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# Creating Superpowers: Capable Communities in Smart Local Energy Systems

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## Abstract

Trends in electrification of heat and transport plus connection of battery storage and renewable generation on electricity distribution networks are creating new challenges for network management as well as new opportunities for households, businesses and communities. Smart Local Energy Systems are a sociotechnical response to these trends, aiming to: a) tackle network constraints by balancing supply and demand at the local level using flexibility, b) create local markets for energy services, c) create efficiencies and social and environmental benefits. To participate in SLES, and capture benefits from them, households, businesses and communities need technical, economic, social and knowledge-based skills and capabilities. The wider energy system must also provide the right regulatory and policy context for SLES to be viable. Therefore, we can think of requisite capabilities as attributable to individual actors, to communities and to "system" levels of the energy system. As network constraints at low voltage levels are created by the collective actions of end users, collective solutions are often (but not always) necessitated and community level capabilities must become accessed and deployed. For example, a community connected to a constrained part of the low voltage network should possess the technical and social capabilities to aggregate flexible energy demand from a threshold number of households in the community - and to configure this flexibility into various network services (e.g. a "peak management" service) which can then be traded in a local energy market. Drawing on learnings from implementing an ambitious smart grid project in the UK (Project LEO) we explore the essential capabilities that communities require and can develop when their activities are coordinated. We consider what sharable skills and resources are needed and accessible through various forms of social capital (bonding, bridging, linking) and ask whether building social capital is an appropriate policy response for promoting SLES. Finally, we highlight energy equity issues arising from unequal distribution of community level capabilities.

## Introduction

Smart Local Energy Systems (SLES) are a response to the need to accommodate increased connection of low carbon generation and batteries into the low voltage parts of the distribution network (the so-called, "grid edge") alongside managing new electricity demands from electrification of heat and transport. By managing these demands on the network "smartly" using ICT architectures of monitoring and control, the local grid can be operated safely whilst simultaneously delivering efficiencies and avoiding the need for expensive and disruptive investments in infrastructure. Therefore, SLES are thought to be a viable and cost-effective approach for carbon reductions whilst also offering a range of technical, social and environmental co-benefits. These include greater local resilience to power failures, greater local economic activity (e.g. in installing and maintaining Distributed Energy Resources) and a variety of social benefits such as building a sense of citizenship, community purpose and identity. This arises as householders move away from the role of a passive consumer of energy supplies and towards a more dynamic role involving actively creating energy services, securing a stable and safe network and in generating local energy supplies – i.e. the role of a "prosumer" (Ford et al, 2019). Integral to SLES are trading platforms where energy services that help the distribution network operate and stay in balance can be auctioned, procured, dispatched, verified and settled and where peers can trade energy, power and electrical capacity.

Large-scale actors have participated in national markets for energy services for many years, but with the advent of distributed renewable generation and storage, smart metering and cheap internet connected monitoring and control systems, participation is now open to small-scale domestic and business customers, at least in theory. This means the formation of new relationships between actors who are learning new roles, for which they will need capabilities: the ability, suitability and willingness to contribute to, and benefit from, local energy systems.

Communities too must learn to act collectively and in new ways if they are to fully benefit from the SLES opportunity. Indeed, many of the benefits of SLES are only realised if a critical number of actors in a community act in a coordinated fashion – for example aggregating and controlling their collective energy demand to deliver network services. The energy system as a whole must also be able to host or integrate a SLES by possessing capabilities such as a conducive planning, policy and regulatory environment, market platforms where services can be traded and sufficient actors of particular types to supply liquidity, competition and necessary services.

This work draws on learnings from Project LEO, an ambitious UK-based smart grid trial now in its 3rd year and funded by the UK government's *Prospering from the Energy Revolution Programme*. Project LEO is a demonstration project, building, at micro-scale, smart local electricity systems and associated local energy markets of the future. By learning by doing, it is growing an evidence base that can inform how we manage the transition to a smarter electricity system, how network operators should function, energy markets can be unlocked, and new business models be developed. To evaluate the project, we have adopted a "capability" approach grown out of development studies and work on human rights. The basic approach has been elaborated to consider both "actor" (i.e. individual household or business), "community", and "system" levels of capability. The approach is also now being used in the design of project tools and project offers, and to provide an analytic frame for making policy recommendations, particularly as these relate to issues of energy justice. The learnings reported here are captured through a quarterly cycle of interviews and workshops with project participants and other stakeholders in the Oxfordshire energy system, alongside analysis of ongoing project reporting.

## Elaborating the Capability approach

The concept of capability offers a way of looking at human needs that highlights what people are able to do: it sees them as actors or agents, making use of available resources in order to survive, thrive and take part in social processes. This marks a step forward from traditional framings of people or organisations on one or the other side of a producer / consumer divide, maximising their individual 'utility' through the disembodied and unaccountable agency of markets. The capability concept is interpreted in many ways, but the basic idea in development studies, where it is probably most widely used, is of a set of characteristics that enable people to develop, individually and collectively, through their own capacities, efforts and access to social arrangements (Sen, 1999).

### *"Actor level" capability frameworks*

This idea of a set of fundamental capabilities, which enable human development and access to systems of welfare, has been used in other analytic frameworks, trying to explain the various dimensions of human capacity to change behaviour, access benefit or to adopt technology. For example the COM-B model (Michie et al, 2014) proposes that an individual's psychological and physical Capability, the Opportunities conferred by social norms and social practices, and embedding physical infrastructure plus conscious and unconscious Motivations interact to generate Behaviour (hence, COM-B). This framework has been used to understand adoption of innovative energy behaviours. For example, it has been used to structure an evidence review of capabilities that encourage more energy-conscious behaviour in the workplace (Staddon et al, 2015). Another capability framework proposes the idea of "carbon capability" (Whitmarsh et al, 2009). This describes the broad capabilities of a citizen able to respond effectively to the climate crisis, both personally and politically. I.e., it identifies an individual's ability and motivation to reduce emissions within the broader institutional and social context. Three dimensions of carbon capability are identified:

(1) cognitive (knowledge, skills, motivations, etc.),

(2) individual behaviour (e.g., energy conservation), and

(3) broader engagement with systems of provision and governance (e.g., lobbying, voting, protesting).

The Centre for Sustainable Energy (CSE) have also produced a capability framework or "capability lens" as part of their "Smart and Fair" research programme, exploring dimensions of a socially-just energy transition. Their "capability lens" is used to understand the sorts of capabilities and attributes likely to be required in the transition to a smarter energy system, and how these distribute across the population (CSE, 2020). The central premise is that the various types of capability (technical, economic, social, personal [e.g., lifestyle related]) required to take advantage of the opportunities offered by the energy transition tend not to be associated with lower income or otherwise vulnerable groups. Therefore, the energy transition creates "a thousand new ways" in which inequities can be deepened and perpetuated. For example, whilst there are several ways that technologies such as Demand Side Response (DSR) may create opportunities for furthering energy justice, there are also multiple risks of injustice that result from introduction of DSR, either by enhancing pre-existing inequities or creating new ones (Calver and Simcock, 2021).

## *“System-level” capabilities*

Other than the carbon capability lens (with its identification of the need for broader engagement with systems of provision and governance), a system-level perspective is absent from COM-B and CSE capability lens. However, In Project LEO, we feel an extension to “system” level is justified, because the capability approach is theoretically aligned with a sociotechnical perspective on energy systems, seeing behaviours and practices as the outcome of actors’ interactions with social, economic, political, communications and material infrastructures. The quality of those interactions will be determined by both actor and system capabilities. Types of “system” capability can be grouped into three domains:

- Regulatory and policy context for local energy systems, including the planning system and codes of practice; specifications of equipment set by regulations, building regulations.
- Economic and market: a local energy marketplace underpinned by IT architecture where services can be safely traded., supply chain characteristics, value propositions, market rules, Investment rules e.g. IRR thresholds, Sufficient actors to supply liquidity, competition and other necessary services,
- Social, cultural and political: trust in governance and political systems, organisational ‘ways of doing things’, social norms (including right of access to affordable energy services).

As with actor-level capabilities, “system”-level capabilities may not be uniformly distributed: some parts of the energy system with disadvantageous rules, regulations and policies, may create a context where local actors and communities are unable to take advantage of opportunities and are at risk of being “left behind”.  For example, only certain parts of the network may have an energy market where flexibility can be traded. Therefore, energy inequities could also apply at system levels.

## *Community-level capability*

In previous work, we have applied actor- and system-level capability lenses to thinking about adoption of key technologies in LEO – Vehicle to Grid technology and control systems for DSR (Banks and Darby, 2021). We have found the framework to be very successful, but also that by focussing only on actor and system levels a conceptual “blind spot” is created. For example, the COM-B framework described above is not concerned with identifying the kinds of capability that arise when a number of individual actors act in a coordinated fashion or are directed to a collective goal e.g. the creation of improved financial leverage through pooling demand for a service. We also find that that the third dimension of the Carbon Capability Framework (i.e. engagement with systems of governance through lobbying and advocacy), is useful in recognising the role of individual actors role in coming together with others to bring about system change, recognising that in order to transition to a low carbon energy system, political systems and governance must be in place which allow the voices of people, communities and organisations to be heard and actioned.

Engagement with systems of provision and governance is often (but not always) achieved by acting together with others. Capability to advocate for the interests of a community is a great example of a capability that is built when a community has lots of “bridging” and “bonding” social capital (discussed further below) – i.e. where there is a dense network of trusted relationships between community members and community groups, such that representatives of the community understand and share the community’s priorities, feel comfortable speaking on the community’s behalf, and advocating for its interests. This is the kind of “community-level” capability that we explore further in this paper, recognising that, at present swathes of energy users are “hard to reach” and not engaged in the energy system. This includes low income and vulnerable householders but also other groups such as tenants of buildings - both residential and commercial.

CSE’s “capability lens” identifies capabilities that are primarily associated with the individual householder, framed as an isolated actor who can or cannot take advantage of the new opportunities in the transitioning energy system. As mentioned, capabilities that arise when householders act collectively are not, currently, within its scope. Given the capability lens’ main purpose is to identify the potential for energy inequity it should be noted that collective action may offer one route by which low income, and, possibly, vulnerable groups may capture the benefits of a transitioning energy system where acting in isolation would preclude this. An example would be recycling revenues from sales of flexibility to fund fuel poverty alleviation in a community.

Therefore, frameworks that aim to help understand the causes of inequity in the transitioning energy system, and how they can be addressed should consider collective or community capabilities and so we feel an important intermediate level of capability is apparent that straddles actor and system domains (Banks and Darby, 2021) which describes to the capabilities that emerge when actors within a community of place coordinate their activities to create new capability which is not (easily) available to actors acting as individuals. We propose that when actors work together they can create “superpowers” which transcend their capabilities as individual actors.

## The need for collective response

There are many ways in which isolated actors can play useful roles in the transitioning system - and benefit from the opportunities without collaborating with peers or others in the community. For example, for many years now, large or intensive energy users (factories, refrigerated warehouses etc) have been able to participate in national markets for DSR procured in the UK through the so-called, Balancing Mechanism. Large players with few but significant flexible energy assets will continue to have an important role in balancing the grid, and in helping with fault rectification. However, the small and many potential assets embedded at the grid edge in homes, businesses, offices and schools etc. (smart appliances, smart heating systems, batteries, photovoltaic roofs) are increasingly needed to play a role, also. The role will require coordination of these many small assets, and will entail new market actors (e.g. technical, commercial and social aggregators) to come forward with new business models and value propositions. We describe a few of these collective responses enabled by community-level capabilities below.

### *Tackling network constraints*

Network constraints resulting from too much demand from households and non-domestic loads (schools, offices etc.) arise when power demands exceed the designed thermal capacity of the substation serving the part of the network in question: the transformers in the substations can overheat and fail. Equally, a combination of high levels of embedded power generation and low local demand can also raise the risk of overloading local energy grids, and reduce the energy system's resilience to sudden changes in frequency leading to temporary blackouts. These types of network constraint created by peaks in demand or generation are often predictable - days, weeks or even months in advance – the spike in demand at winter tea times is one example. To safeguard the network during these peaks, the Distribution System Operator will ask and pay for an increase in generation, decrease in demand, or call on locally-stored power in batteries. Depending on the structure of the network, the connection point of flexibility assets, and the causes of the peak in demand (or generation) it is quite possible that the best means of tackling the constraint is through controlling demand or generation of the small and many assets at the grid edge. This will require monitoring and control systems to be installed on smartened equipment (e.g. batteries, heat pumps, electric vehicle chargepoints) amongst a critical number of end users and a collective response coordinated through a SLES actor: a “technical” and/or “commercial” aggregator. Users must sign up with the aggregator and consent to have their equipment controlled in this way. By acting together end users acquire the superpower of capability to mitigate a network constraint.

### *Enabling new connections of Distributed Energy Resources (DER)*

The UK government and the energy regulator, Ofgem, support community energy schemes and have identified distributed embedded technologies operating at the grid edge (both DSR and DER) as important in achieving *Net Zero* goals (BEIS, 2021). Various funding streams have been put in place to encourage DER particularly for heat pumps, electric vehicles and rooftop solar. Ofgem have also introduced strategies and reforms to electricity markets and the way that DNO’s operate and charge for their services that should, in theory, encourage further connection of DER to the low voltage part of the network. Ofgem state, “new and cost-effective ways of matching supply with demand can also improve system efficiency – using technology such as flexibility platforms, automated demand-side response (DSR), aggregation and trading. We will support this need for increased flexibility by helping markets operate more effectively and providing the correct signals to market participants to take efficient actions” (Ofgem, 2020). So, there is high level support for greater connection of DER’s however, in a context where further connection of new electricity demand and generation will create stress on the LV network, there are two options to ameliorate this: either reinforce the network, or attempt smart grid solutions to create the needed headroom via flexibility. Where reinforcement is chosen the cost will be socialised, i.e., added to everyone’s electricity bill as part of the network charges. Ditto, the cost of procuring flexibility.

But DNO’s have committed to exploring a flex-first approach to solving network constraints where it is more cost effective to do so (because there is less impact on customers’ energy bills). However, to make the flex solution work, end users have to play their part: e.g., adopting control systems that automatically modulate their energy demand from smartened equipment in response to market signals – it is recognised that “small and many” control will be not be possible without automated control of heating, cooling and other power consuming equipment. This should lead to less cost passed on to consumers for reinforcement works, and an easier, less administratively-onerous route to connection of new low carbon technologies. So, everyone in the local community should benefit indirectly (through having low energy bills) and, also, those that are connecting new DER should have the ability to do that without incurring expensive connection fees.

Therefore, making this arrangement work requires an element of energy citizenship – not everyone will benefit directly, but all are expected to play a part in securing a benefit for the community as a whole – which only some will be able to take full advantage of – at least in the short term. This suggests the need for a certain amount of citizenship, altruism or, reframed, "community spirit". Though, because it is only those connecting DER that stand to gain most financially from this arrangement, there is potential for energy inequity to deepen: all in the community are, through their bills, paying for greater access to the network for connections of DER, but only those connecting DER stand to benefit directly from their new equipment and those connecting DER are much less likely to be in a low-income group. It has even been proposed that because those on low incomes are less likely to own the equipment that enables their demand to be flexed in automated and relatively pain-free ways that have no impact on the quality of energy services, these groups will be compelled to flex their demand by making behavioural changes and downgrading their energy services instead. This capability to be flexible in pain-free ways has been termed "flexibility capital" (Powells and Fell, 2019).

## *Peer-to-peer trades of capacity*

Project LEO is exploring how organisations can trade unneeded energy import or export capacity with other organisations that do need it for an agreed period of time, without affecting the network. Every generation site has a contractual agreement stating how much electricity it can export to the grid, its Maximum Export Capacity, or MEC. For example, a solar park may be capable of generating and exporting more power, but it is capped, contractually by its MEC agreement. However, there may be occasions where the solar park can buy unneeded export capacity from another entity connected to the same part of the network to boost their sales of electricity to the grid for a limited period. The same logic applies to the Maximum Import Capacity (MIC), the upper limit on the total electrical power imported at any one time. A factory may need to increase its imported power beyond its contract to meet temporarily increased demand requirements perhaps caused by an intensification of production of a particular product. A third type of peer-to-peer arrangement called, "offsetting" involves an agreement between two parties connected to the same part of the network. Here an increase in generation by one party will be matched by an increase in demand of the exact same amount at the same time by another party. The net result is that there is no change to the load or voltage on the network and safety parameters are maintained. All of these peer-to-peer arrangements involve organisations "getting to know" their network - who else is connected to their part of the network, where network constraints are forecast, and what the opportunities might be for peer-to-peer activities. One LEO partner described the need for this kind information when assembling a Local Area Energy Plan, where it was known that a very large energy user was moving its operations elsewhere, and this could provide an opportunity for a local energy group by opening up some spare capacity (names have been anonymised):

*"Big Magnet Technology Co. is going to move. And they are a huge user of power, three substations just for their one factory…So the community can be going, "alright, so if that demand shifts off the network, given that it's highly unlikely that that level of demand would come back onto the network through whoever would take that building over, what opportunities does that give us that we wouldn't otherwise know that we had?"*

Ofgem expect DNO's to make network data available and to create the platforms where this kind of information can be shared and used in Local Area Energy Planning. These IT architectures and new found access to network data can facilitate collective action and underpin the development of skills, resources and knowledge embedded within communities.

## *Co-design of energy services and low-carbon projects*

There is longstanding recognition that *Net Zero* projects will only take hold and flourish if they have the support of the "local community". For example, the *Go Ultra Low Oxford* project, a trial of the most cost-effective and socially-just approaches to installing EV charging infrastructure, found that users of the chargepoints reported on interactions with neighbours and others throughout the trial, citing interest from passers-by in the technologies, as well as more negative responses such as charger vandalism and parking violations which prevent access to chargers (Hampton et al, 2019). To prevent public assets being destroyed, vandalised or rendered inaccessible it is important that the host community welcomes the technology, understands why it is being installed, and want to see it succeed. A well-understood means of gaining that support is through members of the local community feeling a sense of ownership of the project. This sense of ownership is realised where local community members have been involved, from the earliest stages, in the design and planning of the projects. The Local Area Energy Planning method developed by Energy Systems Catapult requires the key stakeholders to come together in a collective effort to create the plans. CSE have written guidance for Ofgem on how to do this local area energy planning, "well" and describe the components of a "social process" to engage stakeholders, including community representatives and groups, as well as ordinary non-affiliated householders and business owners to co-develop the plans (CSE and ESC, 2020). This is another instance of the need for collective activity to facilitate smart local energy systems.

### *Achieving economies of scale to facilitate SLES technology adoption using collective action*

Project LEO has provided a number of examples of how collective and coordinated activities can facilitate SLES. These include:

- Mobilising a community's collective wishes and needs, and their financial and planning skills to site solar arrays or community scale batteries on or in community buildings such as schools or blocks of flats. This capability, borne out of "bonding" and "bridging" social capital (see below), needs to be complemented with the technical and physical capabilities of having appropriate roof space and right governance arrangement to be able to make decisions for how they are managed.
- Many members signing up with a community aggregator to allow their flexible demand or stable demand profile to be auctioned to an energy supplier offering the best deal. This capability for large numbers to participate in a community-wide scheme particularly draws on a sense of community identity and of being a stakeholder – "doing one's bit".
- Participating in a collective buying scheme (e.g., for solar panels) to reduce the cost of the systems. This kind of scheme particularly benefits the individual household rather than the community as a whole, but households must nonetheless coordinate their buying to leverage the economies of scale.

These examples indicate how relationships within a locality and the resources that individuals and organisations bring to a community will strongly affect its capability to host and participate in a SLES, and engage with the planning system and external sources of funding and expertise. Hence, the quality and quantity of the social networks in a community have a value in bestowing capabilities.

### *Collective action can enable disadvantaged community members to capture SLES benefits*

Local Area Energy Plans can incorporate business models and governance that recycle benefits from collective community activity to vulnerable members of the community, such as those at risk of fuel poverty or to those that do not have the suite of requisite capabilities to capture benefits of smart local energy systems when acting as individual actors. This is the rationale for a "social" or "community" aggregator (Carbon Coop, 2018). For example, a community could come together to fund a community asset from sale of their aggregated flexibility. This is an interesting possibility where the value of flexibility to an individual actor may be so small as to be inconsequential or perhaps even negative once transaction costs are factored in. But, when aggregated, the value becomes significant enough to create change. This idea has been mooted in Oxford in relation to funding the installation and maintenance costs of a publicly accessible electric vehicle charge point and perhaps associated lease on an electric vehicle. For members of the community who would not ordinarily have access to low-cost electric mobility this arrangement would be of great benefit. Having considered the need for collective responses we now consider the types of capability required to achieve these actions.

## Types of community-level capability

The capability approach identifies two broad types of intervention strategy that either work with existing capabilities, or change the offer so that capabilities are not required. These are termed "Fit" or "Transform" strategies:

- "Fit strategies" adapt the offer to work better with existing capabilities in a community: the value proposition should be crafted to fit what is found, rather than communities changing their capabilities in order to adopt the new practice or technology.
- Conversely, "Transform strategies" are about changing the capabilities of households and communities in order to facilitate adoption of the technology. The onus for change is on community, household or business.

In practice, it is likely that a blend of fit and transform strategies will be most effective in stimulating adoption of SLES technology and practices. But some community-level capabilities cannot be changed, for example the orientation of the roofs in a neighbourhood (to facilitate solar PV install), and therefore a fit strategy may be required for some aspects of the offer.

## *Community-level capability types*

LEO Partner, Low Carbon Hub, have identified key characteristics of a neighbourhood thought to influence community-level capabilities. Against each of these characteristics we can attribute a “capability” that can be developed from that characteristic or that detracts from that capability. This is shown in Table 1.

| | **Sub type of domain** | **Capability Description** |
|---|---|---|
| **Location** | Housing type, condition and density. Public / commercial buildings type, condition. | Is the stock generally well-insulated enough to make smart heat pumps feasible? Are the roofs of buildings orientated to facilitate solar ?roofs? Are the public and commercial buildings equipped with HVAC systems and sufficiently well controlled to allow controls which can deliver flexibility to be installed? |
| | Suitable sites for renewables and batteries | Is the neighbourhood capable of further connections of DER, either freestanding on public land or on community buildings? |
| | Open spaces and natural resources | Can enjoyment of local natural resources be used in engagement strategy? – e.g. in framing environmental benefits of SLES and in building social capital (e.g. encouraging people to meet and connect in delivery of open space and nature-focussed projects) |
| | Local climate | Is the local climate conducive to deployment of heat pumps – i.e. temperate? |
| | Meeting places and community buildings | Meeting places in a local community are vital to building up relationships between community members – thereby creating social capital. |
| | Off street parking | Availability of off street parking will facilitate ownership of electric vehicles through making charging and discharging of the EV via a home charge point much easier. Where there is little off street parking other solutions can be explored. |
| | Site of Special Scientific Interest (SSSI). Historic conservation area | Is the capability of the buildings to undergo retrofits or natural areas to host renewable infrastructure affected by SSSI or “conservation area” status? |
| | Local amenities | Local amenities can create anchor loads or capacity trading partners. If local amenities are not present the community’s focus is likely to be on coping with the lack of amenities, and perhaps even campaigning for more local amenities to be provided. This could suck up the community’s energies leaving little resource for other community initiatives. |
| | Specific local issues e.g. air pollution, vandalism, few opportunities | As with availability of local amenities, if there are local issues which are of greater concern then this can negatively impact the community’s capability to engage with less pressing issues or to notice opportunities. Engagement strategy in this context should link community priorities with SLES offers. This is usually achievable for SLES as there are multiple co-benefits resulting from SLES participation. |
| **Energy - Technical** | Local generation profile. Forecast generation profile. | Where a community has generation assets embedded within it, the profile of local generation will determine how much local supply can be used to meet local demand. Certain generation profiles also allow trade of unused capacity. |
| | Local storage profile (including EV charge points) | Where a community has sufficient storage assets embedded within it, these can be used to optimise local consumption of locally-generated energy supplies. High levels of storage also create the possibility of participation in multiple types of local and national energy markets. |
| | Local demand profile. Forecast demand profile | Where a community can shift or reshape its energy demand without detriment it can offer network services. A stable predictable aggregated demand profile of sufficient volume will also be attractive to an energy supplier who may offer a good deal on energy supply. |
| | Capacity agreements | Are there organisations in the community who wish to buy or sell unneeded Maximum Import or Maximum Export Capacity? Is there potential for need for offsetting? |
| | Current and forecast grid constraints | Possible further connections of generation or demand without causing network problems? Is the local DNO prepared to pay the local community for flex provision? |
| | Penetration of smart appliances and equipment. | What is the capability of threshold numbers of households and non-domestic entities to flex their energy demand through ownership of smart appliances and other electricity consuming equipment? |
| | Penetration of Electric Vehicles | Smart-charging and V2X electric vehicles offer battery storage and discharge capabilities which can be used to provide flexibility services and balance local generation. |
| **Financial and legal** | Availability of local capital. Average income levels | Willingness to invest or borrow. Creditworthiness. Capability of threshold numbers of the local community to take financial risks e.g. in investments in shares in a community energy project. |
| | Access to external funding | A key capability for moving energy projects forward is embedded skills in raising funding or having the confidence and skills to connect with external sources of expertise who can raise funding |
| | Access to legal and contractual knowledge | Many studies have found that a key criterion of a community's capability to make local energy projects happen is the availability of technical, project management and financial skills. Communities possessing these skills are also able to reach out to external sources of expertise as necessary – this ability is sometimes called linking social capital and is less prevalent in vulnerable communities. |
| | Tenure profile of the local community and length of residence. | Studies have found that levels of homeownership are positively correlated with presence of “bonding” social capital found in the community. Ditto length of residency (Leviten-Reid and Matthew, 2018). |
| | Local governance and political structures | Existence of civil society organisations that can act as a point of contact with external sources of power and resources, receive funding, employ staff and act as a trusted conduit for information and advice. |
| | Local planning rules and priorities | Local Area Energy Planning must integrate with the wider planning framework and specific development plans for the neighbourhood |

| | | |
|---|---|---|
| **Monitoring, control** | Broadband coverage | Systems founded on smart IT architectures cannot operate without reliable and fast internet connectivity. |
| | Penetration of smart meters | Smart meters are a ready-made IT architecture allowing varying degrees of smart monitoring and control. They are critical to settlement and verification of particular network services |
| | Penetration of smart control systems and other monitoring | Aggregation of the small and many assets at the grid edge is critically dependent on widespread penetration of smart devices allowing automated control and monitoring. |
| | Access to data | Local Area Energy Planning is impossible without key datasets and the capability to analyse and visualise data. |
| **Personal, Social** | Social capital (discussed more fully below) | This can be divided into three types:<br>1. "Bonding" SC – a community with dense networks of trusted social relationships.<br>2. "Bridging" SC – a community's ability for the groups within it to communicate with one another and with other communities.<br>3. "Linking" SC – a community's ability to reach out to external sources of funding, expertise and other resources. |
| | Health profile | A community may have a high number of community members with poor health or who are vulnerable to poor health outcomes if there are changes to their energy services. This may impact the ability of the community to flex energy consumption. |
| | Trust in others and external agencies | Trusted relationships between members of the community and with external sources of power and agency are another feature of social capital, and have been found to be critical in developing community energy projects. |
| | Social norms | Householders will often seek to align their behaviours with what is considered normal and acceptable for the wider community. Therefore, a social norm for adopting an innovative energy practice is helpful for engaging a community. |
| | Local networks and comms channels | Good communications, quick / extensive transmission of new ideas, practices is a feature of communities with lots of bonding, bridging and linking social capital. |
| | Residents with free time | Engagement with agencies promoting new ways of doing things and indeed participating in the promotion of new practices within a community is extremely time consuming. A critical number of residents should have sufficient free time to participate. |
| | Engagement with green issues and social issues | The financial benefits of SLES are yet to be fully demonstrated, especially at this early stage where transaction costs are unknown or known to be high. It is helpful if the local community is motivated to participate in SLES by the prospect of realising the many social and environmental benefits. |

*Table 1: Community capabilities and neighbourhood characteristics*

Many of the capabilities described above derive from the relative strength of core "social" properties of the community. Some of these social properties have been termed "social capital" which is the ability to generate or capture benefits in a community which contribute to general welfare through strong and resilient social networks, trust and willingness to share knowledge, time and goods. High levels of social capital are associated with networks imbued with trust, norms and shared values. High levels of social capital can address many problems and facilitate the spread of innovative ideas and practices. Social capital is theorised to come in a number of forms. The main ones are "bonding", "bridging" and "linking" social capital. Each type facilitates certain kinds of community capability. This is explored further in Table 2.

| | **Description** | **Capabilities deriving from social capital type** |
|---|---|---|
| Bonding | Bonding social capital refers to close ties between people in similar situations, such as family and close friends; the 'glue' that binds groups together. Typified by strong links, homogeneous actors, norms of trust, reciprocity and mutuality. | Helps explain community engagement and activism. Communities with lots of bonding social capital will have a strong sense of community identity. Encourages participation by community members in activities that achieve community-level objectives through the exercise of 'soft sanctions': blame for non-participation and creation of solidarity benefits from interacting with other members of the community (Holman and Rydin, 2012). Lots of bonding social capital can create relationships that foster reciprocity: "I am confident that what I put into this in time and resources will be reciprocated with benefits in kind". |
| Bridging | Bridging social capital refers to looser ties between a wider mixture of people, such as loose friendships or work colleagues. | If bonding capital is the "glue" that binds groups together, bridging capital is a sort of "sociological WD40" that enables diverse groups to "get along" and allow communities to create more outwardly-oriented networks (Putnam, 2001) - e.g., for closely-bonded groups to work with other groups within the community and external to it – building support, generating new ideas etc. Interpersonal communication is enabled when a community has a relatively dense network of social relationships, through a combination of "bonding" and "bridging" social capital. So some communities with higher levels of these types of social capital are more capable than others in hearing about energy innovations, spreading information about a new practice or technology through the community, and being able to coordinate their assets and resources to facilitate adoption of new practices (Darley and Beniger, 1981). One study found that seeking information amongst personal contacts is associated with adoption of innovations such as household energy efficiency behaviours, increasing likelihood of adoption by up to four times, but that there are important differences between types of innovations and communities, requiring tailoring of messages (McMichael and Shipworth, 2013). |

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|---|---|---|
| Linking | This is a special form of bridging social capital, referring to groups' ability to access networks of power and resources beyond their immediate community. | Community projects are often driven by one individual or a small group who commit time and resources and are unified around a key objective (Bridgeman et al, 2019). These individuals are embedded within their communities and have the skills, confidence and knowledge to connect with external agencies and organisations (usually the local authority) that can facilitate planning and provide funding, expertise and other resources. Numerous studies of success factors in community energy schemes show this. Agencies seeking to catalyse energy projects within communities also emphasise the importance of working with embedded individuals and organisations such as schools, local supermarkets, sports and social clubs (JRF, 2014). These stable, valued and approachable organisations confer both linking and bridging social capital. |

*Table 2: Social capital types and the capabilities they confer*

# Discussion

Some community-level capabilities are generic to the adoption of all SLES technologies and practices, others are specific. Here, we discuss the approach considering some capabilities specific to two key technologies in the energy transition: deployment of Vehicle-to-Grid electric vehicle charge points technology, and smart heat pumps.

## *Location*

Charging EV's is greatly facilitated if there is access to secure off street parking. Overall, it is estimated that around 60% of English households have secure off street parking. The Oxfordshire EV strategy estimates that around 66% of households in Oxfordshire have access to secure off-street parking in some form, leaving some 34% of households likely to be parking their vehicles in the streets. However, availability of off-street parking is unevenly distributed. Around 22% of owner occupier households in England do NOT have secure off-street parking. This rises to 52% of the private-rented sector, and 75% of households in local authority housing. Lower-income households are more likely to live in private rented accommodation or in social housing. Therefore, it is likely that households on lower incomes will have less access to secure off-street parking, and will be less able to participate in the smart charging and V2G offer: the uneven distribution of secure parking across income groups can create energy inequity.

## *Technical*

Communities of geography can be connected to the same part of the network that has an existing or forecast network constraint. By acting together to flex their energy demand and generation, the community can head off network constraints, tackle faults, reap financial rewards and create the headroom at the low voltage level for more Distributed Energy Resources to be connected. The most important technical capability is the ability of a critical number of households and businesses to act together by aggregating their flexibility using monitoring and control systems and smart equipment such as smart EV chargers and smartened heat pumps. At least two monitoring and control architectures for application at the grid edge are under investigation in Project LEO: a) Smarter Grid Solutions (SGS) product used for monitoring, scheduling, control and dispatch of larger-scale assets; b) an 'Internet of Things' solution under development using open-source data standards for monitoring and controlling small-scale grid edge assets - primarily demand-side response (DSR) assets such as smart appliances or heat pumps.

## *Economic*

We have seen in Project LEO that where the business case for V2G is not compelling from a financial perspective for individual actors, a community could come together to fund a community asset or support other community-level benefits from sale of their aggregated flexibility. This is an interesting possibility where the value of flexibility to an individual actor may be so small as to be inconsequential (perhaps negative once transaction costs are factored in - the aggregated value may become enough to create change. This idea has been mooted in relation to funding the installation and maintenance costs of a generic publicly accessible electric vehicle chargepoint and possible lease of an electric vehicle.

## *Monitoring and data*

Project LEO has demonstrated the importance of market platforms that can match-make peers to trade capacity between themselves and local area energy planning processes that allow key information to be shared about the characteristics of all the entities connected to the network serving a particular community. Furthermore, that there is also an untaken opportunity to make use of the SMETS2 functionality of smart meters which includes four auxiliary load control switches and an inbuilt comms hub that connects to a Home Area Network (HAN). The HAN allows connection of energy displays, smart appliances and gateway devices which can send data to the internet. Thus, the auxiliary load control switches and the HAN can be used to control enabled devices in the home in response to signals from the DNO or a third party such as an aggregator or a flex market platform configured to control assets. The smart meter is also essential to enabling half-hourly settlement and therefore the viability of time-of-use tariffs.

## *Community and personal capability*

In Project LEO we have found that efforts to catalyse installation of a public electric vehicle chargepoint have depended on the community possessing "linking" type social capital: there are a small number of key individuals in the community who understand the benefits of electric vehicles and would like to see a public chargepoint installed. This small number of individuals have reached out to the local authority to help realise the installation. This has resulted in ongoing discussions and the creation of a strong working relationship between particular project staff and the community representatives. Referring to the relationship between themselves and the community, LCH staff stated:

"*People were picking up on the idea that there was some kind of kind of capability that you could have to receive collaboration [i.e. for the local community to work with external agencies]. Yeah. So you might say they've got that in spades*".

The importance of "linking" social capital in catalysing community energy projects has also been recognised by government who have stated,

*"The most prevalent [success] factor was that projects were catalysed by the actions of committed community group leaders and volunteers. The evidence includes good examples of how local leadership, often delivered by individuals with some background in energy, were instrumental in delivering projects. Other reported success factors include, access to support, connecting with existing groups (sometimes with only a tangential interest in energy) and local needs aligning well with project goals (such as the need to tackle fuel poverty or refurbish a community building"* (DECC, 2013).

Bonding and Bridging Social capital has also been found to be critical. For example, the capability of disparate households within a community to share information about the merits of an energy innovation through having a dense network of trusted social relationships has been shown to increase the likelihood of adoption of particular energy innovations fourfold (McMichael and Shipworth, 2013).

## *Building capabilities*

Our discussion of the relationships between capabilities and adoption of smart energy technologies and practices leads into a consideration of barriers to gaining capabilities and opportunities to overcome the barriers. The capability lens can identify where a capability could be built in a given community, or whether it would make more sense to change the offer. This would have to be decided on a case-by-case basis, as each situation is unique. In practice, it is likely that a blend of "fit" and "transform" strategies will be most effective in stimulating adoption. Calver and Simcock (2021) emphasise that for those with few of the requisite capabilities, targeting support to increase the flexibility capital should play a role. For example, through subsidised access to smart appliances, insulation, energy storage technologies or microgeneration. This would help ensure the potential opportunities of improving the affordability of energy for the most vulnerable can be maximised. Providing training and information for households in the optimal use of smart home technology is also important.

## *Building social capital*

The process of building social capital in communities is beginning to be understood and documented in the literature. Building social capital will create links between people with a shared sense of what is normal, trusted and desirable. These can build commitment and encourage people and organisations to reframe their incentive structure so as to participate in activities that could otherwise fall foul of the "collective action" problem. People will participate if they feel they have a mutual interest in doing so, and that there will be reciprocal benefits forthcoming. It helps enormously if opportunities for people to connect with one another are fun to attend and rewarded through recognition and social approval. It is particularly important to create a sense of social inclusion where people can feel that their contribution is valued; also to develop a norm for prosocial behaviour. This will reduce the sense that others are free riding on an actively-engaged group's efforts, something that can undermine prosocial motivations and actions (Fredericks et al, 2015).

There is also the question of how to create "linking" social capital and embedded knowledge, expertise and awareness of the technical, social and economic benefits of SLES. Project partner LCH and Oxford Brookes University have done extensive work in developing tools which engage communities, including low-income communities, in the process of creating a value proposition for low-carbon projects in their area. The work considers the community's capabilities and records their priorities, barriers and opportunities also. This work and an integrated mapping tool allows a community to begin to assess its own technical and economic resources, and its various forms of social capital, so that a plan can begin to be developed which makes the most of the communities' capability.

### *Equity*

Inequities are inevitable in the energy transition because the actor, community and system-level capabilities will be distributed unevenly, with the likelihood that actors and communities with fewer financial resources or less ability to take risk will be less able to access benefits from SLES and may be left behind. For example, it is very likely that community-level technical capabilities enabled by ownership of smart control systems for smart appliances and equipment will not be associated with low-income communities (Carley and Konisky, 2020). How can we ensure that lower-income communities can also access benefits from coordinated control of smart appliances, electric vehicles and other equipment in a smart local energy system? There is also an equity dimension in the distribution of forms of social capital. For example, impoverished communities have lower levels of bonding social capital than higher-income ones (Larsen et al, 2004), while skills and resources that could be shared across a community (e.g., knowledge of the planning system or financial expertise for linking to external resources) are associated with communities with relatively high incomes and levels of education. In contrast, low-income communities have been found to be relatively unengaged in local planning and policy processes (Pattie et al, 2004).

But low income does not necessarily equal low social capital. How transient a community seems more critical. For example, studies have found that levels of homeownership are positively correlated with presence of "bonding" social capital found in the community, as is length of residency (Leviten-Reid and Matthew, 2018). Long-established working-class communities in older housing estates, where extended families have lived for generations, may have lots of bonding social capital that can be worked with if new ideas, practices and technologies are to be widely adopted. However, if there is too much bonding and not enough bridging social capital, it may be that new ideas tend to stay within tight social groups. And if there is too much bonding and not enough linking, then a very insular type of community can develop where outsiders are distrusted, any deviation from existing ways of doing things is discouraged, and links to external agencies, sources of help and expertise are stymied.

We have found in Project LEO that social housing tenants are much less likely to sign up to the offer of a Time-of-Use tariff that works in tandem with a solar roof installed on their building, than owner occupier residents occupying the same building. Project staff attribute this to a mix of factors include risk aversion, lack of trust and connection with project staff with and the environmental objectives of the innovative energy supply offering. It should be noted that the evidence suggests that people living on a low income make decisions focused on coping with present stressful circumstances, often at the expense of future goals and that people in poverty are less likely to take risks (JRF, 2017).

## Conclusions

In conclusion, we can say that in evaluating Project LEO we have found a clear need for an analytic framework recognising that capabilities to participate in, and benefit from, the energy transition should be attributed to three different levels of the energy system: actor, community and system levels. Capabilities that are acquired when the members of a community act in collective and coordinated fashion are perhaps the least understood of these levels but their importance in creating modes of engagement with the energy system and in building up the viability of Smart Local Energy Systems is undeniable. The establishment of community-level capability of particular types also seems to have promise in ensuring that low-income and vulnerable social groups have a route into accessing benefits from the energy transition which would otherwise be denied to them if acting as individual actors. This paper has only just begun to identify the ways in which community capability level can be helpful. There is clearly a huge research agenda here – particularly, in robustly linking capabilities of various types with participation in SLES, and in identifying effective methods and interventions to build up the sort of capabilities that are needed.

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