

Institution: University of Reading		
Unit of Assessment: UoA13 Architecture, Built Environment and Planning		
Title of case study: Unlocking Energy and Carbon Savings through Demand-Side Flexibility		
Period when the underpinning research was undertaken: 2011–19		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Jacopo Torriti	Lecturer Associate Professor Professor	2011 – present
Period when the claimed impact occurred: 2016–20		
Is this case study continued from a case study submitted in 2014? No		
<p>1. Summary of the impact</p> <p>Decreasing costs and delivering on carbon commitments is a key challenge for the energy industry. A key factor is the balancing of supply and demand. Whereas previously the focus was on supply (and potentially over-supply), research at the University of Reading has demonstrated the significant economic benefits of demand-side flexibility across different sectors. The research has led to two distinct impact themes: (1) the facilitation of Demand-Side Response participation in the GBP24,000,000,000 UK electricity capacity market; and (2) regulatory reform of tariffs bringing about estimated bill savings for UK residential customers of between GBP1,600,000,000 and GBP4,600,000,000 from 2021 to 2045 [Section 5, source 3]. Overall, across all sectors, increasing flexibility of electricity demand (that is, reducing consumption at specific times of the day) would yield savings in the UK in the order of GBP8,000,000,000 per year up to 2030 and allow progress towards a zero carbon electricity system [source 6].</p>		
<p>2. Underpinning research</p> <p>Being flexible with how and when electricity is produced and consumed ensures that the power generated matches usage requirements. This reduces both costs and carbon emissions. To date, the energy industry has typically provided flexibility on the “supply side”. For example, to make sure supply always matches demand, electricity stations have changed how much power they generate. However, continuing to rely on supply-side solutions alone would be expensive and inefficient, sometimes creating situations of over-supply. New ways of creating flexibility are emerging, including demand-side flexibility; this includes Demand-Side Response (DSR) where consumers across sectors can sign up to tariffs and schemes which reward a change in how and when electricity is consumed. Demand-side flexibility is a core research topic at Reading and sits within a wider research agenda on energy demand. Researchers at Reading have been at the centre of the development of viability policy and industry research since this became an issue (from 2010). The two main areas of research findings directly attributable to Reading researchers relate to the sectoral potential of DSR (that is, reducing demand at certain times of the day) across different sectors and the distributional effects of Time-of-Use tariffs (that is, how much consumers will benefit from or pay for new flexible electricity tariffs).</p> <p>Research on DSR across different sectors</p> <p>DSR research at Reading has focused on both the residential sector and small and medium-sized enterprises (SMEs). This was facilitated by the publishing of Torriti’s book [Section 3, ref 4], which crystallised previous research on key concepts around the role of demand-side flexibility and DSR in the transition to a low-carbon economy. In 2011, University of Reading researchers were asked to take part in an advisory group for ESRC and EPSRC on smart energy demand strategies. This led to a funding allocation of GBP38,000,000 for six End-Use Energy Demand Centres, including (Section 3, Grant 1), a centre to which University of Reading researchers contributed by using innovative models linking time-use data with electricity-</p>		

demand profiles in order to determine the timing of energy demand. Running in parallel, a second major Reading-based project (Grant 2) provided for the first time a set of UK-level figures on DSR potential volumes in various sectors of the economy.

This second project made use of empirical DSR data from UK businesses and modelled the sensitivity of DSR capacity to response times and notice periods. The main output of this work [Section 3, ref 2] delivered estimates for the DSR contribution, for different sectors, in the UK Capacity Market (that is, contracts for additional power generation and demand reductions in case of significant imbalances). With increasing renewable energy generation, the aim of the UK Capacity Market is to ensure there is sufficient supply to prevent future blackouts (for example, during periods of low wind and high demand). The research at Reading was unique in that it preceded the set-up of a UK Capacity Market and provided evidence about the different levels of potential contribution of market segments, based on different rules around the Capacity Market. For example, it demonstrated a load reduction of 25% for hotels and 82% for telecommunications. Furthermore, it demonstrated that a 24-hour “warning” period could increase by 30% the capacity available for hotels, warehouses and offices [ref 2]. The research also demonstrated resultant economic impacts (EUR0.5/kW/year to EUR19/kW/year net benefits for all sectors) through a more balanced supply and demand, without impacting the functioning of the businesses [refs 3 and 4].

Research on Time-of-Use tariffs (residential sector)

The research subsequently led to two main Reading-led projects (see grants 3 and 4), which developed clustering techniques enabling a classification of residential electricity demand based on consumption during peak periods and analysed the impacts of Time-of-Use tariffs on different types of customers. The work on the effects of Time-of-Use tariffs in Italy [ref 1] was expanded to the UK context. Two papers [refs 5 and 6] provided the main evidence on the distributional effects associated with Time-of-Use tariffs, by clustering UK consumers and assessing the impacts of Time of Use Tariffs on the electricity bills for different income groups. The methodology makes use of half-hourly smart-meter data and data from the 2014–15 UK Time Use Survey to analyse the distributional effects of Time-of-Use tariffs in terms of customer segmentation, peak to off-peak ratios and synthetic profiles. The findings reveal regional differences (for example, positive effects for high-income groups in London) and household composition similarities (for example, positive effects for households with children not in the high-income group).

In summary, the research findings have demonstrated the economic value, and resultant cost savings, of demand-side flexibility across industry sectors and residential consumers. In addition, for the residential consumer, the research has highlighted the distributional effects of Time-of-Use tariffs between socioeconomic groups. Collectively, this research has informed policy on the UK Capacity Market as well as regulatory reform in support of Time-of-Use tariffs.

3. References to the research

1. Torriti, J. (2012) '[Price-based demand side management: Assessing the impacts of time-of-use tariffs on residential electricity demand and peak shifting in Northern Italy](https://doi.org/10.1016/j.energy.2012.05.043)'. *Energy*, 44 (1). pp. 576-583. doi: <https://doi.org/10.1016/j.energy.2012.05.043>
2. Grunewald, P. and Torriti, J. (2013) '[Demand response from the non-domestic sector: Early UK experiences and future opportunities](https://doi.org/10.1016/j.enpol.2013.06.051)'. *Energy Policy*, 61. pp. 423–429. doi: <https://doi.org/10.1016/j.enpol.2013.06.051>
3. Buryk, S., Mead, D., Mourato, S. and Torriti, J. (2015) '[Investigating preferences for dynamic electricity tariffs: The effect of environmental and system benefit disclosure](https://doi.org/10.1016/j.enpol.2015.01.030)'. *Energy Policy*, 80. pp. 190–195. doi: <https://doi.org/10.1016/j.enpol.2015.01.030>
4. Torriti, J. (2016) [Peak Energy Demand and Demand Side Response](https://doi.org/10.4324/9781315781099). Routledge Explorations in Environmental Studies. Routledge, Abingdon doi: <https://doi.org/10.4324/9781315781099>

5. Yunusov, T.M. and Torriti, J. (submitted) 'Role of household activities in peak electricity demand and distributional effects of Time-of-Use tariffs'. *Energy Policy*. [Working Paper \(2020\)](#)
6. Torriti, J., & Yunusov, T. (2020). [It's only a matter of time: Flexibility, activities and time of use tariffs in the United Kingdom](#) *Energy Research & Social Science*, 69, 101697.

The underlying research has been financed by substantial amounts of peer-reviewed research council funding and published in high-quality academic journals. The research has been innovative and at the forefront of the DSR and Time-of-Use debates, and the expert peer-review process for both funding and outputs gives a major degree of confidence that it meets the 2* research quality criteria. With regard to originality, this was the first research to demonstrate sectoral differences in DSR. In terms of rigour, the research makes use of publicly available datasets and clustering techniques, and replicable statistical analysis.

Research funding

1. EPSRC/ESRC EDF, Transport for London and the International Energy Agency funding: 'Dynamics of Energy, Mobility and Demand' (2013–18). Total project value: GBP4,808,648 (project value for University of Reading: GBP183,484).
2. 2012–13 TSB project 'Assessing the Benefits of Demand Side Response Participation in a Capacity Market'. Total project value: GBP65,994 (project value for University of Reading: GBP46,873).
3. 2017–21 EPSRC Fellowship, 'Residential Electricity Demand: Peaks, Sequences of Activities and Markov chains (REDPeAk)', EP/P000630/1 (research income for University of Reading: GBP615,782).
4. 2017–19 EPSRC project, 'Distributional Effects of Dynamic Pricing for Responsive Electricity Demand (DEePRED)', EP/R000735/1 (research income for University of Reading: GBP181,420).
5. 2018–23 EPSRC/ESRC Centre for Research on Energy Demand (CREDS) Total project value: GBP23,727,343 (research income for University of Reading: GBP1,207,211).

4. Details of the impact

The challenge of moving to low carbon generation is that the variability of electricity supply increases. This is because key technologies depend on both weather and daily and annual cycles. The general view in government and industry is that a more flexible system is required (see BEIS and Ofgem (2017), Upgrading our energy system: Smart systems and flexibility plan). Demand flexibility will need to play a vital role in the establishment of a stable electricity system grid as existing approaches to grid balancing are considered inadequate. DSR allows industry and commercial consumers to adapt by increasing or decreasing the volume and timing of their respective demand consumption. The research at the University of Reading has defined the potential contribution (including costs and benefits) to demand-side flexibility by different sectors of the economy and informed the UK government's decision (2014) to include DSR in the Capacity Market. In the residential sector, the research has looked at the impact of Time-of-Use tariffs on demand and supply across different demographic groups; this has underpinned regulatory reform, which provides greater flexibility and potential cost savings to domestic end-users. While policies and regulations in the energy and climate change domains previously emphasised the need to reduce energy consumption through efficiency measures, they did not, prior to the Reading work, integrate temporary reductions in electricity demand (that is, demand-side flexibility). This research therefore provides a means across both industry and residential sectors to prevent supply and demand imbalance, reduce costs (in the region of GBP8,000,000,000 by 2030) and move towards a net zero carbon electricity system while maintaining security of supply and efficiency of the system.

Research on DSR creating Capacity Market opportunities and changing energy policy

The Capacity Market is a GBP24,000,000,000 scheme through which the national government issues contracts for additional power generation and demand reductions in case of significant

imbalances created by intermittent wind and solar energy, for example.

The long-term research at Reading on demand-side flexibility has generated interest across government departments, the European Commission and beyond. This has resulted in invitations for Torriti to present the findings to the Department of Energy and Climate Change (DECC), the European Commission (Directorate-General of Energy and Directorate-General of Research) and the Energy and Climate Change Committee's inquiry on electricity demand-side measures (2014). University of Reading research [ref 2] delivered estimates of the DSR potential across sectors in the Capacity Market. The research recommended that temporal aggregation could pull together short turn-down slots across a range of clients in the telecommunications, hotel and warehouse sectors to cover a Capacity Market stress event. This facilitated the creation of market opportunities for energy aggregators, and, through the engagement activities during the REF period, a change in national policy, including the DECC decision to include DSR participation in the Capacity Market (2014) [sources 2, 7,8].

In February 2016, Torriti was invited by the DECC onto the steering group for the new DSR policy. The research [ref 2] was subsequently used to evaluate the impact DSR had had on the Capacity Market as part of the BEIS Evaluation of the Transitional Arrangements (2017). It showed that there was a very large increase in the bids for DSR contracts as part of the 2016/17 Capacity Market Auction – 1,834MW compared with the 637MW which bid in the 2015/16 auction [source 9].

More recently, Torriti has been the UK representative member of International Energy Agency Demand Side Management Technical Collaboration Group (since 2018). He is also a member of the British Standards Institution's Energy Smart Appliances (ESA) programme Strategic Advisory Group (since 2019), where his research demonstrating DSR in the residential sector has "helped guide the overall direction of the programme and supported the development of standards for the smart energy system" [Section 5, source 1].

As a result of the research which informed the policy to allow DSR to be part of the Capacity Market, several Distribution Network Operators (DNOs) (for example, Western Power Distribution and UK Power Networks) have opened up market opportunities for demand-side flexibility in the form of quarterly calls for business proposals for DSR participation. This DNO-led market is worth approximately tens of millions of pounds each year. For example Piclo, an independent marketplace for trading sustainable energy flexibility online, supported by BEIS, stated that in a 2018/19 online trial, 456MW were initially advertised by six DNOs and "the market for flexibility services is currently estimated to be worth more than £2.2b every year" [source 5].

Research on Time-of-Use tariffs underpinning regulatory reform

With regard to regulatory change and the introduction of Time-of-Use tariffs, Reading research [Section 3, refs 1,3,4,5,6] has underpinned Ofgem's Market-wide Half-hourly Settlement policy reform [Section 5, source 3], which will deliver positive outcomes for consumers through lower bills, reduced environmental impact, enhanced security of supply and a better quality of service [source 3]. Specifically, the research [refs 5 and 6] demonstrating the "distributional effects across consumer groups [socio-demographic, family types] ... offered unique value and insight assisting the development of the case for reform which will affect all residential consumers" [source 2]. For instance, in relative terms, low-income single parents are among the groups who would benefit most (or lose least). This reform would not have been possible without Torriti's ongoing engagement with Ofgem. He has been on the Academic Panel since 2017 and played a key advisory role in the Impact Assessment for the policy reform, which was published in April 2020 citing his work on distributional effects [sources 2 and 3].

This is a key change in the way electricity pricing works. Currently, most customers are settled on a "non-half-hourly" basis using estimates of when they use electricity, based on a profile of the average consumer usage and their own meter readings (taken over weeks and months). In the words of Ofgem, "The implementation of Market-wide Half-hourly Settlement reform is a key

enabler of the move to a smarter, more flexible energy system. Alongside the smart meter roll out, it will facilitate other changes to the future energy market. It has been estimated that a smart and flexible energy system could bring £17–40 billion worth of benefits by 2050 ... In particular, Ofgem expects Market-wide Half-hourly Settlement to incentivise suppliers to develop and offer innovative products such as Time-of-Use tariffs that help consumers to use energy flexibly in order to realise these benefits” [source 2]. The research also informed the BEIS analysis of the resultant load-shifting which would occur as a result of the Market-wide half hourly settlement reform.

Impact on research investment on DSR for SMEs and domestic demand

The focus of Reading research has been on the residential sector and SMEs. In a 2015 DECC “Invitation to Tender for: Analysis of current and future provision of Demand Side Response in Great Britain”, it is stated: “Some of the most relevant and recent existing research we are aware of in this area includes ... Grunewald and Torriti, 2013” [source 10]. It has therefore impacted the UK government research agenda and investment in research and development (R&D), including the 2018 GBP102,500,000 “Prospering from the Energy Revolution Challenge”, with specific pilot projects on flexibility for SMEs and the residential sector. This R&D investment decision was based on the previous 2017 BEIS report ‘Realising the potential of Demand Side Response’ [source 4], which directly cites the Reading research on the impact of Time-of-Use tariffs on residential electricity demand [ref 1]. On a similar scale, UKRI recognised the societal importance of demand-side flexibility by making it one of the Themes of the GBP23,000,000 Centre for Research into Energy Demand Solutions (CREDS), which was led by Reading (Section 3, Grant 5).

In summary, previous attempts to balance electricity supply and demand have focused on the supply side. But the key challenge of renewable energy (wind, solar) is its intermittent nature, resulting in over- or under-supply at any given time. In order to facilitate cost saving in the region of GBP8,000,000,000 [source 6], the research at Reading has demonstrated the importance of approaching the problem from the demand side. In underpinning UK energy policy reform, its focus on DSR and Time-of-Use tariffs has demonstrated the capability within different sectors for flexibility in usage. This is highly significant in terms of securing a balanced supply of electricity and achieving cost and carbon savings.

5. Sources to corroborate the impact

- [S1] Testimonial from British Standards Institution (BSI)
- [S2] Regulatory and Policy Reform (testimonial from Ofgem and correspondence with DECC)
- [S3] [Ofgem Impact Assessment on Electricity-Market-wide Half-hourly Settlement](#)
- [S4] Department for Business, Energy and Industrial Strategy (BEIS) (2017) ‘[Realising the potential of demand-side response to 2025](#)’. Rapid Evidence Assessment Report. London.
- [S5] Piclo (2019) ‘[Flexibility and visibility – Investment and opportunity in a flexibility marketplace](#)’. Open Utility.
- [S6] [Strbac, G., Konstantelos, I., Aunedi, M., Pollitt, M. and Green, R. \(2016\). Delivering future-proof energy infrastructure. Report for National Infrastructure Commission.](#)
- [S7] [Department of Energy & Climate Change \(DECC\) \(2015\) Electricity Market Reform \(Government Response\)](#)
- [S8] [Future potential for DSR in GB. A report prepared for DECC by Frontier Economics with support from LCP and Sustainability First \(2015\)](#)
- [S9] [Department for Business, Energy and Industrial Strategy \(BEIS\) \(2017\) Evaluation of the Transitional Arrangements Phase 1 - Main Report](#)
- [S10] DECC Invitation to Tender (2015) : Analysis of current and future provision of Demand Side Response in Great Britain. Tender Reference Number: 979/01/2015