LEO Local Energy Oxfordshire

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Annual Synthesis Report - Year 3

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Executive summary

Project LEO was set up to develop a transformative integrated smart local energy system (SLES) in Oxfordshire. It is an ambitious smart grid trial, improving our understanding of how to make the transition to a flexible, renewables-based electricity system with local energy markets, and demonstrating how communities, organisations and businesses can benefit from this.

This synthesis brings together lessons learned during the third year (Y3) of Project LEO. It summarises findings from 15 reports available on the project website, along with material from interviews with project partners in which they reflected on their experience with planning, operating and communicating a proto-SLES.

As the project enters its final year, partners have been considering answers to the question 'How does LEO work?' and their responses are summarised in the latest version of our Theory of Change (ToC), in Chapter 9.

Activities

The first and second years of the project demonstrated the value of a flexible, modular approach to energy transition through the testing of Minimum Viable Systems (MVS), designed for rapid learning. In Y2, LEO partners made progress on organisational, data and connectivity issues that emerged in Y1, with deeper understanding of how to gain flexibility from electric vehicles (EVs), work towards Smart and Fair Neighbourhoods (SFNs), connect new distributed energy resources (DERs), activate demand side response (DSR) in institutional buildings and map the energy landscape of Oxfordshire.

Year 3 saw the start of formal trials of DSO-procured and DSO-enabled services involving grid-edge DERs from the project partners. The first phase of the TRANSITION trials took place between November 2021 and February 2022, with LEO partners providing flexibility, mostly procured by the Distribution Network Operator (DNO). Engagement work continued on several fronts: with the SFNs, building managers, policymakers, potential trial participants and others.

Data gathering, storage and documentation have continued, using quantitative and qualitative methods, as recorded in our published reports, in LEMAP and geospatial datasets (for use by all stakeholders) and in internal documents and datasets. Y3 work has continued to validate LEO's 'agile learning' approach, with partners learning-by-doing and also learning from each other's' written and verbal reporting.

Guiding principles and concepts

The 'Prospering From the Energy Revolution' (PFER) programme, within which LEO sits, aims for social as well as operational benefits. There is a draft ethical framework to guide the project, plus stakeholder engagement principles, that we are testing through the SFN trials. It pays special attention to building trust and productive relationships with more disadvantaged stakeholders so that they are not 'left behind' through being unable to benefit directly from owning DERs.

Concepts that have shaped LEO thinking and activity include:

- Smart Local Energy System (SLES). There is no single agreed definition of this, but from LEO's standpoint it is a local, low-carbon, energy system that engages with all stakeholders in the local area and uses market mechanisms and smart technology to bring value to the DNO network and those connected to it.
- Flexibility – making temporary changes in the way you consume, generate or store electricity when requested, to support a more efficient use of the energy network.

- The Grid Edge is where people make use of the low voltage power the network delivers to homes, businesses and other organisations. The edge of the traditional energy system is becoming the focus of attention, as it is here that new generation is connected, new forms of storage and demand management are being tested, and energy users are engaging with the system in new ways. The grid edge will need to operate very effectively if we are to accommodate the assets needed to work together in balancing local networks without massive investment in new infrastructure.
- Smart and Fair Neighbourhood Trials, which are demonstrating how flexibility services can sit at the heart of a smarter, low carbon, locally-balanced energy system.
- Minimum Viable System, the minimum set of people, technologies and processes necessary to test whether an energy flexibility idea or process works as expected.
- Capability (the ability to perform a task and, in this context, to contribute to SLES). This concept can operate at different levels, including individual actors, organisations, communities and whole systems; and in different domains – financial, technical, digital, social, personal and organisational.
- Value – economic, environmental, social and technical - a basis for SLES engagement and for value propositions suitable for the broad range of potential flexibility providers.
- Local Energy Market. In the SLES context this means achieving coordination of assets through a market-driven approach rather than through centralised rule-based coordination.

Messages from Y3

This report is a synthesis and readers are encouraged to go to the source documents for more detail on each of the topics. Summarising the synthesis, though, we offer these headline messages from Y3 of Project LEO:

The *'capability* lens' is proving useful in analysing and assessing not only the capabilities of potential flexibility providers but also the capabilities of the system as a whole, which needs to be able to host or integrate a SLES with appropriate planning, policy and regulation, along with market platforms where services can be traded. We expect the capability framework to be readily transferable to many situations, making it useful for disseminating and developing LEO's work with 'follower' organisations.

Actor, community and system level capabilities will be distributed unevenly and there may need to be interventions to develop actor and/or system capability. Alternatively, a SLES offer may have to be reconfigured to adjust to local capabilities, if unfair outcomes are to be avoided.

It is not easy to be right or 'fair' in a competitive market. At national level, energy policy rationales are largely based on enhancing competition and consumer protection, and there is a risk of perpetuating old inequities and creating new forms of unfairness, as new technologies, actors and processes are introduced via SLES to people and organisations with different levels of capability. A market-based system will need regulating to secure inclusive participation and a safety net for those in danger of being left behind in energy transition.

Value can be expressed in many ways (e.g. economic, environmental, social, knowledge/skill), and all can be included in value propositions. However, the economic aspect of value is usually the first consideration for commercial decision-makers. While there is a growing case for small-scale flexibility, it is risky to invest in flex-providing assets and the resources needed to manage them without an assured market for the services they can provide. It is proving a lengthy process to build and test such a market, working simultaneously from the grid edge (generators and electricity users) and from the centre (system operators, market designers and platform operators).

Three value-related areas were identified for attention: the need for:

- value-stacking (including revenue-stacking); fair valuation of flexibility against the alternatives;
- reducing barriers to market for DERs that individually have low flexibility but could collectively represent over 22GW; and
- rewarding sustainability or other non-economic value from flexibility services.
- Through preliminary trials, LEO partners grew their understanding of how more efficient *market* operation can reduce participation costs and discovered the time, engagement and other efforts required to prepare assets for flex services when those assets have not been designed with this in mind. Financial returns at present are not adequate to compensate for the time and effort involved in becoming flex-ready.

In the autumn of 2021, the first round of TRANSITION trials built confidence in Distribution Systems Operations (DSO)-procured flex delivery at the very local level. The trials also showed that enabling flexibility from DERs is relatively expensive, technically demanding, legally complex and resource-heavy for short-duration and low-value contracts. In operational terms, energy was not the main business focus for most of the participants from the LEO consortium. There is a role for intermediaries to simplify and communicate value propositions and to take on the more administrative requirements of the trials.

There was limited trial participation with a price celling of £300/MWh, with many service providers maxing out this for their bids. To test whether this is a true representation of cost of service, or an artefact of a non-liquid, non-competitive market, the price ceiling has been increased for the second trial period.

The small sample of V2G in the trials could offer flexibility at intervals, but if scaled up, V2G could offer a useful service in near-real-time.

There are likely to be three options for flex market participants: in a locally-constrained area, only DSO-related services may be possible; in a less- constrained area, stacked services; and where there is no local constraint, full flexibility may be provided to the Energy Systems Operator (ESO) markets.

LEO engagement with six *Smart and Fair Neighbourhoods* has continued to be productive, building knowledge and capability within the communities and the project as a whole. However, developing viable, durable business models that aggregators can work with is also a slow process in current market and regulatory conditions, and getting householders to sign up to heat pump installation has also proved very time-consuming: early-stage SLES development requires time and funds for thorough engagement, along with aggregators willing to work with communities, their assets and activities.

Data-gathering and handling continues to be a major background activity. The process of setting a baseline against which to measure performance was successful in the TRANSITION trials but has been challenging: dynamic and robust methods are needed for fair and accurate settlement. Varying asset types will need careful baselining, and uncertainty will have to be treated effectively to lower the risks of flex provision and procurement.

Mapping continued to be a productive strand of LEO activity, with data being shared with Rose Hill and Eynsham residents via a mapping-and-engagement tool (LEMAP) that brings together public, private and crowd-sourced data on energy demand, resources, buildings, demographics, fuel poverty and network conditions within a single platform. Oxfordshire County Council have also developed a prototype strategic mapping tool that is being tested with local plan, housing and electric vehicle (EV) teams. Other local authorities are showing an interest.

Engagement has continued at local, national and now international level – the last of these via our attendance at COP26 and the launch of the International Community for Local Smart Grids.
There is continued high ambition for net-zero systems expressed nationally and locally but there are disconnects between instruments and tiers of law, *policy and regulation*, with national-local disconnects having the greatest impact on SLES. There is a need for national strategic direction for local energy, and for filling the gaps between policy proposals and implementation mechanisms. Local energy systems need policy certainty in order to thrive; without it, necessary investments in physical assets, infrastructure, skills and organisational capability will not be made.
Electricity market structure and regulation can inhibit SLES and low carbon innovations, for example, when DNOs are restricted from holding a generation licence and from operating electricity storage; and storage assets have unclear legal status.

Looking ahead, there are reasons to be hopeful: many elements of LEO appear to be replicable although a lot remains to be done in terms of creating policy and market conditions for widespread SLES development.

LEO operates in social, technical and economic domains and many processes relate to all three. The most recent Theory of Change diagram reflects the complexity of the project and the inputs of many partners.

Contents

1 Origin, aims, concepts and project structure

1.1 Origin and aims

Changes in how electricity is generated, distributed, traded and regulated call for system-wide rethinking and reconfiguration. In 2018, the Industrial Strategy Challenge Fund (ISCF) set up *Prospering from the Energy Revolution* (PFER), a programme with £102.5m of funding to develop systems to support the move to renewable energy. Eight million pounds of the fund went to the EnergyRev research consortium, to carry out research for smart local energy systems (SLES) that are characterised by the 'four Ds' of decarbonisation, digitalisation, decentralisation and democratisation. Three large demonstrator programmes were also funded to run alongside EnergyREV, starting in 2019: Local Energy Oxfordshire (LEO), Energy Superhub Oxford, and ReFLEX in Orkney. These aim to develop and demonstrate SLES approaches that can

- provide cleaner, cheaper, more desirable energy services
- lead to more prosperous and resilient communities
- develop new business models that are suitable for investment and scalable
- provide evidence on the impacts and effectiveness of novel energy system approaches by the early 2020s.[1]

Project LEO operates in Oxfordshire, a county that will need an estimated 2,050 GWh of renewable electricity (mostly solar) by 2030[2] to contribute its share towards national climate targets. This will need to flow through a distribution network that was not designed for distributed generation or for the new patterns of demand that are emerging, and the necessary changes will call for new skills and processes. LEO therefore aims to develop *a skilled community positioned to thrive and benefit from a smarter, responsive and flexible electricity network.[3]*

At the outset, three goals were agreed: to achieve a local, balanced energy system, ecosystem benefits, and equitable access to energy services. Three-quarters of the way through the project, there is general agreement that these have not changed. If anything, they are even more relevant to developments in the energy scene than they were in 2019.

Progress towards each of the three goals does not always move at the same pace but the interactions between operational, social, data and market aspects of LEO are becoming clearer and stronger. This report illustrates many of the interactions and their significance in working towards the LEO goals.

1.2 Guiding ideas and concepts

Concepts that have been central to LEO throughout Y3 have been:

- **Smart Local Energy System (SLES)**. A SLES connects local and national system infrastructure to deliver value to the community it serves by taking advantage of innovative approaches to provide, move, store, sell and use energy at a local scale. There is no single definition of SLES, but within this project it is viewed as a local, low-carbon, energy system that engages with all stakeholders in the local area and uses market mechanisms and smart technology to bring value to the DNO network and those connected to it.[4] Local and national energy infrastructure, people

[1] https://www.gov.uk/government/news/four-leading-edge-demonstrators-to-jumpstart-energy-revolution
[2] https://www.oxfordshireopenthought.org/energy
[3] Project LEO website, accessed March 2020
[4] https://project-leo.co.uk/wp-content/uploads/2021/06/LEO-D2.8-Value-Chain-for-Flexibility-Providers-v2.1-LEO-cover.pdf, p3

and technologies work together to make, move, store, sell, use and conserve energy locally. A successful SLES creates value for the community it serves and should respond to the community's objectives.[5] In mnemonic form, Ideal characteristics of a SLES can be set out as:

- Smart: technologically innovative, using Information and Communication Technology (ICT) to sense, communicate and automate.
- Local: generation and other assets are close to the people who participate in the system and are served by it; needs are met in ways suited to the local context.
- Equitable: with access to affordable energy services for all.
- Sustainable: especially in terms of zero-carbon transition and resilience.

LEO contributes to developing this concept through experiment and dialogue with sister programmes, policymakers and other stakeholders.

- **Flexibility** – making temporary changes in the way you consume, generate or store electricity when requested, to support a more efficient use of the energy network.

- **Grid Edge**. The grid edge is where people make use of the low-voltage power the electricity network delivers to homes, businesses and other organisations. To quote from Greentech Media 'Innovation and disruption often play out at the boundary, or edge, of traditionally stable and well-understood industries. Over time, change moves inward'[6]. The grid edge concept helps to shift focus from the old hub-and-spoke model of an electricity system to a network model, with many distributed and linked actors and assets.[7] LEO has been carrying out detailed work with assets and with their owners and operators at the grid edge, to translate this fundamental change into viable business arrangements and community benefit.

- A **Smart and Fair Neighbourhood (SFN)** is a community where LEO partners are trialling different flexibility services to learn how smart technology and new commercial models can create opportunities in a local energy marketplace and help us to understand how to do this in an equitable and fair way for everyone.. At the time of writing, six SFNs are set to take part in LEO trials.

- **Minimum Viable System (MVS)**. An MVS represents the smallest set of participants and processes required to test a process or new use for an energy asset or service. It offers an agile way of testing innovations and learning from them. The approach has been scaled up as LEO progresses.

- **Capability:** the power or ability to do something – in our case, to contribute to flexible, low-carbon energy systems. This concept can be used in several domains and at different levels, as discussed below.

- **Value** – economic, environmental, social or technical. The ways in which people assess value are crucial in assessing the attractiveness and viability of value propositions, SLES-oriented business models and Local Energy Market development. Value, and value propositions, have been vital elements of LEO discussions throughout Y3.

[5] see www.project-leo.co.uk/glossary
[6] https://www.greentechmedia.com/articles/read/what-is-the-grid-edge , accessed June 2022
[7] Bouffard, F. and Kirschen, D.S. (2008) Centralised and distributed electricity systems. *Energy Policy* 36, 4504–4508

- **Local Energy Market**. In the SLES context, this means a market for trading flexibility (kW)– the ability to generate, store or use electricity at specific times, to support the network – as well as a market for trading energy itself (kWh).

These concepts appear throughout this report. The last three, in particular, have come into sharper focus over the last year and are addressed in Chapters 2-4. Chapters on the TRANSITION trials (market-based) and on Smart and Fair Neighbourhoods (community-based) follow; then accounts of data and mapping, stakeholder engagement and the policy and regulatory environment for energy transition. The report concludes with a provisional summary of how Project LEO works – the latest iteration of the Theory of Change.

1.3 Project partners and structure

LEO partners include:

- The **project lead**, Scottish and Southern Electricity Networks (SSEN),[8] who are primarily responsible for project management, oversight of systems, marketing and communications.

- **Market operators** who develop and support a marketplace in energy and system flexibility so that contracted service providers can meet network operational needs. Piclo are developing a third-party flexibility exchange platform for trade of DNO-procured and peer-to-peer (P2P) services.

- **System developers**. Opus One are involved in developing the Neutral Market Facilitator (NMF) market platform according to rules set out by Origami Energy and SSEN. This interfaces with the DSO's 'Whole System Coordinator' (WSC) platform which analyses the electrical load on the network.

- **Service providers** that focus on community-led investment, community engagement, planning, mapping and governance (Low Carbon Hub, Oxford City and Oxfordshire County Councils); working with industrial and commercial customers (EdF Energy); and working with the public sector and householders (Nuvve vehicle-to-grid innovation).

- **Flexible asset providers**. Oxford City Council, Oxfordshire County Council, Oxford Brookes University (OBU) and the University of Oxford (UoO) bring flexible load from their estates and vehicle fleets.

- **Researchers** from the UoO and OBU, consolidating data sources and analytic tools to develop local energy system mapping, conduct trials, analyse and evaluate outcomes.

In Y3, it has become possible for several of the project partners to work together more closely at the new 'Energy System Accelerator' premises in West Oxford.[9]

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[8] Work Package 5 of LEO relates closely to the TRANSITION project to accelerate movement from DNO to DSO; this informs the national Open Networks programme.

[9] https://zero.web.ox.ac.uk/oxford-mini-tesa

2 Capability in SLES

We define capability as the ability to act: it relates to what people are able to do as well as to what they have, and it takes social arrangements into account – for example, the ability to speak freely, vote and gain access to public goods – as well as capabilities gained from personal health, strength, temperament and earning ability. The Centre for Sustainable Energy has recently developed a "capability lens" while exploring what a socially just energy transition could look like.[10], and Low Carbon Hub are collaborating with them on taking this work further.

Capability can be assessed at different levels, including individual actors, organisations, communities and whole systems; and in different domains:

- technical/physical (e.g. possession of generation/storage/flex asset, or a suitable site);
- economic (e.g. money to invest in assets and pay for expert advice);
- lifestyle/operational (e.g. ability to shift demand without detriment);
- skills and motivation;
- social capital (e.g. shared values, active social networks, sharable expertise).

These are discussed in a LEO paper, along with the concept of *system capability* - the regulatory and planning context, local market structure and network characteristics.[11]

2.1 Domains of capability

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. Within the system, different types of DER will be capable only of delivering certain types of flexibility service. For example, the ESO Dynamic Containment service requires a very fast and controlled response that favours battery technologies, whereas a thermal asset such as a Combined Heat and Power plant is more suited to longer delivery periods for DSO flexibility services.[12]

These actor, community and system level capabilities will be distributed unevenly. People 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'. Similarly, where a local distribution network does not have the capabilities to host a SLES, that part of the network will not fully participate in energy transition. Capability at all levels can be understood in terms of equity and fairness, and there may need to be interventions to develop actor and/or system capability. Alternatively, a SLES offer itself may have to be reconfigured to adjust to local capabilities if unfair outcomes are to be avoided.

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[10] Roberts, S., Bridgeman, T., Broman, D., Hodges, N. and Sage, C. (20202) Smart and Fair? Exploring social justice in the future energy system. Phase One report and recommendations. Centre for Sustainable Energy, Bristol. https://www.cse.org.uk/downloads/reports-and-publications/policy/energy-justice/smart-and-fair-phase-1-report-september-2020.pdf

[11] Banks, N.W. and Darby, S.J. (2021) A capability approach to smart local energy systems: aiming for 'smart and fair'. Proceedings, European Council for an Energy-Efficient Economy, paper 5-105-21. https://project-leo.co.uk/reports/eceee-report-a-capability-approach-to-smart-local-energy-systems-aiming-for-smart-and-fair/

[12] see https://project-leo.co.uk/wp-content/uploads/2021/06/LEO-D2.8-Value-Chain-for-Flexibility-Providers-v2.1-LEO-cover.pdf

2.2 Capability in practice: vehicle-to-grid

Electric vehicle (EV) batteries, if discharged to the grid (vehicle-to-grid, or V2G), allow access to a range of flexibility markets, including national markets for balancing services and frequency response fault recovery. At scale, V2G offers many potential services, including improving network resilience, reducing the carbon content of electricity supply, optimising use of behind-the-meter solar on-site generation, and new sources of income to vehicle owners from selling exported energy or flexibility services.

A briefing based on LEO experience with V2G charging[13] demonstrates how the idea of capability can be put into practice for assessing potential flexibility benefits in a given situation. It does so at the level of individuals, organisations and communities, highlighting issues such as

- Affordability of an EV;
- Availability of off-street parking;
- Whether an EV is designed to discharge to a standard chargepoint;
- Whether a chargepoint communications protocol is compatible with V2G activity and readable by an aggregator;
- Capacity of a public building for new chargepoint circuits;
- Capacity of substations to take on additional power flows to and from EVs;
- Ability of individual or organisational customers to take on the risks of investing in V2G technology, while financial returns are uncertain;
- Willingness of commercial building landlords to install V2G chargepoints for their tenants;
- Whether customers have devices hosting a V2G app and the digital know-how to use it;
- Whether there is cyber-secure, robust digital connectivity between a chargepoint and the internet;
- Customers' ability to leave their EVs plugged in for extended periods, without interrupting their daily routines;
- (For scaled-up impact), whether a critical mass of customers is able and willing to aggregate their flexibility, and have it monitored and controlled;
- Ability of aggregators and DNOs/DSOs to offer monitoring and control systems to bring down transaction costs for small asset owners;
- Availability of V2G-trained electrical contractors to install chargepoint equipment.

This is a good example of new insight flowing into the project and being developed there, bringing together questions of assets, infrastructures, skills, inclusiveness and equity in while developing the ability to reach specific outcomes. It helps in addressing the challenge of creating business models and value propositions that will work for people with and without the physical, financial, social and knowledge capabilities to participate fully in a local system.

3 Value

Low Carbon Hub have identified four aspects of value that matter to their stakeholders – planet, people, prosperity and perception (do stakeholders perceive the Low Carbon Hub to be living up to their aims of being a transparent, trusted partner that shares knowledge and expertise, openly?) [14] – all of which can be included in value propositions.

[13] https://project-leo.co.uk/reports/vehicle-to-grid-v2g-barriers-and-opportunities-a-capability-approach/

[14] https://www.lowcarbonhub.org/wp-content/uploads/2021/09/LCH-IMPACT-REPORT-2021-LOWRES.pdf

Whilst working with grid-edge assets is challenging, LEO partners remain keen to explore small-scale flexibility, which represents huge potential flexibility for the system that we need to learn to unlock. The reasons for exploring value at the grid edge are operational and also relate to the creation of social and environmental benefit. Some network constraints at secondary substation and feeder level can only be tackled by flexing demand and generation at MPANs (meters) connected at the low voltage level, as in a scenario where many households on a street served by the same feeder switch to an electric vehicle. Smart EV charging, coordinated at street level, would be one way of deferring or avoiding costly and disruptive network reinforcement. Even small amounts of additional revenue from flex provision can benefit some customers, and there are possibilities for community financial benefit from shared assets or the sale of aggregated flexibility. Increasing the flex at grid edge also has environmental value, enabling greater penetration of renewable generation that can achieve substantial behind-the-meter savings, e.g. where social housing landlords install rooftop solar, or P2P trades of capacity enable more low-voltage-connected renewables.

However, the 'prosperity' aspect of value is usually the first consideration for commercial decision-makers. In economic terms, the value of flexibility in different situations can only be estimated in the absence of a functioning market. While there is a growing case for aggregating small-scale flexibility, there are also strong operational and commercial reasons why more traditional forms of flex provision from larger-scale assets are likely to be favoured, at least in the short term. It is risky to invest in flexibility-providing assets without an assured market for the services they can provide, and a lengthy process to build and test such a market, working simultaneously from the edge (generators and electricity users) and from the centre (system operators market designers and platform operators).

There remain challenges – and possibilities – from extending LEO's work on markets 'outwards' to the grid edge and the work at the grid edge 'inwards'. It is not easy to communicate how these two complement each other to build a whole functioning system, but value has emerged as an important concept in bringing them together. There is further commentary on value propositions in Chapter 5 (Smart and Fair Neighbourhoods).

4 Developing a Local Energy Market

In a Local Energy Market (LEM), only flexibility assets (distributed generation, storage and demand side response) within a defined geographical area can participate. These assets can be used to meet local needs in peer-to-peer (P2P) transactions enabled by the DSO, or can be procured to meet DSO needs, or could provide ancillary services in national markets, procured by the Electricity System Operator (ESO). Opportunities to capture value in different markets can be 'stacked' to deliver multiple revenue streams or cost reductions.

It is a challenge to create a marketplace and local energy services where a range of actors (including aggregators and other intermediaries) are able to develop business models and value propositions that work with households, businesses and other organisations with low levels of flexibility and capability to participate in a LEM, even though their aggregated flexibility may be significant.

The focus in Y3 was on how to structure markets for flexibility and to create the technical, operational and contractual conditions for mobilising that flexibility. Activities included summarising lessons from MVS trials, assessing prospects for value stacking and conducting the first round of TRANSITION trials. The market had to be characterised in terms of actors and value propositions. End-to-end processes had to be tested, and IT system architecture had to be fit for market purposes.

Work with SFN residents and interactive mapping helped our understanding of equity, value and the distribution of costs and benefits in a more flexible electricity system.

4.1 Learning from the MVS trials

The MVS trials, running from September 2020 to October 2021, were designed to develop the capability/functionality of DER assets so that they can take part in flex markets. They focussed first of all on understanding the purpose and technical capability of assets: what potential for demand response did they hold? Next, they looked at the instruction, dispatch, and delivery of flexibility (all of which were mostly manual in the early stages). This helped service providers to understand operational requirements for market participation and SSEN to develop an end-to-end process for flexibility procurement.

Later MVS+ trials were aimed at improving asset, market, and platform integration by increasing the levels of automation and flow between delivery stages. As an example of the latter, a commercial MVS took place with four LEO partners in June 2021 to assess DER operators' forecasting accuracy, application of baseline methodology (with the associated metering and data challenges) and the suitability of settlement mechanisms. The data showed that it was difficult to predict the amount of flexibility that three of the five tested DERs would be able to provide during the flexibility events, which resulted in lower-than-expected payments to them. The MVS demonstrated that batteries are suited to providing flexibility in month- or week-ahead markets, as they can provide a reliable amount of flexibility (sometimes through pre-charging), while hydro generation is best suited to the day-ahead market due to the variability of river / weir interactions. V2G chargers may be suited to the month- or week- ahead markets but require reliable behaviour patterns (in aggregate) from a large number of drivers. DERs with low levels of flexibility that rely on weather forecast should consider restricting their focus to the day-ahead market to avoid the risks associated with longer term markets, unless they have access to reliable longer-term forecasts.[15]

Through these trials, project partners grew their understanding of how more efficient market operation can reduce costs associated with participation. The report on MVS trials[16] also stresses the time and effort required to prepare assets for flex services when those assets have not been designed with this in mind. An important secondary effect of the MVS trials was to set up an agile process through which trials can be run and evaluated quickly – an iterative build-measure-learn approach. The commercial MVS trial meant that Origami Energy was soon able to hold individual sessions with the DER owners/ operators to determine what could be done to improve forecasting and data uploading in advance of the TRANSITION trials - the agile learning approach in action.

4.2 Value chain for flexibility

A report from Origami Energy[17] focuses on the value of flexibility services, their interactions and the possibilities for stacking revenue from different types of service, creating a value chain. It covers established services in the ESO (transmission) and DSO (distribution) markets, as well as new P2P services. The report highlights the difficulty of realising the value of new services, given their uncertain value to all market actors, including the Flexibility Service buyer. This uncertainty restricts flexibility development. Four areas were identified for attention:

- Revenue stacking. Flexibility value depends on local network conditions (power flows, capacity, voltage and connected DERs) and other compounding variables (market liquidity, service type, service maturity and technical capability of the flexibility provider). As such, value will change

[15] https://project-leo.co.uk/reports/assessment-of-declarations-baselining-methodology-and-settlement/
[16] https://project-leo.co.uk/reports/minimum-viable-systems-trials-compilation-report/
[17] https://project-leo.co.uk/reports/value-chain-for-flexibility-providers/

over time and the business case for new flexibility will need to rely on several revenue streams being available. Stacking flexibility services reduces overall revenue risk by reducing reliance on any one revenue stream, but may involve third parties to provide market access. The ability to stack more services will be essential to transform flexibility markets and support Net Zero.

- Fair value for flexibility – remuneration for all benefits to market actors and to the country as a whole, as flexibility is increasingly considered an integral part energy transition. Payment should provide fair value against the alternatives to flexibility.

- Route to market. This varies according to a number of factors (service, marketplace, DER type and capacity, and the size of any DER portfolio). Flexibility markets are mostly designed for large DERs or portfolios of DERs. Standardising services across the marketplace, simplifying requirements and reducing barriers to entry further (even through intermediate markets) will enable a significant increase in participation from DERs that individually have low levels of flexibility but could collectively represent over 22 GW. However, a move towards "flexibility as infrastructure" needs to be carefully managed if existing reliability standards are to be maintained, even if some users may be prepared to pay less for a lower standard of service.

- Non-financial value. Flexibility can be used to facilitate greater penetration of low carbon technologies (LCTs) and influence behaviour to create benefit beyond the ESO and DSO. Whilst sustainability values can be hard to realise, this can partly be addressed by recognising them when flexibility solutions are incentivised and procured. Rewarding flexibility solutions which provide a sustainability benefit, or favouring these in market auctions, can promote investment in sustainable solutions.

4.3 Finding routes to market: the 'Swiss Army knife' approach

Low Carbon Hub and Origami Energy built on findings from the early 'Plug-in Projects' to develop their understanding of two issues: how to replace Feed-in Tariff revenue with new Power Purchase Agreement (PPA) models in order to make new projects investable, and how flex services revenue will operate. During Project LEO (and probably well beyond), though, they do not expect services to be certain enough to be investable or bankable but the additional revenues provide some upside to project economics.

As described in their report[18], the aim has become to develop a 'Swiss army knife' approach to developing a flex portfolio of DERs and revenue contracts: something that may be expensive but will be versatile. It could contain, for example, capabilities for Maximum Export Capacity (MEC) trading, ESO services and other P2P trading opportunities, all operating in different markets, including risk management products. This could allow flex providers to provide many services, hopping between them based on what is needed at any time in a given location.

4.4 LEO / TRANSITION trial plan

The TRANSITION trial plan was published just before the start of Y3. It set out the approach for the post-MVS+ periods and detailed how it would be enabled through TRANSITION. The trials are exploring service providers' willingness to make flexibility available and establish the value of services to the DSO and other market actors over three periods:

- 'Frosty Winter' (Nov 2021 to Feb 2022, Trial Phase 1)
- 'Long Hot Summer' (May 2022 to Sept 2022, TP2)

[18] https://project-leo.co.uk/wp-content/uploads/2022/01/D3.7-Routes-to-Market.pdf

- ‘Stormy Winter’ (Nov 2022 to Feb 2023, TP3)

TRANSITION trials are a natural progression from the MVS trials that LEO project partners carried out in Y2 and Y3, with the focus switching from individual DERs to the whole marketplace. Key differences and similarities between TRANSITION and LEO trials are:

TRANSITION (TP1,TP2,TP3)	**LEO (MVS, MVS+)**
Marketplace-driven	DER-driven
Learning focusing on internal DSO processes, interaction with flex providers and commercial aspects of Flexibility Services (prices, DER performance, market liquidity)	Learning focused on enabling DER flexibility, discovery of the end-to-end process for delivery of Services, testing technical capability of flexibility providers and individual elements of the system.
Top down	Bottom up
Non-geographic	Local
DSO development	Grid edge generation
Market actor conflicts	Local benefit
Market models	Asset development
Cost efficiency	New investment models
THE COMMON TASK	
Testing a range of exemplars with limited assets and participants	
Understanding the role of network geography: full trials at all voltages in exemplar places with real communities.	
Understanding the local market and its interaction with other markets, to maximise: • Network access and utilisation • Penetration and uptake of low carbon technologies • Acceptance	

Source: presentation to LEO Monitoring Officers, June 2022

Following publication of the plan, the consortium convened a Delivering Trials Steering Board and working groups to put processes in place. Data from the trials and market reports have been developed from outputs from the NMF using Python and Power BI to produce basic reports to communicate market interactions that are shared with trial participants.

4.5 Phase 1 of the TRANSITION trials

The report on Period 1 (TP1) of the TRANSITION trials[19] records findings from the testing of innovative market arrangements with smart systems and platforms in real-life conditions, involving three bulk supply points and 69 events with 18 assets in 13 primary substation areas.

TP1 concentrated on the fundamentals of running a flexibility market, looking at asset recruitment, building relationships in Oxfordshire, and at how assets and people behave within a market environment. In order to test these relationships, the concepts of forecast events (to test integration of Power System Analysis into the project) and scheduled events (to test market behaviour) were developed. There was a great deal of learning in relation to forecasting, and further work includes developing forecasts from weather data, enabling greater accuracy as constraints move nearer to real time.

4.5.1 Trial recruitment

Two open webinars and a workshop were held to assess recruitment processes for the trials. Participants reported[20] that the main barriers to participation related to

- complexity of the trials and agreements, of which the latter seemed to have been devised for larger market actors;
- the relatively low level of financial reward;
- challenges surrounding internal engagement and organisational governance;
- the technical capability of an organisation's assets to provide flexibility; and
- whether organisations had the resource and skills to participate, including the ability to assess flexibility potential.

Some of these barriers were substantial: all participants had had to invest considerable time and effort into preparing for the trials, from understanding and filling out the contract forms to making sure that their technologies were flex-ready.

On the positive side, net zero/environmental and financial drivers were commonly given as the most important for participation. Others related to taking part in innovation/ collaboration, influencing market designs and decisions, trading existing capacity (grid connections), financial support and having a variety of durations in the market options.

4.5.2 Running the trials

The LEO partners participating in TP1 offered flexibility assets including batteries, run-of-river hydro and V2G. They had different levels of understanding of the energy industry, and the learning curve has been huge. Contracts for flexibility were explored, with the ENA Flexibility Services Agreement (FSA) a starting point. With a standard national agreement (tailored for the trials), there was varying success, with some participants taking a more pragmatic view than others in relation to some of the terms and conditions.

[19] https://ssen-transition.com/wp-content/uploads/2022/04/Ofgem-Report-Trial-Period-1.pdf
Note also the separate TRANSITION progress report at https://project-leo.co.uk/reports/transition-progress-report/
[20] https://project-leo.co.uk/reports/barriers-and-opportunities-market-trials-recruitment/

4.5.2.1 DSO-procured services

The main technologies and time periods tested were battery and Vehicle to Grid (V2G) in the Sustain Peak Management week-ahead market, with 540kWh dispatched over 17 weeks. The figure below summarises the outcomes.

Table 5 - Summary for all Week-ahead auctions for SPM in TP1.

Substation name	Completed auctions	Aggregate Capacity Requested (kW)	Aggregate Capacity Offered (kW)		Number of contracts		Aggregate Capacity Delivered (kWh)	
			Battery	V2G	Battery	V2G	Battery	V2G
BSP C	10	196.32	-	73.4	-	6	-	48.54
BSP A	14	500.24	208	71.6	13	8	493.25	
BSP B	11	51.72	-	25.8	-	8	-	
Total	35	748.28	208	170.8	13	22	493.25	48.54
NMF	19	385.88	128	76.6	8	11	493.25	47.86
Piclo	16	362.40	80	94.2	5	11	181.34	0.68

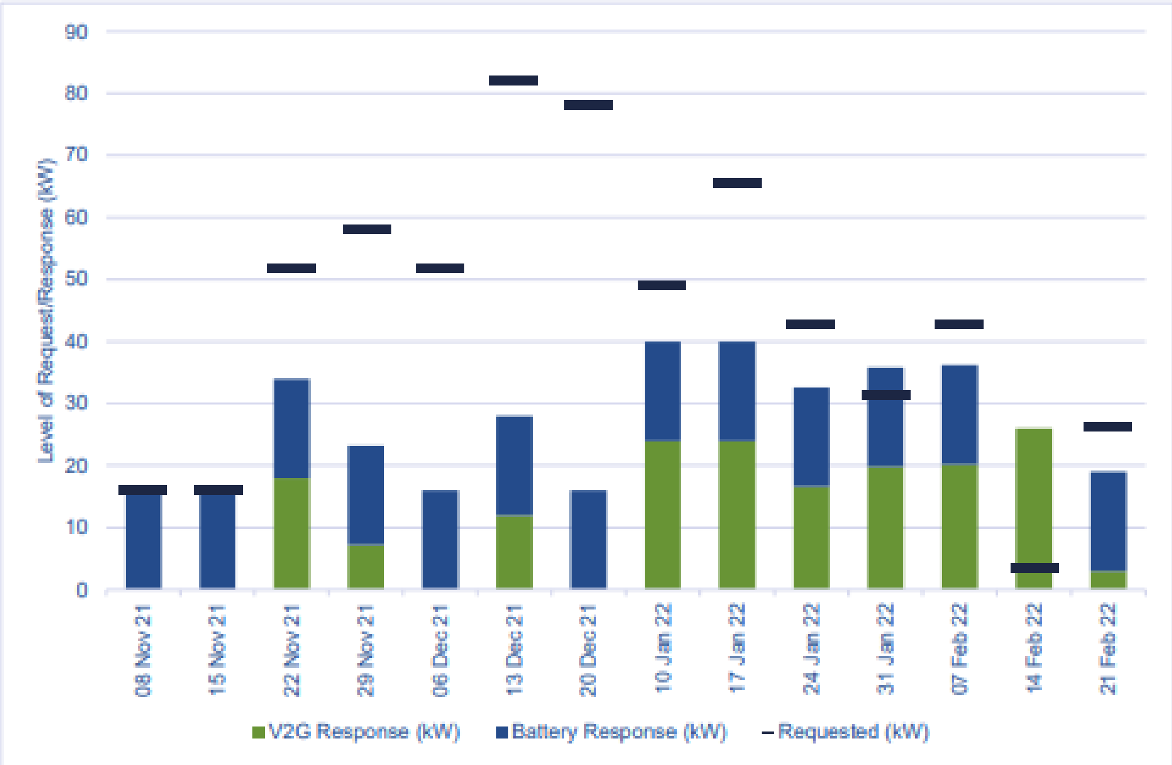


Figure 2 : Response by DER type against requested capacity

Events ran between 15:00 and 19:00, with the end-to-end processes fully developed and represented. These included massive developments in areas such as baselining and settlement, and documenting processes through the Neutral Market Facilitator (NMF and Whole System Coordinator (WSC) into the Power System Analysis (PSA) tools that analyses network needs. Two platforms, Piclo and NMF were used interchangeably for non-Peer to Peer services, to test the user experience in interfacing with the market and allowed for a comparison of these routes to market. The NMF gives a single point of contact between the DSO and platforms from specialist aggregators for EVs or heating appliances, locational aggregators such as local communities, or platforms carrying out an intermediary role such as Piclo. This arrangement demonstrated that multiple platforms can be used as customer interfaces, with one (NMF) hosting all auctions and Piclo being able to host auctions for DSO-procured services.

There were many challenges in enabling DSR, one of which was establishing a process for setting baselines against which to measure outcomes. The baselining product - used for all 69 events - proved successful and enabled the settlement rules to be tested, based on the amount of flex delivered. The V2G sites were useful in learning about the factors affecting when an asset is available for use, for example how the timing of vehicle charging can be affected by a customer's tariff.

In order for flex to be useful to a DSO, there needs to be a measure of the market liquidity behind a particular part of the network. Liquidity indices were developed to enable a view of how much flex is available, which is key to giving confidence to embed flex markets as an alternative to time-consuming and costly reinforcement. Items to be discovered and linked to a *liquidity* index will need to be the percentage of procurement at different timescales, e.g. season, week and day-ahead, depending on the DSO's risk appetite. Other indices include a *reliability* index, where assets in a particular area would be assigned a value based on their historic ability to deliver. This would help the DSO to procure the right amount of flex to satisfy a constraint without having to over-procure or put their assets at risk if there was a failure to deliver. A *competition* index is of less value until there are more assets participating in the trials, but would eventually give an idea of the likelihood on an asset succeeding in flex markets in a given situation.

The prices paid for flexibility were calculated on a Willingness to Pay (WTP) and Willingness to Accept (WTA) basis, with a total contract value (TCV) ceiling price of £300/MWh, split into an availability and utilisation price, each of which had its own ceiling. Part of the challenge that emerged was that using assets for DSO services alone was not attractive to participants, given the time and effort involved.

4.5.2.2 DSO-enabled services

There were three participating service providers: a community centre trading its rooftop solar export capacity, a primary school trading export and import capacity from rooftop solar and a battery, and a run of river hydro generator, trading import capacity. Trading was carried out manually off the NMF platform at first, then via the NMF platform at the end of the trial.

As Oxfordshire is a congested network, DNO approval is needed for any trials that exceed a participant's import or export capacity. If there is a risk to network security, such trials cannot take place.

To ensure that trials trading export and import capacities did not increase the risk to network security, each trial participant exceeding their allocated capacity had to apply for a Temporary Capacity Variation Notices (TCVNs), the necessary DSO approvals for entering into import / export capacity trading. All but one of the interested parties for Exceeding MIC/MEC services have been approved to trade. The unsuccessful TCVN was due to local voltage constraints on the LV network, preventing additional export to the network.

Oxford City Council had planned a project at an open-air heated swimming pool (Hinksey), to replace gas boilers by water source heat pumps, However, the outcome of the connection application was that a new substation would be required, with a long lead time. It was thought that Project LEO might be able to provide a temporary solution, with Oxford City Council being able to loan Maximum Import Capacity from some of its other sites to Hinksey Pool, via the P2P market. It was hoped that this would allow full or partial heat pump commissioning prior to completion of the substation. Again, a connections study showed that this opportunity could not be realised, as a section of cable would become overloaded as it would reach thermal capacity. This experience has had some positive outcomes, though: it improved partners' understanding of TCVNs and strengthened communications between the City Council, its contractors and Project LEO.

4.5.3 Conclusions from TP1

TP1 built confidence in flex delivery at the very local level. Having reached out to industry bodies such as the Association for Decentralised Energy (ADE), and to the Zero Carbon Oxford Partnership, LEO and TRANSITION engaged with over 40 organisations to participate in the trials. Twelve went through the company qualification process, five signed the Flexibility Service Agreement, and five had multiple assets ready to participate in Trial Period 2.

DSO-procured services

From a customer/participant perspective, TRANSITION work with the LEO partners has shown that procuring demand side response and making sources such as solar PV flexible is relatively expensive, technically demanding and resource-heavy for low levels of flex and short-duration contracts. The two market platforms worked well together, representing a central and a satellite market, though further testing is needed. The trials identified that improvements were needed in training and documentation, user experience and platform functionality.

The legal documentation for DSO-procured services is complex, indicating there may be benefits of an intermediary to manage contractual relationships and take or share market risks. For future engagement work with potential participants, information needs to be clear and easily available and, where necessary, LEO should tailor some to specific audiences or present it on a one-to-one basis. It should also be recognised that some challenges (e.g. assessing flexibility potential, gaining the resources and skills needed to participate) may be beyond the scope of LEO to address directly, making a case for collaborating with others.

In operational terms, energy is not the main business focus for most of the participants from the LEO consortium. Understanding the requirement for flex has been hard and again there may be a role for intermediaries to simplify and communicate the proposition, although the attractiveness of this route to market has not been tested.

The small sample of V2G in the trials could only offer flexibility erratically, influenced by behaviours and tariff structure, but V2G could offer a useful service in , if scaled up and if behaviour-based vehicle availability were better understood.

Data from the network is still more robust at higher than at lower voltages, and more monitoring is still needed to assess flex needs.

There are likely to be three options for DSO-procured flex market participants: in a locally-constrained area, only DSO-related services may be possible; in a less- constrained area, stacked services where appropriate (may include ESO services); and where there is no local constraint, full flexibility may be provided to ESO markets.

DSO-enabled services

There was more interest among LEO project partners in DSO-enabled than in DSO-procured flexibility, and the legal documentation – the P2P termsheet – was found to be easy to understand, though it needs some more detail on dispute mechanisms. Finding a peer with whom to exchange capacity can be challenging, though this will presumably become easier as people become more accustomed to the idea of trading and the processes involved.

Looking ahead

Trial Period 2 will include both DSO-procured and DSO-enabled market arrangements, bring in small aggregators, and test complexity and reliability through third party routes to market. More participants are expected in later trials, which will increase the liquidity and commerciality of services.

The risks in DSO-enabled services need to be further tested with more trades and an increased number of participating market participants. As the market for the LEO partners had limited participation with overall price ceilings at £300/MWh, prices are being increased for TP2.
The end-to-end processes depend on clear and timely communication. This can be complicated with the addition of third-party platforms and interfaces, and communication processes will need to be more robust and clearly defined so that information handling does not restrict or prevent effective market operation.

5 Smart and Fair Neighbourhoods

The Smart and Fair Neighbourhood (SFN) trials are demonstrating how flexibility services can sit at the heart of a smarter, low carbon, locally balanced energy system. LEO continues to work with six varied local communities to trial different flexibility services. Through the trials we are exploring how smart technology and new commercial models can create opportunities in a local energy marketplace and help us to understand how to do this in an equitable and fair way for everyone.

Engagement continued in Y3, with an emphasis on developing value propositions and recruiting trial participants. Low Carbon Hub approached this in three ways:

- System-led, starting with flexibility needs in a neighbourhood and identifying people or organisations best placed to meet them.
- Community-led, starting with an understanding of the capabilities and motivations of community members, and the types of flex they can provide.
- User-led, starting from a particular user type and their capabilities, identifying the flexibility they can offer and developing a value proposition and service to facilitate it. This is the approach being taken with trials of Low Carbon Hub energy assets.

The local market trials in Y3 involved only one of the SFNs, deploying a battery-plus-PV system in a school. However, engagement work continued with six neighbourhoods[21]:

Eynsham Smart and Fair Futures: developing a Zero Carbon Energy Action Plan for the Eynsham primary substation area, plus a plan for long-term governance.

Deddington and Duns Tew SFN: preparing to install heat pumps and smart monitoring to help decarbonise a rural, off-gas community; exploring how energy efficiency measures can be installed in households under planning constraints.

[21] Readers may find more information via the Low Carbon Hub website, e.g. https://www.lowcarbonhub.org/p/programmes/smart-and-fair-neighbourhood-trials/ (Accessed June 2022)

Osney Island SFN: coping with increased demand for EVs in a densely-populated urban area; including people without EVs in this transition.

Rose Hill SFN: exploring how a largely residential community with energy assets including battery storage and rooftop PV can change use patterns, generation and storage to balance the grid locally and benefit the community.

Westmill SFN: how to participate in local flexibility markets with established solar and wind farms, along with potential battery storage.

Springfield Meadows SFN: optimising the use of large solar PV arrays on new homes to maximise generation, deliver a net-positive housing development and mitigate risks to local network operations.

While LEO engagement – mostly via Low Carbon Hub and the City and County Councils – continued to be productive in terms of building knowledge and capability within the communities and the project as a whole, the time and effort needed could be considerable. For example, although there had been considerable interest in installing heat pumps in Deddington and Duns Tew homes, but technical, financial and other barriers resulted in a low conversation rate from interest to installation. This indicates the importance of budgeting time and funds for thorough engagement in the early stages of SLES development.

Another issue, also flagged up in our Y2 report, is the need for aggregators to work with SFNs, gathering and distributing value from their assets and activities. Developing viable, durable business models that aggregators can work with is also a slow process in current market and regulatory conditions.

6 Data and mapping

6.1 Data collection, cleaning and management

LEO's data streams can be categorised into foreground (within-LEO activities) and background (from external databases). These are captured differently, but both are securely logged and described through the online Data Sharing Log. However, only foreground data are stored within LEO.

It is easy to overlook the importance of data cleaning, a back-room process that involves systematic processing and filtering (largely in tabular/relational format) to ensure maximum data quality for further processing and analysis. LEO's diverse ecosystem of activities and partners leads to equally diverse datasets, methods and outcomes which need cleaning in keeping with the Data Standards and Protocols[22], with the aim of being FAIR - Findable, Accessible, Interoperable and Reusable. Though not easy to get right or 'fair' in a competitive market, DNO management of data cleaning and processing will add standardisation but may raise further questions around data-cleaning needs for different assets, to validate flex services we have yet to encounter.

The Y3 report on data-cleaning[23] includes the diagram below, which gives an insight into what is involved in preparing data from many sources in the course of an MVS trial, each with its own software and formatting.

[22] ** link needs updating – it led to a workshop report**

[23] https://project-leo.co.uk/reports/data-cleaning-and-processing-march-2021/

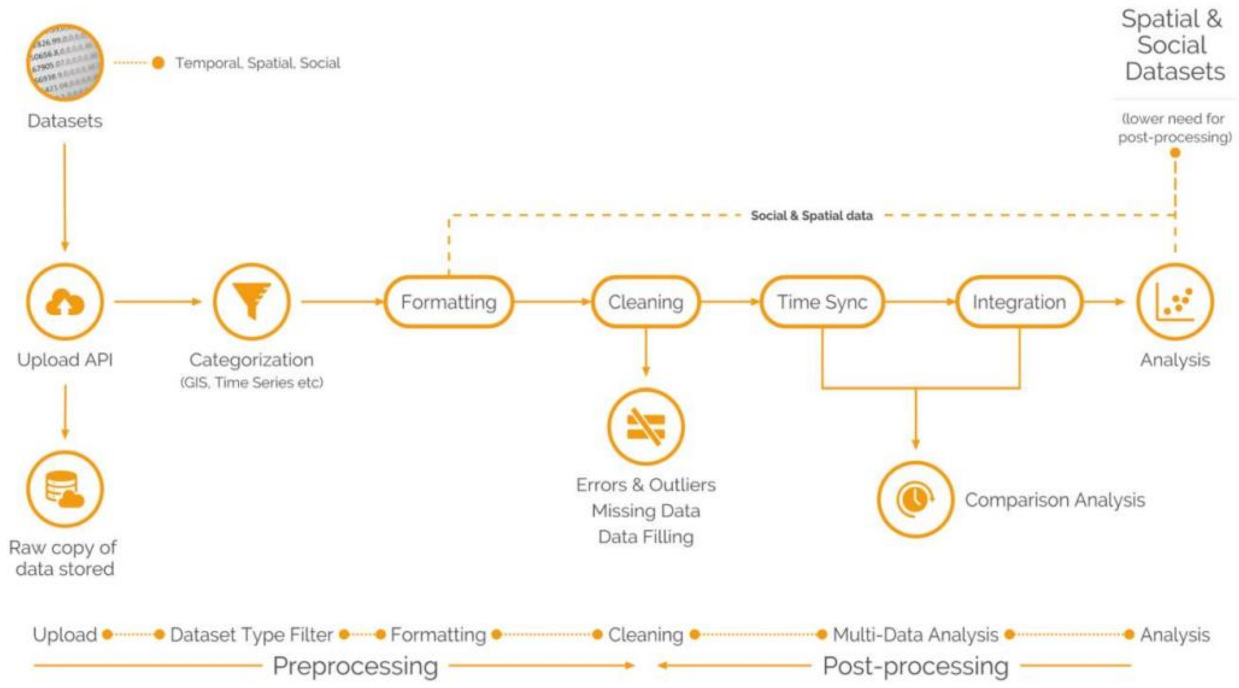


Figure 1. The Methods Flow Diagram above shows how datasets transition through the Pre- and Post-processing stages.

Data cleaning and data quality tools open access to data analysis to internal and external stakeholders. During Y2 they were moved towards more accessible online dashboards. The LEO data-handling tools are hosted on the cloud platform Heroku and the backend code will be made open-access by the end of the project.

LEO adopted a system whereby all shared datasets were issued with a Data Certificate summarising their metadata, in order to help partners and stakeholders understand the data. These certificates were not usable during the TRANSITION trials, as the NMF did not use the same protocol[24] - illustrating the data standards challenges that face flex market actors. However, the certificates will remain in use for LEO activities and represent a standard for adoption by fast followers.

6.2 Mapping

Mapping continued to be a productive strand of LEO activity, with the further development of both the LEMAP tool. - focussed on community use – and the Strategic Energy and Land Use mapping tool. Both bring together public, private and crowd-sourced data on energy demand, resources, buildings, demographics, fuel poverty and network conditions within a single platform.

LEMAP is being codeveloped with the SFN projects at Rose Hill and Eynsham. It can identify suitable locations for low-carbon technologies and estimate energy demand profiles at postcode and property level for different scenarios. It is also a tool for engagement, and the trial with residents explored whether it was possible to identify discrepancies between public and private data. The strategic mapping tool provides a wider area view and is being developed with input from teams across all six Oxfordshire local authorities. Both tools will continue to develop over the remainder of the project.

[24] TRANSITION trial data will however be incorporated with LEO data towards the end of the project.

6.3 Data handling

The third of four LEO Data Workshops was held in November 2021, hosted by UoO, OBU and the County Council and with around 30 participants from 14 organisations.[25] It emerged that having a 'Flex Scan' tool to inform owners of their asset's value in participating in a flexibility market will be very necessary. Project partners can already rely on the Origami Data Template to support pre-processing of data for market trials; additional tools will help support these resources.

Baselining is an important aspect in service validations and settlement. Steps must be taken to ensure that data requirements are met, and that dynamic and robust methods are used for fair and accurate settlement. Varying asset types will need careful baselining, and uncertainty will need to be treated effectively to lower the risks of flex provision and procurement.

Data issues that were raised at the workshop in relation to LEO but have wider relevance included

- How will mapping tools be managed post-LEO? Data coordinators, database storage and access, updating etc. all need to be considered. Will local authorities hold the data, or should it be outsourced?
- What data will LEO benefit most from sharing, and how can commercially sensitive data be protected? Will licensing and storage limit access?
- How can the data best be used by 'fast-followers' - organisations keen to build on LEO experience?
- How should LEO cope with boundaries and the potential mismatch between technical systems and administrative areas. For example, Banbury is in Oxfordshire but served by Western Power Distribution, not SSEN. Who is in charge of mapping for this area?
- What is the appropriate level of aggregation to allow data-sharing without exposing personal data?
- How can data best be presented in the mapping tools, to account for varying stakeholder needs? A plot of carbon intensity may be easily digestible to an SSEN engineer, for instance, but not to the average customer without some context and explanation. Data needs to have proper updating protocols to optimise impact, and understanding the 'backend' of mapping tools will be important for users, particularly where decision criteria are concerned.
- How can the mapping tools be improved to give maximum value to users who share their data, for instance, EV data in LEMAP?
- How might service providers game a system to their advantage?

[25] See report at https://project-leo.co.uk/wp-content/uploads/2022/01/Project-LEO-November-Data-Workshop-Report-1.pdf

7 Stakeholder engagement

Stakeholder Engagement Principles were agreed during Y2, on the basis that:

- The energy system is understood as a socio-technical system.
- Engagement is informed by needs and priorities of stakeholders.
- Engagement is ethical and inclusive.
- The framework for engagement is evidence-based, to assist learning and replication.
- Engagement complies with statutory rules and codes of practice.

All LEO work programmes involve engagement to some extent – with colleagues and external stakeholders in various roles, from potential flex providers to building and vehicle fleet managers to planners and policy makers.

7.1 Community engagement

Effective engagement starts with understanding communities' issues, problems and priorities and considering whether a SLES offer can be framed as a means of addressing these. For example, in a community with limited economic activity and low incomes, SLES participation can be presented as means of reducing energy bills, boosting local economic activity and regeneration via installation programmes, training opportunities for young people, employment of maintenance companies, community benefit funding etc.

The second step involves understanding community capabilities, including knowledge and skills, in order to identify those that need improving, those that can be worked with and those that will have to be worked around (for example, by changing the terms of a SLES offer to make it cheaper). It is important to note that many residents at present interact with energy systems only by using energy in homes and businesses, paying energy bills and, possibly, switching tariffs. Interactions may grow if energy assets and infrastructure (e.g. pylons and wires, solar farms, diesel generators) impinge on daily life, for example, as visual intrusions or air pollution, but more active engagement with the system results from ownership and use of microgeneration, energy efficiency technologies and electric vehicles, and from negotiating the grants, subsidies and installation processes for these.

There is great variation in energy awareness, knowledge and skills between communities, from virtually none to possessing the skills to manage commercial arrangements for a wind turbine. But we have found that *the language and concepts around flexibility and local energy markets appear to be novel for everybody.* There is now a Plain English guide to flexibility on the LEO website, to help in addressing this.[26] National Grid's flexibility markets have been around for a decade or more but participants are confined to larger industrial units and system practitioners. Low Carbon Hub identified a need to work closely with communities to impart the essentials of flexibility and the opportunities from LEMs; also to situate flexibility within a range of approaches that can be brought to a local energy strategy:

- enabling ownership of, or otherwise benefitting from, local renewable generation;
- energy efficiency and tackling fuel poverty;

[26] See https://project-leo.co.uk/the-energy-challenge/flexibility-services/ and https://project-leo.co.uk/the-energy-challenge/understanding-flexibility/

- enabling net zero and carbon reduction pathways;
- enabling behavioural change;
- empowering communities to advocate for local change;
- realising co-benefits of SLES such as employment and training opportunities;
- improving air quality;
- improving mobility.

Y3 also saw Low Carbon Hub work on a systematic process for co-developing SLES value propositions with communities, moving from defining the audience, their needs and capabilities to product development, data flow mapping and the design of a 'customer journey'.

7.2 Community engagement by mapping

The LEMAP tool can facilitate engagement in three ways. There is participatory mapping, which allows residents in a neighbourhood to provide data about their homes via an online survey, and then to obtain mean daily energy profiles and see their annual energy consumption on a map. The 'story map' is a blogging platform in which users such as SFN project managers can visually summarise findings from applying LEMAP to an area. This could be used to communicate technical information with residents, for planning local energy initiatives. The third element of LEMAP is a 'forum' - a chat platform to stimulate communication between administrators and users, project delivery teams and residents.

7.3 National engagement

LEO and TRANSITION both provide insight into how flexibility markets could develop and offer feedback to the Energy Networks Association (ENA) Open Networks Project, Ofgem and BEIS.[27] Project partners stay in touch with national decision-making and operational bodies via the Stakeholder Advisory Board, the PFER Policy and Regulatory Group, and the ENA. There is a strong wish to maintain these connections.

7.4 International engagement

Project LEO was represented at CoP26 in Glasgow, where SSE hosted two well-attended sessions on inclusive and just energy transition, and on communities, cars and flexibility. CoP26 coincided with the launch of an International Community for Local Smart Grids, led by the University of Oxford. The ICLSG aims to share local learnings on a global stage and now has eight organisational members in five countries.[28]

[27] An example from Y3 is at https://project-leo.co.uk/wp-content/uploads/2021/06/LEO-D2.8-Value-Chain-for-Flexibility-Providers-v2.1-LEO-cover.pdf
[28] www.communitysmartgrids.org

8 Policy, regulatory and planning context, present and future

8.1 Reviewing the context

There is a pressing need to develop our understanding of how flexible local energy systems might contribute to realising large-scale climate and social goals, and the changes that will be needed to make such systems viable.[29] From the annual interviews with project partners, there emerged a widely-shared view that local energy systems need policy certainty in order to thrive and that this is not yet in place. Without it, necessary investments in physical assets, infrastructure, skills and organisational capability will not be made. There is also a continuing need for national policy to support local government climate action, not least where building retrofit is concerned.

The LEO Policy and Regulatory Review[30] aimed to describe how international, national and local policy, law and regulation shape prospects for SLES with their associated local energy markets. The UK regulatory framework for electricity was originally designed for centralised supply, with heating and transport services largely supplied by gas and oil. While the framework is changing in response to the growth of distributed supply, storage and electrified heating and transport, it will have to change further, fast, if the UK is to reach its decarbonisation goals. Energy is only now becoming a significant consideration in planning for land use, transport and the built environment.[31] Conversely, SLES issues do not only relate to energy but can be financial, legal or organisational in nature, for example, rules on investing in local energy and the governance of cooperatives.

The main messages emerging from the review were that:

- There are disconnects between instruments and tiers of law, policy and regulation (international, national, and local). National-local disconnects have the greatest impact on SLES.
- Brexit-related legislative instruments on energy show uncertainty over the details of energy system realignment. Uncertainties following Brexit have already had a disproportionate impact on SLES, which are especially susceptible to market shocks because of their small size and novelty.
- Electricity market structure and regulation can inhibit SLES and low carbon innovations, for example, when DNOs are restricted from holding a generation licence and from operating electricity storage;
- Formation of the National Grid Electricity System Operator (ESO) alters the 'upper' structure of the UK electricity supply chain. It is unclear how the split between system operator and transmission operator functions will affect the market, or what the effect on a SLES business case will be.
- Storage assets have unclear legal status, with definitions that conflate storage with generation, this is a setback to their adoption.
- There is a need for national strategic direction for local energy, comparable to that in the 2020 Energy White Paper for large-scale generation; the trend in recent years has been away from policies that support local energy.
- There are serious gaps between policy proposals and implementation mechanisms, nationally and locally. There is an urgent need for local and national policies that fit together better,

[29]The Zero Carbon Oxford Partnership give an idea of the scale of the challenge of reducing carbon emissions from https://www.oxford.gov.uk/downloads/file/7685/zero_carbon_oxford_partnership_roadmap_and_action_plan_-_summary

[30] https://project-leo.co.uk/reports/policy-and-regulatory-review/

[31] https://es.catapult.org.uk/tools-and-labs/our-place-based-net-zero-toolkit/local-area-energy-planning/

building on cross-party support for Net Zero, along with funding to ensure the policies can be implemented.

- Energy equity as a goal is inconspicuous in legal, policy, and regulatory documents: the policy rationales are largely based on enhancing competition and consumer protection. The implication for SLES is that there is a risk of perpetuating old inequities and creating new forms of unfairness, as new technologies, actors and processes are introduced via SLES to people and organisations with different levels of capability. A market-based system will need regulating to secure inclusive participation and a safety net for those in danger of being left behind in energy transition.
- There is a need to bring together energy and planning policy and to continue developing Local Area Energy Planning, to integrate energy fully into the planning system so that citizens can be involved in developing zero-carbon energy plans for their areas. At national level, there is also a need to work towards integration of data protection, competition and energy laws.
- There is a shortage of policy support, finance and planning tools for building retrofit. These are needed to prepare for heating electrification and Net Zero, as well as for relieving fuel poverty.
- Much metering and monitoring data is underutilised or not shared; there is a need to mobilise it in the public interest, with appropriate privacy and security safeguards.
- The smart meter rollout needs prompt completion, with access to the data to facilitate SLES – for example, rooftop PV owners at present need to install second meters in order to access data for verifying flexibility service delivery.

8.2 The Grid Edge in a future energy system

The Grid Edge is set to become the centre of the energy system as we transition to a zero-carbon energy system based mainly on electricity with highly distributed generation and mass switching to electric vehicles and electric space heating. Making these changes quickly is proving a challenge because, among other system-wide complexities, the low-voltage network is currently un-smart (apart from a handful of innovation projects), and operated passively; there is little granular detail about use patterns and how they are changing. Householders and small business owners increasingly want to take action to address the climate emergency but generally have little knowledge or capability to apply to finding solutions.

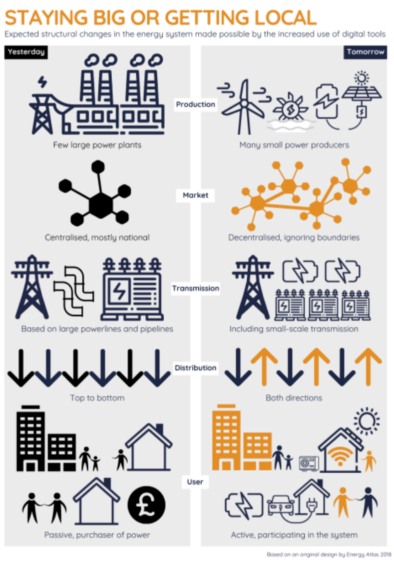


Figure 1: Staying Big or Getting Local (Source: based on an original design by Energy Atlas 2018)

8.2.1 Smart Community Energy Schemes in Smart and Fair Neighbourhoods

The Project LEO Community of MPANs trials will attempt to add to knowledge about the benefits of collective working at the grid edge, by developing and testing the concept in exemplar households and places in Oxfordshire. The SFN trials will test the technical feasibility, commercial viability and social desirability of SCES models and to demonstrate the benefits of behind-the-meter optimisation and community-level coordination of energy use and generation, as distinct from the local authority, regional or national level. We want to understand what the long-term business model is for the Low Carbon Hub, and other community energy organisations like it, in supporting the development of SCESs.

We expect that repeatable business models will likely be hybrid in nature, where public funding or our own community benefit funding pays for expert help and support to help a community-led project to get off the ground. We expect the value stacks underpinning these projects to be about more than purely financial values, for example by building trust in new ways of running the energy system. In this scenario, Low Carbon Hub is acting as the advisor and may also play the role of service provider, aggregating and trading energy and flexibility from community-owned DERs through our People's Power Station (PPS 2.0) cloud platform. A small set of Low Carbon Hub DERs has already been integrated into this to enable automated control and participation in the first LEO / TRANSITION trial period, as reported above.

In Y3, in preparation for the SFN trials, Low Carbon Hub and Origami Energy produced a report on the 'Community of MPANs' concept.[32] They define the concept as:

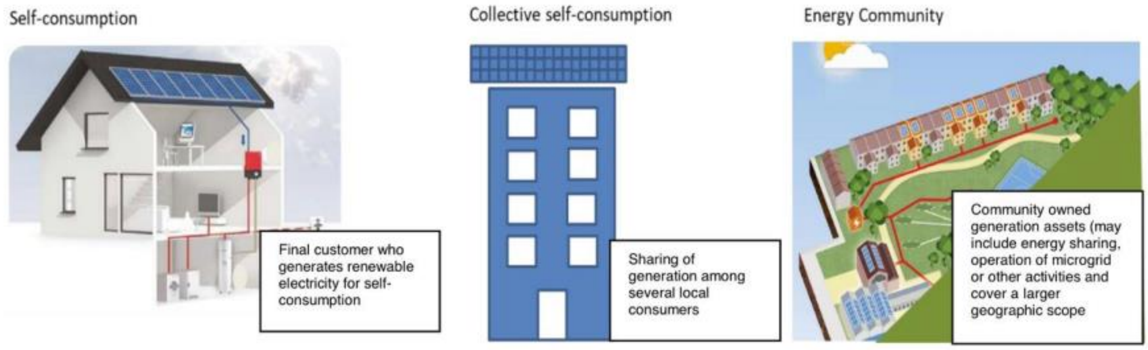
> *'A collaborative scheme between energy system users who co-ordinate the way they consume, generate, and store electricity, and manage their allocated capacity in the system to maximise the benefit to the community, other customers, the network and the system.'*

This definition captures five resources that are available to everyone in the system: level of demand; generation; energy storage, flexibility of generation and storage; and the capacity of their individual and collective connection. It is open to many different mechanisms for the scheme to buy, sell or otherwise exchange energy or capacity, and so a number of different revenue streams can be 'stacked' together, e.g. P2P mechanisms that take out the 'middle-man' while providing a service to the network operator. By referring to allocated capacity, the definition implies that the scheme is aligned to the performance of the system as understood by the network operator. It allows for a scheme coordinator role while maintaining a collaborative, opt-in principle.

The Community of MPANs concept aligns well with a recent paper by the Council of European Energy Regulators that looks at regulatory aspects of self-consumption and energy communities. This paper[33] identified three legal definitions of this type of activity, shown in the diagram below. A Community of MPANs would span the first two of these though probably not the third.

[32] https://project-leo.co.uk/reports/community-of-mpans/

[33] CEER (June 2019) Regulatory Aspects of Self Consumption and Energy Communities. Ref: C18-CRM9_DS7-05-03



Typology of self-consumption and energy communities (CEER, 2019)

The Low Carbon Hub position in developing grid edge trials is that place-based community action is, *a priori,* an important part of a net zero energy system. The new services and outlines of the new local energy market emerging through Project LEO to date have suggested an interplay between physical and virtual ways of managing the whole energy system that might bring our assumption strongly into question. It is possible to imagine some scenarios where no importance at all is given to place in managing millions of small DERs virtually. This applies largely to national services procured by the ESO for system balancing. However, other scenarios favour a system that strongly values location and may operate physically much more as a series of interconnected smart microgrids. This applies largely to regional services procured by the DSO for network balancing and may also include some P2P services enabled by the DSO to optimise use of grid infrastructure.

Individuals and communities are increasingly motivated to 'do their bit' in enabling the energy transition and want Project LEO to help answer the question, 'What can I do to help?' There is also a very strong desire to be able to buy the energy generated from local renewable energy installations directly or through a local energy supplier; people are often surprised that the system does not currently allow them to do that. Conversely, there is still a large section of the population with no knowledge or motivation around these issues, but Low Carbon Hub are focusing on the most motivated given that polls show[34] that their number is high, and their experience tells them that there are no simple, repeatable models to meet the increasingly urgent aspirations of the motivated population.

There is a range of 'precedent projects' around the UK that can inform the development of each SFN trial. There will be a report on the outcomes of the SFN trials in March 2023.

8.2.2 Necessary regulatory changes for SLES futures

The LEO Grid Edge Vision White Paper[35] draws on LEO experience in the context of the Future Energy Scenarios developed by National Grid, pointing to the need to transform the scale of grid edge participation in order to reach Net Zero. Despite the electrification of heat and transport potentially

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[34] Centre for Climate Change and Social Transformations IPSOS MORI poll for Earth Day (April 2021): 73% agree that 'if individuals like me do not act to combat climate change, we will be failing future generations; BEIS Public Attitudes Tracker for winter 2021 shows 86% support for ' renewable energy for providing our electricity, fuel and heat' (including 50% 'strongly supporting'), and 90% support for solar power. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1064032/BEIS_PAT_Winter_2021_Energy_Infrastructure_and_Energy_Sources.pdf

[35] https://project-leo.co.uk/reports/whitepaper-vision-on-the-inclusion-of-small-under-7kw-flexibility-from-the-grid-edge-and-its-role-in-future-energy-system/

increasing annual electricity demand by over 50% (153 TWh) in 2050 compared to 2020 levels, both provide opportunities for smarter system operation using flexibility.

The paper identifies technical, regulatory, commercial and societal challenges, in increasing order of significance. The list of regulatory challenges that LEO partners see as necessary to accommodate decentralised markets complements the analysis of our current situation in the Review above. Note that some of these deal with the boundaries of energy system regulation: the need for a fundamental shift in thinking and framing has been a theme throughout LEO.

Some regulatory challenges identified in the LEO White Paper

- Making energy an integral element of the local authority planning process.
- Enabling communities to provide fair access to members, manage their own energy and flexibility needs and interact with the network as a collective body, with low transaction costs.
- Ensuring flexibility is fairly rewarded, to the benefit of all parties involved.
- Allowing incentives to encourage investment in low carbon technologies (LCTs).
- Focussing regulation on increased infrastructure utilisation, aligning demand with generation and increased LCT whilst minimising scope for unintended consequences.
- Recognising the vital role that energy efficiency plays in delivering Net Zero.
- Recognising the role that millions of DERs with low levels of flexibility play in increasing security of supply.
- Incentivising consumers, prosumers and system operators to optimise their multi-vector energy use - primary energy, storage and output (e.g. hydrogen and electricity for heat, using building fabric as a heat store and adjusting temperature set points on thermostats).

> *'Delivering Net Zero will require a transformation in the scale of active participation at the local level. This will create opportunities to realise the (currently dormant) potential of millions of Small and Medium-sized Enterprises (SME) and domestic assets to support the flexibility needs of the marketplace as the penetration of low carbon technologies (LCTs) increases. For example, by 2050 the ESO Future Energy Scenarios envisage as many as 8m homes will actively manage their heat demand via heat pumps and thermal storage with further 2.4m homes with storage heating, whilst residential electric vehicle (EV) charging infrastructure is anticipated to offer up to 38GW of flexibility.'*
>
> (LEO Grid Edge vision White Paper)

8.2.3 Planning for SLES

The Centre for Sustainable Energy ran a workshop[36] on behalf of LEO in May 2021 for Oxfordshire planners. The aim was to stimulate planners' understanding of SLES, to understand their priorities along with the tools and data they might find helpful, and to gather recommendations on how the statutory planning system can integrate and facilitate SLES locally and nationally.

The workshop was very timely. As the report notes, energy efficiency and performance standards are well understood within the planning system, as are renewable heating systems, but planners are still at an early stage in terms of understanding how the system can integrate requirements for smart energy technologies which flex demand into new developments. *'The main task is to*

[36] https://project-leo.co.uk/reports/project-leo-workshop-1-enabling-and-facilitating-smart-energy-systems-within-the-existing-planning-system/

understand whether we're asking the right questions rather than necessarily jumping to ensure we have the right answers.'

Messages from the workshop emphasised a need for greater engagement between DNOs and Local Planning Authorities (LPAs), to help anticipate, plan for and overcome grid constraints, outline priorities and support a potential business case for SLES. This could include developing scenarios to match a council's spatial strategy, their renewable energy and EV policies, and climate action plans. All the Oxfordshire Councils have declared a climate emergency.

Workshop participants also stressed the importance of building on public support for renewables, mapping renewable energy (RE) potential and data-sharing, and incorporating energy efficiency and smart technologies into new developments. Given that it is hard for planning policy to keep pace with technological developments, it seemed best to have outcome-oriented policy that is tech-agnostic, along with robust methods of assessing outcomes including carbon emissions.

The workshop agenda did not explicitly ask about energy efficiency or zero carbon policies, but planners spoke of a variety of approaches, from supportive policies requiring high levels of energy efficiency in new developments to binding policies with measurable standards for carbon emissions. The Oxford Local Plan and South Oxon Local Plan both require new development to be net zero within a set timeframe, while the consultation draft Salt Cross Area Action Plan in West Oxfordshire includes a requirement that new development should be net zero and fossil free, with 100% of energy consumption met from on-site RE.

At this specialised event, it was possible to go into some detail on matters such as EV charger specifications, retrofitting buildings in conservation areas, and potential conflicts between EV charging provision and moves towards more active mobility. The facilitator noted that planning for heat decarbonisation is more place-specific (and easier) than planning for smart electricity systems as a whole, but that requirements for smart features could be standardised across a local authority area, to ease network stresses. However, there is still a need to have some sort of code or standard for smart developments, along with a way of checking whether those standards are being met. He also noted that planners cannot be expected to do everything – for example, getting smart technology into existing buildings: this could be a role for the DSO, who could make this a condition of agreeing to a new connection.

9 Learning, evaluation and preparation for future SLES: developing the LEO theory of change

As a demonstration project, LEO promotes what proves effective in term of energy transition and SLES. The learn/evaluate remit operates in five main ways:

- Synthesising learnings from the project, to address fundamental questions about the feasibility of SLES in technical, social and economic terms. [i.e., map on to capability categories]
- Evaluating learnings by placing them in the context of other work, e.g., that of EnergyREV, and in the UK regulatory and policy landscape
- Research into SLES ecosystems – actors and their interrelationships.
- Informing design of tools and approaches for use by others – guidance and reports.
- Continued development of a Theory of Change (ToC) that explains *how* change can happen in the course of transition to a renewables-based SLES.

9.1 Development of the ToC

The LEO ToC is revised on a roughly 6-monthly cycle in order to continually improve and refine it as knowledge of the ways LEO is achieving its objectives is accumulated. The revision process is to ask for feedback on the latest iteration from project partners as part of the quarterly interview cycle. This process has resulted in a complex document which, in theory, has the buy-in of project partners. However, the document has become so rich and complex, the challenge is now how to enable project partners and external parties to use the ToC to meet their needs. As part of the second quarterly interviews 2022 we asked project partners to consider the current content and presentation of the ToC and how successful it was in meeting the needs of its various audiences. Their responses are summarized below.

9.2 Existing content and presentation of the ToC

There is consensus that the ToC has great value in mapping all the interrelated elements of the project. In a project as complex as LEO, this bird's eye view allows partners to understand the role their work plays in delivering LEO's overall objectives. It is also a valuable guide to those external to the project, allowing an overview and means of navigating to activities of particular interest. Project activities are set out in a causal sequence, all playing a part as cogs in the machine driving towards the LEO objectives, and with assumptions and enablers required for one step to lead to the next allows the narrative of LEO to emerge. This is a much quicker method of understanding what LEO is trying to achieve and the methods being used to reach its goals than reading voluminous reports.

However, partners noted that for the ToC to have a role in guiding external parties through the project, we must understand who those audiences are and how they would like to use it. This may entail creating different views of the ToC with different levels of detail. Partners were clear that the existing ToC was too complex and heavy with project terms and jargon for an external party to engage with. Some LEO partners also reported being challenged by the complexity and volume of text. It was suggested that two linked versions could be produced – a simple version and a more complex version. The simple version would show the relationships between the broad domains of project activity[1] and have signposts and linkages to a more detailed version.

A layered approach could be achieved through clever graphic design or through presentation as an interactive electronic resource. An electronic version could allow areas to be zoomed, or become "clickable" to take the reader to more detailed information or even to specific datasets or reports. This kind of functionality would open up new uses for the ToC - essentially as a means of navigating the project and guiding viewers to documents, reports and data.

9.3 Possible uses of the ToC

Partners identified a number of possible uses of the ToC :

- As a component of a legacy document for the project to record the approaches taken in LEO in an intuitive and accessible way. Each part of the ToC could be discussed in a report setting out a rationale for the project: "How we delivered LEO". This would be a particularly useful document for fast followers but audiences would include any stakeholder with an interest in LEO – funders, fast followers, academics, any organisation seeking to understand the project.
- As an electronic table of contents and navigation aid for the project and its legacy of reports, datasets, methodologies and learnings. An electronic ToC could play a useful role in navigating the final reporting for the project. As for the legacy document, the users of the ToC as a table of contents would be any organisation seeking to understand the project and wanting a quick way to navigate to reports, data etc of interest.
- As the basis of guidance for fast followers and others to navigate to LEO's approaches to problem solving the challenges of implementing a Smart Local Energy Systems – for example metering and monitoring, mapping capabilities, engaging communities, creating an accessible market platform etc. The ToC would show the general approach to each of these challenges and link to "case studies" which go into more detail on how the issue was approached.

9.4 Structure of the ToC

The ToC is structured to present a flow of cause and effect with arrows indicating how one process or activity leads to the development of another. In general terms, antecedent processes are to the left so the causal flow goes from left to right. However, reflecting the agile learning processes in the project there are also feedback loops in the ToC to show how some processes are iterative.
Each block in the ToC is a stage, process or activity. The different kinds of activity or process are indicated with different coloured blocks as follows:

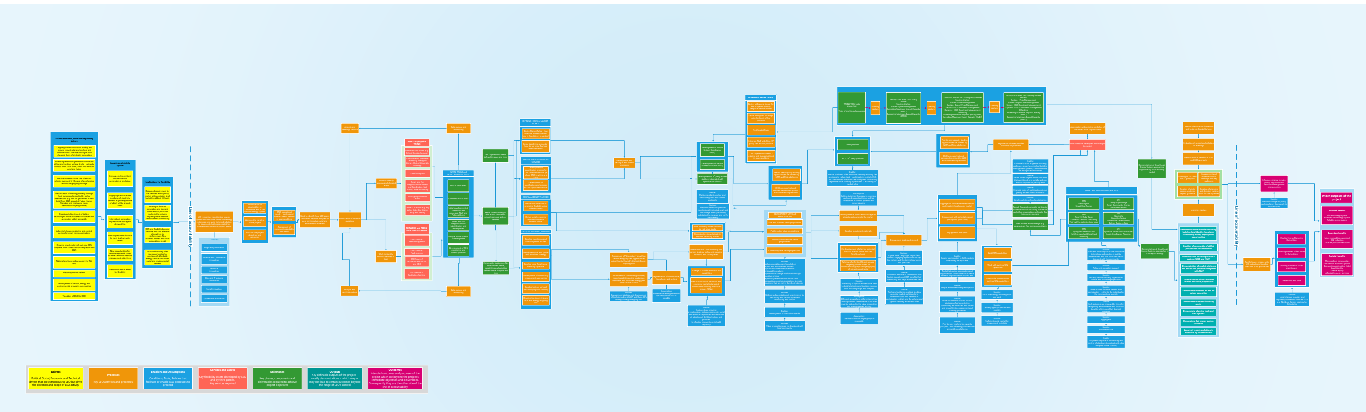
Drivers	Political, Social, Economic and Technical drivers in the wider energy system driving the direction and scope of LEO activities.
Processes	Key LEO activities and processes.
Enablers and assumptions	Conditions, tools and policies that enable LEO processes to proceed.
Services and assets	Key flexibility assets developed by LEO and by third parties. Key network and peer to peer services developed and tested in LEO.
Milestones	Key phases, components and deliverables required to achieve project objectives.

Outputs	Key definable outputs of the project. Mostly demonstrations of aspects of Smart Local Energy Systems and a legacy of reports and datasets. These outputs are LEO products - within the scope of the project and may or may not lead to certain desirable *outcomes* (energy system change) which are beyond LEO's control and scope.
Outcomes	Intended outcomes and purposes of the project which are beyond the project's immediate objectives and deliverables. Consequently, outcomes are shown on the other side of the line of accountability.

The ToC also shows two "lines of accountability" – one on the left between the drivers for the project and the initial project processes and one to the right to show the boundary between what is a LEO "output" and what is an intended LEO "outcome" – i.e. change that we hope to see in the energy system as a result of project LEO.

9.5 Viewing and accessing the ToC

The LEO ToC is viewable on the LEO website[37]. The ToC is also viewable in sections in Appendix 1. Each section has some commentary to explain the contents.



9.6 Next steps for the ToC

The ToC will be subject to at least one further round of revision before LEO finishes. The latest round of interviews has suggested some useful ideas for extracting value from this complex document and for making the information more accessible and navigable. We will be exploring how to present the ToC in various layers of detail using graphic design and electronic formats. We will also consider how it can be used as a guide to LEO for both partners and external stakeholders and how it can play its part in the final reporting for the project.

[37] The LEO ToC is viewable as a file on the Project LEO website here https://project-leo.co.uk/theory-of-change/

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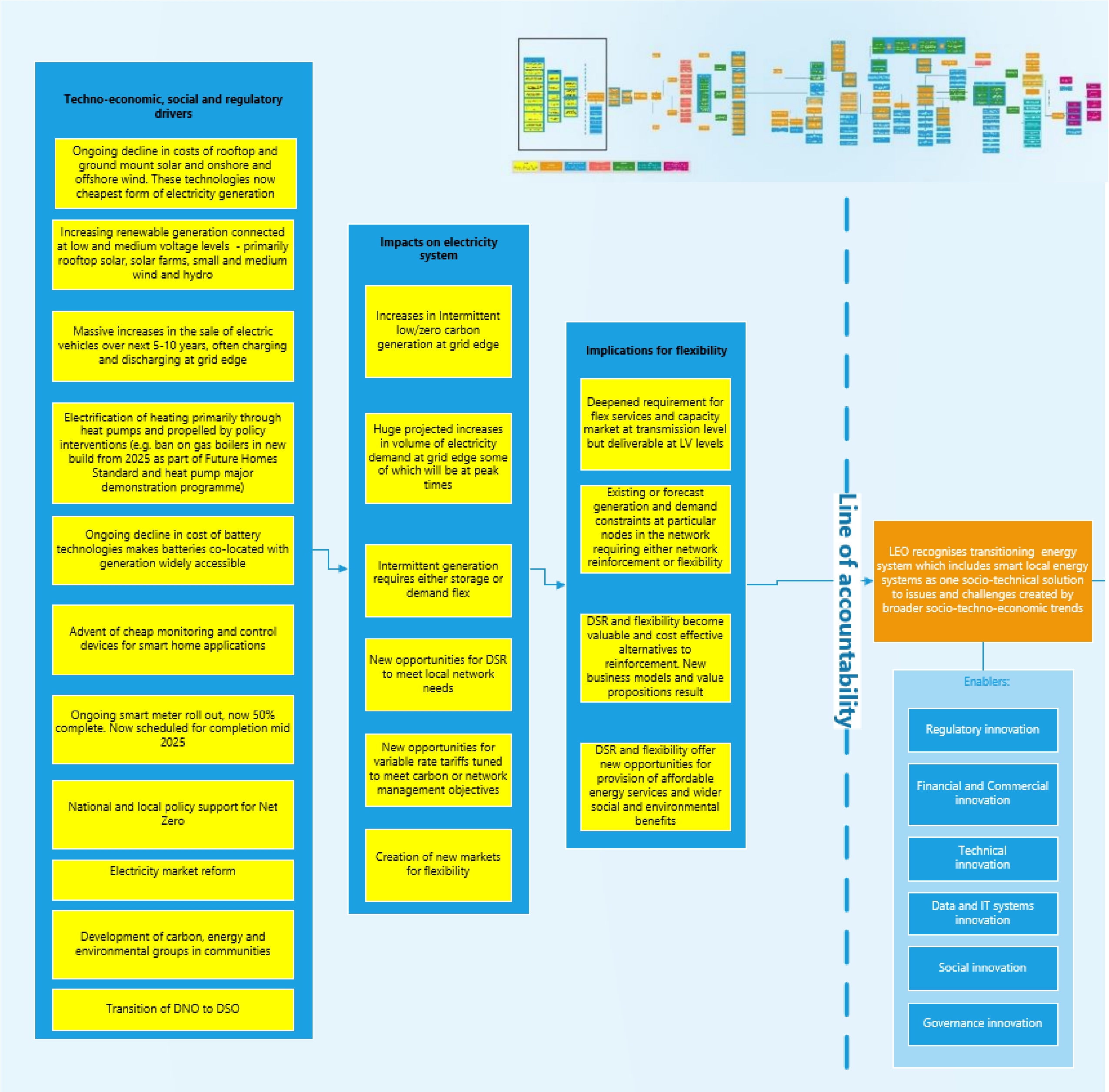
11 Appendix 1: the LEO ToC

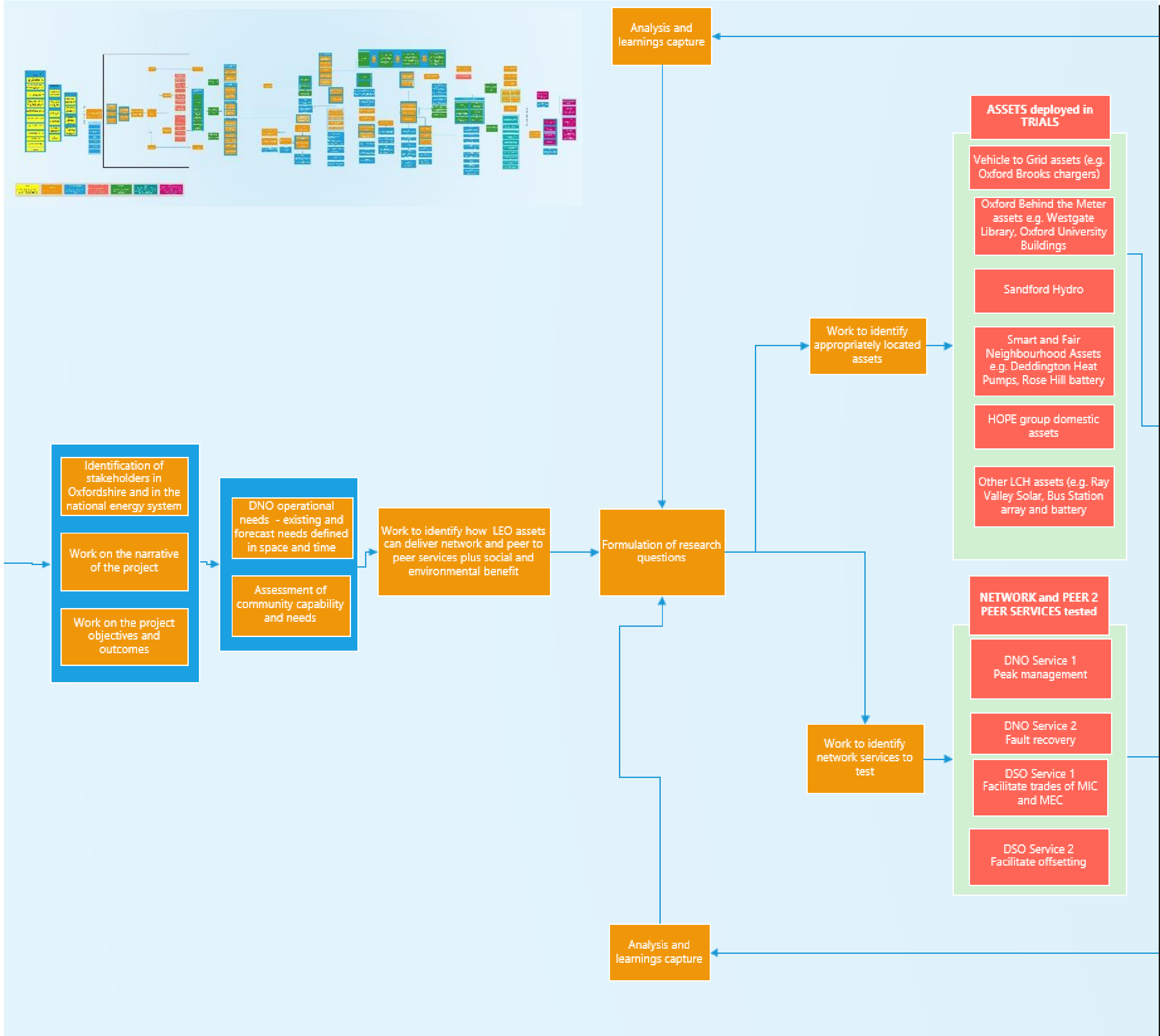


This part of the ToC on the extreme left describes the principle drivers currently transforming the energy system. The first column shows techno-economic, social and regulatory drivers. The second column describes how the drivers are impacting the electricity system in particular and the third column describes what this means in terms of the need for greater flexibility in supply and demand on the transmission and distribution networks. These create the rationale and scope for LEO and are reproduced here:

- Deepened requirement for flex services and capacity market at transmission level but deliverable at LV levels.
- Existing or forecast generation and demand constraints at particular nodes in the network requiring either network reinforcement or flexibility.
- DSR and flexibility become valuable and cost effective alternatives to reinforcement. New business models and value propositions result.
- DSR and flexibility offer new opportunities for provision of affordable energy services and wider social and environmental benefits.

Drivers causing system change and their implications are not within LEO's direct realm of influence and therefore sit to the left of the "line of accountability".

LEO is demonstrating local energy systems that embrace these challenges recognizing that in order to do so there must be enabling innovations in all dimensions of the energy transition. These innovations shown in blue boxes are: innovation in technical factors, data and IT systems, financial and commercial aspects, regulation, governance and social aspects also.

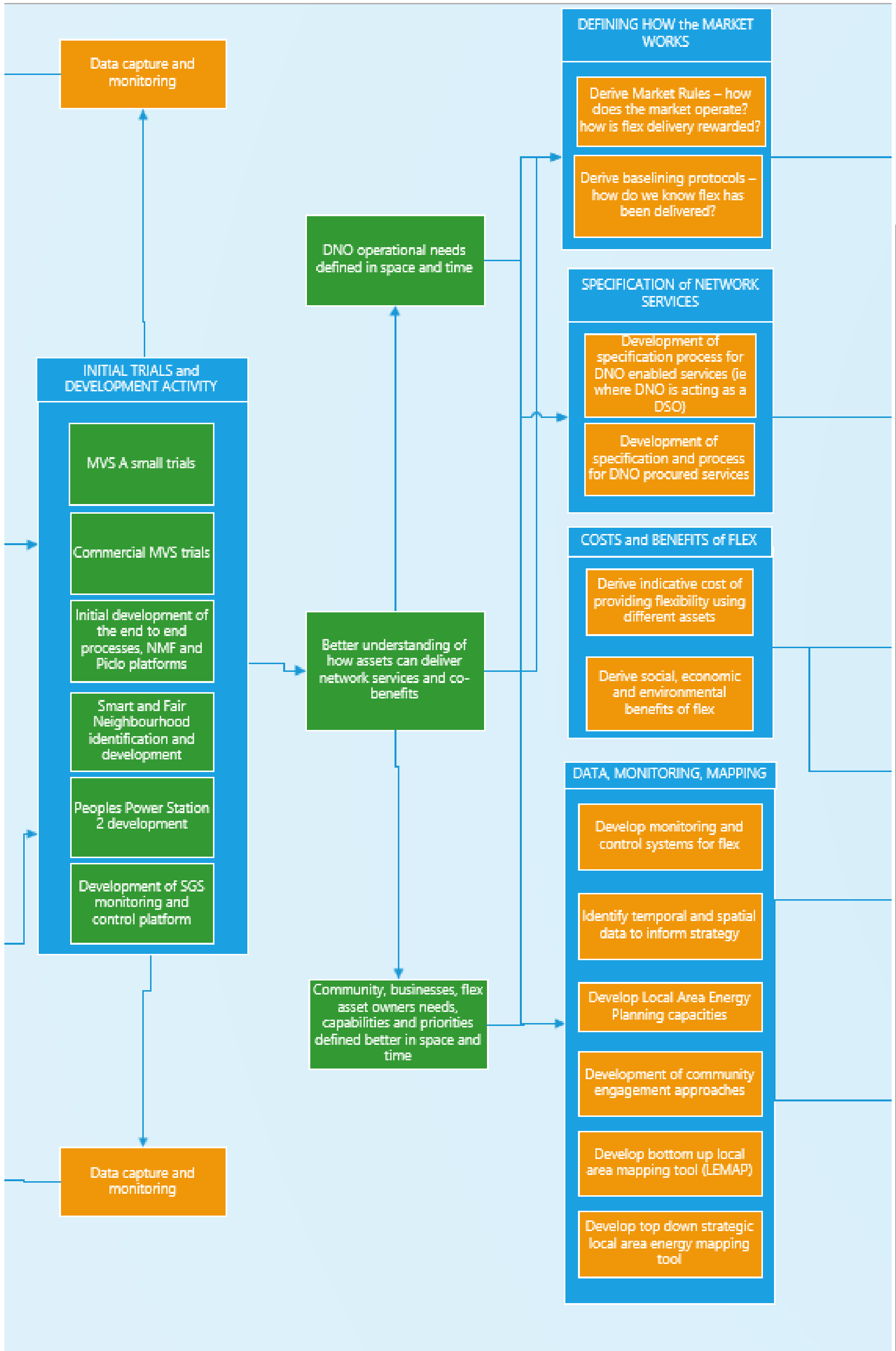


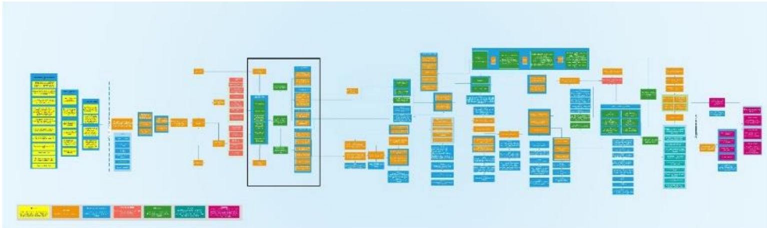
Recognising that smart local energy systems are key to a successful and equitable energy transition, the early part of the LEO began by identifying its key objectives and anticipated outcomes and how these could be weaved into a narrative. Other critical early work was in defining DNO network management needs (spatial and temporal) and also developing methods for assessment of community capability and needs.

Both workstreams lead to thinking about which specific assets owned or potentially controlled by LEO partners could be deployed to create network services. This lead to the formulation of the first iteration of research questions which allowed identification of:

A) the assets required to test those questions (shown in red boxes).
B) the specific DNO services to be tested. These include DNO procured services and Peer to Peer services which are facilitated by DNO systems (also shown in red boxes).

The approach of this programme of work was as light touch as possible, borrowing from agile techniques used in software development: a so called Minimum Viable System (MVS) approach was used to test the ideas, capture learnings from the test and then feed learnings back into the design of the next round of tests. These feedback loops are shown in the “analysis and learnings capture” pathways – leading to further refinement of the research questions.

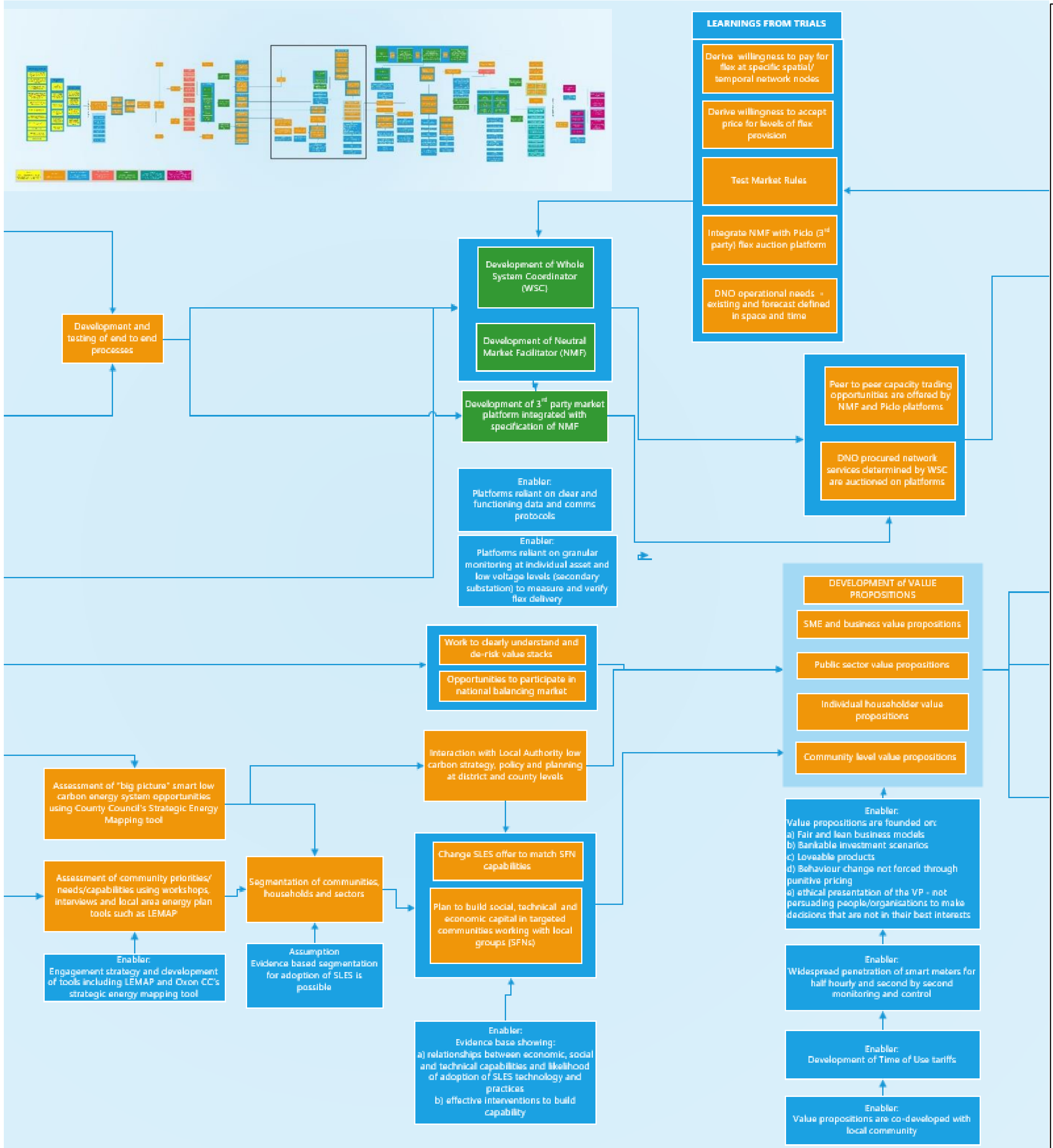




The column of green boxes to signify a set of milestones itemize the initial trials and development activity in the "MVS" and "MVS plus" part of the project. These were:

1. MVS A small trials – tests of the flex potential of assets described in the red boxes in the previous panel: domestic batteries, vehicle to grid aggregation, Sandford hydroelectric, Westgate library HVAC (control of the chillers)
2. Commercial MVS trials – this involved testing of the "Market Stimulation Packages". These were developed as different routes to bring an asset to the flex market depending on appetite for risk. There was also a very limited amount of funding to get buildings flex ready – e.g. by paying for building management system upgrades
3. SSEN and Origami's initial development of the end to end process for taking an asset through the process of bidding flex into the market, delivering the flex event and then verifying and settling it.
4. Smart and Fair Neighbourhoods were identified (6 at the time) as exemplar Smart Local Energy systems each with a different technological focus and business model. Governance / management processes established for their development.
5. Peoples Power Station IT platform began to be developed. This monitors energy performance of assets and could ultimately be used to control them. It is mainly targeted at small grid edge assets
6. Development of SGS control and monitoring platform. This platform is already available as a commercial product and was deployed on the larger low carbon assets including Sandford Hydro and Ray Valley Solar

Following work with these assets the project was able to develop a number of workstreams identified in the yellow boxes. These were: a) Defining how the market works including working up rules for how the flex market should operate, benchmarking protocols etc. b) Specification of network services - both DNO procured (e.g. Sustain Peak Management) and DNO enabled (the peer to peer services such as MIC/MEC trading) c) Costs and benefits of flex. Identifying and beginning to quantify transaction costs and capital costs. Also work to better understand social, economic and environmental benefits of flex. d) Data, Monitoring and Mapping. This workstream brought together numerous data related activities: monitoring protocols, local and strategic mapping of energy resources and capabilities and local area energy planning approaches. Activities (a) to (c) primarily feed the development of the local flex market and flex capability of the assets whilst activities in (d) help understanding of the capabilities and resources at the grid edge – i.e. amongst communities and users of the energy system.



Activities aiming to:

- Define how the market works,
- Specify network services,
- Derive economic, social and environmental benefits of flex

are used to help develop the DNO systems that:

a) analyse the spatial and temporal management needs of the network (the "Whole System Coordinator"(WSC))

b) structure the operation of the flex market and the associated platform which hosts the end to end process of market participation (the Neutral Market Facilitator (NMF).

In this part of the project, project partner, Piclo also developed a "third party" platform that interacts with the NMF and creates an alternative space for registering assets and participating in auctions. Key to the success of NMF and Piclo platforms is secure high quality monitoring data to measure and verify flex delivery.

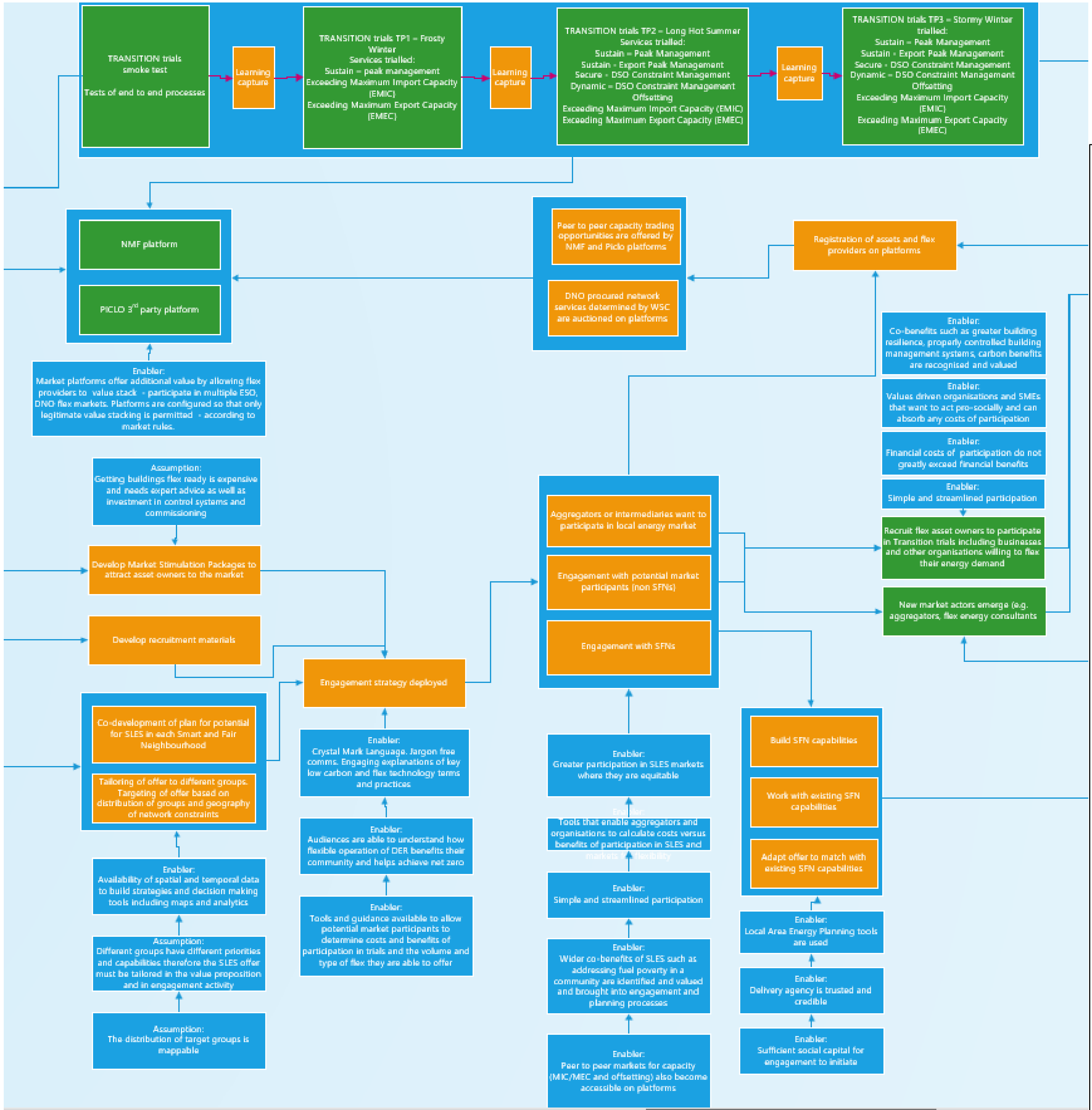
Activities aiming to:

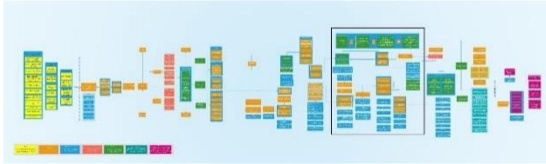
- Derive economic, social and environmental benefits of flex,
- Gather, analyse and present data on grid edge capabilities and resources

are used to:

a) Build support for, and connections with, local government policy, strategy and planning.
b) Co-design local area energy plans and plan Low Carbon Hub's trial Smart Local Energy Systems (SLES), aka "Smart and Fair Neighbourhoods".
c) Develop the value propositions for flex market participation amongst SMEs, Households and the public sector.

Key enablers are: a) a sound evidence base showing the linkages between social, economic and technical capability and ability to participate in SLES. b) fair, loveable and ethical business models c) widespread penetration of smart meters c) availability of supportive tariff structures such as ToU tariffs and d) processes that encourage trust in the value propositions and community ownership over them such as co-design of local energy plans.





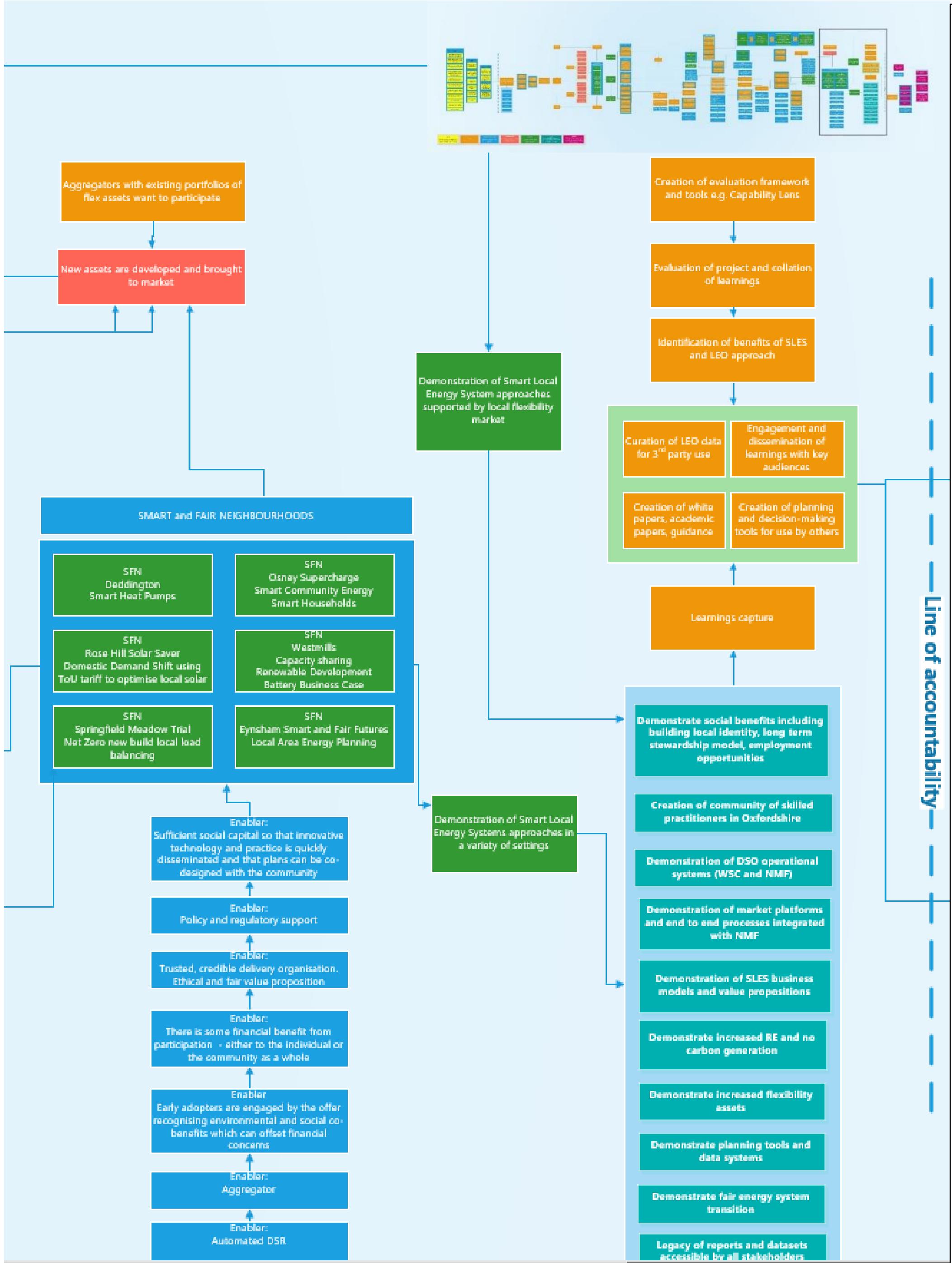
This part of the Theory of Change positions the various TRANSITION trials. These were organized in 4 Trial Periods (TPs):

1. "Smoke tests" – desk based tests of end to end processes
2. TP1 - "Frosty winter" – tests of the service, "Sustain Peak Management" and Exceeding Maximum Import and Export Capacity (EMIC/EMEC) peer to peer services.
3. TP2 – "Long Hot Summer" – additional tests of Secure and Dynamic Constraint management, Sustain Export Peak Management and Offsetting.
4. TP3 – "Stormy Winter" - further tests of TP2 services in a Winter setting.

Learnings from these trials fed back into further development of the Basic Market Rules, design of Piclo and NMF market platforms and analysis of flex market economics (monetized willingness to pay for flex and to deliver it) and a much deeper understanding of the capabilities of assets of different types to deliver flexibility of different types.

Value proposition work led to development of engagement strategy and various communications activities with LEO audiences, including particularly: a) householders living in Smart and Fair Neighbourhoods. b) large organisations capable of delivering flex using their buildings and equipment. c) aggregators.

The aim was to bring more assets and participants to the nascent flex market to create greater competition and liquidity – and explore how compelling the value proposition was to real world actors. Multiple enablers for successful engagement were identified including that the offer was perceived as being fair and ethical and that building operators had the tools and knowledge to robustly assess how much flex they possessed and how much it would cost to deliver it.



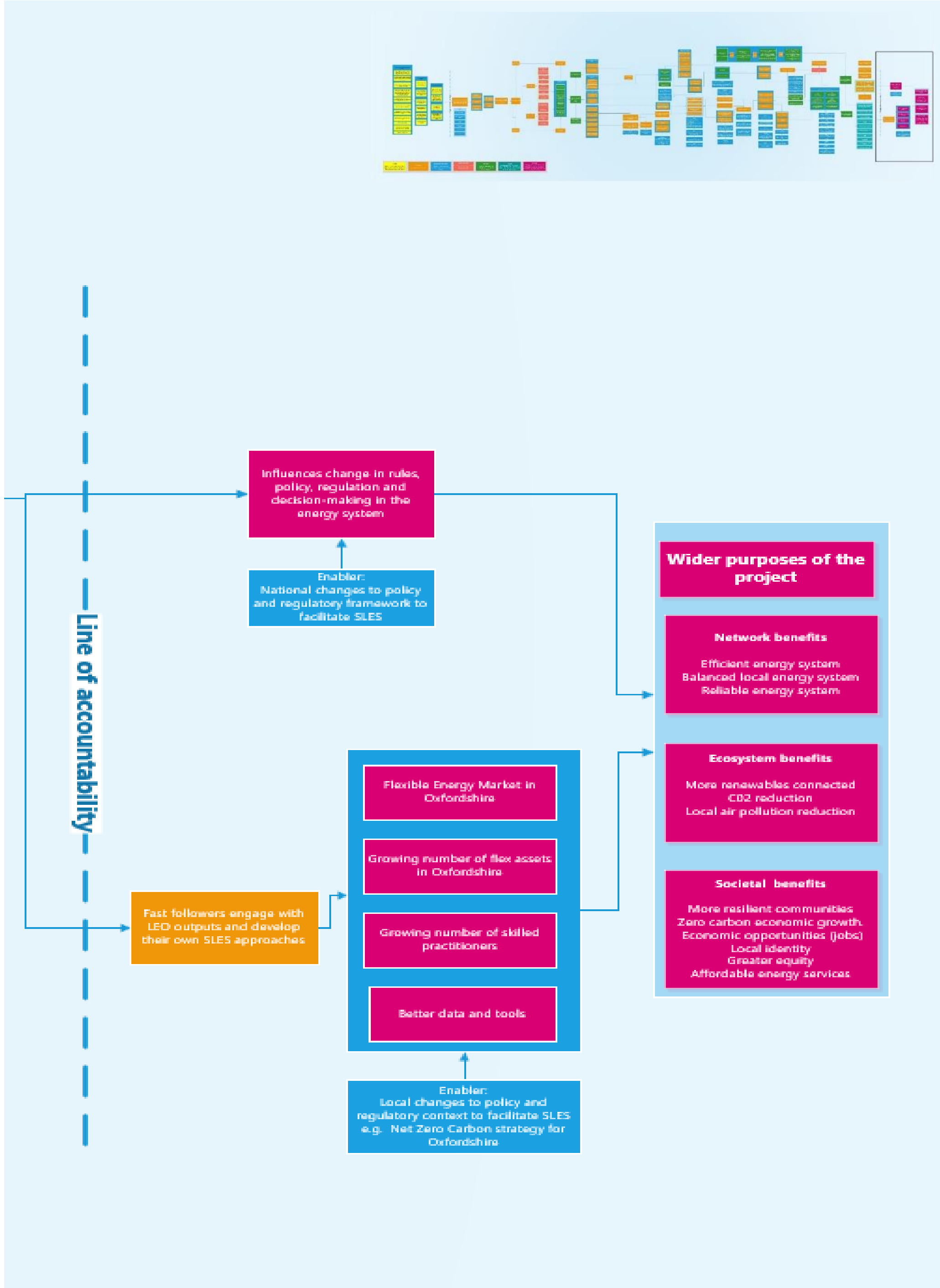
This part of the ToC identifies the 6 Smart and Fair Neighbourhoods developed out of earlier activities and processes. The six SFNs were:

1. Deddington and Duns Tew where LCH aimed to install and, potentially control, smart heat pumps.
2. Rose Hill Solar Saver where residents received an offer to load shift in response to a ToU tariff which would indirectly result in greater consumption of locally generated solar including from panels on residents own roof.
3. Springfield Meadow where there is a need for local load balancing in a new development to ensure DER's can connect.
4. Osney Supercharge where LCH are exploring local load balancing behind a single connection point to the network. DER's installed are a mix of rooftop solar, batteries, local generation from Osney Hydro , electric vehicle charge points, heat pumps and efficiency measures.
5. Westmills windfarm where LCH is exploring capacity sharing with the local community and the economics of a big battery connected to the windfarm
6. Eynsham Smart and Fair Futures where the development of a local area energy plan is under investigation

Multiple enablers for successful SFN's are identified in the blue boxes. These include: sufficient technical, economic and, critically, social "capability" embedded within the SFN communities for the project approaches to work with. Also policy and regulatory support and that the delivery agent is trusted with an ethical and fair value proposition. It is hoped that the ability of certain of these SFNs to participate in local markets for flex will be tested in LEO. Together with the Transition Trials, the SFNs will demonstrate:

- How Smart Local Energy Systems can be enabled and supported by a local flex market
- How SLES can be facilitated using a variety of technologies, planning tools, and types of stakeholder.

The turquoise boxes show the detail of what LEO hopes to demonstrate. Other key activities shown here (in Orange) are the evaluation of these demonstrations and other learnings capture to create a project legacy of reports, guidance, curated data and tools. To structure the learnings capture part of the project a number of frameworks and approaches were developed. These included the creation of an evaluation framework which drew heavily on the Capability Lens developed by the Centre for Sustainable Energy, a code of practice for ethical engagement, a strategy for communications and engagement and a programme of learnings capture which included regular interviews with project partners, writing of ad-hoc reports on specific topics as necessary and annual synthesis reports.



In this final panel the key desired Outcomes of the project are identified. Also listed are the key purposes of the project. Outcomes are defined as the changes to the local and national energy system that LEO wishes to influence or facilitate and should serve the project's wider purpose. As Outcomes rather than Outputs they are to the right of the "line of accountability" i.e. their delivery is beyond the scope and resources of LEO alone. LEO's ToC recognises the following Outcomes:

- Influencing changes in rules, policy, regulation and decision-making in the energy system. This is enabled where there is already a supportive policy and regulatory framework in place.
- Creating the basis for a sustainable flexibility market in Oxfordshire.
- Boosting the number of flex assets in Oxfordshire.
- Growing the number of skilled practitioners: knowledged in the various aspects of creating Smart Local Energy Systems including technical skills related to enabling and delivering flex, planning skills, community engagement and project management skills and financial and business skills.
- A legacy of better specified and helpful data and tools for data curation, analysis and presentation.

Enabling these Outcomes in Oxfordshire will involve changes to the local and national policy, planning and regulatory context and will require other stakeholders, particularly "fast followers" to engage with LEO learnings, adapting approaches and LEO tools for their own context. Strategy documents such as the Net Zero Carbon strategy for Oxfordshire and the ZCOP initiative are supportive of LEO's role in influencing change in the energy system. Outcomes deliver the wider purposes of the project which are a demonstration of how a SLES supported by a local market for flexibility can deliver:

- Network benefits: an efficient, resilient and balanced local energy system which is more cost effective to maintain and operate.
- Ecosystem benefits: with more low carbon energy resources connected at low voltage levels for the network installed in tandem with energy efficiency measures to drive down carbon emissions.
- Societal benefits: greater local sustainable economic activity promoted by the local energy system, creation green jobs, building a greater sense of place, local identity and community spirit, homes and businesses which perform better and are more comfortable places to live and work, more opportunities for local communities and households to act on climate change and build stronger, more resilient neighbourhoods.