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The Potential of Smart Technologies and Micro-Generation in UK SMEs

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Abstract: Small-to-medium-sized enterprises (SMEs) make up 99% of businesses and contribute 13% of energy demand globally. However, much of the demand-side energy research and policy attention to date has focused on the domestic, large commercial and industrial sectors. Previous research on SMEs has primarily concentrated on the drivers and barriers to the adoption of energy efficiency measures. However, less attention has been given to other areas of demand-side management in SMEs, such as the role of 'smart' technologies and micro-generation. The paper aims to contribute to filling this gap. To analyse the potential of smart technologies in UK SMEs, a quantitative model is developed to assess seven categories of smart technologies in ten non-domestic sectors. Overall, the results suggest that smart technologies within the UK SME market offer significant estimated annual energy savings potential of ~£8.6 billion against an estimated energy spend of ~£49.7 billion (representing ~17% savings potential on energy expenditures). From the smart technology categories examined, fleet management, integrated building management systems and smart meters have the potential to offer the greatest energy savings to SMEs, providing estimated total energy savings of ~£7.5 billion annually. To analyse the potential of micro-generation in UK SMEs, interview-based qualitative research was undertaken with 17 SMEs to explore the drivers and barriers to its adoption. The research found that the initial costs, technical feasibility and planning permission on historical buildings were the main barriers, and that the 'green' marketing potential of micro-generation, coupled with ethical reasons and feed-in tariffs, were the main drivers.

Keywords: small-to-medium-sized enterprises (SMEs); energy efficiency; demand-side management; smart technologies; energy policy; energy demand

1. Introduction

Small-to-medium-sized enterprises (SMEs) are an important, but poorly defined, set of diverse sectors and sizes that have received much less attention in demand-side energy research and policy than the domestic and large non-domestic sectors. There is no universally agreed definition of SMEs and although the European Commission [1] has established a European Union (EU)-wide definition based on the number of employees (<250 employees) 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). Despite this, definitions based on the number of employees are the most common.

It is similarly common for countries to break down the SMEs group into sub-sizes. For example, in the UK, three categories are used: micro (0 employee–9 employees—0 employee represents sole traders), small (10 employees–49 employees) and medium (50 employees–249 employees). However, some countries do not do this, such as the USA (SMEs are defined as having <500 employees) and New Zealand (SMEs are defined as having <20 employees). This paper focuses on UK SMEs and as such it uses the UK's definition.

Globally, SMEs make up 99% of all enterprises and contribute 60% of private sector employment [2]. 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 [2]. 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 [2].

Despite their economic importance, SMEs also make an important contribution to energy consumption. Globally, they represent 13% of total energy consumption and 30% of industrial energy consumption, and in the UK they are responsible for 25% of business energy consumption [2]. This paper focuses on demand-side management (DSM) within SMEs in the UK to contribute to filling a much under-researched area. DSM refers to activities and programmes undertaken on the demand-side of energy meters to manage energy consumption in order to meet policy objectives, such as emissions reduction, energy security and reducing consumer energy bills [3,4].

Previous research in the field has concentrated primarily on the drivers and barriers to energy efficiency (delivering more services for the same energy input or delivering the same services for less energy input [5]) in SMEs rather than other aspects of DSM, such as the potential of 'smart' technologies and the uptake of micro-generation (e.g., [6–8]). 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 lighting systems, integrated building energy management systems, smart meters, electric vehicles, Big Data in logistics and transportation, and fleet management. Micro-generation refers to technologies that produce heat or electricity from a low carbon source and are <100 kW, as defined in the UK's Energy Act 2004 [9]. The paper aims to contribute to improving the evidence base on the potential of smart technologies and micro-generation in UK SMEs by answering the following research questions:

(1) What is the energy savings potential of smart technologies in the UK SMEs market?
(2) What are the drivers and barriers to the adoption of micro-generation in UK SMEs?

The limited evidence base on DSM in SMEs in the UK (beyond a small number of bottom-up studies concentrating on energy efficiency) provides an important rationale for focussing on the UK and designing research to improve the evidence base.

The paper is structured as follows: Section 2 discusses energy policy for SMEs, Section 3 outlines and justifies the research methodology, Section 4 presents and discusses the results for the analysis of smart technologies in SMEs, Section 5 presents and discusses the results for the analysis of micro-generation in SMEs, and Section 6 provides the research conclusions.

2. SMEs Policy

SMEs play an important role in the global economy, as highlighted in the previous section. They represent 16–80% of a country's Gross Domestic Product (GDP) depending on its economic structure [2]. For example, in the EU, SMEs represent 30% of GDP [2]. Due to the vast diversity of sectors and sizes that this group contains, governments around the world have experienced challenges in implementing policies that reduce emissions from SMEs. Instead, decarbonisation efforts have focused on other areas, such as the domestic sector, large commercial organisations, the public sector and industry.

The more commonly implemented policies for SMEs revolve around government loans and subsidies for energy efficiency improvements coupled with support to conduct energy audits. These may be channelled through local governments or national governments. Some governments, such as the UK, also encourage financial institutions and other lending organisations to offer loans to SMEs. The loans usually focus on energy efficiency improvements and the lending institutions tend to prefer the larger medium-sized SMEs that can accept larger loans. Table 1 provides examples of lending institutions offering financial support and advice to SMEs for DSM activities (primarily energy efficiency). As the table shows, the types of lending institution vary, such as private banks, non-governmental organisations, European Commission funding, government funding and consultancies.

Table 1. Examples of financial support and advice to SMEs in the UK.

Lending Institution	Details
European Regional Development Funding (ERDF) [10]	65,000 SMEs are expected to receive financial support through ERDF by 2023 (such as through Local Authorities)
Enhanced Capital Allowances (ECAs) [11]	100% tax relief for investments in energy efficiency of £10,000 or more
Royal Bank of Scotland and NatWest [12]	Joint energy efficiency loans of £25,000–500,000 available for SMEs that have had an energy audit
Energy Saving Trust [13]	A loan scheme of £1000–100,000 and free advice for small businesses
Federation of Small Businesses' Energy Service [14]	Free advice and energy audit support (e.g., switching suppliers to reduce energy costs)
UK Department for Business, Energy & Industrial Strategy (BEIS) [15]	Produced a short guide on improving energy efficiency in SMEs

In middle-income countries and developing countries, multi-lateral development banks, such as the World Bank [16], the European Bank for Reconstruction and Development (EBRD) [17], the Asian Development Bank (ADB) [18], the African Development Bank [19] and the Inter-American Development Bank [20], offer financing to local banks to establish loans for SMEs for energy efficiency and micro-generation. Often these programmes are supported through government aid and climate finance, such as through the UK government's International Climate Fund, which is managed by UK Department for Business, Energy and Industrial Strategy (BEIS) [21].

Some local governments in the UK, such as the London Boroughs of Camden and Islington, established alliances of local SMEs and other organisations to work collaboratively to reduce emissions from the non-domestic sectors in their jurisdictions. For example, the Camden Climate Change Alliance (CCCA) was established in 2008 by Camden Council as a not-for-profit membership network using European Regional Development Funding (ERDF) and local government funding [22]. It has a target to reduce carbon emissions by 27% by 2017 [23] and it currently has 323 members [22]. Similarly, the Islington Sustainable Energy Partnership (SEP) is a network of SMEs and other organisations in the London Borough of Islington with Secretariat services provided by Islington Council [24]. The alliance network currently has >60 members and was also established in 2008 [24]. However, few evaluations have been conducted to determine the impacts of such programmes on increasing the take-up of DSM measures, such as energy efficiency and micro-generation. Nevertheless, self-reported data from the SEP suggests that since 2008 the network has reduced emissions by 28,000 tCO_{2e} and saved an estimated £4.9 million in avoided energy costs [25]. Similarly, the CCCA met its interim target of 10% reduction in CO_{2e} emissions on the 2008 baseline year by 2012, and reports comparable statistics to the SEP with a reduction of 27,709 tCO_{2e} and savings of £5.1 million in avoided energy costs between 2008–2015 [22,23].

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, often linked to the internet and enabling external control (though these are not necessary functionalities), in order to improve the efficiency and capabilities of conventional technologies. Various governments around the world are rolling out smart meters in the domestic sector. Smart meters are advanced energy meters that measure consumption in real-time, providing detailed information to utility companies and allowing bidirectional communication, which enables the collection of information about electricity (or gas) fed back into the grid from customers' premises [26] through micro-generation. In the UK, the rollout covers both the domestic and SME sectors and seeks to meet the European Union (EU)'s Directive 2009/72/EC [27], which mandates that member states must achieve at least an 80% rollout of smart meters to small consumers by 2020. The UK is aiming for close to 100% rollout by the end of 2020 [28].

The speed of innovation in technologies to enable the implementation of smart energy systems has resulted in the need to identify how technologies, such as smart meters, demand response (the response of consumers to price changes or incentive payments [29,30]), energy storage (including the use of electric vehicles), integrated building management systems, smart appliances (such as smart heating controls), smart lighting systems, smart meters, Big Data in logistics and transportation, fleet management, amongst many other innovative technologies, in the domestic and SMEs sectors can contribute to meeting government energy policy objectives. Demonstrating energy and carbon savings, reduced costs to consumers, and ensuring energy security are common policy objectives. As such, it is important to establish evidence of energy and carbon savings, cost-effectiveness, consumer acceptance, and usability of innovative, smart technologies in order to inform government policy. Research into the potential of smart technologies in SMEs remains an important gap that this paper contributes to filling by drawing on data and results from the UK Department for Business, Energy & Industrial Strategy (BEIS) [31].

Similarly, there is increased interest in the role of micro-generation (such as on-site solar photovoltaics (PV), heat pumps and biomass boilers) in contributing to energy policy objectives. Policy development is more mature with regards to micro-generation in comparison with smart technologies. However, globally, much of the policy attention has focused on the domestic sector rather than SMEs. Feed-in tariffs are a form of subsidy where energy utilities provide payments to consumers for each unit of low carbon energy that they produce [32]. Feed-in tariffs coupled with information campaigns have been the most commonly implemented policy for micro-generation globally. In the UK, any person or organisation (including SMEs) can apply for feed-in tariffs for micro-generation up to 5 MW from solar PV, wind, anaerobic digestion, hydro and micro-combined heat and power (up to 2 kW) [33].

However, beyond government loans and subsidies, and information campaigns, policies targeted at SMEs have been limited. This is partly due to the weak evidence base on understanding the characteristics and importance of SME sectors in countries (which vary from country to country). This paper aims to contribute to improving the evidence base from a mixed methods perspective, in order to improve both quantitative and qualitative research into DSM interventions in SMEs beyond energy efficiency.

3. Methodology

Previous research (e.g., [34–36]) has focused primarily on bottom-up approaches to investigating energy issues in SMEs, and as a result, there is limited analysis, especially quantitative analysis, that has provided a high-level top-down overview of the market potential. Those that exist (e.g., [37]) concentrate mainly on energy efficiency issues rather than smart technologies. Furthermore, much of the previous research on smart technologies has focused on the domestic sector or wider discussions of the smart grid rather than SMEs. Therefore, a gap remains on top-down quantitative analysis on the potential of smart technologies in SMEs.

The inverse is true with regards to micro-generation. Top-down approaches on the technical and economic potential of micro-generation are more common than bottom-up approaches (e.g., [38–40]). However, one commonality with smart technologies research is that they tend to focus on the domestic sector rather than SMEs. As such, there is a gap on bottom-up analysis, especially qualitative research, on the potential of micro-generation in SMEs. This forms the rationale for the research and the methodology for exploring the potential of both micro-generation and smart technologies in SMEs is discussed in this section.

A pragmatic, purposive methodology was utilised as the most appropriate paradigm within which to answer the research questions due to data availability and accessibility. As discussed above, a top-down, quantitative approach was adopted to estimate the energy savings potential of smart technologies in SMEs, and a bottom-up, qualitative approach was utilised to explore the drivers and barriers to the adoption of micro-generation in SMEs. Due to the different purpose and nature of the data collected for each research area (quantitative data on smart technologies and qualitative data on micro-generation), the data were not combined in analysis procedures and were analysed separately in order to answer their respective research questions. As such a mixed-methods research choice was adopted, as per Saunders et al. [41]'s Research Process Onion framework. This is in contrast to other research choices, such as a mono-method, multi-method or mixed-model approach. Mono-method refers to a single method that is employed, which can be either quantitative or qualitative [41]. Multi-methods are an extension of this where two or more methods are used that are either quantitative or qualitative (but not both) [41]. In contrast, mixed methods refer to the use of two or more methods that are quantitative and qualitative, which is broken down into 'mixed-method' and 'mixed-model' [42]. The former includes quantitative and qualitative methods but they are not combined in analysis procedures, whereas the latter includes quantitative and qualitative methods that are combined in analysis procedures [42]. As such, this research adopts the former research choice.

To reduce the scope of the research, the UK was chosen as the country of focus. As discussed in Section 1, this is due to the limited evidence base on DSM in SMEs in the UK, and as highlighted in Section 2, previous studies have primarily adopted a qualitative bottom-up approach and focused on energy efficiency rather than other aspects of DSM, such as smart technologies and micro-generation.

Research question one has three objectives: to assess the availability and quality of data on UK SMEs, to fill a methodological gap by developing a quantitative top-down approach to the analysis of SMEs, and to estimate the energy savings potential of smart technologies across SME sectors in the UK (rather than assessing the potential in individual SME case studies).

For research question one, 'potential' is defined as the ability for a particular group of smart technologies to result in energy savings (and consequently a reduction in energy expenditures) for SMEs. As such, publicly available secondary data was necessary in to order to produce higher-level estimates across the UK SMEs group. A review of publicly available and accessible data sources in the UK identified that limited data has been collected on SMEs. However, it was possible to extract useful data from government sources, such as the former Department of Business, Innovation and Skills (BIS)'s (now BEIS) Population Estimates [43] and the former Department of Energy and Climate Change (DECC)'s (now BEIS) Energy Consumption in the UK (ECUK) [44] and Digest of UK Energy Statistics (DUKES) [45]. From the data it was clear that, as no direct data on SME energy consumption currently exists publicly, the three data sources could be used together as a proxy to estimate this. Furthermore, using the breakdown of non-domestic sectors provided in these data sources, it was possible to estimate the energy consumption of SMEs in different sectors. Table 2 summarises the data sources, assumptions and methodological approach for research question one.

Table 2. Data sources, assumptions and methodological approach for research question one.

Item	Data Sources, Assumptions and Methodological Approach
Energy Consumption	SME turnover data from BIS Population Estimates [43] was used as a proxy indicator for SME energy consumption in the UK. Within each sector, the proportion of turnover generated by SMEs was applied to the sector's total energy consumption using figures from Energy Consumption in the United Kingdom (ECUK) [44] to approximate sectoral SME energy consumption.
Sector and Business Area Mapping	The Digest of UK Energy Statistics (DUKES) [45] 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 research) • 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)

Table 2. *Cont.*

Item	Data Sources, Assumptions and Methodological Approach
SME Business Area Share	Assumptions were made on the SME share of total energy expenditure across the sectors using energy consumption as a proxy. Based on the sector and business area mapping, the cumulative SME consumption for all of the sectors within each business area 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, as shown below: • Industry (0.3% for Mining, Quarrying and Utilities; 29% for Manufacturing; and 2% for Construction) • 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)
Potential Energy Savings from Smart Technologies	The following data sources on the potential energy savings from each category of smart technology were used: • Smart heating controls [46,47] • Smart meters [48–50] • Integrated building management systems [51–54] • Smart lighting systems [55] • Demand responsive energy management [56] • Big Data for logistics and transportation [57] • Fleet management [58,59]

The following broad categories of smart technologies were examined in order to encompass a range of technological types: smart heating controls, smart meters, integrated building management systems, smart lighting systems, demand responsive energy management, Big Data for logistics and transportation, and fleet management. Data sources on the potential energy savings from each category of smart technology are shown in Table 2. There are few studies that have examined the potential energy savings from smart technologies. As such, the results should be considered in light of the limited data sources available to conduct such analyses. Furthermore, although data sources were scrutinised for evidence quality, few randomised control trials (RCTs) of smart technologies have been undertaken, particularly for Big Data and fleet management, which is partly explained by the complexity, practicality and cost of undertaking RCTs in the smart energy field. As a result, this limits the quality of the data sources available, and the results should be considered as high-level, rough estimations rather than well-validated figures that can be used confidently by decision-makers, industry and researchers. Despite this, a strong focus of this part of the research is the development of a top-down, quantitative methodological approach, which can be easily updated as new evidence comes to light.

A further consideration is the potential overlap in estimated energy savings between smart technology categories. Table 3 summarises where the differences are in the categories examined.

Table 3. Differences between smart technology categories.

Differences	Discussion
Serve different service functions	Smart meter and smart lighting systems both have the potential to offer energy savings but deliver results in different ways. The former supports electricity reduction by using of real-time energy consumption data to facilitate changes to energy consumption behaviour, whereas the latter reduces energy consumption and improves energy efficiency by optimising lighting operation automatically.
	Some smart heating controls can work with other technologies such as smart lighting systems, smart meters and sensors to potentially achieve larger energy savings, but do not have major system function overlap with other smart technologies.

Table 3. *Cont.*

Differences	Discussion
Serve as part of a smart technology package	Smart meters, smart lightings and smart heating controls can act as building services that are controlled by integrated building management systems.
	Smart meters are key components of demand responsive energy management. They collect and send real-time electricity data via wireless networks back to the supplier service operation centres for real-time data analytics.
Serve similar functions but with different areas of focus	Fleet management and Big Data for logistics and transportation are both software-based services and use data analytics techniques, but they each use a different range or type of data for analysis.
	Fleet management technologies focus on asset management and on saving fleet operation costs, including fuel consumption. It mainly uses vehicle data (e.g., engine performance, speed, location, vehicle fuel efficiency etc.) to conduct data analytics and enable better usage and maintenance of vehicles.
	Big Data for logistics and transportation looks beyond managing fleets. It can use any relevant data, such as crowd sourcing data and customer data, to help businesses not only to reduce fuel consumption and to improve service efficiency, but also to predict service trend and needs (e.g., service capacity and customer service usage pattern).

It is beyond the scope of this paper to compare potential differences between specific functionalities and products within each smart technology category. This is an important area for further research.

The primary outputs from the analysis are figures on the estimated annual energy savings potential of different types of smart technologies in different SME sectors, as well as overall across sectors. It is important to note that as a result of the discussions in Table 3, the results broken down by sector and smart technology category are more interesting than the overall figures, as more studies are required to investigate any overlap in potential energy savings between smart technology categories. Section 4 presents and discusses the results.

Research question two has three objectives: to adopt a similar qualitative, bottom-up approach to other studies on SMEs that have focused on energy efficiency and apply it to micro-generation, to identify the most common drivers and barriers to the adoption of micro-generation in SMEs in the UK, and to compare the findings with the results of the other studies.

For research question two, 'drivers' is defined as the key factors that have encouraged (behaviour in social psychology or revealed preferences in economics), or would encourage (attitudes in social psychology or stated preferences in economics), an SME to adopt micro-generation in their premises, and 'barriers' refers to the key factors that discourage them from doing so. A detailed examination of the differences between attitudes versus behaviour is beyond the scope of the research, but the paper discusses high-level patterns in the sample in Section 5.

Previous research on the barriers and drivers for DSM activities in SMEs has received much less attention than studies that have focused on the domestic sector. The key papers that exist (e.g., [6–8,34–36]) focus primarily on energy efficiency activities rather than micro-generation, target specific SME sectors or sizes, and concentrate on specific countries or regions within countries. For example, [6] focused on energy efficiency in UK SMEs, though it included both industrial and non-industrial SMEs; Trianni et al. [7,34] investigated energy efficiency in industrial SMEs specifically in primary metals manufacturing in northern Italy; Backman [8] concentrated on energy efficiency in non-energy-intensive SMEs in Sweden; Pereira and Ferreira [35] explored energy efficiency in industrial SMEs in Portugal; and Onut and Soner [36] focused on energy efficiency in manufacturing-based SMEs in Turkey. Thus, a methodological approach that examines micro-generation in SMEs rather than energy efficiency, does not exclude participation based on SME sector or size, and focuses on the UK (which has received less attention than other countries with regards to DSM research on SMEs), provides an important part of the rationale for this part of the research. Nevertheless, as discussed below, the research outlined in this paper draws similarities to previous research in not aiming to be generalisable, such as nationally or locally representative of UK (or London-based) SMEs.

Due to the nature of the research question, qualitative semi-structured interviews and an online questionnaire were identified as the two most appropriate methods for extracting the required data from SMEs. The research adopted the former method, as the ability to encourage participation in online questionnaires is challenging without incentives due to the limited time that SMEs have to dedicate to non-core business activities. In contrast, face-to-face interviews have the potential to increase greater participation rates due to the more personal nature of data extraction and the SMEs' ability to further understand how the research could be of use to them. Despite this, face-to-face interviews still suffer from the challenge of competing with the core business activities of SMEs.

The purpose of the data collection was not to be nationally or locally representative, but for the sample size of SMEs to be large enough to reach a saturation point (the rate at which no new or relevant information is obtained from each additional interview [60]) for the identification of drivers and barriers to micro-generation. The research identified that the Camden Climate Change Alliance (CCCA) (discussed in Section 2) was a unique opportunity to obtain access to SMEs and to encourage participation. Although this group would be influenced by the local context (they operate in the London Borough of Camden) and they are in the CCCA because they are more environmentally-conscious, identifying the barriers to micro-generation that remain for an arguably more driven group of SMEs than might be the case for the 'average' SME, is useful evidence for shaping how practitioners and policymakers develop solutions to encourage the adoption of micro-generation in SMEs.

To ensure that the semi-structured interviews lasted less than one hour (to encourage greater participation), the scope of the interviews excluded discussions of smart technologies and focused on micro-generation. As such, a mixed-methods approach rather than a mixed-model approach to analysis was adopted (the results for smart technologies and micro-generation are analysed separately), as previously justified. All participants were asked to sign a confidentiality agreement, which outlined the purpose of the research, that the data would be recorded, how the data would be used, and that anonymity would be maintained. 75 members of the alliance were contacted by email and 17 agreed to participate (giving a participation rate of 22.7%). Table 4 shows the 11 areas that were covered in the interviews.

Table 4. Interview questions for research question two.

Interview Question	Rationale
Heard of term 'micro-generation'?	To understand micro-generation familiarity
Know of different types of micro-generation?	To understand micro-generation familiarity
Have installed micro-generation?	To understand attitudes and behaviour
Have considered micro-generation installation?	To understand attitudes and behaviour
Incentives to install micro-generation?	To understand attitudes and behaviour
Obstacles to installing micro-generation?	To understand attitudes and behaviour
Know where to go for further information on micro-generation?	To understand micro-generation familiarity
Know of financial support for micro-generation?	To understand familiarity with available support
Know of feed-in tariffs for micro-generation and how they work? Increases incentive?	To understand familiarity with available support
Alternatives to micro-generation?	To understand attitudes and behaviour
Prioritise energy efficiency/other environmental measures?	To understand attitudes and behaviour

The primary outputs from the interviews were a list of the common drivers and barriers to the adoption of micro-generation in the sample. Section 5 presents and discusses the results. The next section discusses the results for research question one.

4. Smart Technologies in SMEs

The obtained data outlined in Section 3 enabled the estimation of the current make up of SMEs in each non-domestic sector in the UK (as categorised by BIS). Table 5 summarises the calculations.

Table 5. The number and percentage of SMEs by sector in the UK [43].

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%

Commercial offices are dominant and represent a third of the total number of SMEs in the UK (33%), followed by construction (18%) and the combined group of wholesale, retail, transport and storage (15%). Using the approach outlined in Table 2 in Section 3, the results are broken down by sector and category of smart technology (smart heating controls, smart meters, integrated building management systems, smart lighting systems, demand responsive energy management, Big Data for logistics and transportation, and fleet management). The results are presented in Table 6.

Table 6. The estimated annual energy savings potential of smart technologies in SMEs by sector in the UK [31].

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	£35 m	£57 m	£73 m	£33 m	£17 m	£0 m	£865 m	£1081 m
Agriculture, Forestry and Fishing	153,207	£24 m	£33 m	£18 m	£17 m	£4 m	£0 m	£432 m	£527 m
Arts and Other Services	591,020	£8 m	£12 m	£8 m	£6 m	£2 m	£0 m	£160 m	£196 m
Construction	956,105	£8 m	£10 m	£9 m	£5 m	£2 m	£1 m	£8 m	£44 m
Education	267,550	£46 m	£72 m	£83 m	£41 m	£19 m	£0 m	£1069 m	£1330 m
Human Health and Social Work Activities	370,632	£25 m	£42 m	£58 m	£25 m	£13 m	£0 m	£645 m	£808 m
Manufacturing	274,463	£54 m	£131 m	£386 m	£94 m	£88 m	£18 m	£141 m	£912 m
Mining, Quarrying, and Utilities	29,302	£1 m	£1 m	£4 m	£1 m	£1 m	£0 m	£0 m	£7 m
Commercial Offices	1,761,471	£22 m	£37 m	£54 m	£22 m	£13 m	£0 m	£580 m	£728 m
Wholesale, Retail, Transport and Storage	795,935	£68 m	£129 m	£243 m	£83 m	£57 m	£274 m	£2153 m	£3007 m
Total	5,382,132	£292 m	£526 m	£935 m	£326 m	£216 m	£293 m	£6051 m	£8639 m

Overall, the research finds that the application of smart technologies within the SME market offers significant estimated annual energy savings potential in the order of ~£8.6 billion against an estimated annual energy spend of ~£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 categories of smart technologies that are likely to offer the greatest energy savings potential to SMEs in the UK, providing estimated annual energy savings of ~£7.5 billion annually (fleet management is particularly dominant with ~£6.1 billion). From a sectoral perspective, the Wholesale, Retail, Transport and Storage; Education; and Accommodation and Food Services sectors are likely to achieve the greatest estimated annual energy savings potential (of ~£3 billion, ~£1.3 billion and ~£1 billion respectively).

The ~17% savings figure is comparable with the results with DECC [6], which conducted a bottom-up study of the drivers and barriers to energy efficiency in UK SMEs. The research report found that an energy savings potential of between 18–25% exists within the SME group [6]. However, the results of this paper suggest a higher SME market energy savings potential of ~£8.6 billion versus an estimated £1.3–2.7 billion annually from DECC [6]. The differences can primarily be attributed to two main factors: potential differences between the energy savings potential of energy efficiency (the focus of DECC [6]) and smart technologies, and the methodological challenges of top-down, high-level quantitative studies, particularly in relation to estimating potential energy savings using proxy estimations that are based on contexts where limited publicly available datasets exist.

As emphasised in the methodology section, the limited quantity and quality of available energy savings data on smart technologies, particularly in SMEs, means that the results should be considered as high-level, rough estimations rather than well-validated figures. Instead the purpose of this part of the research was to provide a methodological approach to estimating potential energy savings from different categories of smart technologies, and the results should be updated as new, more robust datasets come to light. As such, the research provides a useful contribution to a much under-studied area that warrants further attention.

At the lower end of the estimated annual energy savings potential, mining, quarrying and utilities, and construction are the two sectoral groups with the least potential with ~£7 million and ~£44 million respectively. The breakdown of the data in Table 6 highlights that this is not due to specific technologies, but is generally low across the range of smart technology categories examined. Similarly, from a technological perspective, three technology categories achieve an estimated <£300 million annual energy savings potential overall: demand responsive energy management (~£216 million), smart heating controls (~£292 million) and Big Data in logistics and transportation (~£293 million). However, it is important to note that for some sectors, these technologies have great potential, such as demand responsive energy management and smart heating controls in manufacturing (~£88 million and ~£54 million respectively) and in the sectoral group of wholesale, retail, transport and storage (~£57 million and ~£68 million respectively). Furthermore, the results highlight that there is unrealised energy savings potential across all smart technology categories and sectors (where some cells in Table 6 have £0 million, this is due to the type of smart technology category being less appropriate for the nature of the sector—for example, Big Data in logistics and transportation for commercial offices).

An additional part of the analysis aimed to further investigate the characteristics of the SME group in the UK by using the data and results from [31,43] to breakdown the group by size: micro (0 employee–9 employees), small (10 employees–49 employees) and medium (50 employees–249 employees). Table 7 presents the results, which covers the following characteristics: the percentage of SMEs that each size represents, the number of businesses for each size, the number of employees for each size, the percentage of SME employment that each size represents, the total annual energy expenditure of each size, and the percentage of SME energy expenditure that each size represents.

Table 7. The number and percentage of SMEs by size in the UK [31,43,44].

SME Size	% of SMEs	Number of Businesses	Number of Employees	% of SME Employment	Total Energy Expenditure	% of SME Energy Expenditure
Micro	95%	5,146,000	8461	54%	£19,981,000,000	40%
Small	4%	204,000	3967	26%	£16,121,000,000	33%
Medium	1%	33,000	3183	20%	£13,558,000,000	27%
Total	100%	5,383,000	15,611	100%	£49,660,000,000	100%

Table 7 highlights the importance of the micro-sized SMEs in the UK, which make up 95% of SMEs, have 22 times the number of businesses compared with the other sizes of SMEs combined, have more than double the number of employees than each of the other SME sizes, and have the greatest estimated total aggregated annual energy expenditure in the SME group. However, the total aggregated annual energy expenditures are more comparable between micro-, small- and medium-sized enterprises than the large differences in economic characteristics (such as the number/percentage of SMEs or the number/percentage of employees). Breaking down the diverse group of SMEs by size and sector provides a more useful lens through which to target energy policies aimed at SMEs, rather than viewing them as one homogenous group.

It is important to note that the results are based on the current state of publicly available data. Due to the challenges in collecting good quality nationally representative primary data on SMEs, the estimates require validation as new data become available. Furthermore, the smart energy space is rapidly evolving and as a result, the findings in Table 6 may change significantly as new innovations are developed and commercialised for various sectors. It is beyond the scope of the research to further investigate the reasons behind the findings in Table 6, as the focus of the paper is on what the estimated annual energy savings potential of smart technologies is in SMEs in the UK, broken down by sector and smart technology. This is an important area for further research. However, the focus of Section 5 is methodologically different, as it tries to understand the underlying drivers and barriers to the adoption of micro-generation in UK SMEs.

5. Micro-Generation in SMEs

The 17 interviews were conducted at the premises of the SMEs with representatives that have the authority to make financial decisions on areas such as micro-generation. The specific job titles of the representatives varied, highlighting the complexity of the decision-making process for micro-generation based on the organisation size and structure. In the micro-SMEs (0 employee–9 employees, where zero is a sole trader), the general manager or equivalent makes all of the decisions for the organisation. In the small-to-medium-sized SMEs (10 employees–249 employees), more organisational structures become clear and those responsible for estates management or building services tend to have the authority to make the decisions with regards to micro-generation. Interestingly, a quarter of the UK SMEs interviewed had dedicated environmental or sustainability managers. The rise of Corporate Social Responsibility (CSR) in larger organisations, whether voluntary or as a result of government policy, may partly explain this, as practices filter down to smaller organisations. In the case of voluntary action, this is partially driven by growing changes in customer attitudes and behaviours towards more ethical purchasing, resulting in some SMEs exploiting new market niches.

In synthesising previous related research on the drivers and barriers to energy efficiency (rather than micro-generation) in SMEs (e.g., [6–8,34–36]), it is clear that the main barriers concentrate on three areas: economic, information and competing priorities. Economic barriers revolve around the limited availability of capital to meet the required upfront costs of energy efficiency [6,7,34,35], which has to be met within a context of meeting other investment priorities [35]. There is similarly an internal management push to ensure that payback periods for investments are less than two years [6], despite the cost-effectiveness of many energy efficiency technologies, such as insulation measures. Information barriers are primarily concerned with imperfect information and a lack of technical skills to process the information [8]. Linked to this is trust—the studies highlight that information about technologies, regulations and opportunities for financing are perceived as complicated or untrustworthy [7,34]. The third category, competing priorities, concentrates on the pressure on the limited time, people and operational resources of SMEs. The studies show that a lack of time, potential disruptions to day-to-day operations, and the limited capacity of SMEs to monitor performance are important barriers to energy efficiency [6,8].

The synthesis of [6–8,34–36] also identified that the main drivers for energy efficiency in SMEs revolve around three areas: direct economic drivers, indirect economic drivers and internal drivers. Direct economic drivers primarily refer to cost savings and the potential impacts of reduced costs. For example, the studies highlight that reduced operational costs are perceived to enable increased profitability and to lead to SMEs being more competitive, which could improve economic sustainable growth [6,7,34–36]. This is particularly the case with manufacturing SMEs [6]. Indirect economic drivers are those that have the potential to improve business performance through less tangible factors, such as following what competitors are doing with regards to energy efficiency, installing energy efficiency measures that improve ambience and the customer experience, and identifying that such measures could improve market share but acknowledging that they are difficult to quantify in economic terms [6,35,36]. This is particularly the case with non-manufacturing SMEs [6]. The studies also highlight a number of internal drivers, which are those internal to the SME and not based on external factors. For example, SMEs may use energy management issues as a part of creating more positive internal business cultures [6]. Part of this might revolve around highlighting the importance of training in energy efficiency [7,34]. Some studies similarly emphasise the targeting of trigger points for installing energy efficiency, such when it is installed as part of wider upgrades that are planned to take place in the SME [6]. SMEs are more likely to seek energy efficiency information [7,34] during such periods.

Drawing parallels to the argument made in Section 3 on attitudes versus behaviour, DECC [6] similarly found that what SMEs stated as important drivers and barriers did not necessarily match with what was revealed about their actual behaviour. For example, for capital costs, although SMEs stated that capital costs were an important barrier, 30% of the identified energy efficiency interventions do not require upfront capital costs but implementation rates still remained low at 20%. Similarly with payback periods, the identified energy efficiency interventions with payback periods of less than two years had little impact on their implementation rates, which remained low at 13% [6].

Previous research that has focused on micro-generation in the domestic sector (e.g., [61,62]) has generally come to similar conclusions, as summarised in Table 8.

Table 8. The main drivers and barriers to micro-generation in the domestic sector (adapted from [61,62]).

Drivers	Barriers
Environmental reasons	Lack of awareness and knowledge
Interest in technology	High initial costs
'Green' status and reputation	Low levels of trust in public actors
Long-term economic cost savings	Lack of technical expertise
Energy security and self-sustainability	Mis-selling issues
Encouraging behaviour change in others	Technological inefficiencies
Enhancing property values	Inability to trial micro-generation
Technological efficiencies	Low export tariffs

As Table 8 shows, upfront costs and knowledge are primary barriers, whilst cost savings and the influence of others (in terms of 'green' status) are crucial drivers. Based on Sorrell et al. [63]'s definition of a barrier in this context as: "a postulated mechanism the outcome of which is an organisation's neglect of (apparently) cost-effective energy efficiency opportunities", high initial costs refers to the challenges for consumers in acquiring the required upfront capital to invest in micro-generation, regardless of whether or not the technologies in question are cost-effective. For example, a number of energy efficiency measures, such as insulation, are cost-effective, but they still require an upfront investment, which is an inhibiting barrier for many firms [64].

However, there are some differences between the two sets of research [6,61,62], such as trust and mis-selling issues as important barriers, and environmental ethics and technological interest as strong drivers. Despite this, to date, limited research has been conducted on the uptake of micro-generation in SMEs and this section aims to identify the primary drivers and barriers.

The saturation point for the interviews with UK SMEs was 17 interviews, as the 17th interview produced no additional barriers, drivers or other data. From the interviews with UK SMEs, a quarter of the sample had installed micro-generation but more than two-thirds had considered it. All participants were asked to identify what they considered to be the primary driver and barrier, in addition to listing the drivers and barriers that they face. This overcame the issue of a more frequently cited factor being assumed to be important, as it allowed the participants to state its importance. It is important to note that the findings are not intended to be generalisable, such as nationally or locally representative of UK (or London-based) SMEs.

Initial costs stood out as the most frequently cited and the most important barrier to the adoption of micro-generation with two-thirds of the SMEs interviewed stating it as the primary barrier. As conveyed above, this is different from the cost-effectiveness of DSM technologies, such as micro-generation or energy efficiency, as the barrier focuses on the difficulties that SMEs face in obtaining the required upfront capital for the technologies. For the remaining SMEs in the sample, technical feasibility (suitability) and planning permission were the primary barriers. However, all three of these barriers featured prominently in the sample when participants were asked to list other barriers.

The importance of initial costs is shown in the following quote from an office-based SME, which was a commonly held view in the sample:

> *"The obstacles are money—it costs more . . . most of the measures I don't need to do . . . it cost me £25,000 to put solar panels in, plus another £5000 to strengthen the structure to accommodate the weight."*

The technical feasibility of micro-generation, particularly in terms of the suitability of installing technologies in an urban environment, is represented in the following quote from a transport-based SME:

> *"As far as using solar PV for us...it's not practical—roof space for us is worth quite a lot of money and that is one of the problems in London—roof space is often rented to phone companies for masts and condensers for air con ventilation systems or big power generators, which you can't store anywhere else because of the premium."*

Planning permission, particularly for historical buildings, was similarly mentioned as an important barrier, which prevented SMEs that were interested in exploring the potential of micro-generation on their premises. However, participants stated that this was primarily an initial (though time-consuming) barrier, as once the process had been completed the first time, it was easier to obtain planning permission for subsequent projects (of any form). This is demonstrated in the following quote from a learned institution:

> *"We're in a Grade 1 listed building . . . although I had difficulty getting planning permission initially, as there were lots of bodies to go through (permission is needed from English Heritage, Camden Estates Commission and the Camden Council), now it has been granted, it is much easier to obtain permission for further developments."*

However, this appeared to be more representative of the small-to-medium-sized organisations that had more resources to dedicate to pursuing planning permission. For micro-organisations, the challenges were much greater, as the following quote from a small family-run hotel highlights:

> *"I don't want to ask Camden planning outright . . . they tend to be overworked and tend to reject quickly if it is at all complicated because they have a back-log as they have to by law answer within 28 days or something . . . I've got friends in different Boroughs and it sounds like it is just everywhere . . . so I don't hold out very much for it."*

Figure 1 summarises the identified barriers to the adoption of micro-generation in SMEs, which have been grouped into financial, suitability, internal and external barriers.

An interesting comparison between the results of studies that have examined energy efficiency in SMEs (e.g., [6]) and the results of this research, which has investigated micro-generation in SMEs, is that payback periods of less than two years appear to be less influential in the decision to install energy efficiency [6], but this research found that payback periods of less than two years are an influencing factor in the decision to install micro-generation. Thus, 'long payback periods' refers to the payback periods for various micro-generation technologies exceeding the two-year threshold required for some SMEs to invest.

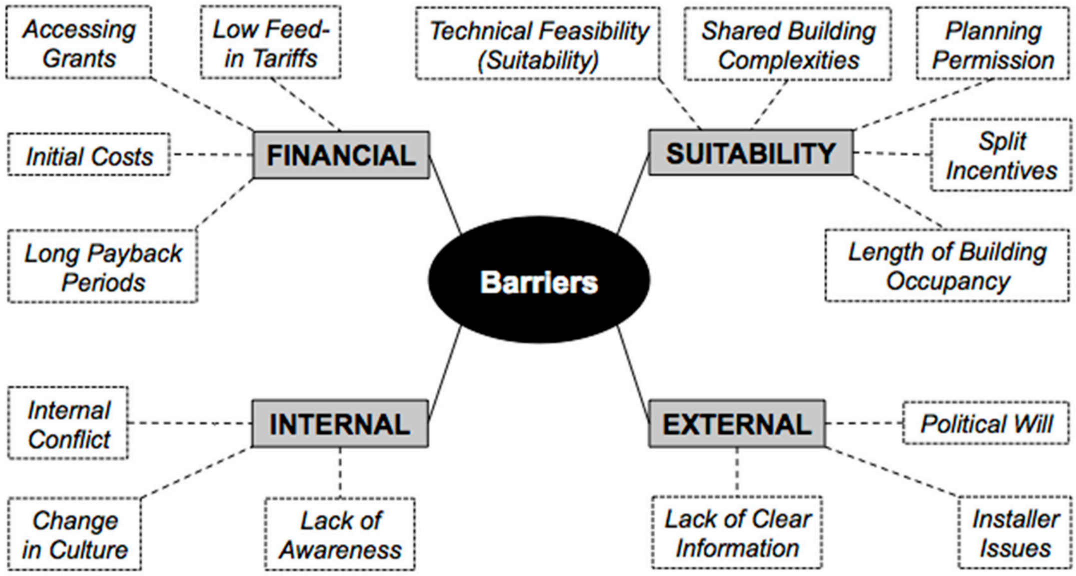

Figure 1. Barriers to micro-generation in SMEs.

For the identification of drivers to the adoption of micro-generation in UK SMEs, three factors are especially dominant as the primary drivers: for 'green' marketing purposes, for environmental reasons and for the feed-in tariffs. All three of these drivers featured prominently in the sample when participants were asked to list other drivers.

The finding regarding 'green' marketing is particularly interesting, as CSR can be used for commercial advantage through attracting clients via visible demonstrations of environmental commitments. This is in contrast to energy efficiency, which is usually less visible. This matches the findings of studies in the CSR literature that have primarily focused on the impacts of CSR in larger organisations rather than SMEs (e.g., [65,66]). The following quotes summarise this impact. The first quote is from a food manufacturing-based SME that had installed a micro-wind turbine and was investigating the installation of a small Anaerobic Digestion plant:

> *"I do it in PR as well—I'm trying to generate a virtuous circle out of it—we do these things and it gives us good PR and exposure [which] helps us [to] sell more stuff [which] generates more money and we can do more things—as we do more things we generate good PR and you get into a virtuous circle."*

The second quote is from an office-based SME that had installed solar photovoltaics and a micro-wind turbine:

> *"Clients will always look at two or three other companies, so for me, I want to give them a way of remembering us ... but I guarantee that every single time they will remember the fact that we have solar panels and a wind turbine ... so we need to make an investment that we wouldn't otherwise make to try and make a return that we can't actually tell investors or the bank what it is—it is completely intelligible and is an investment of time and money. There's absolutely no question that it has helped our business ... I know for a fact that companies have come to us because of the green measures that we have put into place ... and they cite it as their sole reason for coming to us and sometimes pay a bit more for it."*

The importance of 'green' marketing was clear in the sample, but as only a quarter of the SMEs interviewed had actually installed micro-generation, direct evidence of the economic impacts of 'green' marketing for SMEs is less clear. The examples demonstrate positive qualitative impacts from 'green' marketing that are demonstrated through organisational behaviour. However, for the rest of the sample, 'green' marketing is important as an attitude rather than backed-up through actual behaviour.

For other SMEs, the importance of installing micro-generation for environmental reasons was apparent, as highlighted in the following quote from a food manufacturing-based SME:

> *"For me, it's the realisation that the economy is a subset of the environment...it's a very profound change in the way we do things in that I now see money as a tool to move towards sustainability rather than money as an end to things in itself...I'm not doing this to earn more money—I'm earning money to do this."*

Similarly, for the feed-in tariffs that are available for low carbon electricity generation (through the feed-in tariffs scheme) or renewable heat generation (through the renewable heat incentive scheme), participants that had considered (but not installed) micro-generation viewed them as an important incentive, as demonstrated in the following quote from a non-profit-based SME:

> *"Yes I think feed-in tariffs increase the incentive...I hope so anyway—I think it is a good incentive...that is definitely something we'd look at."*

Figure 2 summarises the identified drivers for the adoption of micro-generation in SMEs, which have been grouped into financial, ethics, internal and external drivers.

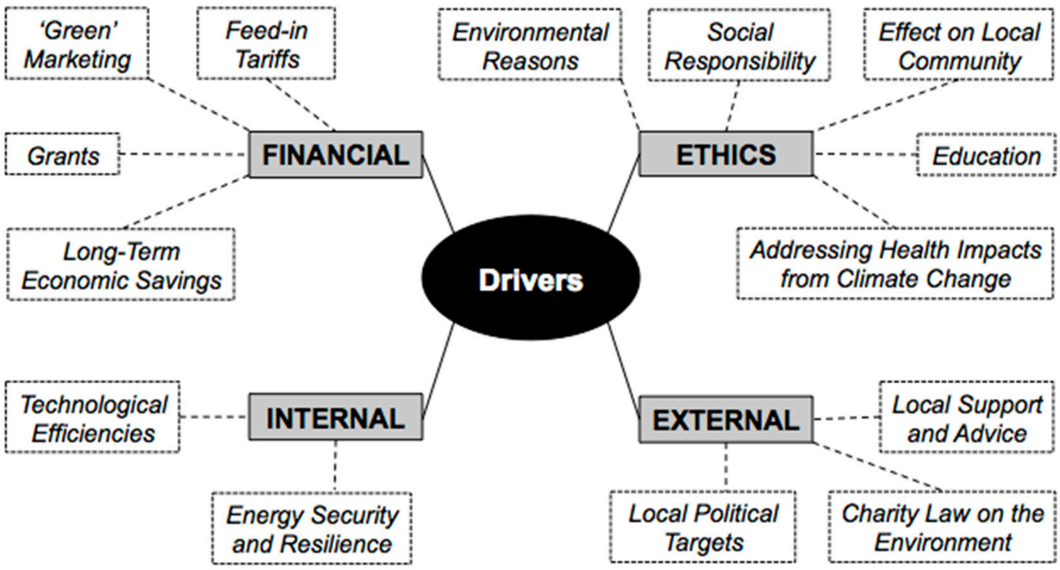

Figure 2. Drivers for micro-generation in SMEs.

Overall, in comparing Table 8 on the drivers and barriers to the adoption of micro-generation in the domestic sector with the results from this paper on SMEs, it is clear that key barriers, such as initial costs, overlap, but other barriers, such as planning permission (particularly for historical buildings) and technical feasibility (suitability), appear to be more prominent for SMEs than households. Despite this, the barriers show more similarity between the domestic and SME sectors than the results for drivers. The importance of 'green' marketing as the primary driver, whether reflected through behaviour (those SMEs that had installed micro-generation) or attitudes (those SMEs that had not installed micro-generation), is different from other studies that have examined micro-generation in the domestic sector (e.g., [61,62]). Some parallels might be drawn to 'green' status and reputation in Table 8, but 'green' marketing primarily focuses on the (difficult-to-quantify) commercial value from attracting clients through visible demonstrations of environmental commitment. It is beyond the scope of this research to undertake a detailed comparison between the SME and domestic sectors, as the focus of the paper is on identifying what the drivers and barriers are to the adoption of micro-generation in SMEs in the UK. Nevertheless, this is an important area for further research.

6. Conclusions

The paper aimed to contribute to improving the evidence base on demand-side management (DSM) in small-to-medium-sized enterprises (SMEs). SMEs are an important group that make up 99% of businesses and contribute 13% of energy demand globally. However, compared with the domestic, large commercial, public and industrial sectors, they are often ignored by government policy due to their complexity and diversity. Previous demand-side research has primarily concentrated on energy efficiency in SMEs rather than other areas of DSM, such as 'smart' technologies and micro-generation.

The results from the smart technologies analysis suggest that there are potential collective annual energy savings of ~£8.6 billion in UK SMEs against an estimated energy spend of ~£49.7 billion (which represents ~17% savings potential on energy expenditures). However, the results broken down by sector and smart technology category are more interesting than the overall figures, as more studies are required to investigate any overlap in potential energy savings between smart technology categories. The analysis found that fleet management, integrated building management systems and smart meters are the three categories of smart technologies that are likely to offer the greatest energy savings potential to SMEs, providing estimated energy savings potential of ~£7.5 billion per year in total across all three categories (fleet management is particularly dominant with ~£6.1 billion savings per year). By sector, the Wholesale, Retail, Transport and Storage; Education; and Accommodation and Food Services sectors have the greatest estimated annual energy savings potential of ~£3 billion, ~£1.3 billion and ~£1 billion respectively.

The key conclusions from the research on smart technologies are that smart technology developers and providers should consider targeting the smart technologies (fleet management, integrated building management systems and smart meters) and the SME sectors (the Wholesale, Retail, Transport and Storage; Education; and Accommodation and Food Services sectors) that appear to have the greatest energy savings potential based on current data. This will also stimulate competition and technological innovation, contributing to reducing the technology costs for SMEs. Secondly, data quality on smart technologies in SMEs is currently poor and more data (and higher quality data) are needed. As such, the key findings and figures from this part of the research require validation once better quality data become available. Academic and industry researchers should target undertaking robust primary data collection to improve the evidence base on SMEs. This will be particularly important for validating the level of potential energy savings from various smart technologies, including whether or not rebound effects (increases in energy consumption) occur in certain circumstances.

The results from the micro-generation analysis identified that the main barriers to the adoption of micro-generation in UK SMEs are: initial costs, technical feasibility (suitability) and planning permission (particularly for historical buildings), and the main drivers are: for 'green' marketing purposes, for environmental reasons and for the feed-in tariffs. There are some common findings with research that has focused on the adoption of micro-generation in the domestic sector, particularly with regards to the barriers, such as initial costs. However, there are notable differences in relation to the drivers, particularly the importance of 'green' marketing. A quarter of the SMEs interviewed had installed micro-generation on their premises, but they stated that the impacts of 'green' marketing on creating commercial value from visible demonstrations of environmental commitment were difficult to quantify, so were assessed more qualitatively.

The key conclusions from the research on micro-generation are that there are notable similarities between the barriers to micro-generation installation in the SME and domestic sectors, but there are noticeable differences with regards to the drivers, particularly the importance of less tangible factors, such as 'green' marketing. There is arguably a potential role for local governments to play in encouraging the establishment of local alliances of SMEs that work together towards shared environmental goals, but which also enhance their economic performance through collaboration, sharing experiences and by encouraging these less tangible factors to gain prominence in increasing the numbers of SMEs that install micro-generation. Due to the generally local nature of SME operations, alliances, such as the Camden Climate Change Alliance (CCCA) and the Islington Sustainable Energy Partnership (ISEP), have demonstrated that local government engagement is more appropriate than national government intervention in encouraging the adoption of micro-generation in SMEs. However, there arguably remains an important role for the UK government to provide information on energy management to SMEs and to provide financial support through feed-in tariffs. Despite this, comments on national level government policy are beyond the scope of this research.

Secondly, the comparison of the research findings to the results on barriers and drivers from related studies, but which focused on different aspects (such as micro-generation in the domestic sector, energy efficiency in SMEs in the UK or energy efficiency in SMEs in other countries, such as Sweden, Portugal, Italy and Turkey), have shown more similarities than differences in the results. This suggests that the identified barriers and drivers have the potential to be applicable across the UK as well as in other countries. However, a crucial caveat to this is that previous research on SMEs has primarily focused on energy efficiency rather than micro-generation. Thus, further research is needed, particularly in other countries and contexts, to determine the degree of similarity between the barriers and drivers for micro-generation and energy efficiency. Additionally, as this part of the research did not aim generalise to the UK SME population as a whole, further research should seek to validate the findings in a nationally representative sample of UK SMEs.

Overall, this paper argues that there is currently unrealised energy savings potential in the SMEs group, part of which could be achieved through the adoption of smart technologies and micro-generation. However, before local and national government policies are designed to realise this potential and overcome the identified barriers, researchers should seek to improve the evidence base and data quality on DSM in SMEs.

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References

1. European Commission. Available online: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en (accessed on 17 April 2017).
2. International Energy Agency (IEA). *Accelerating Energy Efficiency in Small and Medium-Sized Enterprises*; IEA Policy Pathway Series; IEA: Paris, France, 2015.
3. Warren, P. A review of demand-side management policy in the UK. *Renew. Sustain. Energy Rev.* **2014**, *29*, 941–951. [CrossRef]
4. Warren, P. The use of systematic reviews to analyse demand-side management policy. *Energy Effic.* **2014**, *7*, 417–427. [CrossRef]
5. International Energy Agency (IEA). Energy Efficiency. 2017. Available online: http://www.iea.org/topics/energyefficiency/ (accessed on 29 April 2017).
6. UK Department of Energy and Climate Change (DECC). *Research to Assess the Barriers and Drivers to Energy Efficiency in Small and Medium Sized Enterprises*; Her Majesty's Stationery Office: London, UK, 2014.
7. Trianni, A.; Cagno, E.; Marchesani, F.; Spallina, G. Classification of drivers for industrial energy efficiency and their effect on the barriers affecting the investment decision-making process. *Energy Effic.* **2017**, *10*, 199–215. [CrossRef]
8. Backman, F. Barriers to Energy Efficiency in Swedish Non-Energy-Intensive Micro- and Small-Sized Enterprises—A Case Study of a Local Energy Program. *Energies* **2017**, *10*, 100. [CrossRef]

9. Parliament of the United Kingdom. *UK Energy Act 2004*; Her Majesty's Stationery Office: London, UK, 2004.
10. UK Department for Communities and Local Government (DCLG). European Regional Development Fund: England Operational Programme 2014–2020. 2015. Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/453888/England_ERDF_operational_programme_FINAL_140815.pdf (accessed on 29 April 2017).
11. UK Department of Energy and Climate Change (DECC). Enhanced Capital Allowance Scheme for Energy-Saving Technologies. 2014. Available online: https://www.gov.uk/government/publications/enhanced-capital-allowance-scheme-for-energy-saving-technologies (accessed on 29 April 2017).
12. Greenwise Business. RBS Launches Energy Efficiency Loan Fund for SMEs. Available online: http://www.greenwisebusiness.co.uk/news/rbs-launches-energy-efficiency-loan-fund-for-smes-4232.aspx (accessed on 29 April 2017).
13. Energy Saving Trust. SME Loan Scheme. 2017. Available online: http://www.energysavingtrust.org.uk/scotland/grants-loans/sme-loan-scheme (accessed on 29 April 2017).
14. Federation of Small Businesses (FSB). FSB Energy. 2017. Available online: https://www.fsb.org.uk/benefits/advice/fsb-energy (accessed on 29 April 2017).
15. UK Department of Energy and Climate Change (DECC). SME Guide to Energy Efficiency. 2015. Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/417410/DECC_advice_guide.pdf (accessed on 29 April 2017).
16. World Bank. *Energy Efficiency for SMEs. Energy Efficiency Finance*; World Bank Group: Washington, DC, USA, 2015; Available online: http://documents.worldbank.org/curated/en/379251468165570598/Energy-efficiency-for-SMEs (accessed on 29 April 2017).
17. European Bank for Reconstruction and Development (EBRD). *Sustainable Energy Financing Facilities (SEFFs)*; EBRD: London, UK, 2017; Available online: http://www.ebrd.com/what-we-do/sectors-and-topics/sustainable-resources/seffs.html (accessed on 29 April 2017).
18. Asian Development Bank (ADB). *Same Energy, More Power: Accelerating Energy Efficiency in Asia*; ADB: Mandaluyong, Philippines, 2013; Available online: https://www.adb.org/sites/default/files/publication/30289/same-energy-more-power.pdf (accessed on 29 April 2017).
19. African Development Bank (AFDB). Sustainable Energy Fund for Africa. 2017. Available online: https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/sustainable-energy-fund-for-africa/ (accessed on 29 April 2017).
20. Inter-American Development Bank (IDB). *Energy Efficiency for SMEs in Colombia*; IDB: New York, NY, USA, 2014; Available online: https://blogs.iadb.org/cambioclimatico/2014/05/17/energy-efficiency-smes-colombia/ (accessed on 29 April 2017).
21. UK Department for Business, Energy and Industrial Strategy (BEIS). Available online: https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy (accessed on 29 April 2017).
22. Camden Climate Change Alliance (CCCA). Available online: http://www.camdencca.org (accessed on 29 April 2017).
23. Camden Climate Change Alliance (CCCA). Annual Report 2015. Available online: http://www.camdencca.org/content/uploads/2016/02/CCCA-Annual-Report-2015.pdf (accessed on 29 April 2017).
24. Islington Sustainable Energy Partnership (SEP). Available online: http://www.isep.org.uk (accessed on 29 April 2017).
25. Islington Sustainable Energy Partnership (SEP). Annual Report 2015. 2016. Available online: http://www.isep.org.uk/2016/08/18/isep-annual-report-card-2016/ (accessed on 29 April 2017).
26. Depuru, S.S.S.R.; Wang, L.; Devabhaktuni, V. Smart meters for power grid: Challenges, issues, advantages and status. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2736–2742. [CrossRef]
27. European Council. *Directive 2009/72/EC on Smart Meter Rollout*; European Union: Brussels, Belgium, 2009.
28. House of Commons. *Smart Meter Roll-Out, Fourth Report of Session 2013–2014*; Energy and Climate Change Committee, Her Majesty's Stationery Office: London, UK, 2013.
29. Albadi, M.; El-Saadany, E. A summary of demand response in electricity markets. *Electr. Power Syst. Res.* **2008**, *78*, 1989–1996. [CrossRef]
30. Warren, P. Demand-Side Management Policy: Mechanisms for Success and Failure. Ph.D. Thesis, University College London (UCL), London, UK, 2015.

31. UK Department for Business, Energy and Industrial Strategy (BEIS). *Potential of Smart Technologies in SMEs*; Her Majesty's Stationery Office: London, UK, 2016.
32. Her Majesty's Stationery Office (HMSO). *UK Energy Act 2008*; Her Majesty's Stationery Office: London, UK, 2008.
33. UK Office of Gas and Electricity Markets (Ofgem). Feed-in Tariffs. 2017. Available online: https://www.ofgem.gov.uk/environmental-programmes/fit (accessed on 29 April 2017).
34. Trianni, A.; Cagno, E.; Farne, S. An empirical investigation of barriers, drivers and practices for energy efficiency in primary metals manufacturing SMEs. In Proceedings of the 6th International Conference on Applied Energy (ICAE), Taipei, Taiwan, 30 May–2 June 2014; Volume 61, pp. 1252–1255.
35. Pereira, V.M.F.; Ferreira, J.J.M. Barriers to and Driving Forces for Energy Efficiency in the Portuguese Industrial SMEs. In *Design a Pattern of Sustainable Growth: Innovation, Education, Energy and Environment*; Schiliro, D., Ed.; Asers Publishing: Craiova, Romania, 2014.
36. Onut, S.; Soner, S. Analysis of energy use and efficiency in Turkish manufacturing sector SMEs. *Energy Convers. Manag.* **2007**, *48*, 384–394. [CrossRef]
37. Fleiter, T.; Schleich, J.; Ravivanpong, P. Adoption of energy-efficiency measures in SMEs—An empirical analysis based on energy audit data from Germany. *Energy Policy* **2012**, *51*, 863–875. [CrossRef]
38. Scarpa, R.; Willis, K. Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. *Energy Econ.* **2010**, *32*, 129–136. [CrossRef]
39. Watson, J.; Sauter, R.; Bahaj, B.; James, P.; Myers, L.; Wing, R. Domestic micro-generation: Economic, regulatory and policy issues for the UK. *Energy Policy* **2008**, *36*, 3095–3106. [CrossRef]
40. Shimoda, Y.; Taniguchi-Matsuoka, A.; Inoue, T.; Otsuki, M.; Yamaguchi, Y. Residential energy end-use model as evaluation tool for residential micro-generation. *Appl. Therm. Eng.* **2017**, *114*, 1433–1442.
41. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 4th ed.; Pearson Education Limited: Harlow, UK, 2007.
42. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 5th ed.; Pearson Education Limited: Harlow, UK, 2009.
43. UK Department of Business, Innovation and Skills (BIS). *BIS Population Estimates 2015*; Her Majesty's Stationery Office: London, UK, 2015.
44. UK Department of Energy and Climate Change (DECC). *Energy Consumption in the United Kingdom (ECUK)*; Her Majesty's Stationery Office: London, UK, 2015.
45. UK Department of Energy and Climate Change (DECC). *Digest of UK Energy Statistics (DUKES)*; Her Majesty's Stationery Office: London, UK, 2015.
46. Nest. Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results. Available online: https://nest.com/downloads/press/documents/energy-savings-white-paper.pdf (accessed on 16 November 2016).
47. British Gas. *Hive Energy Saving Report*; British Gas: Windsor, UK, 2014.
48. University of Cambridge. EPRG Public Opinion Survey: Smart Energy Survey—Attitudes and Behaviours. Available online: http://www.econ.cam.ac.uk/research/repec/cam/pdf/cwpe1352.pdf (accessed on 16 November 2016).
49. Concerted Action Energy Efficiency Directive. *Smart Meters and Consumer Engagement*; European Parliament: Brussels, Belgium, 2015.
50. UK Office of Gas and Electricity Markets (Ofgem). *Energy Demand Research Project: Final Analysis*; AECOM House: St. Albans, UK, 2011.
51. Natural Scotland. *Building Management System Procurement Guide*; Scottish Government: Edinburgh, Scotland, 2014.
52. Continental Automated Buildings Association (CABA). *Bright Green Buildings: Convergence of Green and Intelligent Buildings*; Continental Automated Buildings Association: Ottawa, ON, Canada, 2008.
53. Roth, K.W.; Westphalen, D.; Dieckmann, J.; Hamilton, S.D.; Goetzler, W. Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential. 2002. Available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/hvac_volume3_final_report.pdf (accessed on 16 November 2016).

54. Brambley, M.R.; Haves, P.; McDonald, S.C.; Torcellini, P.; Hansen, D.; Holmberg, D.R.; Roth, K.W. Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways. 2015. Available online: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/pnnl-15149_market_assessment.pdf (accessed on 16 November 2016).
55. Galasiu, A.D.; Newsham, G.R. Energy savings due to occupancy sensors and personal controls: A pilot field study. In Proceedings of the Lux Europa 2009 11th European Lighting Conference, Istanbul, Turkey, 9–11 September 2009.
56. Kiwi Power. Kiwi Power and Time Inc. UK Partner for Demand Response. 2013. Available online: http://www.kiwipowered.com/files/download/fa6e18841634151 (accessed on 16 November 2016).
57. UPS. Big Data = Big Wins for the Environment. 2013. Available online: http://sustainability.ups.com/media/UPS-Big-Data-Infographic.pdf (accessed on 16 November 2016).
58. Frost & Sullivan. *Benefits of Fleet Management Systems*; Frost & Sullivan: San Antonio, TX, USA, 2012.
59. Teletrac Navman. *Teletrac Customer Survey*; Driscoll Report (2013); Teletrac Navman: Garden Grove, CA, USA, 2013.
60. Saumure, K.; Given, L.M. Data Saturation. In *The SAGE Encyclopedia of Qualitative Research Methods*; SAGE Publications: Thousand Oaks, CA, USA, 2008.
61. Bergman, N.; Hawkes, A.; Brett, D.J.L.; Baker, P.; Barton, J.; Blanchard, R.; Brandon, N.P.; Infield, D.; Jardine, C.; Kelly, N.; et al. UK micro-generation Part 1: Policy and behavioural aspects. *Energy* **2009**, *162*, 23–36.
62. Allen, S.R.; Hammond, G.P.; McManus, M.C. Prospects for and barriers to domestic micro-generation: A United Kingdom perspective. *Appl. Energy* **2008**, *85*, 528–544. [CrossRef]
63. O'Malley, E.; Scott, S.; Sorrell, S. Barriers to energy efficiency: Evidence from selected sectors. *Policy Res. Ser.* **2003**, *47*, 1–159.
64. Anderson, S.T.; Newell, R.G. Information programs for technology adoption: The case of energy efficiency audits. *Resour. Energy Econ.* **2004**, *26*, 27–50. [CrossRef]
65. May, S.K.; Cheney, G.; Roper, J. *The Debate over Corporate Social Responsibility*; Oxford University Press: Oxford, UK, 2007.
66. Banyte, J.; Brazioniene, L.; Gadeikiene, A. Expression of Green Marketing Developing the Conception of Corporate Social Responsibility. *Inzinerine Ekonomika Eng. Econ.* **2010**, *21*, 550–560.

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