry is much more diverse and would include washing products (powder or liquid detergent, stain remover, fabric softener, etc.), the washing mechanism (sink, bucket, washing machine), the drying mechanism (tumble drier, clothes horse, washing line or airing cupboard) and, if relevant, the products and technologies used in ironing (iron, ironing board, TV, etc.). Each of these has the potential to influence the *amount* of energy used in the laundry process, for example if the detergent allows a cold wash, the washing machine has an eco-setting or the drying mechanism means less ironing needs to be done. In a normal energy demand model the energy demand arising from all of these would be the most important output of the model but here it is just one of many because in a demand response model understanding the *timing* of the energy demand and its flexibility is as important as calculating the kilowatt hours.

The second point of interest in Figure 3 is that it zooms in to look more closely at the washing and drying convertor which, in the previous figure was simply represented as a box. The close-up view now shows two convertors: washing clothes and drying clothes. As before, these take input variables and convert them into other output variables. The point here is that it is possible to zoom in and out of the model for the purpose of expanding the detail, as necessary. This might be done where particular parts of the practice seem relevant to its flexibility. For example, empirical research has shown the drying process to be particularly significant (Higginson 2014). Drying laundry had a physical presence that was undesirable and even oppressive. It could feel "like, you know, you're stuck in a Chinese laundry" (Interview 2.3) and could restrict more important activities like children's play. Where more space was available and volunteers were relieved of the "visual intrusion of the laundry hanging up" (Interview 10.3) which reminded them "too much of student days" (Interview 2.3), they were also able to be much more flexible. Several people commented on this: "I've got enough bedding, toweling (to) cross over between housefuls of people so there will be stuff drying either on the rack in the utility room or in the airing cupboard when people are here" (Interview 8.3), or "I'm lucky. The house is big enough that I can leave it stacked up in one of the bedrooms" (Interview 9.3), or "Now that we've got a spare room and we can just shut the door it wouldn't affect us in the slightest" (Interview 10.3). Including ironing in the sequence added again to its complexity.

So, to explore the washing and drying convertors, it would be possible to go down ‘another level’ of detail but this is not done here. The point to remember here is that this is not an attempt to provide a comprehensive map of practices but rather to illustrate a set of concepts and see if it is possible to map them together. Instead the stuff is sent away to another cloud to the right of the figure representing something outside the interest of this system but which will be explored in the next figure.

Closing the Loop: Adding an Adjacent Practice

Figure 4 follows the same principle as Figure 1, which showed a closed system, or feedback loop with dirty clothes circulating around it. However, in this case it tries to represent a broader system and so expands to show practices. The clouds that previously represented the flow of dirty clothes in and clean clothes out have been replaced by an adjacent practice. Two practices are represented, separated by a dashed line – doing the laundry and going to school and so the clothes have been changed to school uniforms. Some parts of Figure 4 have zoomed out again – the washing and drying convertors of Figure 3 are back in their original, single, convertor box. Matching this, there is a ‘wearing uniforms’ convertor that takes clean uniforms in and outputs dirty uniforms. In this figure only one element, stuff (hence the red line), is represented but image and skill will return in the next figure.

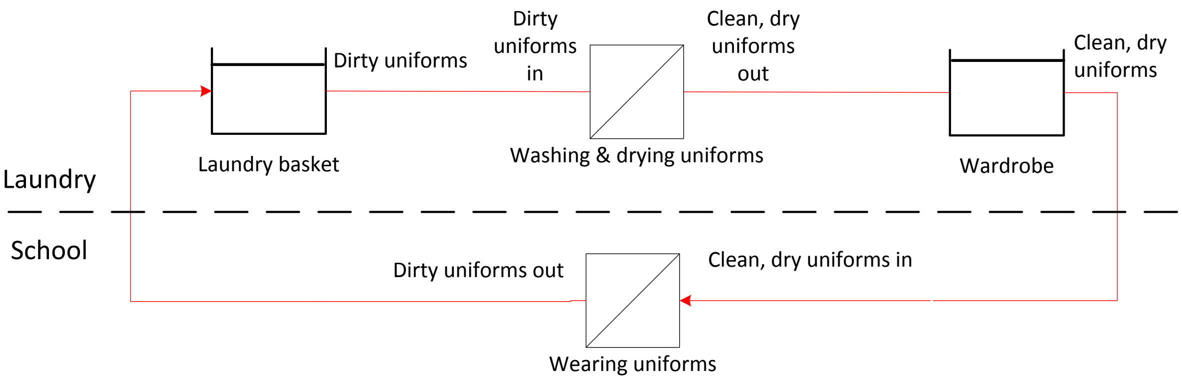

Figure 4

One thing that becomes clear in this figure is that there are additional demands for the laundry. Rather than it being just the elements of the practice exerting demands, it is now an adjacent practice which is being demanding. In other words, going to school requires clean school uniforms and so demands that the laundry is done at a particular time and to a particular standard. The important point is that flexibility might be required in other parts of the system than those in which it has conventionally been thought to exist. Here, for example, flexibility might be found in the adjacent practice – going to school – rather than in the laundry practice. There are other implications to be noticed here but first it is worth expanding out the model one more time.

Adding Skills and Images to the Closed Loop

Producing dirty uniforms is obviously not the purpose of wearing uniforms and so Figure 5 reintroduces meanings and skills, this time as feedback loops in their own right, each with their own pair of stocks and a convertor and still differentiated by colours. All three loops are joined by the 'main' convertor, namely 'wearing appropriately laundered uniforms'. The figure still represents the two practices of laundry and going to school but the boundary between them is no longer as easy to identify.

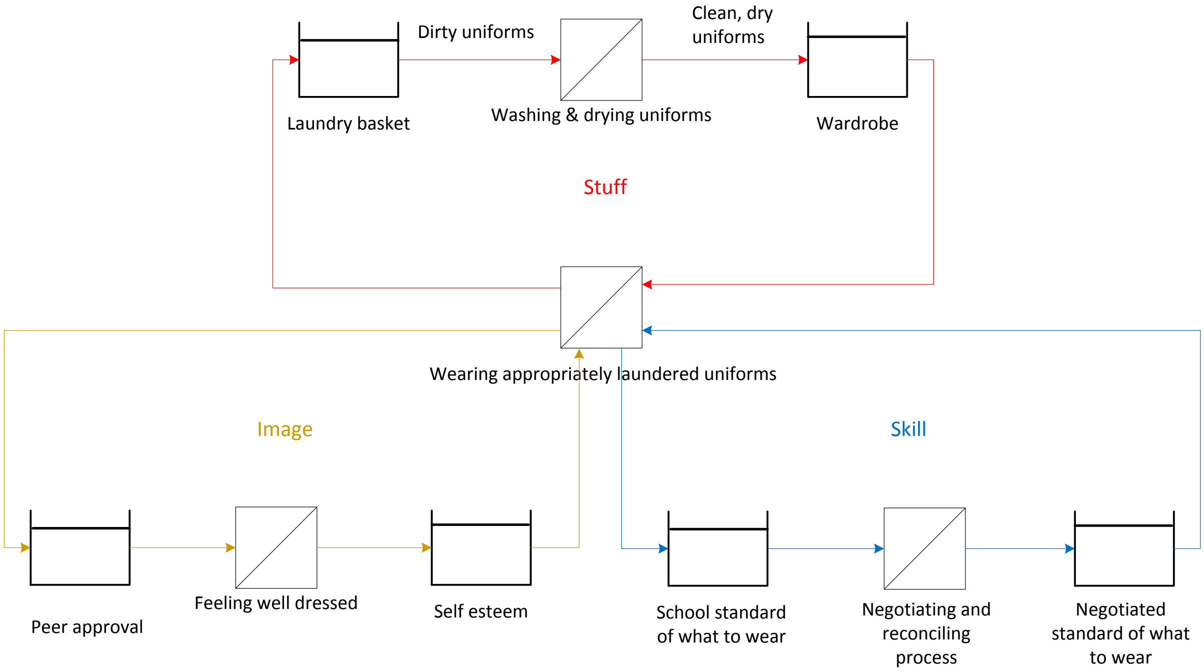

Figure 5

The 'stuff' loop has already been discussed and is obviously the easiest of the three to explain. The 'image' and 'skill' loops would normally deal with all the possible images and skills associated with performing the practices shown here. Each performance would involve a negotiated process by means of which the three elements would be reconciled and integrated. Here, specific examples of image and skill have been adopted to try and ground what might otherwise be a very theoretical discussion but these are just illustrative. So, the first stock in the image loop is 'peer approval'. It can well be imagined how this could rise and fall depending on whether the uniform was clean and fresh-smelling and whether the correct items were being worn in the correct way. Appropriately, the convertor is therefore a feeling; that of being well-dressed, the result of which is 'self-esteem', a stock which may also rise and fall depending on how the peer approval 'rating' had been converted. These stocks and convertors are of a very different type to those in the stuff loop but it is clear that they are just as demanding. It is perhaps easier to see in this loop how submitting to these demands might be rewarding, however.

Nevertheless, although it may seem subtle, it is important to realise that, in terms of both the model and SPT, these are not drivers of behaviour such as would be the case in, for example, a psychological model. In fact, this peer approval, feeling of being well dressed and consequent sense of self-esteem belong to the practice, rather than the practitioner (this is why, for example, the self-esteem relating to being well dressed is not interchangeable with the self-esteem consequent on being able to make a complex intellectual argument – the self-esteem in each case belongs to different practices and so is not the same). Although it is obviously difficult to quantify these sorts of things, the researchers are working on a simple way to measure them which, although necessarily subjective, would allow them to be turned into numbers and so included in future models.

Similarly to the image loop, the skill loop has two stocks and a second convertor. Its first stock is the school standard of what to wear and how to wear it. It is likely this would include a particular standard of cleanliness, as well as specified articles of clothing worn according to the uniform standard. Certain skills would be implicated in achieving this standard but would need to go through a 'negotiating and reconciling process' imposed by each household. This would involve, for example, navigating through the conflicting schedules in the household (work, school, childcare, etc.) and the resultant ability to achieve the school's standards of cleanliness. It would also interact with the requirement to receive peer approval, which may necessitate adapting the set standard by, for example, adopting a particular style of wearing the uniform (a loosened tie, rolled down socks, etc.). It is likely that the result of this would be a 'negotiated standard of what to wear', the second stock in the skill loop. Achieving this negotiated standard requires a subtle but complex combination of skills that may include all sorts of strategies such as removing the uniform and hanging it carefully in the wardrobe for reuse, or wearing it all day so that it required more frequent washing and so was placed in the laundry basket.

The image and skills loop show that individuals are important in practices. As Sefang puts it, individuals are "knowledgeable and skilled 'carriers' of practice who at once follow the rules, norms and regulations that hold practices together, but also, through their active and always localised performance of practices, improvise and creatively reproduce and transform them" (Sefang 2010: 8 in Wilhite 2012). However, to reiterate, it is the interacting practices of going to school and doing the laundry that are driving what is happening, rather than the individual's values or preferences. Similarly, although appliances are being used and rules are being followed, they are not driving what is going on and just understanding them would not reveal the whole picture. It becomes clear that each of the loops interacts with each other one and none of them on their own has sufficient explicatory power to entirely account for energy demand.

This model deals with day-to-day performances of practices. It may seem that the images and skills in a practice evolve on different timescales to the stuff but this is not so. Each iterative performance of every practice involves the three elements being combined in different ways. It may be that the stocks go up and down at different rates but that would be possible to model. It would also be possible, though it is not discussed here, to introduce disruptions that would bring external influences to bear. So, for example, it would be possible to introduce a cultural shift in how school uniforms are worn (perhaps a policy change at the school that bans uniforms, for instance). Similarly, new stuff and skills could be introduced. It might also be possible to produce a model that looks at the evolution of trends over time in relation to all three elements (a 'meta-model') but that is not being done here for the moment.

What has been achieved?

The point of this paper was to try and map a practice as a complex system. It aimed to draw an energy demand model of practice, using simple stock and flow concepts, that describes demand from a practice point of view, taking into account the intrinsic and extrinsic demands of practices. The idea behind doing this is to help create energy demand models that offer a more realistic assessment of the flexibility of energy demand than is currently the case. Practices are difficult to draw but progress has been made. On the one hand, the recognition that using the washing machine is the result of a complex set of interacting processes is, to some extent, common sense. On the other, SPT provides a theoretical underpinning that enables researchers to characterise and so draw the broader system so as to at least have the opportunity of understanding the dynamics at work.

More specifically, SPT opens up the space for analysis and, hence, for possible interventions. Here, for example, flexibility might be understood to have shifted from the washing machine to the culture of the school (where uniforms need to be worn and therefore laundered to an appropriate standard). In other words, interventions might need to shift from the appliance (the stuff) to the culture (the image) and from one practice (laundry) to another (going to school). It is obvious that the sort of intervention being contemplated is of an entirely different order and would be the responsibility of completely different stakeholders.

Of course this insight could have been gained merely through observation and did not necessarily require a model structure of the system. However, this enables the intervention to be seen systemically and its energy value could, at least theoretically, be calculated. It is also easier to notice through the model that changing the school culture would impact on lots of performances of laundry practice and so potentially has a very large impact, whereas changing the washing machine would only alter the laundry practice of the household in which that appliance was kept. This is helpful as it enables an assessment of the size of the intervention worth making.

In trying to think about practices as complex systems, a number of lessons have been learned. First, it is possible. There have certainly been compromises on both sides but the concepts have been able to be mapped together, more or less. Second, it has been helpful to map practices because it suggests that their boundaries can be defined, at least in relation to a definite question. So, for example, the difference between doing the laundry and going to school was determined by the presence of appropriately laundered uniforms. This may seem trivial but one of the problems of mapping (or even naming) practices has seemed to be their amorphous nature. It has been similarly useful to delineate the elements, even though it was clear that they interact with each other. Third, creating a system has enabled a discussion of some otherwise slippery concepts. Using this way of talking about practices may allow them to be more easily described to engineers. Fourth, it has been necessary to think very precisely about what is circulating in an attempt to articulate this. Inevitably there will be errors and the authors welcome comments on this first attempt to do this. However, speaking in specific rather than general terms is necessary for engineers and policy makers to start to get a handle on what needs to be done and how to do it. Fifth, and discussed above, it has helped to locate where the demand in the system actually lies (both the energy demand and the demands of the practices). This suggests new interventions, made useful precisely because they are very different from what engineers would normally consider.

Conclusion

This paper has drawn together the seemingly unlikely subjects of energy demand modelling and social practice theory. In doing do, it has also discussed something of the nature of demand and, therefore, of flexibility. More significantly, however, it has made a first attempt to a create structure for an SPT-based energy demand model. Overall the exercise has been helpful. It has been realised that instead of attributing appliances to households the model needs to attribute a range of practices. The appliances can then be associated with these in order to estimate the energy that is used.

The next important step will be to produce a set of requirements both for modelers *and* SPT theorists. Modelers need to work on the structures of such models (there are no doubt others that have not been discussed here) and practice theorists need to help them understand what causes energy demand, what appliances are associated with this demand, where flexibility might lie and the size and reliability of this flexibility. This will allow increasingly viable practice-based energy demand models to be built and so enable SPT to influence the future of the UK's electricity grid.

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