Energy Superhub Oxford

Report

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Environmental Change Institute eci
Department of Engineering Science
University of Oxford

Executive Summary

Energy Superhub Oxford (ESO) is a £41m demonstration project delivering innovation in smart local energy systems. As countries around the world embark on energy transitions to decarbonise their economies, decentralised and digitised solutions are increasingly important in delivering power, heat and mobility to users. Exploring options for smart local energy systems is a key UK priority.

ESO is one of three large demonstrator projects part-funded by the UK government under its "Prospering from the Energy Revolution" (PFER) programme. Work began in April 2019 and ran until March 2023. ESO's main focus has been on investment in infrastructure for energy storage, electric vehicle charging, low carbon home heating and developing innovative, smart ways of generating benefits from these for users, investors and society at large.

This report has been produced by the University of Oxford team and draws on their research findings spanning each of the major work packages: transport (including private wire and Superhub construction), decarbonising heat, and the transmission grid connected battery, its operation and carbon impact. It also includes a chapter on consortium working practices and concludes with overall learnings from the project.

Project Partners.
ESO is a consortium of six partners led by EDF Renewables (formerly Pivot Power) and including Oxford City Council, Habitat Energy, Kensa Contracting, Invinity Energy Systems and the University of Oxford.

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Transport

ESO set out to accelerate a smooth and just transition to EVs in and around Oxford. The project supported a wide range of activities that have implications for the economic, social, and environmental sustainability of the transition.

Oxford's Hackney taxis

ESO has accelerated the transition to EVs in the Hackney taxi community. Oxford's Zero Emissions Zone will ban diesel taxis in the city centre from 2025, and through ESO, Oxford City Council was able to offer licenced drivers a £5,000 grant towards the purchase of ultra-low emission vehicles (ULEV). These factors led to higher-than-expected take-up of ULEV taxis during the project. Currently, around 26 out of the 107 licenced Hackney taxis in Oxford are electric.

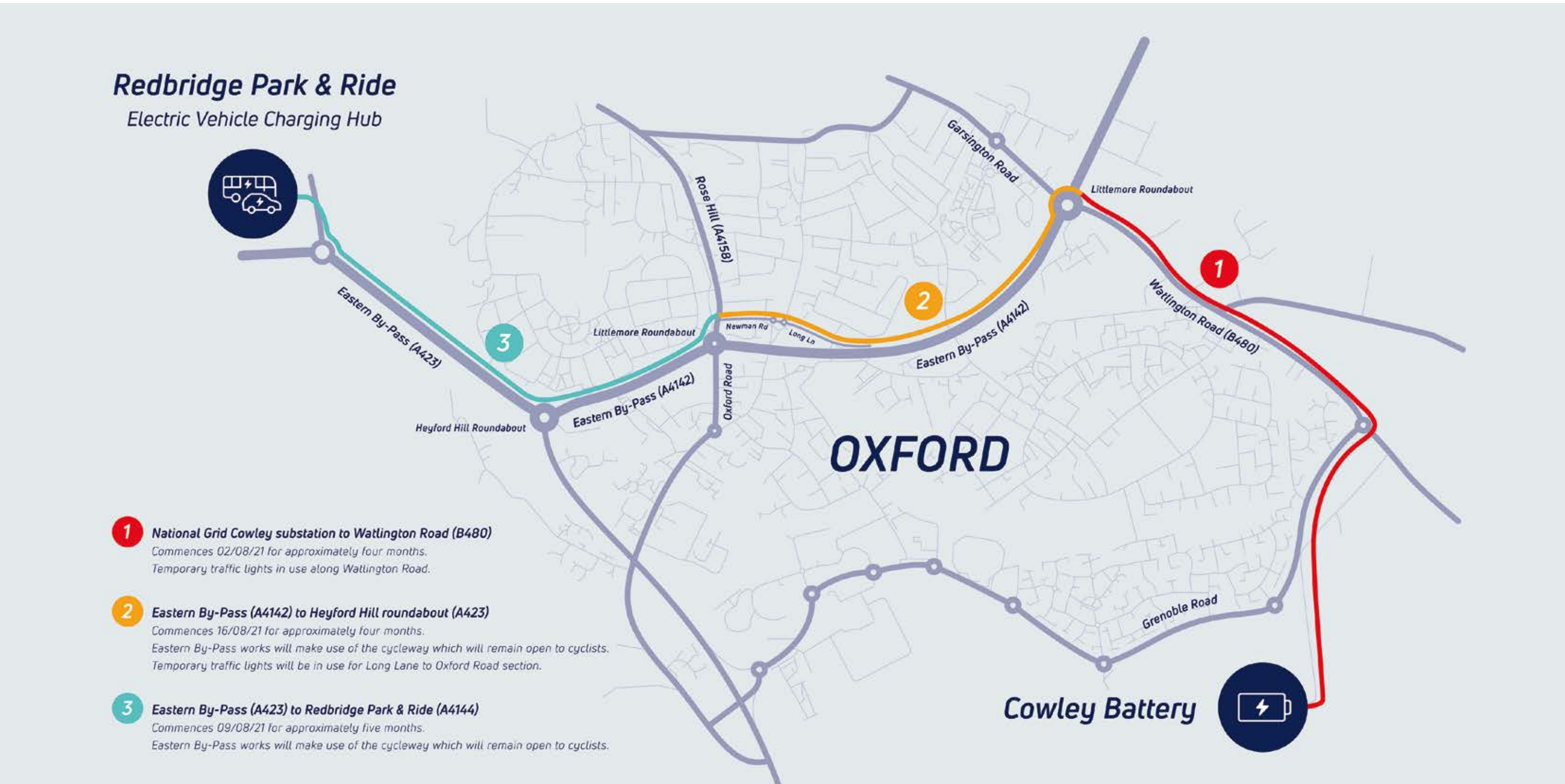
Taxi drivers are generally satisfied with the transition. They reported financial savings on fuel costs, satisfaction with the available charging infrastructure, a quiet and pleasant driving experience, and happy customers. Environmentally, the EV taxis reduced CO_2 emissions by a minimum of 60 tonnes in 2022 alone, plus reductions in other pollutants and noise levels.

However, the EV taxis' high upfront cost, the lack of local EV-specialised technicians, and the taxis' new technology constituted notable concerns to some drivers. Future grants, incentives, and training will be necessary to guarantee a just, inclusive, and smooth transition.

Private Wire and Superhub Construction

A key element of the ESO project is a 6.9 km 'private wire' cable running from the National Grid Connection at Cowley to the Redbridge Park and Ride. Due to being directly connected to the transmission network, the private wire provides large amounts of power and offers an affordable and timely alternative to distribution network connections for public and fleet EV customers. This infrastructure was constructed and is owned by EDF Renewables, whose business model is to offer capacity for large amounts of power to customers on the route.

The private wire enables the Redbridge Superhub to be the first transmission-connected charging hub in the UK, offering up to 10 MW for ultra-rapid charging. In total it currently offers 42 charging points at what is the UK's largest and Europe's most powerful charging hub, with the capacity to extend to hundreds more.



The Oxford Bus Company is committed to using the private wire to enable ultra-rapid charging of its 104 buses which will be electrified under a national scheme, with buses beginning to arrive in the autumn of 2023, contributing to Oxford's air quality objectives as well as net zero plans.

Key lessons in developing and delivering the private wire have included the need for a new and progressive charging structure to make such transmission-connected EV charging projects viable; clarifying metering arrangements for transmission connections; and many planning and construction-related learnings which can be applied in future projects.

User experiences at the Superhub

The Superhub's strategic location and its proximity to major roads plus offering rapid charging were found to be key factors that attract users of different journey purposes, distances, and socio-economic backgrounds. A significant proportion of users come from outside Oxfordshire and are familiar with other public charging stations. Overall, charging experiences at the Superhub exceeded users' expectations, including ease of payment, finding and accessing the Superhub, and the availability of rapid, fully operational chargers.

Surveys found that the Superhub had not influenced users' decisions to drive or own an EV. However, it influenced how they planned their trip routes and boosted their ability to fulfil obligatory and desired trips. The Superhub's impact on accelerating the transition to EV in and around Oxfordshire may be more evident in coming years.

Oxford Direct Services fleet electrification

ESO has accelerated the electrification of the Oxford Direct Service fleet. ESO's contribution of over £1.1m enabled the procurement of 40 additional EVs across a full range of vehicles. These EVs reduced the fleet's carbon footprint by at least 56 tonnes in 2022, plus reductions in other pollutants and noise levels. Further, the per-mile charging cost of around £0.10 was significantly lower than the per-mile petrol/diesel fuel cost of almost £0.29.

Data collection and analysis and strategic planning are essential for electrification. Fleet data collection is a resource-intensive process but will help to optimise the fleet performance in the long term and will maximise fuel cost savings and emission reductions. The availability of EV large vehicle types remains limited, hindering progress in this sector.

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Heat

ESO set out to demonstrate and test smart heat pump operation combined with time-of-use pricing to reduce running costs. Ground source heat pumps (GSHPs) were installed by Kensa Contracting in 57 social housing properties in Blackbird Leys, an Oxford suburb. A further five GSHPs coupled with heat-batteries were trialled in Sonning Common, South Oxfordshire.

User experiences

Most tenants were dissatisfied with their previous heating systems (electric storage heaters) in terms of both cost and comfort, used pre-payment meters and were on low incomes. Overall, tenants expressed high levels of satisfaction with their new heating and hot water systems, the installation process, and customer support. Several tenants reported saving up to 50% on their energy bills. General satisfaction with the systems has not been affected by the energy price crisis of 2022-23.

Funding and policy support

Heat pumps were part-funded by ESO, and partly by the Non-Domestic Renewable Heat Incentive (RHI). The cost per property was around £13,100, including drilling boreholes, full plumbing and installation, and some fabric insulation upgrades.

The business case for investing in ground-source heat pumps remains dependent on subsidy, and public funding became less reliable during the project. For instance, installations did not qualify for Energy Company Obligation funding, and the RHI ended during the project. This influenced uptake by social housing providers, and the project fell short of its initial target of 320 installations.

Flexibility

Market turmoil and technological barriers prevented real-world testing of flexibility through the retail market. There remains only one time-of-use tariff with half-hourly price settlements in the UK, and this became uncompetitive during the project. Two trials were implemented using simulated costs. These demonstrated the technical capabilities of dynamic heating, and lessons were used to improve the tenant experience.

GSHPs with heat-batteries were effectively optimised using price signals, and delivered reliable, responsive heating and hot water to tenants in Sonning Common. These units, known as ‘Kombi’ systems, do not require hot water tanks and are therefore smaller than conventional GSHPs. The success of the ESO demonstration has led Kensa to incorporate Kombi units into its strategic growth plans.

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Battery storage

Battery storage is essential for the future operation of a distributed grid. Through the ESO project EDF Renewables installed the UK's first transmission-connected battery energy storage system, opening up the transmission network to other battery storage developers, who are now applying to National Grid for similar connections.

The battery is the world's first grid-scale 'hybrid' battery, combining 50 MW/50 MWh of lithium-ion storage with 2 MW/5 MWh of a new vanadium redox flow product. By operating these two batteries together it was hoped their complementary efficiency and degradation characteristics would provide better overall performance. Unfortunately, combining the lithium-ion and vanadium flow batteries could not be fully achieved during the timescale of the project, and exploring the benefits of hybrid batteries remains a work in progress.

Battery modelling

The University of Oxford created a digital twin of the battery and undertook degradation modelling to better understand the drivers of degradation and how these can be managed. The study revealed that trading mode, while resulting in shorter battery life, offers high utilisation of the battery (i.e., energy throughput), whereas grid services mode extends battery life but leads to under-utilisation of the available battery cycles. Employing a mixed dispatch mode that combines both trading and frequency response allows for efficient use of the asset whilst maintaining a reasonable lifespan, making the most of the battery's potential under various operating conditions. It also provides an optimal return to shareholders. Grid services have been shown to be particularly profitable under current UK market arrangements and also result in lower battery cycling degradation. However, they do deliver less directly attributable energy-related carbon benefits, and arguably the battery is over-engineered for this purpose.

Battery storage represents a viable investment case for investors who understand and are willing to take the risks involved with energy trading.

Dual mode operation

The lithium-ion battery operates in two modes, both supported by a new machine learning-based Optimisation and Trading Engine, developed by Habitat Energy, which makes automated decisions as to which mode and market each element of the battery is placed in.

1. Grid services mode:

Provides balancing services such as frequency response to National Grid, enabling improved flexibility of the electricity system and ultimately greater amounts of distributed renewable generation on the grid of the future.

2. Trading mode:

The battery is used to import and export at different times of the day to optimise revenues from the spread of energy prices.

The lithium-ion battery has demonstrated strong financial returns over its first 18 months of operation, as well as insights into carbon savings associated with the different modes.

CO_2 savings from battery operation

The CO_2 impacts of the battery system have been analysed for different operation modes and carbon metrics. When applying simple 'average grid emission factors' to all power flows to and from the system, auxiliary loads and other losses appear to result in a 450 tonne CO_2/year increase in emissions. The reasons include insufficient variability in average emission factors and poor alignment between the market signals and the emission factors.

Battery operation in frequency response markets (70-80% of battery activity to date) provides valuable system services, but the carbon attributed to traded volumes is small and has not made up for the emissions attributed to auxiliary loads and losses. However, when operating in this mode, storage can displace inefficient part-loaded 'spinning reserve' gas turbine plant, giving considerable carbon benefits not included in these calculations. Inclusion of this effect shows that the battery system reduces emissions by over 15,000 tonnes CO_2/year when devoting as little as 40% of capacity to frequency response, hugely outweighing the carbon increases calculated above.

Calculating carbon savings from battery operation is complex and contested; methods for doing so require further investigation and improvement. ESO has resulted in follow-on funding for research to explore the impact on carbon emissions of the temporal and locational aspects of storage on the grid.

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Consortium working

The ESO consortium has faced myriad challenges since the start of the project in 2019, including COVID-19 and consequent working practice restrictions and global supply chain shortages, the energy price crisis, changing government and Ofgem rules and support, planning permission delays, changing ownerships of private-sector partners and delays due to fundraising exercises. Despite this, partners have worked positively and effectively together to find new solutions.

Overall impact and potential for replication

A smart, local energy system in Oxford

ESO has delivered a range of innovations, spanning power, heat, transport and storage. It has helped to demonstrate and accelerate the smart, sustainable energy transition at a local level, and many of the activities initiated by ESO will continue to grow beyond the timescale of the project. A smart, local energy system can be achieved in different ways. Compared with some **other projects** funded by the PFER programme, ESO involves greater investments in infrastructure and large-scale technology. It has exploited the synergies involved with the co-deployment of storage, power and transport innovations, although its renewable heat activities were less well integrated.

While the infrastructure and technologies deployed by ESO are geographically concentrated in and around the city of Oxford, its impact spans geographical scales: from national energy markets, to EV chargers for drivers from across the region, to electric taxis across the city, and low carbon heating in one Oxford suburb.

Routes to replication

Many of the innovations pioneered by the project are already being replicated elsewhere. EDF Renewables has already committed almost £200m of investment funding to replicate the transmission-connected model at five other sites in the UK, while Invinity is deploying the flow battery in other projects both in the UK and internationally.

ESO has demonstrated the benefits of delivering high-powered EV charging in the city of Oxford and further instances of this model, including public and fleet charging, are being sought alongside the the new EDF Renewables battery storage sites. Whilst limited to specific transmission-connection opportunities, these will be especially suitable at locations where local grid constraints hinder the roll out of high-powered EV chargers. Oxford has leveraged ESO funding to become a leader in the electrification of local authority and taxi fleets.

Lastly, the project has demonstrated the technical viability of smart-controlled heat pumps, although their deployment continues to rely on public subsidy and barriers remain to the implementation of dynamic heating in social housing.

About the authors

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