# House of Commons Science and Technology Select Committee inquiry on Smart Meters

Response to the inquiry, 22 April 2016

This evidence is submitted by the Royal Academy of Engineering. As the UK's national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering.

The evidence in this response was assembled from reports published by the Academy and our partners and through consultation with our Fellows. These include experts in smart meters, the energy system, consumer behaviour, digital systems and cybersecurity from industry and academia.

**Evidence—from existing smart meters and behavioural science—on how smart meters can be expected to affect consumer behaviour, including in terms of reducing energy consumption and buying more energy efficient products, and how levels of engagement with In-Home Displays change over time**

1. In July 2015, The Royal Academy of Engineering, Arup and ESRC published *Built for living: understanding behaviour and the built environment through engineering and design*[1], which explores how the interplay between people and the designed environment affects a number of areas including the use of energy. It reviews relevant research (although not systematically). The report discusses and cites evidence on the following:

2. A range of factors affect behaviour and need to be considered to ensure the impact of any intervention is maximised[2] - the need to develop behavioural strategies is one conclusion in DECC's smart meter early learning project[3]. Factors include contextual and motivational factors, as well as habitual behaviour. In the case of smart meters, contextual factors include, for example, the ease with which residents can respond to energy use feedback such as manipulating heating controls, the nature of information on smart meters and measures to reduce energy use supplied to consumers or the availability of energy-efficient products.

3. The design and operation of in-home displays and other technologies for feeding back energy use to consumers influences their effectiveness in changing behaviour. Expertise is useful from fields such as ergonomics, human factors and human-computer interaction, along with emerging fields such as persuasive technologies and pervasive computing. For example, it is argued that the human-computer interface (HCI) community should work closely with environmental psychologists[4] to ensure that the design of in-home displays is considered alongside behavioural models.

[1] Royal Academy of Engineering, Arup and ESRC (2015), *Built for living: Understanding behaviour and the built environment through engineering and design*, http://www.raeng.org.uk/publications/reports/built-for-living-understanding-behaviour

[2] Steg, L. and Vlek, C. (2009), *Encouraging pro-environmental behaviour: An integrative review and research agenda*, Journal of Environmental Psychology, 29(3), 309-317.

[3] DECC (2015), *Smart metering early learning project: synthesis report*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407568/8_Synthesis_FINAL_25feb15.pdf

[4] Froehlich, J., Findlater, L. and Landay, J. (2010), *The design of eco-feedback technology*, In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 1999—2008, ACM https://dub.washington.edu/djangosite/media/papers/tmpssyQcm.pdf

4. The HCI community considers specific design elements of feedback technologies, such as the degree of interaction possible, the types of information displayed, the presentation mediums such as graphs or abstract representations and the placement of the physical device[5]. It has also developed ways of evaluating interfaces based on merits such as evocativeness, engagement, understandability and usability. It argues that more detailed evaluation is needed of aspects of feedback technologies such as the frequency with which a feedback system updates, the measurement units or other representation of consumption that are most appropriate to present, the level of granularity of the data, the accessibility and medium of the information, and the ability to make comparisons (either with one's past behaviours or the behaviours of others). Examples of research include papers on technology-enabled feedback[6] and comparative displays[7] (cited in [5]), and on the emotional response to energy visualisations depending on image format[8]. Evaluation of the design and operation of existing smart meters is needed.

5. Others argue that a more nuanced understanding of behaviour through ethnographic research will allow systems to be designed that take into account the context in which people use energy and are based on real-life interaction with systems rather than abstracted models of human behaviour[9].

6. There is a body of knowledge on how feedback to consumers on their energy consumption influences energy use, as reviewed in [10] and other reviews cited in DECC's smart meter early learning project[11],[12]. The former paper [10] concludes that long-term changes in energy use result from consumers changing habitual behaviour or investing in energy-efficient measures, and emphasises the need for well-designed energy advice alongside in-home displays.

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5 Ibid.

6 Fitzpatrick, G., Smith, G. (2009), *Technology-enabled feedback on domestic energy consumption: articulating a set of design concerns*, Pervasive Computing 8, 1, 37-44.

7 Egan, C. (1999), *How customers interpret and use comparative displays of their home energy use*, Proc. European Council for an Energy-Efficient Economy, Panel III, 19.

8 Giacomin J. and Bertola, D. (2012), *Human Emotional Response to Energy Visualisations*, International Journal of Industrial Ergonomics, 42(6), 542—552.

9 Lockton, D., Bowden, F., Greene, C., Brass, C. and Gheerawo, R. (2013), *SusLabNWE: Integrating qualitative and quantitative data to understand people's everyday energy behaviour*, BECC 2013: Behavior, Energy and Climate Change, 18—20 November 2013, Sacramento, CA. Berkeley, CA: University of California http://escholarship.org/uc/item/1c2117bm

10 Darby, S. (2006), *The effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays*.

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

12 Ehrhardt-Martinez, K., Donnelly, K.A., and Laitner, J.A. (2010) *Advanced metering initiatives and residential feedback programs: a meta-review for household electricity-saving opportunities*. American Council for an Energy-Efficient Economy, Washington DC.

7. Technologies may be designed with incorrect assumptions about the homogeneity of people's physical and cognitive abilities[13], understanding of the systems with which they are interacting[14], daily routines and individual preferences that do not reflect the reality of everyday life and the diversity of users. Organisations such as Rica involve older and disabled people in research and product testing to improve the usability of products; indeed Rica has carried out testing of in-home displays for smart meters[15] and has found both positive and negative aspects of the designs, and that a few have design problems which make them impossible for some people to use. However, this is not an area that can be fully assessed by theory or lab experiments. Trials of people using the technology and the interfaces in their own home are vital.

8. In 2013, The Royal Academy of Engineering published *Made for the future: challenges in creating a sustainable domestic supply chain*[16] that addressed how consumers who want to make more sustainable choices can be certain that they are making the right decisions in the way that they obtain, use and dispose of a range of domestic products. It also looked at how technologies from smart metering and smart appliances, that can manage the demands they make on the electricity grid, can have a positive impact on overall energy use.

9. The report indicated that there are many dialogues to be had between designers and social scientists in order to identify the best ways to create appealing goods that are efficient, long-lasting and desirable over the long term. The report considered the role of service-based models of product ownership in extending lifetimes of products and this also needs to be considered in the context of smart appliances.

10. If consumers do own or rent smart appliances, the ease with which they could benefit from smart meters by automatically operating appliances during times of cheaper electricity would be greatly enhanced; however, they would need to be convinced that the savings justified the outlay for new appliances or that alternative ownership models were beneficial.

**Evidence on the extent to which Time of Use Tariffs (which smart meters enable) can be expected to alter patterns of energy usage during the day**

11. There is some evidence that time-of-use tariffs alter patterns of energy usage during the day[17], although no conclusive evidence that they reduced total energy consumption. Others suggest that more research is needed into the impact of time-of-use tariffs, including on consumer attitudes and behaviour including on their acceptance of

[13] Combe, N., Harrison, D., Craig, S. and Young, M. S. (2012), *An investigation into usability and exclusivity issues of digital programmable thermostats*, Journal of Engineering Design, 23, 401—417.

[14] Revell, K.M.A. and Stanton, N.A. (2012), *Affective design and its role in energy consuming behavior; part of the problem or part of the solution?* In, Yong, Gu Ji (eds.) Advances in Affective and Pleasurable Design. 4th International Conference on Applied Human Factors and Ergonomics , CRC.

[15] Rica, Smart metering displays, http://www.rica.org.uk/content/smart-metering-displays

[16] Royal Academy of Engineering (2012), *Made for the future: challenges in creating a sustainable domestic supply chain* http://www.raeng.org.uk/publications/reports/made-for-the-future

[17] AECOM Ltd (2011), *Energy Demand Research Project: Final Analysis* https://www.ofgem.gov.uk/sites/default/files/docs/2011/06/energy-demand-research-project-final-analysis_0.pdf

automation of energy use, and on the impact of the price differential[18]. It is possible that tariffs are effective only if the differential between high price and low price is large and there is an automatic interface to electrical loads (rather than relying on a consumer to read an indicator and decide what to do).

12. With the types of generation being installed, by the mid-2020s, dynamic tariffs may be needed, which can be changed as conditions develop, rather than time-of-use tariffs that are predetermined in periodic tariff reviews. For example, if the weather forecast is for a 12-hour anticyclone across the country accompanied by clear skies and full sun, which will reduce wind power to almost nothing but boost solar photovoltaics, this should be reflected in the dynamic tariff so electric vehicle batteries are not charged unless essential during the night but during the following day. The evidence from recent research projects investigating technical and consumer aspects, for example [19] and [20], will need to be considered.

13. If day-ahead and real-time tariffs are implemented in the future, the switching has to be automated as it will be difficult for consumers to react to changes in price and chose the most appropriate tariffs. Also it must be clear to consumers that the automation doing the switching is acting on the consumers' behalf and not the electricity suppliers', in order to ensure consumer trust is maintained. Early research on designing home energy management systems that allow flexible autonomy yields design guidelines[21], but further research is needed on consumer aspects.

14. Consumers who have their own renewable energy installations are already incentivised to alter the time of data that they use appliances. For example, consumers with their own solar photovoltaic panels are incentivised to run appliances at times of day when there is sunshine.

**Evidence on the expected net savings for the consumer over time, including in the context of the longevity and technical capability of the smart meter technology being rolled out, and whether similar savings could be achieved by other means**

15. A systems approach is needed to ensure that the smart grid is robust over time and the smart meter technology is appropriately specified without the need for costly re-specification at a later date. The IET's Power Networks Joint Vision make a case for a system architect to address the challenge of integrating numerous smart systems whose technical governance arrangements would otherwise be fragmented[22].

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[18] DECC (2012), *Demand side response in the domestic sector - a literature review of major trials (final report)* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48552/5756-demand-side-response-in-the-domestic-sector-a-lit.pdf

[19] Oxford e-Research Centre, Advanced Dynamic Energy Pricing and Tariffs (ADEPT) project http://www.oerc.ox.ac.uk/projects/adept

[20] Bury, S., Mead, D., Mourato, S. and Torriti, J. (2015) *Investigating preferences for dynamic electricity tariffs: The effect of environmental and system benefit disclosure*. Energy Policy, 80 . pp. 190-195.

[21] Alan, A., Costanza, E., Fischer, J., Ramchurn, S., Rodden, T. and Jennings, N.R. (2014) *A field study of human-agent interaction for electricity tariff switching*. In, Proceedings of the 13th International Conference on Autonomous Agents and Multi-Agent Systems, Paris, FR, 05 - 09 May 2014. , 965-972.

[22] IET (2014), *Britain's power system: the case for a system architect - a briefing paper*, http://www.theiet.org/factfiles/energy/brit-power-page.cfm

16. There are serious concerns from experts about whether the choice of standards for smart meters is robust, which will influence longevity of the technology and thus the net saving for consumers. The security standards are also extremely important and must be considered as a high priority. Over a million meters using the old specification (SMETS 1) have been installed but the new specification (SMETS 2) is still not agreed, and the networking standards that have been selected are about to become obsolete: GPRS which is used for wide-area networking is being replaced by 3g/4g from 2023 and the Zigbee variant that has been chosen for home area networking is now essentially orphanned, as the industry is moving to a new standard being pushed by Google. The current choice of standards for the smart meter programme and other critical components increases technological risks[23].

17. There are also concerns about the assumptions used in the economic assessments of the smart meter programme by government; specifically, electricity price forecasts, allowances made for uncertainty, an optimist view of costs and benefits and an unsuitable discount rate[24].

**Evidence of how data from smart meters can be used to optimise national energy generation and storage**

18. A report that explores the potential for the UK to create a 'data-enabled' economy, *Connecting data: driving productivity and innovation*[25], was published by The Royal Academy of Engineering and the IET in November 2015. The sectors explored included the energy sector and the report describes how data from smart meters and other sources will contribute to achieving a more flexible and interoperable system by:

    - Achieving convergence across different energy networks, so that the energy system may be considered as delivering services to its end-users rather than separate electricity, gas or heat networks.

    - Understanding the operation of new types of energy generation, including community energy systems and heat networks.

    - Carrying out local strategic energy system planning, combining data from the energy system with other types of data such as on building typologies and construction types, spatial layouts and tenure type, and potential energy resources.

19. In addition the availability of real-time data will progress the grid moving from one-way to two-way flow, and to be capable of more integrated and complex transmission, distribution and trading. The data can be used in:

    - Optimising decision-making for operation and investment planning – this includes for long-term planning, day/hour ahead forecasting and immediate operational management.

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[23] Anderson, R. and Henney, A. (2012), *Smart Metering – Ed Milliband's Poisoned Chalice*
http://www.cl.cam.ac.uk/~rja14/Papers/SmartMetering-Feb82012.pdf
[24] Ibid.

[25] Royal Academy of Engineering and IET (2015), *Connecting data: driving productivity and innovation*,
http://www.raeng.org.uk/publications/reports/connecting-data-driving-productivity

- Setting tariffs and managing system carbon intensity.

- Using probabilistic techniques to use assets and control demand more intelligently that require sound data.

20. The report also outlines the broader benefits of the data through data sharing with other parties, such as:

    - Local authorities to provide indicators on fuel poverty.

    - Manufacturers of electrical appliances to improve energy efficiencies.

    - City planners for the purpose of designing new energy infrastructure.

    - third parties to develop energy advice products for consumers.

21. Smart meters are a first step in creating a smart grid, and in particular permit a measurement of network conditions that is currently lacking in the distribution grid. This is valuable for District Network Operators (DNOs) in managing operation of the grid[26] and for other real-time data applications.

22. However, there are some difficulties with the architecture of smart meters and associated flows of data. One of the specific technical challenges in the future will be managing the load in final subcircuits - the cables in the street - particularly if or when there is widespread take-up of Electric Vehicles (EVs) and/or heat pumps. The need will be for the DNO to manage load on a postcode level, particularly after a disruption when all heat pumps would switch to max demand and all EV chargers would recognise they needed to go to maximum charge. This is almost impossible when the contractual relationship between consumers and generators is via a national electricity retailer. The smart meter architecture, where the data is centrally processed by the Data Communications Company and sent to the national retailers, with the DNO able only to obtain historic data via the retailers, exacerbates the problem.

**Evidence on the security of smart meters, and the ability of suppliers to maintain security levels in the future**

23. The smart meter network is being installed before its requirements as an Internet-connected energy system have been fully determined, leading to concerns about the functionality, resilience and security level for the smart grid[27]. A systemic fault in the smart meter network could seriously destabilise the grid – this risk could partly be mitigated by appropriate design and specification upfront. However, the threat of cyber attacks – either to gain information, "steal" electricity or disrupt supply - is real and pressing. It is an ongoing battle on a daily basis and the security needs to be continually adapting to the latest attacks.

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[26] IET (2013), *What is a smart grid?* http://www.theiet.org/factfiles/energy/smart-grids-page.cfm

[27] IET (2014), *Transforming the electricity system: how other sectors have met the challenge of whole-system integration*, A report from the IET expert group Power Network Joint Vision http://www.theiet.org/factfiles/energy/pnjv-report-full-page.cfm

24. In particular, there is concern about the technology used in the meters, the communications systems and the DCC. The high-integrity computing industry (supplying systems for railway signalling, military systems and avionics, for example) refers to the international safety standard IEC 61508[28]. This recognises four standards of safety integrity level (SIL):

- games programmes and most mobile phone apps would be counted as SIL 1
- airport ticket barriers, where there is a remote possibility that allowing the wrong person on a plane could have consequences, might be SIL 2
- train door unlocking systems, where a failure could be hazardous but, by itself, is unlikely to cause death or serious injury might be SIL 3
- SIL 4 is used for fly-by-wire avionics and similar where a fault is likely to cause multiple deaths.

This classification is not being used for the smart meter system.

25. Furthermore, there are concerns about a strategic vulnerability being introduced as a result of energy suppliers having the capability to switch off the supply to individual consumers[29]. Disruption to energy and gas supplies at a massive scale is possible, either from cyber attack or errors in software.

[28] International Electrotechnical Commission, Functional safety and IEC 61508 http://www.iec.ch/functionalsafety/

[29] Anderson, R. and Fuloria, S. (2014), *Who controls the off-switch?* http://www.cl.cam.ac.uk/~rja14/Papers/meters-offswitch.pdf