Global Observatory on Peer-to-Peer Energy Trading

UsersTCP

Responsive FLEXibility - Orkney

Author(s): Benoit Couraud, Merlinda Andoni, Sonam Norbu, Valentin Robu, David Flynn

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Key facts

Location (town + country)	Orkney Islands
Duration (start/end dates)	*January 2023 – January 2024 (actual period of the trial/demonstration) Overall, ReFlex is a 5-year project that started October 2019.*
Funding source	*UKRI – Innovate UK*
Project lead (organisation)	*EMEC (European Marine Energy Centre, Orkney)*
Project partners	*Aquatera, Community Energy Scotland, SMS, University of Glasgow, Heriot Watt University*

No. of participants	*37*
Case study type	*Proof of concept*

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Case study statistics

Parameter	As designed	As built
No. of participants	40	37
Generation (kWp)	8000	8000
Storage (kWh)	10000	0
Unit price ($/kWh)	NA	NA
Project cost ($)	8M€	8M€

Summary of case

The Orkney Islands, situated in the northern region of Scotland, boast a significant renewable energy production capacity derived from wind turbines, which occasionally face curtailment due to local grid limitations. This curtailment leads to an approximate loss of 15 to 20% of wind turbines output, predominantly owned by community entities. Concurrently, the Orkney population represents one of the most vulnerable segments in the UK to fuel poverty, attributed to rural demographics and substantial energy expenditure on transportation. Consequently, an experimental framework was formulated to capitalize on curtailed wind energy by redirecting it towards residential Electric Vehicle (EV) charging infrastructure.

This study entailed forecasting of periods of local grid constraints and heightened wind power generation, prompting 37 EV owners to connect their vehicles to the grid. During peak wind energy production intervals, the charging capacity of the EV fleet was remotely augmented to alleviate local grid constraints and harness surplus energy that would have been curtailed otherwise. Findings reveal that, on average, only 20% of EVs are actively engaged in providing grid flexibility, with a mere 16% actually in a position of increasing their charging power due to capacity limitations.

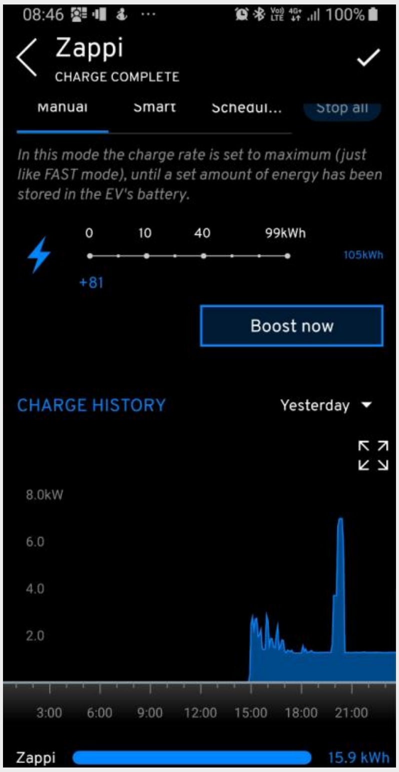
Impact highlights

- **Increase in the consumption of locally-generated renewable energy on the Orkney Islands**. This directly translated to a decrease in wind energy curtailment by the local distribution network operator, thereby affording Orkney residents the opportunity to augment their utilization of wind energy resources.
- **Mitigation of Local Grid Constraints**: By strategically boosting consumption during targeted periods in the Orkney Islands, the objective was to alleviate thermal constraints on the electricity grid. This approach involved the localized utilization of wind energy, thereby diminishing the amount of power downstream these consumption nodes.
- **Electric Vehicle Flexibility**: Participants in this experiment, comprising all Electric Vehicle (EV) owners, were equipped with remotely controllable chargers. These chargers were utilized to amplify charging power during periods of surplus wind turbine production. Consequently, an evaluation of EVs' potential for direct load control demand response schemes was conducted.
- **Enhancement of Wind Turbine Owners' Revenue**: The flexibility afforded by EV chargers facilitated the consumption of electricity that would have otherwise been curtailed. This flexibility effectively reduced wind power curtailment by the grid operator, consequently bolstering revenue streams for wind turbine owners.

Project aims and objectives

- **What problem(s) does the case study aim to resolve?** This case study addresses two primary objectives. Firstly, it endeavors to augment the proportion of renewable energy within the energy consumption mix of the Orkney Islands. Secondly, it seeks to mitigate fuel poverty in Orkney by facilitating access to low-cost energy, namely energy that would have been curtailed and thus can be distributed at a reduced price without compromising the revenue of wind turbine owners.
- **What were the social objectives (if any)?** While not fully executed, one aspect of this use case involved the establishment of a local energy market, granting consumers access to affordable energy. This initiative aimed to enable consumers to diminish their energy expenses.
- **What were the environmental objectives (if any)?** The decrease in wind turbine output curtailment directly correlated with a reduction in electricity imports from the primary grid, which typically exhibit higher carbon intensity. Consequently, this led to a decarbonization of electricity consumption for certain Electric Vehicle (EV) owners.
- **To what degree were participants actively involved in design or operation?** In this use case, 37 Electric Vehicle (EV) owners participated, granting access to their EV charger data and relinquishing control over their EV charger's power during potential curtailment periods. These participants were requested through direct messaging to connect their EVs to the grid when curtailment events were anticipated. While the initial commitment rate was high during the initial events (above 60%), it gradually decreased to a level below 30% with the escalation in event frequency.

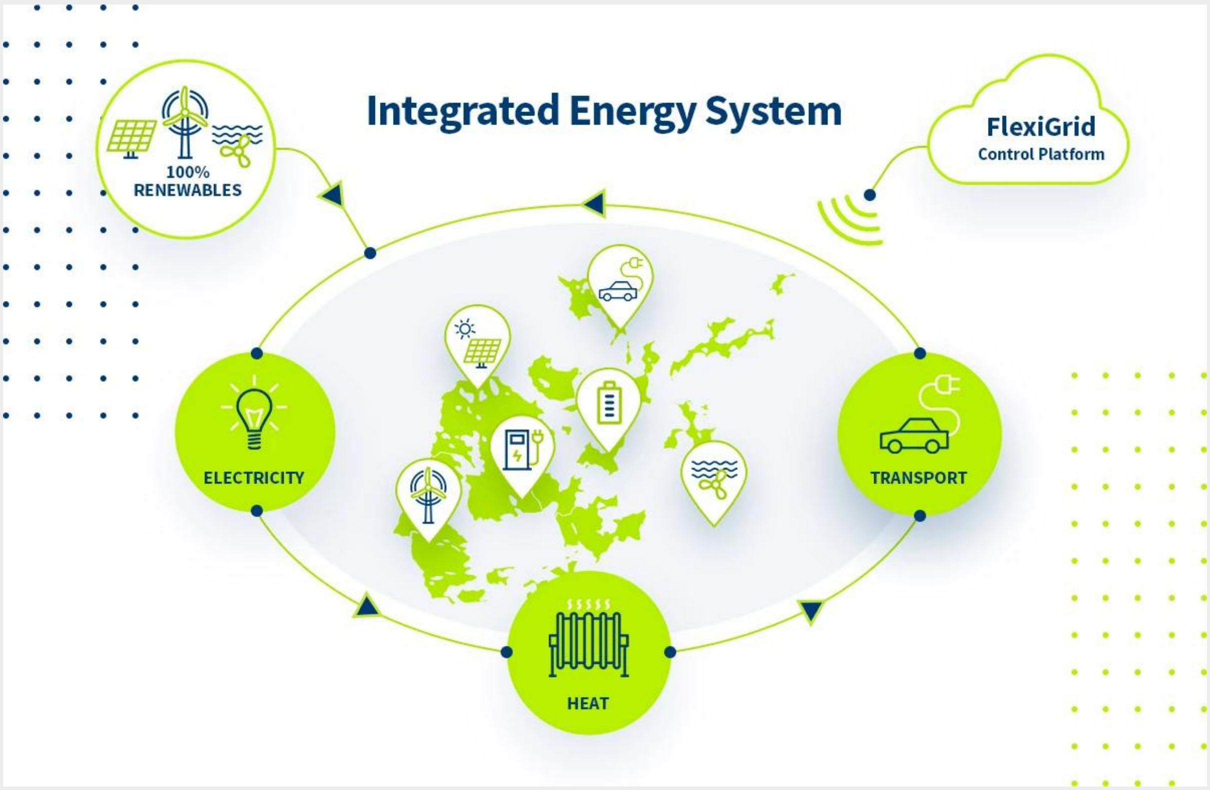
- **Was participation financially or socially incentivised or both?** No financial incentive was set-up for these experiments, which might actually explain the low participation rate when the frequency of demand response events increased.
- **What degree of demand response flexibility was provided?** In this particular use case, demand response flexibility was achieved through direct load control of residential EV chargers. However, this flexibility was contingent upon the availability and connection status of EVs to the grid. Findings indicated that by the conclusion of the experiment, fewer than 30% of participants responded affirmatively to requests for EV grid connection. Furthermore, only 16% of participants were capable of charging or augmenting their charging power, primarily due to the fact that the state of charge of the battery of other participants was full.
- **Quotes from the case study:**
    - Quote from a participant who realised the remote control was successful after an event: "*Ben, Looks like it worked. Screen shot of myenergi app attached.*"

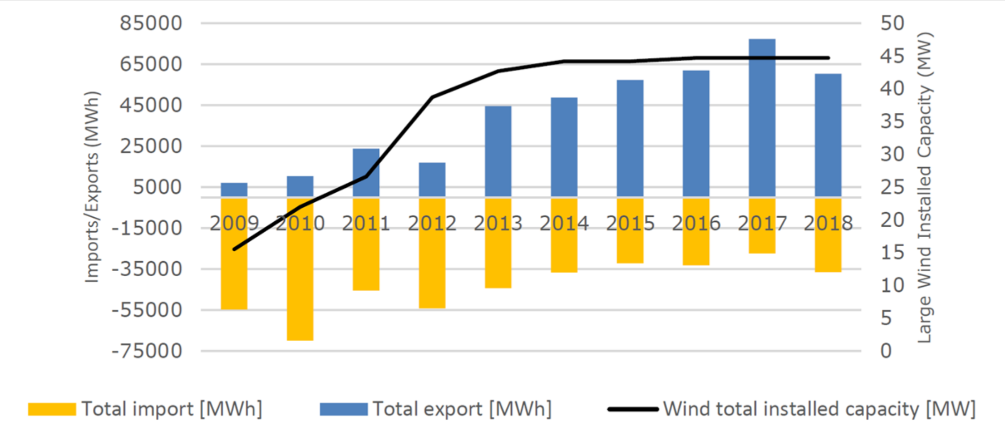


- Quote from a participant who realised that he forgot to respond to the request*: " Ben, Apologise it went completely out of my head until my wife mentioned it at 9:30pm so very sorry for that I had even written myself a note which I ignored. Happy to participate again when required. Thanks"*
- Quote with recommendations from an engaged customer: "
  Ben,
  The e-mail was a bit close to the event and the car was already charged, so I suppressed the 80% max charge setting to mobilise the battery space. If I had been a less engaged member of the public it is likely I'd have not bothered to make the space.
  The fact that it was on a Monday meant the car hadn't been used over the weekend for normal work use. If I'd known it was coming earlier then I'd not have charged up during the week and left more space.
  The idea of the text at 5pm or something would have also been useful.
  I also feel a 'thanks for participating email' to let me know it had happened would have been a good idea. Some degree of excitement and 'membership' of the event would go down well. This IS sexy stuff. We are trying to save the planet. We need to sell it to people harder and more excitedly I'd say.
  Hope this helps."

‘Example of engagement issues encountered during the trials:

“Apologise, it went completely out of my head until my wife mentioned it at 9: 30pm so very sorry for that I had even written myself a note which I ignored. Happy to participate again when required. Thanks.”


Integrated Energy System
FlexiGrid
Control Platform
100%
RENEWABLES
ELECTRICITY
TRANSPORT
HEAT



Description of case

Market value proposition and key activities

The market value proposition of the ReFLEX project consists in taking advantage of renewable energy produced by wind turbines that would be curtailed by the grid operator, if no additional demand were activated. This additional energy demand consists in Electric Vehicles connecting to the grid in order to charge at these specific times of excess production from wind turbines.

The Figure below presents the total yearly import (in yellow) and export (in blue) over the 2009-2018 period along with the total large wind turbines capacity installed (Source: *Aquatera Orkney Energy Audit 2019*).

However, the current status of the grid does not allow high level of production in some part of the network due to thermal constraints and voltage issues. Although voltage issues have been largely resolved thanks to local reactive power production and consumption, thermal issues require either a reinforcement of the grid or curtailment of excess generation. Because of the cost of grid reinforcement, it has been decided to set up an Active Network Management scheme that allows curtailment of wind turbines that cause the grid to fail. Actually, this scheme adopts a LIFO rule (Last In First Out), which means that the last wind turbines that were allowed a connection to the network are the first to be curtailed in case of an event in their geographical zone. In 2018, this led to a curtailment of 16.9% of the local wind turbines generation in MWh. Therefore, there is a strong financial incentive to set up local flexibility that could take advantage of this excess of production. This would benefit financially the local producers, but also to local consumers who could access lower electricity prices for this electricity that would have been curtailed otherwise. However, prices have not been defined within the scope of this project. The value proposition consists in distributing these extra financial gains from Wind Turbines producers to the consumers who have been flexible, with a flexibility assessed based on the participation to the direct load control requests.

In terms of business model, analysis shows that an EV with an average Orkney usage of 7,700 miles per year could deliver an additional revenue of around £100 a year by reducing curtailment of Orkney's generation capacity, assuming that electricity is valued at £150 /

MWh for generators. This value is high for typical wholesale market conditions, but a combination of current high prices and subsidy support through ROCs and FITs for Orkney renewable generators mean this is a reasonable value.

Whilst this is a potentially significant value stream, it is important to note that the revenue would need to be split between three partners: the generator whose curtailment is reduced, the operator of the smart management scheme, and the EV owners. In addition, meeting a third of an EVs annual electricity demand from curtailed generation may be tricky in the major settlements on Orkney as these are in a network zone with relatively low levels of curtailment (circa 5%). More opportunities would exist in the outlining zones where curtailment can rise to 30%.

Main activities of the project consisted in the following:

1. Setting up of the experiments, by installing flexible assets at the end-users premises (EV chargers first, then residential batteries if there is an agreement with the Distribution System Operator)
2. Forecasting of curtailment event and request to end-users to participate in a flexibility events
3. Direct control of flexible assets (EVs and residential batteries)
4. Settlement

Therefore, this project aims to control flexible residential assets such as EVs in order to consume electricity from wind turbines that would have been curtailed otherwise.

Financing/funding (who contributed funding and under what terms)

The ReFLEXproject received funding through UK Research and Development scheme whereby the UK Research and Innovation Council (UKRI) and industrial partners co-funded the study.

In addition, this study was supported by several partners, as outlined below:

1. UKRI co-funded the project.
2. European Marine Energy researchCentre (EMEC) managed the project, provided financial support, developed the peer to peer trading platform for the energy sharing and trading, as well as handled the metering, billing and commercial arrangements for the pilot participant households.
3. SMS (former Solo ENergy) provided hardware for data collection (as smart meter data was not accessible at the time).
4. Community Energy Scotland and Aquatera provided support with local community and local knowledge of the energy landscape
5. Heriot Watt University and University of Glasgow provided additional academic input during the design and development of the project as well as supported community engagement. University of Glasgow was also responsible for the development and deployment of the Responsive Flexibility experimentation with EV chargers.

Legal structure (co-operative; partnership; social enterprise; etc)

The project started as a partnership, which then evolved into a second purpose vehicle

ReFLEX Orkney Ltd that offers access to flexibility assets and affordable electricity offers. Indeed, the project has set up this ongoing organisation aiming to expand delivery of the IES over the coming years and includes the ReFLEX Experience Centre, a customer hub bringing together advice and support across all elements of the ReFLEX.
This ReFLEX Orkney initiative allows people to adhere to its scheme. Becoming a member of ReFLEX Orkney is free, granting access to ReFLEX products and services available to Orkney residents. There's no requirement to purchase any products or services to join. Eligibility requires being 18 or over.
By joining, people become a member of an innovative carbon reduction project. ReFLEX Orkney aims to assist them in understanding their energy consumption better, while they contribute to shaping the project and demonstrating how communities can establish smart local energy systems.

Timeframes including for project initiation; funding cycles; detailed design; legals and contracts; participant recruitment; trial duration; decommissioning; etc

This project was initiated in 2019 and its funding through UKRI concluded in March 2023. The project is still going on through local partners that all aim to propose solutions for decarbonisation and bill reduction of the Orkney Islands.
Participant recruitment: First, a householder energy survey returned over 2000 responses on their capacity to insulate, take part to flexibility events, etc. ; Then, ReFLEX Orkney membership has grown to circa 1,000 by the end of 2022, equal to around 5% of the total Orkney and 10% of households and active participation by around 350 of those members in delivered services population. Also, ReFLEX has supported an increase of over 200 in the number of EVs on Orkney, over 140 domestic EV changepoints, enrolled over 180 people in the local Co-Wheels car club and delivered 5 community electric vehicles. For the trials on flexibility events, a total of 37 EVs agreed to participate. The trials lasted for 4 months in a row, starting in January 2023, with ~10 flexibility events overall.

Stakeholders/project partners involved (organogram)

The ReFLEX project involved 7 partners:

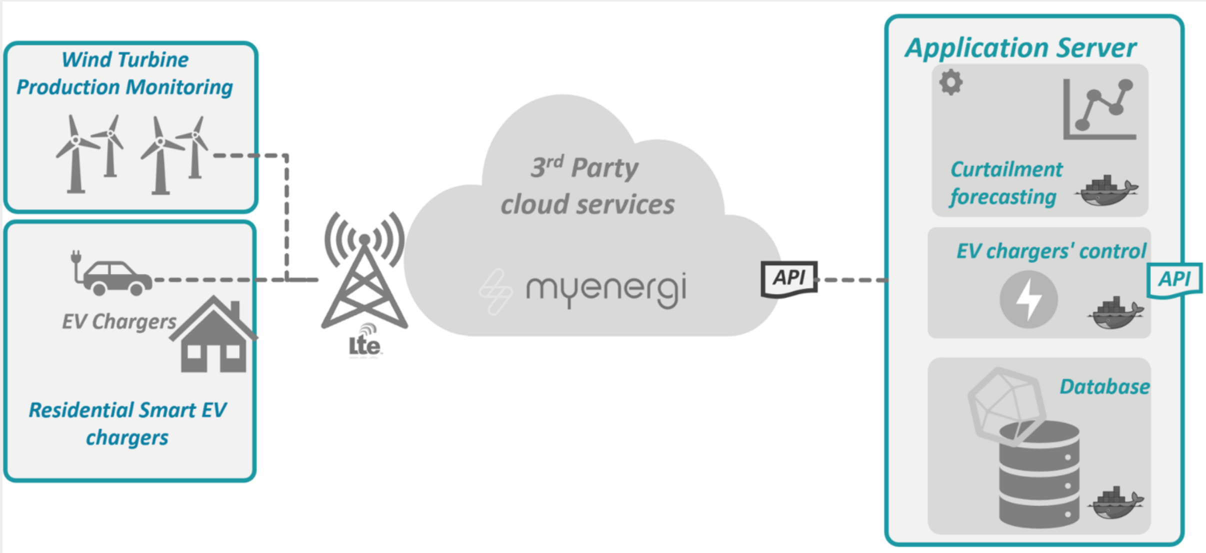
EMEC as the project leader, Aquatera responsible for local studies and electrification of transport, SMS responsible for the design of an integrated energy system plateforme, Heriot Watt, responsible for building consumption studies, Community Energy Scotland, responsible for local studies and households monitoring, Orkney Islands Council, responsible for heat studies, and the University of Glasgow, as a subcontractor responsible for the flexibility experimentation. An organogram can be found below.

<u>Participant types and characteristics</u>:
Participants to the ReFLEX experimentation and data collection were exclusively residents who took part in the ReFLEX initiative, i.e. who had a ReFLEX membership, and who were interested in contributing to a flexible energy system in Orkney. Therefore, there was no other criteria than their willingness to participate. This was made possible thanks to the integration of a dedicated ReFLEX center (a shop that was repurposed to provide local contact with residents in Orkney) and a communication campaign to make inhabitants aware of the ReFLEX offering.

Participant recruitment methods, incentives and protection:
Participants were recruited on a volunteering basis. As a result, they were not paid, and all the remote control that was done on their EV chargers was done at their own risk. They could however take back control at any time, and opt-out of the experiments whenever it was needed. For each experiment, participants were contacted by direct messaging and emails, and people could choose to connect or not their EV to their remotely controlled EV charger.

Case study functional requirements.

- **Regulatory structure and requirements (beyond compliance with existing law)**: The main requirements that had to be met during the experiment were related to data and privacy protection. A data working group was set up in order to address all the requirements from GDPR and other data-privacy requirements, and consent forms were filled by all participants.
- Stakeholder requirements (trial design requirements): the trial required to have the following aspects covered by the stakeholders:
    - Stakeholder responsible for the engagement with participants to the trial to ensure they will participate in the experiments, to let them know when experiments will be held, and to gather their feedback after experiments.
    - Stakeholder responsible for the installation of monitoring and remote control assets based at the residentials premises. For these experiments, this included the installation of remotely controlled EV chargers (Zappi chargers), the connection to the monitoring of Wind speeds and in some cases wind turbines production. This could also have included the monitoring of the grid state and flexibility requests.
    - Stakeholder responsible for software development. This included the design of AI algorithms to forecast times at which there will be over production of wind energy and thus curtailment. This also included the connection to APIs to remotely control EV chargers to increase or decrease the charging power.
- Technical architecture (representation of assets: generation; storage; control; load types (electric vehicles (EVs); heating, ventilation and air conditioning



(HVAC); small and medium-sized enterprises (SMEs); etc): Assets required to run the ReFLEX experiments included:

- Remotely controlled EV chargers,
- EVs
- Monitoring of wind turbines power production
- Server to run the several parts of the code

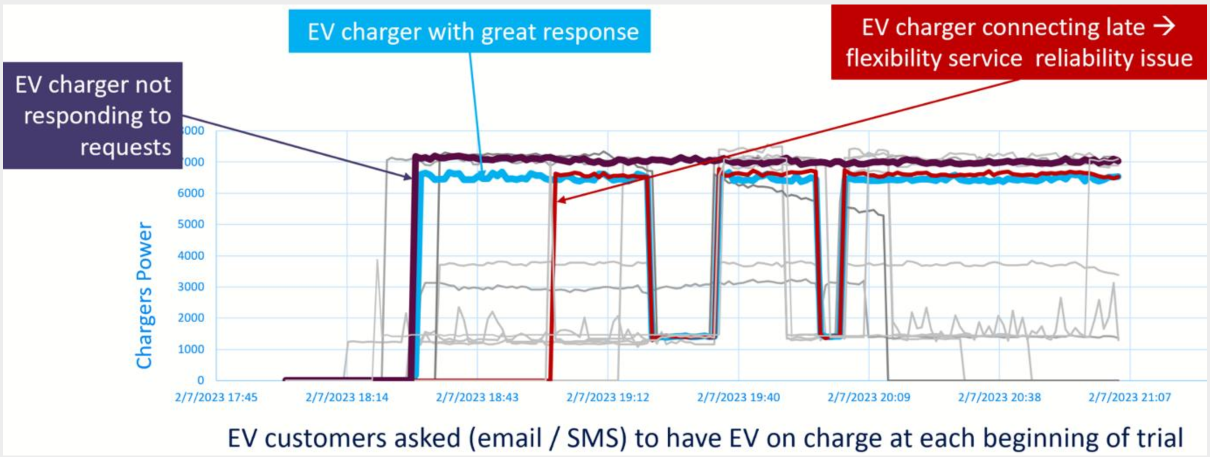
The technical architecture of the solution is presented in the figure below:

On the left hand side, the two main sources of data, that consist in the monitoring of wind speeds and thus wind turbines' production, and EV charging data. These data were collected from 3rd party providers such as myenergy that collects EV chargers data. Then, on the right hand side, all software components were deployed on a server. Each software part is deployed within a docker container to allow an easy deployment and replication process. Therefore the application server consists of a database, a forecasting tool to forecast when a flexibility event is required, and a main program that collects EV chargers' data, requests forecasts of curtailment, and controls EV chargers power. As an example, when the need for a flexibility effort was forecasted, the main control algorithm reduced all connected EV chargers' power after notification to the participants, in order to ensure that all EVs will not be fully charged at the time of the curtailment event, until right before the curtailment was triggered, at which time all EV chargers' power were increased to the maximum charging power.

- **Data architecture (including data ontology/standards where used)**: Data was saved in the same format as the 3rd parties APIs, and did not adopt a particular data model. An explanation of this data architecture is proposed in the description files of the dataset.
- **Financial model (representation of financial flows and markets)**: No markets were set up for these experiments that were executed on a voluntary basis. Participants volunteered to take part in the flexibility event, and wind turbine owners were not directly financially impacted by these experiments

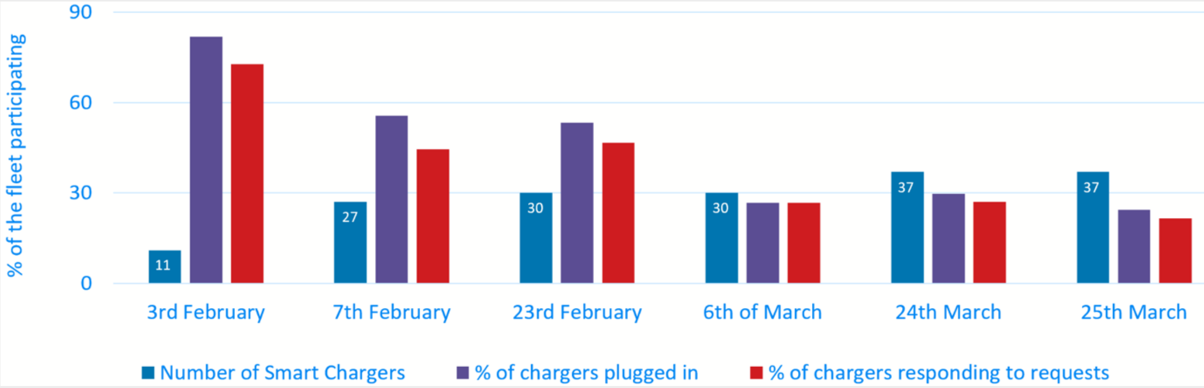
although curtailment postponing might have had an impact on the revenues of the wind turbine owners.

- **Geographical scale**: This project and experiments were limited to the location of the main Orkney Islands.
- **Governance structure (organogram)**: a data governance was implemented in



order to balance the interests of all parties of the project (local users, data providers, organisations and interested public groups). This data governance includes first a data exchange committee, second, the data exchange members, that vote body informing the data exchange committee, and third the data exchange customers that consist of any organisation that requests access to the data.

- **Electricity network ownership (public or private)**: The electricity network in Orkney Islands is operated by SSEN.
- **Management of changes in case study over time (i.e. participants leaving; assets failing; data losses; etc)** : The six flexibility events to avoid wind turbine curtailment showed that several EV chargers were not responding to remote power change requests. The figure below shows an example of responses in a specific flexibility event:



Similarly, as end users took part in the experiments on a voluntary basis, it was shown that the participation rate decreased considerably through time until reaching a constant participation rate of 25% (with no financial incentives)

Key takeaways

- Without financial incentives (or with very low financial incentives), participation rates to flexibility events stays below 25%.
- ICT (Information & Communication Technologies), software and hardware limitations prevent systems to leverage 100% of available flexibility.
- The integration of the network operator to flexibility events is critical to ensure this flexibility is actually addressing an issue and is affecting the way the way is operated.

Outcomes and achievements

What outcomes are anticipated from the pilot? This pilot aimed to demonstrate the flexibility potential from EV chargers in Orkney Islands in order to propose an alternative to wind turbine curtailment.
What outcomes were delivered by the pilot? This pilot actually showed the strong involvement of the community with 25% of participation in flexibility events, but as well showed that it will require a large scale flexibility demonstrator to have a significant impact on wind turbine curtailment in the Islands.

What was the primary goal of the project? (please tick one) *

☒ **Grid integration** - e.g. management of grid constraints; balancing of demand and supply; promote/include distributed energy resources (DER) generation; optimisation of energy behaviour to benefit system; aggregation of participant energy loads.

☐ **Environmental benefits -** e.g. promote or include renewable energy (RES) generation.

☐ **Empowering individuals** - e.g. participants have greater control over preferences; self-sufficiency (autarky); autonomy.

☐ **Local benefits** - e.g. improvement to local economy (job creation etc); independence from other regions; community as focal point for engagement; shared benefits across the community.

☐ **Creating market value** - e.g. economic incentives for participants; access wholesale, balancing and ancillary service markets.

Were there any secondary goals of the project? (please tick as many as apply) *

☐ **Grid integration** - same description as above

☐ **Environmental benefits** - same description as above

☐ **Empowering individuals** - same description as above

☒ **Local benefits** - same description as above

☐ **Creating market value** - same description as above

☐ If other, please give a brief description

Obstacles encountered when conducting the pilot

As it was mentioned, initially, ReFLEX aimed to establish a centralized platform to facilitate comprehensive management of member engagement. This platform was envisioned to seamlessly integrate commercial offerings with grant funding or affordable financing, thereby simplifying the customer journey. Such integration was envisaged to empower ReFLEX Ltd. to coordinate connections among multiple businesses, ensuring a smooth and stress-free customer experience vital for the success of Smart Local Energy Systems (SLES).

For example, a ReFLEX customer engaging in activities such as leasing an electric vehicle (EV), procuring a smart EV ChargePoint, and participating in flexibility provision through residential batteries installed at the customers premises might have needed to interact with eight distinct entities (e.g., an EV retailer, EV broker, EV finance company, Smart EV ChargePoint providers, installer, Energy Saving Trust, OLEV for grant funding, and ReFLEX Orkney Ltd).

However, the project encountered various challenges.

One of the main obstacles was a regulatory challenge. Indeed, in a constrained zone with an Active Network Management system to curtail electricity production, it was not allowed to install flexibility assets such as residential batteries at the residents premises. Indeed, installing such assets would have allowed residents to consume electricity from the batteries during events of wind turbine curtailment, which would have increased the voltage excursions on the network.

Then, warranty agreements typically necessitate direct engagement between product owners and manufacturers, requiring ReFLEX members to interface with manufacturers for any issues regarding smart EV chargers or finance companies for EV warranty concerns.

Another challenge stemmed from compliance with data protection laws and Financial Conduct Authority regulations. The implementation of a sophisticated data-driven project within a closely-knit community highlighted concerns regarding data privacy, security, and governance for ReFLEX. Many ReFLEX members and participants had personal connections with the ReFLEX team, ranging from friendships to familial ties, emphasizing the necessity for a comprehensive approach to data management surpassing mere compliance with GDPR and other regulations.

Prioritizing transparency and accountability in data handling became imperative, especially when amalgamating disparate data sets, each preserving anonymity individually, but potentially leading to the identification of individuals when combined. Consequently, the project undertook more rigorous evaluations of the merged data sets.

Finally, on the technical side, it was shown that experiments and flexibility events depend on the reliability of ICTs, on the involvement of end-users, and on the capability of the flexible assets. As an example, EV chargers that were used for these experiments were not allowed to have a charging power below 1.1 kW. Below this value, charging power had to be set to 0. These are obstacles that required another strategy in the automated remote control of distributed assets.

Key learnings for other pilots

If you were repeating the pilot project: what would you have done differently, what are your key lessons learned and key takeaways?

The ReFLEX project underscored the significance of techno-economic modeling in determining optimal asset sizes and locations, as well as relevant business models. Access to energy data and permits proved crucial, with DNO (Distributed Network Operator) restrictions necessitating alternative flexibility sources to avoid curtailment, highlighting the importance of meticulous planning in SLES (Smart Local Energy Systems) initiatives.

During the operational phase, establishing strong connections with customers and future installers is crucial for flexibility services. In ReFLEX, successful engagement was achieved with 5% of the population becoming members, thanks to parallel customer and community engagement efforts. Community involvement was ensured through various events, local communication channels, and a local shop acting as a point of contact. Future SLES initiatives could benefit from additional services like data visualization and welfare services to enhance acceptability. Initial integration into flexibility schemes in future pilots should target consortium members and customers with significant energy flexibility potential.

From the technical point of view, when selecting technology, considerations should include compatibility with end-users' needs and existing infrastructure. For instance, flexibility devices should be accessible via API for interoperability. Prior to SLES deployment, thorough testing, including compatibility testing between control signals and asset protocols, is crucial. For example, ReFLEX conducted extensive testing on residential batteries to ensure the selected technology provided accessible data and remote control capabilities, emphasizing the need for interoperability testing across SLES services.

While external operators' portals may provide access to data, ReFLEX found that employing a dedicated energy monitoring solution ensures greater accuracy and minimizes unnecessary actions. It's advisable to define requirements for data collection frequency, storage size, and infrastructure. Finally, it became evident that issues such as customer monopolization, data management, and proprietary system licensing are as critical as technical solutions. Regulation changes pose a substantial threat to SLES projects, potentially altering entire business models. Concerns regarding GDPR and personal data complexity necessitate careful attention. Legal requirements differ between individuals installing their own assets and entities installing assets for individuals, with corresponding compliance obligations. Stakeholders leasing SLES assets should prioritize building warrant agreements for added assurance.

Recommendations for policymakers

Please fill in the table below, by including recommendations for policymakers based on your experience of conducting the pilot (in particular obstacles encountered).

What?	Who?	Why- Example from case study?	How?	When?
Assets deployment should be authorised in order to use them to help balancing the system. Tools should be setup to ensure the control will not prevent the current operation of the grid, but deployment of assets is facilitated.	Grid regulator and DNOs	In this project, no residential batteries could be installed at the end users premises because of the risk that people would consume their own electricity in period of wind energy curtailment.	By involving the grid operator in the deployment of flexibility assets, and by enabling the operator to ensure that controls of assets does not prevent any of its operations.	
Enforcing an interoperability standard	Regulatory bodies	In this project, a lot of time was spent on finding and developing solutions that can interact with the remote EV charger controller. This could have been facilitated if all assets “speak” the same language such as Matter.	By enforcing an ontology for energy flexibility, such as SAREF4ENER, or matter.	
Enabling seamless local self-consumption such that energy that is produced locally can directly be consumed locally by end-users, and hence be automatically removed from the main supplier’s bill. This would enable the local energy market and would enable financial incentives to self consume electricity that would have been curtailed otherwise.	Grid regulator	In this project, there was no possibility to provide financial incentives for customers engagement in flexibility events. This could have been facilitated if there was a legal framework to set up local collective self-consumption.	By enforcing the suppliers and grid operators to simply remove from the bills the local renewable energy generation that is self-consumed locally.	

Further information

- https://www.reflexorkney.co.uk/

References

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FURTHER INFORMATION

Contact Pr David Flynn at david.flynn@glasgow.ac.uk or Dr Benoit Couraud at benoit.couraud@glasgow.ac.uk