Local Energy Oxfordshire

December 2021 | Version 6

Low Carbon Hub Portfolio Routes to Market (D.3.7)

Low Carbon Hub & Origami Energy

Context

The UK Government has legislated to reduce its carbon emissions to net zero by 2050. Meeting this target will require significant decarbonisation and an increased demand upon the electricity network. Traditionally an increase in demand on the network would require network reinforcement. However, technology and the ability to balance demand on the system at different periods provides opportunities for new markets to be created, and new demand to be accommodated through a smarter, secure and more flexible network.

The future energy market offers the opportunity to create a decentralised energy system, supporting local renewable energy sources, and new markets that everyone can benefit from through providing flexibility services. To accommodate this change, Distribution Network Operators (DNOs) are changing to become Distribution System Operators (DSOs).

Project Local Energy Oxfordshire (LEO) is an important step in understanding how new markets can work and improving customer engagement. Project LEO is part funded via the Industrial Strategy Challenge Fund (ISCF) who set up a fund in 2018 of £102.5m for UK industry and research to develop systems that can support the global move to renewable energy called: Prospering From the Energy Revolution (PFER).

Project LEO is one of the most ambitious, wide-ranging, innovative, and holistic smart grid trials ever conducted in the UK. LEO will improve our understanding of how opportunities can be maximised and unlocked from the transition to a smarter, flexible electricity system and how households, businesses and communities can realise the benefits. The increase in small-scale renewables and low-carbon technologies is creating opportunities for consumers to generate and sell electricity, store electricity using batteries, and even for electric vehicles (EVs) to alleviate demand on the electricity system. To ensure the benefits of this are realised, Distribution Network Operators (DNO) like Scottish and Southern Electricity Networks (SSEN) are becoming Distribution System Operators (DSO).

Project LEO seeks to create the conditions that replicate the electricity system of the future to better understand these relationships and grow an evidence base that can inform how we manage the transition to a smarter electricity system. It will inform how DSOs function in the future, show how markets can be unlocked and supported, create new investment models for community engagement, and support the development of a skilled community positioned to thrive and benefit from a smarter, responsive and flexible electricity network.

Project LEO brings together an exceptional group of stakeholders as Partners to deliver a common goal of creating a sustainable local energy system. This partnership represents the entire energy value chain in a compact and focused consortium and is further enhanced through global leading energy systems research brought by the University of Oxford and Oxford Brookes University consolidating multiple data sources and analysis tools to deliver a model for future local energy system mapping across all energy vectors.

Front cover image: Adriano Figueiredo of the Low Carbon Hub receiving the first symbolic payment from Brian Wann of SSEN for delivering a flex service from the Oxford Bus Company battery. (April 2020)

Table of Contents

Table of Figures

Table of Tables

Glossary of terms

Flexibility Services and their acronyms

Taken from D2.8 'Value Chain for Flexibility Providers' March 2021

Acronyms as set out in these tables are used throughout this paper

Category	Service	Description	Auction Period	Delivery Notice	Delivery Duration	Minimum Capacity
ESO	Balancing Mechanism (BM)	Main mechanism for balancing electricity system in real-time, usually by adjusting generation levels.	Live	3 mins upwards	As required	1MW
	Capacity Market (CM)	Main incentive to ensure there is sufficient capacity to manage peaks using either generation increase or demand reduction.	4-and 1-year ahead	4 hours	Duration of Notice	1MW
	Firm Frequency Response (FFR)	The provision of fast-acting response to changes in system frequency to help maintain it within target levels. Historically, this has been either dynamic (proportional response to small changes in frequency) or non-dynamic (response for a fixed period following larger changes in frequency). The replacement service, Dynamic Containment and similar services, gradually replace all of the existing frequency services. ***Out of scope in this work[9].***	Monthly	1, 10, 30 secs	10 to 1,800 secs	1MW
	Dynamic Containment (DC)	Post-fault service designed to meet the need of fast-acting frequency response when frequency breaches operational limits (+/- 0.2Hz). This is the newest ESO service. Flexibility providers, mainly with battery storage assets, bid to be available to deliver the service for 24hours day-ahead of the delivery. If accepted, flexibility are paid the accepted price £/MW/h for the 24 hours unless unavailability is declared.	Day Ahead	0.5 to 1.0 sec	[continuous]	1MW
	Optional Downward Flexibility Management (ODFM)	Optional Downward Flexibility Management is a service which allows the ESO to request (renewable) generation output is reduced or demand is increased in real-time to manage the electricity system during particularly low demand at times of high generation, typically summer overnights and early morning.	Week Ahead availability submissions	6 hours to 18 hours	3 hours to 6 hours	1MW
	Replacement Reserve	To enable harmonised procurement of balancing services across European transmission operators using interconnectors with Europe. New service, details and participation requirements are uncertain. ***Out of scope for this work.*** [10]	1 hour	15 minutes	1 hour	1MW
	Short-Term Operating Reserve (STOR)	Provides additional active power from generation or demand reduction at short notice. This service is currently suspended and will be reinstated from April 2021.	Seasonally	20 to 240 mins	2 hrs min	3MW

Table 1: Energy Systems Operator flexibility services descriptions

DSO	Sustain - Peak Management (SPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess demand	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Sustain - Export Peak Management (SEPM)	A Flexibility Service that delivers Flexibility to address a forecasted need to prevent a critical asset (such as transformer) becoming overloaded due to excess generation	Months to Years	Month Ahead to Day Ahead	[2 hours]	1kW
	Secure - DSO Constraint Management (pre-fault) (SDCM)	A Flexibility Service that delivers Flexibility to address an emerging issue that could result in an unplanned outage or an event if not addressed.	DNO-dependant	Week Ahead	[2 hours]	1kW
	Dynamic - DSO Constraint Management (post-fault) (DDCM)	A Flexibility Service that delivers Flexibility after an unplanned outage or fault has occurred	DNO-dependant	120 to 15 mins	Up to 8 hours	50kW (total across all DERs
	Restore	A Flexibility Service that uses Flexibility to support restoration of part or all of one or more Distribution Network or Transmission System following a planned or unplanned outage. Have been trialled[11], but not planned in the near future. ***Out of scope for this work[12].***	DNO-dependant	15 mins	[Up to 8 hours]	1kW

Table 2: Distribution Systems Operator flexibility services descriptions

P2P	Exceeding Maximum Export Capacity (EMEC)	Two Market Actors on a network with an unconstraint path between each other trade a portion of their export capacity so one can increase its existing export for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Exceeding Maximum Import Capacity (EMIC)	Two Market Actors supplied by the same substation trade a portion of their import capacity so one can increase its existing import for an agreed period without affecting the network	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC
	Offsetting (OFFST)	Two Market Actors in a constrained area working together so one increases its demand (or generation) before another increases its generation (or demand) by the same amount, with appropriate fail-safe mechanisms	Subject to agreement	[Month Ahead to Day Ahead]	Subject to agreement	TBC

Table 3: peer-to-peer (P2P) services that are enabled by the Distribution Services Operator

Other Revenue Streams	Wholesale Trading (WT)	Use of Flexibility to trade in the wholesale energy markets via third party trader to take advantage of price differentials between different Flexibility Services	Day Ahead On the Day	Subject to agreement	Subject to agreement	Subject to agreement
	Time of Use Tariffs (ToUT)	Use of Flexibility to manage demand to reduce electricity costs in response to the tariff price signals. Applicable to small businesses and residential consumers.	N/A	Time of Use periods defined in the supply contract	Continuous	N/A

Table 4: other revenue streams available from flexible use of energy

Other terms used in this paper

Arbitrage: the simultaneous buying and selling of a commodity, in this case energy, in different markets or in derivative forms in order to take advantage of differing prices for the same asset.

Aggregator (technical or commercial): aggregators bundle Distributed Energy Resources (DER) together to engage with energy and flexibility markets as a single entity. A technical aggregator bundles DERs together but does not operate in the markets itself. A commercial aggregator contracts with a number of DERs or technical aggregators to sell energy or flexibility services into the market. More detail is given in the definition in Figure 1 taken from the European Consumer Organisation, BEUC, report, 'Electricity Aggregators: starting off on the right foot with consumers.'

Aggregation entails **grouping the energy consumption or generation** of several consumers.

When it comes to **consumers**, an aggregator can set up an agreement with several consumers, based on which he can temporarily reduce their electricity consumption when there is high demand for electricity. He then sells this flexibility i.e. the 'avoided' electricity consumption in electricity markets. An aggregator could also be operating the reverse action and could increase the consumption of an electricity consumer when electricity prices are favourable. Aggregation can be carried out by traditional energy businesses such as **suppliers, or by new entrants such as independent aggregators**. **Independent aggregators** are, thus, electricity service providers. In practice, when consumers engage with them, they have one contract with the supplier and a separate one with the aggregator.

An aggregator can also operate on behalf of a group of consumers engaging in self-generation by selling their excess electricity.

Figure 1: aggregation definition (Source: www.beuc.eu/publications/beuc-x-2018-010_electricity_aggregators_starting_off_on_the_right_foot_with_consumers.pdf)

- **Social aggregator:** in addition to these two forms of aggregator, there may be another role to be played where a route to market is provided for small assets with low levels of flexibility where owners want to avoid the need to understand the market opportunities or to take the burden of participation. The social aggregator is a technical and/or commercial aggregator who provides market access on a not-for-profit basis using agreed shared-risk principles. The purpose of the arrangement is primarily to provide benefit: (i) to the membership on a co-operative basis; or (ii) to the community.

Bankable: a financial model for a new DER that has a low enough risk, that is certain and reliable enough, for a bank to provide project finance.

Co-benefits: added benefits from an activity beyond the direct (often financial) benefits. Examples for renewable energy or carbon reduction projects might be:
- Cleaner air: cutting fossil fuel production;
- Safer and more secure energy supplies;
- Stronger local economy: benefits recycle into the local economy;
- Health and well-being: benefits of a low-carbon lifestyle.

Code Change: a change to the code of standards governing the operation of the transmission and distribution systems.

Distributed Energy Resources (DERs): small-scale units of local energy generation, use and storage connected to the grid at distribution level. DERs can include behind-the-meter renewable and non-renewable generation, energy storage, inverters (electronic devices that change DC, or direct current, to AC, or alternating current, electric vehicles and other controlled loads (separately metered appliances like hot water systems). DER also comprises new technology like smart meters and data services.

https://arena.gov.au/blog/what-are-distributed-energy-resources/

Common examples of DERs include rooftop solar PV units, natural gas turbines, microturbines, wind turbines, biomass generators, fuel cells, tri-generation units, battery storage, electric vehicles (EV) and EV chargers, and demand response applications. These separate elements work together to form distributed generation.

Embedded generation benefits: embedded generation is the production of electricity from DERs directly connected to the distribution network. The distribution network carries electricity from the Transmission Network and embedded generators to homes and businesses. Benefits from embedded generation are predominantly supplier costs that are reduced or avoided by buying from DERs and passed on to the DERs.

Flexibility (or flex) services: making temporary changes in the way you consume, generate, or store electricity when requested, to support a more efficient use of the energy network. A flexibility provider is a user who provides flexibility services by making temporary changes to the way they consume, generate, or store electricity when requested.

Grid edge: this has been defined by Project LEO as 'the points in the electricity grid that are closest to the end users of energy (i.e. at homes and businesses). The term grid edge is used to encompass the varying hardware, software and innovations being developed at the edge of the network, from behind the meter in premises to the secondary substation, to enable smart local energy systems and consumers to become prosumers.' (see www.project-leo.co.uk/glossary)

Hedge or hedging: a risk management strategy for dealing, in the case of this paper, with potential energy price volatility. It is a financial instrument that offsets the risk of the energy price being above or below an agreed 'strike price' by the energy off-taker also having a stake as an investor in the DER.

Hybrid business model: this is where a business model delivers both long-term financial benefit for investors but also a long-term public good that has a non-financial benefit. Revenues are therefore both commercial and social, with the social revenues being provided by community benefit funding.

Investable: a financial model for a new DER whole risk profile is suitable for investment by private individuals or funds. Generally, the risk profile is higher than if the DER were to be bankable (see definition above).

Power Purchase Agreement (PPA): a contract to buy the electricity generated by a DER. The length of time can be from 1 year to as many as 40, depending on the type of contract and the type of DER.

- **Behind the meter PPA:** a contract normally embedded in the lease for roofspace or land where the landlord agrees to buy the energy generated by a DER;
- **Export PPA:** a contract normally agreed with an energy supplier to take all the energy exported from a DER;
- **Sleeved PPA:** PPAs where power is 'sleeved' directly from a single named asset involve the physical transfer of title of the generated energy to the off-taker. To enable this, the off-taker must enter a back-to-back arrangement with their existing licenced supplier who deals with physical trading, billing and settlement;
- **Virtual PPA (VPPA)**: a financial instrument where an investor in a DER also buys a proportion of the energy generated by the DER. It can create a 'perfect hedge' where the investor/off-taker is always protected from energy price volatility by benefiting as the investor when prices are higher than the agreed 'strike price' or by benefiting as the off-taker when prices are lower.

Off-taker: the party who agrees to buy all, or a substantial part, of the energy produced by a DER.

Project LEO Minimum Viable System (MVS) process: this is the process used by Project LEO to work with the minimum set of participants, technologies and processes required to test a new flexibility service, DER use case or service process modification.

Revenue stack: all the different streams of income that make up the total revenue generated by a DER. Particularly relevant for this paper is **Service stacking** where a single DER can deliver more than one flexibility service in a given Settlement Period.

Settlement period: a period of 30 minutes beginning on the hour or the half hour.

TRIAD period: the top three half-hourly peaks of national energy demand across the National Grid, separated by 10 clear calendar days, over the most energy intensive period of the year: November to February. National Grid confirms these periods after the end of the season in March.

Value proposition: how a product or service delivers benefit to a customer by meeting their needs. In this this paper we explore the potential value proposition offered to Low Carbon Hub when it participates in a service, including the full range of benefits accrued in relation to its mission and stakeholders.

Value stack: in this paper, the term value stack is used to mean the cumulative benefits to the Low Carbon Hub's own portfolio of DERs in offering a range of flex and energy allocation services.

Executive Summary

This paper sets out how the Low Carbon Hub (we) will build on technical assessments already done for its portfolio of DERs to learn about how the portfolio of projects can act as a single 'Community of MPANs' in delivering energy allocation and flexibility services. Low Carbon Hub will also learn about what its role could be in taking this portfolio of smart DERs to market, and what the full value proposition is for us to do so.

In doing so, we will build on a previous Project LEO deliverable D2.8 'Value Chain for Flexibility Provider' produced by Origami Energy. We will apply the concepts developed in that paper to the Low Carbon Hub portfolio of DERs so that we can understand the opportunities available to us in terms of revenue stacking and routes to market.

The paper also builds on the LEO deliverable D3.6.1 'Year 1 Plug-in Projects Review' produced by Low Carbon Hub. This reviewed the impact of the Feed-in Tariff (FiT) ending in March 2019, and changes made to embedded benefits through the Targeted Charging Review, to understand how the revenue stack needed to develop for any Low Carbon Hub DER investment project to be commercially viable again. The conclusions from D3.6.1 have meant that our focus needs to be two-fold during Project LEO in understanding our routes to market:

- Understanding how to replace FiT revenue with new Power Purchase Agreement (PPA) models for new projects to be investable; whilst at the same time
- Developing our understanding of how flex services revenue will operate. During Project LEO this can only be as an upside to existing or new projects; services will not be certain enough to be investable and certainly not bankable during Project LEO, and probably well beyond.

We are aiming to develop a 'Swiss army knife' approach to the development of our portfolio of DERs and revenue contracts, as outlined by our independent advisor, Fliss Jones of Everoze:

- A good flex portfolio is like a Swiss army knife. Yes, it costs a fair bit, but wow it's really versatile.
- Just like a Swiss army knife has many functions/tools, so a good portfolio can do many things – frequency response, trading, DSO services, peer-to-peer (P2P) etc.
- If you just use a flex portfolio for, say, MEC capacity trading, it is like buying a Swiss army knife for the toothpick on the end. You've got this inherently versatile powerful tool, but you're choosing just to use it for one service, and a pretty low-value one at that.
- To justify the cost of a flex portfolio, you really need to make the most of its versatility. Rather than just use the toothpick (MEC trading), you need to also deploy the different blades (ESO services), the scissors (P2P), all of it.
- Of course, the toothpick still has value, and when you've got a piece of carrot wedged in your teeth you really appreciate it – but it's not the primary reason why you bought your Swiss army knife.
- You need to use all the tools, to 'stack value', to justify the upfront cost. To be an efficient 'grid citizen', flex providers need to provide lots of different services, hopping between them based on what is needed at that time, in that location. Anything else is inefficient use of a flex portfolio.

1 Introduction

This paper focuses on the Low Carbon Hub as the owner of a portfolio of generating and storage DERs. It will put flexibility services into the context of the post-FiT revenue stack for new DERs and explore: what routes to market there are for Low Carbon Hub in making the investment case for new DERs work; and how to 'upside' the financial model for our existing DERs.

The paper follows up on the conclusions of Project LEO deliverable D3.6.1, 'Year 1 Plug-in Projects Review', as set out in the box below:[1]

> **Conclusions from D3.6.1:**
> - It is possible for small-scale assets to take part in flex markets but there are significant barriers that make this harder than it should be;
> - Transaction costs are already a drag on post-FiT business as usual models; this is likely also to be the case for flexibility services and so there is likely to be an issue of access to new flexibility markets for small assets;
> - Policy environment uncertainty plus market price volatility is making new services difficult to deliver.

It also follows up on conclusions of Project LEO deliverable D2.8, 'Value Chain for Flexibility Providers', as set out in the box below:

> **Conclusions from D2.8:**
> - **Revenue stacking**: because the value of flexibility services varies by network conditions locally, the value will change frequently and so the business case for new flexibility must rely on the availability of multiple revenue streams that can be stacked to reduce risk;
> - **Fair value for flexibility**: the use of flexibility provides external benefits that are not currently rewarded. A fair value could transform flexibility markets and support the delivery of Net Zero;
> - **Route to market**: flexibility markets are largely designed for large portfolios of DERs or large DERs. Standardising services across the flexibility marketplace, simplifying requirements, and reducing the barriers to entry further will enable a significant increase in participation of DERs with low levels of flexibility, an estimated 22,000MW of flexibility;
> - **Non-financial value:** the value of flexibility services is often considered only in financial terms and environmental and social benefits are overlooked.

Low Carbon Hub is taking forward the recommendations from D2.8 in the following ways:

1. trialling the process for identifying and delivering revenue from flexibility services and other revenue streams;

[1] There are examples of portfolios of small-scale assets accessing flex markets that we will address as precedent case studies to inform our work, e.g. Kaluza www.kaluza.com/flexibility-platform/, ev.energy https://ev.energy/ and Social Energy's batteries in ESO frequency response services market https://social.energy/, as well as examples of P2P energy allocation markets emerging, e.g. Urban Chain www.urbanchain.co.uk/.

2. Low Carbon Hub has DERs with low levels of flexibility to deliver flexibility services and will trial a variety of routes to market to learn more about the impact of flex services on the viability of our DERs and the effect of market mechanics on financial returns;
3. 'Learning by doing' in working out solutions to monitor and meter DERs with local levels of flexibility that comply with Code Change P375;[2]
4. Taking part in LEO trials that will contribute to the development of a standard format for peer-to-peer (P2P) flexibility services.

The purpose of this paper is therefore to use the Low Carbon Hub portfolio as a case study that:
- Puts the DSO flexibility service trials into the context of other available markets, such as the ESO market (and particularly trading and arbitrage); and
- Finds out therefore where the best financial value might be for Low Carbon Hub, or indeed any other portfolio owner, including consideration of right risk and reward.

Best financial value does not just rest on the price paid for the service but on establishing routes to market that are:
- Standardised;
- Simplified;
- Where barriers to entry are known and can be lowered cost-effectively; and
- Where costs and benefits of aggregation are known.

NB: *It should also be noted in terms of best financial value that Low Carbon Hub has a particular need is to manage downside risk carefully as investors do not receive the upside from new income; any additional profit arising from new income has to be used for the benefit of the community.*

These well-trodden routes to market are not in yet place for the Power Purchase Agreement (PPA) market in a post-subsidy world, nor are they yet in place for the flex service market though there are examples emerging.[3] This paper will set out how Low Carbon Hub will develop understanding of its own portfolio of DERs to:
- Prioritise services;
- Understand revenue streams, their size and reliability;
- Prioritise project opportunities; and
- Develop full value propositions.

When exploring the value proposition offered by flexibility services to the Low Carbon Hub, we will take into account the full range of financial and non-financial benefits that might accrue to the organisation. We have developed a social impact framework that considers value in terms of 4Ps: people, planet, prosperity, and perception. This stems from our corporate structure as a Registered Society, a social enterprise which has community benefit at its heart.

---

[2] Code Change P375: 'and so can support the use of local metering to verify flexibility services'.

[3] Flexitricity offers a standardised, simplified, known route-to-market for ev.energy, an aggregator of EV chargepoints, though it is more of a relationship approach so far and may not be proven yet as fully commercially viable: www.flexitricity.com/resources/press-release/evenergy-and-flexitricity-partnership-helps-suppliers-unlock-balancing-mechanism-smart-ev-charging/. Habitat, Limejump and others offer standardised, simple routes to market for large-scale assets.

This framework sets out a number of key performance indicators by which we track our progress in achieving our social and environmental mission. These in turn are the benefits we aim to deliver to our key stakeholders. For example, to the investors who provide the funds to develop our portfolio of DERs and the building hosts and landlords from whom we lease the space or the land where our DERs are placed.

The paper will also explore the different roles Low Carbon Hub, or any other community energy social enterprise, might play in the energy and flexibility markets. Given that we own a portfolio of assets and are developing our People's Power Station to control and schedule those assets, the question for Low Carbon Hub is the extent to which we can understand the full range of revenue streams open to us, the ways in which they might stack and the extent to which we might fulfil the roles required for a flexibility services market to work.

The roles Low Carbon Hub might take are broadly:

Trusted bridge between customers and providers in energy and flexibility markets

- Customer acquisition: marketing and sign-up of new customers;
- Ongoing customer advice and support: advisory, interpretation, information provision for existing customers;
- Intelligent customer: understanding what energy and flexibility services are available and how to tell what the best offers are from third party aggregators;
- Project promoter: understanding how generation and demand-side DERs could be put together for new and existing developments where Low Carbon Hub does not own, and would have no on-going role.

Electricity trading and allocation

- Seller or allocator of energy: mainly through different types of PPA, although this could also be a behind-the-meter time of use tariff or wholesale trading.

Flexibility service provider and aggregator

- Technical aggregator of DERs to provide flexibility services: integrating all the kit; characterising its operation; collecting it all into a coherent portfolio that can be taken to market;
- Commercial aggregator of DERs: identifying the best market to take the portfolio to at any point in time and/or space and taking it there;
- Social aggregator of small-scale and community-owned DERs on a 'not for profit' basis where the benefits are shared either with a membership or with a community, and where co-benefits are probably as important as financial value.

This paper therefore builds on preparation for DSO market trial delivery in Project LEO to understand the exploitation opportunities Low Carbon Hub might make for itself beyond LEO as part of its longer-term business planning. It will help us to:

1. Work out what the future business models for Low Carbon Hub could and should be;
2. Understand the value proposition to Low Carbon Hub as the provider of flexibility and what value propositions we could offer to those who may take up Low Carbon Hub services associated with the different roles available to us in a local energy system;
3. Understand Low Carbon Hub competence and appetite to deliver those models;

4. Explore the extent to which these models could be repeated and replicated by other community energy organisations;
5. Understand how successful implementation of these models might combine with the community-led models being developed in D3.8 ‘Community of MPANs Concept and Implementation’ to provide a comprehensive approach to collective local action across the distribution network;
6. Begin to establish a strong evidence base for influencing policy and other organisations to repeat and replicate these models as part of the overall transition to a zero-carbon energy system;
7. Establish ourselves as a ‘go-to’ partner for post-LEO energy systems development opportunities.

We explore these issues using the business model framework set out by the MVS programme of Project LEO: technical feasibility, commercial viability and social desirability. We will use the People’s Power Station 2.0 (PPS 2.0) to operate the Low Carbon Hub portfolio as community of MPANs under a single network node.

Section 2 of this paper therefore addresses **technical feasibility;** section 3 addresses **commercial viability;** and section 4 addresses **social desirability.** Section 5 then explores **potential Low Carbon Hub roles**, both in terms of routes to market for its own portfolio, and how we might scale up our own activity, or support local scalingup by others of flex and energy trading and sharing models at the Grid Edge.

In section 6, we then extrapolate **learning objectives for Low Carbon Hub from Project LEO and the DSO market trials**. Project LEO implementation to date has allowed us to achieve most of the learning objectives in the technical category, though we still have to solve some outstanding technical barriers. Through the Project LEO Trial Periods, we will be focusing much more closely therefore on the commercial and social learning objectives. We expect to achieve a fuller understanding of our post-FiT value chain and how flexibility services could add to it. We also expect to have mapped out potential growth strategies that include delivery of flexibility services. We do not expect to have a fully described and investable or bankable revenue stack that includes flexibility services by March 2023 but we do expect to have a way forward mapped out for future work.

Figure 2 brings these objectives together into visual representation of the Low Carbon Hub programme of activity in Project LEO. It shows how this paper (D3.7) links to the companion piece on the development of Communities of MPANs (D3.8) and shows how the current project might be seen as LEO1 leading on to a more comprehensive implementation of the models and solutions in what might be called LEO2.

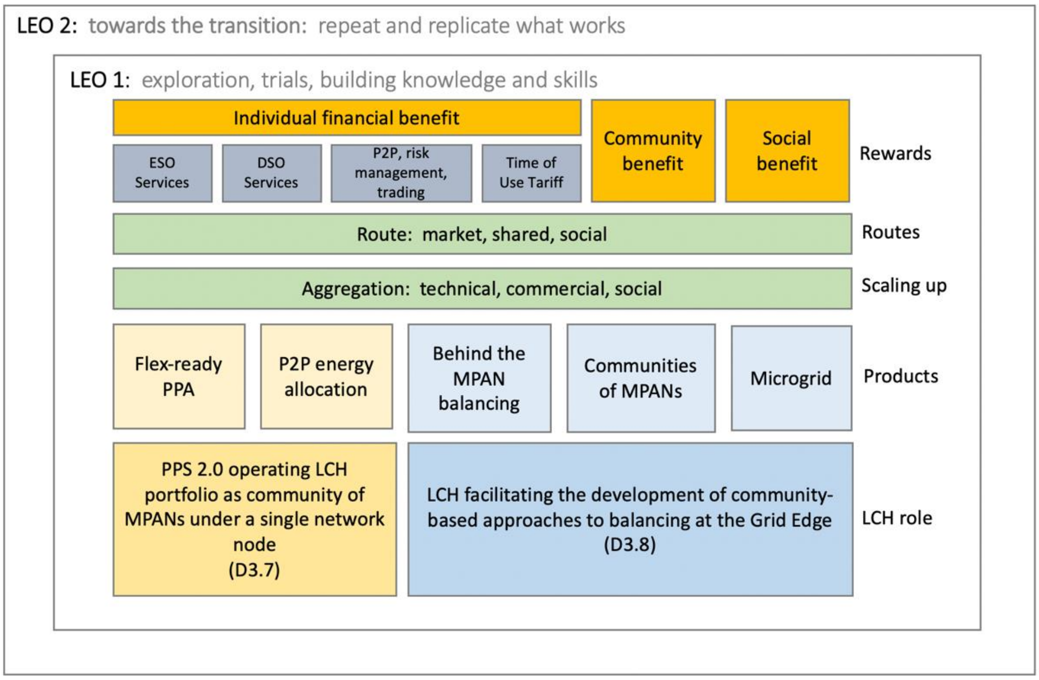


Figure 2: the Low Carbon Hub programme in Project LEO and beyond

2 Technical feasibility

2.1 Low Carbon Hub portfolio description

The current portfolio of DERs owned by the Low Carbon Hub focuses mainly on solar PV projects: 45 rooftop solar PV projects; 1 run-of-river low-head hydro; and 1 battery storage facility. The illustration below is from the Low Carbon Hub Social Impact Report 2021 and gives the details on the generation, carbon reduction and financial characteristics of the portfolio. A new 19MW solar PV groundmount project is in development at Ray Valley Solar (RVS).

The Low Carbon Hub portfolio is characteristic of the technical capacity for renewables available in Oxfordshire. As set out in the *Oxfordshire Energy Strategy 2019*[4] and the *Oxfordshire Pathways to Zero Carbon Report 2021*,[5] by far the major opportunity in the county is for new solar PV projects, both rooftop and groundmount. Most of the small hydro resource has now been developed, and the single 5MW windfarm at Westmills is unlikely to be repeated given the marginal wind resource and few potential sites. Two Anaerobic Digestion (AD) plants take all the kerbside food waste produced in the county. There is some opportunity for smaller-scale on-farm AD using agricultural arisings as the feedstock, and some has been developed.

[4] Oxfordshire LEP (2019) Oxfordshire Energy Strategy www.oxfordshirelep.com/energystrategy
[5] Oxfordshire LEP (2021) Pathways to Zero Carbon www.oxfordshirelep.com/news/article/major-new-report-provides-roadmap-towards-oxfordshire%E2%80%99s-zero-carbon-future

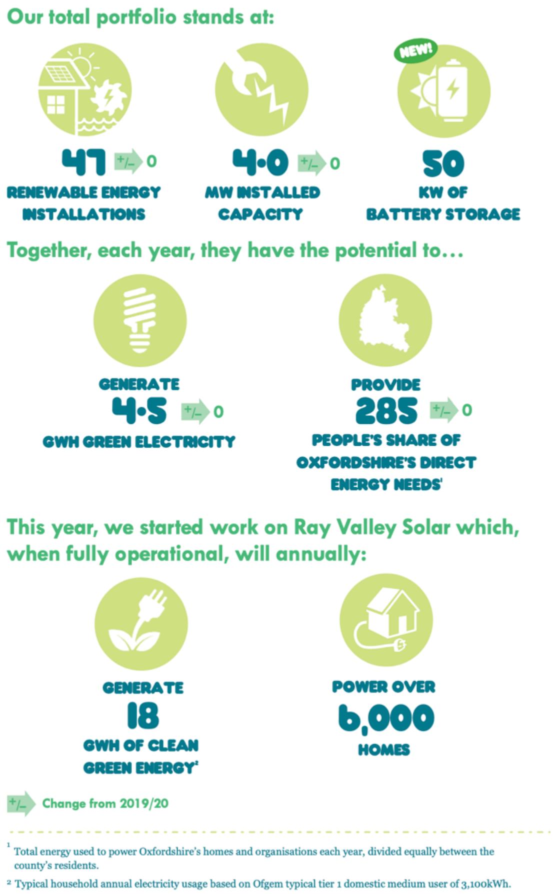


Figure 3: Low Carbon Hub renewable energy portfolio, from Social Impact Report 2021

2.2 Low Carbon Hub portfolio capability

All the DERs owned by Low Carbon Hub, with the single exception of the 30kW Rose Hill battery, have been developed to generate energy and so their technical capability for the purpose of generating and selling energy is taken as read. The question in this section is about the technical capability of the portfolio of DERs to access flexibility markets.

Access to flexibility markets has been proposed as a simple 4-step process by the FUSION project:[6] understand; deploy; test; monetise. Low Carbon Hub has completed most of step 1 and is much of the way through step 2. Step 3 will be the focus of the Trial Periods 1–3 in Project LEO. Step 4 is addressed in section 3 below, 'Commercial viability'.

Having assessed our portfolio and taken our DERs through the Project LEO MVS process, we would suggest some additions and modifications to this model as set out in Table 5:

- We add a new step 2 'Make capable' to recognise that most existing and new DERs will need to be made capable or to be specified capable for delivering flex services. This is suggested from our experience of Project LEO so far;
- We make all the Steps into action verbs;

[6] FUSION project (28 November 2019) Quantifying Flexibility Report www.spenergynetworks.co.uk/userfiles/file/FUSION_Quantifying_Flexibility_Report.pdf

- We rename step 5 (was 4) ‘Stack the revenue’ and add a new Step 6 ‘Stack the value’ to make the distinction between purely financial returns and the full value stack, which will include making a product that meets the needs, drivers and appetites of hosts, landlords and investors based on finding out what people value in each context; and which includes the making of environmental and social value from delivering flex services. There is also the question of what incentives need to be put in place for DER owners to take action in getting flex-ready, given that these new income streams take effort and risk to access and may disrupt existing business models.

Step	Summary
1 – understand	Location, type and capacity of DER, likely flexibility, potential services and usage; inform and engage the people involved, find out what they want
2 – make capable	Data protocols, controls and system integration to make DERs capable of providing flex services; help people to become capable of working the flex
3 – deploy	Interaction with the DER to instruct flex services
4 – test	Commission and prove services that can be delivered using the DER
5 – stack the revenue	Make the DER available to deliver services, agreeing the level of delivery and the invoicing process for services delivered, demonstrating that a commercial and contractual architecture is in place and works
6 – stack the value	Develop valuable products acceptable to DER hosts, landlords, investors and communities and which can provide environmental and social co-benefits

Table 5: 6-step process for using a DER to deliver flex services (based on the FUSION 4-step process)

We have assessed the technical capability of each DER in the Low Carbon Hub portfolio and their potential routes to market as shown in Table 6. Explanations of the acronyms for each service can be found in the Glossary above.[7] The detailed service descriptions can also be found in the glossary above and the detailed assessments by DER are included at Appendix A.

	ESO					DSO				P2P			Other			
	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC	EMIC	OFFST	WT	ToUT	TCM	DCM
Solar Roofs	A			A			A							?		
Ray Valley Solar	A	A	A	A			A									
Rose Hill Battery	A	A	A	A	A	A	A							?		
Sandford Hydro		A		A		A	A									

Table 6: summary of technical capability of Low Carbon Hub portfolio of DERs

Key: green – DER can deliver the service; amber – DER may be able to deliver the service; red – DER not suitable to deliver the service

Nb. An A in the box indicates where DERs may need to aggregate with others to deliver a service

[7] More detailed descriptions can be found in ‘Use Cases and Services to be Trialled Phase 1’ on the Project LEO website: https://project-leo.co.uk/wp-content/uploads/2020/05/Use-Cases-and-Services-to-be-Trialled-Phase-1.pdf

Table 6 suggests a wide range of opportunities for the Low Carbon Hub portfolio of DERs, though for many of the opportunities the individual DERs would probably need to be aggregated with others. The main clusters of potential revenue are around the ESO ODFM service, the DSO SEPM service and all the P2P services. It should be noted that all these services are new (only the ESO ODFM service has been auctioned and that only once) and so data to use in assessing commercial viability for section 3 of this report is very thin.

There is a question on the Time of Use Tariff (ToUT) service in the Other Revenue section of Table 6. Whilst it is true that solar roofs and the Rose Hill battery are not suitable for the ToUT tariffs being offered by some energy suppliers, there might be a case for developing a behind-the-meter ToUT to add to the behind-the-meter PPA that forms the main part of the current revenue stack for those projects, i.e. the question is whether the current agreement could be modified so that the host building shifts its use in response to a signal from Low Carbon Hub such that more of the host's energy requirement could be met from the PVs or via the battery.

2.2 Technical requirements to enable market access

The technical requirements to enable market access are set out for each of the Low Carbon Hub DERs in Appendix A. In summary, each DER type has required additional investment to make it able to: share data; be remotely controllable; and able to be scheduled remotely to deliver a flex service. A particularly difficult issue has been about the ability to share data from online metering for our rooftop solar PV projects: online meter companies are understandably wary of opening their data and communications protocols up to third-party access, even when the third party owns the generation meter in question. The Code Change P375 is good in allowing asset meters to be used in verifying service delivery, but there is work to be done with online meter companies if that Code Change is to have the required impact.

We would also highlight here a skills shortage around both data-handling solutions and communications protocols. It is difficult to find experts in either area who are also technically proficient in putting the right hardware and software solutions in place. For relatively small DERs, such as our solar rooftop portfolio, the cost in dealing with many small (and generally unrepeated) issues of local wiring mean that 'plug- and-play' as a concept for DERs in the flex market is a long way off being a reality.

3 Commercial viability

As a registered society operating community benefit, Low Carbon Hub IPS models its projects to pay shareholder interest and capital as an operational cost, so that all profits made are used for the benefit of the community as set out in the Objects contained in our Rules. Further, we are only allowed to pay shareholders what was originally promised to them in the Share Offer Document; we are not allowed to share 'super-profits' with them, and we have to use any extra profit for community benefit.

This means that, firstly, Low Carbon Hub will need to be very careful about any new risks and liabilities incurred through delivering flex services because our shareholders will not benefit if the objective is purely to 'upside' existing revenue stacks. But, secondly, this means that the extra revenue benefit from flex services will be used to create extra value beyond the purely financial. The relationship between commercial viability and social desirability, the full value stack, is particularly important for Low Carbon Hub. These specific characteristics of the Low Carbon Hub revenue:cost stack is shown in Table 7 summarising the Low Carbon Hub IPS P+L and showing where flex services will add revenue, cost and profit.

Income
FiT income
REGOs
Electricity export
Electricity sales
Other income
Additional flex service income
(Reduced income caused by provision of flex services)
Gross profit
Expenses
Core office costs
Administration
Operations and maintenance
Additional costs for delivering flex services
Shareholder interest and capital
Net trading surplus
Community benefit profit
Additional community benefit from flex service delivery
Depreciation
Additional depreciation expense from capex investment to enable flex service delivery
Net income

Table 7: summary of Low Carbon Hub IPS P+L showing in blue where flex service activity will be shown

Nb: Low Carbon Hub assets are treated as 'wasting assets' for the accounting purposes and so investment value and book value for each asset both net out at nought by the end of the investment period

3.1 A bankable revenue and cost stack: behind the meter

Most of the current Low Carbon Hub portfolio of 47 renewable energy DERs consists of solar rooftops that rely on a revenue stack combining three things:

- The Feed-in Tariff (FiT);
- A behind-the-meter PPA with host schools or businesses giving a discount on their full retail price; and
- An export PPA with an energy supply company.

As discussed in D3.6.1, this stack also included embedded generation benefits that were removed by Ofgem's Targeted Charging Review.[8] In general, however, this revenue stack is very stable and reliable: the FiT increases by the retail price index of inflation every year; and the behind-the-meter PPA is coterminous with the lease for the roofspace giving certainty for the full period over which the investment is modelled. The least certain piece of the revenue stack is the export PPA, but this

[8] The Access and Forward-Looking Charging Review may have a positive impact in reducing the capital cost of connection charges.

represents only a small part of total revenue because the arrays are sized very carefully to the hosts' loads and use patterns.

New projects developed as part of the Project LEO pipeline do not benefit from the FiT and so just have the behind-the-meter PPA and the export PPA. Immediately following the ending of the FiT in March 2019, it was very difficult to make the revenue stack work for new solar rooftop projects, even including the Project LEO grant funding. This situation has eased somewhat as PV costs have continued to fall with the best roofs starting to approach viability again. Whether these projects are fully bankable is in question; Low Carbon Hub IPS has raised 100% of the investment required for these projects as equity from shareholders.

Our assumption in planning the Project LEO pipeline was that flexibility services would allow us to oversize new solar roofs, or add panels to existing ones, in order to make headroom for exporting more electricity and to make money from flex services. The viability problems caused by the FiT ending meant that it was not possible to take the risk on such projects, even with the LEO grant. What we have found, however, in working on the rooftop PV use case for the PPS 2.0, and in developing the Ray Valley Solar specification, is that making the room for flexibility may not be just, or even mainly, about additional panels but about smarter, controllable inverters. Given that inverters need replacing every 10 years, there is an obvious place in the life of a project where these could be upgraded at marginal extra cost over the original expectations in the original financial model.

Low Carbon Hub has therefore reviewed its whole solar rooftop PV portfolio so as to work out a priority list for replacing inverters, or retrofitting existing ones, with a view to enabling the whole portfolio to take part in Project LEO flexibility service trials. The project has been tendered, a contractor commissioned and a set of sprints is underway whereby the priority sites for retrofit are in progress and a priority list for inverter replacement has been identified. One site, where a new PV array will be installed in February 2022, is our pilot project for installing smart inverters as the new standard.

The addition of flexibility services to the revenue stack for these projects will provide an upside on both existing and new solar rooftops for the foreseeable future. The question for commercial viability, therefore, will be about whether the balance between new revenue to be earned and the costs, risks and liabilities incurred in delivering the services will make it worthwhile. And the extent to which technical or commercial aggregation of projects is necessary to achieve scale.

In reviewing the technical capability of the Low Carbon Hub portfolio in section 2 above, a question arose around the part that ToUTs might play in upsiding existing revenue:cost stacks for Low Carbon Hub PV. Clearly, normal ToUTs provided through an energy supplier are not relevant, given the behind-the-meter PPAs in place. But there could potentially be a behind-the-meter ToUT, whereby income from flex services might be maximised by the host shifting its use, increasing or reducing it in order to match times of flex delivery, or to match more closely the pattern of generation.[9] Following the principle of the existing PPA, the benefits would be shared between Low Carbon Hub and the host. In developing this idea, we will need to model dependencies with other services that the ToUT might be stacked with, because a regular response to the ToUT (i.e. predictable price pattern) may change the baseline for the asset and therefore reduce the potential to receive a full utilisation payment from the flexibility market.

A further issue with export MPANs has arisen in readying this set of projects to deliver flex services. This is that having two different MPANs for the same address will cause problems if the host business stops trading. To date, it has not been necessary to apply the distinction between an import or export MPAN, or to worry about having a split in ownership between the import or export MPAN. The introduction of flex services into the equation has changed this situation. As a result, it has been an unexpectedly difficult process to agree export MPANs for our solar rooftop projects that would enable the installations to provide flexibility services by increasing and exporting generation. We are working with SSEN to resolve this issue.

3.2 A bankable revenue and cost stack: exports beyond the meter

A bankable revenue stack for new post-subsidy generation and storage DERs must focus on replacing the certainty of the FiT by selling the energy generated on a contract of the right price and the right length. This is generally in the form of a PPA. The issue for post-subsidy projects in the UK is that the market for these is immature at the required 40-year payback, and the pool of experienced customers is limited. We set out in section 3.2.2 below the different types of PPA it is possible to put in place and the conclusion we have come to so far about which form will suit our purposes best.

We have not identified any other form of income for generation and storage assets that is yet bankable for a new asset. Our understanding of flexibility service markets (DSO or ESO) is that we might expect a maximum 10% upside on expected income depending on the DER, and so we will need to understand the costs, liabilities and risks of taking part in these markets in some detail in order to understand whether they make commercial sense for our portfolio. We discuss this in section 3.3 below, given our understanding so far of the services to be trialled in Project LEO Trial Periods, and the detail of the processes and contracts involved in delivering them.

Of more interest would seem to be the DSO-enabled P2P market where we can optimise use of our connection agreements, or gain access to capacity owned by others, in order then to optimise income generated by our DERs, either as more generation or as selling grid capacity when we don’t need it. We may also want to use these services to reduce the cost of connection for new DERs coming into our portfolio. As things stand, this type of flexibility service would also seem to be much more in our own control because we identify the need and can create long-term partnerships with

[9] Although other price signals to govern the implementation of the ToUT may be better where there is a very high value placed on an infrequent and short-term delivery. Examples of this are: the critical peak price, where flexibility supports the network during periods of very high stress due to high levels of winter demand (the TRIAD period) or when there is a network fault; the rebate penalty, where extra demand causes the network difficulties during a period of stress (TRIADs or when there is a network fault) and is penalised.

other businesses under contractual arrangements controlled by us. We discuss these trades in section 3.3 below.

3.2.1 Wholesale trading

The UK wholesale energy market, into which generated energy is traded, works on a six-season (three-year) hedge purchase horizon. Fix priced contracts for generators rarely exceed three years in duration with market risk reflected in lower pricing for longer duration contracts. Conventional energy supply contracts also require an export MPAN to secure pricing which may not be issued by the DNO until a project is in construction. These revenue risks mean very few backers proceed with projects on a purely merchant basis.

3.2.2 Power Purchase Agreements

The disconnect between the revenue certainty that can be obtained from conventional market hedge purchasing, and a project's 40-year lifespan, can be addressed in one of two ways: by modelling market risk or by contracting directly with a customer. Modelling of risk is usually based on expert projections of future energy price curves. Due to the inherent uncertainty in this approach, viable debt finance is unlikely to be available and post-subsidy projects that have proceeded are likely to have been equity-backed.

The second, direct contracting approach, is undertaken via a long-term PPA for the sale of energy to a counterparty with sufficient consumption. Corporate PPA's are a reasonably well-established and growing means by which power from a generator can be purchased directly by a consumer alongside their existing energy supply contract. They offer the potential for long-term energy cost certainty for off-takers and predictable long-term revenue for utility-scale renewable energy projects.

In the UK's post-subsidy context, long-term revenue certainty is essential to the bankability and financing of generation projects and therefore also essential to growing the amount of renewable energy generation on the grid to provide assets that can operate in a flex services market. PPAs are the engine to drive the proliferation of renewable energy generation assets and symbiosis with the flex market must be ensured to grow a project's revenue stack. Growing the revenue stack has the potential to lower the commodity price and increase their appeal to off-takers, further driving growth in uptake and the deployment of flex-ready projects.

There are three main forms of PPA available for exported generation: direct sale to energy supplier; sleeved PPA with commercial off-taker; and virtual PPA also with a commercial off-taker:

1. **Direct sale of exported generation to energy supplier**
   This is the business-as-usual form of PPA where a relatively short-term fixed price is agreed with an energy supplier. These contracts normally have a maximum life of 3 years and so the timing can be the critical factor in determining the price, as we have seen with some clarity this year. They are relatively easy to put in place and have a clear contractual structure that is common to all the energy suppliers in its main shape.

   Many suppliers also have an ESO offer where they act as commercial aggregator to access the ESO market for flexibility services. Terms may need to be varied in order to allow notification of down-time when flex services, such as SEPM, are being delivered but there would seems to be relatively little difficulty in achieving this if our experience to date proves repeatable.

2. Sleeved PPA

PPAs where power is 'sleeved' directly from a single named asset involve the physical transfer of title of the generated energy to the off-taker. To enable this, the off-taker must enter a back-to-back arrangement with their existing licenced supplier who deals with physical trading, billing and settlement. Contracts are as a result complex, dealing with numerous market risks and the fit between the generation and consumption profiles (see Figure 4).

Sleeved PPAs are generally indexed from a starting commodity price. The largest up-takers of PPAs in the UK to date have been supermarkets who favour RPI or CPI linking of opex to match their forward revenue. Historically energy price inflation has however been volatile and has not tracked RPI or CPI inflation. Other indexing options such as fixed annual rates or a 'collar and cap' tracking electricity commodity pricing are also possible.

A number of local institutions have been engaged in discussions and workshops through Project LEO to ascertain their interest in contracting a local PPA to help grow the market for larger-scale renewable energy projects in Oxfordshire. Collectively these institutions represent approximately 200 GWh of annual energy consumption within the county. The starting premise for these engagements was that the clear chain of custody provided by a sleeved PPA would be an essential characteristic. It was instead apparent that this structure presented a number of key barriers and these have been further understood during further discussions with institutions. Key points from the workshops are set out below:

1. **Contractual complexity**

   Although the total volume of energy consumed is significant, and above the necessary threshold to ensure transaction costs do not make a P2P PPA unviable, few individual institutions have the staff resource to divert to investigating available options, are sophisticated energy purchasers or have the resources required to obtain and retain specialist advice.

2. **Tender constraints**

   The complexity of public procurement is an inhibitor to P2P development of PPAs. An open tender is likely to result in a remote generator with a lower price scoring better than local sources.

3. **Tender price risk**

   A long-term PPA, that spans the duration of multiple energy supply contracts, can inhibit an institution's ability to obtain best value from the market as those supply contracts are re-tendered. This is an unquantifiable risk and so forms a considerable barrier to up-take.

In addition to the above, introducing contractual mechanisms into a sleeved PPA to enable a project to deliver flex services alongside could add further complexity. This uncertainty is likely to be perceived as a significant risk for energy suppliers and will only erode the value for the generator and off-taker.

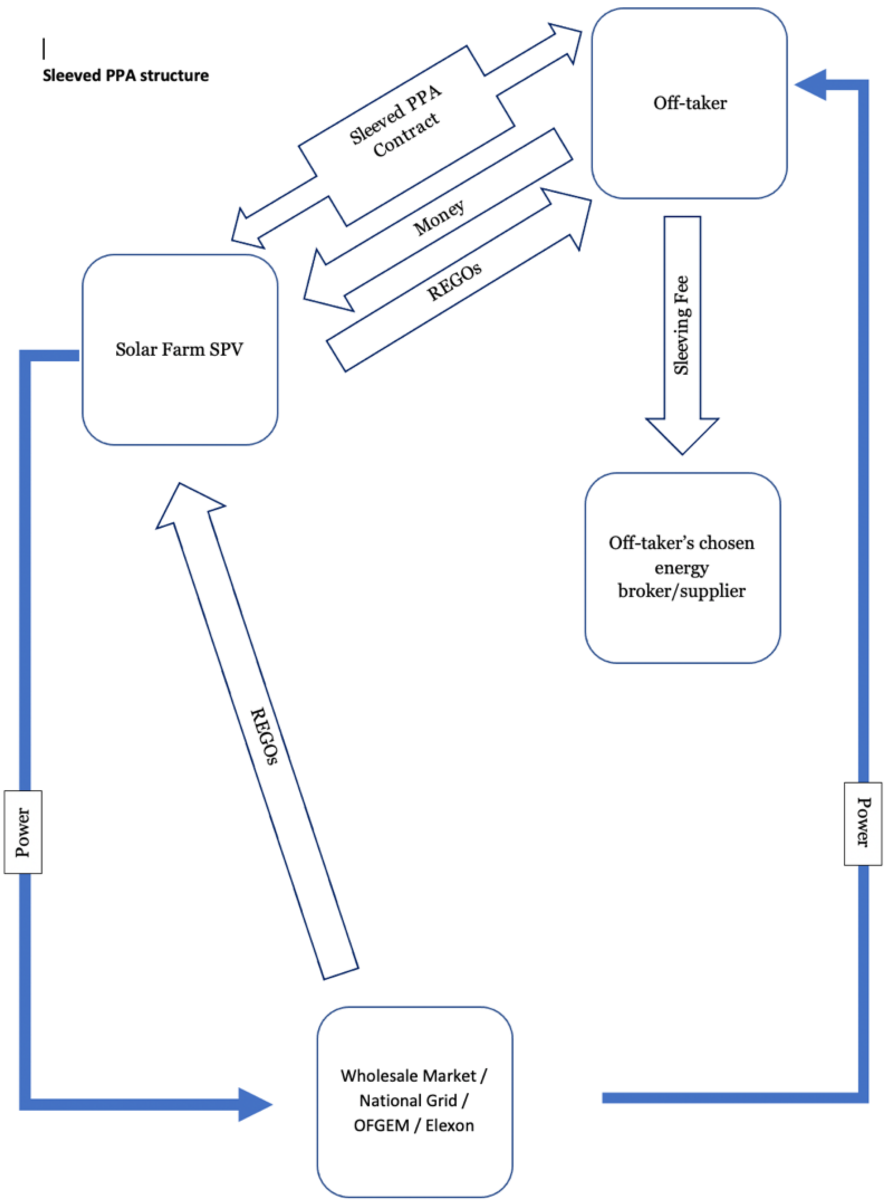


Figure 4: sleeved PPA structure

3. Virtual PPA (VPPA)

A VPPA acts as a price-hedging instrument, replacing a variable price cashflow with a fixed price, providing the off-taker and generator with predictable price for energy over an agreed period of time. It is a purely financial arrangement, with no 'title' to energy transferred from the generator to the counterparties.

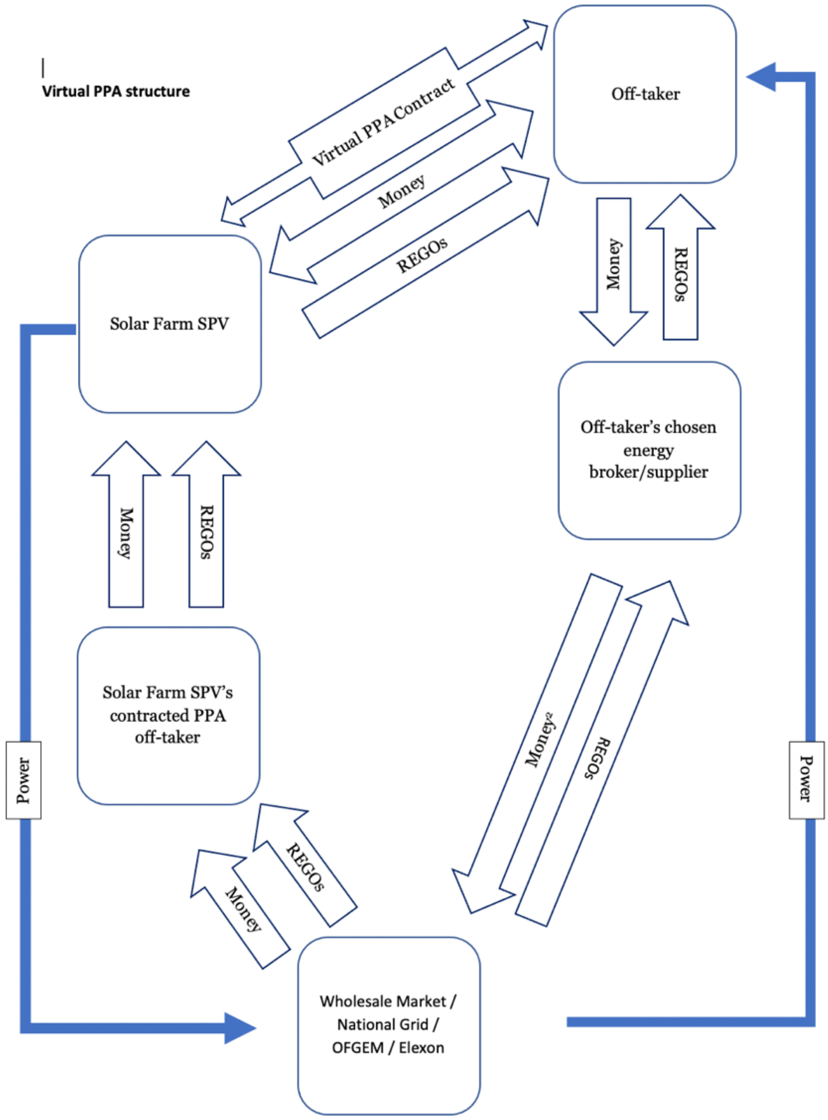


Figure 5: Virtual PPA structure

The generator and off-taker independently trade energy in the wholesale market via their separate energy supplier contracts (see Figure 5). Both parties agree a 'strike price' which the generator will receive for all energy exported to the grid for the duration of the contract. If the wholesale energy price drops below the strike price, the off-taker buys their energy for less from the wholesale market and uses their savings to compensate the generator, who has received a price below the strike rate for the energy they sold during the same period.

Conversely, if the wholesale price rises above the strike price then the off-taker is paying more for its energy in the wholesale market, and the generator compensates the off-taker from its marginal revenue against the strike price. This arrangement is summarised in Figure 6.

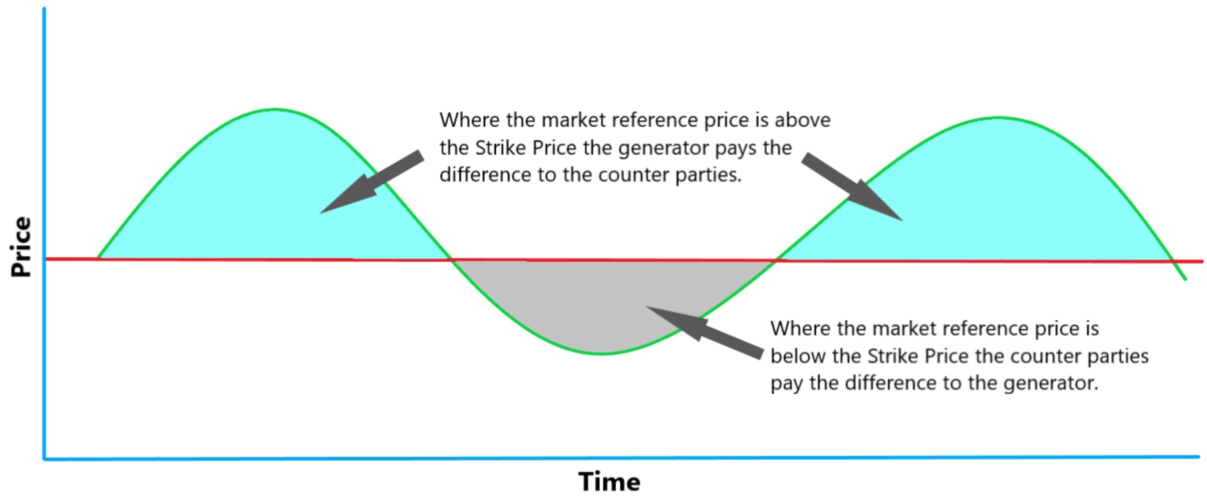


Figure 6: how the VPPA deals with period where the market reference price is above and below the strike price

VPPAs have a number of benefits:

1. Predictability of income and energy bills

The VPPA furnishes the generator with long-term predictable revenues which makes a project lower risk and more investable. The VPPA counter parties are not themselves put at financial risk because any deficit they are required to pay across to the generator will be off-set by savings in their own imported energy costs because these broadly follow the same market fluctuations. The time periods where fluctuations against the strike price occur can be anything from near real-time, day-ahead trading to the longest duration fixed price supply contracts that can be procured by the generator.

2. Creating a perfect hedge

VPPAs are effective tools to manage energy price risk but, if all parties' energy trades are conducted on the same basis, VPPAs can eliminate risks (and benefits) of the hedge to the off-takers by creating a near 'perfect hedge'. The generator's sale price to the market and their own wholesale purchase price track each other and net off against each other.

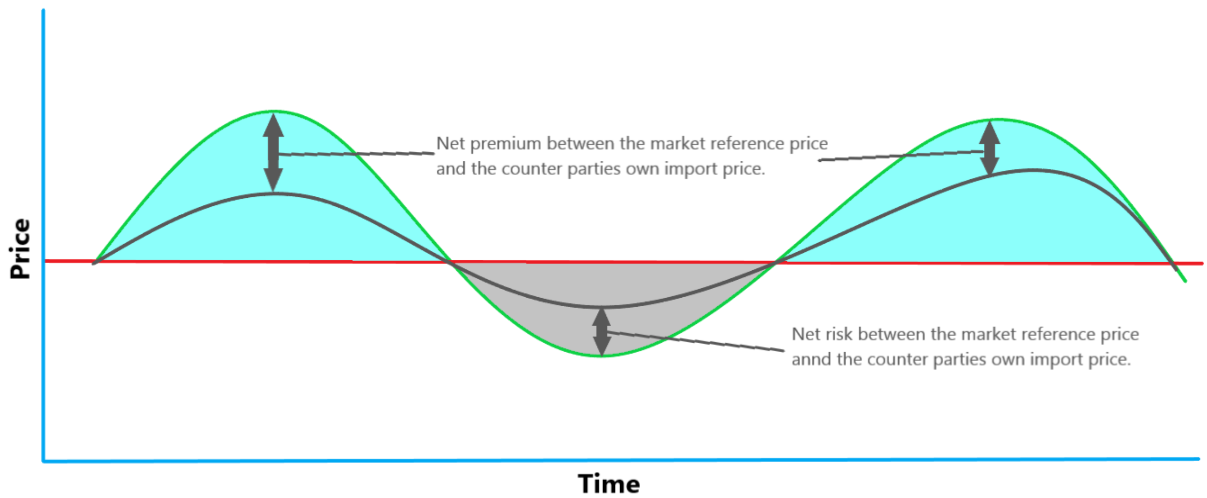


Figure 7: creating a perfect hedge

A perfect hedge is only possible where off-takers have complete autonomy over how they buy energy and can align procurement with the generator. The reality might more like be a mitigation of risk as highlighted in Figure 7.

3. Less contractually complex than standard PPAs
VPPAs are a much lighter contract than sleeved PPAs, not requiring the same complexity to manage energy market and risk factors. They also enable parties to have different suppliers.

4. Can involve multiple generators and buyers
VPPAs are very flexible and have the significant advantage of facilitating multiple generators and off-takers to participate in the same contract. This has the potential to further capitalise on the efficiency of lighter transaction costs and even to enable institutions to be both investors and customers, managing investment returns against operational costs.

5. Progress towards institutional targets
VPPAs can offer a straightforward path to delivering CO_2 emissions savings for off-takers as well as corporate social responsibility (CSR)+ goals linked to the local economy.

VPPAs are not without their complexities, not least the need for off-takers to understand the accounting impacts they have, given that they are derivatives. From the point of view of creating a local PPA that can dovetail with the provision of flex services, however, it looks like a practical option. Flex services are unlikely to be inhibited by the same contractual dependencies as sleeved PPAs with the contractual provision for flex largely managed between the generator and energy market. The benefits of the value stack for generators can be passed on to off-takers in a lower strike price, further increasing the chance of market growth.

3.3 Flexibility services: potential additions to the revenue stack

There are three main types of flex services and each has a different route to market:

- ESO services are auctioned by the Energy System Operator for the overall energy system;
- DSO-procured services are auctioned by the Distribution System Operator for the local energy network; and
- P2P services are enabled by the DSO and auctioned through the DSO flex market.

A summary description of the full set of services is included in the glossary above.

3.3.1 Assessing additional revenue per DER per service

Table 6 shows our assessment of the services our DERs are technically capable of delivering. We repeat it here for ease of reference (key is given above):

	ESO					DSO				P2P			Other			
	BM	CM	DC	ODFM	STOR	SPM	SEPM	SDCM	DDCM	EMEC	EMIC	OFFST	WT	ToUT	TCM	DCM
Solar Roofs	A			A			A							?		
Ray Valley Solar	A	A	A	A			A									
Rose Hill Battery	A	A	A	A	A	A	A							?		
Sandford Hydro		A		A		A	A									

Potential revenue from flexibility services for each DER can be difficult to assess because some services are new and some have a relatively short history from which to draw assumptions. For ESO services, for example, the ODFM service has only been auctioned once and all bids were rejected for the 2021 summer period because there was no need for the service. For the DSO services, there are known nominal values for SPM, SDCM and DDCM, as set out in lookup table from D2.8 reproduced at Appendix B. But SEPM is new and so there is not yet any history to draw from.

For the P2P services, these are all new and so there is no information yet to use in building a commercial case for delivering them.

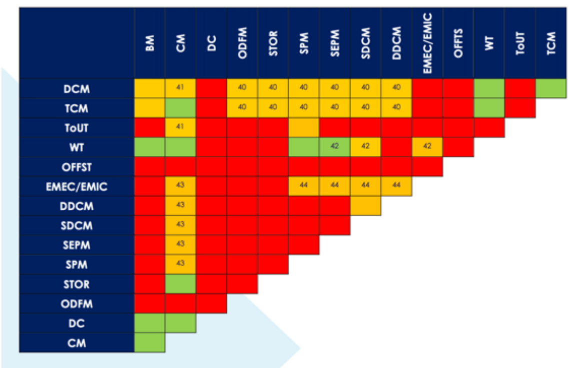
Looking at the service:DER Table 6, it is clear that the Low Carbon Hub portfolio is likely to concentrate on areas where there is as yet no information, i.e. ODFM, SEPM and the P2P services. Our approach will therefore need to be to learn what we can from LEO Trial Periods, at the same time as developing our understanding of the transaction costs of delivering the services, so that we can build a provisional commercial case by the end of LEO. In doing this, we will expect to develop a repeatable financial model for flex service delivery that should be of use to others: by service, by DER and by portfolio.

An area that will need further thought is the Balancing Mechanism given that our solar portfolio and our battery looks capable of delivering that service.

3.3.2 Stacking revenue from different services by portfolio

Having worked out the capability and potential earnings from individual flex services by individual DERs, there is then the question as to whether delivery of flex services and therefore income from them can also themselves be stacked.

D2.8 sets out how the services interact for coincident delivery and adjacent delivery. Figure 8 and Table 8 and following, also from D2.8, show the difference between them.



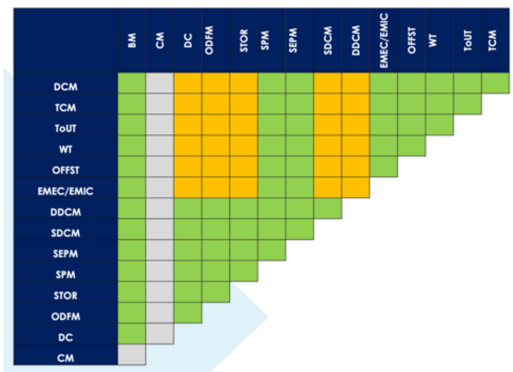


*Table 8 and Table 9: showing interaction between services for **coincident** delivery (8) and **adjacent** delivery (9)*

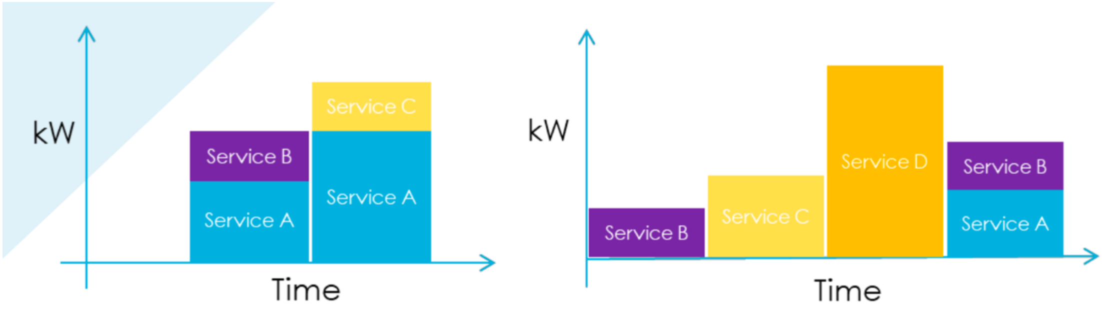


Figure 8: the difference between coincident delivery on the left and adjacent delivery on the right

These tables suggest that it is worth exploring coincident delivery for the ESO services and Wholesale Trading for Ray Valley Solar (RVS) but that delivery of these services would not be compatible with periods where ODFM or SEPM was being delivered. RVS has agreed an export PPA with Ecotricity for the rest of the Project LEO delivery period and ESO service delivery can be included in that. We will expect to work with Ecotricity during LEO to understand better how the services fit together and what the benefits are of delivering them.

The other DER with the widest ranging capability for delivering services is the Rose Hill battery. In this case, it is likely that coincident delivery of ESO and DSO services will likely require aggregation. The question will be what the relative balance of benefit is between delivery of procured services or P2P services and also the extent to which the battery could enable a ToUT addition to the existing behind-the-meter PPA with Rose Hill primary school.

The capability of Sandford Hydro Ltd (SHL) and the solar rooftop fleet focuses much more on the export peak management services (ODFM and SEPM) and the P2P services. These are not compatible with each other for coincident delivery, except for the possibility that EMEC could be used to buy extra export capacity in order to deliver DSO services. RVS and SHL are likely to be the DERs best placed for an exploration of this possibility.

Figure 9 from D2.8 shows how a combination of adjacent and coincident services can be put together to deliver a required duration and capacity for a flexibility service from a portfolio of DERs. RVS is big enough to deliver a set of services on its own because it meets the minimum threshold of 1MW for ESO services and the minimum for DSO services is only 1kW. It will be interesting to see how our portfolio of assets can combine to provide more than the sum of the parts. Or indeed to use the method to put together a desired pattern of delivery across the portfolio that can be used to make quick decisions on auctions – a technical aggregation of DERs leading to a potential commercial aggregation.

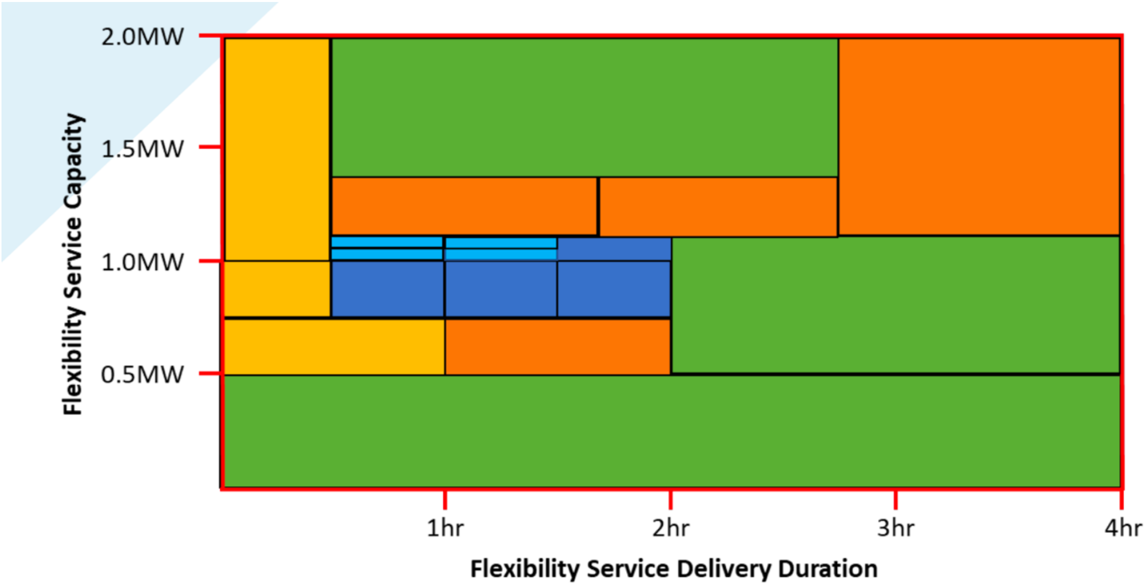


Figure 9: how a portfolio of different assets can work together to deliver a flexibility service (the different colours each represent a different DER)

3.3.3 Accessing flexibility

Having solved issues of technical capability, the remaining issues to address in terms of access to flexibility markets are around:

- The operations and finance capacity required to engage with markets, the human resource and any new technical resources required;
- Additional transaction costs, for example legal advice for signing contracts;
- The risk premium required to be included in revenue stack modelling to cover any risks and liabilities involved in new contracts for service.

Table 10 shows a simplified version of the 'swim lane' diagram for the Sustain Peak Management developed in preparation for the Project LEO flexibility market trials. Each time the arrow crosses the line between SSEN and the flex service provider represents a potential point where transaction costs, risks or liabilities might be incurred. As part of the LEO trials, Low Carbon Hub will be tabulating the transaction activities and calculating the transaction costs, risks and liabilities associated with them.

To date swim lane diagrams have only been produced for SPM and EMEC because these are the services being trialled in Trial Period 1. We will expect to produce a method during TP1 that can be applied to the services being added in TP2 and 3, so that we have a whole view of the costs of accessing flex service markets as well as the benefits.

These exercises will also inform our understanding of the potential for Low Carbon Hub to act as either/or a technical or commercial aggregator for its own or others' portfolios of DERs.

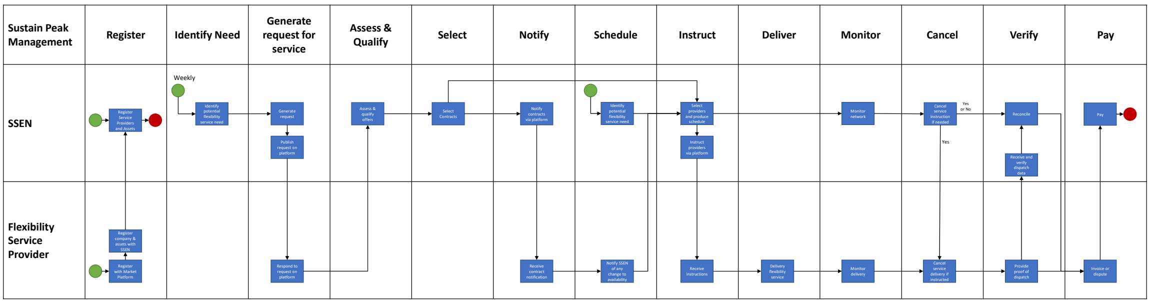


Table 10: swim lane diagram for Sustain Peak Management service

3.3.4 The revenue stack for post-FiT DERs in the Low Carbon Hub portfolio

In summary, there are issues with the full revenue stack for any DER post-FiT. For batteries as well, as explored in D3.6.1, capital costs currently make the addition of storage to any DER using the Low Carbon Hub financing model very difficult. Rose Hill battery has been implemented as a wholly funded community benefit-plus-grant project because it has a payback period of over 300 years. Project LEO will inform us as to potential ways to stack revenue that, along with cost reductions analogous to the cost curves experienced with PVs, will allow us to identify the point at which investment in battery storage becomes viable for the Low Carbon Hub portfolio.

Table 11 below shows the position on commercial viability for the Low Carbon Hub portfolio as it currently stands. On the left, the PPA models used are shown and whether that means that the DERs are commercially viable without grant. To note is that both RVS and SHL currently have short-term export PPAs with energy suppliers but both might benefit particularly well if we can negotiate sleeved PPAs, or preferably a VPPA, with local institutions.

On the right the table shows potential upside from flex services and other revenue. Of note here is the question mark around behind-the-meter ToUTs: whether they are possible to construct as an addition to existing behind-the-meter PPAs and what benefit they would achieve for host and Low Carbon Hub as a result.

The far right-hand column is ready to show the total potential benefit we might get from new PPA, flex services or other income. We expect to have some idea of these benefits as a result of taking part in the Project LEO Trial Periods but do not expect to achieve new, fully bankable additions to the revenue stacks by that point.

	PPA					Viable without grant	Flex		Other				Potential benefit	
	FiT	BTM	Export	Sleeved	vPPA		Upside	Bankable	WT	ToUT	TCM	DCM	£ ComBen	Viability
Solar Roofs – Pre LEO										?				
Solar Roofs - LEO										?				
Ray Valley Solar														
Rose Hill Battery										?				
Sandford Hydro														

Table 11: viability matrix for the Low Carbon Hub portfolio of DERs

4 Social desirability

We will look at the social desirability of operating the Low Carbon Hub portfolio of DERs as a community of MPANs from two perspectives:

1. Firstly, from the perspective of Low Carbon Hub as owner and operator of the portfolio; and
2. Secondly, from the perspective of our customers: our investors; our hosts and landlords; and the wider community of Oxfordshire.

4.1 The Low Carbon Hub value proposition: as service provider

In developing the Low Carbon Hub portfolio of DERs into a community of MPANs that can deliver energy allocation and flexibility services, the business model requires that we understand what the benefits are for Low Carbon Hub in providing those services. We include at Appendix D the 'Strategyzer' business model canvas being used by Project LEO. This recognises the list of building blocks that make up the value proposition for new products and services. From that list, our starting position is that the Low Carbon Hub needs being met in operating its portfolio as a community of MPANs are mainly around:

Newness: satisfying the Low Carbon Hub need to contribute to the development of new products and services that will enable the grid edge to operate smartly in a way that maximises the connection of embedded renewable energy and allows the connection of electric heat and transport technologies to take place in the required numbers;
Performance: improving the performance of the Low Carbon Hub portfolio of DERs;
Customization: tailoring the operation of the portfolio to the requirements of particular energy and flexibility services;
Cost reduction: reducing the cost of operating the Low Carbon Hub portfolio;
Risk reduction: reducing the risk of operating the Low Carbon Hub portfolio; or reducing the risk of selling the portfolio into new energy and flexibility markets;
Convenience/usability: making it easier for the Low Carbon Hub portfolio to 'plug-and-play' in the new markets.

We will use the Strategyzer template included at Appendix D to explore and develop the value proposition for Low Carbon Hub as service provider as part of the development of the full business model.

4.2 The wider Low Carbon Hub value proposition: investors; hosts; community

In assessing the overall value proposition that participation in flexibility services creates for the Low Carbon Hub, we can also consider the benefits and value it adds in terms of the enabling us to achieve our wider mission – how it helps us with the pains and gains of carrying out our daily jobs, and our role in relation to the wider community. This in turn helps us strengthen our own offer of financial, social and environmental benefits to key stakeholders such as our investors and project partners.

Low Carbon Hub already has an established offer to its investors, hosts and landlords, and the wider community of Oxfordshire. Our 4 Ps model measures our social impact around the following four areas: people, planet, prosperity and perception. We have set out on our website how we define and measure each metric at www.lowcarbonhub.org/about/our-impact/.

4.2.1 The offer to Low Carbon Hub investors

Our Share Offer Documents are very clear about the community benefit mission of Low Carbon Hub IPS investments. So legally, we are allowed by the legislation[10] to offer a decent return to investors that is enough for us to attract and retain their investment. Equity is not protected by the 2005 financial regulations and so there is no recourse to the Ombudsman if anything goes wrong. We have to emphasise that equity is at risk at all times. Investors are invited to invest in order to achieve good outcomes across the whole range of our value proposition: people, planet, prosperity and perception. We do have investors who tend towards either end of the implied spectrum here and managing that tension is one of the things that we take very seriously.

We report annually to investors in two ways to demonstrate how we are achieving the value proposition offered to them in the Share Offer Document. We report to them on the performance of the various Low Carbon Hub portfolios of investment in the Annual Performance Summary and on the overall social impact achieved by Low Carbon Hub activities in the annual Social Impact Report.[11]

4.2.2 Offers to hosts and landlords

Low Carbon Hub has two main offers for potential hosts:

1. **The solar rooftop behind-the-meter offer**
   This offer is mainly about **P**rosperity in giving the host business or school a discount on their electricity. Both schools and businesses are then interested in **P**lanet from the point of view of

[10] The Co-operatives and Community Benefit Societies Act 2014
[11] Annual Performance Summaries www.lowcarbonhub.org/about/resources/ and Social Impact Reports www.lowcarbonhub.org/about/our-impact/

being able to identify carbon savings. Businesses are particularly interested in **P**erception so that they are seen by neighbours, local authorities and customers as doing their bit on climate change and being good neighbours. **P**eople tends to be less important for both types of host, probably because the actual working of the solar PV tends to feel quite distant from the workforce or the students, although there have been some lovely examples of teachers using the installations in science and maths classes.

2. The large-scale DER offer to landlords and developers

These relationships tend to be solely about finance, because the relationship is transactional and often at arm's length through lawyers. The Hub tends to get brought into projects if they are marginal for mainstream investors in terms of their commercial viability.

We are seeing potential new offers to landlords and developers coming through, however, as a result of the work we are doing on sleeved and virtual PPAs. This is where local institutions might find a wider value stack available to them in working with us where they can combine local generation with a PPA that includes claimable carbon benefits and allows them to represent their 'good neighbourly' qualities by working with us.

We are also seeing the potential for new partnerships with financial institutions, particularly pension funds, as Environmental, Social and Governance (ESG) policy becomes the norm and institutions are required to report on their performance. We discuss this potential in our white paper, 'ESG policy and practice: models for collaboration between pension funds and the community energy sector, with particular reference to 12 Acre Farm, Eynsham'.[12]

4.2.3 Benefit delivered by DER

Table 12 gives a summary of how each DER owned by Low Carbon Hub contributes to the whole value proposition offered to investors and to hosts/landlords.

	To investors				To hosts/landlords				Additional benefit					
	People	Planet	Prosperity	Perception	People	Planet	Prosperity	Perception	Hosts	Investors	Place	Community	ComBen	O+M
Solar Roofs – Pre LEO														
Solar Roofs - LEO														
Ray Valley Solar														
Rose Hill Battery														
Sandford Hydro														

Key: green – DER does deliver; amber – issues to address; grey – not relevant to this DER; blue – to be seen

Table 12: delivery of the Low Carbon Hub value proposition by DER

12 [add web address for ESG paper]

As noted in the key, we show grey squares where the benefit is not relevant to that DER and amber squares where we have, or have had, issues to address with hosts or investors. For example, some investors are worried about the impact of large-scale solar groundmount projects on the environment, in terms of land use and impact on wildlife. And projects part-funded by LEO grants contain risks to investors because of the post-grant calculation of financial value.

We have shown on the right-hand side of Table 12 a list of types of benefit that might be generated from new PPA models or new flex service delivery. This list may not be complete and will be the subject of exploration as we deliver Project LEO trials and can gather evidence about what the value stack might be beyond the purely financial.

4.3 Risks and liabilities

As well as the benefits we offer through our value proposition, we also have to take into account how risks and liabilities might affect that offer. Key: green *– DER does deliver; amber – issues to address; grey – not relevant to this DER; blue – to be seen*

Table 13 shows the basic promise we make to hosts and investors: for hosts, we offer certainty in delivering the promised benefits, no or little effort to them in making the project happen and no additional liability to them in hosting the DER. For investors, we again offer a target financial return, that the DERs we install are all ethical in terms of their delivery and contribute community benefit funds to support the ethical mission of Low Carbon Hub, and that the projects are low risk commensurate with the nature of community benefit society regulations.

	To hosts			To investors			Additional risks/liabilities		
	Certainty	No effort	No liability	Certainty	Ethical	Low risk	Hosts	Investors	LCH overall
Solar Roofs – Pre LEO									
Solar Roofs - LEO									
Ray Valley Solar									
Rose Hill Battery									
Sandford Hydro									

Key: green – DER does deliver; amber – issues to address; grey – not relevant to this DER; blue – to be seen
Table 13: the offer to hosts and investors around risks and liabilities

In identifying and quantifying the full value proposition for post-FiT DERs and for the delivery of new flex services, Low Carbon Hub must also be aware of and consult with its main stakeholders around any additional risks and liabilities these new ways of working might generate. We cannot risk losing our investor base or our constituency of motivated local businesses and institutions by chasing new products and services where the risks and liabilities might outweigh any additional benefits. As with the benefits, we expect to be able to populate the right-hand columns of Key: green *– DER does deliver; amber – issues to address; grey – not relevant to this DER; blue – to be seen*

Table 13 as we work through the LEO trials and understand how the new products and services operate.

5 Flexibility service business models: potential roles for Low Carbon Hub

The introduction to this paper (section 1) set out three major groups of roles the Low Carbon Hub might play in energy and flexibility trading. The first one of these, **Trusted Bridge,** is about how Low Carbon Hub can continue and broaden its existing Helpdesk product for communities to cover these areas and perhaps add to that a potential role in acquiring new customers for third party service providers. The first of these is a role already played by Low Carbon Hub CIC and for which it has demonstrated the necessary skills and competences over many years. The second is one that Low Carbon Hub CIC and IPS have chosen not to play because of the conflict of interest it represents between community benefit and benefit to the third-party service provider. We do not expand further on these roles here because this paper is about Routes to Market for the Low Carbon Hub IPS DERs.

The second category **Energy Trading and Allocation** mainly covers the role already played by Low Carbon Hub IPS in developing its portfolio of generation DERs and sees an expansion of that role into developing and being the central actor in a local institutional VPPA arrangement. The Low Carbon Hub IPS history as a developer of generation DERs working with many of the main local institutional actors and bigger locally headquartered businesses means that it should be well-placed to expand its role into the development of local PPA trading arrangements, such as a local VPPA.

The Low Carbon Hub IPS role around the third category, however, **Flex Service Provider and Aggregator,** is less clear-cut; we have no proven track record and so no evidenced competence in delivering either of these roles. Project LEO requires us to play both roles with regard to our own portfolio of DERs in delivering the Project LEO flexibility service trials, however, and so we consider here to what extent this experience might lead us into a new area of business development. Table 14 summarises these potential roles and gives a sense of how well Low Carbon Hub is placed to fulfil them.

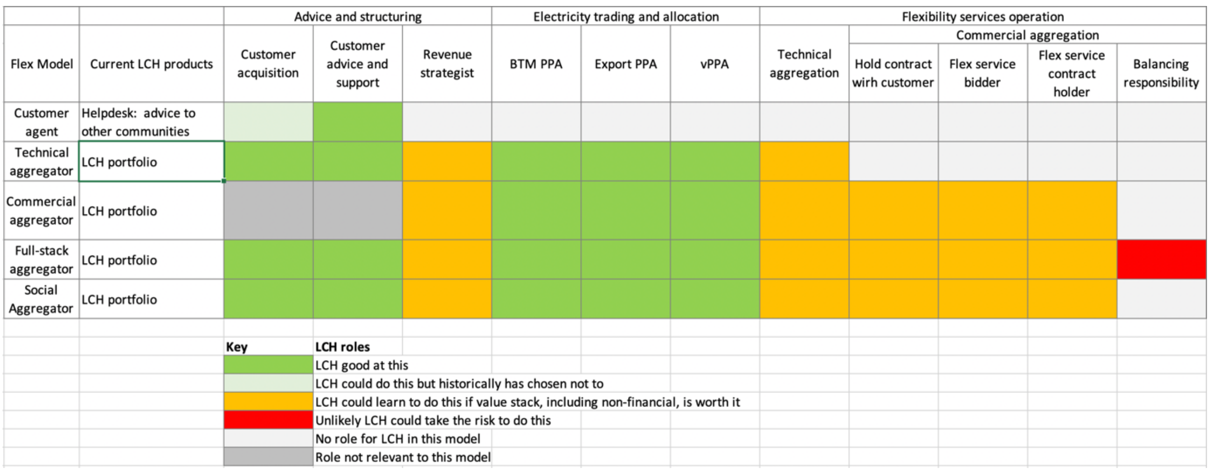


Table 14: summary of potential roles Low Carbon Hub might play in providing energy allocation and flexibility services

Nb. The UK market generally allocates the balancing responsibility to a combination of the DSO and Elexon. Where the 'full stack aggregator' role may require some balancing responsibility, we are clear that Low Carbon Hub is not well-placed to take on that responsibility

We have included the potential new role of 'Social Aggregator' in Table 14 where a route to market is provided for small assets with low levels of flexibility for owners who want to avoid the need to understand the market opportunities or to take the burden of participation. The social aggregator is a technical and/or commercial aggregator who provides market access on a not-for-profit basis using agreed shared-risk principles. The purpose of the arrangement is primarily to provide benefit: (i) to the membership on a co-operative basis; or (ii) to the community. This is a role that might particularly suit Low Carbon Hub because of our community benefit purpose, but it still poses the same questions in terms of our ability to deliver the required role on our own.

There are three main routes open to us in moving into the aggregator role and scaling up in that role: we can build our own platform and software; we can enter into a 'Software as a Service' (SaaS) contract with a platform owner or developer; or we can partner with a platform owner or developer. These routes are set out in Table 15.

In terms of the 'Build our own' route Low Carbon Hub CIC has already developed its Helpdesk product which could easily be adapted to the flex service Customer Agent role. Low Carbon Hub IPS is already in the process of building the PPS 2.0 as a technical aggregation product for our own portfolio of DERs; but there are question marks about the extent to which we could develop this product as a way of scaling up our activity in flex markets for customers outside our own portfolio. In Table 15, we suggest that this role might particularly suite a route to market where we partner with a trusted organisation whose mission and purpose are aligned with ours given the 'not-for-profit' nature of the social aggregator role and where a hybrid business model might be more appropriate for Low Carbon Hub than a fully commercial one.

Model	Current or potential LCH products	Routes		
		Build our own	SaaS	Partnership
Customer agent	Helpdesk: advice to other communities			
Technical aggregator	LCH portfolio only			
	Other community energy DERs			
	Local pool			
Commercial aggregator	LCH portfolio only			
	Other community energy DERs			
	Local pool			
Full stack aggregator	Customer			
	Commercial			
	Full stack			
Social aggregator	Customer			
	Commercial			
	Full stack			
Key				
	Likely to be, or is already, a successful product			
	A risk of failure if LCH goes it alone			
	Not relevant to this product			

Table 15: routes to developing the flex service provider models

The process we expect to follow in understanding the roles, the required competencies and therefore our suitability to fulfil them is as set out in Table 16:

Step	Summary
1. Role description	Understand and describe the role in detail
2. Skills audit	Identify the skills and competencies required to undertake the role; critical mass of people and expertise required to operate safely
3. Risks and liabilities	Identify whether there is a trusted and understandable contractual architecture; what is the nature of the risk profile; what are the liabilities needing to be covered
4. Learn from exemplars	Scan of the current landscape of providers; how much of what they say is the 'truth of the future'; who could be trusted partners; how are providers marking out territory and making products
5. Assess Low Carbon Hub IPS competencies	What are current Low Carbon Hub IPS track record and competencies; to what extent could required skills and expertise be brought in-house; to what extent could these be out-sourced; what skills and competencies are needed to be the 'intelligent customer'

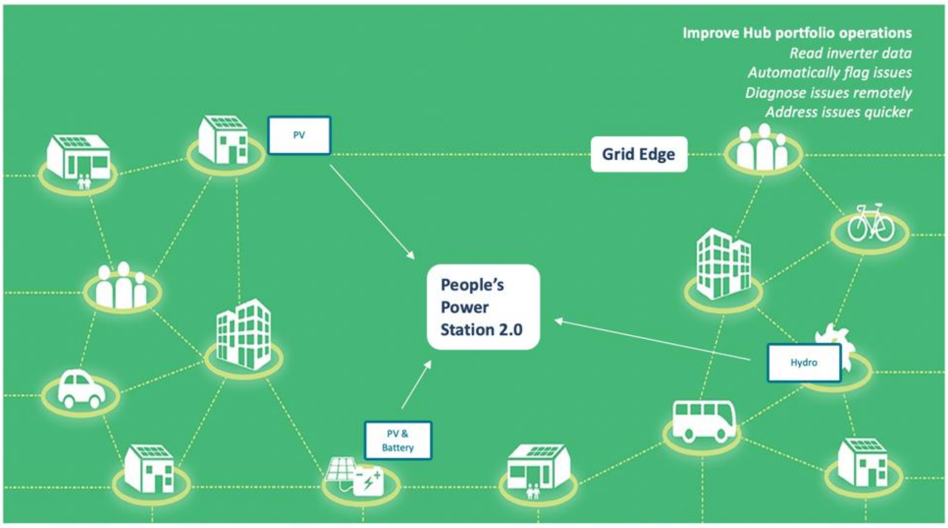
Table 16: process for understanding Low Carbon Hub roles in providing flexibility services

5.1 Future development of the People's Power Station

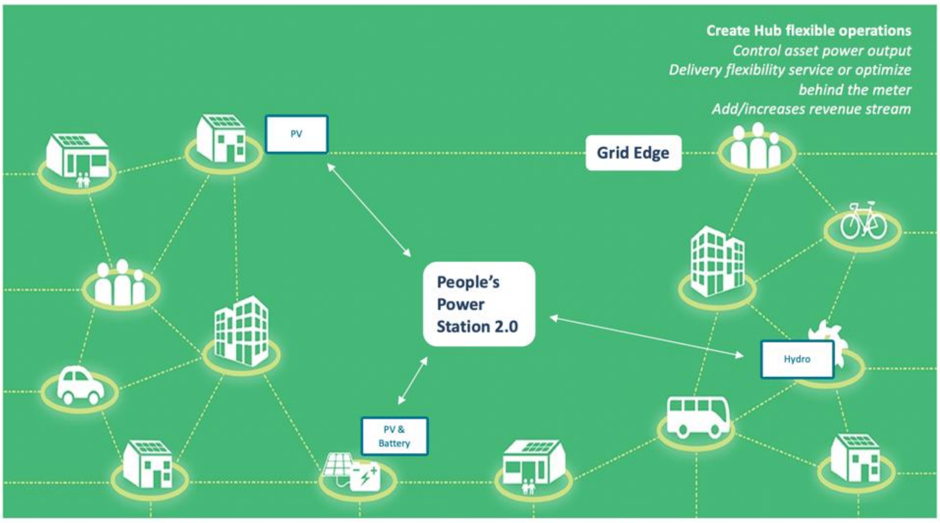
Low Carbon Hub is already in the process of developing its own technical aggregation platform. We started work on developing PPS 2.0 right at the very beginning of Project LEO when we began to understand the technical barriers to trading flexibility: DERs need to be remotely controllable and able to be scheduled remotely to be available and able to deliver flexibility services as required within the terms of a Flexibility Services Agreement with the DSO. They need, in other words, to be smart. Making a DER smart requires kit to be installed on-site that can then integrate with a scheduler and with the market, either directly or through a third-party aggregator.

The full configuration of PPS 2.0 is shown at Appendix C. Five use cases are being implemented during Project LEO that will allow the Low Carbon Hub portfolio of assets to be technically integrated with the SSEN flex market for delivery of flexibility services and could allow them to be aggregated as a portfolio for delivery of some services.

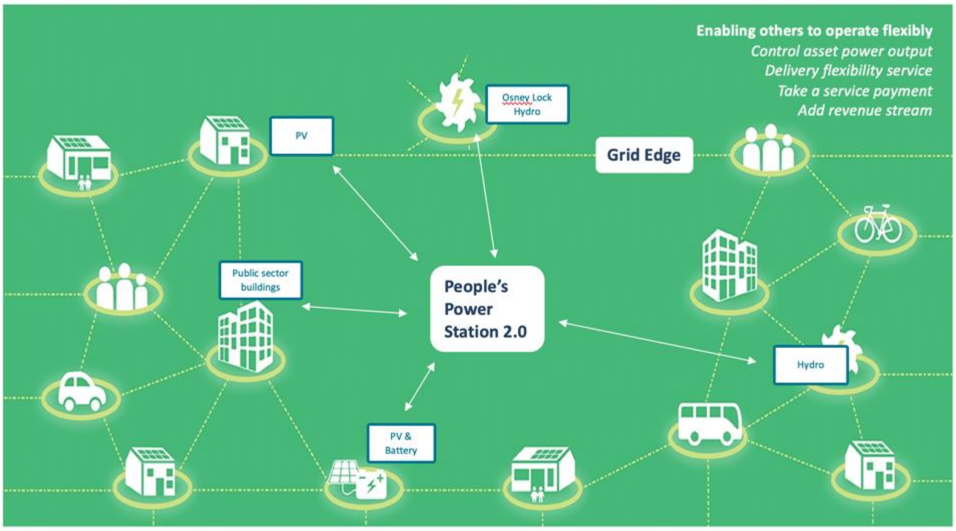
The illustrations in Figure 10 show the stages we expect to complete in developing the technical capability of the PPS 2.0, from improving the operations of the Hub portfolio through to enabling others to take part in delivering flex services and ultimately in helping many communities of small assets to take part. We expect to complete stages 1 and 2 in Project LEO so that we can assess with some practical experience what the future of PPS 2.0 could be and therefore what roles Low Carbon Hub IPS might play in technically aggregating flexibility services for others as well as ourselves. We would hope to complete some trials of stages 3 and 4 that can inform our understanding of the potential future aggregation roles for Low Carbon Hub.



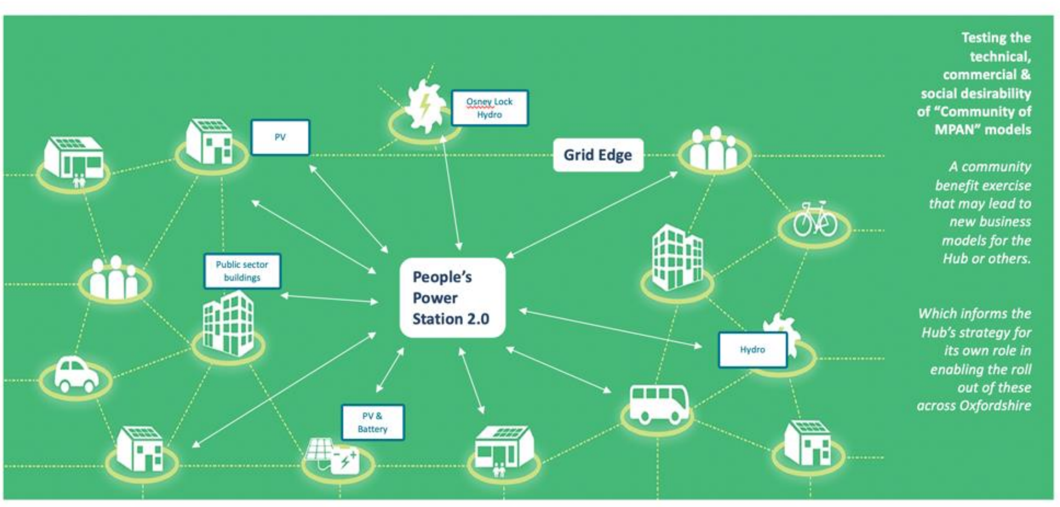
Stage 1: improve Low Carbon Hub portfolio operations



Stage 2: create Low Carbon Hub flexible operations



Stage 3: enable others to operate flexibly



Stage 4: test the value proposition for the Communities of MPANs model (see D3.8)

Figure 10: stages of development of the Peoples Power Station 2.0

As we deliver each stage of development, we will be building our understanding of the role and full value proposition if Low Carbon Hub IPS were to act as a technical aggregator since this is the business case that needs to be viable if we are to maintain the PPS 2.0 post-LEO. Figure 11 shows how this basic business model will be developed and what might be additional if we were to develop opportunities for commercial aggregation as an upside to the basic model.

PPS2.0 provides technical aggregation

Deliver our LEO commitments

Assess diagnostic data for optimized operations

New business models are either …

…"behind the meter" optimizations of existing business models, …

… involve bilateral contracting with a third-party commercial aggregator that then participates in flexibility markets within the limits of the contract, or …

… providing a service to optimize operation of others' assets (without trading in markets; e.g. city council location)

PPS2.0 enables commercial aggregation

Technical aggregation via PPS2.0 platform plus …

Business operations to sell energy or flexibility into markets.

New business models could also include being the commercial aggregator for other organizations with assets.

Figure 11: aspects of the business model for the PPS 2.0 as technical aggregator or commercial aggregator

By the end of Project LEO, we expect to have defined the business case for the aggregation models to the extent that we can either proceed with confidence or stop the project with no regrets as shown in Figure 12.

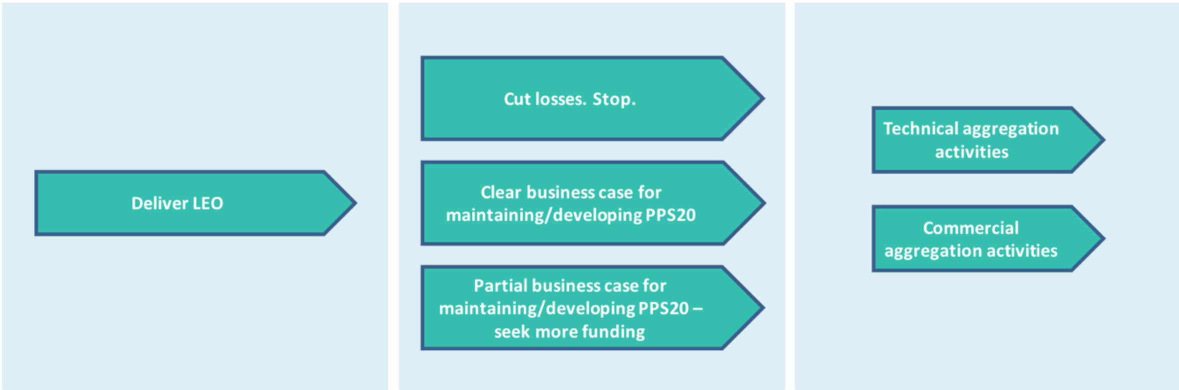


Figure 12: go/no-go decisions for PPS 2.0

5.2 Pooling energy and flexibility services

Should our experience of Project LEO suggest that there is a viable business model for PPS 2.0 as a technical aggregator, even if that business model is a 'hybrid' one where commercial revenues are supplemented by community benefit revenue, then there may be further routes to market Low Carbon Hub could explore.

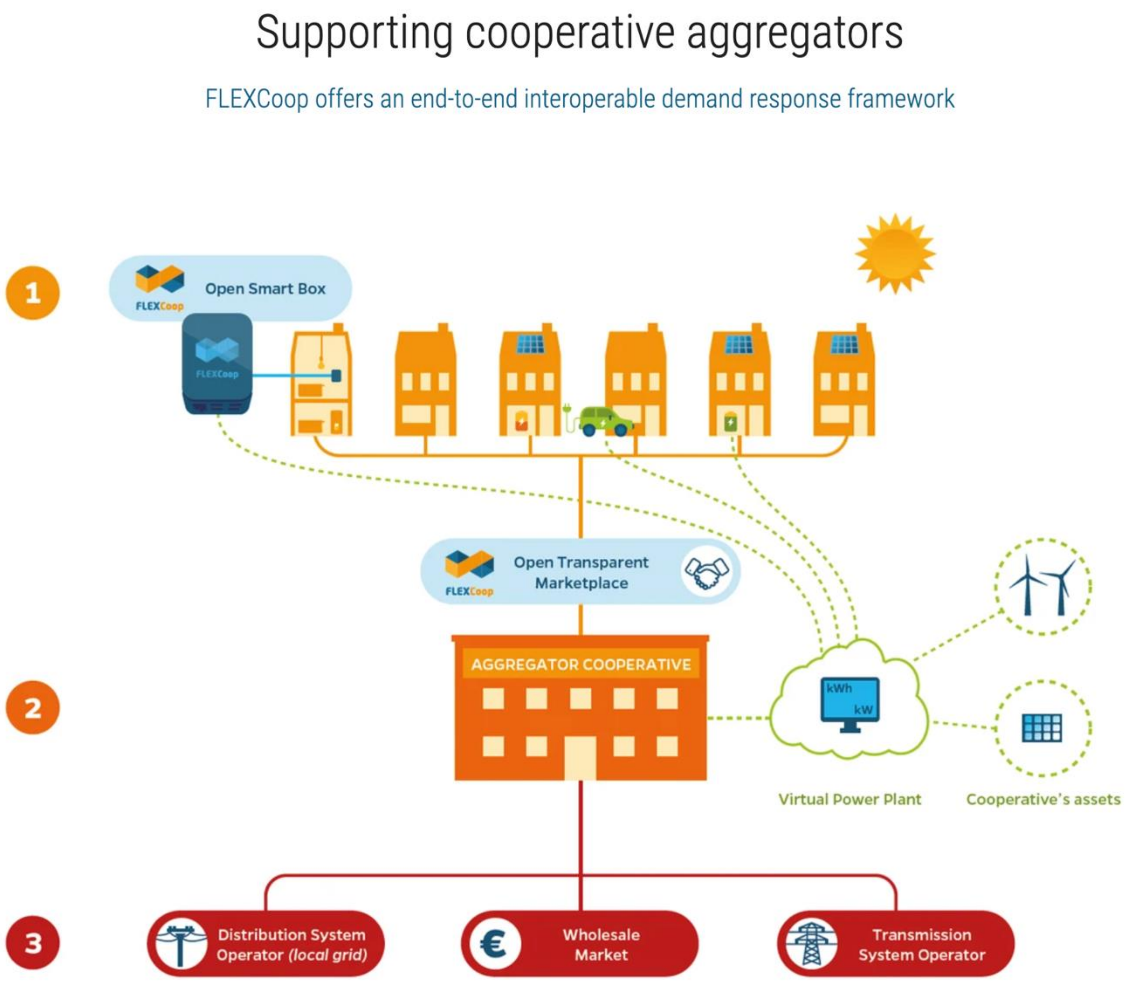


Figure 13: FLEXCoop diagram outlining their Co-operative Aggregators model

Figure 13 is from a Horizon 2020-funded project called FLEXcoop.[13] It is a picture that includes all the pieces currently being developed in Project LEO and gives a sense of the sort of system that could be developed using Low Carbon Hub assets as the core and bringing in SFN-scale[14] Community of MPAN models to create a sum much more financially, socially and environmentally valuable than the parts.

A further addition to this model could bring in energy allocation services through a sleeving pool concept that could be added to a flexibility services aggregator model. This could provide a very comprehensive set of energy and flexibility services to members of the pool, at the same time as helping the local grid to deal with congestion and constraints. Figure 14 is from a Regen study for Bristol City Council on how a Sleeving Pool might be developed.[15]

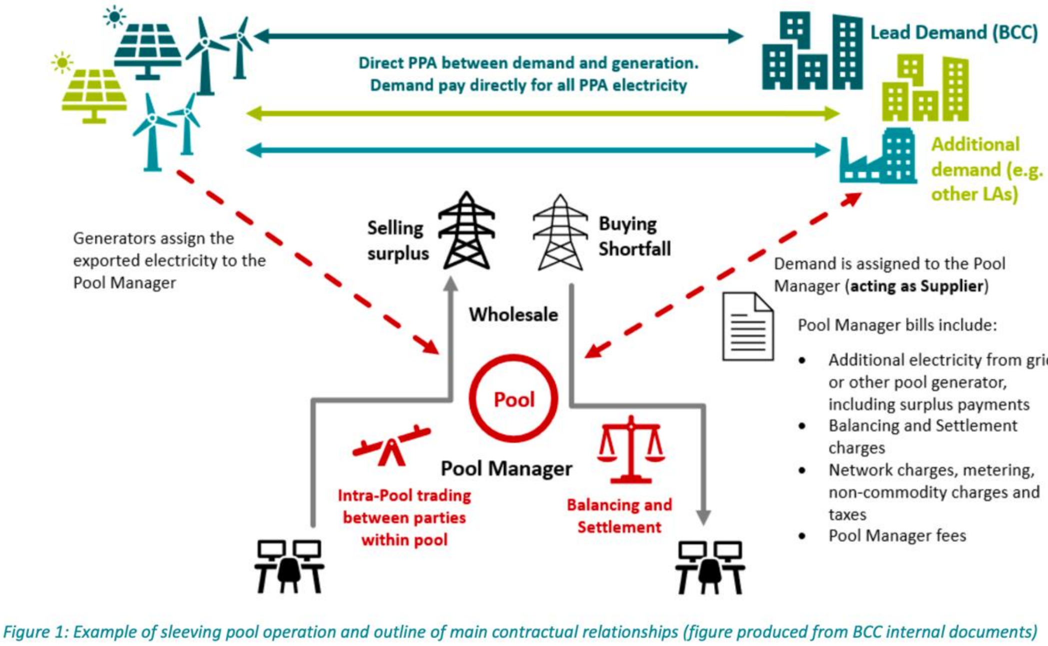


Figure 14: Regen's Sleeving Pool concept

The scale being considered in the Regen study for Bristol is already commensurate with the scale of Low Carbon Hub's own portfolio (see Table 17). The DERs included in Project LEO and currently under discussion for post-LEO partnerships with local institutions could grow this significantly. Adding financial instruments to the pooling concept through a locally networked VPPA as well as energy and flexibility services might be a further interesting addition to explore.

We will expect therefore to scope out a feasibility study, using Project LEO experience and evidence, for developing the pooling concept in Oxfordshire to include flexibility services managed through the People's Power Station. A core of large-scale assets and demand may also allow such an arrangement to include management of smaller-scale, community-led collectives as a marginal extra cost and so provide a local, Oxfordshire-wide mechanism for enabling maximum access to the new energy system.

[13] FLEXcoop: Democratising the energy market through introduction of innovative demand response tools and novel business models for energy cooperatives www.flexcoop.eu/

[14] Smart and Fair Neighbourhood – Project LEO trials https://project-leo.co.uk/our-trials/place-based-trials/

[15] Regen (February 2021) Bristol City Council – Electricity Sleeving Pool. Feasibility analysis. www.regen.co.uk/project/feasibility-analysis-of-bristol-city-councils-electricity-sleeving-pool/

Table 1: Generation portfolios modelled for the feasibility study with associated matching with BCC annual and half hourly demand.

Scenarios modelled for the study (illustrated in Figure 2)	Total capacity of generation (MW)	Total annual output of generation (MWh)	% of annual BCC demand (c. 43 GWh) met	Calculated annual surplus (MWh)	Calculated annual shortfall (MWh)
Baseline – BCC's existing generation	7.4	16,029	c. 37%	993	29,533
Scenario 1 - a mixed generation portfolio of solar and wind	23.1	44,262	c. 102%	16,360	16,667
Scenario 2 – a portfolio with predominantly new solar	28.1	43,883	c. 101%	16,052	16,738

Table 17: Sleeving Pool scenarios from Regen's feasibility study for Bristol City Council

6 Learning outcomes

The summary of learning outcomes we expect to gain through work on the Low Carbon Hub Routes to Market is shown in Table 18. We have tried to locate a clear boundary between Project LEO and subsequent potential projects and confine our learning outcomes here to what is achievable in LEO.

We expect to add to the capability assessments for each DER in our portfolio, included in Appendix A, by adding to the technical feasibility understanding of the commercial viability and social desirability of each service they could deliver.

We then expect to have constructed and tested a full business model and value proposition for operating the portfolio in a technically aggregated way through the PPS 2.0 and to have assessed the potential for Low Carbon Hub to use the PPS 2.0 for moving into commercial aggregation or into partnership for doing that.

We further expect to have produced an outline business case for two potential growth strategies for the PPS 2.0 through 'pooling' models. This work should enable us to make an informed go/no go decision on maintaining the PPS 2.0 beyond LEO, probably as a hybrid between commercial and community benefit revenues.

Through the trials we will learn	As a result we will be able to	How are we doing so far	Notes
Technical feasibility: Low Carbon Hub portfolio of DERS can deliver flex services			
What are the technical characteristics of ESO and DSO procured services	Identify which services our DERs can deliver		Using service descriptions and methods identified in D2.8 Detailed case studies in Appendix B
What are the technical characteristics of P2P services	Identify which services our DERs can deliver		Using service descriptions and methods identified in D2.8 Detailed case studies in Appendix B
What modifications are needed for existing DERs to deliver flex services	Specify technical improvements that will make our DERs able to deliver flex services		SHL gate automation, variable speed drives and full system integration implemented and used for MVSs
			Rooftop PV portfolio data sharing and automation solutions in process
What modifications are need for new DERs to deliver flex services	Specify new DERs so that they can deliver flex services		Rose Hill Battery data and scheduling implemented and used for MVSs
			Ray Valley Solar in construction and MVS+ deliverable scheduled for Feb 22

How can Low Carbon Hub DERs be technically aggregated	Deliver Low Carbon Hub DERs as an aggregated set of assets and so bid into auctions with a minimum size limit larger than any single DER		4 Use Cases in development through the PPS 2.0: LV monitoring PV rooftops SHL integration RVS integration
	Stack service delivery (coincident or adjacent) in a way that is more than the sum of the parts		We will use the methods and processes identified in D2.8
Commercial viability: the revenue stack for existing and new DERs			
What is the revenue benefit from flex services for existing DERs	Model what is the upside from delivering flex services		Existing DERs are supported by the FiT and well-known export PPAs with energy suppliers and so already have a bankable revenue stack
How to make a bankable revenue stack for new DERs post-FiT	Identify the right type of PPA and the right customers for it		The long-term PPA market in the UK is not well-developed, particularly if the life of the DER is longer than 20 years. There are a number of models that could be used.
	Model what flex services could provide to the revenue stack		From D2.8 we know that the financial value of flex services is uncertain, particularly for DSO-procured and even more so for DSO-enabled
What are the transaction costs for delivering flex services	Bid into auctions at the right price to make delivery viable		Swim lane diagrams and contracts have been produced for TP1 services (SPM and EMEC) but
What are the costs for making necessary technical improvements to DERs	Model the payback period for extra capital expenditure based on actual auction prices		Learnings in this area will be little more than anecdotal by the end of LEO given the numbers of DERs involved
What are the risks and liabilities arising from flex service contracts	Identify with our Investment Committee what the appetite is for new risks and liabilities		This has been done for new contracts associated with LEO Trials but on the basis that these are 'light touch' for the trials
What are the financial benefits and risks of the aggregator roles: technical, commercial, and social	Assess the commercial viability of the PPS 2.0 based on Low Carbon Hub DERs		Our assumption so far is that the PPS 2.0 will need a 'hybrid' business model where Low Carbon Hub community benefit is used as part of the revenue stack
	Model the amount of new assets that would need to be recruited to make the PPS 2.0 commercially viable		We may not gain all the learning we need to complete this objective; it may remain a 'thought experiment' based on extrapolating LEO experience
	Quantify the O+M benefits of the PPS 2.0		So far, we have found potential benefits in aggregating the rooftop PV but have not quantified them
Social desirability: the value proposition for Low Carbon Hub as a service provider			
What roles can and should Low Carbon Hub IPS play in the flex market	Understand what is the Low Carbon Hub IPS best role to achieve its own vision and purpose		Options assessment based on skills audit, review of exemplars and learnings arising from above. We are unlikely to gain all the learning we need to complete this objective; it may remain a 'thought experiment' based on extrapolating LEO experience
What are the gains and pains for existing Low Carbon Hub DERs	Understand what gains would be achieved and what pains avoided		Examples of gains could be: increased community benefit; O+M and admin efficiencies; learning to share with other community energy social enterprises
What are the gains and pains for new DERs			Examples of pains avoided could be: loss of agency in the new energy system; loss of control over our own data
Social desirability: the value proposition for Low Carbon Hub customers: investors and hosts/landlords			
What are the benefits and risks for existing Low Carbon Hub DERS	Understand how we can add to the 4 Ps value proposition already in place for the Low Carbon Hub investor		Eg SHL generates less energy (even though paid more) and so does not achieve as much carbon reduction
	Understand the balance of benefit from the point of view of the host or landlord		Eg SHL and benefits to the EA from better control but potential risks from storing water
What are the benefits and risks for new DERs	Understand what the risks are 4 Ps value proposition already in place for the Low Carbon Hub investor		

	Understand the balance of benefit from the point of view of the host or landlord		
Social desirability: the co-benefits of delivering the services			
Place-based	Understand the additional benefits that might arise including: - health and well-being - local jobs and active communities - biodiversity gains - public acceptance of new ways of living		This might include specific network benefits
For the wider community			This might be summarised into the term 'enabling environment' where public policy, business; and civic society are all aligned behind a vision of the future energy system and ready to say 'yes' to major changes

Table 18: learning outcomes expected

7 Conclusions

We have the following tentative conclusions to draw from the work we have done so far.

1. We are at an early stage in developing both post-FiT energy allocations service and new flex services and markets. The risks are therefore large in proportion to benefits, and so the market for developing new renewable energy DERs tends to be dominated at the moment by large developments backed by large investors. These institutions are focused on achieving a simple, trusted contractual architecture for a long-term post-FiT PPA. They will contract with aggregators to access flex markets where it is easy, simple and de-risked to do so.

2. There is, however, a very large existing, and potential, pool of flexibility in small-scale assets and the energy system will need them all to deliver flex services in the long term. Low Carbon Hub's experience in developing new small-scale assets to be capable of delivering flex services, and making its existing assets capable, should give useful insights into how the trusted, and simple, contractual and technical solutions might be developed whereby everyone at the grid edge can plug-and-play to the benefit of the energy system and themselves.

3. The technical and commercial barriers to accessing flex markets are significant, however. And the rewards are not large, given the balance DSOs have to maintain between the cost of buying flex services and the cost of upgrading the local energy network. They are obliged to deliver the lowest-cost option because everyone pays for the electricity network through our energy bills, currently about 27 pence per day. However, the need for flex or for new infrastructure is growing as we increase local renewable energy generation and make the transition to electric heat and electric transport. And so it is very important to develop highly liquid flex markets, or other forms of participation such as sharing flex at the community level. What we hope to learn from participation in LEO is:

- How to reduce the cost of participation. How to make it super-easy to participate;
- Ways in which the pricing structure could be optimised, for example dropping availability payments and increasing utilisation payments. This would make the revenue-stacking methods we outline in this paper easier to do;

- What a ‘fair’ price for flex services might be, and how DSOs might be helped by Ofgem to be able to value flex in the most holistic sense, taking into account co-benefits for the wider system and society;
- Whether ESG models developing in the finance industry could be used in the energy industry to give a premium price to portfolios that deliver environmental and social outcomes.

4. With increasing attention on ESG policy and delivery frameworks, the community energy ‘profit-for-a-community-purpose’ model suggests a potentially powerful way of aligning energy network needs, and large institutional investment goals, with benefit to the wider community. Business models will need careful development, because the community benefit society organisational model can only use profit from ‘upsiding’ existing financial models to benefit the community; investors will bear any risk but not be able to gain any additional reward.

5. There are many roles Low Carbon Hub might play in the emerging local energy and flex markets. And it is tempting to try and do them all. We have developed a process in this paper for exploring and evaluating the landscape of potential roles and routes to market as we currently understand them. We hope the learning we gain from this process will be of use to other community energy partners in the UK and internationally as we all work out how to move decisively and confidently into the zero-carbon energy transition. The most important thing, we think, is to work out how individuals and communities can have real agency in proposing solutions and promoting dialogue.

8 Recommendations

From the work we have done to date, we would offer the following recommendations:

1.1. Metering: we need a simple, trusted and universal approach to accessing smart meter data that balances data transparency and individual agency;
1.2. Export MPANs: regulation needs to support the existence of separate ownership of import and export MPANs where DERs installed behind the meter are owned by a separate entity;
1.3. P375: the ability to use individual DER meters to verify delivery of flex services is welcome. Some further work is necessary, however, to help online metering services to enable the use of the data where a physical generation meter, for example, is programmed to send its data to a third-party service. The meter and data are owned by the owner of the DER, but the third-party service operators are reluctant to enable that data to be sent both to the owner and to a flex market operator;
1.4. Trusted, understandable, simple contractual architecture: contracts as they are developing for flex markets are based on existing ESO market contracts that are designed for few, big DER owners or aggregators. These contracts are onerous for smaller actors and need some thought in developing the ‘plug-and-play’ market architecture we think will be necessary in the medium term;
1.5. Setting prices that take into account wider systems benefits and wider community and environmental co-benefits is not a straightforward thing to do. We wonder whether an Ofgem sandbox approach to the commercial and social conditions, as well as the technical conditions, is needed in order to explore these issues ‘in the wild’.

Appendices

A: Capability assessments for Low Carbon Hub DERs

A1: Rooftop PV

1. **About Low Carbon Hub's rooftop PV**

   Low Carbon Hub operate 46 solar PV installations hosted by 38 institutions across Oxfordshire, mostly on the rooves of schools and businesses. These range in size from 10.4 kW installed at Middle Barton Primary School to 813.05 kW at Crompton Technology Group. Being spread across the county, the installations are also spread across different primary/secondary substations in both rural and urban areas and some are in non-SSEN operated distribution network areas. Given the relatively small scale of most of these installations the following routes to market discussion focuses on their aggregated participation in the export peak management services and P2P trading.

2. **Implications for participation**

a. **Control of inverters**

Unlike most large-scale groundmount solar farms, which often come with dedicated control systems and sophisticated monitoring, most rooftop PV generators have limited monitoring and control capability as standard. For Low Carbon Hub sites, monitoring consists of a combination of generation and export meters to measure the energy output of the installation and calculate site self-consumption. Only on the very largest sites (Prodrive and Crompton Technology Group) was any inverter-level monitoring installed. None of Low Carbon Hub's rooftop solar PV installations have control over inverter output; however, the latest sites built with Solis inverters have Solis Demand Response Enabling Devices installed, which function as relays to prevent the installations exporting in the event of a loss of mains connection.

To participate in flexibility markets, and particularly those requiring limitation of generation, control of the inverters is a necessary first step. Low Carbon Hub are working on the integration of the rooftop solar PV portfolio into the PPS 2.0, which will act as its monitoring and control interface for all DERs. PPS 2.0 is being designed to be technology agnostic, and so in its development Low Carbon Hub are avoiding using proprietary inverter monitoring and control equipment. Given the variety in data communications technologies used by different inverter manufacturers and the range of inverter capability, it may be the case that some installations cannot be integrated (and therefore controlled) without replacing inverters with those that are capable of the control required.

The level of control required for participation in the export peak management services for both the ESO and DSO markets remains to be seen and would impact the cost of making solar PV installations 'flex-ready'. For example, if the markets require partial turndown of generation this will likely be technically more complex than total shutdown of the installation using a relay.

b. **Impact on host organisations and Low Carbon Hub**

The host organisations on which Low Carbon Hub's solar rooftop PV installations are situated benefit from the use of the solar electricity generated by these installations, with most hosts being financially better off from its use. The cost of the electricity, which is sold to the hosts by Low Carbon Hub, is usually scaled according to the price of their regular electricity supply, meaning that the hosts will make savings on their electricity by using solar electricity instead of the electricity from their regular electricity supplier.

For these organisations, many of which are schools with constrained budgets, this arrangement will save them thousands of pounds each year, in addition to their associated carbon reductions. Participation in flexibility markets requiring limitation of solar generation will naturally have a negative financial and environmental impact for the hosts of the installations that Low Carbon Hub choose to participate with.

Electricity sales to host institutions constitutes a significant proportion of the Low Carbon Hub's revenue from these installations and have a direct impact on returns to investors and the ability of the Low Carbon Hub to generate community benefit profits For participation in flexibility services requiring downturns in generation, the financial compensation must be adequate to cover the costs of lost revenue, including any compensation that may be considered for host organisations.

3. **Requirements for participating in P2P trading services**
For P2P trading, participating installations must have a Maximum Export Capacity (MEC) with which to trade. Low Carbon Hub installations smaller than 30 kW have not historically been given export MPANs due to their size, and any export revenue for these sites comes through the FiT scheme as Deemed Exports. For these and other future sites <30 kW, export MPANs must be generated, a process which as of writing remains unclear as this cannot be done through SSEN. Further clarification on the exact export metering requirements for P2P trading is needed, as – if a formal export meter with half-hourly metering is required – this will result in additional costs to solar PV owners and may impact on existing revenue (e.g. deemed exports).

4. **Alignment with flexibility services**
The following section consists of a comparison between the requirements of each flexibility service and the capabilities of Low Carbon Hub's rooftop solar PV portfolio. The requirements for each service have been taken from the Origami presentation to Low Carbon Hub of 3 March 2021 related to flexibility and the SFN projects.[16] The name of each flexibility service is given in red, amber or green, based on the suitability of the solar PV portfolio for delivering such a service.

   a. **ESO-procured services**
      i. **Balancing Mechanism**
      Requires fast delivery speed (~ 3 mins). Will require integration of solar PV into PPS 2.0 and will likely require aggregation of several sites.
      ii. **Capacity Market**
      Requires an increase in generation that cannot be provided by solar PV as it will (under normal operation) already be generating the maximum power possible given the weather conditions.
      iii. **Dynamic Containment**
      Not possible with the technology installed and the functionality of PPS 2.0.

[16] https://project-leo.co.uk/our-trials/place-based-trials/

iv. **Optional Downwards Flexibility Management (ODFM)**
Day ahead notification resulting in turn down of generation. This can be achieved but may require aggregation of several DERs.

v. **Short Term Operating Reserve (STOR)**
Requires increased power output at short notice (~20 mins). This cannot be achieved with solar PV.

b. **DSO-procured services**

i. **Sustain Peak Management (SPM)**
Solar PV installations will already be generating the maximum power for the given weather conditions so cannot increase generation on demand.

ii. **Sustain Export Peak Management (SEPM)**
May require aggregation of multiple DERs.

iii. **Secure – DSO Constraint Management (pre-fault) (SDCM)**
Requires generation turn-up so cannot be achieved.

iv. **Dynamic – DSO Constraint Management (post-fault) (DDCM)**
Requires generation turn-up so cannot be achieved.

c. **DES-enabled P2P services**

i. **Exceeding Maximum Export Capacity (EMEC)**
Solar PV would be well suited to EMEC, particularly during the early morning, late afternoon and overnight. It is also highly unlikely that a high MEC will be needed for these sites during the winter, which would couple well with assets requiring higher MECs, for example, Sandford Hydro. Long-term trading with these assets could be a possibility. During the summers, some solar PV sites could make use of additional MEC to prevent curtailment of generation.

ii. **Exceeding Maximum Import Capacity (EMIC)**
Low Carbon Hub does not have ownership over the import connection at any of its solar PV sites and so would have to trade the MIC on behalf of the site owners. Further discussion is needed about the feasibility of such an arrangement.

iii. **Offsetting**
Offsetting could be implemented for sites which may be oversized compared to their MECs, and which would experience generation curtailment during periods of peak generation.

d. **Other services**

i. **Wholesale Trading**
More information is needed on this service to understand the requirements of an asset to participate. May require aggregation.

ii. **Time of Use Tariffs**
Not relevant for this DER.

iii. **Transmission Charge Management**
Not applicable to this DER.

iv. **Distribution Charge Management**

Not applicable to this DER.

A2: Rose Hill battery

1. **About Rose Hill Battery**

   Rose Hill Battery was installed at Rose Hill Primary School in October 2020. It is a 50 kWh battery, with a maximum charging power of 15 kW and a maximum discharging power of approximately 16 kW. The school is also host to a Low Carbon Hub solar PV installation with a total installed capacity of 28.08 kW. The site has a Maximum Export Capacity of 30 kW.

   The battery is connected to Low Carbon Hub's PPS 2.0 system which sends setpoints to the battery for control and monitoring purposes. In normal operation the battery will charge off the excess energy generated by the solar PV installation, releasing the energy during periods where the school would instead be importing electricity from the grid.

2. **Requirements for performing a flexibility procedure**

a. **Charge**

For the battery to be able to deliver power on demand, it must have the sufficient charge available. This has implications for its use in fast-reaction services such as Short-Term Operating Reserve (STOR), as the battery cannot participate until it has an adequate state of charge. At the maximum charging power of 15 kW, the battery can charge to full in approximately 3 hours, which is the minimum advanced warning required to guarantee that the battery can deliver a service in time. At the maximum discharging power of 16 kW, the battery could discharge for approximately 3 hours from full charge. Therefore, 3 hours is the maximum service length the battery could provide.

As the battery will often be discharging in the afternoon/evening to utilise the stored solar electricity, the excess battery power available for a flexibility service may be lower than the maximum discharging power of 16 kW.

b. **Financial**

The size of Rose Hill Primary School (installed PV capacity <30 kW) means that the site does not have an export PPA agreement. Instead, export revenue is accrued through deemed export as part of the FiT scheme, whereby it is assumed that 50% of all solar PV generation is exported. Therefore the only revenue stream potentially impacted by flexibility services is the direct sale of the electricity to the school.

Assuming a typical electricity rate of £0.13/kWh, the discounted rate paid by the school is £0.0975/kWh. If the battery was adequately charged from the solar PV and discharged into the grid during a flexibility service, the lost revenue would also be £0.0975/kWh. In this situation, the required flexibility rate for the battery to break even would be the same as the school's discounted electricity rate of £0.0975/kWh.

If instead the battery had to charge from empty from the school's supply, the cost to Low Carbon Hub to charge the battery would be £0.13/kWh which, combined with the lost sales of the electricity to the school, would result in a total cost of £0.2275/kWh. Therefore to guarantee that the battery can deliver a service regardless of the state of charge of the battery initially, the rate paid for a turn-up flexibility service must be greater than £0.2275/kWh.

3. **Requirements for participating in P2P trading services**

   The battery itself does not have a MEC as it is situated behind the meter at the school – this is allocated to the site itself. Given that the installed capacity of the solar PV installation is smaller than the MEC, the MEC can only be exceeeded by discharging the battery. During normal operation, the battery will only discharge when the school would be importing from the grid, with the discharging power matching the site load. Therefore the site MEC will never be exceeded in normal circumstances. MEC could, however, be exceeded while delivering flexibility services during periods of high generation and low site demand. The likelihood of this occuring requires more analysis.

4. Alignment with flexibility services

The following section consists of a comparison between the requirements of each flexibility service and the capabilities of the battery. The requirements for each service have been taken from the Origami presentation to Low Carbon Hub of 3 March 2021 related to flexibility and the SFN projects. The name of each flexibility service is given in red, amber or green, based on the suitability of Rose Hill Battery for delivering such a service.

a. ESO-procured services

i. Balancing Mechanism

Requires fast delivery speed (~ 3 mins). The ability of the battery to respond to this service requires the battery having already charged and an automated methods for the battery to discharge once the ESO instruction has been received. Will likely require aggregation.

ii. Capacity Market

Delivery notice of ~4 hours allows adequate time to charge. Participation would likely require aggregation with other assets due to the small flexibility capacity of the battery.

iii. Dynamic Containment

Fast (~1 sec) response time required. Ramp rate of the battery is too slow to effectively respond to a service of this type.

iv. Optional Downwards Flexibility Management (ODFM)

If battery were empty, charging at maximum charging speed for 3 hours could be used to provide this service. May require aggregation.

v. Short Term Operating Reserve (STOR)

Requires increased power output at short notice (~20 mins). This can be achieved if the battery has the necessary charge prior to receiving the instruction to deliver. May require aggregation.

b. DSO-procured services

i. Sustain Peak Management (SPM)

The payment rate for SPM flexibility services needs to be sufficiently high to cover the lost revenue from sales to the school and cost of charging if the solar exports are low. It is unlikely that the MEC would prevent participation in this service.

ii. Sustain Export Peak Management (SEPM)

As with ODFM, the battery could charge from empty to provide this service for up to 3 hours. May require aggregation.

iii. Secure – DSO Constraint Management (pre-fault) (SDCM)

The payment rate for this service must be high enough to cover the lost revenue from sales to the school and cost of charging if the solar exports are low.

iv. Dynamic – DSO Constraint Management (post-fault) (DDCM)

More information is required on the requirements of a DER asset to deliver this service. In particular, required flex capacity and delivery speed are critical.

c. **DSO-enabled P2P services**

i. Exceeding Maximum Export Capacity (EMEC)

It is unlikely that additional MEC is necessary for operation of the battery unless the solar generation is high, site usage low and the battery is needed to deliver a generation-up flexibility service.

Could sell MEC during the winter when generation is low.

ii. Exceeding Maximum Import Capacity (EMIC)

Rose Hill School's MIC is high enough to charge the battery from the grid even during periods of high site usage. Low Carbon Hub do not have the authority to trade the school's MIC.

iii. Offsetting

The battery could participate in the service, providing either a generation upturn or downturn. In the case of a downturn (the battery charging from the grid), the revenue gained must be greater than the school's grid electricity rate.

d. **Other services**

i. Wholesale Trading

Not relevant to this DER.

ii. Time of Use Tariffs

Not relevant for this DER.

iii. Transmission Charge Management

More information is required for how this service would work with a DER of this type.

iv. **Distribution Charge Management**

More information is required for how this service would work with a DER of this type.

A3: Sandford Hydro

1. About Sandford Hydro

Sandford Hydro is a hydroelectric power plant situated near Sandford-on-Thames. It consists of three Archimedes screws, with a total installed capacity of 440 kW. The plant's generation is highly variable throughout the year, with the primary generation period between October and April, although this is highly dependent on the weather conditions. The connection agreement for the hydro includes a maximum export capacity (MEC) of 400 kW, meaning that the hydro generation can be limited during peak generation times. This gives Low Carbon Hub the potential to sell MEC in the summer and buy it during the winter.

Low Carbon Hub have an operating agreement with the Environment Agency that sets out parameters by which the plant will operate throughout the year, typically through the dictation of upper river levels that must be maintained. To prevent the hydro draining the river of water, a hands-off flow of approximately 3 m^3/s is in place, meaning that if the flow in the river is below this level, the hydro must turn off. Each of the three Archimedes screws is capable of taking a flow of approximately 8.3 m^3/s, giving a total plant flow capacity of 24.9 m^3/s. Therefore, the plant will be operating at full capacity when the local flow in the river is approaching 28 m^3/s.

As part of the MVS trials, Low Carbon Hub have explored the capability of the plant to provide on-demand flexibility in the form of generation turn-up by storing water upstream of the hydro. This can be accomplished by slowing down or turning off one or more of the screws to raise the upper river level and holding it there, before ramping the screws back up to increase the power output above what it would be generating without this storage phase.

2. Requirements for performing an active power flexibility procedure

a. River conditions

The increased power output during a flexibility event arises due to the additional flow required by the hydro to restore the upper river level to its regular operating point. It is therefore the case that to provide additional power the flow through the plant must be below 24.9 m^3/s prior the start of the storage phase. When the plant is operating at full capacity, and so the flow in the river exceeds 28 m^3/s, there is no potential for additional power output.

Sandford Hydro has been a regular participant in MVS trials since October 2020. During these trials, the river conditions at Sandford have been monitored regularly to gain an understanding of when the hydro is most likely to be available. During this period, the earliest month that the hydro was able to provide flexibility was April 2021, with the hydro having reached full capacity during October and river flows remaining high until mid-April, where the flows decreased during periods of dry weather. This is a trend that was also seen in the previous winter of 2019–20.

Naturally, there is a large amount of variation in the river conditions due to variable weather. To examine the trends over a longer time period, Figure 15 and Figure 16 demonstrate the distribution of the days when the hydro would be expected to be running at less than full capacity, based on historic river data from 2000 to 2013.

Based on this data, the months where the hydro could reliably be envisaged to have the capacity available to provide flexibility services are May – October, with a good chance of flexibile capacity also being available in April. For the typically high-flow months (November – March), there is a high likelihood of the plant being unavailable for flexibility services, with

38 of the 69 months having less than 10 days where the flow in the river was low enough. However, 21 of the 69 months had more than 20 days of the flows being low enough, demonstrating that the winter months tend to be towards the extreme ends, with either particularly low flows or particularly high flows.

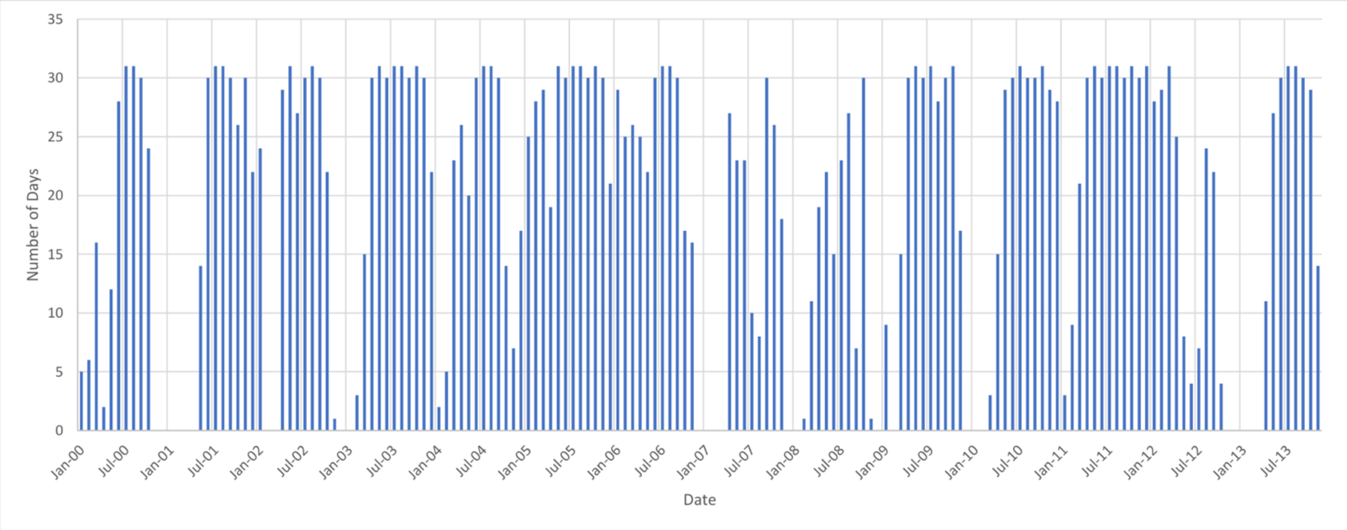


Figure 15: days during the months of 2000–13 where Sandford Hydro could be expected to be below full flow capacity

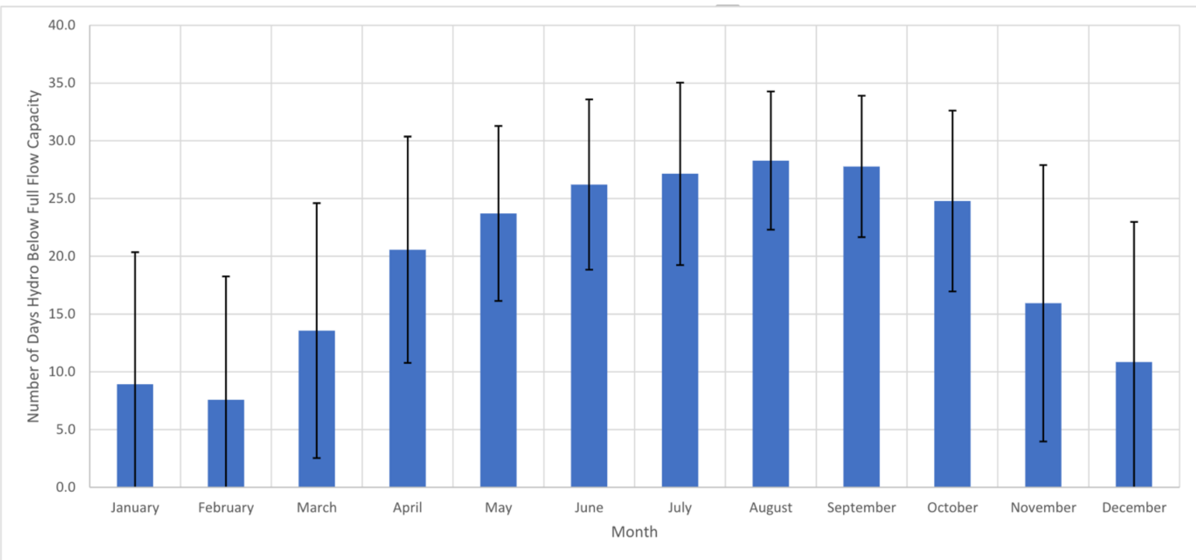


Figure 16: average number of days where Sandford would be below full capacity based on river flow data from 2000–12

The data also demonstrates that the flow conditions tend to persist for several months. In the winters of 2000–01, 2002–03, 2006–07, 2007–08, 2008–09, 2009–10 and 2012–13, the hydro would be unavailable for flexibility for more than 80% of the time. On the other hand, the historic data shows that there are some winters where the hydro could conceivably have provided flexibility services for the entire winter. Examples of this are 2005–06 and 2011–12 where the hydro would be below full capacity for more than 85% of the time.

Financial

In order to raise the upper river level and store water upstream of the plant, the hydro must reduce the speed of one or more screws. This results in a loss of revenue due to the lost generation over the storage periods, which must be at least recompensed by the flexibility service revenue. The data also shows that there is sometimes a period after the service window where the hydro power varies strongly due to large, but slow, fluctuations in the river level as a result of these sudden large changes in screw speed. These also have implications for revenue outside of the storage and delivery periods. An example of this is shown in Figure 17.

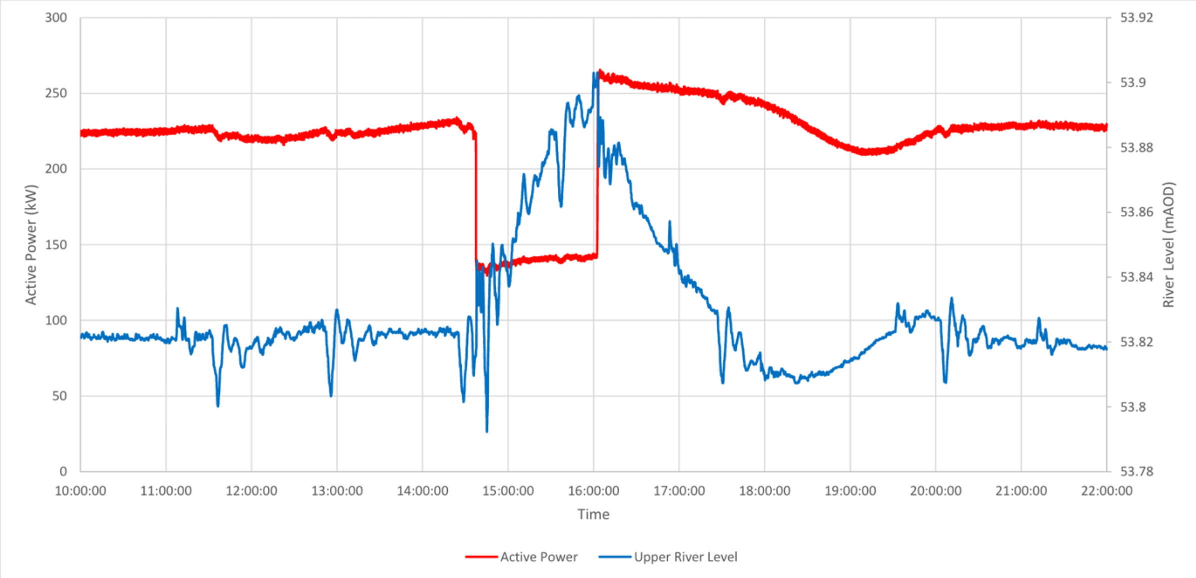


Figure 17: an example of the power output and river flow response at Sandford Hydro during the delivery of a flexibility service requiring the upturn of generation

Analysis of the three most typical MVS trials from April 2021 (the fourth included a system trip shortly after the delivery period) reveal that the average revenue gained from the flex delivery would be £8.00 (an average of 26.7 kWh for 1 hour at £300/MWh). The revenue generated from regular revenue streams (FiT and PPA sales) during the 12 hour period encompasing the service window was, on average, £577, or £48/hour. The flexibility service therefore make up a very small proportion of the hydro's revenue during these periods.

By taking a baseline of the preceding power output before the storage period, the expected revenue for each 12 hour period without a flexibility event taking place can be calculated. Based on this, the expected loss of revenue from FiT and PPA sales compared to normal operation was calculated, and therefore the rate required from the flexibility service for the hydro to break even. The results are summarised in Table 19.

	Trial 1	Trial 2	Trial 3	Average
Flex Service Revenue	£6	£6	£12	£8
FIT & PPA Revenue	£579	£596	£559	£578
Predicted Revenue Without Flex Event	£604	£614	£588	£602
Revenue Lost	£25	£19	£29	£24
Required flex rate (£/MWh)	1248	928	730	969

Table 19: revenue from active power MVS trials in April 2021. The flex service revenue is based on a flex rate of £300/MWh. The FiT & PPA Revenue and Predicted Revenue Without Flex Event are based on the 12-hour period encapsulating the flex event.

There is clearly lots of variation in the losses, and therefore the required payment rate required from flexibility services to break even. Despite this, these rates are all significantly higher than those used for the commercial MVS trials in June 2021 (£300/MWh), suggesting higher financial compensation is required for flexibility services to be viable for a DER of this type.

Requirements for participating in P2P trading services

Sandford Hydro's connection agreement states a Maximum Import Capacity (MIC) of 10 kVA and Maximum Export Capacity (MEC) of 400 kVA. With the installed capacity of the hydro being 440 kW, this leaves 40 kW of additional capacity that is potentially going unused for periods of the year, particularly during winter. Additionally, there may be periods when the plant may need more than 10 kW of power, hence would benefit from additional MIC. During the summer months, where it is unlikely that the MEC will be exceeded, the hydro could also participate in the market by selling MEC.

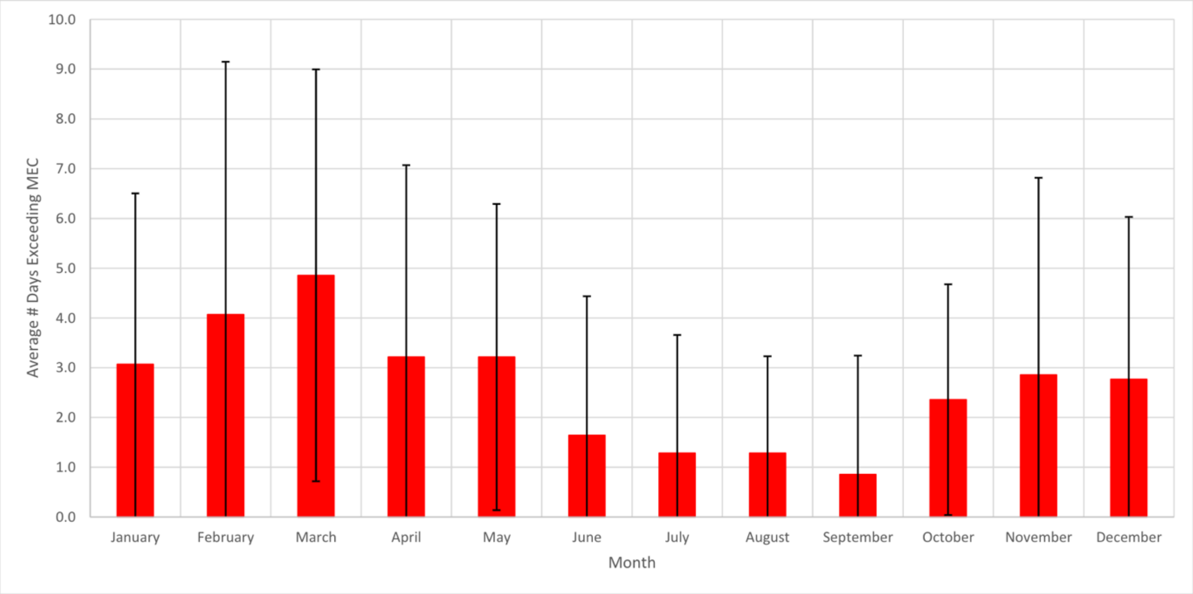


Figure 18: average number of days per month where the average Sandford Hydro power output would exceed the MEC based on historic data from 2000–13

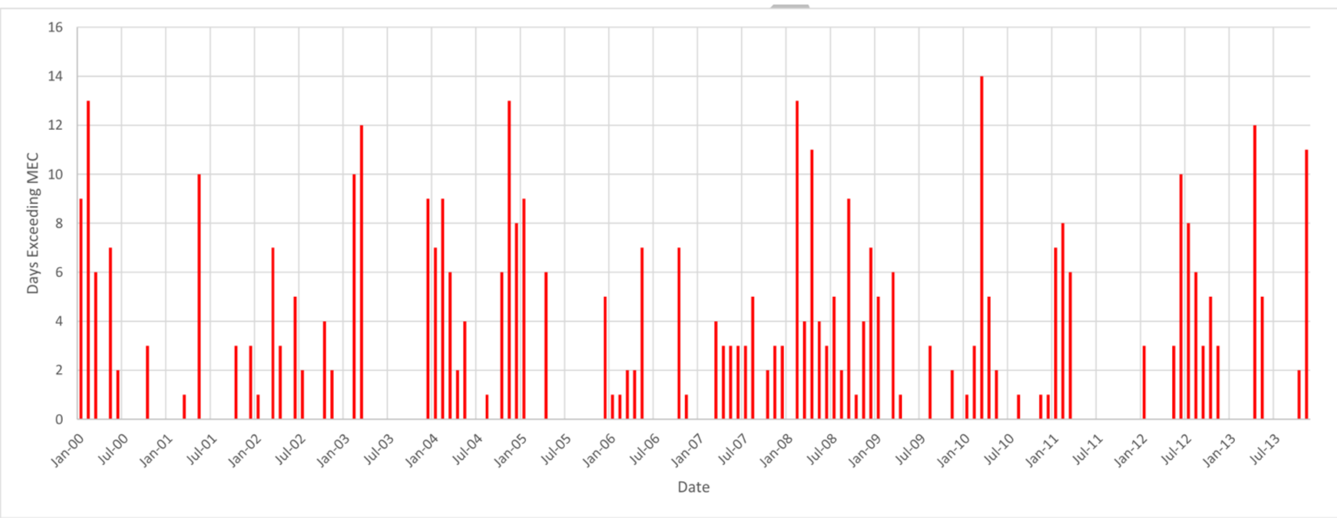


Figure 19: days during the months of 2000–13 where the average power output of Sandford Hydro would be expected to exceed the MEC

Figure 18 and Figure 19 show the number of days per month where the average power output of the plant would be expected to exceed 400 kW, based on the generation model using data from 2000–13. This shows that the hydro, on average, would expect to exceed its MEC 31 days a year, the majority being in the period November – May. The potential revenue loss due to the curtailment of the hydro generation on these days would be approximately £1,692 per year based on current FIT and PPA rates, with £1,395 of that coming from November – May. For the hydro to break even, the maximum cost of buying MEC, or paying another partner for upturn in demand during an offsetting service would be approximately £165/MW/day, assuming the requirement of 40 kW additional capacity for the months November – May (7 months).

3. Alignment with flexibility services

The following section consists of a comparison between the requirements of each flexibility service and the capabilities of the hydro. The requirements for each service have been taken from the Origami presentation to Low Carbon Hub of 3 March 2021 related to flexibility and the SFN projects. The name of each flexibility service is given in red, amber or green, based on the suitability of Sandford Hydro for delivering such a service.

a. ESO-procured services

i. Balancing Mechanism

Requires fast delivery speed (~ 3 mins). Hydro requires a storage phase and so cannot participate in this market.

ii. Capacity Market

Delivery notice of ~4 hours. Participation would likely require aggregation with other assets due to the small flexibility capacity of the hydro.

iii. Dynamic Containment

Fast (~1 sec) response time required. Hydro is not capable of this reaction speed.

iv. Optional Downwards Flexibility Management (ODFM)

Day ahead notification resulting in turn down of generation. This can be achieved but may be limited by the river conditions, as it is potentially unsafe to turn down the screws during high flows as this could lead to flooding.

v. Short Term Operating Reserve (STOR)

Requires increased power output at short notice (~20 mins). This cannot be achieved with the hydro due to the need to store water prior to delivering increased power.

b. DSO-procured services

i. Sustain Peak Management (SPM)

The potential of the hydro to deliver a sustain peak management service has already been demonstrated through the MVS process. However, the hydro is often unavailable during the winter months due to high river flows, which may cause a mismatch between the availability of the hydro and the periods of peak demand. The difficulty in predicting the hydro power output in advance could also prevent participation in long-term contracts. Whether

SPM is required between April – October needs to be understood. May need to aggregate with other DERs.
The payment rate for SPM flexibility services needs to be sufficiently high to cover the lost revenue from the storage phase of the delivery.

ii. **Sustain Export Peak Management (SEPM)**
Would require turn-down of generation. May be limited by the river conditions, as it is potentially unsafe to turn down the screws during high flows as this could lead to flooding. May need to aggregate with other DERs.

iii. **Secure – DSO Constraint Management (pre-fault) (SDCM)**
Flexibility required to address an emerging issue on the network. Whether the hydro can participate is dependent on the required delivery speed and whether the potential flexibility provided by the hydro is enough to make the service viable. May require aggregation.

iv. **Dynamic – DSO Constraint Management (post-fault) (DDCM)**
More information is required on the requirements of a DER asset to deliver this service. In particular, required flex capacity and delivery speed are critical.

c. **DSO-enabled P2P services**

i. **Exceeding Maximum Export Capacity (EMEC)**
Hydro would be well suited to MEC trading throughout the year, buying MEC during the winter (particularly November – May) and selling during the summer. The viability of this depends on how far ahead the trades take place, as there are some years where generation could be very high during the summer months, limiting the ability of the hydro to curtail generation to not exceed its reduced MEC.

ii. **Exceeding Maximum Import Capacity (EMIC)**
The hydro's low MIC of 10 kVA means that there is potential for buying MIC when the plant needs additional power, e.g. for reversing the screws for trash screen cleaning.

iii. **Offsetting**
When the conditions are such that the hydro is able to exceed its MEC, it would typically do so for several days, requiring the service partner to increase energy demand for long periods.
Could find a partner to temporarily decrease energy demand during periods where the MIC needs to be exceeded.

d. **Other services**

i. **Wholesale Trading**
More information is needed on this service to understand the requirements of an asset to participate. May require aggregation.

ii. **Time of Use Tariffs**
Not relevant for this DER.

iii. **Transmission Charge Management**
Hydro could increase demand during the Triads periods, but this will require

a storage phase, as per the SPM service. Triad periods typically occur during the winter when the hydro is at full capacity and so cannot provide flexibility.

iv. Distribution Charge Management

Not applicable to this DER

A4: Ray Valley Solar

1. About Ray Valley Solar

Ray Valley Solar is a small utility-scale (19.2 MW) groundmount solar PV plant located in the village of Arncott near Bicester. It consists of 35,906 bi-facial 535 W panels mounted on fixed frames and 82 inverters with a capacity of 185 kW each. Its generation profile will follow a predictable solar curve with a significant summer peak.

The project has an export connection limit of 13 MW. Solar farms are generally designed with a similar sizing ratio (1:1.4–1.5) to this to maximise their annual yield. Compliance with export limits is generally delivered through a static design, inverter AC capacity matching the lower figure. Ray Valley Solar has however been developed with an active design with additional AC capacity (15.17 MW), enabling it to trade additional export capacity. Low Carbon Hub will have the potential to buy MEC in the summer, sell MEC in the winter and to trade offsetting during the same periods.

The project also has a planning consent for the provision of battery storage at the site. As part of the MVS trials, Low Carbon Hub will be able to explore the added capability that different storage options could add to the plant to provide further on-demand flexibility.

The project will be constructed in 2021, with commercial operation expected in early 2022.

2. Requirements for participating in P2P trading services

Ray Valley Solar's connection agreement states a Maximum Import Capacity (MIC) of 50 kVA and Maximum Export Capacity (MEC) of 13 MW. With the installed AC capacity of the plant being 15.17 MW, this leaves 2.17 MW of additional generation capacity that will potentially be going unused for periods of the year, particularly during summer. The solar generation curve (example in Figure 20) will mean that a significant proportion of the MEC will be going unused for periods of each day across the year, and this will be particularly high in winter. The MIC is suffcient only for the operation of the plant.

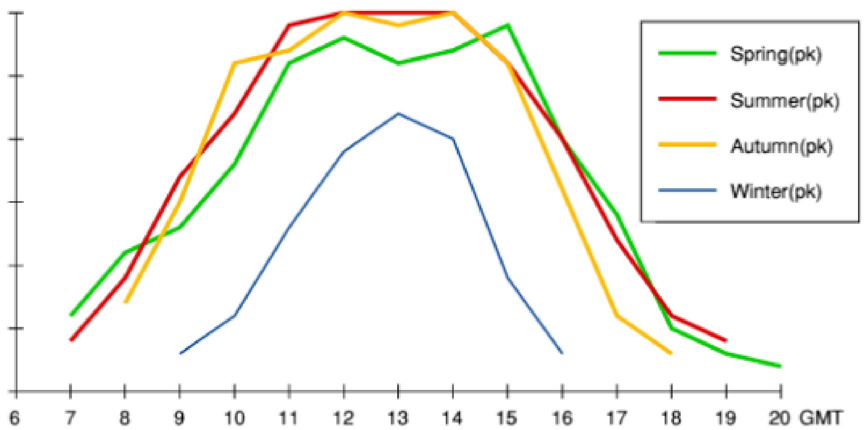


Figure 20: solar generation curve example

Trading of MEC to increase export during periods of peak generation, or to sell spare capacity during periods of low generation, will be at negligible oportunity cost to the plant and will therfore need only to exceed transaction costs to be viable. Turn up or down of the plant in line with any required operational profile to deliver MIC/MEC or offsetting is also covered within the contracted O&M services agreement and neither is anticipated to have a material impact on the lifespan of the plant.

Curtailment of the plant, reducing generation and export from the expected performance within the limits of the plants connection agreement, will impact the revenue and finacial performance for investors. Any services delivered that result in this must therefore have a potential revenue in excess of lost revenue to be considered. This oportunity cost can be calculated in near real time based on the plant's solar irradiation meters. The worst case will be £14 per minute based on the initial power purchse agreement (PPA) and peak generation.

The initial PPA agreement in place for the sale of energy provides for planned shut-downs for provision of services. For the purposes of MVS trials, these must be notified to Ecotricity in excess of 24 hours prior to delivery. In addition to the generation PPA, Ecotricty also offer a balancing market service which trades generation assets at zero commercial risk. This offer is being considered as an additional learning strand on the potential value stack of ESO and DNO services for an asset such as Ray Valley Solar.

3. Alignment with Flexibility Services

The following section consists of a comparison between the requirements of each flexibility service and the capabilities of Ray Valley Solar. The requirements for each service have been taken from the Origami presentation to Low Carbon Hub of 3 March 2021 related to flexibility and the SFN projects. The name of each flexibility service is given in red, amber or green, based on the suitability of Ray Valley Solar for delivering such a service.

a. ESO-procured services

i. **Balancing Mechanism**

Requires fast delivery speed (~ 3 mins). As noted above, Ecotricity's management of this service is being considered and the plant control system is designed to enable it to participate in this market.

ii. **Capacity Market**

Delivery notice of ~4 hours. As above, this is an expected part of Ecotricity's proposed service.

iii. **Dynamic Containment**

Fast (~1 sec) response time required. Although capable of this reaction speed, Ray Valley Solar is unlikely to be able to provide the required control.

iv. **Optional Downwards Flexibility Management (ODFM)**

Day ahead notification resulting in turn down of generation. As above, this is an expected part of Ecotricity's proposed service.

v. **Short Term Operating Reserve (STOR)**

Requires increased power output at short notice (~20 mins). This cannot be reliably achieved with Ray Valley Solar as availability would be only during limited periods of high irradiation.

DSO-procured services

i. **Sustain Peak Management (SPM)**
Ray Valley Solar is unlikely to have headroom capacity to respond when SPM is required.

ii. **Sustain Export Peak Management (SEPM)**
Ray Valley Solar is well suited to providing this service subject to the financial constraints identified above.

iii. **Secure – DSO Constraint Management (pre-fault) (SDCM)**
This service is not deemed to be appropriate for solar generation.

iv. **Dynamic – DSO Constraint Management (post-fault) (DDCM)**
More information is required on the requirements of a DER asset to deliver this service. In particular, required flex capacity and delivery speed are critical.

b. **DSO-enabled P2P services**

i. **Exceeding Maximum Export Capacity (EMEC)**
Ray Valley Solar would be well suited to MEC trading throughout the peak generation season and is designed with additional AC capacity to enable it to do so. It would have significant capacity to buy MEC during the summer and sell during the shoulders of the day, overnight and most significantly during the winter.

ii. **Exceeding Maximum Import Capacity (EMIC)**
Ray Valley Solar's low MIC of 50 kVA and asset design means that there is potential for buying MIC but only when storage is introduced to the site. The likely need for all available MIC for operate the plant means it will not have MIC to sell.

iii. **Offsetting**
When the conditions are such that the plant is able to exceed its MEC, there is significant potential for the asset to trade. This will have some long-range seasonal predictability but better visibility day-ahead so a flexible trading partner would be required.

c. **Other services**

i. **Wholesale Trading**
More information is needed on this service to understand the requirements of an asset to participate.

ii. **Time of Use Tariffs**
Not relevant for this DER.

iii. **Transmission Charge Management**
The asset's likely generation profile means that it will not be able to participate in this.

iv. **Distribution Charge Management**
Not applicable to this DER.

B: Look-up table for DSO flexibility services from D2.8

14 Appendix G – Per DER lookup table for revenues from DSO Flexibility Services

	SPM		SEPM		SDCM		DDCM	
	Utilisation	Availability	Utilisation	Availability	Utilisation	Availability	Utilisation	Availability
Nominal Value (taken from table 6)	£270/MWh	£15/MW/h	N/A	N/A	£155/MWh	£101.7/MW/h	£271.43/MWh	£15.45/MW/h
Technology [57]	Potential Value (£/MW) [58]	Potential Value (£/MW)[59]	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)	Potential Value (£/MW)
Battery Storage	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Combined Heat and Power	1080	300	n/a	n/a	620	2034	1085.72	309
Commercial Demand	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Domestic Demand	1080	300	n/a	n/a	620	2034	1085.72	309
Gensets	5400	1800	n/a	n/a	3100	12204	5428.6	1854
Hydro (run of river)	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Industrial Demand	5400	1800	n/a	n/a	3100	12204	5428.6	1854
Solar PV	2700	750	n/a	n/a	1550	5085	2714.3	772.5
Wind	2700	750	n/a	n/a	3100	12204	2714.3	772.5

[57] Colour coding system taken from Table 3
[58] Utilisation Potential Value: Green value based on 20 hours per year, Yellow value based on 10 hours, and Amber value based on 4 hours.
[59] Availability Potential Value: Green value based on 120 hours per year, Yellow value based on 50 hours, and Amber value based on 20 hours.

Table 20: look-up table for DSO flexibility services

C: PPS 2.0 configuration and use cases

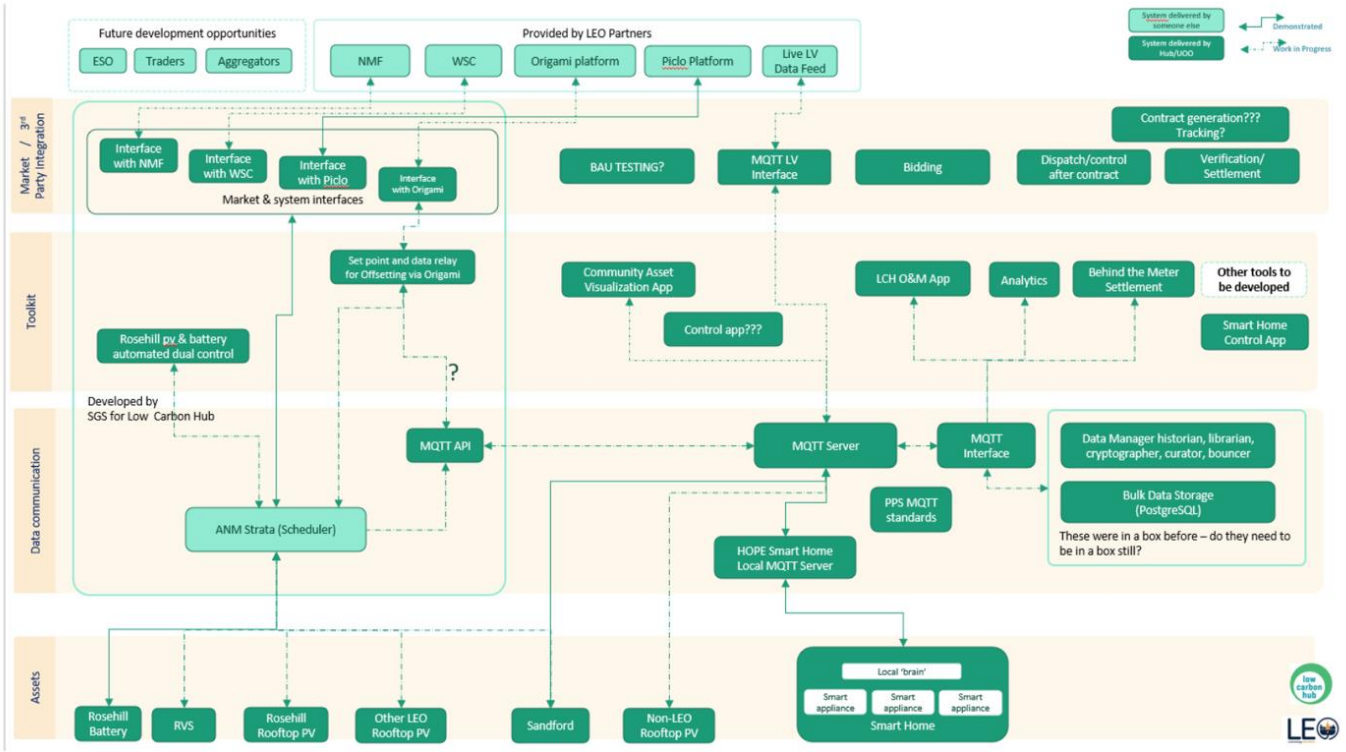


Figure 21: PPS 2.0 technical configuration: ANM Strata (left-hand side) and Internet of Things (right-hand side)

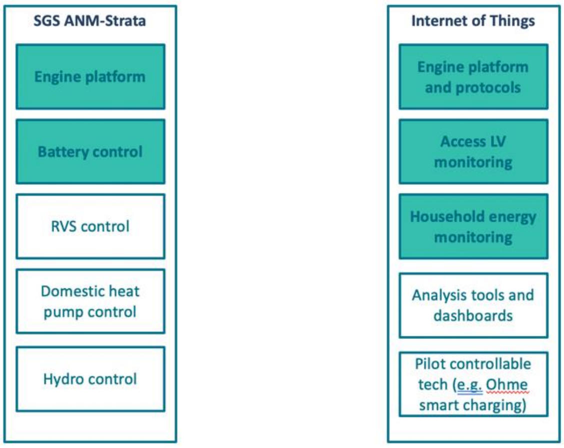


Figure 22: PPS 2.0 use cases and how they are organised by ANM Strata and Internet of Things

D: Business models and value propositions

D.1 The 'Strategyzer' Business Model Canvas: Value Proposition Building Blocks

Building Block	Description[17]
Newness	Value Propositions satisfy an entirely new set of needs that customers previously didn't perceive because there was no similar offering. This is often, but not always, technology related. Cell phones v ethical investment funds.
Performance	Improving product or service performance has traditionally been a common way to create value, e.g. improved processor speeds in laptops.
Customization	Tailoring products and services to the specific needs of individual customers or Customer Segments creates value. In recent years, the concepts of mass customization and customer co-creation have gained importance. This approach allows for customized products and services, while still taking advantage of economies of scale.
"Getting the job done"	Value can be created simply by helping a customer get certain jobs done, e.g. Rolls-Royce Royce manufacture and service their jet engines, enabling airlines to focus on running their airlines.
Design	Design is an important but difficult element to measure. A product may stand out because of superior design. In the fashion and consumer electronics industries, design can be a particularly important part of the Value Proposition.
Brand/status	Customers may find value in the simple act of using and displaying a specific brand. Wearing a Rolex watch signifies wealth
Price	Offering similar value at a lower price is a common way to satisfy the needs of price-sensitive Customer Segments. e.g.no-frills airlines design entire business models specifically to enable low-cost air travel. Cheaper products can make products affordable to whole new market segments. So value propositions are based around the provision of free services (e.g. email and online newspapers) where the 'cost' comes in exposure to advertising or data access.
Cost reduction	Helping customers reduce costs is an important way to create value. Salesforce.com, for example, sells a hosted CRM application that relieves buyers from the expense and trouble of having to buy, install, and manage CRM software themselves.
Risk reduction	Customers value reducing the risks they incur when purchasing products or services. For a used car buyer, a one-year service guarantee reduces the risk of post-purchase breakdowns and repairs. A service-level guarantee partially reduces the risk undertaken by a purchaser of outsourced IT services.
Accessibility	Making products and services available to customers who previously lacked access to them is another way to create value. This can result from business model innovation, new technologies, or a combination of both. For example, car clubs make access to car use more affordable.
Convenience/ usability	Making things more convenient or easier to use can create substantial value. With iPod and iTunes, Apple offered customers unprecedented convenience searching, buying, downloading, and listening to digital music. It now dominates the market.

[17] Taken from the article: Strategyzer support: How do I use the Value Propositions building block of the Business model canvas? Viewed 25.2.21 https://strategyzer.uservoice.com/knowledgebase/articles/1194370-how-do-i-use-the-value-propositions-building-block

D.2 Hybrid Business Model

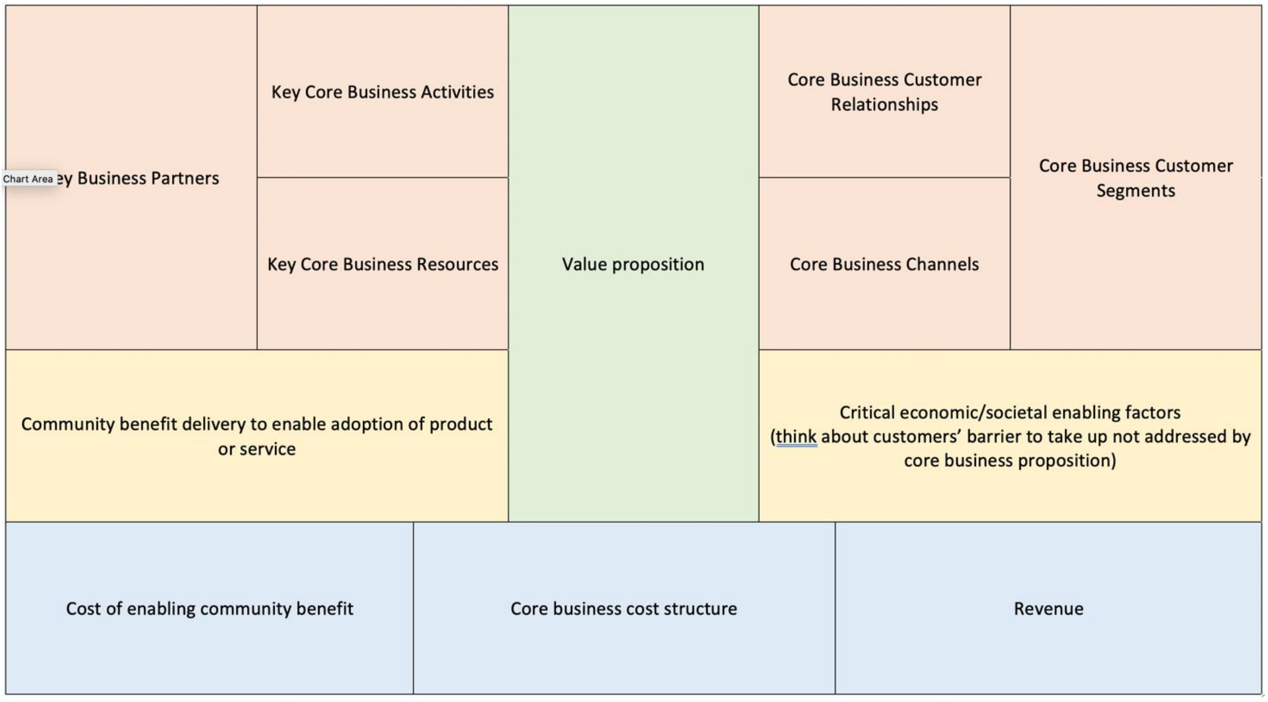


Figure 23: business model canvas for a hybrid business model

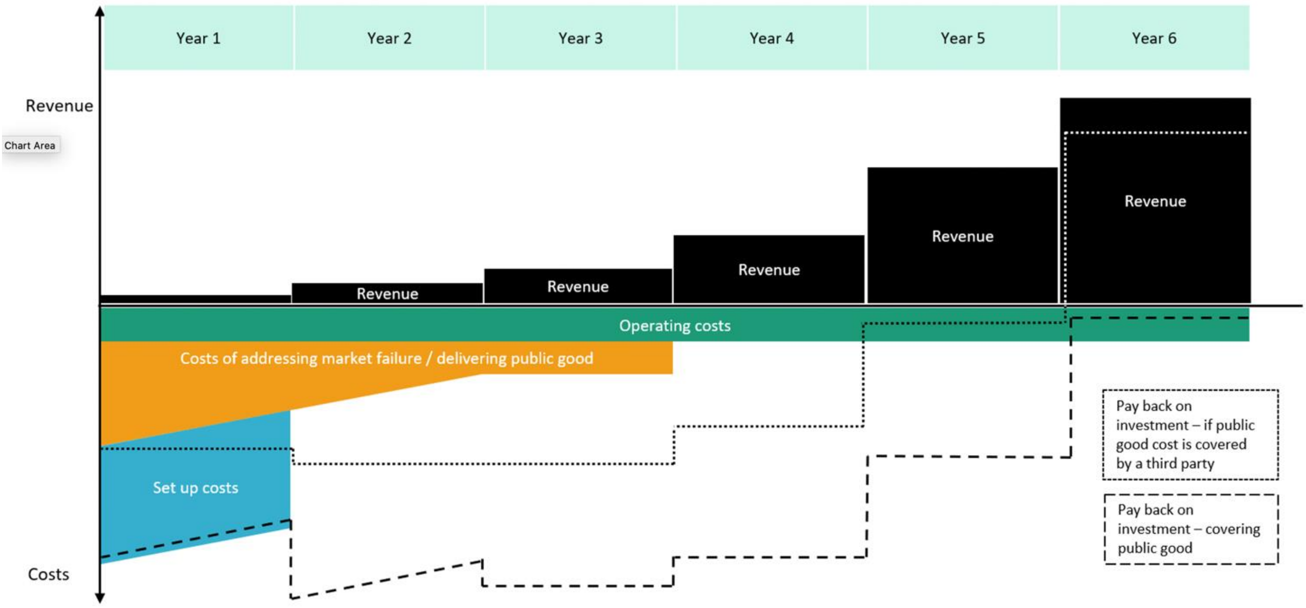


Figure 24: comparison of payback on investment in a new business model where public good is created alongside a commercial return