

# Characterising a local energy business sector in the United Kingdom: participants, revenue sources, and estimates of localism and smartness.

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## Abstract

Local and decentralised energy initiatives increasingly contribute to decarbonising energy systems. This trend is facilitated by emergence of new actors, ownership modes, business practices, and value sources in energy markets. However, there are no explicit, standardised criteria for what may constitute a local, potentially “smart”, energy business sector. We therefore provide a first characterisation of a local energy business sector in the United Kingdom, through a literature review and an empirical analysis derived from a business database. We also propose a framework for characterising businesses, using a matrix to assess their degree of localism and smartness. Our findings reveal an emergent sector comprising diverse entities, including organisations with limited energy market experience. Embryonic business innovations are being translated into various revenue sources. However, businesses have as yet made limited use of digital systems for smart operation, and despite distinctive forms and degrees of localism, many aspects remain to be addressed. This implies opportunities for this sector to create value by tackling localism and smartness elements. Further research should include more quantitative elements in our characterisation to map the sector with effective participation of businesses through a sectoral survey.

Keywords: Local energy businesses, Characterising smart local energy systems, United Kingdom

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## 1. Introduction

Energy market liberalisation is associated with successive socio-technical and political-economic changes worldwide. Many countries have reorganised formerly public, centrally-planned energy systems by incorporating new private sector actors, forms of ownership, government institutions, legislation, and technologies (Jegen & Wüstenhagen, 2001; Markard et al., 2004; Pollitt, 2012; Sioshansi, 2001). Historically, the United Kingdom (UK) energy system evolved from decentralised, small systems (Lehtonen & Nye, 2009) to larger, centralised power plants and grids, in public ownership, before privatisation in the 1980s-1990s (Grubb & Newbery, 2018; Winskel, 2002). Pro-liberalisation reforms during the 80's and 90's resulted in entrance of new actors (Grubb & Newbery, 2018; Lehtonen & Nye, 2009; Thomas, 2016); these included a minority of organisations from other sectors - e.g. universities (Mazhar et al., 2017; Trencher et al., 2014) and social enterprises (Hiteva & Sovacool, 2017) -, and new forms of ownership, business practices, and value sources (Dutra & Barbalho, 2017; Engelken et al., 2016). Additionally, environmental pressures have led to concerns over climate disruptions, mobilising a wide policy/legal commitment to decarbonisation (Kern & Rogge, 2016). However, the paths to a zero-carbon transition are still subject to scrutiny and uncertainty (Li & Pye, 2018). This includes debate around the potential for more decentralised energy systems (Barton et al., 2018) to support decarbonisation and reduce overall transition costs.

The UK has been an active participant in debates about the role of decentralised and local energy, and has a variety of initiatives and demonstration projects. Among others, Cornish homes and businesses<sup>1</sup> are testing a local renewable energy market; a local non-profit enterprise, Aberdeen Heat and Power<sup>2</sup>, supplies affordable heat to low income households and public buildings, and sells electricity to the grid. Although some actors emphasise the particular role of local authorities (LAs) working with the private sector (Ford et al., 2019) to leverage investment

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<sup>1</sup> See <https://www.centrica.com/innovation/cornwall-local-energy-market>

<sup>2</sup> See <https://www.aberdeenheatandpower.co.uk/about/>

(Devine-Wright, 2019), this does not seem a "sine qua non" condition for a local energy business (LEB) sector. Private businesses are engaging and/or delivering value locally, through commercial partnerships<sup>3</sup> and/or direct benefits to communities<sup>4</sup>. Government policies also recognise the role of private entities in local energy (Fuentes González et al., 2019)<sup>5</sup>. The key point on "being local" is therefore that various energy businesses, with differential commitment to localities, might be categorised as "local". Thus, a local energy sector may not be focused exclusively on public-private partnerships, or on any other single business structure. In the literature, to our best knowledge, there is however no formal characterisation of a LEB sector. Likewise, given that digitalised solutions are increasingly relevant to decarbonisation (Ford et al., 2019), any characterisation needs to consider estimates of how "smart" local energy businesses are. What constitutes "local" and "smart" in energy businesses is subject to debate, therefore we have adopted the definitions of local and smart constituent elements developed in Ford et al., (2019). Hence, "localism" is defined as businesses with relationships to local stakeholders; local involvement in decision-making, and some local ownership of assets. "Smartness" is defined as businesses using real-time information and communication technologies; automating aspects of business operation and systems regulation; and using machine learning or artificial intelligence to inform decision-making and engage people.

The above raises the following research questions about the composition of a UK LEB sector: a) what kind of organisations are participating? b) what types of energy business are being carried out? c) what energy technologies and sources are involved? d) what is the degree of smartness and localism? and e) what is their past and future trajectory? Addressing these questions will provide information to better understand and characterise a UK LEB sector, as well as to support (future) innovations and coordinated strategies for a more decentralised, clean, affordable, resilient, and democratic energy system. Our work therefore contributes to the state-of-art literature and debate around local energy systems.

The paper comprises the following sections. In section 2, a systematic literature review, encompassing UK and European academic evidence as well as grey literature, is provided the theoretical background. Section 3 explains the method used to construct a first-of-kind business database, which is the starting point for sector characterisation. The fourth section provides an empirical characterisation of a UK LEB sector, derived from database analysis, based on summary descriptive statistics and a matrix which estimates degree of localism and smartness. Section 5 discusses the findings. Finally, section 6 concludes.

## 2. Literature review

This section explores the state-of-art literature on business opportunities, and UK and European experiences, in the context of local, decentralised energy. The literature search strategy is detailed in Appendix A.

### 2.1. New energy business opportunities

The energy mix and vectors have evolved throughout the sector's history, including transformations in environmental governance in the early 1990s (Abbott, 2012). This evolution concerns not only centralised energy production/consumption structures, but also more decentralised, local, and latterly "smarter" structures (Ford et al., 2019). In this context, an emerging diversity of energy services provides new opportunities to create, capture, and deliver value.

As a fundamental aspect of energy services, electricity provision provides business opportunities to deliver value through reliability/availability, flexibility, carbon avoidance, and easing congestion - offset or delay of network investments - (Pöyry, 2019a). New energy business models are expected to address value creation to serve customers' needs, breaking away from existing market silos through more local integration, and using digitalisation (Dutra & Barbalho, 2017). This digitalisation enables businesses with few capital assets to target specific customer services (asset-light approach), such as intermediation via aggregators or digital platforms, peer-to-peer exchange, mini-grids, or off-grid (Glachant, 2019). Businesses with a positive balance between guaranteed long-term revenues and fixed cost generation assets, in the context of bilateral contracts or regulated schemes, are also key in supporting new business models. Capturing, exploiting these opportunities will require grid/network innovations (Glachant, 2019), as new types of exchange between incumbents will occur. In relation to local scale opportunities, PWC details different business models relevant for local energy systems as follows (PWC, 2014). *Transmission/distribution network manager*, focused on hard infrastructure, advancing system features including reliability, and engaging with distributed generators through charges for network connections. *Product innovator*, who invests in data analytics and develops superior products from commodities to home energy devices, satisfying

<sup>3</sup> See <https://www.goodenergy.co.uk/our-energy> for an example

<sup>4</sup> See <https://www.banksgroup.co.uk/projects/renewables/hook-moor> for an example

<sup>5</sup> See <https://www.webarchive.org.uk/wayback/archive/20170401055145/http://www.gov.scot/Topics/Business-Industry/Energy/CEPS2015>

different needs in order to engage with customers and build up brand reputation and product expansion. *Partner of Partners*, which offers not only conventional energy services, but also other related ones through a network of qualified providers. *Value-added enabler*, who collects mass supply and demand data to provide insights into consumption patterns and non-accessible information valuable for customers and businesses. A final category, *Virtual utility*, which acts as aggregator and then intermediary between distributed generators, and/or as integrator of other (more innovative) energy services provided by third parties. At a retail level, new business models are also emerging, such as wholesale prices with cap; flat prices regardless of consumption; brokers or bill providers; combined energy service provision and on-site generation; and back-end services for new companies (Kenefick, 2019).

New energy businesses will be relevant in terms of value creation, retention, and delivery, in the context of continuing decentralisation (localism) and technological progress (smartness) of energy systems. Smartness seems particularly important for local, decentralised energy systems in regards to improving connectivity, information processing and analysis, and consumer/stakeholder engagement. Indeed, smarter structures can facilitate integration of energy services, including those currently operating in the UK, like electric vehicle (EV) charging (Andrews, 2017; Morris & Hardy, 2019), district heating (ADE, 2018b; Lowes et al., 2018; Millar et al., 2019), energy efficiency and retrofitting<sup>6</sup> (Liu, 2018) - some authors include other demand-side measures (Eyre & Killip, 2019) -, energy storage<sup>7</sup> (Morris & Hardy, 2019), and even energy systems demonstrators (Flett et al., 2018). Multi-vector entities may offer energy-related services at specific locations, such as university campuses (Mazhar et al., 2017), and community-owned energy production initiatives deliver value to communities or localities (Braunholtz-Speight et al., 2018; CEE, CEW, & SPEN, 2019). LAs involved in energy services (Grant Thornton, 2016) may also act as intermediaries between private and public interests, due to their territorial powers, knowledge, and resources (Webb, 2014). Beyond the significance of more local and smarter energy architectures, new small and medium enterprises, as well as some households, are also becoming key actors (EIC & ESC, 2016; ADE, 2020) in this evolving energy landscape.

This suggests that an interesting triad, formed by localism and smartness elements, as well as new actors, is influencing current and future energy businesses. Examples of emerging local, decentralised UK energy businesses in the literature, potentially addressing smartness elements and shaped by their participants, can be used to explore options for characterising a UK LEB sector.

## 2.2. Emerging UK local, decentralised energy businesses

While the state-of-art literature does not provide a formal characterisation of a UK LEB sector, there are particular examples associated with the concept. One example is the market penetration of bioenergy-based innovations (De Laurentis, 2012), which not only produce electricity or biofuels, but also biofertilisers, and inject gas into the grid; such initiatives may involve farmers and other local stakeholders as a way of collecting enough feedstock for energy production. Another study (Hiteva & Sovacool, 2017) illustrates UK local energy businesses, focusing on one cooperative, which works on retrofitting and energy usage, and one municipally-owned supplier which buys directly from the wholesale market and offers better terms and conditions, and tariffs for customers; this business uses revenues to cover overheads and make further savings. Another example is found in a sample of LA-oriented UK energy projects, examined in Webb et al., (2017), mostly focused on sustainable heat and retrofitting. The authors note that the majority are integrated into existing council structures, capacities, and cross-sector partnerships; independent businesses are however emerging, and these are both commercial and non-profit entities, including public ESCos, private-led ESCos, and bencoms<sup>8</sup>.

In a seminal study, Brown et al. (2019) analyse UK prosumer business models as a set of archetypes. First, *distributed generation* projects are defined as those behind the meter for self-consumption and injection into the grid. Distribution network operators are expected to be key to deploying these initiatives through investment in digitalisation and associated innovation, with the aim of using energy resources locally to gain flexibility (EY & Eurelectric DSO members, 2019; Pöyry, 2019b). Second, *micro-grids* are described as locally owned and operated small distribution networks, with a virtual energy company which may be responsible for billing customers who consume within the local network. Third, a *local energy company* is understood as a local generation owner using the existing distribution network to provide better rates for local customers. Fourth, *P2P models* are conceived as prosumers trading (distributed) generation among themselves without a third party supplier<sup>9</sup>. Fifth, *flexibility services* are conceived as adding value through voltage optimisation and real-time supply/demand matching, and

<sup>6</sup> See <https://www.gov.scot/publications/energy-efficient-scotland-route-map/> for an example.

<sup>7</sup> See <https://www.energylivenews.com/2019/12/02/uk-energy-storage-sector-sees-massive-growth/>

<sup>8</sup> Community benefit societies.

<sup>9</sup> However, it is currently necessary to have a contract with a supplier for technical reasons, and prosumers assume transmission costs.

are offered by a wide range of projects. Incumbents and new entrants, including demand-side projects (ADE, 2016, 2018a), need to accumulate and manage flexibility capital, in other words, "*the capacity to responsively change patterns of interaction with a system to support the operation of that system*" (Powells & Fell, 2019). For example, estimates based on European countries like Sweden and Germany suggest significant opportunities for hour-to-hour flexibility in use of residential space heating (NCM, 2017). Beyond the specific flexibility scheme, technological platforms - like Piclo Flex in the UK or Enera in Germany (Schittekatte & Meeus, 2020) - are key enablers, as they allow timely, accurate, and effective coordination, and matching between supply and demand. Sixth, in the context of *transportation models*, prosumers may charge EVs using local generation and storage; some companies are improving local prices by buying from the grid when prices are lower and renewable generation is higher. There are also public electric transport services. The UK is however likely to need a more developed, sustainable charging infrastructure, including smart grid systems and storage capacity; fast charging systems would only be necessary for emergencies (Andrews, 2017). Projections of demand for smart charging and vehicle-to-grid (V2G) services suggest a sharp increase in the next decade (Element Energy, 2019; Energy Taskforce, 2020; Haslett, 2019). In some European countries like France, Sweden and Germany, peer-to-peer initiatives help co-fund infrastructure; consumers rent the best-located charging point from companies or individuals, also eventually allowing them to buy electricity (Vanrykel et al., 2018). Seventh, some businesses provide end-services with competitive tariffs and long-term agreements via an *energy services company or ESCo*, which owns the infrastructure and takes responsibility for service quality/reliability. *Solar-as-a-service* and *Heat-as-a-service* businesses are examples of this archetype. Other emerging businesses in this category offer *multi-vector services contracts*, with comprehensive retrofitting and efficient generation technologies either directly or indirectly through an ESCo (also noted in Bergman & Foxon, (2020); profits are sometimes allocated to a community fund. Challenges, however, remain in the UK; these are related to creating innovative value propositions and business models from an end-user perspective (Hussain & Thirkill, 2018). European examples include experiences of value proposition (improvement) and business model (re-)design. Case study comparison of one public- and one private-sector led sustainable urban district in France, involving housing, shopping centres and offices, and innovative energy efficiency/usage, show how the private-led, network-based project was able to implement transformations in its business model, and then improve its value proposition, customer interface, supply chain, and financial model. By comparison, the LA-led project focused only on areas with grant funding, restricting improvements to value proposition and supply chain (Gauthier & Gilomen, 2016). A further example is a Dutch comprehensive retrofit ESCo which creates value by investing in residential flats (which receive a share of profits) and establishing strong networks/partnerships with other entities, in order to generate savings (Hiteva & Sovacool, 2017). Three comprehensive retrofit programmes in France, Germany, and Finland are also analysed; smarter elements such as smart controls/thermostats, internet of things and cloud-based intelligence, as well as owners' involvement in a public-private-people partnership, are identified as key elements of differentiation in Finland (Pardo-Bosch et al., 2019). This type of initiative may facilitate more customers becoming prosumers without worrying about the investment in assets. From a local energy perspective, both approaches, *energy-as-a-service* and *multi-vector services contracts*, could achieve high levels of localism and smartness, as elements such as relationships with local stakeholders, local involvement in decision-making, real-time information, and business automation/self-regulation may be effectively addressed. The above archetypes provide useful information on more local, decentralised energy initiatives, though with focus on prosumerism; we note that localism does not necessarily imply prosumerism. Likewise, no specific information on what type of entities and their characteristics and condition, at a sectoral level, is provided, nor insights into their degree of smartness.

Ivanova et al. (2019) define emerging UK local energy services' archetypes, distinguishing between *local consumer services* (including ESCos, energy efficiency, advice, and fuel poverty schemes), *local generation* (community-owned/managed assets for local use), *local supply* (including LAs-based projects), *micro-grids* (parallel or independent decentralised grids), and *virtual private networks* (trial projects for local balancing purposes within current networks).

The above evidence shows various types of local energy initiatives operating in the UK, although their penetration, in terms of total number of projects, installed capacity, technologies, and customers, is unclear. Moreover, the evidence suggests an important role of digitalisation in some energy businesses (e.g. micro-grids, flexibility services, transport, etc.), although its effective degree of penetration at a sectoral level is unclear. Archetype specifications, particularly those in Ivanova et al., (2019) and Brown et al., (2019), indicate some convergence in definitions, which can be tested through further evidence. This will help to establish a more systematic perspective on the universe of potential constituents of a LEB sector, as well as to compile useful information, and to derive policy lessons.

### 2.3. Reflections on the need for a UK local energy business sector characterisation

The state-of-art literature suggests that there is neither a characterisation of a UK LEB sector, nor an integrated vision across types of energy business which addresses localism and smartness elements. We conjecture that there is a lack of evidence and uniform criteria for defining local and smart. An empirical characterisation based on their components (Ford et al., 2019), rather than their abstract definition, therefore seems appropriate. The evidence also suggests a new wave of more local, decentralised energy initiatives. This time, however, incumbents and new entrants are not only big private companies, but also local organisations (e.g. universities, farmers, community groups, LAs); some of these will be more committed to localised energy systems, as ways of opening markets, improving transparency and engagement with stakeholders, and securing revenues. The UK energy sector is thus becoming more varied, encompassing a cross-sector mix of investors, from LAs to universities, to community energy groups, to investment funds focused on (community) small/medium scale projects, to commercial heat and power developers. Furthermore, the evidence unsurprisingly regards digitalisation as a factor in the opportunity structure for (new) energy businesses. This justifies our approach to considering smartness alongside localism. Nevertheless, limited progress in digitalisation need not impede the operation of local cross-vector integration in any given energy business, though such integration may involve consortia rather than a single business<sup>10</sup>. This can be seen, for instance, in current combined heat and power projects using various forms of storage. A new LEB sector is currently emerging in the UK, which is influenced by progress in digitalised technologies (smartness). A need for sharper characterisation of this sector is evident, in order to support sustainable sectoral growth in the context of decarbonisation, decentralisation, digitalisation, and democratisation (4D) of energy systems. In the next section, we provide a first step towards such a characterisation, using qualitative criteria.

### 3. Methods: database construction

We developed a database of 699 companies, providing a representative picture of the UK market. The key criterion for inclusion in the database was that a business addressed at least one constituent element of localism. The database primarily uses information provided by Bureau van Dijk through its product FAME®, a time series database of UK and Ireland businesses<sup>11</sup>. We extended this data by integrating information from other sources. The process of identifying companies and gathering extra information used the terms "local", "community", "district", and "university" in the database as filters on company names. Other websites were also explored to identify more companies<sup>12</sup>. Each company's parent entity was checked in order to find and include related companies, where appropriate. Once a sample of companies was identified in the database, their websites (where available), notes to the financial statements on UK Companies House website, media articles, and other online sources, were searched for extra information. This includes the number of customers, revenue streams/sources, technologies and installed capacity, provision of benefits to communities, and ownership, where available. Due to heterogeneity of information sources, and lack of useful information in some cases, our database does not have complete uniformity of content about each company. Some comparisons presented here may hence involve only those companies where relevant information was available. The constituent elements of localism and smartness revealed in (Ford et al., 2019) were used to develop a qualitative scale based on such constituent elements. Based on the available information, best judgement was used to estimate and map the degree of localism and smartness of each business included in our database according to a matrix. Details about the classification process and specific examples are in Appendix B. We also carried out a descriptive statistical analysis which informs the main findings.

### 4. An empirical characterisation of a UK local energy business sector

This section presents an empirical characterisation of a UK LEB sector based on a first-of-kind business database. Themes emerging from preliminary analysis are examined here. Two points are developed as follows: firstly, descriptive statistics are used to characterise the sector; and secondly, a matrix for characterising UK local and smart energy businesses is proposed.

<sup>10</sup> As exemplified in Prospering From an Energy Revolution (PFER) Programme demonstrators – See [www.energyrev.org.uk/about/pfer-demonstrators/](http://www.energyrev.org.uk/about/pfer-demonstrators/)

<sup>11</sup> A University of Edinburgh license was used for this study.

<sup>12</sup> Such websites are detailed as follows: [localenergy.scot](http://localenergy.scot) - [communityenergyscotland.org.uk](http://communityenergyscotland.org.uk) - [communityenergyengland.org](http://communityenergyengland.org) - [communityenergywales.org.uk](http://communityenergywales.org.uk) - [theade.co.uk](http://theade.co.uk) - [biogas.org.uk](http://biogas.org.uk) - [adbioreources.org](http://adbioreources.org) - [scottishrenewables.com](http://scottishrenewables.com) - [renewableuk.com](http://renewableuk.com) - [aleo.org.uk](http://aleo.org.uk) - [districtenergy.org](http://districtenergy.org) - [euroheat.org](http://euroheat.org) - [heatandthecity.org.uk](http://heatandthecity.org.uk) - [energy4all.co.uk](http://energy4all.co.uk) - [energysavingtrust.org.uk](http://energysavingtrust.org.uk) - [uk.ramboll.com](http://uk.ramboll.com) - [resourceefficientscotland.com](http://resourceefficientscotland.com) - [pureleapfrog.org](http://pureleapfrog.org) - [ukerc.ac.uk](http://ukerc.ac.uk)

#### 4.1. Local energy businesses in the UK: a sample-based descriptive statistical analysis

Most of the database of 699 businesses consists of private limited companies (94.8%)<sup>13</sup>. Circa 93% of the sample individually have no, or just one, subsidiary - 587 businesses. The remainder mostly have between 2 and 5 subsidiaries, as in Figure 1; these subsidiaries show that there are related companies which may also pertain to the sector, and that any sector characterisation should consider their inclusion in mapping and analysis.

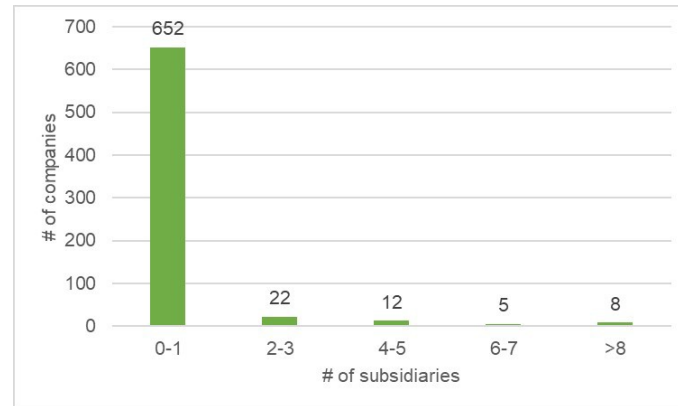


Figure 1: Companies and their subsidiaries (N=699)

A number of companies were also part of a corporate structure, with other related companies identified in our database. Figure 2 shows a simplified version of corporate structures identified in our sample. One structure is a root company with a series of intermediate companies, which link to entities that run energy businesses. The latter entities may also invest in other energy businesses (yellow and green areas). This seems common in bigger companies and investment funds (which open ownership to any investor). The grey area involves a root company (which may run an energy business too) with an energy business subsidiary, potentially with more dependants. Some LA-based, community-oriented, and private companies operate under this structure. Under the purple area are some LA-based, community-oriented, and biogas-based companies. In this case, there is a common root company or owner which invests in companies that run (various) energy businesses; the latter may in turn invest in subsidiaries. The red area represents the same idea but here, the root companies or owners are not the same. Most of these cases are investment funds, community-oriented entities, small/medium-scale producers, and LA-based organisations. Some businesses are therefore part of more complex corporate structures than others. More information may be available which we have not accounted for, due to resource or data limitations. Nevertheless, the examples above represent most of the cases where a corporate structure is observed.

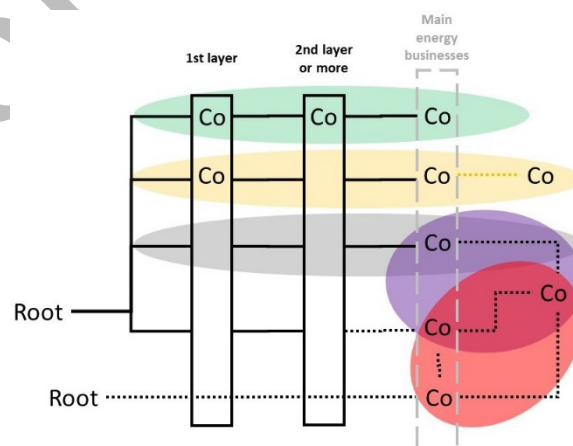


Figure 2: Types of corporate structures in our sample

We classify all companies (stand-alone and those identified in corporate structures) according to the following criteria which aim to identify their "purpose" in the context of LEB sector structure. First, a *core business* is any

<sup>13</sup> Around a quarter (27.8%) complete "full" and "group" financial accounts, which implies that more information is available in the company financial statements.

entity created to directly run energy businesses, regardless of overall corporate structure (e.g. holding, investment vehicle or stand-alone entity). Second, an *investment vehicle* is any company, which is part of a corporate structure that not only depends on a parent company, but also contains other dependent companies. Third, a *holding* is any company that contains other dependent companies without having a parent entity. More than 90% of the entities in our database are directly carrying out energy business (core business and derived categorisations). Circa 9% of this group have a dual classification, either *core business/investment vehicle* or *core business/holding*. In the former classification, most companies were direct energy businesses, with dependent energy entities and a parent company<sup>14</sup>. In the latter classification, no parent company was found. The details are shown in Figure 3.

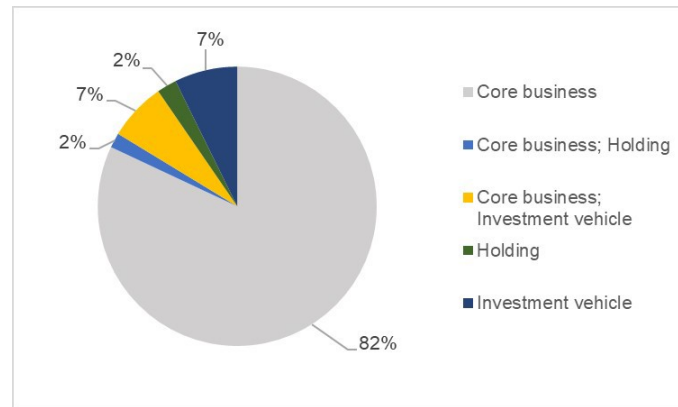


Figure 3: Purposes of companies (N=699)

The above classification may imply overlapping categories. However, as shown above, circa 91% of the entities are direct energy businesses, with a small proportion potentially acting indirectly via subsidiaries. The remainder (9% - holding companies and investment vehicles) consists of entities active in energy provision through other primary roles. Including them would give a better idea about what a more local, decentralised energy business sector might look like in reality.

In terms of ownership, as noted in Figure 4, most businesses are privately-owned (77%). Community interest companies comprise 6% of the sample<sup>15</sup> and others are owned by trusts, foundations or community groups (14%). Councils and universities own the remainder (3%). This information shows who is behind the sector, as well as providing some insights into the way that benefits are provided. We use the latter to define companies' degree of localism.

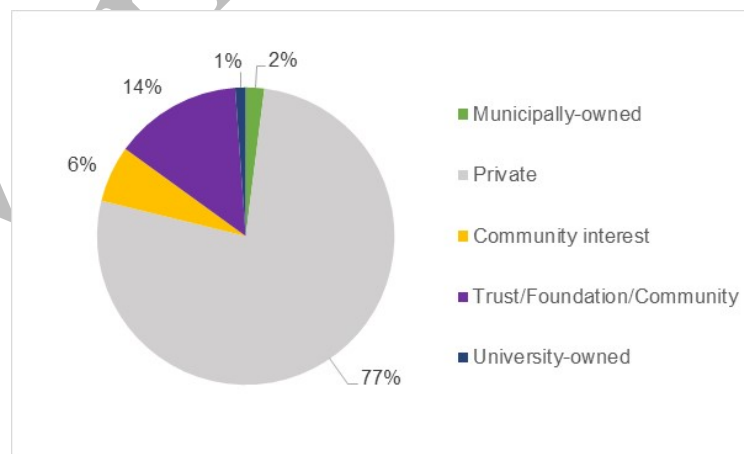


Figure 4: Companies ownership (N=699)

<sup>14</sup> In some cases, there was insufficient information about the role of an entity in running energy businesses directly or through subsidiaries; nor was it possible to include such subsidiaries in our database.

<sup>15</sup> A type of limited company conceived to benefit communities rather than shareholders.

As a proxy for company size, we use companies' average assets and adopt the Companies House<sup>16</sup> company accounts guidance thresholds to determine the size of each company. Our criteria are detailed as follows:

- Micro entity, average assets are less than £316,000
- Small company, average assets are between £316,001 and £5,100,000
- Medium company, average assets are between £5,100,001 and £18,000,000
- Large company, average assets are greater than £18,000,000

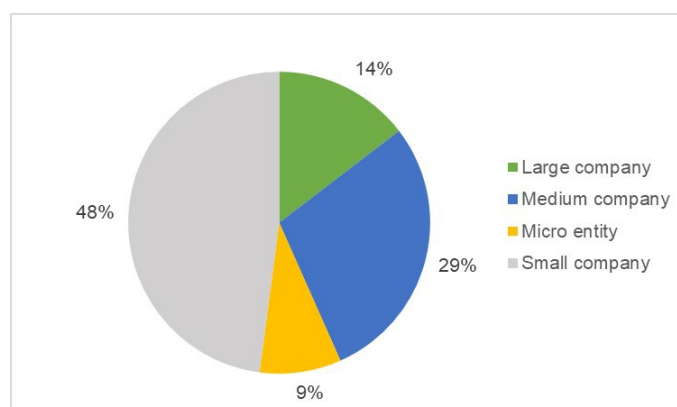


Figure 5: Size of companies based on average assets (N=699)

We consider assets, because the largest proportion should be fixed-assets, which would not vary significantly over the period of business operation. Furthermore, assets represent all the resources needed to generate sufficient income/turnover to cover business costs. Assets are hence a proxy for estimating company size. Using this proxy, Figure 5 shows that almost half of the businesses in our sample are small (typically with one employee), 29% are medium-sized (typically with five employees), 14% are categorised as large (typically with 37 employees), and 9% are categorised as micro (typically with 1 employee).

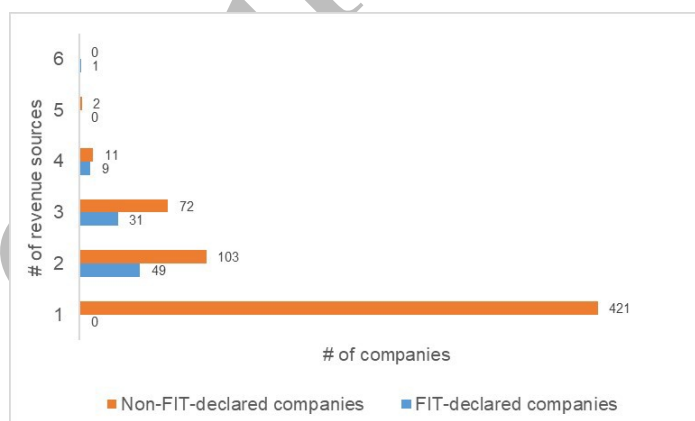


Figure 6: Number of revenue sources by number of companies (N=699)

Figure 6 examines companies' revenue sources with the aim of gaining insight into how they generate income. Most of the businesses (421 out of 699) have just one revenue source. 276 of these sell electricity to the grid<sup>17</sup> using renewable sources/technologies such as solar PV (118 businesses with circa 652 MW of estimated capacity), wind (97 businesses with approximately 713 MW), hydro (50 businesses with around 30 MW), and biogas (11 businesses with nearly 15 MW). The remainder, 145 out of 421 businesses, are mainly involved in gain on investments<sup>18</sup> (67), heat and power services (27), power purchase agreements or PPA (18), district heating (8),

<sup>16</sup> See <https://www.gov.uk/government/publications/life-of-a-company-annual-requirements/life-of-a-company-part-1-accounts>

<sup>17</sup> In the case of no explicit information about the energy company's revenue sources, it is assumed that, given the company's nature and purpose, its main revenue source is the production and sale of electricity to the grid (which may be either connected or not to the trunk transmission system).

<sup>18</sup> This is not limited to investments in financial instruments, but includes investments in energy businesses as well.



retail supply of electricity (6), retail supply of gas and electricity (4), benefits management (3), and enhanced frequency response services (2).

The sample also includes businesses which have two or more revenue sources (188 out of 699). In addition to selling electricity to the grid, most of these businesses (154 out of 188) have revenues from renewable obligation certificates (ROC), PPA, production of biofertiliser, gain on investments, food, and general, waste management. The main technologies used by these businesses are onshore wind (932 MW of estimated capacity related to 53 businesses), solar PV (462 MW related to 44 businesses), biogas (115 MW related to 29 businesses), offshore wind (1802 MW related to 9 businesses), and waste-to-energy (130 MW related to 7 businesses). In addition, there are storage, hydro, combined heat and power (CHP), and biomass technologies in use, although each of these technologies is associated with less than 6 businesses. A proportion of the businesses receive public subsidies. Almost 13% (90 out of 699) declare receipt of Feed-in-Tariff (FiT) benefits; most of these businesses have two (49) or three (31) revenue sources; the main related technologies are solar PV (33 businesses with nearly 118 MW of estimated capacity), wind (23 businesses with circa 33 MW), biogas (21 businesses with approximately 38 MW), hydro (14 businesses with nearly 330 MW), and CHP (6 businesses with circa 2.9 MW); the remainder consists of one storage business (1.2 MW) and one heat pump. The main additional revenue sources, apart from the FiT, are sales of electricity to the grid, PPAs, gain on investments, production of biofertiliser, sales of gas to the grid, heat and power services, and renewable heat incentive benefit (RHI).

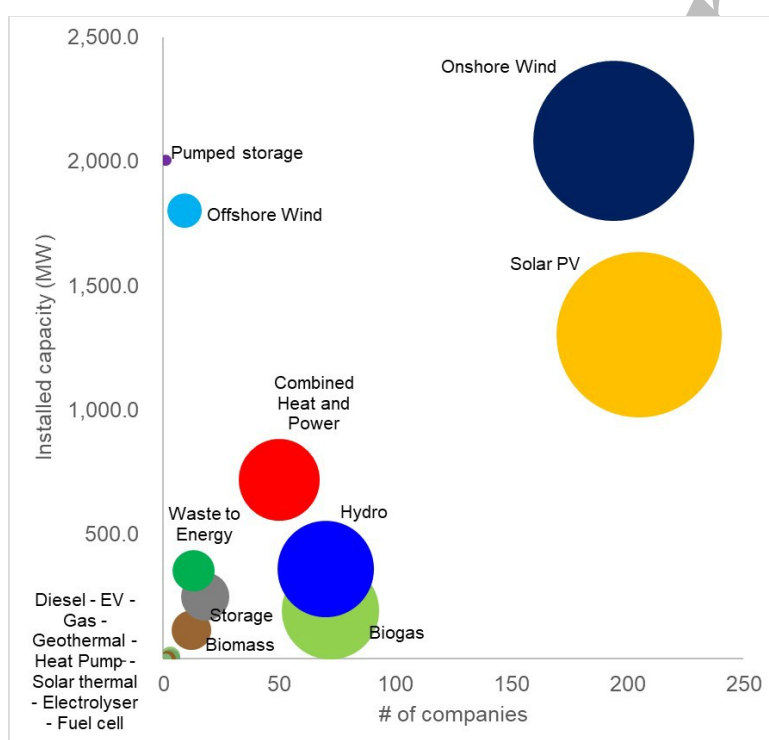


Figure 7: Estimated installed capacity by source/technology and related number of companies (N=606)

Figure 7 shows the estimated installed capacity by technology and number of companies involved in a particular technology (each bubble's size is determined by the number of companies). If we consider the quotient between these variables, which gives an idea of the average capacity, the largest are associated with pumped storage, offshore wind, waste-to-energy, CHP, storage, and onshore wind. In contrast, those related to diesel, heat pumps, solar thermal, electrolyser, and fuel cell sources/technologies are the smallest<sup>19</sup>. Biomass, Biogas, Gas, Solar PV, and Hydro projects are in an intermediate range. The most recurrent associations between energy sources/technologies and revenue sources across businesses are shown in Table 1. This offers insights into how each technology contributes to revenues. Further research is needed to examine other aspects like value proposition and financing capital investments.

<sup>19</sup> No information about installed capacities was available for the three EV and one geothermal projects included in our database.

Table 1: Most recurrent associations between energy sources/technologies and revenue sources across businesses

Energy source/technology	Revenue source
Pumped storage	Selling electricity to the grid; Tourism attraction
Wind offshore	ROC; Selling electricity to the grid
Waste to Energy	Selling electricity to the grid; Waste management
CHP	Heat and power services
Storage	Selling electricity to the grid
Wind onshore	Selling electricity to the grid
Biogas	Fertiliser; Food waste management; Selling electricity to the grid
Biomass	District Heating
Gas	District Heating
Solar PV	Selling electricity to the grid
Hydro	Selling electricity to the grid
Diesel	Selling electricity to the grid
Heat Pump	FiT; Selling electricity to the grid
Solar Thermal	Gain on investments; Heat and power services; Other non-energy services
Electrolyser	Hydrogen energy storage
Fuel cell	Hydrogen energy storage

An important aspect of local energy businesses is how they interact and engage with stakeholders, especially in relation to project implementation/delivery/benefits, routine decision-making (e.g. how value created is delivered to localities; in what ways energy provision is carried out etc.), or ownership (Ford et al., 2019). These aspects should independently lead to the creation, offer, and delivery of direct monetary and/or non-monetary value for localities. We say "independently" because an organisation may not have open ownership; instead, it may provide value for localities by engaging locally in either project implementation/delivery/benefits or decision-making. The above can be further explored to analyse other potential routes to value creation, offer, and delivery. Localities may be determined by geographical, societal, economic, or legal criteria. We focused on collecting data about companies from whom information on (direct) benefits for communities was available. As revealed in Figure 8, more than one third (36%) of the businesses declare to deliver some type of benefit to communities, chiefly comprising community funds. In this group, there are also businesses that provide benefits through local ownership, and others, such as community interest companies, that are assumed to deliver benefits by definition, although there are no further details about these in published reports (benefit by virtue of legal structure). Further research is needed to assess how effectively such energy businesses are providing benefits to communities/localities, and the corresponding social and economic implications.

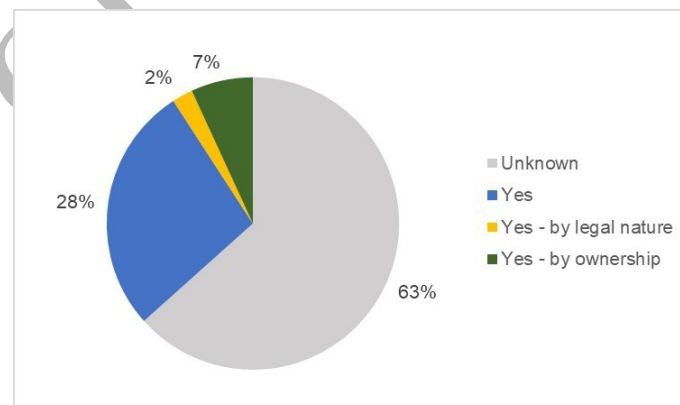
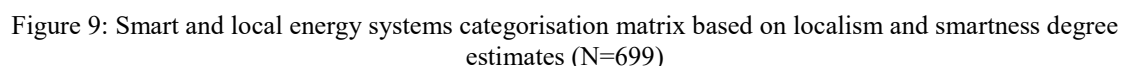


Figure 8: Companies from whom information on (direct) benefits for communities was available (N=699)

This analysis uses the elements specified in (Ford et al., 2019) to address the concepts of local and smart in the context of energy systems. This does not imply uniformity across businesses, as each one has particular characteristics (different technologies, involvement with stakeholders, ownership schemes, legal forms, etc.). Consequently, we propose a way of characterising energy businesses by establishing degrees of localism<sup>20</sup> and smartness for each business.

Figure 9 shows the smart and local energy systems categorisation matrix. It shows the combined localism and smartness ratings for each energy business, represented by number of companies in each quadrant of the matrix. The results are based on a qualitative scale, which uses the constituent elements of localism and smartness to define each case. More details on matrix categorisations, based on levels of localism and smartness ("*Energy Systems*", "*Smart & Local Energy Systems*", "*Transition*", "*Local Energy Systems*", and "*Smart Energy Systems*"). as well as on the qualitative scale and assessment procedure, are given in Appendix B. The green and red arrows represent optimistic and pessimistic trajectories, if these energy businesses were one rating higher or lower (different from our estimate) along both axes, respectively.



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Our estimates show a concentration in rating 1 (Low) of smartness, but scattering between ratings 1 and 3 for localism. This means most of the businesses in our database are categorised as constituents of Local Energy Systems, though with different levels of localism; only a few are under Transition. Tables 2, 3, and 4 show the ownership, company size, and distribution of benefits for each quadrant of the matrix<sup>21</sup>.

In terms of ownership (Table 2), privately-owned companies are most likely to have low levels of localism (ratings 1 and 2); third-sector organisations and more socially-oriented businesses unsurprisingly show high levels of localism (rating 3). Nevertheless, there are some privately-owned businesses with high levels of localism. This implies that, among the mix of local energy providers, there are: increasing numbers of privately-owned businesses, such as those owned and operated by farmers and landowners; companies which engage with communities/residents or participate in partnerships with LAs and/or third sector organisations; investment funds open to any investor; and district energy residential management entities. This evidence reveals increasing localism with a mix of business ownership, and size, although predominantly medium, small, and micro scales. Table 3 supports this claim.

Delving into Table 3, we estimate that companies' distribution across sizes and LES categorisation ratings is varied. Yet no micro entity appears in the intermediate Transition zone with localism ratings of 2 and 3; this could denote that no micro entity can as yet afford the resources for a high degree of both smartness and localism. In addition, no large company is allocated to the Transition zone. This could indicate that such businesses are either primarily focused on more traditional energy services, with low levels of both localism and smartness, or are committed to strengthening their services by delivering some form of local value. This may also be a viable form of business innovation to achieve higher levels of smartness.

A very small number of the businesses are close to operating as a SLES<sup>22</sup> (levels 3 of localism and 2 of smartness), due to their participation in storage initiatives, as well as their social, community, or public ownership (2 businesses). Others are less comparable to an integrated SLES model (5 businesses) given that they are privately owned or "less local", but nevertheless participate in storage initiatives, and either work with LAs or provide some direct benefits to communities. Some "less local" businesses are defined as "smarter" (14 businesses with levels 1 of localism and 2 of smartness), given their involvement in storage initiatives which provide flexibility in (system) operation. Over half of the businesses (55%) included in the LES categorisation with levels 2 and 3 of localism, and over 70% in the transition zone with the same levels of localism (2 and 3), are provide local benefits. It is important to recall that, in our definitions, localism does not exclusively mean improved or direct benefits to communities. Furthermore, the above is based on estimates, the best judgement of performance according to the information we could gather.

Table 2: Ownership distribution of companies by ratings combination in the matrix (N=699)

Ownership	LES (1,1)	Transition (1,2)	LES (2,1)	Transition (2,2)	LES (3,1)	Transition (3,2)
Municipally-owned					14	
Private	223	14	273	5	22	
Community interest companies					43	
Trust/Foundation/Community				95	2	
University-owned					8	

Table 3: Size distribution of companies by ratings combination in the matrix (N=699)

Size	LES (1,1)	Transition (1,2)	LES (2,1)	Transition (2,2)	LES (3,1)	Transition (3,2)
Large company	37		58	2	5	
Medium company	89	6	68	3	34	1
Small company	93	7	130		104	1
Micro entity	4	1	17		39	

<sup>21</sup> The combinations of localism and smartness in all tables below are defined as follows: (localism,smartness).

<sup>22</sup> The acronym for Smart & Local Energy Systems.

Table 4: Benefits provision distribution of companies by ratings combination in the matrix (N=699)

Benefits provision	LES (1,1)	Transition (1,2)	LES (2,1)	Transition (2,2)	LES (3,1)	Transition (3,2)
Unknown	223	14	193	2	11	
Yes			66	3	122	1
Yes - by legal nature					16	
Yes - by ownership			14		33	1

## 5. Discussion

This characterisation of a UK LEB sector is intended to provide initial insights into the state of the sector, in line with the following research questions: a) what kind of organisations are participating?; b) what types of energy business are being carried out?; c) what energy technologies and sources are involved?; d) what is the degree of smartness and localism?; and e) what is their past (history) and future trajectory?

Current literature does not explicitly characterise local energy businesses or the sector. Instead, it suggests that liberalised markets may have been a catalyst for new forms of local, decentralised energy. Others argue however that the liberalised market is not a "free" market, but a market dominated by a few entities operating as an oligopoly or even monopoly<sup>23</sup>. The latter may be responsible for the slow pace of inclusion of new actors and decentralisation of energy markets. In these circumstances, a local, decentralised energy sector may require a considerable period to develop and changes to market regulation.

The evidence, from both literature and database, suggests, however, that opportunities are being translated into new energy vectors and, therefore, new businesses and value sources. This context is bringing new actors into the market. In relation to research question a), these include "less-experienced" universities, third sector organisations, and LAs, which are addressing elements of digitalisation, consumer engagement, prosumerism, and supply chain development. Of course, this does not exclude more established or experienced private sector actors. European examples could be further explored to help policymakers and business managers implement pro-decentralisation measures, where justified by benefits. Our findings demonstrate that new actors, including those with little experience in the energy sector, are formally and effectively involved in more local, decentralised energy businesses in the UK<sup>24</sup>.

Concerning research questions b) and c), the literature implies "a forthcoming wave" of more local, and smarter, UK energy businesses. They are expected to address the 4Ds more effectively than conventional energy businesses. Archetypes for UK local energy businesses in the literature are useful for identifying, classifying, and understanding such initiatives. Further work on explicit and more unified definitions of a LEB sector may help establish a common basis for coordinated, focused policy and research efforts. Based on our database, we note that current local energy businesses have a variety of revenue sources. For example, organisations such as bioenergy or waste-to-energy businesses cover a wider section of the supply chain, and have more than one revenue source. There are also businesses involved in activities such as aggregation (3), carbon dioxide production (1), hydrogen energy storage (1), microgrid operation (1), electricity supply for EVs (1), water supply (2), and even tourism services (1). Hence there are embryonic forms of innovation and a diversity of entrepreneurial activities and value sources. Nevertheless, most businesses are involved in conventional energy vectors, using now established technologies like solar PV and onshore wind. Likewise, public funding/subsidies remain significant in local energy development.

In regards to research questions d) - the degree of smartness and localism - and e) - their past (history) and future trajectory – using the matrix shown in Figure 9, we estimate that most of these businesses have not yet integrated digital or smart systems. In relation to localism, evidence from our database suggests that some businesses need more innovative ways to create/strengthen ties with stakeholders, in order to address all elements of localism beyond monetary benefits. This could include involvement in decision-making beyond benefits delivery, as well as further opportunities for project ownership and partnerships between community, public, and private sectors. Other aspects, beyond the elements of localism addressed here, could be considered and further developed.

<sup>23</sup> See <https://www.ft.com/content/40ef9ff8-fd4b-11e7-9b32-d7d59aace167>

<sup>24</sup> Many companies in our sample report under a disclosure regime requiring only limited public information, which makes data collection more difficult. Even so, links are revealed between literature and empirical findings.

Despite the absence of a formal historical approach to a LEB sector in the literature - perhaps, because this sector involves various initiatives with different historical backgrounds and evolution -, there is considerable scope for developing a Smart & Local Energy Sector. Real time management and usage, smart engagement with customers, use of artificial intelligence, new forms of ownership/decision-making, more innovative corporate structures, and new financial instruments/markets may be pathways to more local, smarter energy businesses. The trajectory will be hugely influenced however by governments and policy-making to create the conditions for a stronger decentralised, democratic, and digitalised UK energy system, capable of accelerating decarbonisation. Policy recommendations are as follows:

- I. Develop criteria for establishing a LEB sector. This should help formulate more coordinated policies, and measures to promote sustainable growth of the sector. Our methodological approach, including more quantitative elements and an effective participation of real businesses through a sectoral survey, provides one option.
- II. Establish policy support for investment in local energy businesses providing innovative clean energy services.
- III. Consider a unified financial, business disclosure regime to support transparency, informed policy and effective development of the sector.
- IV. Devise policy to support integrated smart, local systems with a local stake in clean energy.

## **6. Conclusion**

This work is a first attempt to characterise a UK LEB sector, using literature review and empirical evidence. The approach is open to debate and improvement, particularly in regards to the qualitative scale, matrix and allocation methodology which could be strengthened by more detailed surveys. This may help improve reliability in classification of businesses according to degree of localism and/or smartness. Previous research has not explicitly characterised the sector, highlighting one of the main contributions of this study. New characterisations need to be substantive and comparable to inform public policies. Furthermore, new insights into financial models and the instability of local energy businesses are needed to support innovation, value creation, and therefore the sustainability of the sector. These themes require further research.

The UK LEB sector seems promising. Enterprises are using a variety of technologies and legal structures, in many cases having more than one revenue source. Embryonic business innovations include using technologies to facilitate wider supply chain coverage (e.g. waste-to-energy projects or biodigestors which collect and treat their “raw material”), or spin-off businesses (e.g. biodigestors which produce biofertilisers or a pumped storage plant that also runs as a tourist attraction). Literature highlights novel integrated schemes and/or technologies, combining retrofitting, micro-grids, energy-as-service, and district heating. Nevertheless, UK development of a local, decentralised, integrated sector is slow and limited. Innovations to develop a smarter sector, capable of creating, delivering and retaining local, as well as whole system, value, are needed.

The paper aims to further the debate about local energy sector development. It not only addresses questions about the participants, current and future trajectory, businesses and technologies, and revenue sources, but also identifies a future research agenda concerned with: more quantitative assessment of localism and smartness; a common basis for more coordinated promotion of the sector; finance, and insights into value creation and innovation. Our next steps are more detailed analysis of the database, and exploration of opportunities to develop new local energy businesses.

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## Appendix A. Search strategy

The literature search strategy considered three search engines: Scopus®, Web of Science®, and Google®. The first two were used for capturing academic evidence, whereas Google was used for collecting grey literature evidence (considering the first 20 pages of results only). The academic evidence was limited to articles, review articles, book chapters, and books, and was managed through EPPI Reviewer®. The following terms were used in all search engines: *"local"*, *"community"*, *"district"*, *"communal"*, *"decentralised"*, *"distributed"*, *"embedded"*, *"energy"*, *"business structure"*, *"business model"*, *"business"*, *"finance"*, *"funding"*, and *"financing"*. The exclusion criteria for the selection of titles and abstracts (first stage), prior to the whole content revision (second stage), applied to documents that: address nuclear energy; chiefly deal with fossil fuels; exclusively refer to countries outside the European Union and the UK; and use mathematical simulations (e.g. optimisation-based studies) as the main foundation for conclusions. After applying these criteria, the selected papers consisted mostly of in-depth case studies, interviews, surveys, document analysis, comparative analysis, workshop reports, and sectoral reports. In addition, some evidence was directly included based on our best judgement, knowledge, and specific sources of interest. The sources of interest are detailed as follows: The Association for Decentralised Energy (ADE), Centre for Research into Energy Demand Solutions (CREDS), UK Energy Research Centre (UKERC), and Energy Systems Catapult (ESC). As a result, 33 academic from Scopus and WoS, 7 grey literature-based documents from Google, and 42 direct-source academic and grey literature-based documents, namely a total of 82 documents, were available for research purposes; 57 documents (out of 82 documents) were finally included in this paper. The reminder will be considered in future papers.

## Appendix B. The smart and local energy systems categorisation matrix

The smart and local energy systems categorisation matrix is a 5x4 matrix. The x-axis represents "localism" and y-axis represents "smartness". The matrix shows categorisations based on the different levels of localism and smartness reflected in a qualitative scale detailed below. We refer to "system" instead of "business" because we do not want to limit the application of this matrix and methodology to businesses/companies only. Instead, we want to extend the use of these tools to other energy-related research subjects, where possible. A system may be defined as a group of various energy businesses, a mix of multi-vector energy entities, etc. Such boundaries are beyond the scope of this work. Nevertheless, as long as any energy-related research subject can be assessed according to its degrees of localism and smartness, we do not see significant limitations in using this matrix.

The logic behind the categorisations and their position in the matrix is explained as follows. There are two extremes in the matrix, namely "*Energy Systems*" and "*Smart & Local Energy Systems*". In the former, projects do not present any identifiable way of engagement with localities by addressing any of the constituent elements of localism; the information and communication technologies used by these projects are minimum or sufficient to make decisions accordingly to run energy businesses reasonably well - most of the state-of-art energy projects would be allocated to this categorisation. In the latter, on the contrary, projects encompass all constituent elements of localism and smartness; such initiatives offer opportunities for engagement in projects (e.g. through benefits provision or other measures), involvement in decision-making, and shares in asset ownership. They are also capable of collecting and using data in real time, adjusting operations automatically, and engaging people potentially through machine learning or artificial intelligence. As the category of "Smart & Local Energy Systems" is assumed to have the highest levels of localism and smartness, there is a "*Transition*" zone where projects have some ability to respond to the environment by adjusting their operations or service provisions automatically or semi-automatically. When initiatives address constituent elements of localism, we assume they are more local initiatives or "*Local Energy Systems*". When projects address more advanced elements of smartness, namely automatic adjustment of operations or services provision and data generation to engage people in decision-making, planning, etc., we assume they are smarter initiatives or "*Smart Energy Systems*".

The numbers inside the circles represent the number of companies allocated to a specific intersection of localism and smartness. Each rating is associated with a specific level of localism and smartness, based on a qualitative scale as follows:

### Localism:

*Level 0 - Aloneness:* No links or involvement with the community and/or other stakeholders can be found.

*Level 1 - Participation:* There are signs of participation in specific initiatives with communities and/or stakeholders, in terms of global participation in the project, decision-making or asset ownership, but they are diffused, isolated, not clear, or not part of an institutionalised policy. Only one element (out of 3) is usually present as part of the business commitment with localism.

*Level 2 - Involvement:* There is (a degree of) involvement with communities and/or stakeholders in terms of global participation in projects, decision making or asset ownership. A combination of two elements (out of 3) can be found in a clearer way, as part of the commitment with localism.

*Level 3 - Engagement:* There is a deeper engagement with communities and/or stakeholders in terms of global participation in projects, decision-making and asset ownership. All elements of localism are therefore present in the business.

### Smartness:

*Level 0 - Inferior:* The level of information and communication technologies is minimum or under development. Data are not gathered and used in real or near real time.

*Level 1 - Acceptable:* The level of information and communication technologies allows collection and use of data in real or near real time. Effective decision-making is carried out to help the business run reasonably well.

*Level 2 - Improved:* In addition to an acceptable level of information and communication technologies, the business can respond to its environment by (automatically or semi-automatically) adjusting its operation to optimise service provision.

*Level 3 - Advanced:* In addition to collection and use of data in real time, and automatic adjustment of operations, the business is able to generate and use data to engage people in decision-making, planning, and/or governance.

*Level 4 - Smart:* The business is capable of collecting and using data in real time, automatically adjusting its operation to provide an optimal service, and effectively engaging people, by having some degree of machine learning or AI embedded.

The assessment took into account the elements of local energy and smartness used in (Ford et al., 2019), namely for smartness: information and communication technologies, automation and self-regulation, ability to learn system dynamics, and smarter decision-making; and for localism: local and community stakeholders, decision-making processes, and asset ownership. As shown above, once a pool of companies for potential examination was identified in the database, after using key terms as filters on company names and visiting relevant websites, an information collection process was carried out in order to extend the information contained in FAME©. This implied examining various online sources of information, such as financial statements on UK Companies House's website, media articles, among others. After that, a pool of extra information for most of the companies included in our database was collected, which included information about customers, revenue streams/sources, technologies and installed capacity, provision of benefits to communities, legal structures, and ownership. This information was considered to estimate, based on the qualitative scale shown above, the degrees of localism and smartness. The whole process is shown below in Figure B.10.

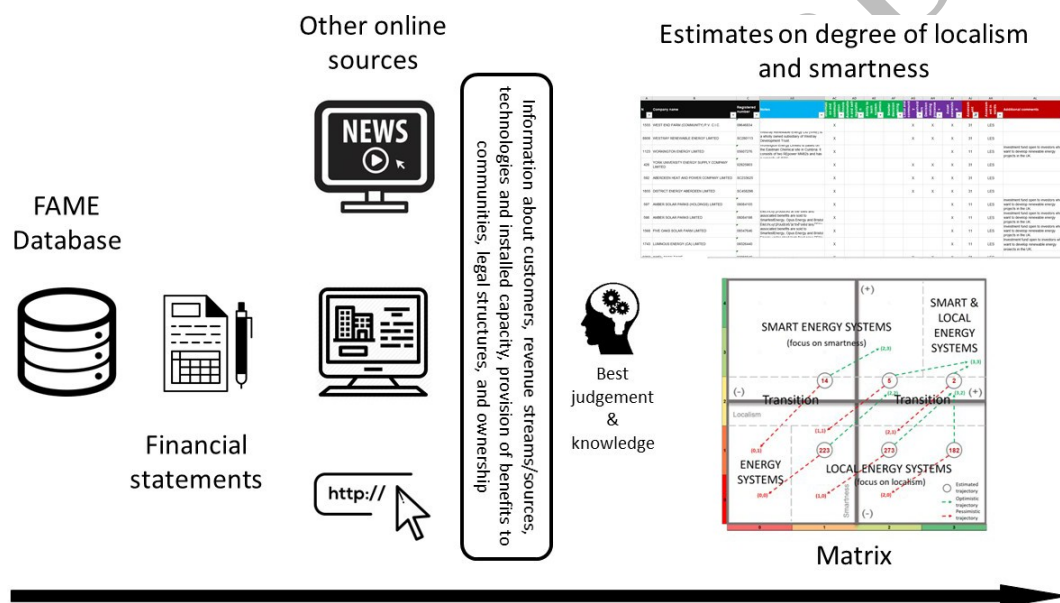


Figure B.10: Assessment process for degrees of localism and smartness.

Company name	Acceptable	Improved	Advanced	Smart	Local and community stakeholders engagement	Decision-making processes involvement	Asset ownership	Assessment	Assessment in words	Additional comments
ASSYNT HYDRO LIMITED	X				X	X	X	31	LES	
FIRST CENTRAL HEATING COMPANY LIMITED	X				X	X		21	LES	Local/on-site enegy schemes. Work with developers. Liaison with residents.
GREEN HIGHLAND ALLT CHOIRE A BHALACHAIN (255) LIMITED	X				X			11	LES	Largest independent hydro developer in the UK which works with landowners, government agencies, utility companies, communities, and multinational businesses to provide bespoke, turnkey solutions to deliver hydropower potential.

Figure B.11: Example of assessment for localism and smartness.

As an example, three cases examined in this work are shown above in Figure B.11. The first one is a Hydro project with an estimated installed capacity of 0.225 MW, owned by a Trust which provides benefits for localities; thus, according to the qualitative scale shown above, it is assumed that all the constituents elements of localism are met, and the level of smartness is acceptable. The second case is a privately-owned local district heating scheme located in a property development in London, based on CHP with an installed capacity of 10 MW. According to its website, the services provided include delivery of energy strategy, ESCo services, billing and metering, and

resident liaison. Thus, it is assumed that two constituent elements of localism would be met, namely local and community stakeholders engagement, and decision-making involvement; the level of smartness is assumed to be acceptable. The third case is a 0.750 MW, privately-owned hydro project, developed by the largest independent hydro developer in the UK which works with landowners, government agencies, utility companies, communities, and multinational businesses to provide bespoke, turnkey solutions. We thus assume that only one element of localism would be met, namely local and community stakeholders engagement and the level of smartness is acceptable.

Of course, the above-mentioned examples are only representative cases of estimates for the degree of localism and smartness. Each case included in the database has its own particularities. There are cases in which more subjective elements and knowledge play a key role, given the information available.

Once the rating for localism and smartness, and intersection in the matrix, was obtained for each company, businesses were clustered and mapped in the matrix so as to allocate them to a specific category. The nature of companies allocated to each combination of localism and smartness, and therefore to a specific category in the matrix, is shown as follows:

### **Local energy systems categorisation**

*Localism (1) & Smartness (1):* under this combination of localism and smartness, there are small/medium-scale projects owned by investment funds who open ownership to investors; energy businesses from whom the provision of benefits to communities is not clear, although they belong to corporate structures which do so or work with LAs; and energy projects which provide benefits beyond money to communities mainly through waste management and recycling, local employment, educational visits or reduced tariffs to customers. Thus, it is expected that at least one of the constituent elements of localism is met. Concerning these examples, at least some degree of either local assets ownership or engagement with local stakeholders through benefits provision is expected. Likewise, we assume that their degree of smartness allows them to collect and use data close to real time, or in real time, and therefore carry out decision-making processes accordingly to run energy businesses reasonably well. All these businesses are privately-owned.

*Localism (2) & Smartness (1):* under this combination, there are companies which belong to corporate structures that provide monetary and/or non-monetary benefits to communities, in some cases with third-sector organisations or LAs involved in benefits decision-making or management; small/medium "not-for-dividend" companies funded by eco-bonds open to investors; investment funds which explicitly invest in community-scale energy projects (sometimes involving benefits for communities); organisations working on local energy provision schemes through partnerships with LAs, property developers, residents or local companies (sometimes involving benefits for communities); and local energy producers (e.g. farmers, landowners, other local companies), some of whom provide benefits for communities. Thus, it is expected that at least two of the constituent elements of localism are met. Concerning these examples, at least some degree of either local assets ownership and engagement with local stakeholders through provision or local retention of benefits, or such benefits provision, local retention and decision-making involvement through partnerships are expected. In terms of smartness, the same criterion shown in the previous categorisation is assumed to be applicable to this allocation within the matrix. All these businesses are privately-owned.

*Localism (3) & Smartness (1):* in this case, most of the projects are owned by trusts, foundations, or community groups, as well as universities and LAs. Under this combination there are also community interest companies, private cooperatives, as well as organisations which share ownership and/or benefits with community groups. It is therefore assumed for these cases that the three constituent elements of localism, namely engagement with communities and/or stakeholders in terms of participation in projects through benefits provision, decision-making involvement, and local asset ownership are met. In terms of smartness, the same criterion shown in the previous categorisation is applicable here.

### **Transition categorisation**

*Localism (1) & Smartness (2):* under this combination of localism and smartness, there are small/medium-scale storage projects owned by investment funds who open ownership to investors. Thus, it is expected that at least one of the constituent elements of localism is met. Concerning these examples, at least some degree of local assets ownership is expected. Likewise, in terms of smartness, not only the assumptions made for the cases above are assumed to be applicable here, but also the ability of responding to the environment and adjusting the operation to optimise the service provision.

*Localism (2) & Smartness (2):* in this allocation, there are privately-owned storage initiatives which either provide monetary or non-monetary benefits for communities or work with LAs through partnerships on local energy provision schemes. Thus, it is expected that at least two of the constituent elements of localism are met. Concerning these examples, at least some degree of engagement with stakeholders through benefits provision or local asset ownership, in combination with decision-making involvement are expected. Again, in terms of smartness, not only the assumptions made for the cases above are assumed to be applicable here, but also the ability of responding to the environment and adjusting the operation to optimise the service provision.

*Localism (3) & Smartness (2):* under this combination of localism and smartness, there are entities owned by trusts, foundations or community groups involved in storage initiatives. Therefore, it is assumed that the three constituent elements of localism, namely engagement with communities and/or stakeholders in terms of global participation in projects through benefits provision, decision-making involvement and local asset ownership, are met in these cases. In addition, in terms of smartness, not only the assumptions made for the cases above are assumed to be applicable here, but also the ability of responding to the environment and adjusting the operation to optimise the service provision.