Focus on electricity tariffs: experience and exploration of different charging schemes

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Abstract
There is a growing need to adjust demand to match supply in electrical networks (rather than vice versa, under the 'predict and provide' model). The move towards more dynamic pricing is part of the development of 'active demand', a way of discouraging usage when systems are under stress, and making renewable generation more viable. What is it realistic to expect from time-varying or capacity-related tariffs and associated methods of network management, including direct load control? Electricity tariffs are devised by experts but used by non-experts, and as yet we do not understand much about what different tariff types mean in terms of everyday practices.

This paper analyses material from six focus groups carried out in the UK for the ADEPT project (Advanced Dynamic Electricity Pricing and Tariffs). Householders discussed the general principle of time-varying pricing, and considered six options including a static time-of-use tariff, critical day pricing, real-time pricing, and capacity charging/load-capping. The groups were chosen on the basis of being all-electric households (1), prepayment customers (2), adopters of new technologies (solar PV, electric vehicles, heat pump) (3), customers with experience of a basic time-of-use tariff (4), and credit customers, with and without experience of switching supplier (5, 6). The emphasis was on 'workability', and on the concepts and concerns associated with different tariffs. The responses offer insights into customers' knowledge about usage and network operation. They indicate how various tariffs might work in relation to household routines, and they illustrate concerns about privacy, safety and control.

Introduction: demand response and dynamic tariffs
Electricity regulators are developing rules and standards for grids, networks, generation plant and end-use appliances that are integrated with information systems (hence 'smart'). This is partly an attempt to use traditional power generation more efficiently, and partly a response to the increased generation that is fed into medium- or low-voltage distribution networks, rather than into the high-voltage transmission grid. There is an emphasis on managing demand to match supply in real time, known as 'active' or 'responsive' demand.

Demand response is the term most commonly used to describe the ability to *reduce* demand at particular times, or to *shift* it to a time when supply is more plentiful. It is seen as having great potential value at a time when both supply mix and demand patterns are changing, and when there is pressure to decarbonise supply (e.g., Strbac et al., 2012). The adoption of demand response as a means of managing networks marks a shift from the traditional 'predict and provide' paradigm.

'Smartness' is now being extended from the transmission grid into medium-and low-voltage distribution networks, and from large industrial and commercial customers to small businesses and the residential sector. Smart meters, with their ability to collect and transmit data and to act as hubs for the remote control of appliances, are the most widely-known 'smart' artefacts. They have been a focus for policy attention, not least because they sit at the interface between customer and supplier.

In the European Union, recent recommendations on preparation for rollout of smart metering systems open with the upbeat statement that

> Smart grids mark a new development on the path towards greater consumer empowerment, greater integration of renewable energy sources into the grid and higher energy efficiency, and make a considerable contribution to reducing greenhouse gas emissions and to job creation and technological development … (EC 2012, para. 1)

The document goes on to note that smart metering systems should

> … include advanced tariff structures, time-of-use registers and remote tariff control. This should help consumers and network operators to achieve energy efficiencies and save costs by reducing the peaks in energy demand. This functionality, together with [customer feedback information, updated at least every 15 minutes] … is a key driving force for empowering the consumer and for improving the energy efficiency of the supply system. *It is strongly recommended that the smart metering system allows automatic transfer of information about advanced tariffs options to the final customers …* (ibid., para 4.2 (f), our emphasis)

and

> … *allow remote on/off control of the supply and/or flow or power limitation*. This functionality relates to both the demand side and the supply side. It provides additional protection for the consumer by allowing grading in the limitations … It is needed for handling technical grid emergencies. It may, however, introduce additional security risks which need to be minimised (ibid., para 4.2 (g)).

These extracts illustrate three issues relevant to this study: the introduction of new and more complex tariffs, the attempt to empower users through better consumption feedback and other information, and the potential for remote control of distributed supply and end-uses. These are primarily addressed using expert technical knowledge, yet electrical systems are mostly used by non-experts. This is not reflected in the research literature, which is heavily weighted towards the technical aspects of smart grids, with far less material on implementation. Yet there are many uncertainties in relation to the acceptability of different options for tariffing, control and communication. In a recent paper on acceptance of distributed generation, Maarten Wolsink comments that '… there are large expectations about smart grids, and on the other [hand] there remains a complete lack of understanding of the need for institutional change required to establish them' (Wolsink 2011, 833).

As smart grids are developed, we are seeing the end of the simple divide between 'the supply side' and 'consumers', and the beginning of more complex arrangements which require new rules and systems to be negotiated and designed. If dynamic tariffs are introduced to encourage users to balance demand with available supply, for example, what does this mean for utility billing and marketing operations, consumer protection from financial or service loss, and public education? How acceptable is increased direct load control (DLC) of heating or other end-uses, in order to allow network operators to balance loads? What safeguards or incentives might be needed to increase acceptability? How and when should smart meters be rolled out, and who will be responsible for technical standards, data security and communications? UK Department of Energy and Climate Change web pages that explain aspects of the smart metering programme to the public illustrate some of the complexity[1].

The ADEPT project addresses the question 'How complicated can, or should, a dynamic electricity tariff be?' Widespread smart metering makes dynamic tariffing feasible for all customers. But at what point might customer benefits outweigh transaction costs? Who gains and loses from different types of tariff, and what form do the gains and losses take (e.g. avoided investment in new capacity because of reduced peak demand; lower or higher bills; understanding and control of energy use)? What types of enabling technology, such as smart meters, customer displays, and remote switching, are needed in order to make dynamic tariffing work for all parties? Increases in distributed generation, plug-in electric vehicles and electric heating[2] add to system complexity, but also increase the potential for demand response in the residential sector. Hence there is a special interest in customers with all-electric households, and in those with microgeneration, heat pumps or electric vehicles. This part of the project addresses understanding, workability and equity in connection with six different tariff types, through an analysis of responses from six focus groups.

Background to the focus group research

The debate on dynamic pricing and smart grids is not yet well-joined-up, partly because of mismatches in priorities and vocabulary. In addition to the expert/non-expert divide, utilities tend to talk in terms of system optimisation, along with the potential to empower customers and reduce bills; while consumer advocates tend to focus on potential adverse consequences for customers who cannot easily change their usage patterns, on who is to pay for enabling technologies, and on privacy issues (Renner et al, 2011).

Household consumption patterns and technology adoption are affected by people's ideas of the 'good life', and by their daily routines, as well as by physical factors, and are often the outcome of negotiation between household members (e.g. Aune 2007, Caird and Roy, 2007; Stephenson et al., 2010). We started from the position that responses to changing energy systems are influenced by all these factors, rather than in the manner assumed by neoclassical economics (Biggart and Lutzenhiser, 2007). We also assumed that people interpret such developments in the light of what they learn from formal and informal sources, and from their experience as consumers, appliance users and, increasingly, microgenerators (Darby 2006, 2013). A focus on energy services can help to balance the usual emphasis on technology and economics in energy policy debates (Sovacool, 2011); and household composition and dynamics are significant when considering the potential for demand reduction or demand response (Garabuau-Moussaoui, 2009; Gram-Hanssen, 2010; Wallenborn et al., 2011).

1. http://www.decc.gov.uk/en/content/cms/tackling/smart_meters/smart_meters.aspx. The situation in the UK is unusually but not uniquely complex.

2. The three elements of demand reduction, electrification of demand and decarbonisation of supply are central to many low-carbon strategies, including the UK Low Carbon Transition Plan of 2009 and its successor Carbon Plan (2011).

Residential users in the UK contribute significantly to diurnal peak demand, but until recently there has been no compelling argument for involving them in load-shifting (Shaw et al., 2009). However, the situation is changing as more distributed generation, more electrical space and water heating, and more electric vehicles come on stream, partly because of local network management issues. Recent data show that 25 % of all Great British[3] residential usage is subject to a basic time-of-use (TOU) tariff, and much of that is controllable by some form of remote switching (Hesmondhalgh and Sustainability First, 2011). So a version of residential demand response is already in place, but we do not yet know how far it can usefully be extended and made more sophisticated.

A recent survey of 620 UK customers on these basic TOU tariffs found that their overall profile was slightly skewed towards socio-demographic groups ABC1[4] and higher household incomes. Almost three quarters of the sample were satisfied with their tariff, particularly if they did *not* use electrical storage heating. Storage heating allows customers to make the most of inexpensive night-time supply, but it has a reputation for being difficult to control, supplying too much heat in the morning and too little during the evening. TOU customers who rely on it as their main heating source are more likely to belong to social groups C2DE[4], have lower incomes, live in private rented accommodation, and to be either young or very elderly (Consumer Focus, 2012).[5] The Consumer Focus survey uncovered several concerns about TOU tariffs, mainly difficulties in understanding bills and a lack of knowledge about how to make the most of off-peak rates. There were also difficulties in understanding and operating the specialised heating systems that are often associated with the tariffs.

The UK government business case for smart meter rollout assumes that 20 % of residential consumers will adopt static TOU tariffs by 2030[6], in addition to the ~15 % who are already paying for electricity in this way (Consumer Focus, 2012). (They account for ~25 % of usage, as noted above, because they are more likely to have electric heating.) The ADEPT focus groups offered an opportunity to test the realism of this assumption, while exploring reactions to more complex tariffs in terms of day-to-day living. They also allowed us to examine another issue that is central to estimating the potential for active demand and smart grids: the acceptability of DLC. There are early indications that some residential customers are willing to allow some external control of domestic end-uses, provided it does not interfere with comfort, there is some financial compensation, they are well-informed about the nature and scope of the load control, and there is a focus on good customer service (Saele and Grande, 2011; VaasaETT, 2011; Darby and McKenna, 2012). How applicable are these findings to conditions in the UK?

3. Note that Great Britain = United Kingdom minus Northern Ireland.

4. A = higher managerial/administrative/professional. B = intermediate managerial/administrative/professional. C1 = Supervisory or clerical and junior managerial, administrative or professional. C2 = skilled manual. E = casual workers and unwaged.

5. There is now a new generation of storage heaters that may prove more acceptable, but most policy attention is given to heat pumps, which pose their own challenges with respect to carbon impact and demand response potential (Fawcett, 2011).

6. That is, tariffs which remain constant for specified times of day for long periods. They are distinct from 'dynamic' tariffs, in which the unit cost of electricity varies more randomly, in connection with wholesale spot prices.

Method

RECRUITMENT OF FOCUS GROUP PARTICIPANTS

This study is based on an understanding that energy users are members of social units, such as the household, local community, firm, or voluntary organisation, each with its own dynamics, ways of communicating, networks and routines. It also recognises that electricity users are influenced in their actions by the physical, technical and organisational possibilities open to them. For example, customers are unlikely to benefit noticeably from tariffs that incentivise storage or DLC if they have no substantial and 'shiftable' end-uses; while adoption of solar PV seems likely to make them more receptive to smart metering and associated services.

We therefore aimed to talk with customers living with different types of 'hardware', in different social situations, and with differing levels of experience of the liberalised electricity market. We decided to use focus groups rather than individual interviews in order to generate situations in which respondents could react to propositions in everyday conversational language, and in which their interactions would develop reactions to a topic (Robson, 2002). The groups were not, of course, representative of the UK population; no statistical significance can be attached to the findings from them. However, they were recruited to a standard set of criteria, in order to give gender and age balance and to cover a range of socio-economic groups, housing and tenure types. There were specific requirements for each group, as follows:

1. All-electric households
2. Prepayment meter users (likely to be on low incomes)
3. 'Early adopters' of solar PV (5), electric vehicles (2) or heat pump (1)
4. Householders in Belfast with experience of a three-band time-of-day tariff
5. Households who had switched supplier during the previous 12 months
6. Households who had not switched supplier during the previous 5 years.

Participants were recruited by two specialist agencies, and offered £35 (€43) each for taking part in a 75-minute session, or £50 (€61) for the London group. Eight members were recruited for each group, to allow for some 'no-shows'; in the event, eight took part in in every group apart from the final one, which had seven members. Recruitment, the conduct of the groups and data management were carried out in accordance with Oxford University ethical guidelines. A protocol and a selection of tariff options were piloted with colleagues before the group meetings took place during August 2012 in Banbury, (Groups 1, 2, 5 and 6); London (3); and Belfast (4). More details of the households are given in Table 1, with the exception of the Belfast group[7].

7. Recruitment here was more problematic, as it proved difficult to find customers on the TOU tariff. There are also sensitivities about demographic data in Northern Ireland, and the recruiting agency was not able to provide details. However, the recruitment criteria were the same as for the other groups. The only obvious difference between Belfast and the other groups, apart from tariff, was the gender balance.

SELECTION OF TARIFF TYPES

Three time-varying tariff 'families' can be distinguished in the literature and examples of each were selected for the investigation, giving five tariff options:

- tariffs to bring about rapid load response at times of system stress (critical peaks) – Option 2, presented as a 'day by day' tariff and based on the French 'Tempo' tariff (Crossley, 2011);
- 'static' TOU tariffs, to moderate demand at specified times when high demand routinely occurs – Option 1;
- dynamic or real-time tariffs, reflecting wholesale spot prices, and encouraging demand to follow availability of variable supply – Options 3 and 5. In Option 4, the customer is offered a cashback when buying a 'smart' appliance (directly/remotely-controllable), in return for providing demand response. This lends itself to real-time pricing, although the customer is not obliged to be on a time-varying tariff.

We also included *peak-load-related pricing* as Option 6 in our selection of tariff types. This charges customers in relation to their contracted peak demand (kW). It is relatively simple, and can reflect the costs of systems with multiple small generators better than energy-based pricing (kWh) (Gruenewald, 2011)[8]. Some combination of energy-based and capacity- or peak-load-based pricing already operates in some European countries, e.g. Norway, Sweden and Italy (Hierzinger et al., 2012; Bertazzi et al., 2005).

We selected six possible tariff types for consideration, which were presented to participants on sheets of paper, one at a time, as shown in Figure 1.

RESEARCH QUESTIONS

Specific questions addressed were:

- What types of tariff are most immediately attractive, and why?
- What are the household types and daily routines that make it likely that a customer will benefit from particular types of tariff?
- To what extent will people consider altering their practices as a consequence of adopting a time-varying tariff?
- What are the concerns raised by novel tariffs or load control arrangements?
- Is the appeal of time-varying tariffs likely to be affected by ownership of new technologies such as solar PV, electric vehicles or heat pumps?
- What do electricity customers say about awareness of their usage patterns and network management? What sort of public education might be needed in order to prepare people for more 'active demand'?

8. Note that demand response operates through energy wholesale markets and ancillary services markets, while capacity charging relates to capacity markets. There can be opposition to embarking on capacity charging as an economic framework that conflicts with that of the wholesale and ancillary energy markets. However, it arguably mirrors the logic and economics of distributed generation better, where costs are related to capacity far more than to operation.

CONDUCT OF THE FOCUS GROUPS

Each group discussion followed the same general pattern. Following the welcome and introductions, the moderator gave a brief outline of the idea of time-varying pricing, approximately as follows:

> The general idea behind this research is that electricity costs more to supply at some times than at others. That is because when the demand is high – when we have lots of machinery and lights and cookers and appliances switched on at once – extra power stations have to be switched on. And the ones that are switched on to meet this extra demand cost more to run for each unit they supply. Demand is often twice as high at six o'clock in the evening as it is at four o'clock in the morning, and it is also higher in winter than summer. It may cost 2–3 times as much to supply a unit of electricity at the busiest time of day as at the quietest. But most of us pay the same amount regardless of what time of day we are using power.
>
> If we can control the use more carefully, then the cost of supplying power can be lower than it would otherwise be, and everyone can benefit from this. To encourage this, there have already been changes to pricing in various countries, to charge low rates when it's easy to supply the demand, and more at other times (similar to rail fares.) We already have a simple version of this, with the Economy 7 tariff that gives cheap night-time electricity, but the idea is to try out other tariffs that will encourage people to switch off at peak times and move some of their use to other times.

The introduction thus concentrated on conveying the message that electricity had different value at different times of day, and on the issue of lowering peak demand. The question of adjusting demand to coincide with variable supply from renewables was raised in most groups at some point, but it was left out at the beginning, to deflect arguments about the perceived merits and drawbacks of renewable generation.

After the introduction, the moderator invited general comments on the idea of time-varying pricing. Then participants were then given six sheets of paper with the tariff options, one at a time, as shown in Figure 1. They had a few minutes in which to look at each and discuss it with their neighbour, if they wished, and then with the whole group. After each tariff type had been considered individually, participants were invited to 'vote', using red, green and yellow stickers, to show whether they would reject or accept each option, or be willing to consider it further. Finally, they were invited to comment on the reasoning behind their 'yellow' votes. Each discussion was recorded, and the moderator's assistant observed, took notes, and occasionally contributed.

Groups 3 and 4 followed this pattern, with slight variations. The members of Group 3 were recruited because they had invested in solar PV, a heat pump, or an electric vehicle, and their discussion began with each talking about their reasons for adoption of these technologies, and their experiences of them. Group 4, held in Belfast, consisted of householders who were on a three-band time-of-day tariff, and the discussion included a section in which they commented on their experiences of the tariff.

The moderator made it clear to each group that the tariff options for consideration were similar to those that had already

Time-of-use tariff: three price bands, all year round

20 p/unit
4–7 pm Monday–Friday

12 p/unit
8 am–4 pm and
7–12 pm, weekdays

12 p
8 am
–7pm
w/ends

8 p/unit
Midnight–8 am
every night

8 p
7–12 pm
w/ends

Fridge magnet reminds you about prices at different times of day. Meter measures how much you use during each period.

1

Day-by-day tariff

41 p daytime, 15 p 11 pm–8 am
22 days a year, up to 5 days at a time
(but never weekends or public holidays)

9 p daytime, 7 p 11 pm–8 am
43 days a year (but never Sundays)

6 p daytime, 5 p 11 pm–8 am
300 days a year

Display panel tells you what the current price is, and every evening it tells you whether it will the following day will be red, yellow or green.

2

Real-time (flexible) price with day-ahead notification

Price varies hour by hour, according to demand and cost of supply

Price may go high without much warning

Guarantee that you won't lose out financially. If you need to pay more than you would have done on your previous tariff for the same number of units, your supplier refunds the difference.

Hourly price is forecast each evening for the day ahead, online. You also get a text or email alert if cost is likely to go above 17 p/unit.

3

Cashback on new appliances that allow network control

You get a cashback of £20 when you buy a new washing machine, dishwasher or other appliance, provided it is enabled so that the electricity network operator can switch it off for up to 20 minutes at a time, when the network is under pressure.

Tariff could be flat-rate *or* time-of-use *or* day-by-day *or* real-time

You have a manual override switch, in case you are in a hurry when the network operator switches off your washing machine etc.

4

Real-time price with day-ahead notification and 'smart' appliances that you control

Price varies hour by hour, according to demand and cost of supply

You programme your fridge, freezer, and washing machine (maybe other appliances as well) to switch off when the price goes above a level that you choose.

You have a manual override switch, and the fridge and freezer are programmed to switch on if there is any danger of the food spoiling.

5

You pay a standing charge according to how many appliances you want to be able to switch on at once

The standing charge depends on your 'peak' load – how much you use *at once*. For example, £55 a year if you don't go above 3 kW at a time (electric kettle = ~2 kW), £85 if you stay below 9 kW, £170 below 15 kW, £425 below 30 kW.

If you go over your agreed load, then the power cuts out and you have to switch one or more appliances off. Then you can reconnect your supply using the trip switch by the meter.

A display tells you what your load is at any time, with an alarm if you are getting close to your limit.

6

Figure 1. The six tariff options presented to each participant. The backgrounds of each text box were as follows:

- *red (the potential 'downside' of the tariff);*
- *yellow ('neutral' information);*
- *green (more positive aspects);*
- *and blue (enabling technology or other support).*

been adopted or trialled elsewhere. The knowledge that the options had not been dreamed up out of thin air for this exercise seemed to encourage more serious interest in discussing their merits or disadvantages.

The moderator later transcribed the group discussions and coded the transcripts in consultation with the assistant. The transcripts were analysed, along with notes made during the discussions, in relation to the questions posed above. The votes were summarised, along with participant characteristics, as shown in Table 1.

The focus groups gave rise to lively discussions and useful insights. Most participants were engaged and interested, and several said at the end of the session that they would now look out for further developments. Some limitations should be borne in mind, though. First, participants were asked to absorb quite a lot of new concepts and information within a short time, at the end of a working day, and their questions and responses have to be understood in that light. Although we had tried to present each tariff as clearly as possible, with the colour-coding shown in Figure 1, the moderator was often asked to explain further and usually obliged. Particularly for the later groups, she would also sometimes offer a few words of 'framing' when introducing options. She should perhaps have said less and allowed the discussion to take its course more often, but judged that it was more important to keep the conversation informed and flowing in the limited time available. These framings or explanations tended to encourage more thoughtful responses (also, perhaps, more favourable responses). A second limitation of the study is the immediacy of the responses, although this immediacy is still useful as an indicator of what utilities and government can expect initially when offering new tariffs. As a couple of participants remarked, it would have been useful to return a week later and continue the discussion after a period for reflection. Thirdly, it is worth noting that the tariffs were presented in the same order to all groups. The responses will have been influenced by this.

Findings

WHAT TYPES OF TARIFF ARE MOST IMMEDIATELY ATTRACTIVE, AND WHY?

The most obvious feature of the right-hand side of Table 1 is the relative popularity of the static three-band TOU tariff: 38 of the 47 participants gave it a 'green' vote, and only two voted against it. Below, the options are listed in order of preference.

Option 1: Static time-of-use, three bands

This option was popular partly because some respondents (including all those in Group 4) already had experience of something similar, and because others had experience of the two-band tariffs that have been offered in the UK since the 1960s. It was also clear that predictability was important, as shown by this discussion comparing the relative merits of the 'critical day' and the static TOU tariffs:

> F1: I feel it's not much notice, the day before [i.e., warning of a 'red day' with option 2]. If you plan something for the next day and then you're told that evening [before] …
>
> F2: Yes … if you come home late and you're planning for the next day … and then you find when you get back and it's too late to make any change. Whereas that other one [option 1] you know, every single day, that time is our peak time … (Group 2)

Most of the uncertainty and unease about the static TOU tariff came from Group 2. They noted that the TOU tariff would be impractical for shift workers; more positively, that they would use timers on their appliances to benefit from the tariff if they became available. A woman in Group 1 also advocated timers, along with easily-visible information about price bands:

> My washing machine, my dishwasher, tumble drier, haven't got timers and those big fat timers wouldn't fit under the work surface, so I … hope that manufacturers, very quickly, would catch up and put timers on all of your appliances so that you can set them. And … if it was that clear on my refrigerator [a fridge magnet showing price bands], I would do my washing, my tumble drying, from midnight.

Option 2: Critical day pricing

The 'drama' of this type of pricing meant that it was fairly easy to understand, and also provoked some strong reactions. Chief among them was the fear of high charges at the coldest times of year; this tended to weigh more heavily than the attraction of low prices for 300 days each year. The use of displays to give day-ahead notice of prices was thought to be useful, but some participants were still uneasy about whether their supplier could be trusted to stick to the rules:

> M1: Do you want to be making your decisions the night before each time?
>
> M2: D'you have to keep a little diary to say, you know, I've had 20 ['red' high-cost days] … two left? Are you going to remember, a year later, if they charge you for 23 or 24 days?
>
> M3: Would you ever be able to check if your bill was right? (Group 5)

Option 6: Standing charge related to peak usage

The main anxiety related to the perceived threat of restrictions, such as blackouts in the middle of parties. One participant commented that the tariff seemed a bit 'third world'. There was also concern about equity, as in this woman's response:

> We have four children, we've grandchildren, often all in the house at the same time … we get visitors so the kettle'll go on … washing in the washing machine … whereas my next door neighbour is a gentleman on his own…he's got a very good pension … to be penalised because we've got a busy household … I don't think that's fair … (Group 2)

However, option 6 was slightly more popular than real-time pricing, perhaps because of its relative simplicity.

Options 3 and 5: Real-time pricing, with and without smart appliances

The rationale behind these options was puzzling to several participants, for example:

> F: 'the thing is, with this one, if you're going to guarantee you're not going to lose out … if you're going to get your money back, who cares? What's the point? (Group 1)

Table 1. Household details and attractiveness of different types of tariffs.

	Green - acceptable
	Yellow - willing to consider
	Red - unacceptable

	Age	Socio-Economic Group	Employed	Single person	Children	All-electric	Owner-occupier	Apartment = 1; terrace = 2; semi = 3; detached = 4	Prepay = 1; quarterly payment = 2; monthly direct debit = 3	Switched supplier in last year = 1; 1-5 yrs ago = 2	Owns solar PV, electric vehicle, heat pump	Option 1 (3-band static TOU)	O2 (Daily pricing. Tempo-type tariff)	O3 (Real Time Pricing)	O4 (RTP + cashback on smart appliances to allow DLC)	O5 (RTP+ programmable appliancess; user sets cut-off prices)	06 (Capacity-related standing charge)
Banbury all-electric																	
M	35	C1	FT			√	√	3	3								
M	65	C1	0		1	√	√	2	2	1							
F	46	B	FT	√		√	√	1	3								
F	44	C1	FT		1	√	√	3	3								
M	48	B	FT		1	√	√	4	2	1							
F	64	C2	PT			√	√	4	3	2							
F	49	B	FT	√		√	√	2	3	2							
M	65	B	0			√	√	4	3	1							
Banbury prepayment																	
M	40	C1	FT	√				2	1								
F	50	C2	FT		1			3	1	1							
F	57	E	0	√				2	1								
M	25	D	PT		1			1	1								
F	65	E	0	√				3	1	2							
M	24	C1	FT	√		√		1	1								
F	31	B	0		1			1	1								
F	25	C1	FT					2	1								
London																	
M	35	B	FT		1		√	4	3	2	EV						
F	41	C1	PT		2		√	3	3	1	PV						
F	39	C1	FT		2		√	3	3	2	HP						
M	47	C2	FT		2		√	4	3	2	PV						
F	48	B	FT	√	2		√	3	3	2	PV						
M	29	B	FT				√	1	3	2	EV						
F	53	C2	FT		2		√	3	3	2	PV						
M	33	C1	FT		2		√	2	3	2	PV						
Belfast																	
F																	
F																	
F																	
F																	
F																	
F																	
F																	
M																	
Banbury, recent supplier switch																	
M	50	C1	FT	√			√	3	3	1							
F	40	C1	FT	√			√	3	3	1							
M	53	B	FT		1		√	2	2	1							
F	41	B	PT		2		√	4	3	1	PV						
M	39	C1	FT	√				1	3	1							
M	55	C2	FT				√	3	3	1							
F	49	C2	FT	√			√	3	3	1							
M	43	C2	FT		2		√	3	3	1							
Banbury, non-switchers																	
F	50	B	FT		2		√	3	3		(solar thermal)						
F	45	C2	FT		4			3	3								
F	40	C1	PT		one			4	3								
M	52	C1	FT				√	4	3								
F	48	D	PT		one		√	3	3								
M	40	C2	FT		2		√	3	3								
F	46	C1	PT		2		√	3	2								
												2R	12R	29R	34R	27R	28R
												9Y	25Y	12Y	8Y	20Y	10Y
												36G	10G	6G	5G	0G	9G

F: Are they doing this because they want people to stop being ignorant of the 'price' of electricity? Like wasting water? (Group 1)

The dominant response to the real time tariffs was that they would be too unpredictable to affect peoples' behaviour; and that DLC would be too invasive to be acceptable, at least at first:

F: I think we could possibly get a bit scared about these new invasions in our life … I can remember them saying about plastic cards, that we wouldn't have money one day, and it seemed ridiculous, and with the internet … we can't live without them now … (Group 1)

Interestingly, Option 5, which offered the user more control over when equipment would be switched on and off, had a high number (20) of 'yellow' responses, although no-one voted 'green'. This perhaps reflects the experimental nature of this type of tariff. As yet, it is too technically complex for general rollout.

Option 4: Cashback offer on smart appliances

Respondents almost all agreed that £20 (€24) would not be enough to compensate them for loss of control over appliances, even with a manual override. However, a few were prepared to consider this type of arrangement, as shown in this conversation:

M: I think I'd need more than 20 quid cashback …

Moderator: About how much would you want?

M: Well, if they want to turn it off at their whim and I want to use it, they should give it to me!

F (also solar PV owner): I wouldn't have a problem with it, cashback, if it would save the country, I'd go with it. But I think you'd have to pick your appliances. A fridge wouldn't work, would it, to cut that out for 20 minutes … a washing machine, fine.

M: And it wouldn't be a bad idea if they said, you're more likely to get it [switch-off] between 4 and 7 pm … (Group 5)

WHAT ARE THE HOUSEHOLD TYPES AND DAILY ROUTINES THAT MAKE IT LIKELY THAT A CUSTOMER WILL BENEFIT FROM PARTICULAR TYPES OF TARIFF?

Several participants immediately recognised that they might benefit financially from a static TOU tariff because they are normally out of the house at peak times. They would not need to make any changes in order to do so. Another factor was the extent to which participants were relaxed about the timing of their household functions:

M: … if [Option 4, with smart appliances] is going to encourage more people to buy energy efficient appliances, then that's got to be a plus. I can't see that it makes a huge amount of difference to anyone that the dishwasher goes off for 20 minutes … if at the end of that period it's going to come back on. I think if you're going to be late for a meeting because the washing machine's going to be off for 20 minutes, you seriously need to buy more pants [laughter].

F: How about if you're in the shower?

M: That's not one of the appliances in this, is it? I mean … how often do you put the washing machine on as you go out the door to do something? So provided it's done when you get back in, it doesn't matter whether it's waited 20 minutes or half an hour. (Group 1)

TO WHAT EXTENT WILL PEOPLE CONSIDER ALTERING PRACTICES AS A CONSEQUENCE OF ADOPTING A TIME-VARYING TARIFF?

Some participants commented that they had some scope for benefiting if they were willing to make changes, because they were normally at home and had some flexibility in timing their washing. A minority said that they might make some changes, mostly with laundry and dishwashing. Cooking routines were seen as non-negotiable.

In Group 4, where all participants were on a three-band TOU tariff, their comments indicated that they had changed to the tariff mostly because it offered them guaranteed savings over their bills from their previous supplier, for at least a year. The time-of-use element was secondary: it more or less fitted with their way of life, but most of them were unlikely to make any major changes. A chef commented that the tariff suited his work patterns well, but that he might make some changes to his usage on days when he was at home:

I do three long shifts as a chef, so I'm at home four days, and I don't get home [on work days] till after 7 anyway, so [it only makes a difference] just probably on the days I'm off …

Another Group 4 participant described how the idea of going on the TOU tariff had come to her, leading to a discussion about willingness to alter routines:

I work in an office and they had a big push for reducing their usage in the evenings, because it was dearer for them … a group of engineers. So we were pushed … that at a certain period things should be turned off … flexi-working … I know that they had a generator to cover the power … it was quite a big operation … So that's what made me look to do it at home. If they were doing it and they were saving, there must be a pound in it for me too.

Mod: And did it change the way you used electricity at home too?

F1: … the way I work, I'll be up fairly early in the morning … when you're out all day, it doesn't change your routine too much …

F2: You see, I'd like to save money but the tariff wouldn't make me do things at different times, 'cause I do things that suit me [murmur of agreement] … And if I can't be bothered, I don't …

Mod: So when you went on this tariff, it didn't make any difference to you?

F2: Not to my lifestyle, no.

Faced with option 2, though, there was a clear perception that people *would* want to alter their routines on 'red' days, and Table 1 shows only 12 objections.

WHAT ARE THE CONCERNS RAISED BY NOVEL TARIFFS OR LOAD CONTROL ARRANGEMENTS?

Where the general concept of time-varying pricing was concerned, the main single anxiety was about energy services: would they be reliable? One man reflected that:

> M: People … run electricity round their lives. Whereas where we seem to be heading is, we'll run our lives round electricity … The point I'm making is, whatever the costs are, I would put … my wife'd put [laughter] the washing machine on … I don't think it would make a lot of difference to us whether it was cheaper at 8 o'clock or at 4 in the afternoon … Unless there was huge differences in the savings, costs, I don't think it would. (Group 6)

An immediate concern was that tariffs would become even more complex than they already are:

> F: When you look at your bill, you want them to say 'units cost this much and you've used this much'. That's it. Not 'We've worked this out and we're going to divide by that and … this was this-rated and we've bought this back' … So they could be literally conning us all out of loads of money … (Group 1)

> M: Are these the types of tariff the regulator's trying to get away from, where people get confused?! (Group 3)

While some participants were happy to leave appliances on while they were out of the house, or at night, several expressed some concern about possible inconvenience or danger:

> F: I don't like … having appliances on in the middle of the night, because I was told that it's a fire risk … A remote risk, but once you've been told something like that …[9] (Group 3)

A few participants were concerned about noise if appliances were running at night – more likely to be a problem for those living in small homes or apartments. Several spoke about how time-varying tariffs would affect people according to income, household size, work patterns (as shown in the comment on Option 6 above), and age:

> F: I think some of the elderly people I know, they would just be lost, trying to do something like that [Option 2] … my grandparents and that, they'd see red. They'd turn the whole thing off. (Group 6)

It is worth noting that Group 2 members (prepayment meter users, and probably the most socio-economically disadvantaged of the groups) awarded fewer 'green' votes than any other group. This appeared to be because of apprehension about the financial risk and inconvenience of time-related pricing, and relatively little experience of market participation. (Switching supplier has been problematic for prepayment meter users, and only two of the eight group members had switched during the previous five years).

The other main anxiety was about privacy ('Big Brother') and loss of control:

> F1: Isn't that [Option 4] sort of an invasion into your personal life, you know?
>
> F2: That's taking decisions out of your hands. Even though you said it's got an override switch, if you're busy doing something else … there's certain days when we'll stick the washing on and we like to get it done, washed, dried and put away, because we don't have much time. (Group 2)

IS THE APPEAL OF TIME-VARYING TARIFFS LIKELY TO BE AFFECTED BY OWNERSHIP OF NEW TECHNOLOGIES SUCH AS SOLAR PV, ELECTRIC VEHICLES OR HEAT PUMPS?

Group 3 participants were all owners of technologies that are promoted as low-carbon: solar PV (five), plug-in hybrid electric vehicles (two), or a heat pump (one). They claimed to be motivated by a mixture of financial and environmental considerations, and were happy with their choices. The owner of the heat pump commented that she used it as an air-conditioner in summer: 'that's a big advantage that you don't get with your normal central heating system'.

Asked whether ownership of PV panels affected their view of a time-varying tariff, the responses were mostly positive. Quoting from three PV owners in turn:

> F: … they [the installer] said, don't have everything going at once … use one thing at a time and then you maximise what you get out [of your panel] and then all of a sudden you become very controlled! But previously … everything was going at once …
>
> M: I'm a teacher, I'm off [i.e., on leave] for six weeks of maximum sun … Normally, we do our washing machine and dishwasher overnight, just because it's most convenient, but in the summer … if it's a nice day then yes, I'd tend to do all the bedding and all the towels … I would tend to maximise it …
>
> F: … the prices [for importing, own-generation and exporting] are so different, yeah, I think for me it's about using it while you've got it.

The EV owners were alarmed at the thought that DLC might interrupt charging at a time when they needed to use the car in a hurry:

> M: 30 minutes can give you 80 % of your battery charge, so if you really have to go out, 30 minutes is sufficient time. And if it's switched off for 20 minutes, then I have no clue … that'd be a nightmare … I do it overnight, because I'm asleep … the noise is minimal. So I wouldn't … I'd be wary if it did it this way [according to Option 4].

WHAT DO ELECTRICITY CUSTOMERS HAVE TO SAY ABOUT AWARENESS OF THEIR OWN USAGE AND NETWORK MANAGEMENT?

There was quite a hunger for better information on usage. For example, the first reaction of the Belfast group to Option 2 was to the information that customers would have a display panel in their homes:

> F: That display panel would be very interesting. Watch your current price.

9. For example, see this discussion by the UK Consumers' Association: http://conversation.which.co.uk/energy-home/unattended-kitchen-appliances-fire-risk-washing-machine-tumble-dryer/.

> F: D'you know what you're using today? … We all want to save money, but we don't actually want to have to do a whole lot
>
> F: It's why you'd want a display. (Group 4)

A few participants noticed the risk that a time-varying tariff could be self-defeating if it led to load-shifting on a large scale. For example, one of the prepayment customers pointed out, in connection with options 1 and 2, that

> If people had a display unit like that and it would pinpoint … tomorrow is going to be a 'high' day … and everybody decides that tomorrow we're going to hardly use anything, so the following day, which maybe would be [low unit prices], everyone decides, I'm going to do everything I was going to do yesterday, that would shift the usage… [and] if everyone knows that between 4 and 7 it's peak time, they're going to think right, it's 7 o'clock, we're just going to do the washing, we're just going to do the cooking, it's just going to shift it [the peak]? (Group 2)

There was quite a widely-held view that if there is a problem with supplying electricity at particular times, the responsibility lies with suppliers to put this right, along the lines of 'predict and provide':

> F: Shouldn't their focus be on providing us with cheaper electricity and new technologies rather than saying to us, eat your tea at a different time please, or use a smart meter … I'm happy to pay because I want underfloor heating. I know it's expensive, I don't need a smart meter to tell me, but please, spend your money on windfarms or tidal generating, show me you're spending your money on something that will make it more cheap in the future, not power stations that are inefficient to run [i.e., peaking plants]. In a sense, they're targeting us … (Group 1)

However, there were also signs of people developing their thinking over time, as in these conversations:

> F: Surely you can store electricity? You're saying that it's got to be windy at 6 o'clock?
>
> M: Electricity isn't stored … just manufactured about 3 seconds before we use it. So a windfarm or any tidal, whatever, can't just be switched on. But I've only learned this recently … (Group 1)

Discussion and summary

Tariff development has to take into account many aspects of electricity use, including climate, hardware, back-office practices, end-uses, information flows, regulation and daily user routines. The significance of specific types of buildings, appliances, and practices in the functioning of electrical systems is becoming very obvious, and so is the complexity of engaging with millions of end-users (some of whom are also generators), in order to provide reliable energy services while maintaining or improving system efficiency.

These focus group findings illustrate some of the issues to be considered when developing an active demand side for electricity systems. In general, they also show how acceptance of dynamic tariffs will be influenced by what occupants see as the 'core business' of their home. Financial considerations were clearly important, and participants stressed the importance of some sort of guarantee that they would not lose out from real-time pricing. But reliable, safe, controllable and timely energy services emerged as the main concern.

Most of the participants grasped the basic principles of each type of tariff, in the short time they had in which to consider. There were a few misunderstandings – for example, mistaking unit costs for cost per day, or (most often) not fully grasping the reasons for compensating people to restrict usage at certain times. But the findings demonstrate that, even in a country where electricity suppliers are viewed with scepticism or cynicism (Consumer Focus, 2012), there is a willingness to consider new tariffing possibilities, particularly if they are accompanied by accessible displays to keep customers informed. There seemed to be a widespread readiness to adopt static time-of-use tariffs. In the light of that, the government estimate of an additional 20 % of the population adopting some form of static TOU tariff seems justified, particularly given that the target date is still 17 years away. The question then becomes one of how much people would then change their usage patterns in response to a new tariff. From our respondents, it looks as though TOU tariffs are mostly adopted because they fit with existing routines or because they are seen as incidental to some other benefit, e.g. guaranteed bill savings. The TOU tariffs may then *reinforce* those load-management-friendly routines, but the signs were that most people would not make substantial changes in timing their activities, with changes mostly relating to laundry and dishwashing.

Critical day pricing and peak-load-related charging had a measure of support (around a fifth of participants) and several 'undecideds' (~50 % and ~20 % respectively). However, the focus groups also showed resistance to the perceived uncertainty and risk of real-time pricing and direct load control; this was most marked among the prepayment meter users. Beyond this sense of uncertainty and risk, there was a visceral unease about DLC and what was seen as an invasion or disruption of household decision-making. Over half of the participants gave a 'red' vote to each of the three options that involved real-time pricing even when, as in Option 3, there was a guarantee that the customer would not lose out financially. There was general resistance to complex tariffs on the grounds that they were difficult to understand and would be used to cheat customers; some participants commented that the transaction costs of more complex tariffs could outweigh the benefits.

The ownership of solar PV, electric vehicles or a heat pump seemed to be associated with better understanding of system operation, as might be expected. Interestingly, though, this group of 'transition technology' owners cast the highest number of yellow votes but the lowest number of green votes, perhaps because they appreciated that more was at stake for them than for the average customer.

These findings point to some practical considerations for developing time-varying tariffs in the UK, and also towards the educational implications of doing so. Customers need time to absorb and test new tariffs, and they need to know and respect the reasoning behind them.

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