**Business Models and Financial Characteristics of Community Energy in the UK**

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**Abstract**

Where energy systems are dominated by large-scale actors, community energy represents an alternative model: a decentralised and participatory approach to delivering low-carbon energy projects. This paper presents the first UK-wide quantitative analysis of business models, financing mechanisms and financial performance of community energy projects, using data from a new survey of the sector. We find that business models depend partly on the energy technology used and on project size, in addition to fine-tuning of operations to local contexts. While larger projects rely more heavily on loan financing, community shares are the most commonly used and cheapest financial instrument in the sector. Community energy has thus pioneered low cost citizen finance for renewables, but its potential to grow is threatened by reductions, and instability, in policy support. Over 90% of the projects in our sample made a financial surplus in our single year snapshot, but if we remove income from price guarantee mechanisms, such as the Feed-in Tariff scheme, we find that the number of projects in surplus falls to just 20%. Renewed support and/or business model innovations are therefore needed for the sector to realise its potential contribution to the low-carbon energy transition.

**Main**

Local energy projects delivered by community groups could potentially play a pivotal role in realising the transition to a low-carbon energy future1. Community energy schemes offer an alternative to large-scale energy provision, with various forms of community energy already found across Europe, North America and elsewhere2-6. In the UK, the term “community energy” is generally associated with small civil society organisations and/or social enterprises running projects that encourage energy saving and efficiency, or that generate renewable electricity. These projects are typically grounded in the motivation to accelerate decarbonisation through both decentralisation *and* democratisation of the energy system, and address issues such as fuel poverty and energy justice7-14.

The growth of the sector in the UK has been driven by a combination of the decreasing cost of renewable energy technologies, and government policies (see Table 1)2, 5. However, more recently government support for small scale renewables has been substantially scaled back2, 15. Most notably, Feed-in Tariff rates fell more than 50% from 2015 to 2016 for many technologies (see Supplementary Information Table 2), and the scheme is now closed to new projects. In this challenging low-subsidy environment, project development and investment has slowed significantly16.

**Table 1. Principal forms of government-mandated price support for small-scale low carbon energy provision referred to in this paper**

|  |  |  |
| --- | --- | --- |
| **Scheme** | **Dates open to new projects** | **Energy scope** |
| Renewables Obligation (RO) | 2002 – 2017 | Electricity generation |
| Feed-in Tariff scheme (FITs) | 2010 – 2019 | Electricity generation |
| Renewable Heat Incentive (RHI) | 2014 – 2021 | Heat generation |

Notes: These schemes offer eligible projects a guaranteed price for the electricity or heat they generate. In some cases the schemes operate differently across the UK’s devolved nations, and each scheme involves a complex set of scale and technology bandings, and eligibility and administrative requirements. Further information on these schemes can be found at <https://www.ofgem.gov.uk/environmental-programmes>. Further information on wider government support for community energy can be found in Braunholtz-Speight et al 20182.

These recent developments emphasise the importance of understanding how the community energy sector is financed. However, there is currently very limited empirical evidence on the financing of community energy activities 7, 17 Studies in Germany and Belgium note the mixture of motivations reported by citizens investing in community energy18, 19;further studies in Germany note the substantial size of the renewable energy cooperative sector there20, and its success in raising finance from cooperative members21.The literature on the UK community energy sector focusses mainly on the qualitative exploration of the definitions, motivations and challenges for projects, and how they engage with questions of justice and poverty7-9, 11, 13, 22-30. While sector-wide surveys have played an important role in establishing the size and structure of the sector, gathering some data on finance, these do not offer project-level analysis on financial performance10, 16, 31. A government-convened working group on Community Energy Finance offered insight into difficulties faced by community projects, but did not present an analysis of empirical data32. We are only aware of one previous quantitative study of community energy business models at project level, which compares the costs of community-owned and commercially-owned wind and hydro energy projects in Scotland33, 34. The study provides valuable detailed evidence of the distinctiveness of community energy, finding that community projects face additional risks and transaction costs compared to commercial projects. However, its scope does not include other aspects of business models (such as finance or revenue), other business model types, and projects in other parts of the UK. In this paper, we fill an important gap in the community energy literature by providing the first UK-wide analysis of the financing mechanisms and financial performance of individual community energy projects. We are also the first to systematically characterise community energy business models using quantitative methods. We perform our analysis using a novel and rich dataset on the financial characteristics of community energy projects, collected in a survey of the UK community energy sector undertaken by the authors in 2017-18.

**The Financing Community Energy survey**

We use data from the new Financing Community Energy survey of the UK community energy sector conducted in 2017-18. The survey structure is based on the Business Model Canvas35 which analyses organisations’ value propositions and associated activities; customers; resources; and costs and revenues. For each project’s energy generation and financial flows (costs and revenues), we collected data for only the most recent 12-month period for which it was available, to minimise the administrative burden on participants and maximise the number of projects included in the dataset. Our analysis of the community energy sector is therefore cross-sectional rather than longitudinal (see the Methods section for further discussion).

We received substantive responses to our survey on 145 projects from 48 organisations. To obtain more data on certain technologies, we supplemented the survey data with information on a further 8 projects from organisations’ published financial statements and reports. This extra data gives a total of 153 projects and 56 organisations in our dataset. However, as published documents provide less extensive data than our survey, the data on the additional 8 projects is used only in the summary of project characteristics by technology (Table 4).

Of the 153 projects, the majority (139) are electricity generation projects, with a total capacity of about 41MW. A further 6 projects are heat generation projects, and 9 projects involve no direct energy generation. Other surveys of the sector found 228 community energy organisations in England, Wales and Northern Ireland in 2018, of which 204 were engaged in electricity generation, with a total of 168 MW operational capacity16. In Scotland, there was a total of 81MW of community-owned renewable electricity generating capacity in 201736. Our survey dataset therefore captures approximately one-sixth of the UK community energy sector in terms of installed generation capacity.

Our analysis first provides a taxonomy of the project business models employed in the community energy sector. We then analyse the financial characteristics of community energy projects; the mechanisms by which they have been financed; the price they charge their customers; and the importance of the FITs, and other incentive schemes, to project revenues.

**A taxonomy of community energy projects**

To shed further light on the structure of the sector we applied cluster analysis to produce the first ever quantitative data-driven taxonomy of community energy business models in the UK. A cluster analysis of the survey results helps to identify similarities and differences between community energy projects, to complement case study research. The clusters also present a ‘menu’ of business models that can be used to inform the design of new projects.

Our taxonomy has two parts, based on two runs of the cluster analysis. The first run used project-only variables, omitting the project location and all the variables that related to the organisation running the project. This analysis produced three broad clusters (Table 2) shaped largely by the type of energy activity undertaken (generation vs demand-side activities) and by the type of technology employed.

The second cluster analysis run used all variables, including those relating to the organisation as a whole (such as turnover, number of members, and legal structure), and the project location. Here, the three broad clusters splintered into many smaller ones producing twelve clusters in total (Table 3).

The two runs of cluster analysis map closely on to one another (Table 3). Taken together, they suggest that while technology and activity are important drivers of business models, within the three broad clusters, community energy organisations have fine-tuned their business models. This fine-tuning includes different means of accessing finance and other resources (such as varying reliance on community shares, loans and grants), and offering a range of value propositions to different customers (such as funding other local projects, providing educational opportunities, cutting CO2 emissions, and reducing energy bills).

**Table 2. Taxonomy of UK community energy from cluster analysis of survey data: clusters using only project-level variables**

|  |  |  |  |
| --- | --- | --- | --- |
| **Cluster name** | **Number of projects** | **Number of organisations** | **Key characteristics of clusters** |
| Standalone renewables | 20 | 16 | Wind, hydro, and ground-mounted solar electricity generation projects, and one biomass heat network |
| On-site customer renewables | 85 | 22 | Almost entirely rooftop solar PV projects, but also one solar thermal, one hydro, one wind and one biomass boiler. Electricity sold to customer in building (solar rooftop) or via private wire. |
| Demand-side activities | 14 | 10 | A mixture of energy efficiency and fuel poverty advice projects, and renewable energy generated for own use (rather than selling) |

Of the twelve clusters, the ‘Demand Side Services’ and ‘Energy as a Sideline’ projects stand out as significantly different from the others, and they also form the third cluster in the project-level cluster analysis. The other ten clusters are differentiated partly by technology, with a clear divide between solar rooftop and other generation technologies – also reflected in the project-level cluster analysis. Other variables, such as whether the organisation runs multiple projects, has paid staff or is entirely volunteer-run, the type of customers it deals with, and how it finances its projects, are part of the fine-tuning we note above.

**Table 3. Taxonomy of UK community energy from cluster analysis of survey data: clusters using project, organisation and location variables**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Project-level cluster (Table 2)** | **Cluster name** | **No. of Projects** | **Energy activities** | **Organisation** | **Finance and Resources** | **Revenues and Customer Sectors** |
| Standalone Renewables | Multi-Financed Hydro and Wind | 4 | Hydro and wind electricity generation at small-medium to large scale | Coops and other companies, single projects only | Mix of financing instruments; often pay for sites and other resources | FITs only |
| Standalone Renewables *and* On-site Customer Renewables | Large Wind Selling to Grid | 5 | Wind with mean capacity of >2MW | Coops and other companies with part-time staff | All use loans, some community shares | RO, energy sales to wholesalers or local grid |
| On-site Customer Renewables | Medium Scale Generation with Mixed Financing | 9 | Wind, hydro, solar ground-mount and biomass heat: mean capacity >1MW | Coops and other companies with some paid staff | All use loans, some community shares | FITs and sales to energy companies |
| Small/ Medium Solar Rooftop | 9 | Solar rooftop PV – mix of scales | Volunteer-run coops | Community shares, most resources free | FITs and energy sales to mix of sectors |
| Multi-Site Solar on Public Sector Roofs | 35 | Solar rooftop PV mostly <50kW capacity – sometimes with energy efficiency also | All coops with some paid employment, running multiple projects | Community shares; sites free, some resources free or in house (e.g. legal services) | FITs and energy sales, mostly to public sector |
| Professionalised Solar Rooftop Coops | 13 | Solar rooftop PV – mix of scales | Coops with multiple projects and paid staff | Community shares main financing instrument; many resources paid for | FITs and energy sales to mix of sectors |
| Small Multi-Project Generation for Third Sector Groups | 12 | Mostly solar rooftop PV (but some heat) | Volunteer coops running multiple projects | Mix of financing instruments | FITs and energy sales to third sector |
| Small Solar Rooftop | 9 | Solar rooftop PV mostly <50kW capacity | Mostly volunteer-run coops | Finance mostly community shares; mix of free and paid resources | FITs and energy sales to mix of sectors |
| Smaller Scale Multi-Project Coops | 4 | Multiple solar rooftop PV <50kW capacity | Volunteer-run coops | All using community shares, some loans and grants also. | Mix of public, private and third sector customers; |
| All three project-level clusters | Multi-Tech Generation including Partnerships | 6 | Hydro, wind and solar rooftop PV | Companies with paid staff | Grant and loan finance; sites free, other resources paid or in-house | Hydro and wind sold to grid, solar to local customer |
| Demand-side Activities | Demand Side Services | 6 | Energy efficiency advice and installation, and fuel poverty reduction work. | Mostly coops, paid staff & volunteers | Grants, loans | Customer fees, energy services contracts, some work free of charge |
| Energy as a Sideline | 7 | Rooftop solar PV, heat, and electricity storage | Small scale third sector sports and leisure clubs. | Grants and self-financing | FITs and savings on own energy bills |

Note: for further explanation of use of terms please see Methods section on data gathering.

We find that the most common aspects across the current business models in the community energy sector include: a predominance of electricity generation particularly through solar PV; not having charitable status and not being linked to a charitable ‘parent’ body; employing three full-time staff at most on average (although there are rare cases of employing up to ten staff); relying on at least some volunteers (and up to 90 in some projects); relying on FITs for revenue and community shares for finance; mainly working with one type of customer only; and typically emphasising environmental value propositions over social and economic value propositions.

**Costs, revenues and performance of energy generation projects**

Our sample includes 84 solar rooftop, 15 wind, 12 hydro, 4 solar ground-mount, and 2 biomass projects with sufficient data to calculate financial performance. Table 4 presents summary statistics on the average project characteristics by technology. (The table does not include data on the two biomass heat projects, due to the risk of compromising data confidentiality.)

We find there is substantial heterogeneity in the size, costs and revenues of community energy projects across the different technologies. Wind and solar ground-mount projects tend to be substantially larger than others in terms of generation capacity and performance, costs and revenues. The mean solar rooftop project is smaller, at 74kW capacity; but this size remains much larger than typical UK domestic solar rooftop (<4kW capacity)37.

Table 4 also presents two measures of the financial performance of projects. Annual costs per unit generated are highest for wind projects and lowest for solar rooftop and biomass. In contrast, the return on capital expenditure (CAPEX) is higher for the average wind project than the average solar or hydro project. With the caveat that the sample is very small, biomass heat compares very favourably in terms of return on capital with other technologies (21p per £ CAPEX). The differences in performance observed across technologies may reflect various factors, including: project-specific characteristics such as age and size, both of which may have significant impact on original capital expenditure figures; organisation-specific characteristics, such as expertise of personnel and learning by doing; as well as the features of the technologies themselves.

We find that the average annual financing costs across all projects is £46,500 per annum (excluding projects with zero financing costs). The average total CAPEX across these projects are £865,900. Therefore, community energy projects on average face annual financing costs equal to about 5% of their initial total CAPEX.

**Table 4. Energy generation project characteristics by technology**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Hydro | Wind | Solar ground | Solar roof |
|  |  |  |  |  |
| Number of projects in sample | 12 | 15 | 4 | 84 |
| Capacity (kW) | 163 | 1,862 | 3,428 | 74 |
|  | (162) | (2,741) | (2,304) | (168) |
| Total capital expenditure (£ 000s) | 1,097 | 3,255 | 5,992 | 87 |
|  | (979) | (4,187) | (6,387) | (170) |
| Annual operating costs (£ 000s) | 25 | 136 | 172 | 3 |
|  | (32) | (182) | (205) | (13) |
| Annual financing costs (£ 000s) | 29 | 161 | 318 | 4 |
|  | (37) | (219) | (370) | (9) |
| Annual generation (MWh) | 472 | 4,317 | 3,385 | 56 |
|  | (458) | (7,512) | (2,289) | (111) |
| Annual revenue (£ 000s) | 91 | 552 | 730 | 11 |
|  | (93) | (818) | (900) | (25) |
| Annual surplus (£ 000s) | 37 | 256 | 240 | 4 |
|  | (39) | (489) | (328) | (7) |
| Capacity factor | 0.36 | 0.27 | 0.11 | 0.09 |
|  | (0.15) | (0.14) | (0.01) | (0.03) |
| Annual cost per kWh (£) | 0.12 | 0.15 | 0.12 | 0.11 |
|  | (0.05) | (0.18) | (0.10) | (0.09) |
| Return on capital costs (£) | 0.11 | 0.18 | 0.10 | 0.12 |
|  | (0.05) | (0.10) | (0.03) | (0.05) |

Notes: Table shows mean characteristics with standard deviations (the square root of the variance) in parentheses.

Only data from fully operational projects are included. Some projects for which revenue data is missing are excluded.

Operating Costs refers to expenditure on running the project. Financing Costs include all repayments of borrowing and payments to shareholders. Operating Costs *do not include* Financing Costs.

Annual surplus = (annual revenue – annual operating costs – annual financing costs)

Capacity factor = (annual generation / (365 \* 24 \* capacity)).

Annual cost per kWh = (annual operating costs + annual financing costs) / annual generation. See Methods section for a discussion of this metric and a comparison with the LCOE metric.

Return on capital costs = (annual revenue / total capital costs).

Costs, revenues and generation figures are based on a single year of project data. See Methods section for further discussion of the implications.

**How have community energy projects been financed?**

Data on financing mechanisms are available for 136 projects (89% of the total). Around three quarters of projects (77%) use just one or two external financing instruments to fund their projects. Over one third (37%) of projects also use the organisation’s pre-existing funds to undertake a project. Community shares38 are the most frequently used instrument, with 102 issues of community shares in our dataset. In addition, there are 73 loans, 54 grants, and 9 ‘other’ instruments, mostly bonds.

Focussing on operational energy generation projects (121 of the 136 with financing data), the size of capital expenditure (CAPEX) is related to how the finance is raised: larger projects rely more heavily on loans, and smaller projects rely more on community shares. There seems to be a threshold around a CAPEX of £200,000: 88% of generation projects above this threshold use some loan finance, but only 17% of projects below this threshold reported using loans. However, community shares still account for a significant proportion of total capital raised for all but the largest scales of project as Figure 1shows. Community shares account for almost all the finance raised by projects with a CAPEX of less than £200,000 (the majority of projects); but a much smaller proportion of the total finance raised by projects costing over £1.5m. Grants form a relatively small part of total capital at all project scales, although they may be important at early stages of project development (and are important for projects in the Demand-Side Services cluster).

**Figure 1: Percentage of capital raised by different instruments, in relation to scale of project capital expenditure.**

Notes: For each size category of project capital expenditure (CAPEX), the chart shows the proportion of total finance raised for all projects in that CAPEX range, by different instruments (namely, loans, community shares, and grants). Where less than 100% of CAPEX is shown as being raised, this is due to some instruments that only raised relatively small sums being omitted from the figure. Where more than 100% of CAPEX is raised, these organisations retain surplus funds for reinvestment in future projects, in agreement with investors. Chart based on 111 energy generation projects with sufficient data on financing and CAPEX to perform the analysis.

We use regression analysis to consider whether there is a statistical relationship between the cost of finance and the instrument type (see Methods for details). We find that community shares charge an interest rate that is 2 percentage points lower than loans on average (community shares typically pay interest rather than dividends – see Supplementary Information). To put this finding into perspective, the average size of the financing instruments in the regression sample is about £306,000; the first year’s interest payments on this would be about £6,200 lower if financed by community shares rather than loans (see Methods section for details).

These findings are striking because, unlike conventional equity, community shares are neither saleable to third parties for profit, nor do they necessarily give the holder a claim to the proceeds of a sale of the issuing company’s assets38. Therefore, the prospect of capital gains, that might encourage conventional shareholders to accept lower interest payments, is not available to community shareholders. Further, there do not appear to be many cases of community shares refinancing risky early-stage loans: most projects that issued community shares did not use loans at all. We explore alternative explanations for the interest rate difference in the Discussion.

We now turn to the marketing mechanisms employed to attract funds. Despite the growth of online alternative finance platforms, such as Ethex or Crowdfunder, that can reach potential investors across the UK, around half the community share issues in our dataset were made using local marketing only, e.g. through local newspapers and the organisation’s own website. Many others were marketed nationally but via community energy networks, rather than general alternative finance online platforms. There is a clear gap between the scale of funds raised by these different mechanisms, with general large-scale marketing raising the largest sums (see Table 5). However, local marketing has the lowest mean interest rates in our data, with rates on average 0.8% lower than energy specific UK-wide marketing (a significant difference at the 1% significance level). It is also notable that locally-marketed community shares raised enough to cover project CAPEX for 32 of the 43 projects in the table (74% of these projects). This suggests that many community energy projects have succeeded in raising the capital they need through relatively cheap local finance.

**Table 5. Community Shares: marketing mechanisms and funds raised**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Number of share issues | % of total | Total amount raised | Mean amount raised per share issue | Mean interest rate on shares |
| General online platforms – UK wide | 9 | 10 | 6,362,856 | 706,984 | 4.33  (1.00) |
| Energy specific marketing – UK wide | 38 | 42 | 7,881,930 | 207,419 | 5.06  (0.33) |
| Local marketing | 43 | 48 | 4,248,498 | 98,802 | 4.26  (0.83) |
| Total | 90 | 100 | 18,493,284 | 205,481 | 4.60  (0.79) |

Notes: We find that the difference in mean interest rates between energy specific marketing and local marketing is statistically significant at the 1% level (t-statistic of 5.64). The difference in mean interest rates between energy specific marketing and general online platforms is statistically significant at the 10% level (t-statistic of 2.14). The difference in mean interest rates between local marketing and general online platforms is insignificant.

**What do community energy project finances look like without the Feed-In Tariff and similar schemes?**

As the FITs and RO schemes are now closed to new projects, we examine the importance of revenue from these schemes to community energy business models. The overwhelming majority of generation projects in our dataset accessed FITs, RHI or RO revenues (only 2 projects did not). Of these, we used 110 projects with sufficient detail on annual costs and revenues to perform a simple calculation to examine their dependency on these schemes (note that existing projects are not affected by cuts to FITs rates and the closure of the FITs and RO schemes: see Methods for details). We find that 92% of these projects (101 projects) were in financial surplus (i.e. total annual revenues exceeded total annual costs) for the year for which data was provided; however, after removing the price scheme revenues, only a fifth of the projects (22 projects) were in surplus. As these projects were designed to draw on FITs or similar revenue streams, it is not surprising that removing those revenues would push many projects into deficit. Yet, it is notable that 22 projects do not suffer this fate in our exercise; and so in the rest of this section we examine their characteristics in more detail.

Of the 22 projects, 5 were commissioned in the two years prior to the survey date, and were financed primarily by community shares, but reported no financing costs. Quite often, community shares are issued with the stipulation that they pay no interest for the first year or two of generation38, which may be the case with these projects. Subtracting community share interest payments, at the rate given for each project, from these projects revenues leaves three out of five of them making a loss without FITs revenue.

Four other projects had additional revenue that was not directly linked to levels of energy generation (e.g. environmental grant funding, or land rental to a commercial partner); 2 projects gained revenue in the form of savings on the organisation’s own energy costs. The remaining 12 were all solar rooftop projects that sold electricity to the owners or occupiers of the building where the solar panels were located. For 10 out of these 12 projects, the customer used at least 80% of the electricity generated, at a price between wholesale and typical retail prices (see the next section).

This analysis suggests only a small number of existing projects – those selling most of the electricity they generate to on-site customers – could generate a financial surplus without price support. Further, the 22 projects highlighted above are mostly small scale (less than 50kW generation capacity), and 18 were left with an annual surplus of less than £3,000 without price support revenues. In the context of such small surpluses, year-on-year variation in weather conditions and operational costs can have a significant bearing on project financial performance. The long-term price guarantee offered by schemes such as the FITs plays a significant role in de-risking projects and attracting finance39, 40.

**Different types of customers pay different rates for community energy**

Community energy generation projects sell to a range of customers, including energy companies, other companies, community and third sector organisations, and public sector bodies. We find that energy companies pay the lowest rates on average, equal to just 5.03 pence per kWh in our sample (Table 6). This low rate is to be expected, as projects selling to energy companies are competing with wholesale rather than retail prices. Of community energy’s retail customers, 6 out of 25 community or third sector customers in our dataset received energy for free (‘zero rate’ customers); the remaining 19 customers pay an average rate equal to 6.33 pence per kWh. Private sector companies that are not energy companies pay a slightly higher rate equal to 6.87 pence per kWh. Public sector organisations pay 2.28 pence per kWh or 45% more on average for their energy than energy companies (and 0.99 pence per kWh more than community or third sector customers). However, this rate may still represent a significant saving on retail market electricity prices: average non-domestic electricity prices were over 10 pence per kWh for most of the period (2015 – 2017) to which these data relate41.

**Table 6: Energy prices charged by community renewable generators by type of customer**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Customer type | Average customer rate  (pence per kWh) | Number of customers | Excluding recipients of free energy | |
| Average customer rate  (pence per kWh) | Number of customers |
| Energy Company | 5.03  (0.66) | 12 | 5.03  (0.66) | 12 |
| Other Private Sector Company | 6.24  (3.48) | 11 | 6.87  (2.95) | 10 |
| Community or Third Sector | 4.81  (3.39) | 25 | 6.33  (2.28) | 19 |
| Public Sector | 7.32  (1.54) | 51 | 7.32  (1.54) | 51 |

Notes: Table shows mean customer rates by customer type, with standard deviations (the square root of the variance) in parentheses.

**Discussion**

This paper sheds new light on how community energy organisations have developed small-scale energy projects, often with significant citizen-funding, in an energy system dominated by large-scale actors and commercial finance i.e. the UK energy system42. We find that, while organisations fine-tune the details of their business models to their context, the sector is dominated by renewable electricity generation, for which two basic project business models have been developed. First, larger projects have become increasingly professionalised and ‘bankable’, as shown by their ability to raise commercial loans alongside citizen finance. Second, many organisations run rooftop solar PV projects that supply an on-site customer as well as the grid, and are small enough to be mainly funded through community share issues. Whilst international comparisons are limited by the scarcity of literature, we note that these UK community solar projects appear to be similar to German renewable energy cooperatives in terms of financing structure and cost of capital, although German cooperatives tend to be larger in terms of capital raised20, 21. We further find evidence that UK community energy projects benefit from a local discount in fundraising, with locally-marketed community share issues the cheapest category of finance in our dataset (other than grants).

Our analysis shows that bringing social finance approaches into the renewables sector has helped community energy to pioneer innovations that can make a significant contribution to the energy transition. In the field of social finance, innovations such as crowdfunding and community shares have emerged as a response to the difficulties that social enterprises have with accessing finance from traditional lenders43, 44. Meanwhile, in the energy sector, it is argued that progress towards a low carbon transition is hampered by dominant actors being ‘locked-in’ to the existing system by short term economic pressures45-47. However, expanding and diversifying the energy investor base can increase the flow of finance into renewables and other transition technologies48, because different actors invest according to different criteria49, 50.

We suggest that, through its emphasis on environmental and social value propositions, community energy has developed alternative investment criteria that have successfully lowered financing costs for small scale renewables through diversifying the investor base. Previous research in the UK51, Belgium18 and Germany19, 21 finds that people invest in community energy projects for a mix of financial and non-financial reasons, and local investors may invest larger sums18. Our analysis shows that, while it is clear from previous research that community projects can face additional costs and challenges32-34, a community approach may also bring some financial advantages.

However, most of the business models in our data were built in an energy market where revenue was substantially de-risked by price guarantee schemes39 such as the FITs. While citizens’ investment motivations may be mixed, the financial security offered by such schemes were likely particularly important for people investing their own money40. What can our study say about future prospects for community energy in contexts like the UK (and also Germany52, 53), where FIT schemes are now closed?

Firstly, we note that renewable heat and self-financing demand-side projects are currently a rarity in the UK sector16. Yet the projects of this type in our dataset show a financial surplus. The growing availability of technologies (e.g. LED lights for energy efficiency) and continued financial support for renewable heat (the RHI for heat generation), coupled with the reduction in support for renewable electricity, may lead to growth in these activities as community energy groups seek new business models54.

Secondly, even discounting those with special circumstances, we find that 11% of renewable energy projects still showed an annual surplus without FITs (or other price scheme) revenues. This finding suggests that some new renewable electricity projects may be viable in a post-FITs world. Our analysis indicates key elements of post-FITs renewables business models to be: rooftop solar PV as the generation technology; a building with high energy demand as the site; and a customer willing to pay. Our data shows public sector bodies pay, on average, the highest prices for community-generated electricity; but we also find projects on private sector rooftops that show a surplus without FITs revenues.

However, without some form of price stabiliser it is hard to see the number of projects using community renewables business models returning to its previous rate of growth in the short term. One source of price stability could be a floor price for exported electricity, as suggested by community energy sector associations55. Another mechanism might be Contracts for Difference auctions. The UK already runs such auctions for large scale renewables and has opened them to remote island wind56. The auctions may benefit some future community projects using the Standalone Renewables business model, but could benefit many more if other technologies were also able to participate. Thirdly, policy could encourage, or even mandate, public sector bodies to purchase community-generated energy on long term contracts. Given the growth of the community energy sector to date, the low cost of community capital, and the wider social benefits it offers, these three measures would appear to be promising routes forward for both expanding renewable generation capacity, and supporting the delivery of positive social impacts through the energy transition.

**Methods**

**Survey design and data collection**

The survey formed part of the Financing Community Energy research project led by Professor McLachlan, which was funded as part of the UKERC research programme. In the early stages of this research project, Community Energy England (CEE) and Community Energy Wales (CEW) launched their State of the Sector Survey 2017 (SOTS 2017), which addressed some of the same topics. The Financing Community Energy project signed a Memorandum of Understanding with CEE to share survey data where possible, to maximise the benefit from the two data collection exercises.

The survey questionnaire covered characteristics of community energy organisations, and of the projects they run. With regard to organisations, it included legal structure, annual turnover, numbers of paid staff and volunteers, and numbers of members. In relation to each project, topics included:

* energy activities (including electricity or heat generation, and energy efficiency);
* ownership (sole or partnership type);
* financing (details of each instrument type, value, terms etc.);
* resources employed (including sites, technical, financial and legal services, general administration);
* costs (operating and financing);
* revenues (values and sources);
* value propositions (a range of economic, social and environmental propositions);
* customers (types, rates paid, etc.); and
* other beneficiaries.

These categories were based on the Business Model Canvas approach to analysing business models (see Supplementary Figure 5), adjusted to take account of the project’s particular interest in financing mechanisms, and the characteristics of the community energy sector as the project team understood it.

The format of some of the questions was designed to complement the SOTS 2017 to facilitate data sharing. Pre-set multiple choice formats were used as far as possible to facilitate data coding and quantitative analysis. Some free text qualitative questions were also included, particularly in relation to organisations’ future plans: responses to these questions have been fed into other parts of the overall research project and are not reported in this paper.

The survey sample was constructed with reference to the SOTS 2017 respondents list, data on community energy organisations in Scotland held by the social enterprise consultancy SCENE, and through internet searches, searching attendance lists at sector events, and through Local Energy Scotland sending a survey link to their members via their newsletter.

The survey received research ethics approval from the University of Manchester in October 2017. Informed consent was obtained in writing from all survey participants. The questionnaire was piloted in October – November 2017 with three community energy organisations. Only minor changes were made after the piloting process, and the pilot data forms part of the survey dataset analysed in this paper. The full survey was launched in November 2017 and closed in May 2018. During January and February 2018 it was suspended in England, Wales and Northern Ireland to avoid an overlap with the 2018 iteration of the SOTS. The survey was available to complete online, or by telephone interview with the project team. Two methods of completing the survey were offered because the team were conscious that community energy is a heavily surveyed sector. Allowing research participants to choose the most convenient participation method ensured the survey achieved sufficient responses for a meaningful quantitative data analysis, while also reducing the administrative burden on research participants.

In total the researchers contacted 280 organisations, of which 83 responded and 48 completed the survey, providing data on 145 projects. Not all projects are included in all the analysis presented here. Complete data was not available for some projects, limiting the kinds of analysis that could be performed. Further, some projects were classified as ‘stalled or on hold’, and so by their nature did not have complete data. Data were collected on an additional eight projects using published accounts and reports only. These data are used in Table 4, to provide greater coverage of the hydro, wind and solar ground-mount technologies, but are not otherwise used in the analysis.

**Cluster analysis**

We used data on 119 projects for cluster analysis, as the projects that had missing values related to any of the business model aspects had to be excluded. Missing values were predominantly due to respondents not having access to some of the information required in the survey, for example because of lost paperwork or limited documenting.

Unlike in the performance and financial analysis (please see the next section), the two bioenergy projects were not excluded in the cluster analysis, as their anonymity would be preserved when aggregated into clusters. However, we did re-run the cluster analysis without these two projects to test whether the results would change. The exclusion of these two projects has not affected the composition of the clusters in any of the runs (i.e. either in the run with all variables, including those related to the organisational level and location, or in the run with only project-level variables). Excluding those two projects has also had little effect on the silhouette coefficients and the shapes of the clusters on the t-SNE plots. As the presence or otherwise of the bioenergy projects does not affect our cluster analysis results, we have kept those projects in the sample. The analysis runs with those projects excluded are available on request from the authors.

The cluster analysis was performed using R 3.6.157 and packages *dplyr58*, *cluster59*, *factoextra60*, *ggplot261*, *Rtsne62,* *dbscan63* *fpc*64 and *clustMixType65*. Partitioning around medoids (PAM), hierarchical agglomerative clustering (HAC), density-based clustering and k-prototypes clustering were the four clustering methods applied to the dataset.

We included different combinations of organisation-level variables (e.g. legal structure of organisation) and project-level variables (e.g. type of energy activity, type of customer) in several analyses runs. The first run used all 48 variables; the second run omitted the variables for organisation turnover and project location; and the third run omitted all the organisation-level variables (such as turnover, number of members, number of volunteers, number of staff employed, ownership structure, charitable status, and year of foundation), and project location, and used only the 40 variables relating to the operation of individual projects.

Before running the analyses, we created a heatmap of the dissimilarity in the community energy dataset, using the daisy function with Gower distance that can handle mixed types of variables. The heatmap (Supplementary Fig. 1) demonstrated that the dataset did contain patterns, compared to a heatmap of random data. We then performed a sanity check on the dissimilarity matrix through outputting the most and the least similar pairs of projects, with expected results.

We used two key types of validation statistics to compare the results of the four clustering methods: the within-cluster sum of squares (WSS) and the average silhouette width (see Supplementary Table 1). The WSS was significantly better for PAM (1.8901) than for the next best method using this metric: HAC (4.5846). The average silhouette width for PAM (0.3058) was slightly lower than for HAC (0.3798), but significantly better than for the next best method using this metric: density-based clustering (0.1485). The validation results were similar for the analysis run that included only project variables i.e. with organisation and location variables excluded. In this run, density-based clustering showed somewhat better average silhouette width (0.2910) than PAM (0.2690). However, in this analysis run, the density-based clustering method only yielded one cluster of 68 projects, with the remaining 51 projects designated as outliers, which did not provide meaningful insights. On the basis of these validation statistics (reported in Supplementary Table 1), we selected PAM as our main clustering method.

For PAM clustering, we calculated and plotted silhouette width (Supplementary Fig. 2) to select the optimal number of clusters. Twelve clusters corresponded to the highest silhouette width (0.4054) for the first analysis run where all variables were used, with thirteen and three clusters for the second and third runs respectively (with the highest silhouette widths of 0.4327 and 0.4026 respectively). Results of the first two analysis runs were very similar to each other; therefore we have omitted the second analysis run with thirteen clusters as it did not add any extra insights to the results.

We then visualised the clustering using the t-Distributed Stochastic Neighbour Embedding (t-SNE) technique. The t-SNE technique decreases the number of dimensions while preserving the structure of the dataset. The resulting figures are presented in the Supplementary Information file for both the twelve-cluster and three-cluster runs (Supplementary Fig. 3). The figures illustrate which business models are well-defined and distinct (for example, clusters 4, 11 and 12 in panel (a) of Supplementary Fig. 3) and which business models are more diffuse and might share similarities with other types (for example, clusters 6, 8 and 9 in panel (a) of Supplementary Fig. 3). Similar plots for other clustering methods (Supplementary Fig. 4, panels (a) and (b)) give a less clear-cut allocation of projects into clusters.

In relation to the variables present within the clusters, it is important to explain the value proposition variable. We constructed a list of value propositions potentially offered by community energy organisations to their customers, based on a review of the wider community energy literature. Survey participants were asked to say which of these value propositions they felt were important in their customers’ decision to use their services (e.g. to buy electricity). In the cluster analysis, the value propositions were categorised as environmental, economic or social, and projects were coded according to whether participants selected environmental, economic or social propositions (or a mixture) as important. Environmental value propositions included providing renewable electricity, reducing CO2 emissions, and tackling climate change. Economic value propositions included electricity generation regardless of origin, reducing energy bills, dealing with known trusted organisation, benefiting local economy, enabling customer to meet planning requirements, and enhancing customer reputation. Finally, social value propositions included bringing community together, generating community benefit, and providing educational benefits. Further research could investigate customer perspectives on the value propositions offered by community energy organisations.

**Performance and financing analysis**

This paper uses data collected for a single year of project operation. Therefore, we provide a cross-sectional analysis that involves looking at the sector at a moment in time, rather than assessing how it changes over time. It is particularly important to bear this in mind for the project performance characteristics presented in Table 4: because generation, revenue, and operating costs may vary considerably from one year to the next, these data may not be representative of project performance in other years. Future research may wish to address these issues by collecting survey data on project performance over a number of years to construct a panel dataset.

As renewable energy generation is affected by weather conditions it is important to note that, although data were collected between November 2017 and May 2018, as noted above, the data do not relate to the project performance during the months the survey was open. Rather, organisations reported data that relate to a 12 month period – more specifically, the most recent financial year for which data on the project are available. As the data reflect project performance over a 12 month period, they will reflect project performance over a sustained period of time rather than during an individual month or season of the year. Furthermore, we do not typically expect that community energy projects will vary that much in terms of their performance from one year to the next, especially in a systematic way (such that variations over time would not average out across projects when performing statistical tests e.g. when performing t-tests of means). Nonetheless, we cannot be sure that information during one 12 month period is representative of a different 12 month period. This is an issue with any cross-sectional dataset.

The absence of data with a time-dimension means we also do not aim to assess performance over the lifetime of a project e.g. by measuring the Internal Rate of Return. Likewise, we analyse costs in terms of cost per unit of kWh of generation, rather than Levelised Cost of Energy (LCOE). Costs per kWh is a similar metric to a LCOE in that it involves dividing operating costs and a capital cost recovery component (in the form of an annual financing cost) by electricity generation. However, unlike the LCOE, it provides an annual snapshot rather than discounting the predicted costs and generation over a project’s entire lifetime.

In order to better understand the importance of financing characteristics for community energy projects, we explore whether there is a statistical relationship between the interest rate (cost of finance) and the instrument type. We are particularly interested in comparing community shares with loans, because the majority of community energy projects are financed using these instruments. (Grants are also a common source of finance but do not charge interest.) To do this we first note the mean interest rates for community shares and loans in our sample are 4.58 and 5.58 respectively. Therefore, the difference in means is 1.01 percent points. Performing a *t* test on the equality of the mean rates, we find that the means are statistically different at the 1% significance level (t statistic of 3.03). Thus, community shares charge a statistically lower interest rate than loans on average.

A comparison of means may however be misleading because the size of the finance obtained and the financing term (duration) may also influence the interest rate. We therefore compare the difference in interest rate between community shares and loans while holding these other characteristics constant. We do this by estimating a linear regression model. We proceed by defining three dummy variables that capture the instrument type:

*CommunityShare* = 1 if the financing instrument is community shares, and = 0 if it is not community shares.

*Bonds* = 1 if the financing instrument is bonds, and = 0 if it is not bonds.

*Loans* = 1 if the financing instrument is loans, and = 0 if it is not loans.

Although all three instrument types are included in our model, we need to include only two of these three dummy variables in the regression equation (further explanation can be found in Wooldridge, 201466). We choose to include the *CommunityShare* and *Bonds* dummy variables. Therefore, *Loans* is chosen to be the base group (or benchmark or omitted group) and are the group against which comparisons are made. We choose loans as the base group because we are especially interested in looking at the difference in interest rate between community shares and loans.

We then estimate the following linear regression model:

where the dependent variable *IR* is the financing interest rate of financing source *i*. *IR* is a continuous variable that can take non-integer values.. *CommunityShare* and *Bonds* are defined above. As explained above, we compare how these financing instruments are associated with the interest rate relative to the omitted category which is loans. In equation (1) we also include the variables *Size* and *Duration* to control for the size and duration of the financing instrument, respectively. *Size* is defined as the monetary value of the financing source (in £ millions) and *Duration* is a dummy variable equal to 1 if the finance term is 240 months or more, or indefinite/not specified, and 0 if a relatively short-term duration (less than 240 months). to are coefficients to be estimated. Finally, is an error term. We estimate equation (1) using Ordinary Least Squares.

Each observation on financing source *i* belongs to an organisation that may use one or more sources of finance for its community energy project(s). Outcomes for different financing sources within organisations are likely to be correlated. As we cannot assume that the error term is independently distributed within organisations, we cluster standard errors at the organisation level.

In specification (1) the continuous variables (*IR* and *Size*) enter in levels. An alternative approach that allows for a non-linear relationship between the dependent and explanatory variables is to enter the continuous variables in logarithms. We find our results are robust if we use a logarithmic functional form (results are available on request). However, here we present the results with variables in levels because in this case the coefficients have a percentage point interpretation.

The results from the estimation of regression (1) are given below. Coefficients are reported with cluster robust standard errors in parentheses, and t-statistics from two-tailed tests that the corresponding population coefficient values are equal to zero in parentheses.

se = (0.585) (0.706) (0.667) (0.091) (0.777)

t = (8.76) (-2.85) (-0.98) (2.02) (1.87)

R2 = 0.2457 Observations = 118

The estimated coefficient on the dummy variable *CommunityShare* (-2.016) indicates that there is a difference in the interest rate between community shares and loans of 2.016 percentage points on average in our sample, while holding constant the size and duration of the finance. The t-statistic indicates that this difference is statistically significant at the 1% level. To put this finding into perspective, the average size of an individual financial instrument (i.e. a single loan, or share issue) in the regression sample is about £306,000. Therefore, for the average project, the annual interest payment for the first year would be on average lower by £6168.96 (2.016% of £306,000) if financed by community shares rather than loans. This does not take into account compound interest and repayments in later years of a project; it is simply intended to illustrate what the interest rate differential between loans and community shares means in terms of actual amounts a community energy project might pay in interest on the initial principal sum. In the paper, the figures are given rounded for greater readability: thus we speak of a “2 percentage points” difference in interest rates, and an average repayment differential of “about £6,200”.

We also find that projects financed by bonds do not have an interest rate that is significantly different from loans. In addition, we find that instruments that have a longer duration and larger value have higher interest rates on average.

We investigate whether these results are sensitive to outliers. We do not find any evidence of observations with large estimated residuals that may affect the estimates. We also investigate the distribution of the dependent and explanatory variables by inspecting the raw data and by using a leverage-versus-squared-residual plot. From this analysis we identify two observations with large leverage due to outlying values on the explanatory variables. However, our central findings on the difference in the interest rate between community shares and loans are robust to dropping these observations from the analysis. Therefore, they are not affecting our conclusions.

The impact of the removal of price guarantee schemes is calculated by simply subtracting all price guarantee scheme revenue (FITs, RHI or RO) from total project revenue, project by project, for the single year of revenue data that we collected. It is important to note that, for the FITs, projects retain the tariff rate for which they initially qualified for the rest of their lifetime, including an inflation adjustment; unlike the RO, the FIT is not subject to annual variations in price due to market conditions. The RO scheme revenues are affected by year-to-year market variation, but this variation is not itself affected by the scheme being closed to new entrants. Therefore, the data do not only reflect the performance of community energy under the tariff rates available to new projects at the time of data collection.

The contribution of this analysis is to allow an appreciation of the extent to which actual projects are reliant on price scheme revenues. There is no consideration of how projects might have been designed if the schemes had not been available, which is a more complex question. Therefore, these results do not in themselves show that it would be impossible to design a future project to make a financial surplus without a price guarantee scheme; nor, given that we have just one year’s data, do they test “viability” of a project over its lifetime.

To investigate whether different types of customers pay different rates for community-generated energy, we calculate mean rates paid by the four different types of customer (energy companies, other private sector, public sector, community and third sector). As noted in the main body (Table 5) we find the mean rates differ, with the mean rate lowest for energy companies and highest for public sector customers. Performing a *t* test on the equality of the mean rates paid by energy companies and public sector organisations, we find that the means are statistically different at the 1% significance level (t statistic of 3.69).

**Data availability**

We hope to make the data available, subject to anonymisation requirements, via the UKERC Energy Data Centre, and are currently in discussion with staff there about how best to arrange this.

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**Author contributions**

Professor McLachlan led the research project. Professor McLachlan, Dr Mander, Dr Sharmina, Dr Manderson, Dr Hardy, Dr Hannon and Dr Braunholtz-Speight contributed to the conception, framing and design of the survey research. Dr Braunholtz-Speight conducted the survey, and supervised the work of Miss Birch and Mr Walsh; he also conducted the analysis of the composition of project finances, and the impact of price support mechanisms. Dr Sharmina designed and conducted the cluster analysis. Dr Manderson conducted the econometric analyses of financing instrument interest rates, and provided descriptive statistical analysis. All authors jointly wrote the paper: Dr Braunholtz-Speight led the writing; Dr Sharmina, Dr Manderson and Professor McLachlan, Dr Hannon, Dr Hardy and Dr Mander contributed text and extensive comments on the structure and content of several drafts of the paper.

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**Supplementary Information**

**Community Shares**

Community shares are a form of equity issued by cooperative societies, with several distinctive characteristics. Firstly, they are withdrawable but not transferable – in other words, they can be sold back to the issuing society at face value, but they cannot be sold to a third party at a profit. In addition, they confer voting rights on the basis of one shareholder (or one member of the cooperative) one vote, rather than one share one vote.

Further, they do not necessarily pay dividends to shareholders. The regulation of payments to shareholders varies depending on the type of society that has issued the shares:

* ‘bona fide cooperatives’ are permitted to distribute profits to their members as a dividend;
* ‘community benefit societies’ are not permitted to distribute profits to their members as a dividend, but are permitted to pay interest on members’ share capital, if funds permit, and generally .

The great majority (81%) of community energy cooperative societies in our dataset are community benefit societies (“bencoms”), and therefore pay interest rather than dividends.

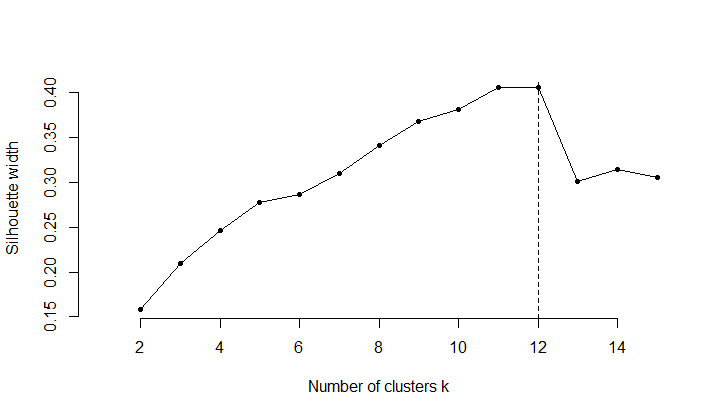
Further information can be found at <http://communityshares.org.uk/>

**Cluster Analysis**

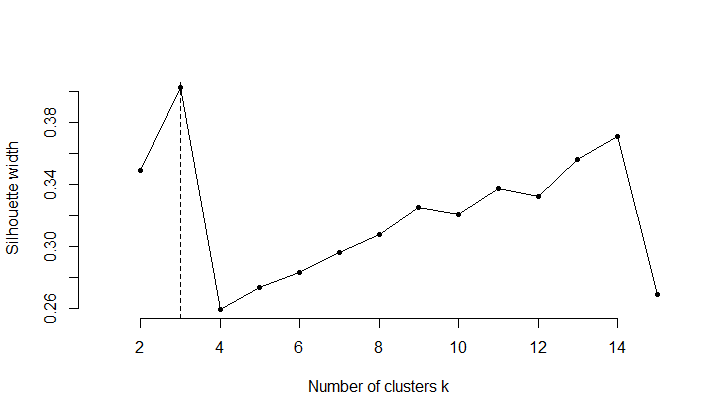


**Supplementary Figure 1. A heatmap of the dissimilarity in the community energy dataset (the red colour means high similarity, and the blue colour means low similarity between projects)**

(a)



(b)



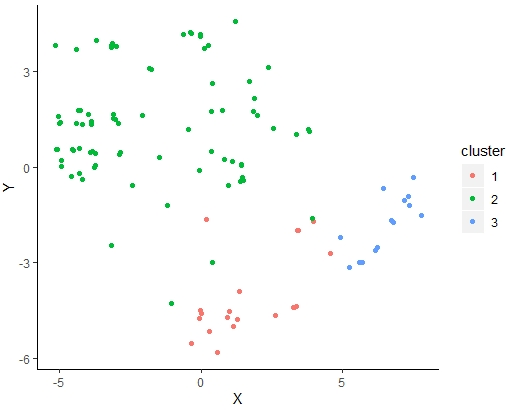
**Supplementary Figure 2. A silhouette plot for the partitioning around medoids (PAM) clusters: (a) including project, organisation and location variables; (b) including only project variables**

Supplementary Fig. 3 illustrates which business models are well-defined and distinct (for example, clusters 4, 11 and 12 in panel (a)) and which business models are more diffuse and might share similarities with other types (for example, clusters 6, 8 and 9 in panel (a)). Similar plots for other clustering methods (Supplementary Figure 4 panels (a) and (b)) give a less clear-cut allocation of projects into clusters.

(a)



(b)



**Supplementary Figure 3. Community energy projects allocated to clusters through partitioning around medoids (PAM) and the t-Distributed Stochastic Neighbour Embedding (t-SNE) technique: (a) including project, organisation and location variables; (b) including only project variables**

Key to cluster numbers

1. Multi-Financed Hydro and Wind
2. Small/ Medium Solar Rooftop
3. Multi-Site Solar on Public Sector Roofs
4. Professionalised Solar Rooftop Coops
5. Demand Side Services
6. Small Multi-Project Generation for Third Sector Groups
7. Small Solar Rooftop
8. Large Wind Selling to Grid
9. Medium Scale Generation with Mixed Financing
10. Smaller Scale Multi-Project Volunteer Coops
11. Multi-Tech Generation including Partnerships
12. Energy as a Sideline

**Supplementary Figure 4. Community energy projects allocated to three clusters through hierarchical agglomerative clustering (left panel) and k-prototypes partitioning clustering for mixed-type data (right panel), including project, organisation and location variables**

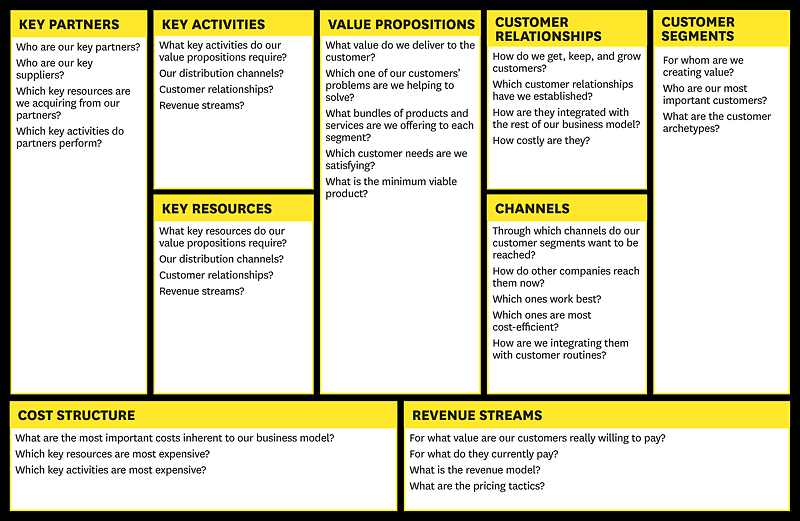
**Supplementary Table 1. Within-cluster sum of squares and average silhouette widths for partitioning around medoids (PAM), hierarchical agglomerative clustering (HAC), density-based clustering (DBSCAN) and k-prototypes clustering for two analysis runs: (a) including project, organisation and location variables; (b) including only project variables**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Clustering method | Within-cluster sum of squares | | Average silhouette width | |
| (a) | (b) | (a) | (b) |
| PAM | 1.8901 | 1.7592 | 0.3058 | 0.2690 |
| HAC | 4.5846 | 4.1289 | 0.3798 | 0.4033 |
| DBSCAN | 5.4931 | 5.5016 | 0.1771 | 0.2910 |
| K-proto | 5.8715 | 5.0860 | 0.1485 | 0.2530 |

**Supplementary Table 2. Feed-in Tariff Scheme rate changes 2015-2016 for average community renewable energy project sizes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Electricity Generation Technology** | **Capacity (kWp)** | **Rate per kWh** | | **Percentage change** |
| **Q4 2015** | **Q1 2016** |
| Rooftop solar PV (middle rate) | 74 | 9.61 | 2.66 | -72 |
| Ground-mount solar PV | 3428 | 4.75 | 0.95 | -80 |
| Hydro | 163 | 12.64 | 6.73 | -47 |
| Wind | 1862 | 2.76 | 0.94 | -66 |

Notes: FITs rates vary by technology and scale of project: and, for rooftop solar PV, by whether the building the solar panels are installed on is rated “high”, “middle”, or “low” in energy efficiency. The table illustrates the changes in FITs rates from Q4 2015 to Q1 2016 for the average size project for each FITS-eligible technology in our dataset (see Table 5 for more details of average projects). Full details of all tariff changes, which also included changes to the capacity scale bands used to calculate tariffs, can be found at <https://www.ofgem.gov.uk/environmental-programmes/fit/fit-tariff-rates>



**Supplementary Figure 5. The Business Model Canvas (**Osterwalder 2013)

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