Appendix 5.2: What is the evidence from the international experience of smart meters?

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Summary

1. This appendix surveys existing evidence on the roll-out and impact of smart meters internationally. Pilots have been run in many jurisdictions over the last 20 or so years, and there are a number of studies which aggregate and draw conclusions from their results. There have also been a small number of pilots in the UK. Mass roll-outs have been completed in a handful of jurisdictions over the last decade. This paper looks at Sweden, Italy, the state of Victoria in Australia, and the states of Texas and California in the USA, all of which have experienced substantial roll-outs. Between them these jurisdictions contain in the region of 57 million smart meters.

2. Evidence from pilot schemes is informative for understanding the impact of smart meters on energy consumption, 'peak load shifting' and programme design features.

3. The evidence from mass roll-outs is more diffuse, but can begin to give some insights on the uptake of innovative time-of-use tariffs facilitated by smart meters and on some aspects of consumer engagement.

4. The evidence reviewed below suggests the following conclusions:

- There is substantial evidence from pilots that smart meters can achieve reductions in energy use, particularly in conjunction with informational prompts such as detailed and informative billing and in-home displays. Figures in the region of those found in pilot studies in the Republic of Ireland, of 2.5% reduction in overall energy consumption from smart meters with static time-of-use tariffs in conjunction with information prompts such as in-home displays, seem reasonable.

- Pilots have shown that time-of-use pricing has the potential to lead to quantifiable and substantial peak load shifting. Estimates in the region of 3 to 10% of peak demand seem reasonable based upon a range of sources.

- The uptake of time-of-use tariffs on an opt-in basis appears to be relatively limited so far. Texas has around 12% of domestic customers on different forms of time-of-use pricing, however, as a substantial number of these were placed on these tariffs automatically, it is accurate to say that we are not aware of any jurisdiction that has more than between 5 and 12% of consumers on voluntary time-of-use tariffs. The situation in Texas is described in more detail in case study 5 below.

- Static time-of-use tariffs, such as those with daily peak and off-peak tariffs, or free evenings or weekends, appear to be the most popular variety of time-of-use tariff, with dynamic or real time pricing currently taken up in few places. An exception to this may be critical peak pricing and critical peak rebate tariffs, however, where prices or rewards for not using energy closely reflecting wholesale prices are offered during a capped number of potential stress events per year.

- Settlement practices have been changed to use more granular data from smart meters in most jurisdictions where they have been rolled out in large scale (Victoria, Australia, and Texas, USA), and may be hampering the uptake of innovative time-of-use tariffs in areas where it has not (Sweden, Italy).

- Of those jurisdictions we have spoken to, none have explained that changing the settlement system is inherently a difficult or costly process. Italy had encountered some difficulties in changing the system once in operation, but this seems likely to be related to the relatively unique technological solution for transmitting smart meter data currently used in this country.

- We have been unable to gather consistent evidence looking at indicators such as switching times, customer satisfaction scores, numbers of complaints and switching rates, which might together give an indication of smart meters' impact on overall consumer engagement. However, we are aware that smart meters have in some instances helped reduce switching times between suppliers (in Sweden and in the state of Victoria in Australia), and are likely to have helped reduce the number of customer complaints (in Sweden). We note that the number of customer complaints over the period in which smart meters were rolled out in Texas appears to have fallen, while in Victoria it appears to have risen.

- We consider that this limited ability to draw wide ranging conclusions on the effects of smart meters is largely because almost all programmes of mass roll-out are still in their infancy and because there are limited ex-post evaluations in this area.

Introduction

5. This appendix seeks to provide information on the international experience of smart meters which is of relevance for the potential remedies discussed in the Notice of Possible Remedies. In particular, this appendix also seeks to provide international evidence relevant to two hypotheses that are of interest to the investigation:

   (a) that smart meters can achieve significant consumer benefits such as energy reduction, and peak 'load shifting', where consumers use less energy during peak times of high demand and/or limited supply, but that changes in the settlement process will be needed to help achieve this; and

   (b) that smart meters may play a role in significantly improving customer engagement and the general functioning of the retail energy markets.

6. The first hypothesis is directly relevant to Remedy 13 in the Remedies Notice, the requirement that domestic and SME electricity suppliers and relevant network firms agree a binding plan for the introduction of a cost-effective option to use half-hourly consumption data in the settlement of domestic electricity meters. The second hypothesis is more broadly relevant to a range of proposed remedies: the stronger the evidence that smart meters improve

engagement in the market, for example, the stronger the case for such proposed remedies to be temporary measures until full smart meter roll-out.

7. This appendix does not aim to explore the nascent and planned roll-out in GB,[1] the details of the settlement process, or the costs and benefits of Remedy 13 in the Remedies Notice (more details of which are in Section 5 of the provisional decision on remedies.

8. This appendix also focuses on electricity smart meters and does not give much information on gas smart meters. Initial research on gas smart meters has suggested that there are fewer of this type of meter both rolled out to date and planned to be rolled out, and that there has been a much smaller body of published research and discussion in this area.

9. This appendix begins by outlining what is meant by a smart meter, and what the functionalities are that these devices can provide. The potential benefits following these new functionalities are then discussed, the coverage of smart meters internationally is set out, evidence is presented from pilots and then from full roll-outs through a number of jurisdictional case studies. Finally some conclusions relevant for the investigation are drawn.

Smart meter functionality: what are smart meters and what can they do?

10. Smart meters, or advanced meters as they are also known,[2] come in a variety of forms with a number of different functionalities. They may also be connected into wider systems with the ability to collate and distribute data, and these wider systems are frequently termed smart or advanced metering infrastructure. When combined with 'smart' elements within distribution and transmission networks, these wider systems are frequently referred to as 'smart grids'.

11. As the purpose of this appendix is to provide information to help assess the hypotheses set out in the introduction, we refer to smart meters simply in relation to the key features that have the potential to facilitate greater engagement from domestic and SME consumers in the retail electricity markets and to realise benefits through reduced energy use and load-shifting.

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[1] These are discussed in Appendix 5:1 Smart meter roll-out in Great Britain.
[2] Generally an advanced meter is defined as a meter that is at least capable of providing half-hourly electricity and hourly gas information that is remotely accessible by the supplier and to which the customer can have timely access (one-way communication). A smart meter, in addition to being able to provide half-hourly electricity and hourly gas information, is also capable of two-way communication, from the supplier to the meter and has additional functionalities such as the ability to upload and download data and providing real time information to an in-home display. See for example DECC (2013), *Smart Metering Implementation Programme, Smart Metering for Non-Domestic Customers*, p7, paragraph 1.4; and p9, Table 1. We explain some of these differences in paragraphs 12 & 13.

These features are set out and described below, preceded by a short description of traditional 'dumb' meters which are currently predominant in GB.

Traditional or 'dumb' meters

12. Traditional household or SMEs' dumb meters are simple electro-mechanical devices that measure the volume of energy consumed at a premises. This technology has existed since the 1880s[3] and is in large part a relic of the system that was in place before privatisation and the introduction of retail competition.

13. Advances over and above this limited level of functionality are described below.

One-way communication

14. A first step away from basic dumb meters involves producing meters that can be read remotely, as mentioned in footnote 2, above, meters with this functionality are frequently referred to as advanced meters. These devices monitor consumption and transmit it to a central location such as the energy retailer. This will typically be at a given interval, for example 15 minutes to an hour, or the meter may store this information and then transmit it monthly. These meters are more prevalent in areas that undertook early roll-outs of smart meters (eg Sweden and Italy).

Two-way communication

15. A second step in smart meter development involves enabling two-way communication, where energy retailers or other central agents are able to send information or commands back to the meter itself. This may achieve a number of things:

    (a) It can facilitate the provision of information to consumers, for example regarding price.

    (b) It can remotely disconnect consumers, for example if they wish to terminate their contract, change supplier or have run out of credit or not paid their bills.

[3] Public Utility Commission of Texas (2010), *Report to the 82nd Texas Legislature: A Report on Advanced Metering as Required by House Bill 2129*, p7.

(c) It may facilitate remote load control, where price or other information is sent to the customer's household to enable appliances in the house to be turned on or off, for example through connection to smart thermostats, heating, power storage devices, electric vehicles or other devices.

In-home displays

16. In addition to the smart meter itself, which is frequently a box of similar size to a traditional meter, located discretely out of view in the home or even outside of it, many smart meter systems are, or can be connected, to in-home displays. These displays allow consumers to monitor their energy use in real time. When combined with price information, which is set either in advance or which updates in real time, consumers are able to see the cost of their energy consumption in real time as well. In addition to displaying real time information, many in-home displays can be configured to allow consumers to view their stored data and analyse how their consumption and expenditure on energy varies over periods of time.

Interface with websites and other services and devices

17. The granular data produced by smart meters can be combined with other services and fed into other systems such as websites that allow households to view their energy consumption through online web-portals. These are frequently provided by energy retailers, distribution system operators (DSOs), governments or regulators. This application can be taken further by websites which allow households to download spreadsheets or other records of their energy use over periods of time and which can be used in conjunction with PCWs to allow consumers to view potential tariffs based on their past consumption patterns.[4]

Coverage

18. Smart meters of varying types have been rolled-out in a number of jurisdictions around the world, in Europe and the USA in particular.

19. These have primarily been for electricity, although gas smart meters can also be found in some areas. GB has an estimated total of 997,200 electricity smart meters and 666,200 gas smart meters in domestic properties.[5]

20. These roll-outs have been undertaken for a number of rationales. Many countries have been motivated by environmental reasons due to smart

[4] See for example the Midata programme for energy in GB and the Green Button in the USA.
[5] See DECC (2015), *Smart Meters, Great Britain, Quarterly report to end September 2015*, pp8 & 9, table 1.

meters' potential for energy reduction and load-shifting, as discussed below. Other motivations are to save the potentially substantial costs involved in manually reading meters or to be better able to cope with system stress events. Preventing fraud and underpaying of electricity bills can also be a motivation.

21. Typically earlier roll-outs have involved less sophisticated meters, for example with one-way rather than two-way communication, and without in-home displays. Later roll-outs meanwhile have more frequently had two-way communication and in-home displays or means for connecting to web-portals, smartphone apps or other means for monitoring and reacting to energy use and price fluctuations.

22. Settlement systems (the process by which suppliers' contracted positions are matched with their customers' consumption ex post) have been changed to varying degrees following the installation of meters.

European Union

23. Within the European Union (EU), the provisions of the Third Energy Package[6] required that Members States conduct a cost-benefit analysis (CBA) of rolling-out smart meters by 3 September 2012, with a subsequent roll-out if this assessment was positive. For electricity, there is a target of 80% roll-out by 2020 for Member States proceeding with a roll-out for smart electricity meters.

24. There is no European target for the roll-out of gas smart meters. However, the Retail Markets Interpretative Note states that this should happen in a 'reasonable period of time'.

25. Cost-benefit analyses were positive and roll-outs are therefore underway or being planned for electricity meters in 16 Member States. These are Austria, Denmark, Estonia, Finland, France, Greece, the Republic of Ireland, Italy, Luxemburg, Malta, Netherlands, Poland, Romania, Spain, Sweden and GB.

26. Seven Member States (Belgium, the Czech Republic, Germany, Latvia, Lithuania, Portugal and Slovakia) found negative CBA's for the large scale roll-out of electricity meters. However, Germany, Latvia and Slovakia found positive CBA's for a subset of consumers.

27. The outcome of the CBAs for the remaining four Member States (Bulgaria, Cyprus, Hungary and Slovenia) is not yet available.[7]

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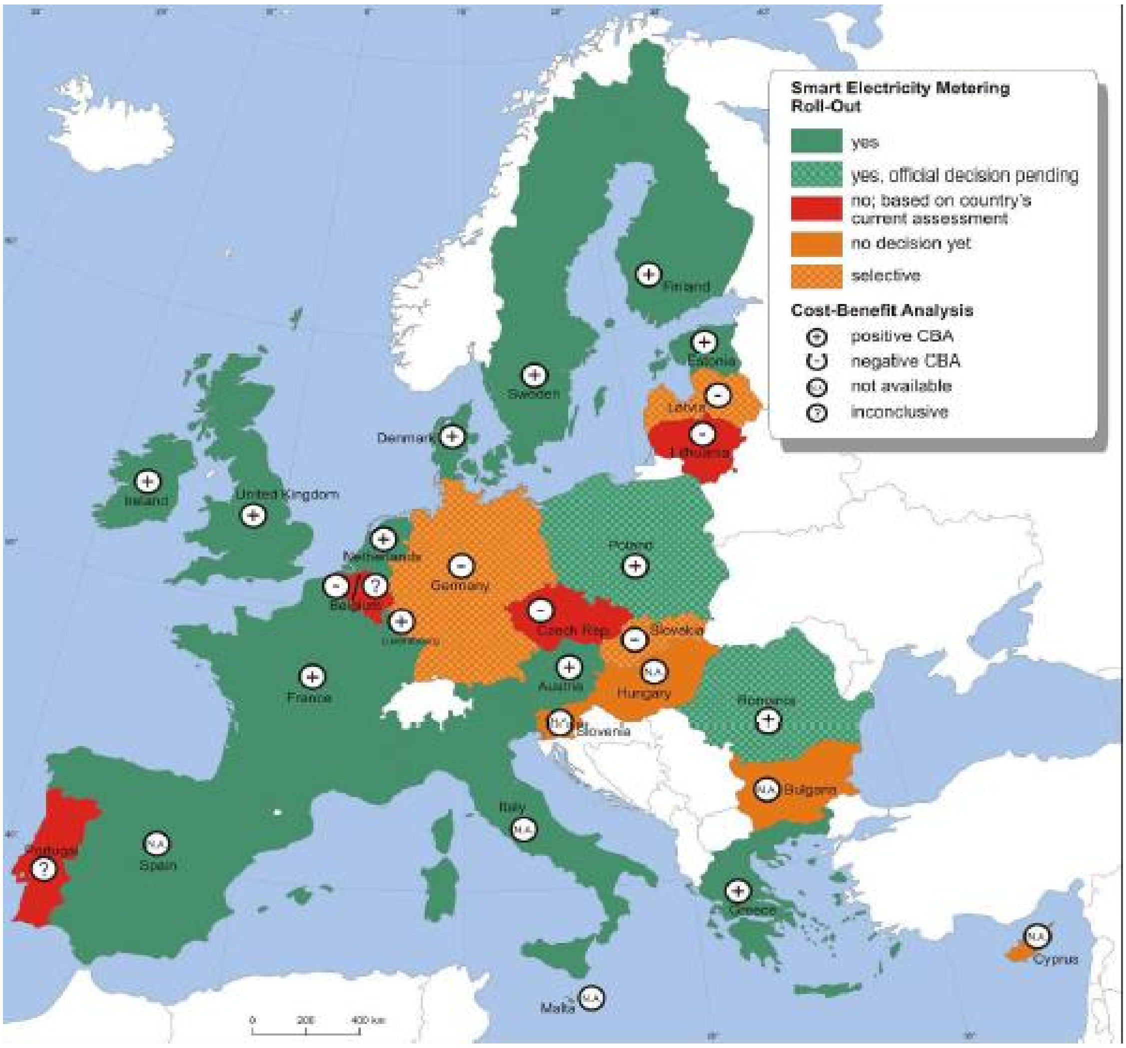
[6] Annex I.2 to the Electricity Directive (2009/72/EC) and the Gas Directive (2009/73/EC).
[7] We do not have information on Croatia as data were collected before its accession to the EU.

28. The map on the following page illustrates the roll-out intentions of the EU Member States.

Figure 1: Overview of CBA outcomes and intentions for electricity smart metering large scale roll-out (for more than 80% of consumers) in Member States, by 2020 (status – July 2013)



Source: European Commission, *Cost-benefit analyses & state of play of smart metering deployment in the EU-27 (June 2014).*

29. By 2020, it is expected that almost 72% of European consumers will have a smart meter for electricity while 40% will have one for gas.[8]

30. As of June 2014, three Member States had already largely completed their roll-outs of electricity smart meters: Finland, Italy and Sweden. These three countries had 45 million smart meters installed between them.[9] We describe

[8] European Commission, (June 2014), *COMMISSION STAFF WORKING DOCUMENT: Cost-benefit analyses & state of play of smart metering deployment in the EU-27.*
[9] European Commission, (June 2014), *Report from the Commission: Benchmarking smart metering deployment in the EU-27 with a focus on electricity.*

the roll-out and experience of Sweden and Italy in case studies 1 and 2 later in this document.

31. Only seven EU countries had committed or were intending to roll-out gas smart meters by 2020 as of June 2014. These were the Republic of Ireland, Italy, Luxembourg, the Netherlands, the UK, France and Austria.[10]

The USA

32. The USA has a significant number of smart meters, spread over multiple states and energy jurisdictions. A significant impetus to smart or advanced meter roll-out was given through the American Recovery and Reinvestment Act of 2009, which provided significant investment funding for advanced meters and grids.[11]

33. According to 2015 Energy Information Administration data, the most recent figures reported in the Federal Energy Regulatory Commission's annual Assessment of Demand Response and Advanced Metering Staff Report,[12] 51.9 million advanced meters were operational and there were 138.1 million electric meters, meaning a 37.6% penetration rate.

34. Penetration rates across the USA can be seen in the table on the following page, reported by Reliability Entity areas, which are set out in the map below the table.

35. A full list of corresponding penetration rates can be found in the following table.

Table 1: Estimated advanced meter penetration by region and customer class (2013)

NERC Region	*Customer Class*			
	Residential	*Commercial*	*Industrial*	*All Classes*
AK	5.2%	2.3%	0.0%	4.8%
FRCC	59.3%	63.2%	80.2%	59.6%
HI	22.5%	28.7%	57.5%	23.3%
MRO	18.0%	14.7%	19.9%	17.7%
NPCC	10.8%	13.7%	23.2%	11.1%
RFC	24.8%	18.0%	16.1%	24.0%
SERC	26.9%	24.0%	20.7%	26.5%
SPP	34.8%	35.8%	41.4%	35.1%
TRE	79.0%	81.4%	48.1%	79.1%
WECC	61.7%	60.4%	52.0%	61.5%
Unspecified	15.7%	17.5%	70.2%	17.0%
All Regions	37.8%	36.1%	35.2%	37.6%

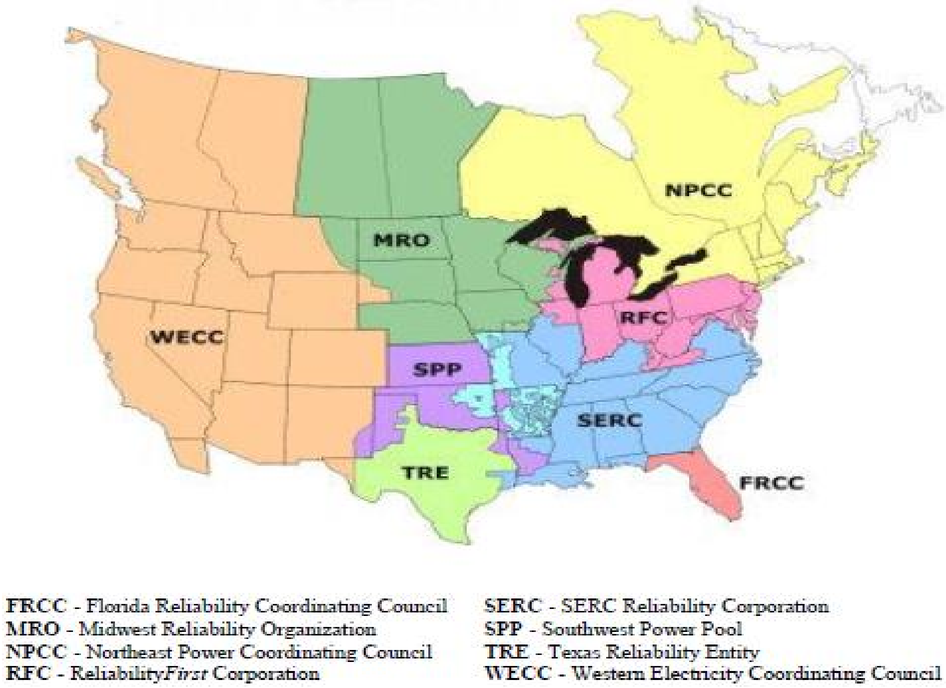
Source: EIA, 2013 Form EIA-861 Advanced_Meters_2013 data file.

[10] ibid.
[11] ibid.
[12] Federal Energy Regulatory Commission (December 2015), *Assessment of Demand Response and Advanced Metering, Staff report*.

Note: Although some entities may operate in more than one NERC region, EIA data have only one NERC region designation per entity. The 'unspecified' category represents respondents to the EIA-861 short form, which were not required to report a NERC region. Commission staff has not independently verified the accuracy of EIA data.

36. The different electricity coordinating councils can be seen on the map below.

Figure 2: NERC regions



Source: North American Electric Reliability Corporation NERC, regional entities.

37. As can be seen, as of 2013, advanced meters represented more than half of the meters in three regions: 79.1% of meters in Texas Reliability Entity (TRE), 59.6% in Florida Reliability Coordinating Council (FRCC), and 61.5% in Western Electricity Coordinating Council (WECC).[13]

38. Within these jurisdictions, we give more information in case studies 4 and 5 on smart meters in Texas and California.

39. We do not currently have information about the number of gas smart meters in the USA.

Australia

40. Outside the EU and the USA, Australia is one country where significant numbers of smart meters have been rolled out, particularly in the state of Victoria. Case study 4, below, gives more detail on this.

[13] Federal Energy Regulatory Commission (December 2015), *Assessment of Demand Response and Advanced Metering, Staff report*.

41. We do not currently have information about the number of gas smart meters in Australia.

The potential benefits of smart metering

42. Numerous potential benefits have been suggested by proponents of smart metering. These are widely reflected in the CBAs of countries that are proceeding with roll-outs and elsewhere. These cover a large array of benefits ranging from savings for suppliers from reduced home visits for meter readings to behaviour change as consumers reduce their demand or shift load to cheaper periods in response to price signals.

43. Many CBAs, such as GB's,[14] find that smart meters are cost-effective due to the 'passive' benefits they are likely to yield, for example reduced home visits for meter reading, better information for distribution [and transmission] system operators yielding savings on grid costs, savings for energy suppliers in terms of call centres and complaint costs following from errors with bill readings and grid costs.

44. We focus here on three main potential benefits frequently associated with smart meters that are more 'active' in nature, and also most relevant to the hypotheses set out at the start of the appendix: that smart meters have the potential to change the way consumers consume energy and that they may facilitate significant changes in energy retail markets. These three potential benefits are:

    (a) energy consumption reduction;

    (b) peak load shifting, made possible through the introduction of time-varying tariffs; and

    (c) increased customer engagement and consumer empowerment leading to better-functioning retail markets.

Energy consumption reduction

45. Smart meters have the potential to lead to reductions in energy consumption through a number of channels. In particular:

[14] DECC (2014), *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB): Impact Assessment*, pp14 & 15.

- Better awareness of patterns of energy use. This can be through more detailed feedback such as through bills showing daily use profiles and other methods of feedback.

- Continual salience of energy use. In particular, through in-home displays, ‘energy orbs’, web portals or smartphone apps, the potential for greater awareness through real-time monitoring of energy use and/or price may serve as a frequent reminder to conserve energy where possible.

- Learning about energy use, appliances and efficiency over time. Real-time monitoring of energy use through in-home displays, web portals and smartphone apps has the potential for consumers to learn more about the actual energy use of their appliances over time and to form energy saving habits. This benefit is shown in academic experimental evidence[15] and also by pilot studies and randomised control trials such as in the Republic of Ireland.

46. In a meta-analysis of European Member States’ CBAs, the EU JRC Science and Policy Reports’ *Smart Grid Project Outlook 2014* report found that most EU Member States assumed an average reduction of 2.6 % in total energy consumption, plus or minus 1.4%. There is an average assumption of 3% reduction in total energy consumption, plus or minus 1.3%, for the countries that have already proceeded, or are proceeding, with a wide scale roll-out of smart metering systems.[16]

47. GB’s CBA assumes annual reductions of 2.8% for electricity (credit and prepayment meters); 2% for gas credit and 0.5% for gas prepayment meter.[17]

Load shifting, made possible through time-of-use tariffs

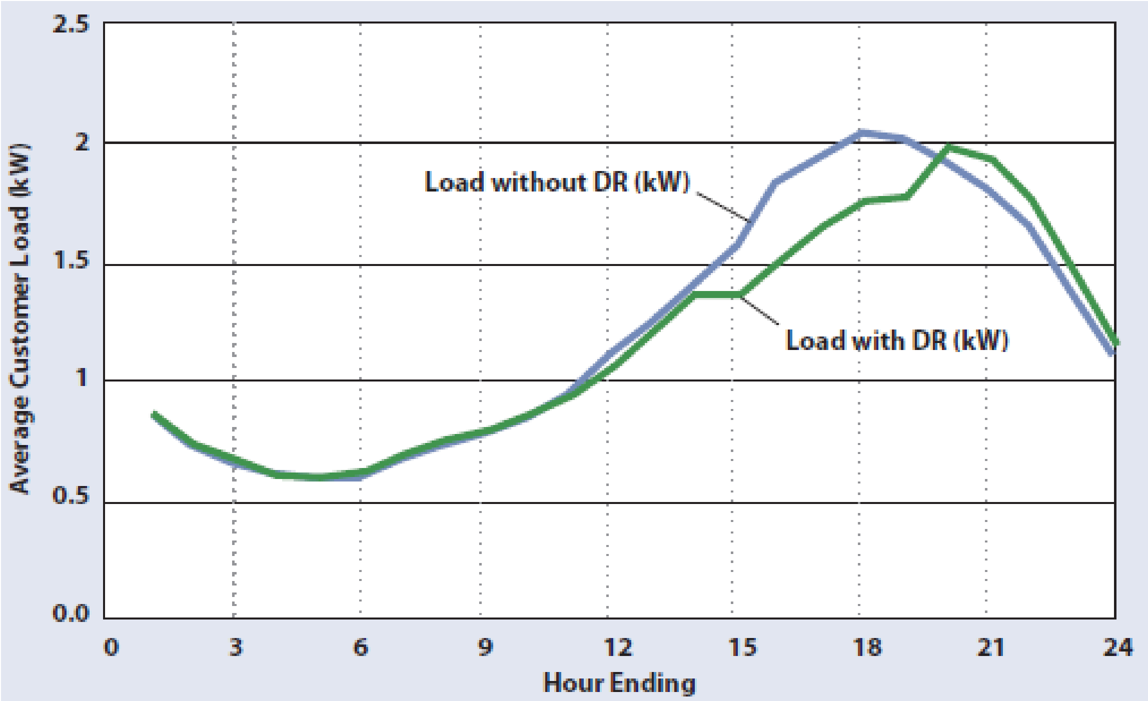
48. With time-of-use tariffs, which are discussed in further detail immediately below, comes the incentive for consumers to shift their energy consumption from periods of high price to low price, which are typically times of high demand and/or low supply.

49. This is illustrated by the altered load profile below plotted by authors from The Brattle Group 2012, *Time-Varying and Dynamic Rate Design* with data

[15] See for example: *Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use*, Jessoe, Katrina, and David Rapson. 2014, *American Economic Review*, 104(4): 1417-38.
[16] EU JRC Science and Policy Reports *Smart Grid Project Outlook 2014*, p90.
[17] DECC (2014), *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB): Impact Assessment,* p47.

compiled by Georg, Bode and Hartmann in their 2011 ex-post evaluation of Pacific Gas and Electricity Company's Time-Based Pricing Tariffs.[18]

Figure 3: Average customer load with and without critical peak pricing on event days



Source: Brattle Group 2012, *Time-Varying and Dynamic Rate Design.*

50. In this instance, a critical peak pricing tariff, explained in greater detail below and facilitated by smart or advanced meters using granular interval data, can be seen to shift consumers' load away from an existing peak, and also to flatten the profile somewhat.

51. In the meta-analysis of European Member States' CBAs, the EU JRC Science and Policy Reports' *Smart Grid Project Outlook 2014* report referred to above, EU Member States used a range of expected load-shifting of between less than 1% and 9.9 %.

52. *The Smart Grid Project Outlook 2014* considers that the variation can be mainly attributed to the different characteristics of the smart meter programmes, for example the degree to which they provide information feedback through in-home displays and/or use pricing mechanisms, and also the degree of shiftable load which is expected to be in place due to different heating systems and other patterns of appliance use.[19] Further factors that are likely to be relevant here are the ratio of peak to off-peak prices, which is

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[18] There are a number of evaluations of this programme. The most recent of which we are aware, from 2013, is available here: 2013 Load Impact Evaluation of Pacific Gas and Electric Company's Residential Time-based Pricing Programs, Final Report.

[19] EU JRC Science and Policy Reports *Smart Grid Project Outlook 2014.*

likely to be driven primarily through patterns of wholesale prices, and supplier incentives to encourage customers onto time-of-use tariffs, which is likely to be heavily influenced by settlement practices.

53. In GB's CBA, DECC's 2014 *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB) (Impact Assessment)*, does not explicitly state the percentage of peak load reduction it assumes, but states that it is in line with recent trials which found peak load reductions in the region of 3 to 10%.[20]

Time-varying, dynamic and innovative tariffs

54. A key potential benefit of smart meters is that they can facilitate the provision of a variety of tariffs that suppliers are unable to offer with traditional dumb meters. The key element of smart meters' functionalities here is the ability to record and transmit the time at which the energy was used.

55. A number of key tariffs are identified by theory and by nascent widespread use in jurisdictions where smart meters have been rolled out. These key tariffs are described in turn below:

(a) Static time-of-use tariff

Under this form of tariff consumers are billed at different rates for their consumption in different predefined time bands. For simplicity there is often a peak price and an off-peak price, with a set of times for weekdays and weekends to demark this. An example of their simplest expression is the Economy 7 tariff in the UK which provides for a lower tariff rate for seven off-peak hours. Free weekends or night times are also possible. These tariffs are designed to roughly reflect the difference in the average cost of procuring energy in the wholesale market for energy suppliers at different times. Tariffs can be tailored to closely reflect conditions of supply and demand in the relevant area. In some schemes there is also a shoulder or mid-peak period. Other schemes use a 'super-peak' for only a small number of hours in for example summer months when there is heavy demand for air conditioning in certain areas.

Moreover, these tariffs are simple and easy to understand for consumers. They also give customers a degree of certainty over the price differentials

[20] DECC (2014), *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB): Impact Assessment*, p60.

they will face, and consumers remain insulated against extreme spikes in wholesale market prices, as under traditional tariffs.

(b) Dynamic time-of-use, or real-time pricing, tariffs

Dynamic time-of-use tariffs are tariffs where prices change over time but do not do so following a predetermined pattern, as in static time-of-use tariffs. Real-time pricing is the purest example of this. A real-time pricing tariff closely matches the price paid by the consumer to the prices experienced in wholesale markets and which therefore reflects conditions of supply and demand. The price paid by the customer for their consumption at any time will closely reflect the cost for their supplier of procuring energy in the wholesale market.

Customers are usually made aware of hourly prices on either a day-ahead or an hour-ahead basis.[21] The granularity at which this can be done is determined by the granularity at which the smart meter can record the customer's usage data. It has also been noted that without automating technologies it is difficult for consumers to respond to prices at a frequent enough rate and so response to these tariffs tends to be at a less granular level.[22]

Real-time pricing essentially allows consumers to closely manage their demand and so make savings by using energy when it is cheapest, however it also exposes them to risk from spikes in wholesale market prices if they have demand which they are not able to reduce, or if they are not able to react in time.

(c) Critical peak pricing

Critical peak pricing schemes are a common kind of dynamic time-of-use tariff under which users face a lower standard tariff price for most of the year but know that during particular stress events they will face periods of particularly high prices. There is typically a limited number of events of this kind, for example up to 15 days per year, and customers are typically notified of an upcoming stress event a day in advance.[23]

Critical peak pricing tariffs have the advantage of being easy to understand for consumers. They are also effective in situations where relatively infrequent price spikes are a particular cause of concern. It has

[21] Brattle Group (2012), *Time-Varying and Dynamic Rate Design*, p15.
[22] ibid, p15.
[23] Brattle Group (2012), *Time-Varying and Dynamic Rate Design*, p14.

also been observed that these tariffs have been effective in producing load reductions at peak times.[24]

Various combinations of critical peak pricing, static time-of-use and dynamic time-of-use are possible and exist in some areas. For example where peak and off-peak hours are defined in advance, with fixed prices during off-peak, and dynamic prices during peak hours.

(d) Critical peak rebates

Critical peak rebates are a kind of dynamic tariff which are similar to, but the reverse of, critical peak pricing: during stress events customers are sent an alert, then are rewarded for any reductions in load they are able to achieve.

This tariff has advantages in that it does not expose customers to risk, and does not have any effect on prices during non-peak hours.

The key difficulty with tariffs of this form is that they require the calculation of a baseline against which the customer's consumption during the stress event needs to be compared. This is naturally difficult and prone to error.

56. The above variety of tariffs essentially allows consumers to select different risk-reward combinations. This trade-off is helpfully illustrated graphically by the Brattle Group in their 2012 report for the Regulatory Assistance Project charitable organisation in the figure below.[25] In addition to the main time-of-use tariffs explained above, the Brattle Group report also describes a number of further tariffs as follows:

- **Inclining block rate**: consumption within a given period, for example a monthly billing cycle, is divided into differently priced 'blocks', such that the first 'block' of electricity is priced at one rate, and once consumption passes a certain threshold it is priced at a higher level, and so on.
- **Seasonal rate**: consumption within different seasons is priced differently.
- **Super peak time-of-use**: a tariff where there are a small number of peak hours with a particularly big difference between peak and off-peak prices, typically only for a few months a year. This is suited to some particularly hot climates.[26]

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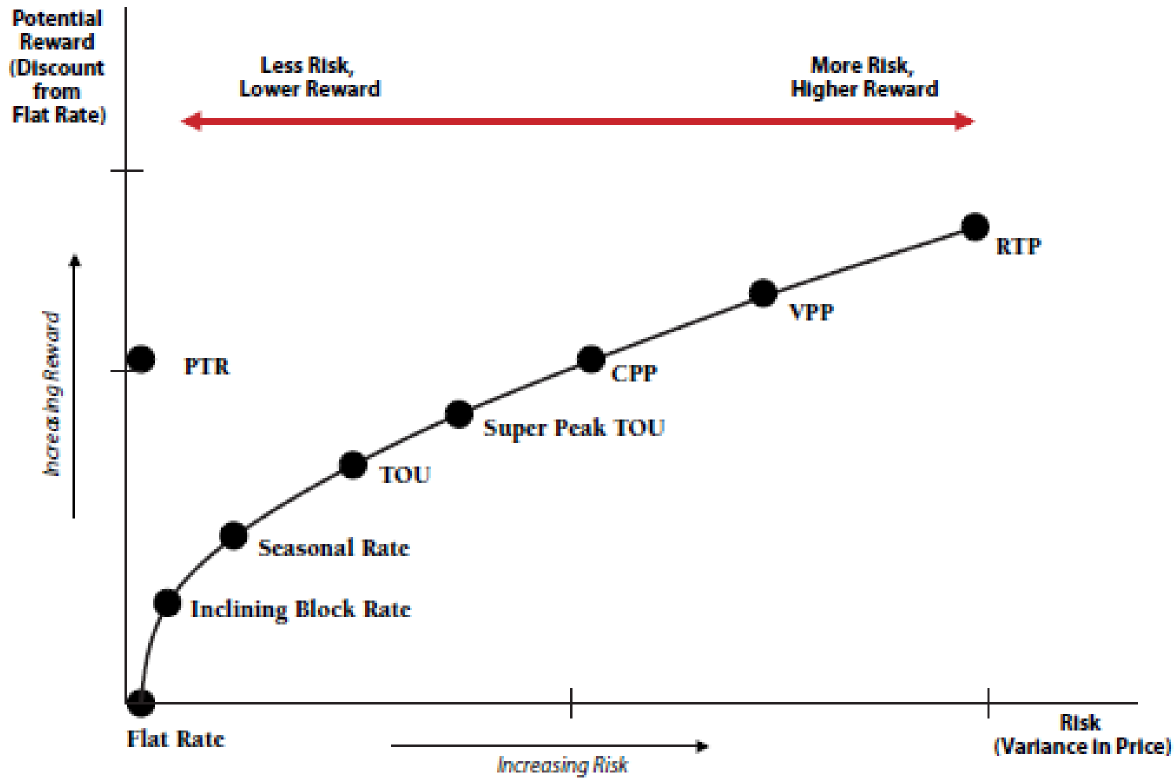
[24] ibid.
[25] Ibid.
[26] ibid, p13.

- **Variable peak pricing**: this is the same as critical peak pricing, in that there are a capped number of peak events each year, but the rate during these peak events is variable and determined by wholesale market prices rather than fixed in advance.

Figure 4: Conceptual representation of the risk-reward trade-off in time-varying rates



Key:
PTR – peak time rebates (similar to critical peak rebates)
TOU – time of use
CPP – critical peak pricing
VPP – variable peak pricing
RTP – real time pricing

Source: Brattle Group 2012, *Time-Varying and Dynamic Rate Design.*

57. As can be seen from the figure above, real-time pricing has the greatest potential for potential rewards, as savvy customers may be able to time their consumption to periods when wholesale prices are particularly low, for example on windy days when there are high levels of renewable energy on the system.

58. These tariffs also have the potential to be combined with automation technology which allows the consumer directly, or indirectly through a third party service, to set parameters by which consumption will change in response to price information, but without the consumer having to actively respond to information to achieve this. For example, in Oklahoma Gas and Electric's SmartHours Plus Programme, customers are given a smart thermostat into which they are helped input their preferences for price and

temperature, in a way that allows the thermostat to adjust energy use based on temperature in the home and price signals sent by the supplier.[27]

Increased customer engagement and consumer empowerment leading to rejuvenated retail markets

59. It appears highly plausible that smart meters may have the ability to improve the competitive dynamics of retail markets through a number of means. These primarily involve improving the customer experience in a number of small ways which cumulatively help customers to engage with energy retail markets more effectively. For example:

- More accurate billing could result in fewer complaints and greater customer satisfaction and engagement.

- Faster and more reliable switching could make moving between suppliers more easy and worthwhile.

- Greater understanding of energy use and availability of time-of-use tariffs could encourage consumers to take more interest in choosing retail offers from suppliers.

60. This general idea is reflected in the European Commission's Staff Working Document Cost-benefit analyses & state of play of smart metering deployment in the EU-27, which notes that

> The introduction of smart meters will have an impact on the competitive pressure within energy supply markets. Provision of accurate and reliable data flows due to smart metering infrastructure would enable easier and quicker switch between suppliers for both consumers and suppliers. To this end, the consumers will be able to choose from different offers that better adapt to their consumption patterns.[28]

61. However, the same document notes that as of June 2014, this impact was generally only possible to quantify qualitatively, as had been done by GB in its CBA.[29] The Netherlands meanwhile went so far as to assume that smart

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[27] OG+E – SmartHours FAQs webpage.
[28] European Commission, (June 2014), *COMMISSION STAFF WORKING DOCUMENT: Cost-benefit analyses & state of play of smart metering deployment in the EU-27*, p61.
[29] DECC (2014), *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB): Impact Assessment*.

metering roll-out could be expected to increase the number of consumers switching suppliers from 9% per year in year 2010 to 15% per year in 2050.[30]

62. While we have been able to find some evidence in this area through our country case studies, outlined below, the measures that would really reflect possible changes here are typically unavailable. For example, while we have been able to find some evidence on reductions in switching times, and of improvements in customer satisfaction, we have not been able to find evidence similar to the survey evidence commissioned as part of the investigation[31] such as the proportion of consumers with an awareness of the ability to switch, or who have ever considered switching.

Evidence on the benefits of smart meters 1: experimental evidence, pilots programmes, and randomised controlled trials internationally

63. Some of the benefits of smart or advanced meters have been analysed on limited groups of consumers numerous times through academic experiments, pilot programmes and randomised control trials.

64. Typically these evaluations focus on energy reduction and load shifting. Frequently they combine smart meter deployment with a number of design factors that may be expected to drive changes in behaviour, such as time-of-use tariffs, in-home displays with real-time feedback, and various other informational stimuli.

65. Generally these programmes find evidence that smart meters in conjunction with a combination of these measures are effective in leading to energy reductions and peak load shifting. One such trial is the Commission for Energy Regulation's (CER) 2009/10 trial in the Republic of Ireland.[32] A number of studies have aggregated and assessed large numbers of pilot schemes to analyse their results. Two of these are Faruqui and Sergici (2009),[33] of The Brattle Group, and a study funded by the European Smart Metering Industry Group.[34] There have also been four significant trials in the UK, the findings of which we summarise below.

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[30] European Commission (2014), *Smart Grid Projects Outlook 2014.*
[31] GfK NOP (2015), Customer survey report.
[32] CER (2011), *Smart Metering Information Paper 4- Results of Electricity Cost-Benefit Analysis, Customer Behaviour Trials and Technology Trials*, p16.
[33] Ahmad Faruqui and Sanem Sergici (2010), 'Household response to dynamic pricing of electricity: a survey of 15 experiments', *Journal of Regulatory Economics*.
[34] VaasaETT (2011), The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison.

The CER smart metering trials for electricity customers

66. The CER undertook a large scale, 12-month smart meter pilot between 2009 and 2010 with the aim of 'trialing a number of different smart metering enabled energy efficiency measures with a view to measuring their impact on customer consumption'.[35] This has been referred to as one of the most comprehensive and well-designed trials,[36] and similarities in climate and other regards between GB and the Republic of Ireland mean that it is likely to be of strong relevance to GB.

67. The trials involved a roll-out of 5,000 smart meters across homes and businesses, chosen to constitute a representative sample, including control groups, to allow a robust experimental design. A six-month recording period of electricity use was also used in advance of the trial in order to establish household usage benchmarks.

68. The measures trialled were static time-of-use tariffs, sending customers more detailed monthly or bi-monthly data making use of enhanced information on energy use allowed by the smart meter, in-home displays giving real time and day, week and monthly comparisons, a financial reward for reducing total energy use through an overall load incentive, a web account with detailed energy use, targeted mainly at SMEs.

69. The key findings were that static time-of-use tariffs in conjunction with the informational stimuli above were found on average to reduce domestic electricity usage by 2.5% and peak usage by 8.8%.[37] Results were smaller for the SME trials, at 0.3% overall consumption reduction and 2.2% peak reduction, although this latter set of results was not found to be statistically significant.[38]

70. As the trials were focused primarily on evaluating energy reduction potential from smart meter enabled measures, the trial did not give any evidence on customer engagement in the market. Survey evidence was, however, also collected, and 54% of participants surveyed at the end of the trial considered that the trial had made them more aware of energy usage, and 'only 18%

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[35] CER (2011), *Smart Metering Information Paper 4- Results of Electricity Cost-Benefit Analysis, Customer Behaviour Trials and Technology Trials*.
[36] Frontier Economics and Sustainability First for DECC (2012), *Demand Side Response in the domestic sector- a literature review of major trials. Final Report*.
[37] CER (2011), *Smart Metering Information Paper 4- Results of Electricity Cost-Benefit Analysis, Customer Behaviour Trials and Technology Trials*, p17.
[38] ibid, p19.

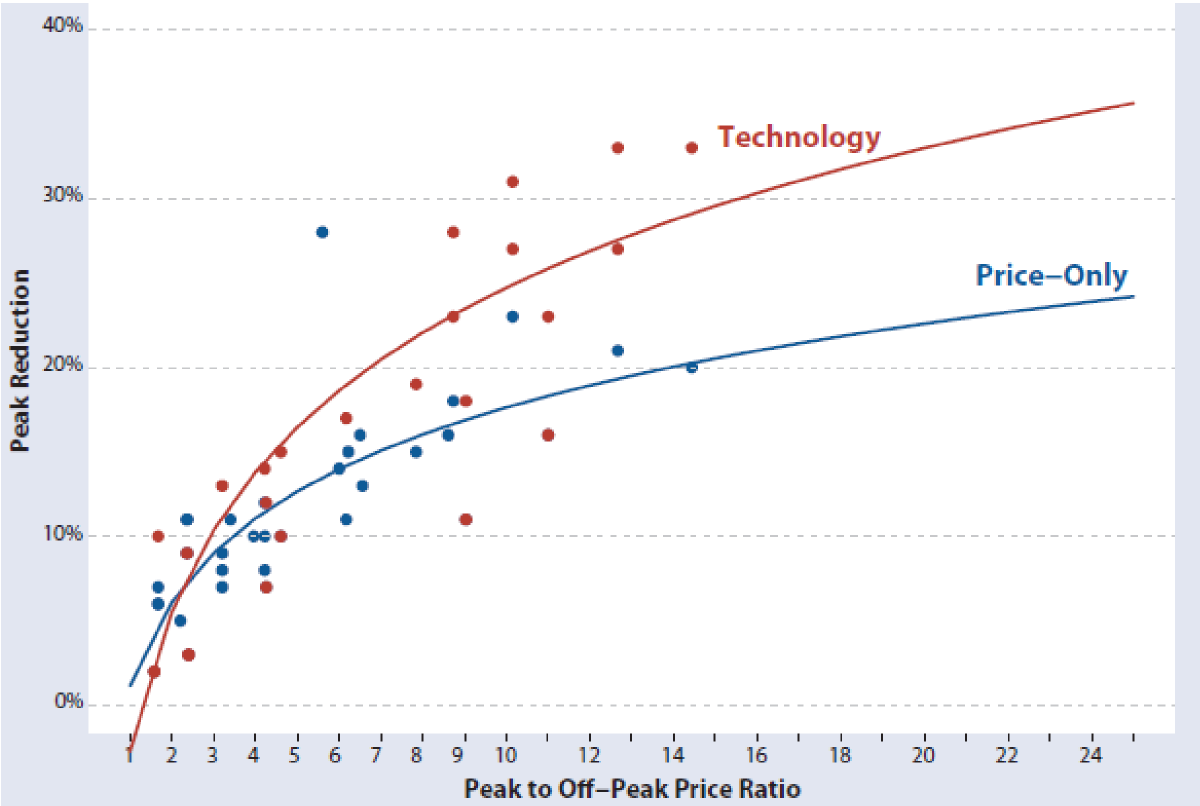
stated there had been no impact on the way their household [used] electricity'.[39]

Surveys of pilots and trials

71. A survey of 15 experiments, trials and implementations between 1996 and 2007, in the USA, Europe and Australia, by Faruqui and Sergici of the Brattle Group found that time-of-use rates could lead to a reduction in peak demand of between 3 and 6%; that critical peak pricing tariffs could lead to a drop in peak demand of between 13 and 20%; and that enabling technologies such as remotely controlled air conditioning units and other appliances in combination with critical peak pricing led to a reduction in peak demand of between 27 and 44%.[40]

72. The results of this survey are reproduced in the Brattle Group (2012) *Time-Varying and Dynamic Rate Design* graphically. This is shown in the figure below.

Figure 5: Pilot impact versus price ratio (with and without enabling technology)



Source: Brattle Group (2012), *Time-Varying and Dynamic Rate Design*.

[39] CER (2011), *Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report*, p19.
[40] Ahmad Faruqui and Sanem Sergici (2010), 'Household response to dynamic pricing of electricity: a survey of 15 experiments', *Journal of Regulatory Economics*.

73. The results are described by Faruqui and Sergici as the ‘Arc of Price – Responsiveness’, with time-of-use tariffs facilitated by smart meters leading to reductions in peak energy use. These increased with the peak to off-peak price ratio, but in a declining manner. This effect is further explored in a paper by the authors surveying the results of 126 pricing experiments, of which 74 have data complete enough to identify the relationship between the ratio of peak to off-peak prices and energy use.[41]

74. Faruqui and Sergici further found that ‘enabling technologies such as in-home displays, energy orbs and programmable and communicating thermostats boost the amount of demand response’.[42] This is demonstrated by the difference between the ‘Price-Only’ and ‘Technology’ lines of best fit in the figure above.

75. The authors of the study funded by the European Smart Metering Industry Group conducted a 2011 survey of about 100 pilots involving smart meters and covering over 450,000 residential consumers. These pilots were broken down by their different sample groups to give 460 samples, which were then categorised according to 22 variables related to the structure of the pilot and the external factors that might influence its outcome. Ensuing analysis allowed the designers to assess ‘feedback programmes’ in which informational measures were used to give customers better information on their energy use, and ‘pricing pilots’ were time-varying tariffs such as static time-of-use tariffs, critical peak pricing, critical peak rebates and real-time pricing were used.

76. The study found that there was considerable potential for information feedback to reduce energy consumption, with measures such as in-home displays, detailed invoices and webpage feedback giving significant energy savings. These are illustrated graphically, along with the number of trials involved, below.

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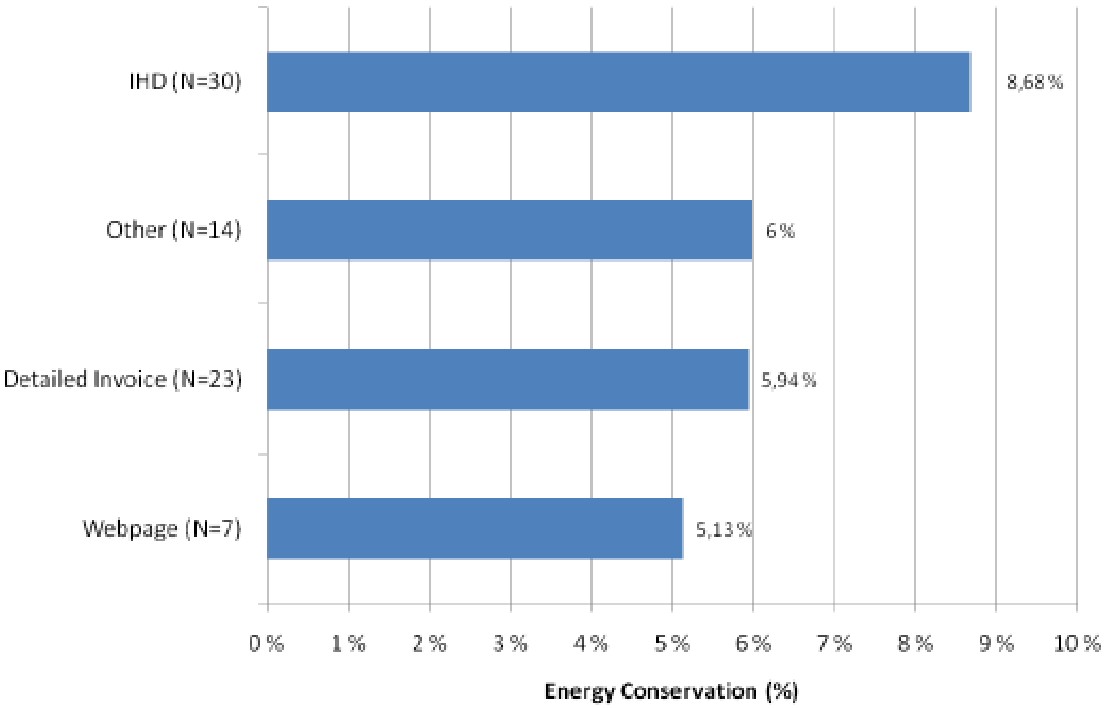
[41] A. Faruqui and J. Palmer (Brattle Group) (2012), *The Discovery of Price Responsiveness – A Survey of Experiments involving Dynamic Pricing of Electricity*.
[42] ibid, p1.

Figure 6: Overall consumption reduction as per feedback pilot type

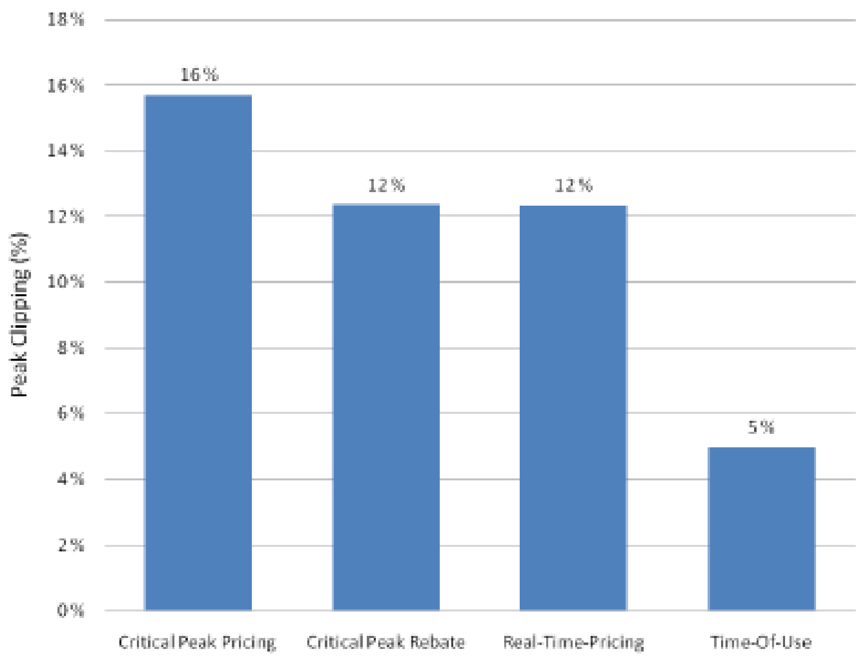


Source: VaasaETT (2011), *The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison*.

77. The study found that there was also considerable potential for load shifting, referred to as 'peak clipping', from these tariffs, with average load shifting (excluding the effects of automation, or remote load control) of between 5 and 14%, with critical peak pricing being the most effective tariff in this area.[43] This is shown in the figure below.

[43] VaasaETT (2011), *The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison*.

Figure 7: Dynamic pricing's potential for peak clipping



Pilot type	Sample size
TOU	N=215
CPP	N=69
CPR	N=16
RTP	N=15

Source: VaasaETT (2011), *The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison.*

78. A further key conclusion of the study is that socioeconomic factors and understanding consumer needs in different areas were crucial to programmes' success or failure. This is summarised in the report as follows:

> During piloting, there can be a technological focus or a preconceived opinion that the technology is what decides program success. Our findings challenge this focus. **The central difference we found between pilot success and failure is the ability of the program designers to meet consumer needs through the demand side program.** Meeting a need is the foundation of consumer engagement and thereby of a program success. The technology is the enabler within this value chain. Therefore, unless a technology is equipped to act as a support to consumer engagement, it will not create savings or improve systems efficiency. Smart meters fulfil their potential due to the fact that they can support consumer engagement to a market-appropriate level through feedback and dynamic pricing and/or home automation.[44]

[44] VaasaETT (2011), *The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison*, p3.

Evidence of load shifting from major trials in the domestic electricity market in the UK

79. Only four major trials have been conducted in the UK, three with static time-of-use tariffs and one with a dynamic time-of-use tariff.

80. Evidence from these trials is mixed but it appears to suggest that domestic customers respond to economic incentives to shift electricity demand away from peak times. A response to time-of-use tariffs was observed in all four trials but some results hold only for a subgroup of households in the control group and others may not be statistically significant.

Table 2: Evidence from trials in the UK

Trial	*Year*	*Number of participants*	*Average reduction in peak demand*	*Tariff type*
Energy Demand Research Project Trials	2007-10	194 (EDF) 1,352 (SSE)	Varied- up 10%	Static time-of-use
Northern Ireland Powershift trial	2003-4	100	Small reduction	Static time-of-use
Customer-led Network Revolution trial	2012-13	574	1.5%-11.3%	Static time-of-use
Low Carbon London residential Demand Side Response trial	2013	922	Varied (4-10%)	Dynamic time-of-use

Source: CMA analysis.

81. The Energy Demand Research Project consisted of two time-of-use trials – EDF and SSE.[45] Both trials looked at the application of a time-of-use signal accompanied by an in-home display. In the SSE trials participants also received some combination of monthly bills with graphs and web information.

82. Estimates of the magnitude of the shifting effect varied by trial but were up to 10%.[46] The EDF trial showed that the effect was stronger with smaller households (one or two people).[47] Load shifting in the SSE trial was smaller than for the EDF trial.

83. A shift in demand away from peak was also observed in the Powershift trial.[48] The trial consisted of 100 prepayment consumers on a time-of-use tariff, and an additional control group of 100 prepayment consumers with a flat rate tariff.

[45] AECOM (2011), *Energy Demand Research Project: Final Analysis*.
[46] Frontier Economics and Sustainability First for DECC (2012), *Demand Side Response in the domestic sector- a literature review of major trials. Final Report*, pp53–54.
[47] The EDF trial found that a time-of-use tariff reduced weekday evening peak demand approximately by 11%, for households with less than three occupants. See Frontier Economics and Sustainability First.
[48] The trial tested a time-of-use tariff with low, medium and high price periods. The hours of operation for these differed between weekdays and weekends. See Gill Owen and Judith Ward, Sustainability First (2007), *Smart meters in Great Britain: the next steps? Paper 6: Case studies*.

Consumers on the time-of-use tariff experienced lower consumption at peak periods relative to the control group. However, it is not clear whether this result is statistically significant.[49]

84. More encouraging results emerged from the Customer-Led Network Revolution[50] project, which trialled a time-of-use tariff scheme[51] in a control group of 574 domestic users between October 2012 and September 2013.

85. On average, when compared to users in the control group, customers on the time-of-use tariff had lower consumption during the peak period, between 1.5% and 11.3% less than the control group, on weekdays, and higher consumption at other times.[52]

86. More recently results from the Low Carbon London trial on a dynamic time-of-use tariff have been published by researchers at Imperial College London.[53] The trial consisted of a treatment group (922 households) which opted to receive a dynamic time-of-use tariff[54] and a control group (3,437 households). Both groups were considered to be representative of the London population. The treatment group was exposed to two types of trial events:

(a) Constraint management: these events aimed to measure the potential for dynamic time-of-use demand response to relieve distribution network constraints by incentivising households to reduce their consumption at peak times through a high electricity price coupled with a low price in the surrounding hours.

(b) Supply following: These events probed the response of households to simple high or low price signals of varying duration.

87. Results from the trial show that consumers changed their electricity consumption in reaction to changes in electricity prices. Over the year, 95% of

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[49] Consumers in the trial group, who mostly had low incomes, were found to benefit from the lower off-peak prices in the time-of-use tariff passively (that is, without having to change their behaviour), as a lot of their electricity use was already at off-peak times. See Frontier Economics and Sustainability First for DECC (2012), *Demand Side Response in the domestic sector- a literature review of major trials. Final Report*, p50, paragraph 89 and p38, paragraph 69.

[50] Customer-led Network revolution. Insight Report: Domestic Time of Use Tariff. A comparison of the time of use tariff trial to the baseline domestic profiles.

[51] Electricity prices were higher during the weekday peak period (4pm-8pm) throughout the year and lower in off-peak periods. See Customer-led Network revolution. Insight Report: Domestic Time of Use Tariff. A comparison of the time of use tariff trial to the baseline domestic profiles, p3.

[52] Customer-led Network revolution. Insight Report: Domestic Time of Use Tariff. A comparison of the time of use tariff trial to the baseline domestic profiles, p3.

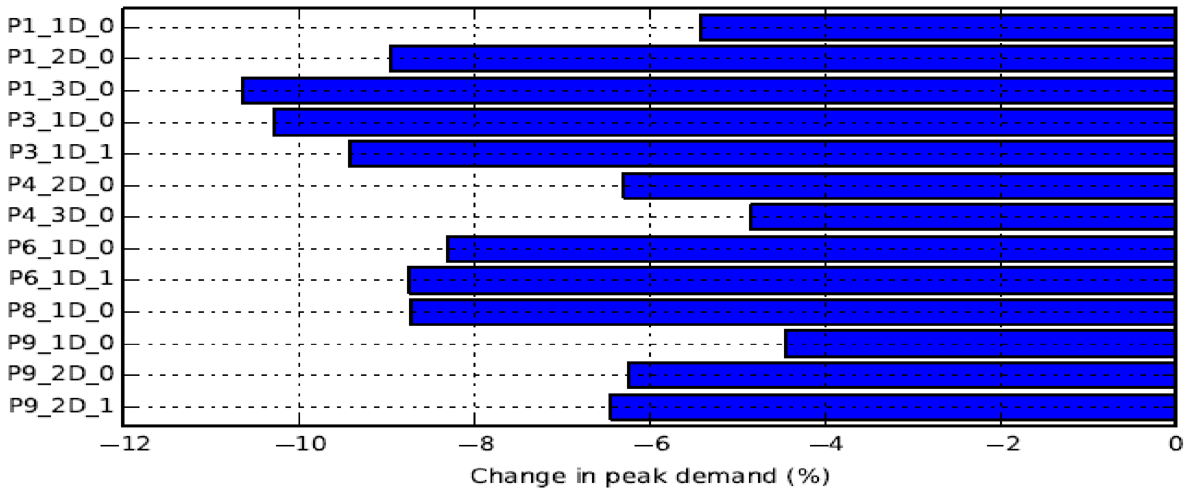
[53] J. J. Schofield, R. Carmichael, S. Tindemans, M. Woolf, M. Bilton, G. Strbac,'Residential consumer responsiveness to time-varying pricing', Report A3 for the "Low Carbon London" LCNF project: Imperial College London, 2014.

[54] Tariff prices were given a day ahead via the smart meter in-home display or text messages. Customers were issued high (67.20p/kWh), low (3.99p/kWh) or normal (11.76p/kWh) price signals and the times of day these applied. All non-time-of-use customers were on a flat rate tariff of 14.228p/kWh. See Report A3 for the "Low Carbon London" LCNF project: Imperial College London, 2014, p32.

households in the treatment group saved money relative to what they would have spent had they been on the standard flat tariff of the control group.

88. Consumers reacted to constraint management events by reducing demand by an average of 0.05kW/household during peak hours. Overall peak demand was reduced by approximately 5 to 10% across the dynamic time-of-use group.

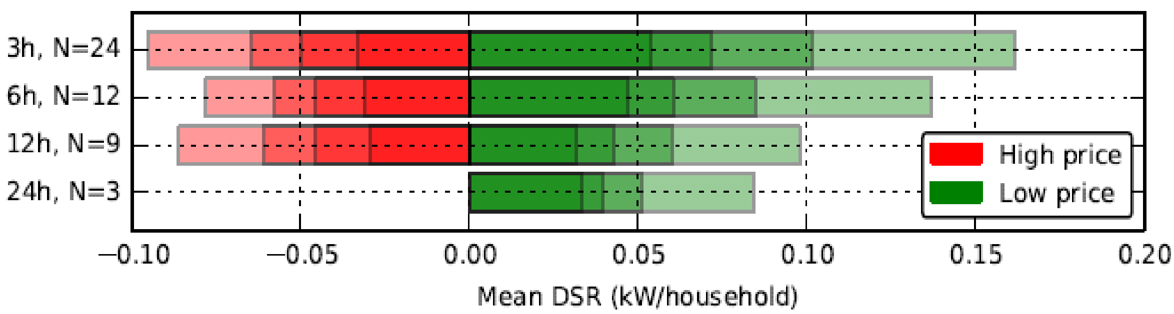
Figure 8: Peak demand change over the high price period of the constraint management events



Source: Low Carbon London LCNF project: Imperial College London, 2014.

89. Customers also responded to supply following events showing a mean reduction in consumption of approximately 0.03kW/household for all households.

Figure 9: Effect of event duration on demand responses



Source: Low Carbon London LCNF project: Imperial College London, 2014.
Notes:
1. N is the number of events.
2. Bars from lighter to darkest shading represent the average for subgroups of the most engaged 25%, 50%, 75% and 100% of households in the control group.

90. Across all trials and household, Imperial College London estimated that the high price signal resulted in a decrease in demand of 0.04kW/h and the low price signal resulted in an increase of 0.03kW/household.

Consumer attitude to time-of-use tariffs

91. Researchers at University College London used two major nationwide surveys to measure consumer demand for a range of demand-side response tariffs in GB[55]. Two interesting results emerged from their work:

- Almost a third of people indicated they were in favour of switching to a static time-of-use tariff.
- People who were currently on a legacy time-of-use tariff (such as Economy 7) were consistently more likely to say they would switch to the next-generation static time-of-use tariff than the general population.

Evidence on the benefits of smart meters from full-scale roll-outs

92. In addition to trials and pilots, we have examined the experience and effects of a number of large scale roll-outs. Both sources of evidence are likely to have strengths. Pilots and trials are able to incorporate control groups, which allow for a clear counterfactual to be established. Mass roll-outs are more secure against risks that trials or pilots may have limited external validity due to opt-in biases or biases as households in the sample know their behaviour is being observed.

93. The case studies below examine the roll-outs in Sweden, Italy, the state of Victoria in Australia, and the states of Texas and California in the USA. These have been informed by conversations with regulatory or government officials in these areas as well as desk-based research.

94. For each case study, we have endeavoured to set out the background of the roll-outs, the functionalities of the meters installed, whether there have been changes to the settlement system, the impacts in terms of energy consumption, peak load shifting and the uptake of time-of-use tariffs, and the impacts in terms of factors relevant to consumer engagement.

95. While evidence from mass roll-outs has the potential to be highly informative for the effects of GB's future roll-out, we have found that there is frequently limited available evidence on the key indicators we are interested in. We consider this is largely due to the recent nature of many roll-outs, and a lack of ex-post evaluations.

[55] UCL (2015), Is it time? Consumer attitudes to time of use tariffs.

Case study 1: Sweden

Background

96. Initial thinking regarding smart meters began in Sweden in 2002, with surveys and viability assessments. In 2007 a law was passed which mandated at least monthly meter readings for domestic customers and hourly meter readings for large non-domestic customers by 2009. This requirement led to the roll-out of advanced meters for all Swedish customers, to avoid the high costs of reading traditional meters manually on a monthly basis.

97. The key years of the roll-out were between 2003 and 2009, affecting 5.2 million meter points.[56] Meters were installed by the circa 1,600 DSOs in Sweden.

98. The Swedish energy market has retail competition, with around 125 suppliers currently active.

99. In 2013 it became a legal requirement that any customer who wishes to have hourly metering is able to do so. A pre-condition is that the customer has a supply contract that needs hourly metering.

Meter functionalities

100. There are a variety of different levels of functionality of the smart meters in Sweden. This is primarily because the legislation that drove the roll-out did so by mandating a minimum of monthly meter readings, and did not at the same time specify the nature of the smart meters that might be used to achieve this. 90% of these meters do, however, have the capacity to transmit hourly data, although many may not be connected to the relevant communications infrastructure to be able to do so more frequently than at monthly intervals.

101. For the same reason, in-home displays do not come as standard with smart meters in Sweden.

Changes to settlement

102. Sweden currently uses monthly settlement between retailers and wholesalers, which is in line with the standard monthly reading of meters mentioned above.

[56] European Commission (2014), *Commission Staff Working Document: Country fiches for electricity smart metering*.

103. It is considered possible that this arrangement may be a factor limiting incentives for retailers to encourage consumers to take up granular time-of-use tariffs. Uptake of these tariffs in Sweden is discussed below.

Outcomes – energy use, load shifting and take up of time-of-use or innovative tariffs, customer engagement

104. Energy use in Sweden has fallen in recent years, including since the roll-out was completed in 2009. However, it is not considered possible to attribute this directly to smart meter roll-out due to other confounding factors.[57]

105. We are not aware of any evidence on peak load shifting.

106. There has been some development in terms of tariffs which make use of the data that comes from the smart meters. In particular:

- Around half of customers are on tariffs for which energy prices vary monthly. This is likely to follow the pattern of monthly settlement practice where energy suppliers are charged based on the sum of electricity consumed by their customers each month.

- Take-up of more granular time-of-use tariffs has been limited. Hourly time-of-use tariffs are only being used by around 8,600 household customers of 5.2 million customers, which is 0.17%.[58]

107. A key reason for the limited take up of more granular time-of-use tariffs, in addition to limited incentives for suppliers to encourage this, due to the monthly settlement pattern, is considered likely to be because the savings from these tariffs have been small due to low wholesale energy prices in Sweden for the last two to three years.

108. Switching rates do not appear to have changed considerably over the period smart meters were rolled out. In 2004 household switching rates were 5%, in 2009 they were 11.5% (when the smart meter roll-out was finalised) and in 2014 they were 10.1%.[59]

109. The roll-out of smart meters has, however, allowed a reduction in the time taken for customers to switch between retailers. Previously the customer could only switch on the first day of the month, and either the customer or the DSO had to manually read the meter at this time. The procedure now that

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[57] See Statistics Sweden – Electricity supply and use 2001–2014 (GWh).
[58] We understand that the number of larger consumers on time-of-use tariffs is much higher. Hourly metering for non-household customers has also been in place for a longer period of time.
[59] All data is from the Swedish Statistics Bureau.

smart meters have been rolled out is that customers can switch any day of the month and the switch takes a maximum of two weeks.

110. It is also considered that the roll-out of smart or advanced meters has led to a reduction in complaints to energy companies and regulators regarding billing, and has increased consumer satisfaction, although there is not a significant degree of data available on this.

111. Data on the number of complaints received by the Swedish Energy Markets Inspectorate is available in the period since October 2013. The trend in the two full years for which data are available, 2014 and 2015, shows a reduction in complaints, with 1,846 and 1,506 complaints respectively.[60] However, we consider this data is too limited to draw substantial conclusions.

Case study 2: Italy

Background

112. The roll-out of smart or advanced meters for low voltage customers began in 2000, when Enel Distribuzione, the national DSO that distributes electricity to around 85% of Italian customers, began to roll out smart meters voluntarily. This was supported by a regulatory agreement allowing cost recovery of around €70 per meter.[61]

113. Between 2001 and 2006, Enel Distribuzione therefore rolled out smart meters to almost 85% of all Italian customers, constituting around 31 million meters.[62]

114. In 2006, it was mandated that all low voltage meters across Italy should be replaced by smart meters. This led to the replacement of the remaining 15% of meters as well as the full completion of the Enel Distribuzione roll-out.

115. The retail market was opened to competition for household customers and SMEs in 2007, although approximately 70% of domestic customers and 50 to 60% of small businesses might still be on a default tariff (universal supply regime) based on ex-post wholesale prices.

116. From 1 July 2010, the Italian Authority for Electricity and Gas approved the entry into force of a mandatory time-of-use tariff. It was mandated that smaller low voltage customers (mostly domestic) should be metered according to

[60] Data are complaints received by the Swedish Energy Markets Inspectorate.
[61] The same amount that was already embedded in the tariff system of traditional meters.
[62] A few Enel Distribuzione customers received a smart meter later than 2006.

three time bands: on-peak, off-peak and intermediate, while larger low voltage customers should me metered on an hourly basis.

117. Domestic customers in the universal supply regime are billed on two time-band prices (peak vs intermediate and off-peak); while SMEs are billed according to three time-band prices: peak, intermediate and off-peak. The time-of-use mandatory requirement does not apply to customers in the ‘free market’.

118. We understand that Enel Distribuzione and all other suppliers operating in the free market are therefore able to offer tariffs that compete with the default regulated tariff to smaller low voltage customers, but they are not able to use any more granular time-of-use data than that of the three time bands of peak, off-peak and intermediate. Competition is therefore on aspects such as price and service quality, rather than offering particular time-of-use tariffs.

Meter functionalities

119. Smart meter roll-out began particularly early in Italy. The meters have limited elements of two-way communication.

120. The communication means used by the meter involves sending signals along the electricity power line, which limits the amount of information that can be transmitted.

121. There are some very small display components on the meter, but these are not typically visible in the home, and display only the current energy use and not the current price or value of consumption. A pilot involving advanced meter displays has been recently completed on a small scale and the regulator is now considering how to deploy such functionality on a larger scale.[63]

122. As the typical lifespan of a meter is 15 years, it is currently being considered what the desirable functionalities are for the next generation of meters.[64]

Changes to settlement

123. Settlement is done on the basis of the two or three time-band blocks upon which customers are billed, the data from which is aggregated on a monthly basis.

[63] AEEGSI, consultation paper 186/2015, www.autorita.energia.it/allegati/docs/15/186-15.pdf
[64] AEEGSI, consultation paper 416/2015, www.autorita.energia.it/allegati/docs/15/416-15.pdf

124. It is currently being considered whether it would be advantageous to move to hourly settlement for all customers.

Outcomes – energy use, load shifting and take up of time-of-use or innovative tariffs, customer engagement

125. The introduction of a mandated time-of-use tariff led to a small reduction of about 1% in peak consumption over the period 2010 to 2012.[65] Two reasons appear to have prevented a larger shift occurring:

(a) Consumption during off-peak hours was very slightly above the 'indifference threshold' even before the introduction of the time-of-use tariff as households' electricity consumption per capita in Italy is very low relative to many other countries.[66]

(b) The price signal conveyed to the customers was low in comparison with time-of-use tariff experiences in other countries, due to the tiny price difference between peak and off-peak hours. We understand the advancement of solar PV has significantly reduced the difference between peak and off-peak prices, to the region of typically only 15%.

126. The overall savings achieved by all the residential customers on the time-of-use tariff in the period July 2010 to June 2012 have been estimated by an independent research centre (RSE)[67] at around €6.45 million. However, the change in the behaviour of the Italian users has not been negligible as 60% of the restricted customers have moved their consumption according to the price signal provided by the time-of-use tariff. There has been no development of more granular time-of-use tariffs following the introduction of smart meters. Indeed, it has been observed that many customers would in fact prefer less granular and non-time dependent (ie flat rate) tariffs that retailers are able to provide in the free market.

127. There has been no particular impact on switching rates. However, as smart meters were largely rolled out before retail competition was introduced, there is no obvious basis for 'before and after' analysis.

128. It is considered, however, that customers have become more aware of their energy use, and in particular the relatively cheaper prices during some time bands (nights and holidays).

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[65] 22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013), Impact of the enforcement of a time-of-use tariff in Italy. Maggiore, S. ; R.S.E. SpA, Italy ; Gallanti, M. ;Grattieri, W. ;Benini, M.
[66] See Eurostat, Households consumption of electricity per capita, MWh per capita, 2013.
[67] RSE website, 'About Us' page.

Case Study 3: Victoria

Background

129. Victoria's smart meter roll-out began in 2009 and was effectively completed at the end of 2013. There are currently 2.8 million meters installed.

130. Victoria is part of the Australian National Electricity Market wholesale electricity market for the electrically connected states and territories of eastern and southern Australia.

131. Victoria introduced full retail contestability in 2002, and removed retail price regulation on 1 January 2009. By June 2014 Victoria had the largest number of active retailers selling to small customers in Australia, at 20. It also has high switching rates of around 30% per year.

132. Victoria is described by the Australian Energy Market Commission as being a 'test-bed' for energy retailers to develop new products, partly due to the prevalence of smart meters.

Meter functionalities

133. The Victorian meters are two-way devices that can transmit data at half-hourly intervals.[68] They do not come with in-home displays as standard, but a number of retailers and distributors have customer portals and apps that allow users to connect and monitor their usage and manage their bills more effectively. The meters may also have the potential to allow remote load control, but this is not happening at present.

134. In 2013, the Victorian government launched a price comparison website which includes all generally available retail offers. This website, called Victorian Energy Compare, was previously known as My Power Planner.[69] Victorian Energy Compare allows users to upload smart meter data to the site, but can also be used without meter data. The functionality that allows users to upload their smart meter data is considered to be one of the first of its kind globally. In late 2015 the tool was updated and now incorporates the ability to compare gas and solar offers in addition to electricity. Since this site was originally launched in 2013, it has received over 350,000 unique visits.

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[68] Department of State Development, Business and Innovation (2013), *Minimum AMI Functionality Specification (Victoria)*.
[69] See the Victorian Energy Compare website.

Changes to settlement

135. The settlement system in Victoria has changed following the roll-out of smart meters. Wholesale settlement remains ‘settlement by differences’, however, since the roll-out of smart meters, all second tier[70] retailers’ loads are settled on the interval data from smart meters, rather than via load profiling as previously occurred. We understand that settlement now occurs predominantly through the use of interval data and not load profiles.

Outcomes – energy use, load shifting and take up of time-of-use or innovative tariffs, customer engagement

136. Due to the relatively recent roll-out of smart meters, significant analysis of benefits realisation has not yet been possible.

137. The most recent public assessment is by the Victorian Auditor-General. The findings were of benefits realisation below the expectations at the outset of the programme. For example, the report considered that market research conducted in 2014 found that two-thirds of Victorians did understand what the benefits provided through smart meters were, and that many were still unaware of their ability to help minimise energy bills.[71]

138. No significant information on energy use reductions or peak load shifting was available.

139. A relatively small number of customers are now on time-of-use tariffs, however. After around 18 months since this became possible, around 10,000 customers have taken up flexible pricing (around 0.4% of total meter points). This has been in particular a three-part time-of-use tariff with a government and industry agreed network structure, which was introduced in September 2013. A number of other innovative static time-of-use tariffs such as AGL Energy’s ‘AGL Free Power Saturdays’ (free electricity all Saturday) and Dodo’s ‘Hour of Power’ (free electricity between 6am and 7am every day) are or have been offered.

140. While this take up has been moderate, based on the Victorian government’s analysis, flexible pricing offers are being priced increasingly competitively by retailers.

141. There have been some benefits in terms of customer engagement. In particular, Victoria is now considerably ahead of other Australian states in

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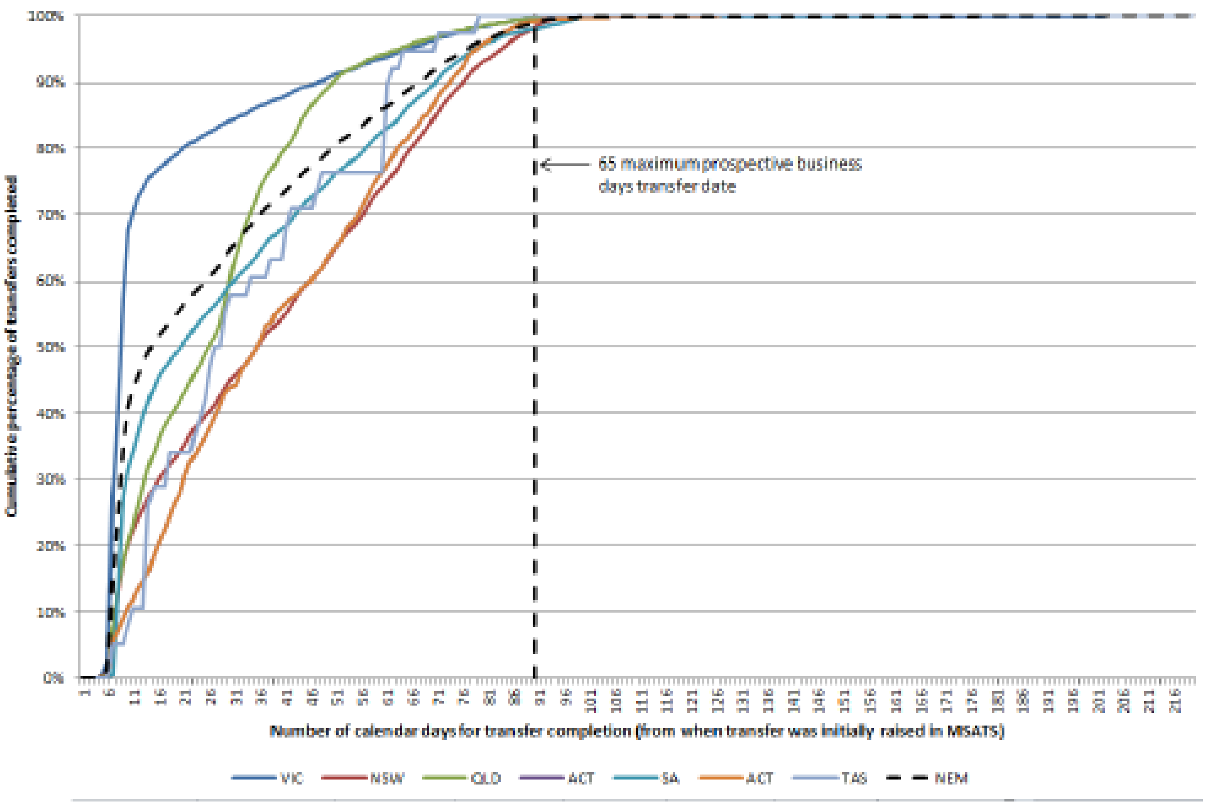
[70] Second tier retailers are retailers that are not incumbents, meaning that they were not assigned franchises in the period up until 2002. These retailers make up a significant proportion of the market.
[71] See Victorian Auditor-General (2015), *Realising the Benefits of Smart Meters*.

terms of times for customer transfer between suppliers when switching, with over 70% of switches completed in around nine days. These relative switching times are demonstrated graphically in the figure below.

Figure 10: Cumulative percentage of customer transfer completions in a certain number of calendar days



Source: Australian Energy Market Commission (2014), *Review of Electricity Customer Switching Final Report*, p20, Figure 4.3.

142. The same review considered that this lead by Victoria was largely attributable to smart meters.[72]

143. Switching rates are high in Victoria, at around 30% per year, and have been trending slowly up over the last three years. Smart meters have not been directly linked to this, however.

144. Data on number of complaints to retailers do not suggest a trend of growing satisfaction with the market, with complaints rising from 0.7 per 100 customers in 2005/06 to 9.4 in 2013/14. We note that these figures do not yet include the latest reporting year (2014/15).

[72] Australian Energy Market Commission (2014), *Review of Electricity Customer Switching Final Report*.

Table 3: Complaints received by energy retailers in Victoria, 2005/06 to 2014/15

	2005/06	*2006/07*	*2007/08*	*2008/09*	*2009/10*	*2010/11*	*2011/12*	*2012/13*	*2013/14*	*2014/15*
Electricity retailer complaints (per 100 customers)	0.7	0.8	1.0	2.3	2.1	4.2	4.6	6.6	9.4	n/a

Source: Essential Services Commission, *Energy Retailers Comparative Performance Report – Customer Service, reports 2009/10 to 2013/14.* References for this data series are Energy Retailers Comparative Performance Reports (2009-10, 2010-11, 2012-13, 2013-14).
Note: Data includes billing, marketing, transfers and 'other' complaints.

145. Data on the number of complaints received by the Victorian Energy and Water Ombudsman show a similar trend, although we do note that the number of electricity retail complaints has fallen by a considerable 44% in the last year for which data is available (2014/15).

Table 4: Complaints received by the Victorian Energy and Water Ombudsman, 2005/06 to 2014/15

	2005/06	*2006/07*	*2007/08*	*2008/09*	*2009/10*	*2010/11*	*2011/12*	*2012/13*	*2013/14*	*2014/15*
Electricity retailer complaints (total)	-	11,904	14,994	23,398	25,534	32,973	42,025	51,344	55,160	30,730

Source: Victoria Energy and Water Ombudsman, *Annual Reports, 2011 and* 2015.
Note: Data includes billing, marketing, transfers and 'other' complaints.

Case study 4: Texas

Background

146. Texas began its roll-out of smart meters following the passing of the House Bill 2129 by the 79th in 2005 Texas Legislature. This bill encouraged the implementation of smart metering by directing the establishment of a non-bypassable surcharge for a utility to recover costs incurred deploying smart meters and associated infrastructure.[73]

147. Large scale roll-out began in 2008/09 and we understand has been largely completed. As of early 2015, 6.7 million smart meters were in service in the Electric Reliability Council of Texas' (ERCOT)[74] areas that have retail competition. These areas account for 75% of load in Texas, the remaining

[73] Public Utilities Commission of Texas (2010), *Report to the 82nd Texas Legislature – A Report on Advanced Metering as Required by House Bill 2129*.
[74] The Electric Reliability Council of Texas operates the electric grid and manages the deregulated market for 75% of the state.

areas being served by municipalities with default tariffs and electric cooperatives that have not chosen retail competition.

Meter functionalities

148. To qualify for cost-recovery surcharges, meters must:

(a) supply automated meter readings, with two-way communications;

(b) have the ability for the meter to supply real-time access to energy usage to customers and energy suppliers; and

(c) record and store data at 15-minute or shorter intervals and be able communicate with load control devices within the home.[75]

Changes to settlement

149. ERCOT began settling suppliers and wholesalers on 15-minute data from smart meters in December 2009. It was mandated that ERCOT should be able to use 15-minute data for all smart meters no later than 31 January 2010. Accurate settlement was one of the key rationales for the roll-out of smart meters.

150. ERCOT currently settles 97% of its load in competitive areas with 15-minute interval data.

Outcomes – energy use, load shifting and take up of time-of-use or innovative tariffs, customer engagement

151. There is currently little available evidence in terms of evaluation of the results of the Texas roll-out for energy reduction and peak load-shifting. However, we understand publications are expected in 2016.

152. Interesting developments have, however, taken place with regard to innovative tariffs and their uptake. In particular, in 2014 there were:

- 290,328 residential customers enrolled in static time-of-use tariffs, including 'Free Nights' and 'Free Weekends';

- 410,765 enrolled in peak time rebates tariffs; and

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[75] Public Utilities Commission of Texas (2010), *Report to the 82nd Texas Legislature – A Report on Advanced Metering as Required by House Bill 2129*, p15.

- 16,676 enrolled in real-time pricing tariffs.[76]

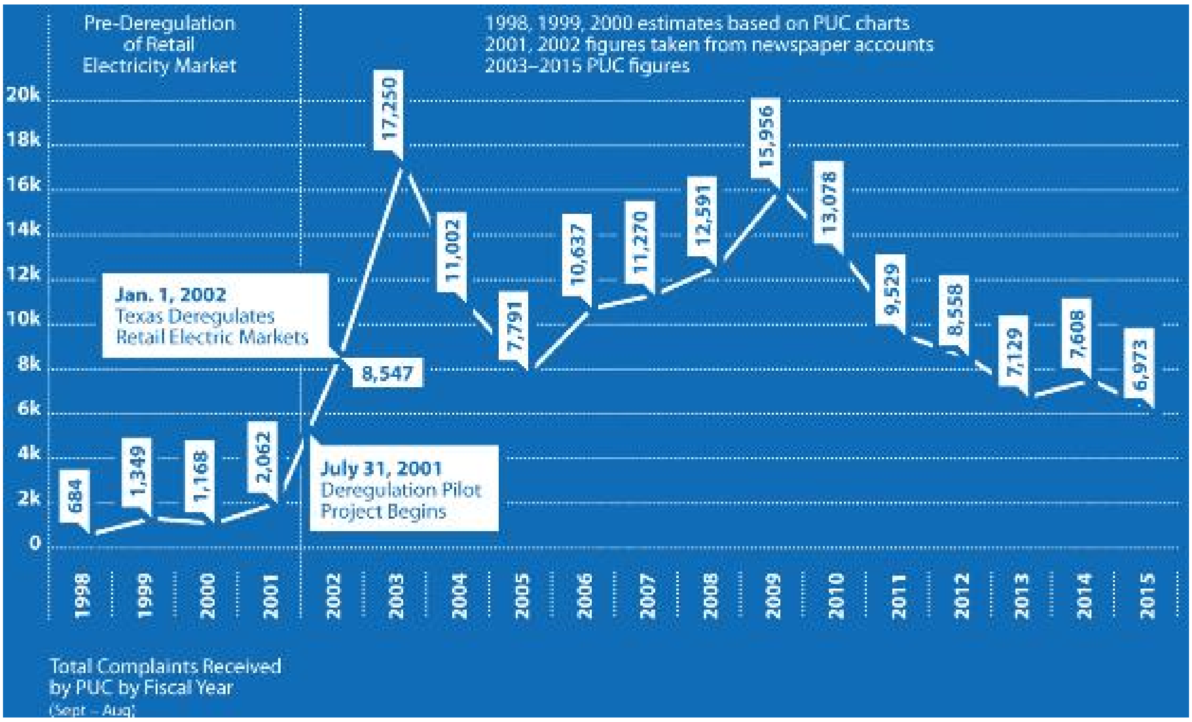
153. In total this represents around 12% of residential customers enrolled in tariffs with some kind of incentive for demand response. It is, however, important to note that these figures may be subject to measurement error, and that of those on the peak time rebates tariffs, a large proportion were opted in automatically. Excluding all customers on the peak time rebates tariffs would mean 4.6% of customers had opted onto a time-of-use tariff. It is therefore reasonable to say that between 5 and 12% of customers have opted onto one of these tariffs.

154. These customers have also not been subject to any peak events since this has happened.

155. We are not aware of any significant evidence of the impacts of the smart meter roll-out on customer engagement other than number of complaints.

156. Complaints data from the Public Utility Commission of Texas sources, compiled by the Texas Coalition for Affordable Power,[77] shows a trend of complaints falling over the period since large scale roll-out began in 2008/09. This is shown on the following chart.

Figure 11: Total electricity-related complaints or inquiries received by the Public Utility Commission of Texas, 1998 to 2015.



[76] Paul Wattles, Senior Analyst, Market Design & Development (2015), *Retail Smart Grid Trends*, UT Energy Week: 'How Smart Grids Enable Consumers'.
[77] A non-profit corporation pooling the buying power of 170 cities and other political subdivisions in Texas.

Source: Texas Coalition for Affordable Power (2015), *Snapshot Report: 2015 PUC Complaint Data*.

157. This trend in terms of complaints may suggest a positive trend for customer engagement with the market, but it is not possible to conclude on the impact of smart meters in this regard.

Case study 5: California

Background

158. Electricity in California is predominantly distributed and supplied to end-use customers by three large investor-owned utilities, the Pacific Gas and Electric Company, commonly known as PG&E, Southern California Edison, or SCE Corp, and San Diego Gas & Electric, known as SDG&E.

159. Retail prices are set through regulatory proceedings and there is no retail competition.

160. Around 2002, these companies began to develop and have approved business cases to allow them to recover the costs of smart meter roll-out over a five-year period. These business plans were approved and roll-out followed soon after. PG&E and SCE Corp completed their roll-out between around 2008 and 2012, and SDG&E completed theirs between 2011 and 2012.

161. PG&E has installed around 5.1 million smart electricity meters, SCE Corp around 5 million and SDG&E 1.4 million, giving a total of around 11.5 million meters installed in California by these three major utility companies.[78]

162. Prior to smart meter roll-out, meters were physically read monthly. Savings from eliminating these costs, as well as load reduction, were key motivations for the roll-out.

163. Customers are currently placed by default on monthly inclining block rates, where the price of additional energy consumption rises as various thresholds are passed in terms of consumption during the month. As noted below, this is soon set to change, with all customers due to be moved on to more granular time-of-use tariffs of some form, on an opt-out basis, from 2019.

[78] The Edison Foundation Institute for Electric Innovation (2014), *Utility-Scale Smart Meter Deployments: Building Block of the Evolving Power Grid, IEI Report September 2014*.

Meter functionalities

164. The meters rolled out in California are capable of two-way communication, and of interacting with websites and third party systems for allowing consumers to view the volume and cost of their energy use in real time.

165. It was not mandated that meters should come with in-home displays, partly because it was hoped that markets would develop to deliver these and other third parties would provide systems such as smart thermostats and remote load control. The development of markets and uptake in these areas has been limited however, for example with little remote load control currently in use.

Changes to settlement

166. As California has no retail competition and retail tariffs and prices are set through regulatory proceedings by the California Public Utilities Commission the question of reforms to settlement is much less relevant.

Outcomes – energy use, load shifting and take up of time-of-use or innovative tariffs, customer engagement

167. While we do not have systematic information summarising the experience of mass roll-outs in California, we do have some information on particular companies' programmes, for example as can be found in the *2013 Load Impact Evaluation of Pacific Gas and Electric Company's Residential Time-based Pricing Programs Final Report,* submitted by Nexant for PG&E.

168. The report states that as of 1 April 2014, PG&E had three time-based tariffs in operation, although only two were open to new enrolment. The first of these tariffs was a critical peak pricing tariff, while the second two were time-of-use tariffs, with peak, off-peak, and in one case partial peak prices. The critical peak pricing tariff had 119,000 customers enrolled by the end of 2013. The two static time-of-use tariffs had 97,000 customers enrolled in total.

169. On the eight stress event days called under the critical peak pricing tariff in 2013, which was in some cases combined with the static time-of-use tariff, an average load reduction of 44.2 MW was achieved. This was equivalent to between 13 and 19% load reductions.

170. The static time-of-use tariffs also produced significant peak load reductions on stress event days, although the methodology in the report highlights that these may be subject to considerable error.

171. With respect to the uptake of time-of-use tariffs more broadly, it is considered that numbers in this area have been relatively small, and that the major

utilities do not face significant incentives to encourage customers to move on to these tariffs. As of April 2015, only 3.4% of PG&E's residential customers were on time-of-use tariffs, while SCE Corp and SDG&E had only 0.52% and 0.6% of customers on these tariffs.[79]

172. It is interesting to note that for this reason the California Public Utilities Commission has in July 2015 issued a decision[80] which will mandate that starting in 2019 all customers will be moved onto time-of-use tariffs on an opt-out basis. This is expected to provide in the region of 3 GW of demand response in peak times, out of a total peak demand of around 48 to 50 GW, therefore constituting around 6% of peak load. It has not yet been decided what exact form of time-of-use tariff might be used for this purpose.

173. We are not aware of any significant information regarding changes in indicators of customer engagement in California following the roll-out of smart meters, although we are aware that there were some initial difficulties in some areas that may have led to a rise in complaints.

Conclusions

174. The evidence reviewed above suggests the following conclusions:

- There is substantial evidence from pilots and trials to suggest that smart meters can achieve reductions in energy use, particularly in conjunction with informational prompts such as detailed and informative billing and in-home displays. Figures in the region of those found in pilot studies, such as in the Republic of Ireland, of 2.5% reduction in overall energy consumption from smart meters with static time-of-use tariffs in conjunction with information prompts such as in-home displays, seem reasonable.

- Pilots have shown time-of-use pricing has the potential to lead to quantifiable and substantial peak load shifting. Estimates in the region of 3 to 10% of peak demand seem reasonable based upon a range of sources.

- The uptake of time-of-use tariffs on an opt-in basis appears to be relatively limited so far. Texas has around 12% of domestic customers on

[79] *DECISION ON RESIDENTIAL RATE REFORM FOR PACIFIC GAS AND ELECTRIC COMPANY, SOUTHERN CALIFORNIA EDISON COMPANY, AND SAN DIEGO GAS & ELECTRIC COMPANY AND TRANSITION TO TIME-OF-USE RATES,* CPUC, July 2015. p29.
[80] *DECISION ON RESIDENTIAL RATE REFORM FOR PACIFIC GAS AND ELECTRIC COMPANY, SOUTHERN CALIFORNIA EDISON COMPANY, AND SAN DIEGO GAS & ELECTRIC COMPANY AND TRANSITION TO TIME-OF-USE RATES,* CPUC, July 2015.

different forms of time-of-use pricing, however as a substantial number of these were placed on these tariffs automatically, it is accurate to say that we are not aware of any jurisdiction which has more than between 5 and 12% of consumers on voluntary time-of-use tariffs.

- Static time-of-use, such as those with daily peak and off-peak tariffs, or free evenings or weekends, appear to be the most popular variety of time-of-use tariff, with dynamic time-of-use or real-time pricing currently taken up in few places. An exception to this may be critical peak pricing and critical peak rebate tariffs, however, where prices or rewards for not using energy closely reflecting wholesale prices are offered during a capped number of potential stress events per year.

- Settlement practices have been changed to use more granular data from smart meters in most jurisdictions where they have been rolled out in large scale (Victoria, Australia, and Texas, USA), and may be hampering the uptake of innovative time-of-use tariffs in areas where it has not (Sweden, Italy).

- Of those jurisdictions we have spoken to, none have explained that changing the settlement system is inherently a difficult or costly process. Italy had encountered some difficulties in changing the system once in operation, but this seems likely to be related to the relatively unique technological solution for transmitting smart meter data currently used in this country.

- We have been unable to gather consistent evidence looking at indicators such as switching times, customer satisfaction scores, numbers of complaints and switching rates that might together give an indication of smart meters' impact on overall consumer engagement. However, we are aware that smart meters have in some instances helped reduce switching times between suppliers (in Sweden and in the state of Victoria in Australia), and are likely to have helped reduce the number of customer complaints (in Sweden). We note that the number of customer complaints over the period in which smart meters were rolled out in Texas appears to have fallen, while in Victoria it appears to have risen.

- We consider this limited ability to draw wide ranging conclusions on the effects of smart meters is largely because almost all programmes of mass roll-out are still in their infancy and because there are limited ex-post evaluations in this area.