Smart technologies in the SME and domestic sectors: evidence and policy options

Abstract:
Smart technologies refer to the use of digital and communications technologies based on signals. They include a vast and growing array of technologies, such as smart appliances, smart equipment, smart heating controls, smart lighting systems, building energy management systems, smart meters and demand-side response, amongst others. This rapidly evolving area is being driven through innovation that seeks to develop new business models for improving the efficiency of the way energy is consumed and managed.

Smart energy is an important area of focus for the UK Department for Business, Energy and Industrial Strategy (BEIS). BEIS is currently exploring how smart technologies impact its policy objectives for energy security, affordability for consumers and reducing carbon emissions. There is much potential for innovation and market (and system) disruption through the development of the smart energy system, and this paper identifies key evidence gaps and discusses recent government research in this area. In particular, the paper discusses two much understudied areas where evidence gaps remain: the potential of smart technologies in small-to-medium-sized enterprises (SMEs) and the role of smart heating controls in the domestic sector. It concludes with a discussion of future research and policy work to determine the role of smart technologies in the future energy system.

Keywords:
Energy Demand, Energy Efficiency, Energy Policy, Energy and Environment

1. Introduction

The role of 'smart' energy is gaining increased attention in government policy and industry. Although a universally agreed definition of 'smart' does not currently exist, common elements include the increased use of information and communications technology based on signals (a definition used within the UK Department for Business, Energy and Industrial Strategy (BEIS)), often linked to the internet, in order to improve the efficiency and capabilities of conventional technologies.

There is much potential for innovation and market (and system) disruption through the development of the smart energy system, and this paper aims to identify the key evidence gaps and discuss recent research from BEIS on smart technologies. In particular, the paper focuses on the potential of smart technologies in small-to-medium-sized enterprises (SMEs) (section two) and the role of smart heating controls in the domestic sector (section three). It concludes with a discussion of future research and policy work to determine the role of smart technologies in the future energy system (section four).

The speed of innovation in technologies to enable the implementation of smart energy systems has resulted in the need to identify how categories of technology, such as demand-side response (DSR – the response of consumers to price changes or incentive payments – Albadi and El-Saadany, 2008), energy storage (including the use of electric vehicles), integrated building management systems, smart meters, smart heating controls and smart appliances (such as smart lighting systems), can contribute to meeting government objectives. Demonstrating energy and carbon savings, reduced costs to consumers, and ensuring energy security are key objectives of BEIS. As such, it is important to establish evidence of energy savings, cost-effectiveness and consumer acceptance of innovative, smarter technologies.

There is a growing body of research undertaken in academia, industry and government on the potential for DSR and energy storage. However, much of this work has focussed on the domestic sector, large non-domestic sectors or integration at the distribution level (in the case of energy storage). The role of smart technologies in SMEs is much understudied and this paper discusses the results of a recent UK government-commissioned research project to contribute to filling this evidence gap. Similarly, the smart heating controls market is fast-developing and understanding the energy savings, cost-effectiveness and usability of these technologies is crucial for understanding their potential uptake by consumers and what impact this could have on the energy system.

2. Potential of Smart Technologies in SMEs

2.1 Importance of SMEs

As with defining ‘smart’, there is no universally agreed definition of SMEs. Although the European Commission has established a European Union (EU)-wide definition based on the number of employees (<250) and turnover (≤€50 million or a balance sheet total of ≤€43 million), in other countries, it is based on investment in machinery (such as in India: <10 crore rupees) or total assets plus turnover (such as in China: ≤RMB 400 million plus ≤RMB 300 million). Furthermore, some countries, unlike the European Commission, China and India, do not break down the SME group into sub-sizes (micro, small and medium). For example, in the USA, SMEs are defined as having <500 employees and in New Zealand, SMEs are defined as having <20 employees. With the exception of India, the majority of countries use employee numbers as the basis for defining whether or not an organisation is categorised as an SME. This paper uses the European Commission’s definition.

Globally, SMEs make up 99% of all enterprises and contribute 60% of private sector employment (IEA, 2015). In the UK, they represent 25% of business energy consumption (IEA, 2015). From an innovation perspective, SMEs play a crucial part in developing new technologies and products. For example, in the USA and the EU, they carry out 20% of research and development activities, and in Australia, they represent 90% of businesses engaging in innovative activity (IEA, 2015). Another metric of innovation, patent applications, similarly highlights their importance. In China, SMEs account for >60% of domestic patent applications, in the USA, they represent 35% of all transnational patents, and in the UK, 50% of all patents are obtained by SMEs (IEA, 2015).

Despite their economic importance, SMEs also make an important contribution to national energy consumption, but they have received much less attention than other groups in research and government policy around the world.

2.2 Aims and Methodology

In 2014, the former UK Department of Energy and Climate Change (DECC – now BEIS) commissioned a bottom-up qualitative research project to fill an important evidence gap on the barriers and drivers to energy efficiency in SMEs. A key part of the study was to identify the barriers to SMEs in conducting energy audits (see DECC, 2014a). To build on this work, the department commissioned a top-down quantitative research project to explore the energy savings potential of different categories of smart technologies.

The research had the following aims:

- To estimate the potential savings for UK SMEs by better understanding the technical potential of smart technologies currently available to them
- To comment on the availability and quality of data available on SME energy use and energy savings from different smart technologies
- To suggest various strategies to remove observed barriers to adopt smart technologies by SMEs

This paper concentrates on the first aim, but the full results can be found in BEIS (2016a). The project utilised the European Commission's definition of SMEs and the former DECC's classification of non-domestic sectors, as shown in table one alongside the number SMEs estimated to be in each sector in the UK.

Sector	Number of SMEs	Share of total businesses (%)
Agriculture, Forestry and Fishing	153,207	3%
Mining, Quarrying and Utilities	29,302	1%
Manufacturing	274,463	5%
Construction	956,105	18%
Wholesale, Retail, Transport and Storage	795,935	15%
Accommodation and Food Services	182,447	3%
Commercial Offices	1,761,471	33%
Education	267,550	5%
Human Health and Social Work Activities	370,632	7%
Arts and Other Services	591,020	11%
Total	5,382,132	100%

Table1: the number and percentage of SMEs in non-domestic sectors in the UK (BIS Population Estimates, 2015)

The study took a high-level top-down approach, reviewing and utilising publicly available data sources. Due to the limited data available on SMEs, providing greater primary data is a key area for further research and evidence gathering. As a result, the secondary data analysis conducted in this research used the assumptions and estimates summarised in table two.

Item	Assumption
Energy Consumption	SME turnover data from *BIS Population Estimates* (BIS, 2015) was used as a proxy indicator for SME energy consumption in the UK. Within each sector, the proportion of

Item	Assumption
	turnover generated by SMEs was applied to the sector's total energy consumption figure from *Energy Consumption in the United Kingdom* (ECUK) (DECC, 2015a) to approximate sectoral SME energy consumption.
Sector and Business Area Mapping	The *Digest of UK Energy Statistics* (DUKES) (DECC, 2015b) provides data on energy expenditure from 2014 according to three business areas. • Industry (Mining, Quarry and Utilities; Manufacturing; and Construction) • Domestic (not relevant to this study) • Other Final Users (Agriculture, Forestry, and Fishing; Wholesale, Retail, Transport and Storage; Accommodation and Food Service Activities; Commercial Offices; Education; Human Health and Social Work Activities; and Arts and Other Services)
SME Business Area Share	Assumptions were made about the SME share of total energy expenditure across the sectors using energy consumption as a proxy. Based on the sector and business area mapping indicated above, the cumulative SME consumption for all the sectors within each business was calculated. This was then compared to the total consumption in that business area to determine the ratio of SME consumption to total consumption for each sector. These assumptions are listed below; • Industry (0.3% for Mining, Quarrying, and Utilities; 29% for Manufacturing; and 2% for Construction); and • Other Final Users (5% for Agriculture, Forestry and Fishing; 19% for Wholesale, Retail, Transport and Storage; 9% for Accommodation and Food Service Activities; 6% for Commercial Offices; 11% for Education; 6% for Human Health and Social Work Activities; and 2% for Arts and Other Services)
Energy Source SME Expenditure	Using the breakdowns by energy source type from DUKES (DECC, 2015b), assumptions were made on the levels of energy expenditure by UK SMEs in each sector and on the following energy source types: coal and solid fuels, natural gas, electricity, petroleum products, and heat and other fuels (including biofuels).

Table 2: the methodological approach and assumptions of the research

Further details on the research aims and methodological approach can be found in BEIS (2016a). However, in summary, the energy savings potential estimates are based on estimates of energy expenditures and energy consumption (using turnover as a proxy) mapped onto estimates of the number of SMEs in non-domestic sectors in the UK. Due to the nature of the research questions and the availability of data, a pragmatic and inductive research philosophy was thus the most appropriate paradigm for the research. The methodological approach is summarised in figure one.

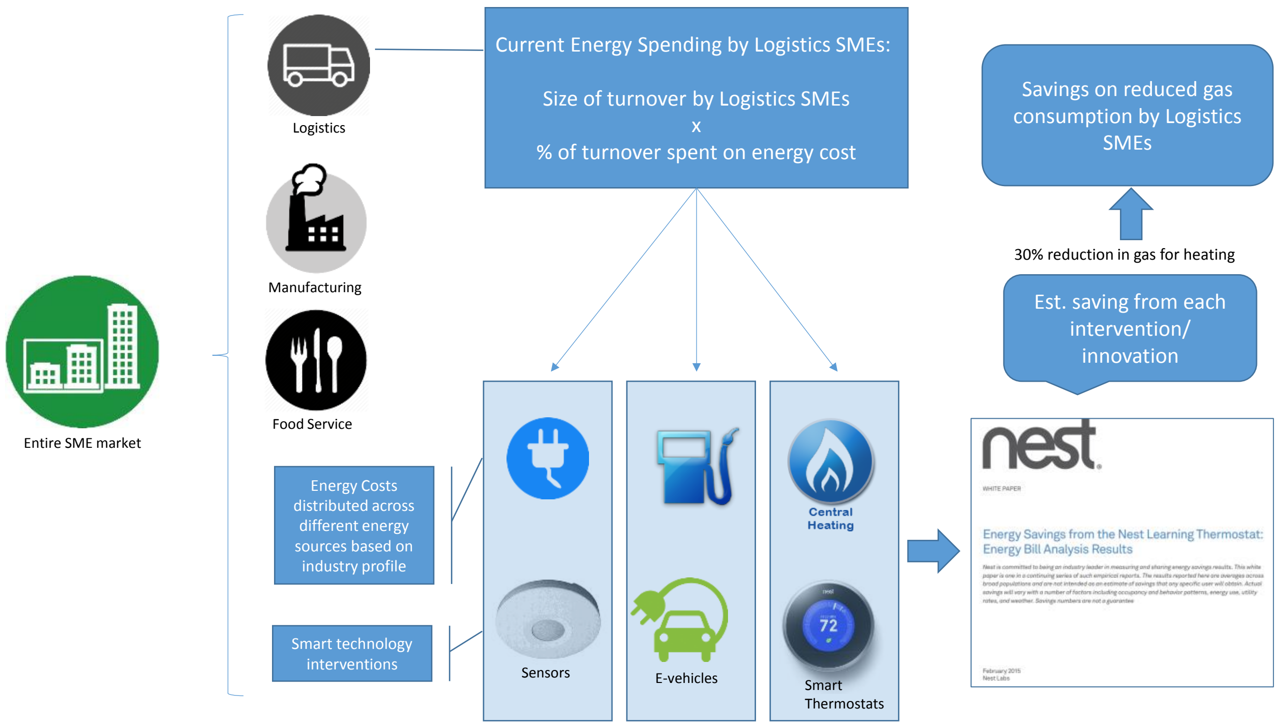

Figure 1: the methodological approach for the research (BEIS, 2016a)

2.3 Results and Implications

The research covered a diverse range of smart technology categories: smart heating controls, smart lighting systems, smart meters, integrated building management systems, demand responsive energy management, big data for logistics and transportation, and fleet management. The purpose was to provide high-level findings on the role of broad categories rather than specific technologies. However, this paves the way for further research to collect and combine primary bottom-up and top-down research to identify the impacts of specific technologies in individual sectors (for example, time-of-use tariffs in commercial offices or occupancy-based smart heating controls in the arts sector).

Table three summarises the main results from the project. The results are broken down by sector, but BEIS (2016a) also provides a breakdown by energy source and by SME size (micro: 0-9 employees (0 employees are sole traders), small: 10-49 employees, and medium: 50-249 employees, as per the European Commission's definition of SMEs).

Scenario	Number of SMEs	Smart Heating Controls	Smart Meters	Integrated Building Management Systems	Smart Lighting Systems	Demand Responsive Energy Management	Big Data in Logistics and Transportation	Fleet Management	Total Annual Energy Savings
Accommodation and Food Service Activities	182,447	£35m	£57m	£73m	£33m	£17m	£0m	£865m	**£1,081m**
Agriculture, Forestry and Fishing	153,207	£24m	£33m	£18m	£17m	£4m	£0m	£432m	**£527m**

Arts and Other Services	591,020	£8m	£12m	£8m	£6m	£2m	£0m	£160m	**£196m**
Construction	956,105	£8m	£10m	£9m	£5m	£2m	£1m	£8m	**£44m**
Education	267,550	£46m	£72m	£83m	£41m	£19m	£0m	£1,06m8	**£1,330m**
Human Health and Social Work Activities	370,632	£25m	£42m	£58m	£25m	£13m	£0m	£645m	**£808m**
Manufacturing	274,463	£54m	£131m	£386m	£94m	£88m	£18m	£141m	**£912m**
Mining, Quarrying, and Utilities	29,302	£1m	£1m	£4m	£1m	£1m	£0m	£0m	**£7m**
Commercial Offices	1,761,471	£22m	£37m	£54m	£22m	£13m	£0m	£580m	**£728m**
Wholesale, Retail, Transport and Storage	795,935	£68m	£129m	£243m	£83m	£57m	£274m	£2,153m	**£3,007m**
Total	**5,382,132**	**£292m**	**£526m**	**£935m**	**£326m**	**£216m**	**£293m**	**£6,051m**	**£8,639m**

Table 3: the annual energy savings potential of smart technologies in SMEs by sector (BEIS, 2016a)

Overall, the study finds that the application of smart technologies within the SME market offers significant energy savings potential in the order of approximately £8.6 billion against an estimated energy spend of around £49.7 billion (representing ~17% savings potential on energy expenditures). From a technological perspective, fleet management, integrated building management systems and smart meters are the three smart technologies likely to offer the greatest energy savings to SME, providing estimated energy savings of roughly £7.5 billion annually. From a sectoral perspective, the Wholesale, Retail, Transport and Storage; Education; and Accommodation and Food Services sectors are likely to achieve the greatest energy savings (of around £3 billion, £1.3 billion and £1 billion respectively).

The ~17% savings figure from this top-down research is comparable with the results from bottom-up studies such as DECC (2014a), which suggests an energy savings potential of between 18-25% within the SME group. However, the results suggest a higher SME market energy savings potential of £8.6 billion versus an estimated £1.3-2.7 billion annually from DECC (2014a). The differences can primarily be attributed to two main factors: potential differences between the energy savings potential of energy efficiency (the focus of DECC, 2014a) and smart technologies (the focus of BEIS, 2016a), and the limitations of top-down, high-level studies, particularly in relation to predicting maximum possible savings data. These limitations are discussed in more detail in BEIS (2016a).

3. Potential of Smart Heating Controls in the Domestic Sector

3.1 Importance of the Domestic Sector

The domestic sector represents 27% of the UK's greenhouse gas emissions (DECC, 2015b). Energy efficiency and micro-generation (technologies that produce heat and/or electricity from a low carbon source and are <100 kW in size – UK Energy Act, 2004) have been a strong focus of domestic sector energy policy in the UK. However, the role of smart technologies in homes is gaining increased attention. The country is currently rolling out smart meters in order to meet the EU's Directive 2009/72/EC, which mandates that member states must achieve at least an 80% rollout of smart meters to small consumers (domestic and SMEs) by 2020. The UK is aiming for close to 100% rollout by the end of 2020 (House of Commons, 2013). In addition, a smart energy strategy is forthcoming, which focuses on the role of DSR, energy storage, smart appliances and innovation in pushing forward the development of smart energy systems.

3.2 Aims and Methodology

The market development of smart heating controls is fast-developing category of smart technologies. There are an increasing number of manufacturers and retailers offering innovative products with a vast array of functionalities. Standard heating controls, such as overall on/off switches, boiler thermostats, central timers, room thermostats and thermostatic radiator valves (TRVs), have a high market penetration and give consumers more controls over the amount of energy that they use. Smart heating controls have a growing market penetration and cover a much broader range of functionalities, such as remote control (through smartphones), automation (the automatic switching on and off of heating systems in response to occupancy), learning algorithms (which learn the heating patterns of consumers), and zonal control (which allows the installation of separate heating circuits in different parts of the dwelling with their own programmer and room thermostat).

However, the evidence on the energy savings, cost-effectiveness and usability of heating controls is limited, and the project aimed to review and assess the quality of the UK evidence. The project utilised a systematic scoping review to comprehensively gather and analyse the evidence. This included a robust and transparent search strategy, the development of inclusion and exclusion criteria to reduce the scope of the evidence review, and the application of a quality assessment scale to assess the research and reporting quality of documents. The search strategy (including the search terms and the databases employed) can be found in BEIS (2016b). The inclusion and exclusion criteria are listed in table four.

Inclusion Criteria
Screening 1
1. Documents that are written in English
2. Documents that are UK based
3. Documents that are available and accessible online within the project's timeframe
4. Documents where their title or abstract indicate any evidence base for one or more types of domestic heating controls in terms of either (1) energy savings (or factors contribute to energy savings such as internal temperatures or heating duration), (2) cost-effectiveness or (3) usability. The types of domestic heating controls included were: central timers, room thermostats, programmable thermostats, TRVs and weather compensators, as well as more advanced heating controls such as zonal control, learning algorithms, remote control and Time Proportional and Integral (TPI) controls.
Screening 2
5. Documents that, when read in full, meet all of the criteria set for the screening 1 and provide an evidence base discussed in 4.
Quality Assessment
6. Documents that score 6 or above on the quality assessment scale
Exclusion Criteria
Screening 1 & 2
1. Documents that report new method(s) for controlling domestic space heating

	but do not evaluate their energy savings potential, cost-effectiveness or usability.
2.	Documents that only study the effect of heating controls on energy demand along with other energy efficiency measures (such as building fabric improvements), so that the sole effect of energy savings due to heating controls could not be isolated.
3.	Documents that are shorter version of another document that has already been included (e.g. a conference paper that has been developed into a journal paper).

Table 4: the inclusion and exclusion criteria employed in the research (BEIS, 2016b)

The most important stage in conducting evidence reviews is the assessment of the quality of the documents that meet the inclusion and exclusion criteria (Warren, 2014). The project applied the quality assessment scale shown in figure two.

Reporting Quality:

- 2 points: Are the rationale and research questions clear and justified?
- 2 points: Does the document acknowledge resource contributions and possible conflicts of interest?
- 1 point: Are the methods used suitable for the aims of the study?

Research Quality:

- 2 points: Has the document been peer reviewed or independently verified by one or more reputable experts?
- 1 point: Do the conclusions match the data presented?
- 1 point: Does the author / publishing organisation have a track record in the area?

Figure 2: the quality assessment scale employed in the research

Further details on the research aims and methodological approach can be found in BEIS (2016b). However, in summary, the project undertook an evidence review using systematic techniques (search strategy, inclusion criteria, quality assessment and data synthesis) to gather and synthesise the UK evidence on the energy savings, cost-effectiveness and usability of different types of heating controls. Similarly to BEIS (2016a) (discussed in section two), due to the nature of the research, a pragmatic and inductive research philosophy was the most appropriate paradigm for the project. A current research project is gathering and synthesising the international evidence in this area, the results of which are forthcoming.

3.3 Results and Implications

The research covered a diverse range of heating control types: central timer (including digital), room thermostat, TRVs, weather compensators, time proportional and integral (TPI) controls (which use an algorithm to closely control internal temperature), zonal control, automation (including self-learning), and remote control. It is clear that there is a lack of evidence (whether robust or poor quality) on the energy savings, cost-effectiveness and usability of heating controls, and it is clear that further research, particularly in the form of field trials, is needed to understand these aspects in more detail.

The results are summarised in table five.

Control Type	Impact on Energy Saving	Impact on Cost-effectiveness	Impact on Usability	Confidence
Programmer/timer (including digital)	Lack of robust evidence	Lack of robust evidence	Lack of robust evidence	N/A
Room thermostats	Single test. 12% gas saving compared to boiler thermostat only. Unrealistic ‘weather’ & house temperatures.	Lack of robust evidence	Lack of robust evidence	Very Low
Thermostatic Radiator Valves (TRV)	Single test. 30% gas saving compared to room thermostat only. Unrealistic ‘weather’ & house temperatures.	Lack of robust evidence	Lack of robust evidence	Very Low
Weather compensation	Lack of robust evidence	Lack of robust evidence	N/A	N/A
Time Proportional Integral (TPI) controls	Large field trial. TPI in place of standard thermostat. No effect on efficiency of modulating condensing boilers.	Lack of robust evidence	N/A	Good
Zonal control	Series of trials in one house. 12% gas saving compared to a Building Regulations compliant system.	Acceptable payback for cheaper systems	Lack of robust evidence	Modest
Automation (including self-learning)	Two homes only. Learning zonal control 8%-18% gas saving.	Lack of robust evidence	Lack of robust evidence	Very Low
Remote control	Lack of robust evidence	Lack of robust evidence	Lack of robust evidence	N/A

Table 5: the energy savings, cost-effectiveness and usability of different types of heating controls

Overall, the study finds that there is limited evidence relating to the energy savings, cost-effectiveness and usability of heating controls. Not only is there a lack of robust evidence for most types of heating controls, but there is generally limited evidence in existence. Quantitative evidence has been generated from models, test houses, individual occupied homes and large-scale field trials of occupied homes. Whilst large-scale trials in occupied homes could provide the most compelling evidence about the impacts of heating controls, limited trials have been conducted in the UK literature. It is clear that large-scale field trials that combine quantitative, measured data with qualitative surveys are needed, but these are expensive to undertake and require careful planning.

Studies on usability are particularly limited in the literature. The studies that have been conducted tend to focus on the requirements for users rather than the consequences of poor design. Consequently, the energy impacts of a heating control that is difficult to use are unknown. For example, a study commissioned by the former DECC in 2014, which conducted a large-scale field study in Newcastle, showed that in-home advice and an information leaflet did not significantly reduce gas consumption compared with residents that received no advice (DECC, 2014b). The implications of the research are discussed in more detail in BEIS (2016b).

4. Conclusions

The paper aimed to identify key evidence gaps and discuss recent research from BEIS on smart technologies in the SME and domestic sectors. In particular, it focused on the potential of seven different types of smart technologies in SMEs and the role of a wide range of different types of smart heating controls in the domestic sector.

The UK government is currently conducting research into smart energy systems and is gathering evidence on the energy and carbon savings, consumer impacts and contribution to energy security of smart technologies, such as demand-side response (DSR), energy storage (including the use of electric vehicles), integrated building management systems, smart meters, smart heating controls and smart appliances (such as smart lighting systems), amongst other innovative technologies. This will inform its future smart energy policies.

What is clear from the two research reports discussed in this paper is that the smart energy space is a fast-developing area that is fostering innovation and disruption. To keep pace with the fast developments in the market, there is a crucial need to strengthen the evidence base in order to inform the development of smart energy policies. The "Potential of Smart Technologies in SMEs" report showed that from existing data, there are potential collective savings of ~£8.6 billion in SMEs against an estimated energy spend of ~£49.7 billion (which represents ~17% savings potential on energy expenditures). Fleet management, integrated building management systems and smart meters are the three smart technologies analysed that are likely to offer the greatest energy savings to SMEs, providing estimated energy savings of roughly £7.5 billion per year. By sector, the Wholesale, Retail, Transport and Storage; Education; and Accommodation and Food Services sectors are likely to achieve the greatest energy savings of around £3 billion, £1.3 billion and £1 billion respectively (BEIS, 2016a).

The "Scoping Review of Heating Controls" report showed that there is a lack of evidence (whether robust or otherwise) on the energy savings, cost-effectiveness and usability of smart (and standard) heating controls (BEIS, 2016b). The current deployment of smart heating controls in the UK is unknown, though the latest government statistics from the English Housing Survey 2014-2015 show that amongst English houses with gas central heating, 99% have central timers, 85% have at least one room thermostat and 76% have thermostatic radiator valves (TRVs) (Department for Communities and Local Government (DCLG), 2016). New government research will aim to identify the current deployment of smart heating controls in England. It is clear that large-scale field trials that combine quantitative, measured data with qualitative surveys are needed to strengthen the evidence base on smart heating controls.

Overall, this paper argues that smart technologies have the potential to have a positive impact on energy and carbon savings, consumer bills and energy security, but the evidence base needs to be significantly strengthened before smart energy policies are implemented. This is to prevent unintended consequences, such as rebound effects (increased energy consumption), lack of consumer acceptance and negative market disruption (such as reduced competition). However, it is clear that this is an area fostering large amounts of innovation that will have important impacts on the future energy system.

Bibliography

1. Albadi, M. and El-Saadany, E. (2008) “A summary of demand response in electricity markets”, *Electric Power Systems Research*, 78, pp. 1989-1996
2. European Commission website (2016) “What is an SME?”, can be downloaded from: [accessed on 26/08/2016]
3. European Council Directive 2009/72/EC on smart meter rollout
4. House of Commons (2013) “Smart meter roll-out”, *Fourth report of session 2013-2014*, Energy and Climate Change Committee, London: HMSO, UK
5. International Energy Agency (IEA) (2015) *Accelerating energy efficiency in small and medium-sized enterprises*, IEA Policy Pathway series, IEA, Paris
6. *Smart meters rollout target reference*
7. UK Department for Business, Energy and Industrial Strategy (BEIS) website (2016), can be downloaded from: https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy [accessed on 26/08/2016]
8. UK Department for Business, Energy and Industrial Strategy (BEIS) (2015) – smart energy definitions
9. UK Department for Business, Energy and Industrial Strategy (BEIS) (2016a) *Potential of smart technologies in SMEs*, Forthcoming, UK Government
10. UK Department for Business, Energy and Industrial Strategy (BEIS) *Scoping review of heating controls*, Forthcoming, UK Government
11. UK Department for Communities and Local Government (DCLG) (2016) *English Housing Survey: Energy Report 2014*, July 2016, UK Government
12. UK Department of Business, Innovation and Skills (BIS) (2015) *BIS Population Estimates 2015*, October 2015, UK Government
13. UK Department of Energy and Climate Change (DECC) (2014a) *Research to assess the barriers and drivers to energy efficiency in small and medium sized enterprises*, November 2014, UK Government
14. UK Department of Energy and Climate Change (DECC) (2014b) *Advice on how to use heating controls: evaluation of a trial in Newcastle*, UK Government
15. UK Department of Energy and Climate Change (DECC) (2015a) *Energy Consumption in the United Kingdom* (ECUK), July 2015, UK Government
16. UK Department of Energy and Climate Change (DECC) (2015b) *Digest of UK Energy Statistics* (DUKES), UK Government
17. UK Energy Act 2004, London: HMSO, UK
18. Warren, P. (2014) “The use of systematic reviews to analyse demand-side management policy”, *Energy Efficiency*, 7, pp. 417-427