THE DINGLE ELECTRIFICATION PROJECT: CUSTOMER FLEXIBILITY TRIAL

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Author: Ciaran Geaney, ICT Project Lead, The Dingle Electrification Project

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1 Glossary of Acronyms

A	Ampere
%	Percent
AC	Alternating Current
ADMD	After Diversity Maximum Demand
AM	Ante Meridiem: Before Noon
API	Application Programming Interface
ASHP	Air Source Heat Pump
BER	Building Energy Rating
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicle
CAP	Climate Action Plan
Cat5e	Category 5e Cable
CCS	Combined Charging System
CIO	Chief Information Officer
CO2	Carbon Dioxide
CO2eq	Carbon Dioxide Equivalent
CoAP	Constrained Application Protocol
COP	Coefficient of Performance
COVID-19	Coronavirus Disease
CP	Charge Point
CRU	Commission For Regulation of Utilities
CS	Central System
DC	Direct Current
DER	Distributed Energy Resources
DPIA	Data Protection Impact Assessment
DPO	Data Protection Officer
DSO	Distribution System Operator
EEA	European Economic Area
eHeat	Electrified Heat
EM	Energy Meter
EN	European Standards
ENA	Energy Networks Association
EPRI	Electric Power Research Institute
ERI	Environmental Research Institute
ESB	Electricity Supply Board
EU	European Union
EV	Electric Vehicle
EVs	Electric Vehicles
FSP	Flexibility Service Provider
GIS	Geographic Information System
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure

I.S.	International Standard
ICT	Information And Communications Technology
IEEE	Institute Of Electrical and Electronics Engineers
ISO	International Standards Organisation
JSON	JavaScript Object Notation
JWT	Json Web Token
km	Kilometre
kV	Kilovolt
kVA	Kilovolt-Amps
kW	Kilo Watt
kWh	Kilowatt Hour
kWp	Kilowatt Peak
LAN	Local Area Network
LV	Low Voltage
MaREI	Marine Research and Innovation Co-Ordinated by The Environmental Research Institute
min	Minutes
MQTT	MQ Telemetry Transport
MQTTS	Secure MQ Telemetry Transport
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt Hour
NNLC	National Networks Local Connections
NSAI	National Standards Authority of Ireland
NWA	Non-Wires Alternatives
OCPP	Open Charge Point Protocol
OH	Overheat
P2P	Peer-To-Peer
PM	Post Meridiem: After Noon
PV	Photovoltaics
SBC	Single Board Computer
SEAI	Sustainable Energy Authority of Ireland
SEMO	Single Electricity Market Operator
SERVO	System-Wide Energy Resource and Voltage Optimisation
SFTP	Secure File Transfer Protocol
SOC	State of Charge
SSH	Secure Shell Protocol
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TSO	Transmission System Operator
UG	Underground
UK	United Kingdom
US	United States of America
UTC	Coordinated Universal Time
V2B	Vehicle-To-Building

V2G	Vehicle To Grid
V2H	Vehicle To Home
V2X	Vehicle-To-Everything
VPN	Virtual Private Network
VPP	Virtual Power Plant

2 Executive Summary

In line with ESB Networks' vision to enable the transition of customers towards becoming active energy citizens and to facilitate the Electrification of Heat & Transport, the Dingle Project customer flexibility trials set out to better understand the impact and capability of clean energy enabling technologies and residential scale distributed energy resources in offering flexible energy services to the electricity grid.

The Dingle Project commenced in late 2018 with the testing phase of the customer flexibility trials spanning a 4-month period between October 2021 and January 2022 and involving 15 participating properties with controllable clean energy enabling technologies. The results are directly related to those 15 participating properties and electricity consumers, and conclusions should be considered with recognition of the limited scale of the trial and resulting impact on the electricity network.

Three use cases were developed to, 1) examine the impact of fixed time-based tariffs and control on customer demand by reducing or minimising energy consumption during the morning and evening peaks on the grid, 2) better understand the capability of clean energy enabling technologies to change and optimise their operation and support to the network, in response to short term, dynamic pricing signals, and 3) understand the capability of clean energy enabling technologies, both load reduction and energy storage, in responding to on-demand flexibility utilisation calls and its impact on the network.

The clean energy enabling technologies involved in the demand response scenarios were EV charging, heat pump domestic hot water heating, residential battery energy storage systems with solar PV, and a number of vehicle-to-grid chargers and compatible vehicles.

The first two use cases assessed the effectiveness of aligning demand, activated by clean energy enabling technologies, even in the absence of market-wide flexibility schemes, with periods incentivised by supplier off-peak tariffs, and highlighted the potential for new challenges for the network operator associated with managing new peaks during these traditionally off-peak periods. The second of these two use cases proved that the clean energy enabling technologies could be controlled to be responsive, on a day-ahead horizon basis, to potential scenarios, while at the same time being optimised to collectively operate in the best economic interests of the electricity consumer.

The third use case demonstrated the capability for manually triggered demand response to be provided by these residential sited technologies, for the advantage of grid operators recognising the potential that such services may evolve further in coming years. The trials also highlighted that where electricity consumers offer to provide a stack of flexibility services, that it may be necessary to set limits and thresholds on certain flexibility services such that some availability is retained for the provision of the manual demand response.

While energy storage from domestic battery energy storage systems and vehicle-to-grid provided the greatest response under the tests conducted, real-world supplier tariffs influenced the flexibility potential of EV charging and V2G. Customer energy behaviours and lifestyles also had a significant impact on the availability for demand reduction from both EV charging and V2G due to their mobile nature, as response from these technologies is not available when the vehicles are either not charging or not connected to the chargers, meaning a limited response may be available during the day.

The results from the trials demonstrated the potential of clean energy enabling technologies to deliver home energy optimisation and demand response energy services to the grid, while also highlighting the challenges, both human and technical, in implementing residential customer flexibility. The Dingle Project concluded that residential customer flexibility is not viable as a least cost, technically advantageous option to mitigate against localised LV and MV constraints at the smaller 15 kVA and 33 kVA rural transformers. It was felt that the flexible solution at this level could be undone too quickly with uptake of electric vehicles by a small number of additional customers. In contrast, it is considered that residential customer flexibility could be more suited to larger housing developments where there would be greater difficulty in implementing the physical network reinforcements and the non-wires alternative flexible solution would be expected to be workable for much longer.

3 Introduction

The Dingle Project was part of the ‘Future Customer’ and ‘Climate Action’ roadmaps in the ESB Networks Innovation Strategy [1]. ESB Networks’ vision for the future is to enable and facilitate the Electrification of Heat & Transport by maximising and developing the capability of the existing network to support its customers’ changing energy requirements and in turn enabling the transition for customers to become active energy citizens whose actions will directly impact the low carbon electricity grid of the future.

This document outlines the activities undertaken by ESB Networks in assessing the capability of clean energy enabling technologies and residential scale distributed energy resources to offer flexible energy services. The report also describes the challenges in implementing that capability and an assessment of whether these energy services truly offer a viable non-wires alternative to traditional network reinforcements when provided at a residential level. Secondary learnings from aspects of the trial such as the Electric Vehicle trial are also documented in this report.

3.1 Dingle Project Background

ESB Networks has a pivotal role to play in Ireland’s transition to a low carbon economy, powered by clean electricity. Electricity holds the key to a low carbon energy future. By removing carbon from electricity generation and electrifying heat and transport, Ireland can address a substantial portion of its carbon emissions as the country strives towards net-zero emissions by 2050 and a 51% reduction in emissions by 2030 [2].

Electricity customers will play a central role in the transition to an all-electric future. Only by understanding and responding to their needs and behaviours, will it be possible to create the energy system of the future. The learnings from new technologies deployed on the Dingle peninsula will assist ESB Networks in the development of a smart, resilient, low carbon electricity network of the future.

The Climate Action Plan 2019 [3] set out targets which were reinforced by the Climate Action Plan 2021 [4] that by 2030, Ireland would have the following mix of technologies:

- 80% of all electricity needs met using renewable energy sources;
- 950,000 EVs; and
- 600,000 Heat Pumps;

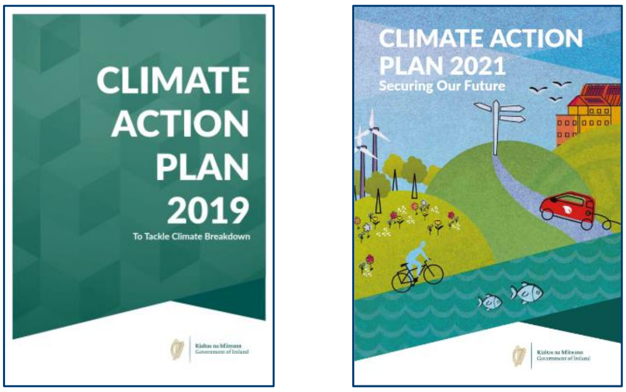


FIGURE 1 CLIMATE ACTIONS PLANS 2019 & 2021

It is forecast that the rate at which customers adopt electric vehicles (EVs) and heat pumps will increase out to 2030, and it is probable that the medium voltage (MV) and low voltage (LV) electrical network will become constrained in some areas at certain times. This will be more pronounced in rural parts of the network where an individual device consumes a larger proportion of the available transformer capacity; e.g., a single 7 kW EV charger can consume almost 50% capacity on smaller 15 kVA transformers.

The Dingle Project set out to develop a living test environment whereby real tests could be conducted to further ESB Networks' understanding of typical clean energy enabling technologies, their capabilities, behaviours, and how customer interaction with the technologies can influence the subsequent impact on the electricity network.

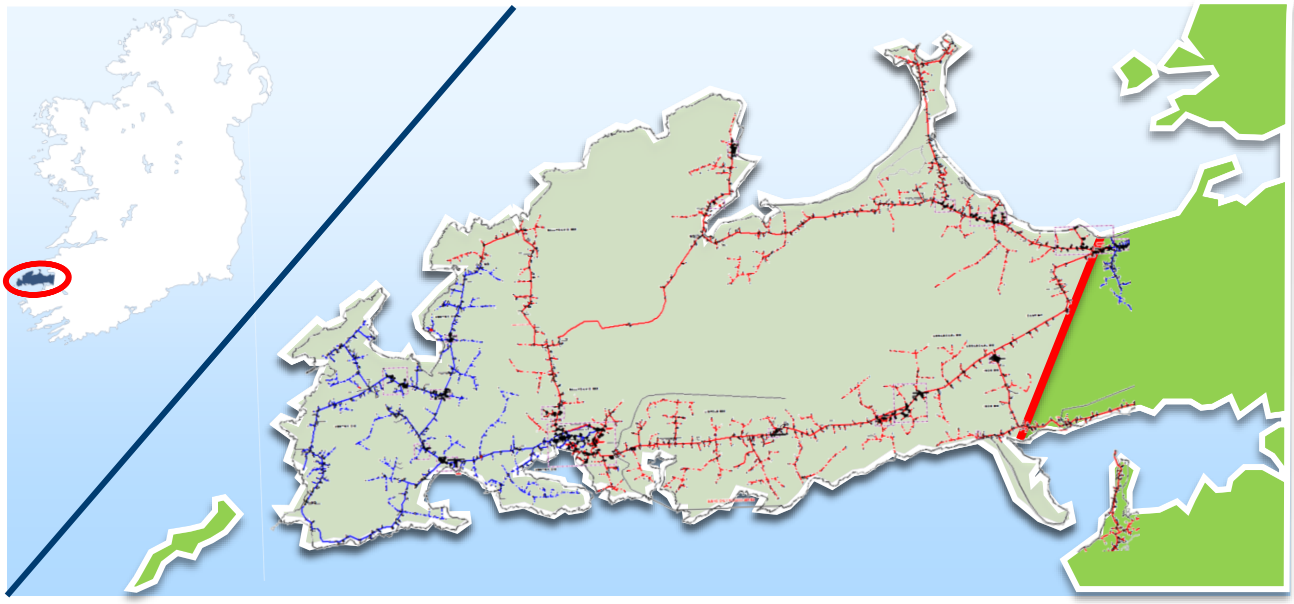


FIGURE 2 DINGLE PENINSULA & ELECTRICITY NETWORK

The Dingle Peninsula, Co Kerry, was chosen as the location for the project for several reasons including the emergence of complementary initiatives in the area focused on reducing the peninsula's overall carbon footprint. Recognising that achievement of the Dingle Project's objectives would require buy-in and collaboration at all levels of the community, it proved to be a logical decision to choose Dingle due to increasing community engagement on low carbon transformation.

The Dingle Project was established with four distinct objectives:

1. **Network Reliability:** With a societal-wide increase in reliance on the electricity network for the provision of electric power to heat homes and power electric vehicles, the Dingle Project wished to trial a number of new technologies on the overhead electricity network across the peninsula to minimise the instances of and duration of certain types of faults;

2. **Residential Customer Flexibility:** ESB Networks wished to understand the potential for clean energy enabling technologies such as electric vehicle chargers, batteries, and air-source heat pumps to be controlled in a way to minimise their impact on the electricity network and at times, be operated in a way so as to provide energy services to the Distribution System Operator. This

type of control may facilitate additional electrification of heat and transport without the immediate need for significant, physical reinforcement of the distribution network;

3. **Peer-to-Peer Energy:** The project also intended to trial one form of peer-to-peer energy services to determine the impacts, if any, that might arise on the local electricity network and to better understand the infrastructure that would be required to support such services; and

4. **Active Energy Citizenship:** Recognising the transformation in energy usage and behaviours that would be required by individual citizens to enable a low carbon society incorporating extensive electrification of heat and transport, ESB Networks was interested in better understanding some of the blockers and enablers to such a transformation. It was considered that the outcomes of this social research might help inform policy in support of wider uptake of low carbon and clean energy enabling technologies across society.

ESB Networks' National Networks, Local Connections (NNLC) programme estimates that over the coming years, it will require 50% of all EV charging technologies and 25% of Heat Pump technologies in the premises of active energy citizens to act on signals either sent directly by ESB Networks or by market agents working on its behalf to support the smooth operation of the electricity network. The learnings from the Dingle Project will be taken into consideration by NNLC as its programme proceeds and focus turns to demand side services from residential customers.

3.2 Dingle Project Reports

In addition to this report on Customer Flexibility, the Dingle Project has produced several reports detailing the learnings and outcomes of the project including some given below:

- Active Energy Citizenship & Community Engagement – an overview of the energy citizenship development strategy; engagement, empowerment and evaluation, which was implemented in collaboration with project participants and other project partners; and

- Learnings from the Peer-to-Peer Energy Trading Objective – garnered from the activities undertaken in furtherance of the P2P objective of the Dingle Project;

Each of these reports along with many other publications are available on the ESB Networks website.

3.3 Recruitment of Participants

The Dingle Project had three main headline trials (Solar PV trial, EV trial and the ambassador programme) which required willing participants to be recruited. The first group of participants to be recruited were the 5 project ambassadors. These individual and their families were selected after a long and arduous process with careful consideration to ensure a broad range of demographics were included. These households would receive the full suite of clean energy enabling technology being deployed on the project including Solar PV panels, an Air Source Heat Pump (ASHP), a residential scale battery energy storage system (BESS) and an EV Charge Point with the use of an Electric Vehicle (EV) for a year. Additional energy monitoring sensors would also be installed to provide historical and real-time metering information via a dedicated web and mobile application for the customers.

Separately, 20 additional participants were selected through a competition to be included as part of the Solar PV trial. These participants all received 2.1 kWp of Solar PV at their premises and energy monitoring sensors to provide historical and real-time metering information via a dedicated web and mobile application. It was initially intended that these participants would take part in the Peer-to-Peer (P2P) energy trial but unfortunately that element of the project did not proceed.

For the EV trial, a further 10 participants were selected from over 350 applicants. Several criteria were used to aid the selection process, but it was important that their typical driving patterns would result in a minimum number of kilometres being completed each week. Additionally, it was important to have people from all demographics and areas of the Dingle Peninsula in order to fully assess the different requirements customers have for EV charging and to better understand how that impacts the demand on the electricity network.

Imagery and map data from ESRI/ArcGIS

FIGURE 3 OVERVIEW OF DINGLE PENINSULA & PARTICIPATING SITES

When the Dingle Project was originally conceived in 2017, consideration was given to establishing a concentration of trial participants on one part of the network. It was thought that it would have been technically advantageous to have had participants clustered together such that the stresses on the electrical network could have been assessed. However, recognising the project’s other objective of better understanding how active energy citizenship could be developed across the peninsula, for which this clustering was not considered advantageous, a peninsula-wide recruitment process was established. The dispersed distribution of trial participants across the Dingle Peninsula was considered more likely to support wider local community engagement and dissemination than would have been the case under a more concentrated, clustered arrangement.

4 Dingle Project – Customer Flexibility Objective

ESB Networks will need to develop the network to facilitate participation of customers in future flexibility services or markets. It is forecast that there will be a significant amount of demand side response capability in customers' premises by 2030. This will require investment in new control systems and assets to allow future Demand Side Response, even at domestic level, to offer various flexibility services to the energy system in Ireland. Domestic and network level control technologies will be important in delivering a network with sufficient capacity and visibility to facilitate customer flexibility.

The Dingle Project Customer Flexibility trials set out to demonstrate these control capabilities of residential clean energy enabling technologies and provide ESB Networks with insights into the data and systems that it will need to meet the changing needs of its customers. All pilots and deliverables under the customer flexibility objective were categorised under three main headings; LV Vision, Flexibility Services of Customer Sited DER, and MV Vision and Control.

A number of internal reports have been produced to capture learnings for ESB Networks including the LV vision deliverables which focused on piloting a solution for mapping the LV network suitable for rollout on a national scale. A follow-on activity involved the development of an integrated MV-LV electrical model suitable for software simulations to study the impact of clean energy enabling technologies on the network. The deployment of more than 35 monitoring devices on the LV network at specific points across the Dingle Peninsula aided the validation of the network simulations. The data from the LV monitors was also used to gather real data to assess the impact of the installed clean energy enabling assets on the network and better understand the outcomes of the flexibility tests.

The next set of deliverables focused on flexibility services from customer sited distributed energy resources and clean energy enabling technologies. Real devices were installed in participating residential properties to determine if they can be controlled in a reliable manner to provide demand response services, and what the benefits could be if utilised to resolve potential thermal or capacity constraints on the network.

The objective also sought to document the impact of the installed clean energy enabling technologies on the MV network and to appraise the protocols used to enable this type of vision and control. It was intended that the learnings from this objective would help to inform ESB Networks of a potential for future non-wires solutions to enable additional load arising from the electrification of heat and transport.

4.1 Customer Flexibility

The Customer Flexibility objective aimed to assess if residential scale clean energy enabling technologies and Distributed Energy Resources (DER's) could offer flexibility as a service for a non-wires solution to network reinforcement. It was anticipated that the rate of electrification of heat and transport would increase due to the targets and initiatives set out in the Climate Action Plan 2019 [3]. While the rate of adoption of EVs and heat pumps may be behind the curve as of March 2022, the 2030 targets were reinforced in the Climate Action Plan 2021 [4] and the forecast increase in demand up to 2030 remains valid. Without network upgrades or alternative measures, this anticipated increase in demand from additional electrification could potentially result in some parts of the MV and LV electrical network becoming constrained at certain times.

This Customer Flexibility objective set out to deliver demonstrations which could be used to compare conventional network reinforcement approaches with a non-wires solution to accommodate the additional load of EVs and eHeat. At the outset, the non-wires solution proposed for the Dingle Project trials assumed that loads such as smart EV chargers, heat pumps and smart immersion controllers would be controlled to provide diversification of demand reduction capability in tandem with energy storage from batteries to offset network constraints.

On conclusion of the trials, ESB Networks better understands the feasibility and challenges associated with deferring a conventional network upgrade by employing a non-wires, flexible solution and further projects and pilots will explore this area into the future.

4.1.1 Clean Energy Enabling Technologies

Initially the Dingle Project had sought to cluster the roll out of technologies into concentrated geographical areas on the peninsula and thereby creating a focused demonstration and representation of an electrical network that is supporting a low-carbon community. However, the recruitment and uptake of participants for the trials did not result in the intended clusters, as explained previously.

As part of the Dingle Project, 35 properties across the peninsula were equipped with low carbon and clean energy enabling technologies as follows:

- 20 properties fitted with 2.1 kWp of solar PV;
- 10 properties fitted with controllable, smart electric vehicle chargers;
- 5 properties fitted with a smart EV charger, residential scale hybrid battery energy storage system and integrated to existing 2.1 kWp of solar PV, air-source heat pump;
- 3 properties underwent deep retrofits;
- 32 properties fitted with energy monitoring sensors;

The data gathered from the trials allowed for aggregation of trial sites to understand the impacts on the electricity network had those customers been located physically and electrically adjacent to each other. The dispersed nature of the trial participants across the Dingle Peninsula is also considered to have supported wider local community engagement and dissemination than would have otherwise been the case under a concentrated energy community scenario. For 3 of the 35 locations outlined above, they did not receive energy monitoring sensors for the following reasons; the first property was up for sale, the second building was a public community facility that was not in use during the pandemic and the third building could not get wired or cellular communications which meant it would not have been possible to retrieve the data, so no sensors were installed.

Details on each of the deployed clean energy enabling technologies across the Dingle Project are given in the following sections.

4.1.1.1 Battery Energy Storage System

A sonnenBatterie hybrid 9.53 battery energy storage system (BESS) from sonnen GmbH was deployed at each of five project ambassador properties. Each of the installed systems were specified with 5 kWh of energy storage capacity and incorporated an existing 2.1 kWp solar PV array.

FIGURE 4 SONNENBATTERIE 9.53 HYBRID BATTERY & SOLAR INSTALLATION

The configuration of the installed systems enabled a maximum inverter discharge of 2.5 kW. The installed system satisfied the requirements under the EN 50438:2013 standard which was required at the time of installation and was commissioned with the appropriate protection settings for Ireland. The system was connected to the home local area network (LAN) via Cat5e ethernet connection which enabled third-party control through the command application programming interface (API).

4.1.1.2 Air-Source Heat Pump

Mitsubishi Electric Ecodan heat pumps were installed at all 5 ambassador properties. For 3 of these sites, the works were completed as part of a full deep retrofit while for the other 2 properties, the Mitsubishi units were installed to replace existing, non-controllable devices. At each location, an outdoor Monobloc air source heat pump was installed in conjunction with an indoor hot water storage unit as shown in Figure 5.

FIGURE 5 MITSUBISHI ELECTRIC ECODAN HEAT PUMP

The Mitsubishi Electric Ecodan units utilize an inverter driven heat pump compressor. This inverter-based control regulates the system to modulate the heat output according to the exact capacity required and was shown to have an approximate average coefficient of performance of between 3 and 4. This means that for every kilowatt of electrical power input, 3 to 4 kilowatts of heat were produced.

4.1.1.3 Solar PV Installations

In addition to the 5 project ambassador properties, twenty further properties were fitted with a solar PV array with a maximum output of 2.1 kWp. Each array consisted of 7 no. 300 W panels and utilised BeON 1 Microinverters [5].

A dedicated energy meter was installed to enable the customers track the energy production from the installed array. No control or monitoring capability resides within the installed microinverters and it was envisaged that the recipients of the solar PV installations would have participated in the Peer-to-Peer energy trials.

FIGURE 6 SOLAR PV ARRAY

4.1.1.4 Electric Vehicle Chargers

Electric Vehicle chargers from Wallbox Chargers were procured and installed at 15 properties on the Dingle Project. A regular 32 A smart EV charger was installed at all 15 locations initially, however for 5 of those properties, a bi-directional, vehicle-to-grid charger was installed for approximately 3 months in place of the regular charger towards the end of 2021 and into January 2022.

The Wallbox Pulsar Plus charge points are 32 A (7.4 kW) single-phase chargers. They can be controlled via a mobile application by the customers and are also compatible with Open Charge Point Protocol version 1.6 JSON (OCPP 1.6J) [6] [7] for charge point management systems. The charger connects via Wi-Fi and Bluetooth to enable the customer to control the charging and configure charging schedules to align with lower tariffs periods.

FIGURE 7 WALLBOX QUASAR

FIGURE 8 WALLBOX PULSAR PLUS

The Wallbox Quasar Vehicle-to-Grid chargers are single-phase units and were installed with a maximum current rating of 25 A (6 kW) to align with the microgeneration thresholds in Ireland. These chargers can be instructed to discharge energy from the connected electric vehicle back into the home with surplus energy exported to the electricity network. Like the Pulsar Plus models, they can be controlled from the Wallbox mobile app and from third party charge point management systems via Modbus TCP. Connectivity to the chargers is provided by Wi-Fi, ethernet and Bluetooth.

4.1.1.5 Energy Monitoring Sensors

A low-cost solution was employed to deliver real-time energy monitoring at each of the participating properties. Energy meters from Shelly [8] with the ability to measure voltage, instantaneous active and reactive power along with energy consumption were installed on the connection between the utility revenue meter and the customers distribution board. Additionally, a dedicated Shelly energy meter was installed on the output of the solar PV array for those participating customers with solar.

FIGURE 9 SHELLY EM

FIGURE 10 SHELLY 3EM

Several properties had a three-phase grid connection and an alternative three-phase energy meter from Shelly [9] was installed in these cases.

4.1.2 ICT Overview

To deliver the Dingle Project Customer Flexibility objective, the information, communications, and technology solution required several elements as outlined below:

- Clean energy enabling assets and sensors for control and monitoring
- Field gateways with bespoke software drivers to interface with the clean energy enabling assets and sensors at each premises
- Communications to each of the participating premises for connectivity with installed field gateways
- Cloud-based platform with several tools for interfacing and managing installed gateways, data storage and visualisation, ingestion of pricing profiles, activation of demand response events.

The following sections of this report detail all aspects of the ICT solution.

4.1.2.1 Digital Platform Strategy Overview

The strategy for the digital platform required by ESB Networks' Dingle Project was to procure a single ICT solution that would support and enable both the flexibility trials and Peer-to-Peer (P2P) energy trials. It was also intended that the platform would enable the transition of participants to become Active Energy Citizens by providing them with their energy production and consumption data such that they could make informed and proactive decisions on how they interacted with the electricity network. The rationale behind the sourcing of a single platform was three-fold: [10]

1. Minimise the integration challenge between distributed energy technologies / monitoring devices in trial participant premises and centralised controlling ICT systems and architecture;
2. Provision of a comprehensive and fully integrated single interface for all technology trials and control; and
3. Cost minimisation;

While ESB Networks did not envisage having an enduring role in the operation of market-facing P2P energy services into the future, considering that such services would be most appropriately delivered by parties who are active in energy trading [11]. Nevertheless, with plans for rollout of distributed energy technologies in its Dingle trial site in support of its flexibility trial, ESB Networks viewed the Dingle Project as a possibility to carry out a limited P2P trial across participating active energy citizens and the local community on the Dingle Peninsula. It was intended that those participants for whom Solar PV had been installed, would be invited to participate in the P2P trial together with other consumers within defined energy communities.

It was envisaged that the integration challenge of multiple platforms to support the flexibility trial and P2P energy trial would potentially be overly burdensome in the context of the trial timeframe and objectives of the Dingle Project and as such it was decided to source a single platform that could deliver the full suite of functionality required. As it transpired, ESB Networks ultimately decided not to proceed with a P2P trial as part of the Dingle Project, yet the platform it procured provided that modular add-on capability had that functionality been required.

4.1.3 Cyber Risk & Data Protection

Cyber security and data protection were high priorities from the outset and included as a key element in the procurement of all services and technologies required.

4.1.3.1 Cyber Security

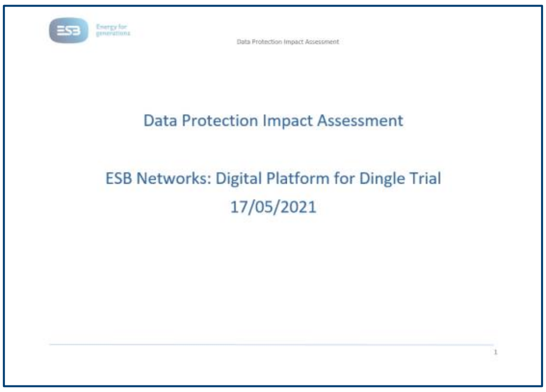
ESB Networks ensured that a professional risk assessment was completed on the proposed technical solution for the Dingle Project in advance of the procurement activities for the Customer Flexibility trials and ensured that each clean energy enabling technology and service aligned with this risk profile.

A pragmatic approach was adopted with the risk assessment assessing the innovative and short-term nature of the Dingle Project against the potential risks. The assessment took account of the limited number of participants in the trial, the storing and processing of customer data, the software as a service (SaaS) cloud-based elements hosted by a third party and that the nature of the trial was not business critical. Some mitigating measures included the limiting the number of participating premises where control of clean energy enabling technologies was possible.

4.1.3.2 Data Protection

ESB Networks ensured that appropriate safeguards were put in place including the completion of several Data Protection Impact Assessments (DPIA's). DPIA's were completed for individual clean energy enabling technologies prior to their integration into the larger, centralised GreenCom Networks platform, i.e., the platform procured to support the Flexibility Trial, which had its own dedicated DPIA.

The DPIA for the overall GreenCom Networks platform which enabled the Dingle Project Customer Flexibility trials was very comprehensive. It outlined the services and tools included as part of the GreenCom Networks platform along with the specific integrations with the participating customers' clean energy enabling technologies and monitoring sensors. Dedicated sections of the DPIA outlined the purpose of processing, trial duration, data fields, and the high-level flow of data. It was also noted that the data would be collected and processed on the Legal Basis of Contractual Necessity. Each participant on the Dingle Project had signed Terms and Conditions specific to their trial which outlined the data processing activities to be performed, specific to that trial.



Energy for generations

Data Protection Impact Assessment

Data Protection Impact Assessment

ESB Networks: Digital Platform for Dingle Trial
17/05/2021

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Figure 11 DPIA for GreenCom Networks Platform

The DPIA outlined the obligations on ESB Networks as Data Controller and GreenCom Networks as Data Processor to apply on completion of the project in terms of appropriate management of the collected customer data. GreenCom Networks has, subsequent to completion of the Customer Flexibility Trials, disposed of the environment and tools created for the Dingle Project including all customer data while ESB Networks has retained an anonymised copy of the technical data and measurements for further research purposes.

4.1.4 GreenCom Networks Platform

The technology platform to deliver the Dingle Project Customer Flexibility objective was provided by GreenCom Networks. The main purpose of the platform was to enable the residential customer flexibility trial through the aggregated control and monitoring of customer sited clean energy enabling technologies. For the Dingle Project, the GreenCom Networks solution emulated the role that an aggregated virtual power plant or flexibility service provider would play. Several flexibility use cases were developed and implemented during the trial to demonstrate the impact that different optimisation algorithms and control schemes could have on the electricity network on the Dingle Peninsula.

The following graphic in Figure 12 shows an overview of the technology roll-out at the project ambassador premises and the integration between each of these technologies and ESB Networks, via the GreenCom Networks' cloud-based 'digital' platform.

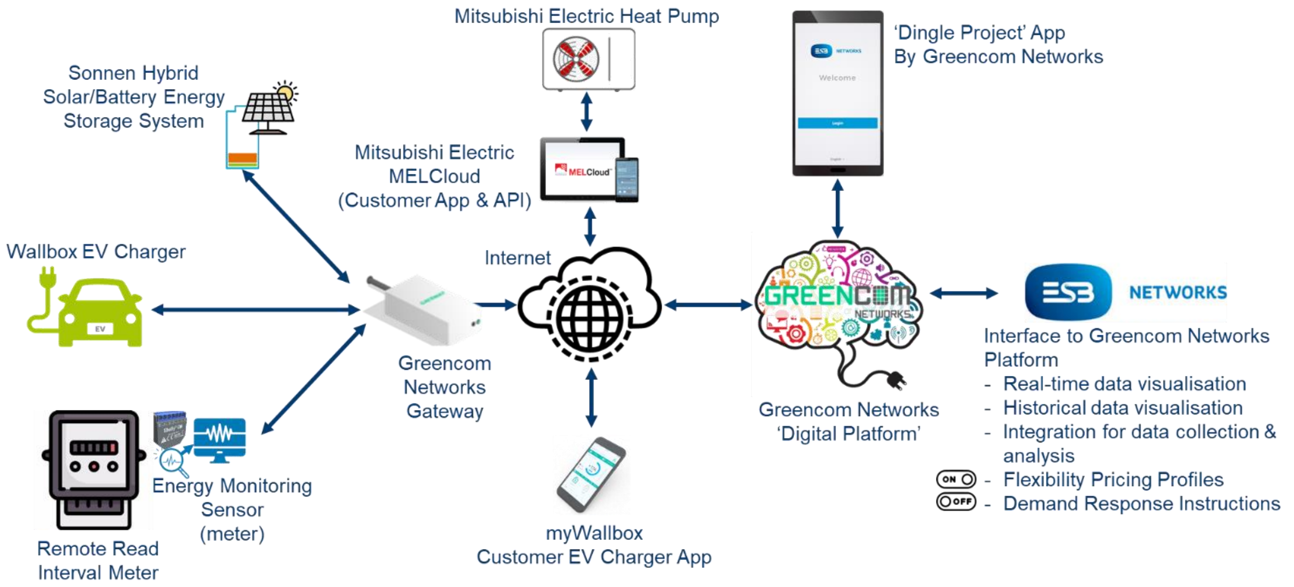


FIGURE 12 PROJECT AMBASSADOR ICT INTEGRATION

The integrations to each of the individual clean energy enabling assets and sensors is described in greater detail in Section 4.1.4.1.

The GreenCom Networks platform included several data collection, visualisation, and operational tools. The high-level diagram in Figure 13 shows the secure Message Queueing Telemetry Transport (MQTTS) data transport between the field gateways at each participating premises and the cloud-based databases that store the collected measurements. Hypertext Transfer Protocol Secure (HTTPS) connectivity allows customer visualisation of the live and historical data via the GreenCom Networks Boost web and mobile applications, while separated HTTPS connectivity allowed ESB Networks to monitor and manage the performance of the field gateways, configurations, and services.

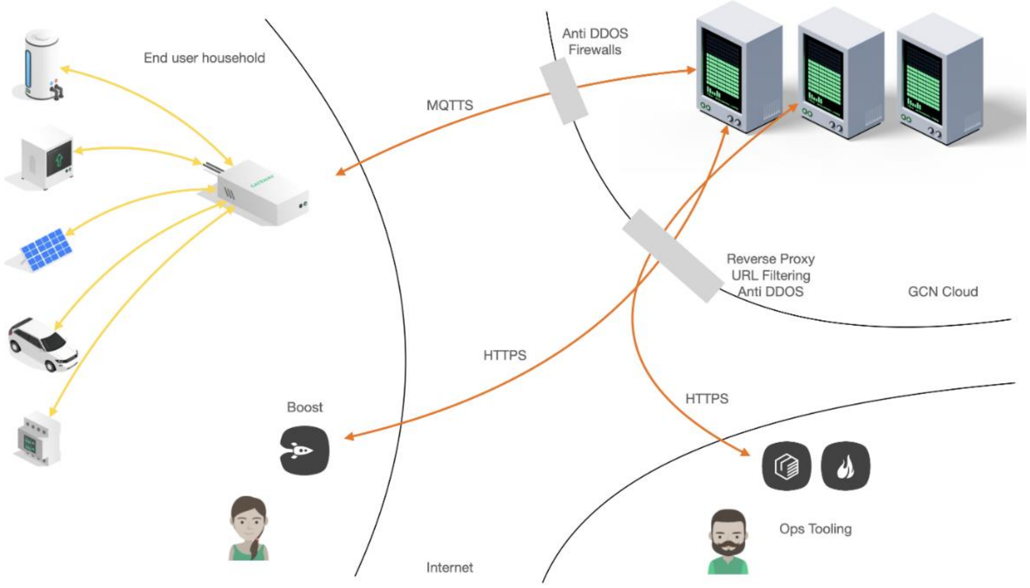


FIGURE 13 HIGH LEVEL GREENCOM NETWORKS PLATFORM ARCHITECTURE

4.1.4.1 Field Gateways & Software Integrations

A low-cost gateway device was installed at each of the participating properties. Its purpose was to interface with the assets and sensors deployed at each property, as part of the trial, to enable the control and monitoring of those devices.

Specific drivers and integrations for each technology enabled data to be collected from each of the devices and facilitated the control of the EV chargers, battery systems and heat pumps.

4.1.4.1.1 ELECTRIC VEHICLE CHARGERS

The installed Wallbox Pulsar Plus chargers are compatible with Open Charge Point Protocol version 1.6 JSON (OCPP 1.6J) [6] [7]. A dedicated driver was developed by GreenCom Networks in consultation with Wallbox Chargers. It was deployed to each of the relevant gateways enabling it to act as the Central System (CS) and facilitated the connection with the relevant Pulsar Plus Charge Point (CP). This driver enabled the gateway to auto detect the presence of the Wallbox Pulsar Plus Charge Point and to monitor several important parameters including Voltage, Active Power Import and Energy Import. The control capability enabled the commencement, suspension and cessation of charging as required.

Wallbox Quasar bi-directional chargers are compatible with Modbus TCP. A dedicated driver was developed by GreenCom Networks in consultation with Wallbox Chargers. It was deployed to each of the relevant gateways enabling it to act as the Client and facilitated the connection with the relevant Quasar V2G Charge Point (CP).

This driver enabled the gateway to auto detect the presence of the Wallbox Quasar V2G Charge Point and to monitor several important parameters including Voltage, Active Power Import, Active Power Export, Charger Status and Vehicle State of Charge (SoC). The control capability enabled the commencement, suspension and cessation of charging as required including the ability to change directly from charging to discharging.

4.1.4.1.2 AIR SOURCE HEAT PUMPS

The installed Mitsubishi Electric Ecodan air source heat pumps were fitted with the Melcloud Wi-Fi module enabling the heat pump to be monitored and controlled by the customers via the Melcloud mobile application. The mobile app leveraged an application programming interface (API) to fetch the relevant information from the Melcloud servers while also relaying any command instructions for the heat pumps.

GreenCom Networks, in conjunction with Mitsubishi Electric, developed a cloud-to-cloud based driver that enabled the collection of data from the heat pumps at the ambassador premises. This was enabled via the guest access capability within Melcloud to grant a GreenCom Networks account access to the control and monitoring capabilities of the Melcloud platform. This driver collected measurements including Hot Water Energy Consumed, Heating Energy Consumed, Outdoor Temperature, Tank Temperature amongst others. It enabled the control of the hot water heating by leveraging the Forced Hot Water Mode on and off as required and the entire system could be commanded off as required during some of the manual demand response tests discussed in Section 4.1.5.3.

4.1.4.1.3 BATTERY ENERGY STORAGE SYSTEM

The Battery Energy Storage System (BESS) installed at each of the ambassador premises was a sonnenBatterie Hybrid 9.53 from sonnen GmbH. A dedicated driver was developed by GreenCom Networks and it was deployed to each of the relevant gateways enabling it to detect and connect to the sonnen BESS at that location.

A command API on the sonnen units enabled the monitoring and control of several setpoints and modes of operation including active power charge and discharge. The sonnen system provides measurements including battery state of charge, solar production, grid feed-in, battery voltage, along with power and energy measurements for import and export.

When the sonnen systems were set to manual mode, they relied on third-party commands and these HTTP based commands from the GreenCom Networks gateway controlled the battery systems in accordance with the flexibility and optimisation use cases.

4.1.4.1.4 ENERGY MONITORING SENSORS

The energy monitoring sensors from Shelly are Wi-Fi based units. When connected to the home Wi-Fi network, the dedicated software driver from GreenCom Networks could detect and retrieve the measurements and payloads from the sensors. The sensors support multiple protocols, messaging formats and reporting intervals but the CoIoT protocol was used in this case and issued measurements every 15 seconds. CoIoT is based on the Constrained Application Protocol (CoAP) but with some additions. All payloads are JavaScript Object Notation (JSON) encoded. The sensors delivered electrical measurements including Voltage, Active Power and Energy imported and exported.

The 20 premises on the Solar PV trial utilised micro-inverters that did not have any inherent control or monitoring capability. At these locations, 2 Shelly sensors were deployed to monitor the main metered connection to the grid and separately the output of the solar PV array. At all other participating premises on the project a single shelly sensor was deployed to monitor the main metered connection to the grid for near real-time measurements.

4.1.4.1.5 FIELD GATEWAYS

The field gateways deployed to each participating premises is designed upon the Raspberry Pi single-board computer (SBC). The gateways, with their software drivers and machine learning algorithms, manage and optimise the energy flows between the clean energy enabling technologies deployed at that property in the economic interests of the customer.

The gateways are connected back to a centralised messaging broker hosted within the GreenCom Networks cloud-based infrastructure. A dedicated environment was created for the purposes of the Dingle Project and to ensure segregation of data with other projects and GreenCom Networks customers.

4.1.4.2 Operational Platform Tools

The GreenCom Networks platform included several operational, web-based tools for the management of the field gateways, monitoring of installed assets and measurements and for the customer visualisation application.

'Icehub Toolbox' was the gateway management tool that enabled the monitoring of gateway performance and connectivity, driver firmware updates along with any required driver configuration changes.

The 'Site Operations' and 'Asset Operations' tools enabled ESB Networks' and GreenCom Networks' engineers to monitor the measurements and parameters recorded for each participating property. The asset focused tool provided access to every technical measurement obtained through the bespoke driver integrations while the site-based tool visualised both the measured and calculated metrics that were provided to the customer visualisation application.

The 'Boost' application was the dedicated customer visualisation tool. It was accessible via any web browser on mobile or desktop devices and was also made available as a native app for both iOS and Android based mobile devices. The application provided both real-time and historical energy information for the customers and several displays were available including a tiled dashboard with customisable widgets, an animated graphic showing the notional energy flows between the installed assets in the home, and a report viewer where users could trend multiple metrics over different timeframes. Further information on the customer interface is given in Section 4.1.4.5.

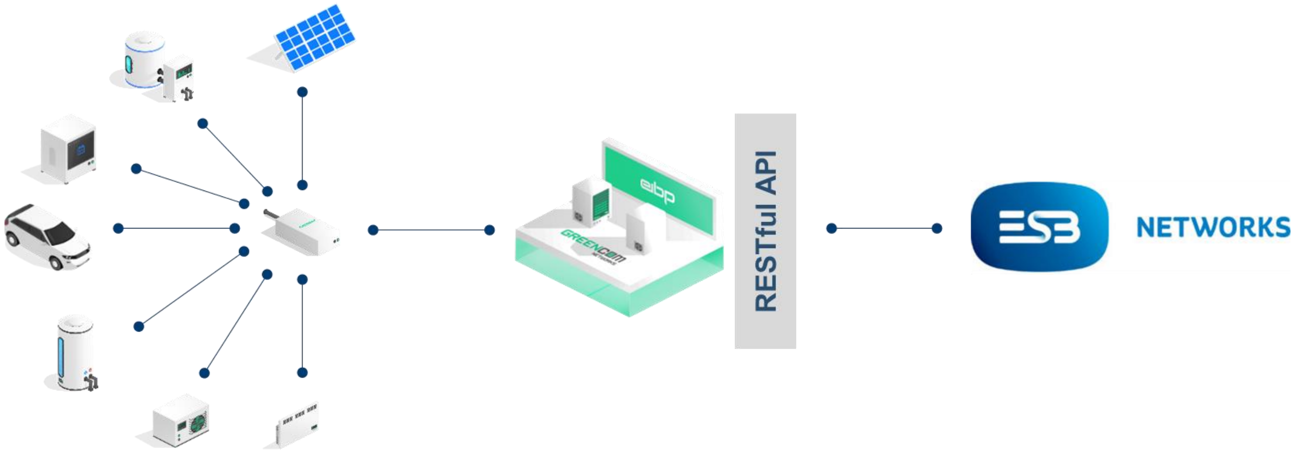


FIGURE 14 DEMAND RESPONSE API CONTROL

Separately, a dedicated application programming interface (API) endpoint was developed which was used to accept instructions from ESB Networks as part of the manual demand response tests. This API instruction allowed ESB Networks to specify what sites were requested to respond along with the desired response duration. An example of the instruction request payload is given below whereby all

15 locations with controllable assets were instructed to reduce demand to a minimum and leverage energy storage where available, for a period of 20 minutes:

```
  {
       "duration-in-minutes": 20,
       "esb-ids": [
           "ESB-016","ESB-017","ESB-029","ESB-032","ESB-037",
           "ESB-003","ESB-019","ESB-020","ESB-022","ESB-005",
           "ESB-010","ESB-015","ESB-024","ESB-025","ESB-033"
        ]
    }
```

Secure File Transfer Protocol (SFTP) was used to upload pricing information each day to the GreenCom Networks platform. The pricing data was loaded from supplied comma separated value (*.csv) files into a cloud-based database within the GreenCom Network environment and was utilised by the economic optimisation running for each of the participating properties. Further information on the creation and use of the pricing files is given in Sections 4.1.5.3.1 and 4.1.5.3.2.

4.1.4.3 Security and Data Protection

Cyber security and data protection form a key element of the technical approval process for procurement of any works or services that include ICT elements. During the procurement of the GreenCom Networks solution, several questionnaires were completed by GreenCom Networks with documentary evidence provided to back up the answers given. These questionnaires dealt with items including ISO 27001:2013 certification, encryption of data at rest and in transit as well as confirmation that all data is processed within the European Economic Area (EEA).

Evidence was requested in relation to policies and procedures regarding high availability, resilience and recovery, vulnerability management, management of data retention, archiving and deletion. All this information was assessed to ensure the levels of cyber security and data protection were to a suitable standard.

A dedicated environment was created for the purposes of the Dingle Project and to ensure segregation of data with other GreenCom Networks projects and customers. The field gateways communicated with the centralised environment through a 256-bit encrypted virtual private network (VPN) tunnel. This tunnel was used to transport messages and payloads from the field gateway to the centralised messaging broker via secure MQTT that utilised Transport Layer Security (TLS) v1.2 encryption. Single sign-on (SSO) was utilised for user authentication to the GreenCom Networks operational tools with user permissions defined by several role types from super admin to technician to end customer. SSH-key authentication was used to provide security for the SFTP storage location while users with an appropriate client id and client secret could obtain a JSON Web Token (JWT) required to authenticate any Demand Response API commands.

4.1.4.4 Optimisation and Machine Learning

The GreenCom Networks solution incorporated the optimisation of clean energy enabling assets under its control in the economic interests of the customer. This ensured that the customer extracted the most benefit from energy produced from solar PV, where installed, and minimised the spilling of excess energy to the grid. Alternative optimisation algorithms were available, but it was felt that the economic optimisation was the most likely one that future customers would use initially.

Furthermore, the tests that were planned as part of the flexibility trials centred around costs and movement of energy consumption based on fictitious tariff data supplied to the GreenCom Networks platform. The first flexibility scenario was driven by a fictitious, regular, block-shaped tariff and focused on the potential of the control technology and mathematical algorithms to move clean energy enabling demand such as EV charging and domestic hot water heating into regular, cyclical patterns during off-peak periods, and in that way manage their impact on the local network on a sustainable basis. The second scenario was driven by a more agile and dynamic fictitious tariff than that used in Scenario 1, and examined the responsiveness of the same clean energy enabling technologies, control schemes and algorithms to the day-ahead pricing and the potential for the network impact of these same discretionary loads to be minimised, closer to real time.

A significant factor in the successful implementation of the optimisation algorithms was the machine learning capability of the GreenCom Networks platform. With the captured data from the measurement sensors and clean energy enabling technologies, a unique running schedule was produced for the operation of the relevant technologies at each property. Due to the unique and changing behaviours and energy needs of each property, these running schedules were updated daily with a 36 hour look ahead forecast. For each location, the system continually learned from the past energy needs, recent usage patterns and considered weather impacts to produce the most efficient running schedule for that particular property.

4.1.4.5 Customer Interface

The GreenCom Networks solution provided the participating customers with a web and mobile app interface to view their real-time and historical energy usage. In the case of the project ambassadors, they could visualise what their EV charger, heat pump, battery and solar systems were doing along with the remainder of their household consumption.

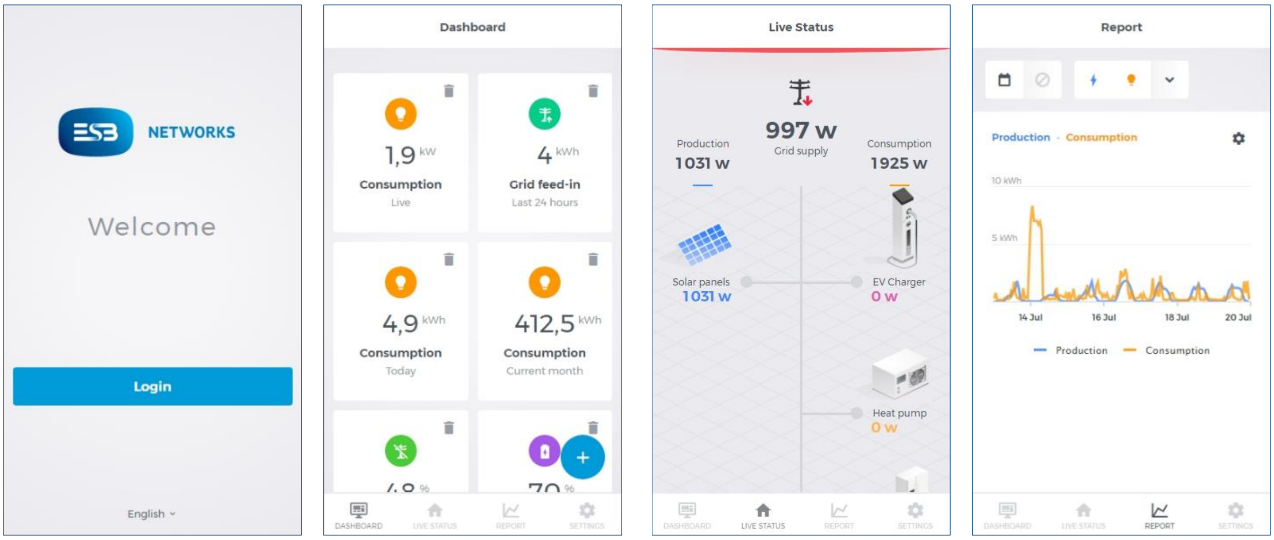


FIGURE 15 GREENCOM NETWORKS WEB APP INTERFACE

The interface also provided additional metrics such as energy self-consumption and grid independence and each of the available parameters could be calculated over several available time periods. In the case of the EV Trial and Solar PV trial participants, they could visualise what their EV charger was consuming or exporting, or their Solar PV was producing, together with the remainder of their household consumption.

With the trial area being a native Irish speaking area, an Irish language option was developed and coded into the interface to allow users to view the dashboards and information on desktop and mobile devices through Irish.

4.1.5 Flexibility Scenarios

Flexible technologies like electric vehicles and energy storage with solar can provide ‘flexibility services’ to electricity networks. By releasing power back to the grid at times of high demand, and storing it during times of lower demand, local 'flexibility services' unlock additional capacity and support the connection of more low-carbon technology like wind power [12].

As part of its Open Networks Project [13], the Energy Networks Association (ENA) defined several active power services; Sustain, Secure, Dynamic and Restore [14]. These products, which share several common features and are used to support the management of the distribution system for demand driven use cases, have been used commercially in a flexibility market in the United Kingdom for the past few years.

Reactive power services were not investigated as part of the Dingle Project following pilots as part of the StoreNet [15] [16] and RESERVE [17] H2020 projects where various forms of Volt-Var and voltage setpoint control schemes were explored with varying degrees of success using similar battery energy storage systems and solar inverters.

4.1.5.1 Active Power Products

The ENA active power products formed the basis for the flexibility scenarios that were trialled in the Dingle Project customer flexibility tests. ESB Networks’ National Networks Local Connections (NNLC) programme is also adopting these active power products as part of its flexibility pilots [18].

All products require a change in power import or export and are differentiated by how they are scheduled, the notice periods and response times. There are also minimum aggregated thresholds to be satisfied for participation in the UK’s commercial flexibility market which were not considered as part of the Dingle Project.

A description of each of the defined active power products proposed for use in the initial pilots [18] for ESB Networks’ National Networks Local Connections programme are given below.

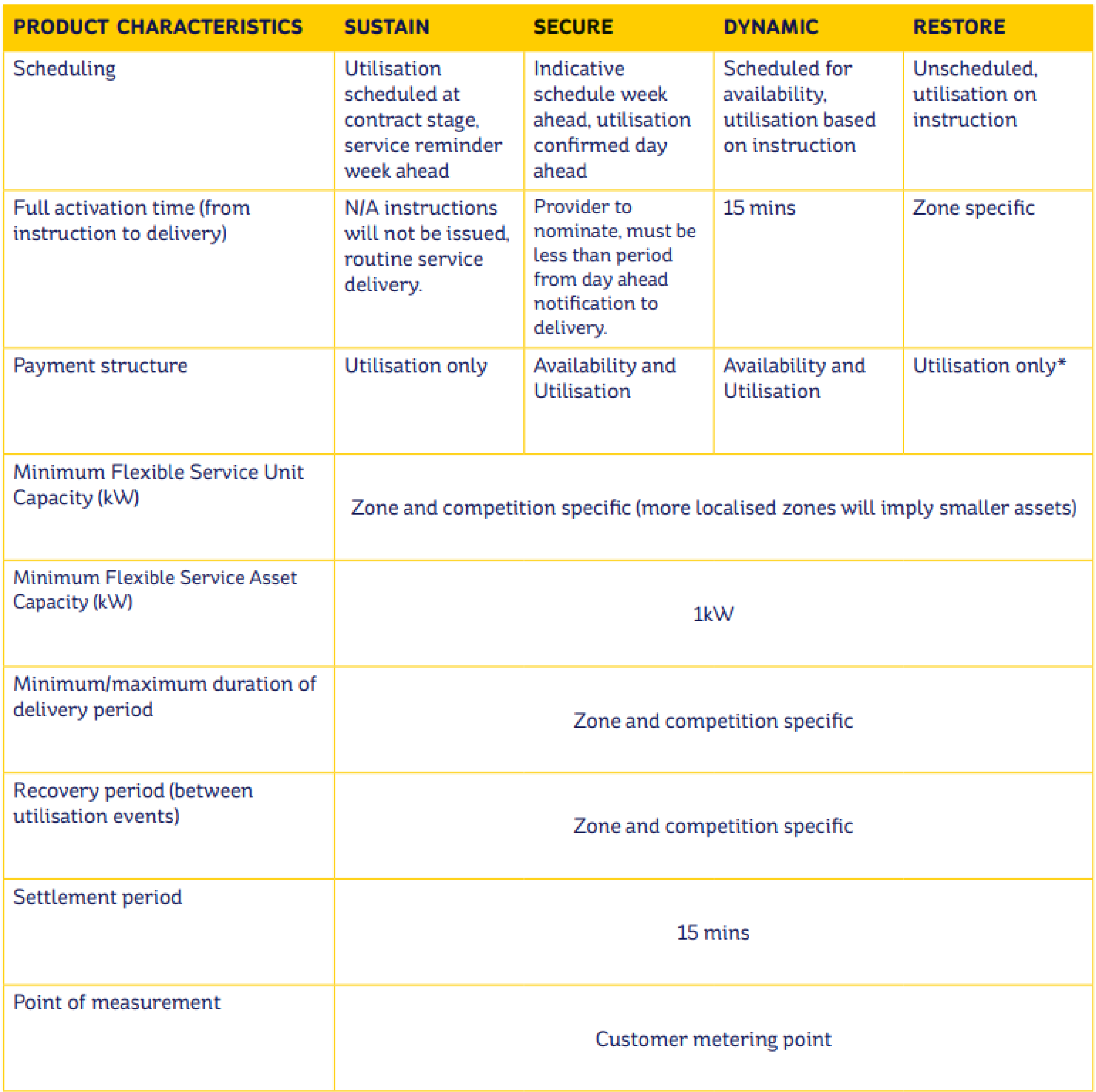
SUSTAIN: MW scheduled utilisation service
Scheduled congestion management: regular procurement of an active power service, scheduled ahead of time, to ensure that network capacity is not exceeded. For example, to mitigate a consistent known issue in a particular area every day at peak time.

SECURE: MW scheduled availability, utilisation on medium notice (days)
Pre-fault congestion management: procurement of an active power service, ahead of time but utilised based on conditions closer to real time, when a network limit is forecast to be breached. For example, to manage a pre-planned outage or cover an N-1 contingency (overload following loss of one transformer).

DYNAMIC: MW scheduled availability utilisation at short notice (minutes)
Post fault congestion management: procurement of a service, utilised based on a fault or unforecastable event occurring, to return network to within capacity limits. For example, the dynamic product can be used outside of an already defined service window when there is an unexpected fault.

RESTORE: MW unscheduled utilisation on rare events
Procurement of a service following loss of supply where a flexible service provider (FSP) will be instructed to either remain off supply, or to reconnect with lower demand, or to reconnect and supply generation to support increased and faster load restoration under depleted network conditions.

Due to the scheduling of availability for the Dynamic service, an availability payment is typically given, however due to the unpredictable requirement for the Restore product, no availability payments are given and instead the utilisation payment is much greater.



PRODUCT CHARACTERISTICS	SUSTAIN	SECURE	DYNAMIC	RESTORE
Scheduling	Utilisation scheduled at contract stage, service reminder week ahead	Indicative schedule week ahead, utilisation confirmed day ahead	Scheduled for availability, utilisation based on instruction	Unscheduled, utilisation on instruction
Full activation time (from instruction to delivery)	N/A instructions will not be issued, routine service delivery.	Provider to nominate, must be less than period from day ahead notification to delivery.	15 mins	Zone specific
Payment structure	Utilisation only	Availability and Utilisation	Availability and Utilisation	Utilisation only*
Minimum Flexible Service Unit Capacity (kW)	Zone and competition specific (more localised zones will imply smaller assets)			
Minimum Flexible Service Asset Capacity (kW)	1kW			
Minimum/maximum duration of delivery period	Zone and competition specific			
Recovery period (between utilisation events)	Zone and competition specific			
Settlement period	15 mins			
Point of measurement	Customer metering point			

Figure 16 Proposed NNLC Flexibility Product Design Criteria

Figure 16 was developed by ESB Networks' National Networks Local Connections programme and provides information on the proposed scheduling, activation times and payment structures for each of the active power products. It is interesting to note the 1 kW minimum flexible service capacity which highlights the potential for smaller, potentially residential assets to participate.

4.1.5.2 Flexibility Marketplace

The Dingle Project trials did not include the commercial aspects of procuring flexibility services via a flexibility marketplace and instead focussed on the technical capability and reliability of clean energy enabling technologies to provide such services and the resultant impact on the low and medium voltage distribution network.

However, when considering each of the products in Section 4.1.5.1, it is important to understand how availability and utilisation of these services are typically measured. The peak capacity of the installed clean energy enabling technologies is the maximum change in power that can be imported or exported at any given point in time. It is measured in kilowatts or megawatts. The availability period is the amount of time when that capacity would be available. This can be difficult to predict for services leveraging EV charging and V2G capability because when the respective vehicles are not charging or not connected in the case of V2G, there is no capacity available from those assets.

Should the utility call upon or dispatch the flexibility service provider to provide active power services, typically the utility would pay the flexibility service provider and ultimately pay the end customers for the volume of energy response provided. Energy volume is measured in kilowatt hours or megawatt hours. Other metrics that may influence such payments are the percentage of energy delivered against what the utility and flexibility service providers requested and the speed of that response.

4.1.5.3 Dingle Project Flexibility Use Cases

Several flexibility scenarios were scoped out during the detailed design phase of the project. The final scenarios leveraged the Sustain, Secure and Dynamic active power services as described in Section 4.1.5.1 with some adaptations as outlined below.

4.1.5.3.1 SCENARIO 1 | SUSTAIN

The first use case aligns with the Sustain product whereby energy usage associated with EV charging and heat pumps is scheduled away from the peak times of day. The main difference with the ENA defined Sustain product is in the scheduling and notice periods. For the Dingle Project, the desired profile is defined and loaded to the GreenCom Networks platform at least 24 hours ahead of time. On several occasions such as bank holidays and holiday periods it was loaded several days ahead of time.

For this use case, the demand reduction is achieved by altering the pricing information provided to the GreenCom Networks platform for each hourly period. The default tariff profile at each location had been configured with typical day/night pricing but for this scenario, additional high price periods were input for 7 AM to 9 AM and 5 PM to 7 PM daily. Due to the economic optimisation running on the gateways at each property, the optimal schedule for operation of the clean energy enabling assets automatically adjusted the EV charging and heat pump water heating away from the high price periods. Where installed, energy storage was also leveraged to discharge energy from the batteries during times of higher price to further minimise the notional cost to the end customer and reduce their energy consumption from the grid.

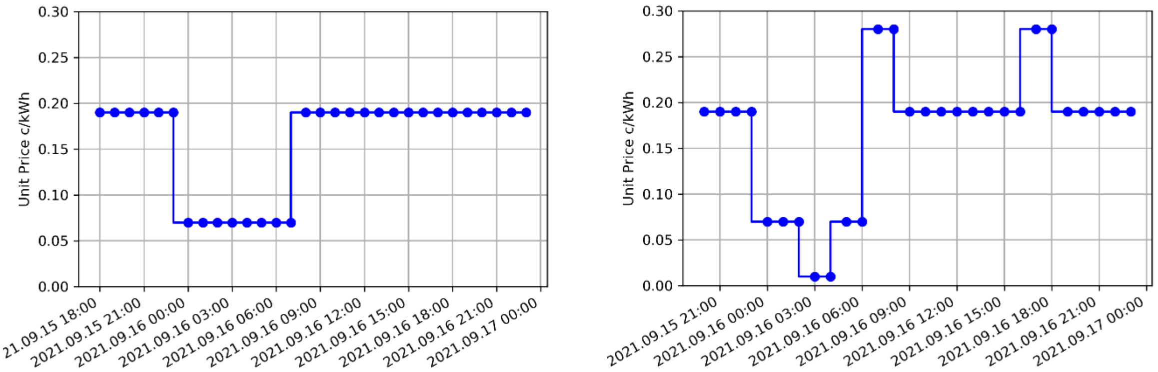


FIGURE 17 SCENARIO 1 | SUSTAIN PRICING PROFILES

An example of the day/night and modified day/night profiles are shown in Figure 17. The modified day/night profile shown here also includes an additional low price period during the night. This was included to understand the response of the GreenCom Networks controller and the clean energy enabling technologies in aligning energy consumption with this low price period. A flexibility product such as this could potentially be suited to areas on the network where a network constraint is consistent, periodic, and predictable in nature.

Like the ENA Sustain product, the intention is that these profiles are fixed weeks or months ahead of time and not changed except when contractual commitments to the utility or flexibility service provider (FSP) may change. These tests also enabled ESB Networks to better understand the potential impact that new energy retailer tariffs may have on the electricity network if adopted on mass by customers who have technologies such as heat pumps and EV chargers.

4.1.5.3.2 SCENARIO 2 | SECURE

The Secure product may be useful when short term forecasting of generation and demand or known operational issues highlight anticipated network constraints and because of this it was assumed by the Dingle Project that the levels of response would vary from day to day.

For the Secure active power use case, the input signal is much more variable, and the notice and scheduling period is much shorter and is in the order of days instead of weeks or months. For the Dingle Project, day ahead scheduling was implemented. As with the Sustain product, the implementation of the Secure use case is also via fabricated pricing profiles uploaded to the GreenCom Networks platform. The pricing profile for the Sustain use case was fixed based on times of day when demand reduction was required but the pricing profile for the Secure use case tests was variable and derived from forecasted wind and demand data. It could also have been derived from other forms of source data such as market pricing, forecasted carbon intensity, forecasted renewables and even from a grid constraint management system.

Initially the Dingle Project aimed to leverage the publicly available Octopus Energy Agile tariff data [19]. This approach was taken because it provided an easily consumable pricing dataset for the day ahead with enough variability to fully test the response and control of the GreenCom Networks platform over the installed clean energy enabling technologies. However, following the surge in energy prices in late 2021 across Europe and the UK, the AgileOctopus Tariff [20] continually exceeded its price cap of 35p/kWh, and the resultant profile was almost continuously a flat line. That profile did not provide the variability in price that was desired for the Dingle Project and thus an alternative solution was required.

The alternative solution that was developed was based on forecasted data from the Single Electricity Market Operator (SEMO) website who operate the wholesale electricity market for Ireland and Northern Ireland. Using the forecasted wind and forecasted demand data for the island of Ireland, a calculation was performed to determine the amount of forecasted demand that had to be met by other forms of generation. It was decided that for the Dingle Project, energy consumption would be incentivised when energy from wind was forecast to be higher and unincentivized at times when less wind was available on the system. With the typically lower levels of demand at night, wind energy generally accounted for a larger proportion of the generation mix and the resultant fictional prices were typically lower. At periods of low wind or when system demand was forecasted to be high, wind energy would make up a smaller percentage of the generation mix, and notional prices were higher.

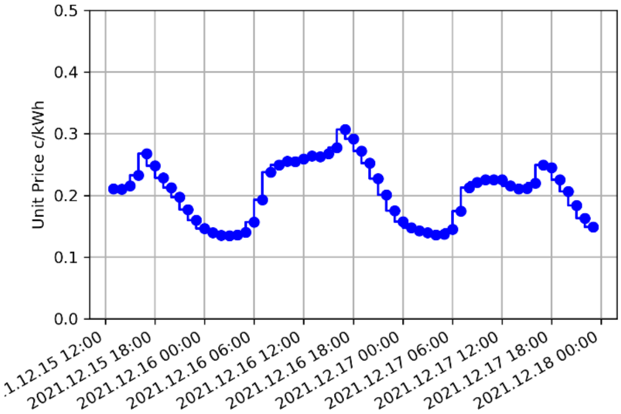


FIGURE 18 SCENARIO 2 | SECURE PRICING PROFILE

The market data was fetched daily for the subsequent 2 to 3 days and the calculations performed. The longer time span ensured a more consistent profile was produced for the GreenCom Networks platform on a daily basis. Figure 18 gives one example of a profile produced for the period between the 15th to 18th of December 2021. This profile shows notional periods of higher unit price for the hours around the typical evening peak at 6 PM with much lower unit prices during the night time period until the traditional morning rise commences around 6 AM.

The variability of these profiles tested the GreenCom Networks optimisation engine to follow the changing requirements on a daily basis and reconfigure the optimal scheduling and operation of the installed clean energy enabling technologies. As before, the controller aimed to consume energy when the notional price was lower and reduce consumption, with the assistance of energy storage where available, when price was higher. These tests emulate the scenario whereby a constraint management system may require customers to adjust their energy usage for the following day in order to manage a pre-planned outage or cover an operational contingency on the distribution network.

4.1.5.3.3 SCENARIO 3 | DYNAMIC

For the Dingle Project, the scenario 3 use case is similar to the Dynamic active power product. The purpose of this use case was to demonstrate the capability of the GreenCom Networks platform and the installed clean energy enabling technologies in responding to a manual instruction requesting all specified sites to reduce their controllable demand to the minimum, supplemented by energy storage discharge where available, and maintain that response for the requested duration. The intention of this use case is to provide the maximum amount of support to the grid from each of the requested sites, as fast as possible.

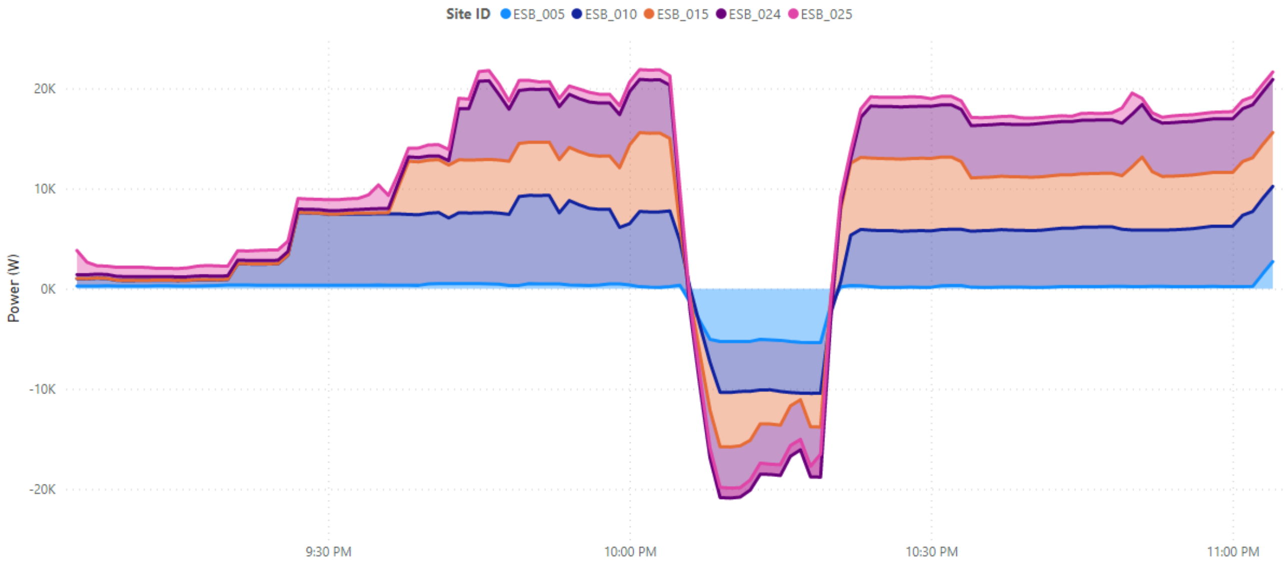


FIGURE 19 SCENARIO 3 | DYNAMIC/RESTORE V2G TEST

To enable this type of aggregated control, akin to a virtual power plant (VPP), an API endpoint was created within the GreenCom Networks platform to accept the instructions or utilisation calls from ESB Networks as outlined in Section 4.1.4.2. The API call allowed exact sites to be specified along with the desired response duration. The ability to configure which sites were requested to respond also allowed targeted testing of specific technology types such as those sites with V2G capability as shown in Figure 19. The test presented in Figure 19 represented a nett change of 35-40 kW across the aggregated V2G sites on the Dingle Peninsula for the duration of this test.

Further development would have been required had additional control elements been required in the utilisation calls. One possible example would have been to specify the scale of response, either in terms of kilowatts or as a percentage of the available capability. Additional control such as this could have value if interfaced with a constraint management system where specific quantities of demand reduction would be required and may differ from one area to another.

4.1.6 Tests & Results

This section provides an overview and commentary on the outcomes of the use case tests explored as part of the customer flexibility trials. The performance of the clean energy enabling technologies is discussed with respect to their response to the requested demand reduction energy service.

4.1.6.1 Scenario 1 / Sustain

The Sustain use case intended to replicate the impact of fixed time-based tariffs and control on customer demand by reducing or minimising energy consumption during the morning and evening peaks on the grid. However, for various reasons including lifestyle behaviours and actual supplier tariffs which are explained below, it has not been possible to demonstrate conclusively through data analysis, that there was a substantial reduction in the levels of demand during daily peak periods or a substantial increase in demand during daily off-peak periods, directly as a result of the tariff-following control signals issued from the GreenCom Networks Platform. All the analysis in this section focusses on a circa 3-week period between the 8th of November 2021 and the 2nd of December 2021. The profile used during this period was based on a day/night tariff with additional peak periods between 7 AM to 9 AM and 5 PM to 7 PM daily. It also included a low price period between 3 AM and 5 AM.

There is some visual spurious inverse correlation in Figure 20 between the off-peak periods and higher levels of electrical demand, but when analysed statistically, the relationship is not so strong and a reduction in demand during the morning and evening peak periods was difficult to determine.

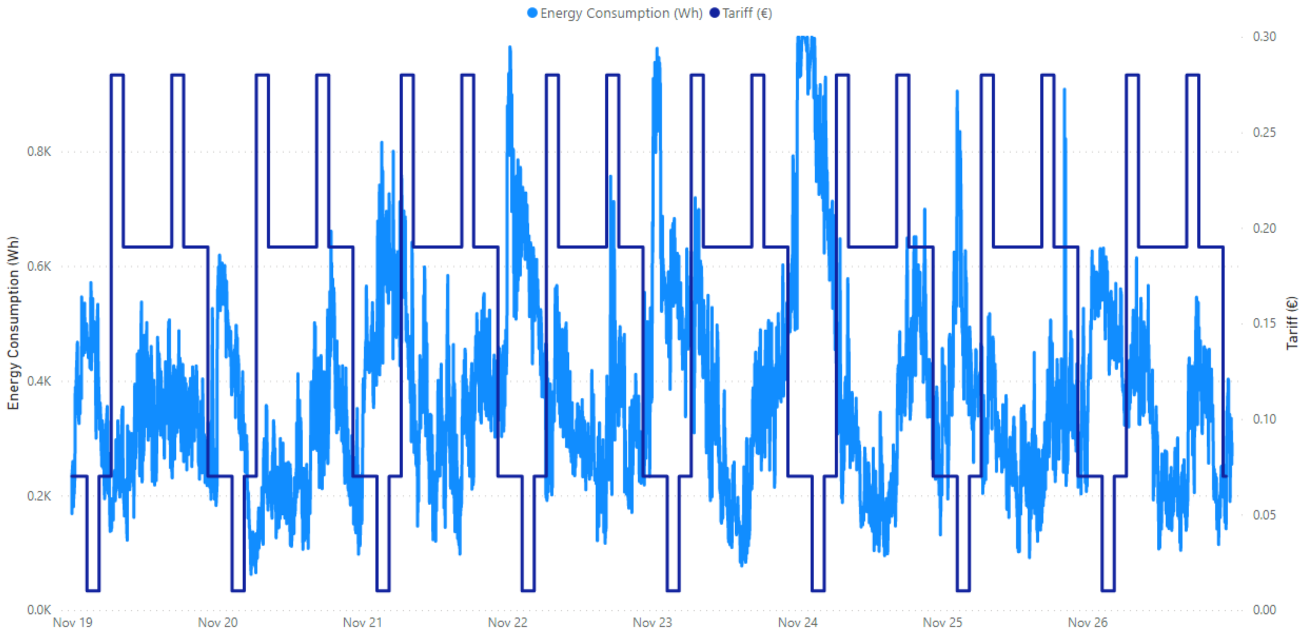


FIGURE 20 SCENARIO 1 / SUSTAIN – 7 DAYS OF AGGREGATED ENERGY CONSUMPTION VS. TARIFF

There are several contributary factors to these results but primarily, it was due to the type of controllable assets installed coupled with the normal energy usage behaviours and lifestyles of the participating customers. Of the controllable clean energy enabling technologies installed, two thirds of participating customers only had EV chargers while the other third had a battery energy storage system and a heat pump to complement their EV charger. Demand such as water heating and EV charging allow some scope for scheduling to off-peak times however, other domestic activities such as cooking are unavoidable and account for most of the energy consumption during the peak times.

EV Charging

For the EV and V2G participants, their EVs were typically plugged in to charge during the night. This was because most vehicles were not in use during that time but also many participating customers, having had day/night meters installed, leveraged lower energy prices from their supplier's real night rate tariff between 11 PM and 8 AM. Therefore, the energy usage behaviours of these customers aligned to times when real energy costs were low, happened to coincide with when charging was typically scheduled by the GreenCom Networks system.

Figure 21 shows that most charging occurred during the night period, coincident with the tariff pricing used in the GreenCom Networks optimisation, while it also shows several sites utilising the GreenCom Networks charging-override feature to charge outside of the optimal times with a noticeable spike around 10AM. The blue trace shows the tariff which the GreenCom Networks system was trying to align the EV charging to. The columns represent an average of the daily energy consumed during each hourly period at each participating site.

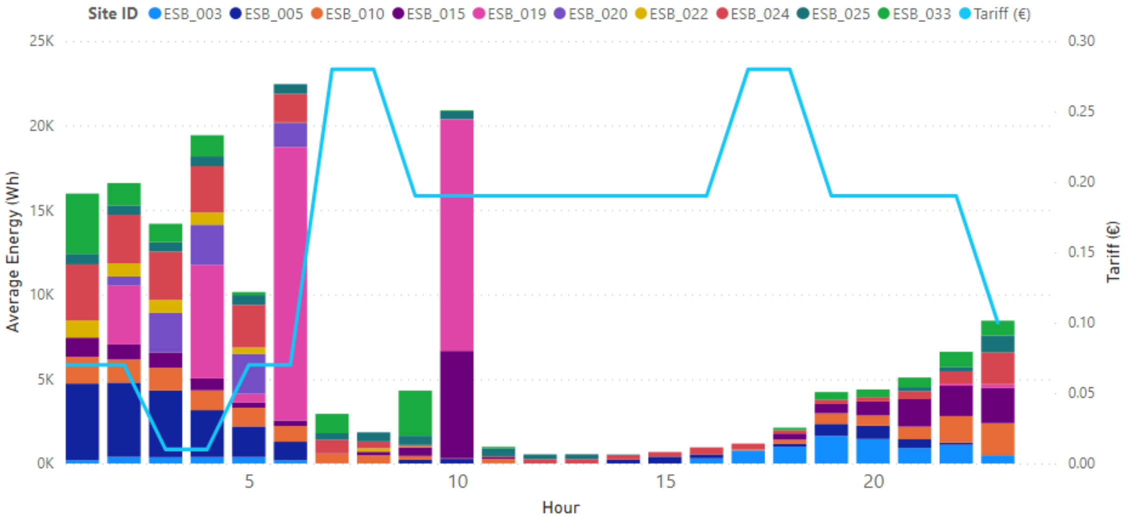


FIGURE 21 SCENARIO 1 / SUSTAIN – AGGREGATED EV CHARGING VS TARIFF

Figure 22 shows that the pattern of EV charging at the ambassador properties was not significantly different to that at the other EV-only properties, as shown in Figure 21. Charging was predominately completed during the night period with small amounts completed using the override feature during the day at some sites over the 3 week period.

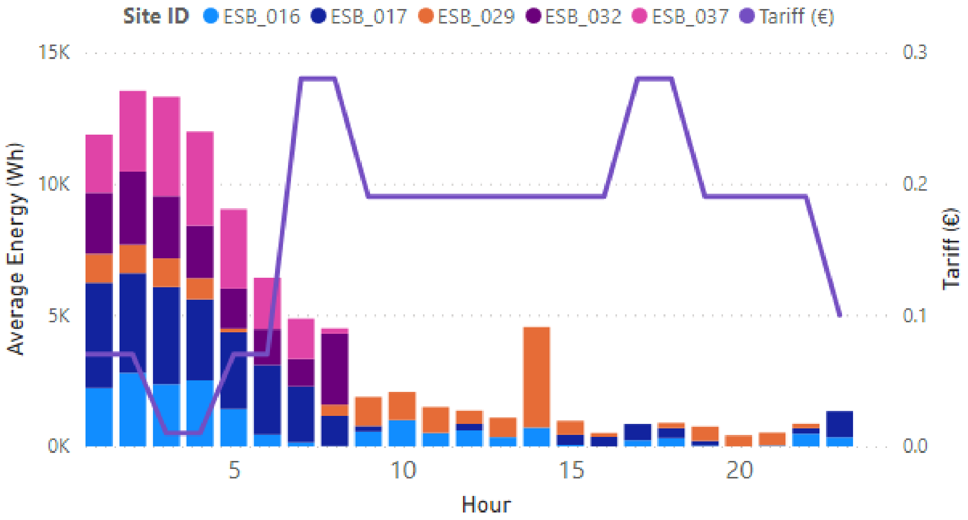


FIGURE 22 SCENARIO 1 / SUSTAIN – AGGREGATED AMBASSADOR EV CHARGING VS TARIFF

Heat Pumps

For the 5 ambassador properties, the impact of the heat pumps on the level of demand during the peak periods was negligible as minimal water heating was required at these times. Furthermore, the GreenCom Networks system did not have exclusive control over the hot water heating. Figure 23 represents the aggregated energy consumption for hot water heating for 3 of 5 ambassadors during this period. No energy data was available from 2 locations at that time. The heat pump hot water heating was left in its 'Auto' mode but during periods where the GreenCom Networks system was given an extra low price, between 3 AM and 5 AM, energy consumption clearly increases as the hot water heating was forced on by the GreenCom Networks system to maximise the notional savings to the customer by reducing the hot water heating needed at other times.

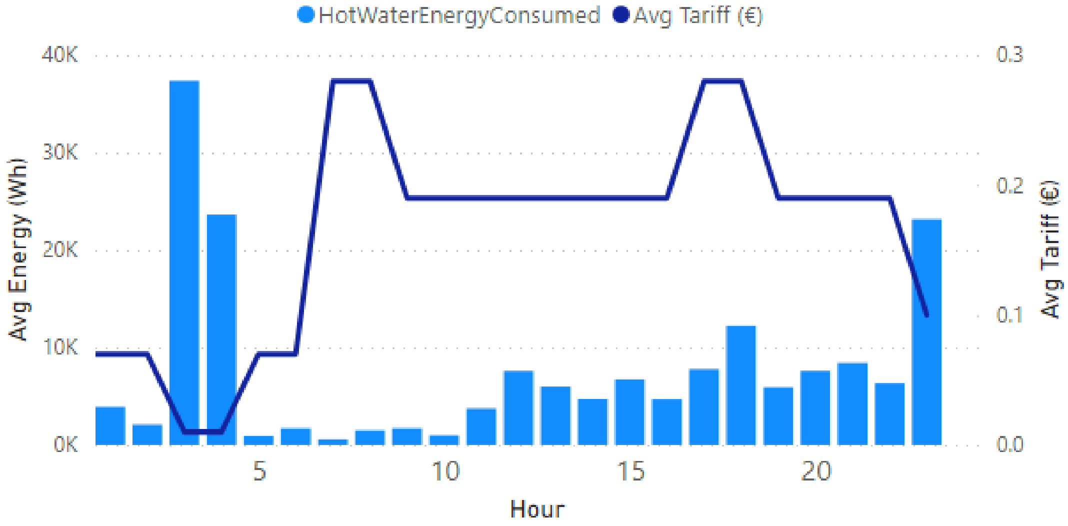


FIGURE 23 SCENARIO 1 / SUSTAIN – AGGREGATED HEAT PUMP ENERGY CONSUMPTION VS TARIFF

Battery Energy Storage Systems

The battery energy storage systems at the ambassador properties did operate well by discharging energy during the morning and evening peaks. Figure 24 and Figure 25 demonstrate that a large charge of the batteries was performed during the low-price period between 3 AM and 5 AM bringing the battery state of charge up to almost 100% ahead of the morning peak. The charging shown during the day between the morning and evening peaks is primarily based on the available solar at the property during this period and can vary from one location to another.

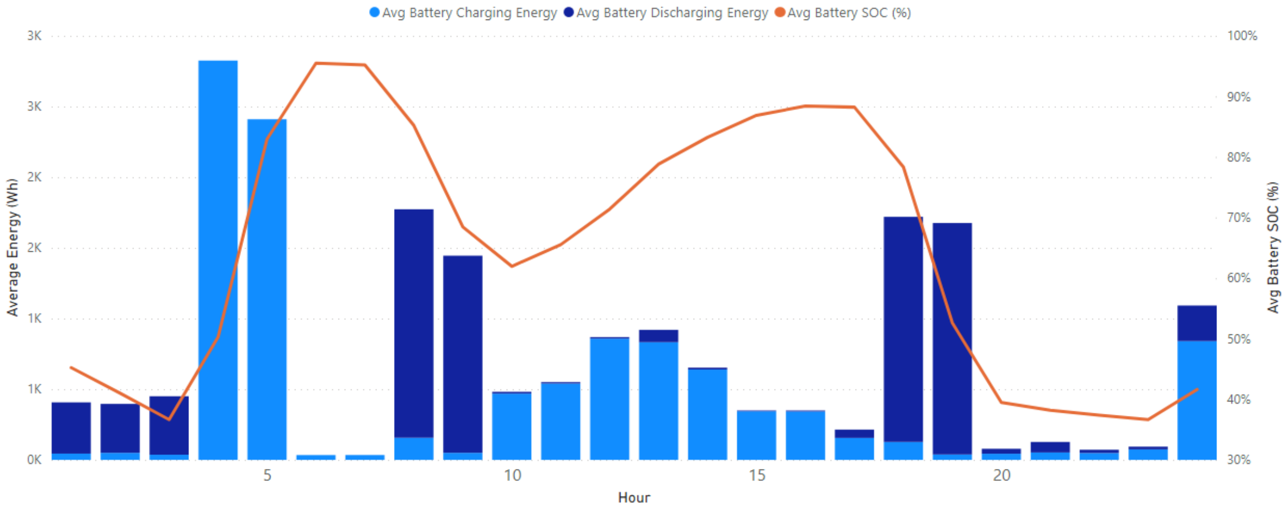


FIGURE 24 SCENARIO 1 / SUSTAIN – BATTERY ENERGY STORAGE SYSTEM OPERATION

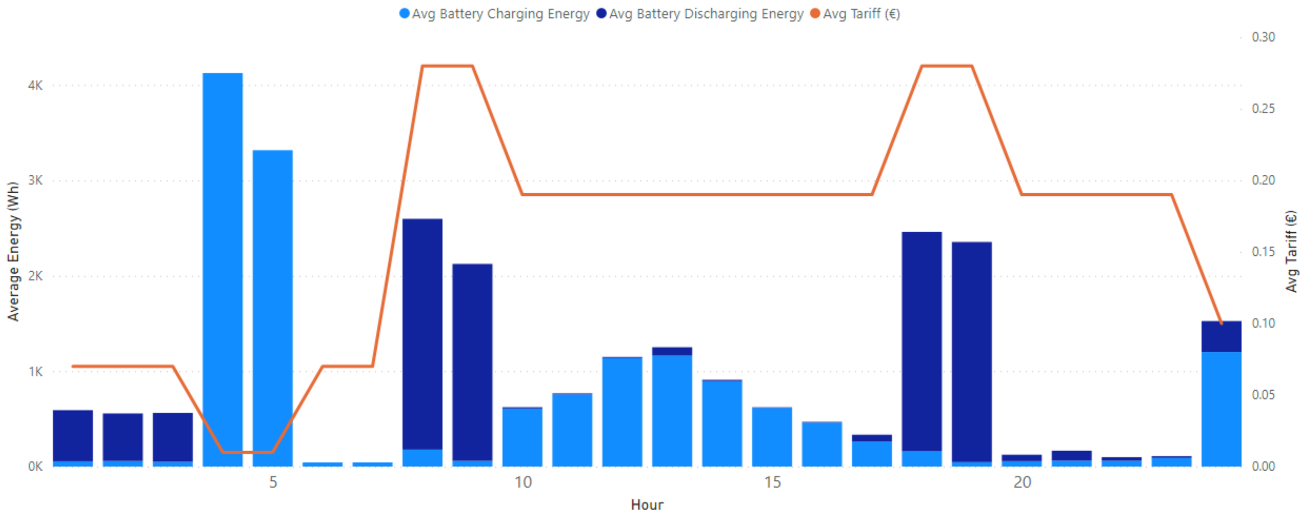


FIGURE 25 SCENARIO 1 / SUSTAIN – BATTERY ENERGY STORAGE SYSTEM OPERATION VS TARIFF

One enhancement that would be recommended for the future is to match the battery discharge more closely with the live consumption rather than forecast consumption of the property and minimise energy spilled to the grid. This feature was not built into the software integration to limit the frequency of active power setpoints issued to the battery energy storage system. However, considering that the balancing of battery discharge to meet the energy consumption of the properties was based on forecasted data, the GreenCom Networks algorithms performed well, and only minimal energy was spilled to the grid as shown in Figure 26. Figure 26 plots the tariff data from the GreenCom Networks controller against the aggregated grid import (combined energy consumed by the properties) and the aggregated grid feed-in (excess energy spilled into the grid).

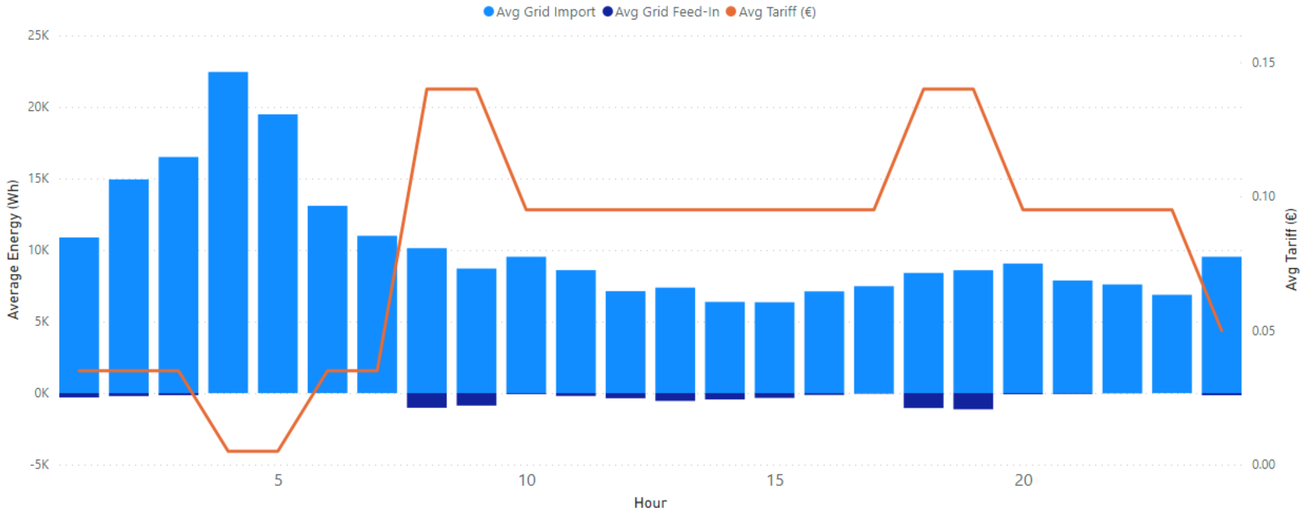


FIGURE 26 SCENARIO 1 / SUSTAIN – AVERAGE AGGREGATED GRID IMPORT / FEED-IN VS TARIFF

The data demonstrates that while a reduction in energy consumption from the grid was achieved during the morning peak, the recharging of the battery energy storage system following the morning peak and ahead of the evening peak, was primarily dependent on the energy produced by the connected solar PV array and considering the period shown is during winter when solar output is much reduced, the system appears to adequately recharge to deliver an acceptable level of demand reduction for the evening peak. Furthermore, the energy usage associated with the participants lifestyle and behaviours directly impact the ability to adequately recharge the battery energy storage system during the day.

Summary

The Scenario 1 tests demonstrated that the battery energy storage system delivered the most effective autonomous demand reduction in line with the tariff profile used to inform optimization within the GreenCom algorithm. Energy consumption was highest when the domestic water heating and charging of the battery energy storage system leveraged the incentivised low price period, while EV charging was largely unaffected by provided profile. Charging predominately took place during the off peak 11 PM to 8 AM period because, along with the vehicles not being in use, the customers were driven by real energy costs that led them to leverage their energy suppliers' lower night rate tariffs. Those who required charging outside of the optimal times used the provided override feature and, in many cases, charging anxiety led many to overuse this feature.

It was relatively uncommon for an EV not to be fully charged by the start of the morning peak and it was more common for the system to prohibit charging from commencing during the evening peak until later at night in accordance with the optimal scheduling of the charging. There was some energy fed into the grid during periods when the batteries were discharging and while it was not to the economic benefit of the customer due to the absence of a market payment, it did offer additional support to the grid.

For the electricity network, it is clear to see that customer energy behaviour can be split into two categories, movable and non-movable. The movable, schedulable elements such as EV charging are heavily influenced by supplier tariffs with virtually no demand reduction capability available from EV charging during the morning and evening peaks. Without automated demand reduction using energy storage, moving daily domestic activities like cooking, lighting, and showers will require a much greater level of customer awareness and buy-in to avoid the traditional daily peak times. The anticipated increase in EV charging over the coming years will be a challenge with the timing of charging being driven primarily by available supplier tariffs and incentives.

4.1.6.2 Scenario 2 / Secure

The Scenario 2 use case aimed to better understand the capability of the clean energy enabling technologies and the GreenCom Networks control solution in optimising its operation in response to shorter term, more dynamic input signals. While dynamic tariffs are not currently in use in Ireland, they are more mature in other European jurisdictions where smart meter rollouts are already complete. With ESB Networks' smart meter roll out due to conclude at the end of 2024 [21], it is anticipated that energy suppliers will offer newer, more agile tariffs to their customers in the future. It is then expected that technology providers may adapt their products to leverage the innovative capability that newer tariffs could unlock.

The Scenario 2 test period, reported in this section, spans the period between the 18th of December 2021 and the 22nd of December 2021. Figure 27 plots the aggregated energy consumption across those 15 sites with controllable assets, against the derived tariff pricing that was input to the GreenCom Networks optimisation system, with hourly granularity and daily variation of the pricing data evident.

The combined energy consumption across the 15 sites was relatively periodic throughout this period. The derived pricing input was also quite similar each day except on the 22nd of December, when particularly low prices were derived for certain hours. This low price was reflective of high levels of wind energy forecast for that period, with this wind predicted to be capable of supplying almost 90% of grid demand during that time, and little or no wind curtailment anticipated to be implemented for operational grid stability reasons. Note that on 21st December circ. 12:30 AM, the graph shows energy consumption falling to zero. This was because of a short-term loss of energy measurement data for that period and not a consequence of the optimisation or control.

As with the previous use case, visually there appears to be an inverse correlation between lower tariff pricing and higher energy consumption, but this is spurious in nature and not directly because of the GreenCom Networks control over the clean energy enabling technologies.

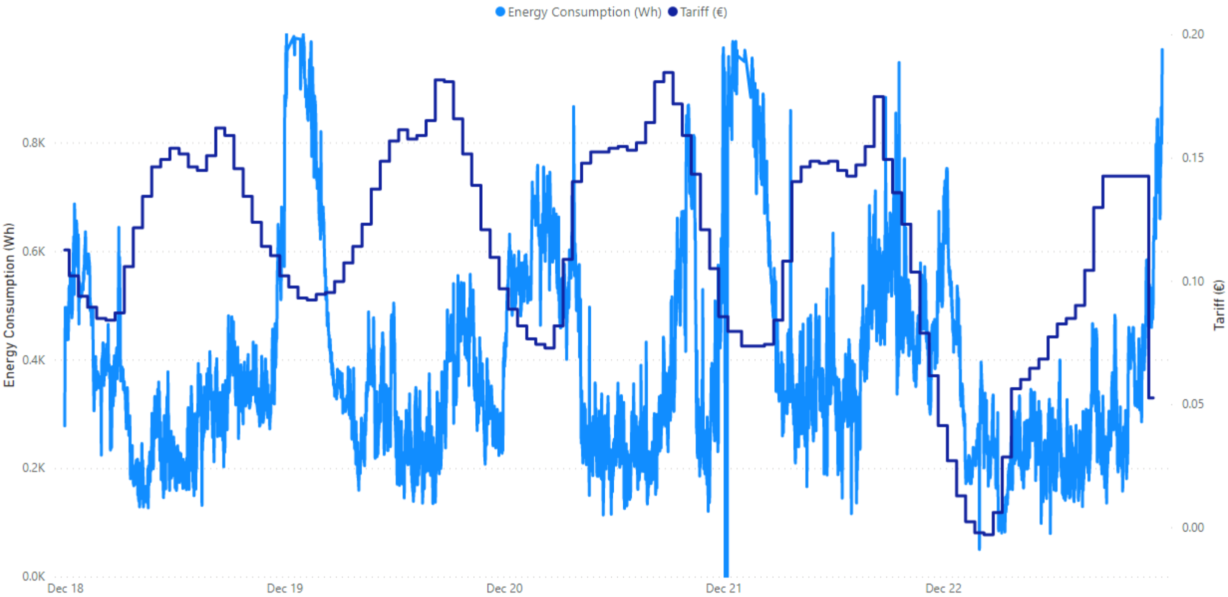


FIGURE 27 SCENARIO 2 / SECURE – DYNAMIC TARIFF PRICING VS AGGREGATED ENERGY CONSUMPTION

The evening peak in grid demand is reasonably periodic in terms of magnitude and time of day. Because of the methodology to calculate the tariff pricing being based upon the ratio of forecasted demand to forecasted wind on the grid, the highest tariff prices tend to align with the grid evening peaks while the lowest price periods are more variable and occur when wind is forecast to meet a larger proportion of the grid demand during the night valley. There was also limited scope to increase demand during the day, at times when the derived tariff price was low, because typically EVs were not connected to their chargers and battery energy storage systems were already being charged from the available solar.

EV Charging

The pattern of EV charging by the 10 EV champions in Figure 28 is similar to the previous scenario 1 use case, with most charging occurring during the off-peak night rate period.

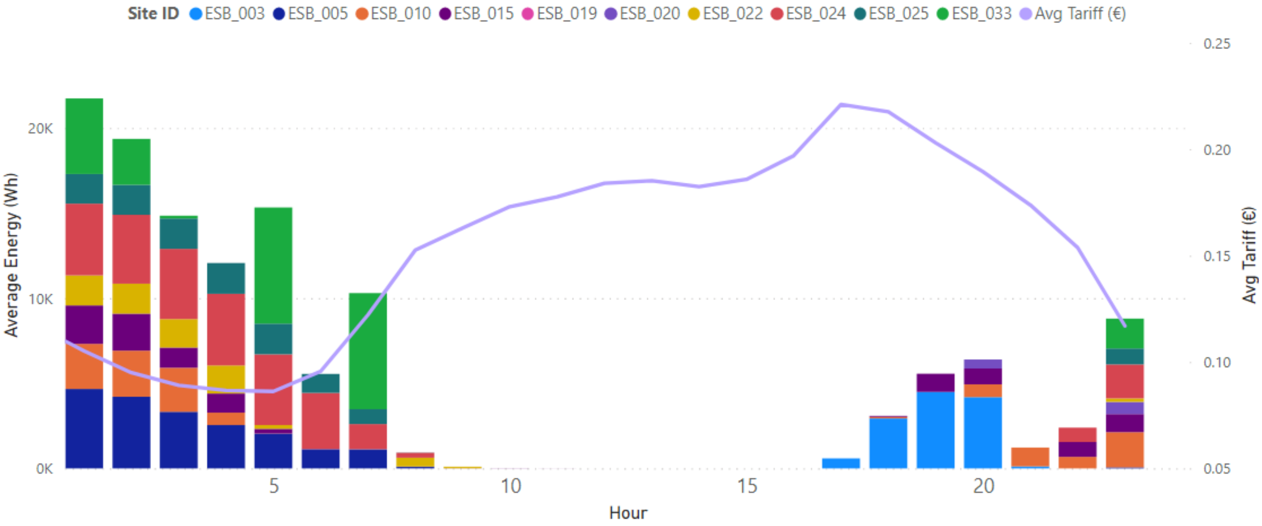


FIGURE 28 SCENARIO 2 / SECURE – EV CHARGING VS TARIFF

This so happened to coincide with lower tariffs fed into the GreenCom Networks' optimisation engine, consistent with low levels of system demand and higher wind at these times. What is evident are the instances of charging outside the optimal times where customers leveraged the override feature. Together, this demonstrates the strong motivation that customers have in both, aligning EV charging with periods where real cost savings are made based on actual supplier tariffs, and managing their own charging rather than allowing third-party control systems to manage it. For some, reduced charging anxiety outweighed the potential cost savings and potential benefits to the grid.

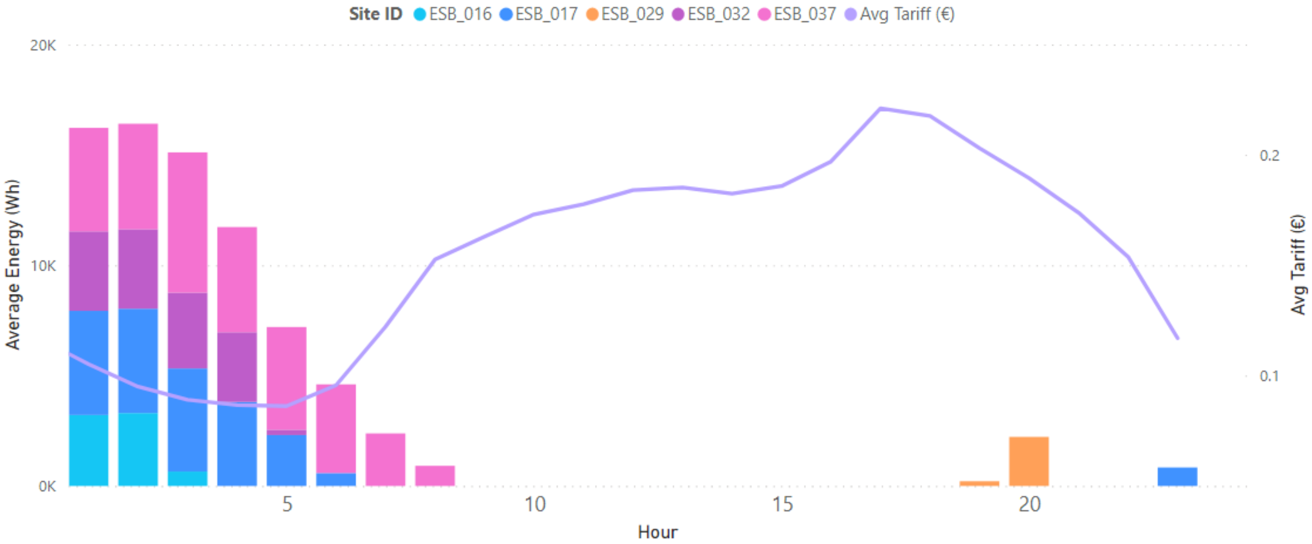


FIGURE 29 SCENARIO 2 / SECURE – AMBASSADOR EV CHARGING

Figure 29 represents the charging patterns of the 5 ambassadors with most following the same behaviour as the other EV champions. Charging was done primarily at night during the lowest price periods while there are some instances where some customers did use the override feature to charge at other times.

Battery Energy Storage Systems

For the 5 ambassador properties, the battery energy storage system again performed best in terms of its operation and response to the changeable pricing inputs. Figure 30 plots the aggregated hourly average of battery charging energy and discharging energy against the average tariff value across the period.

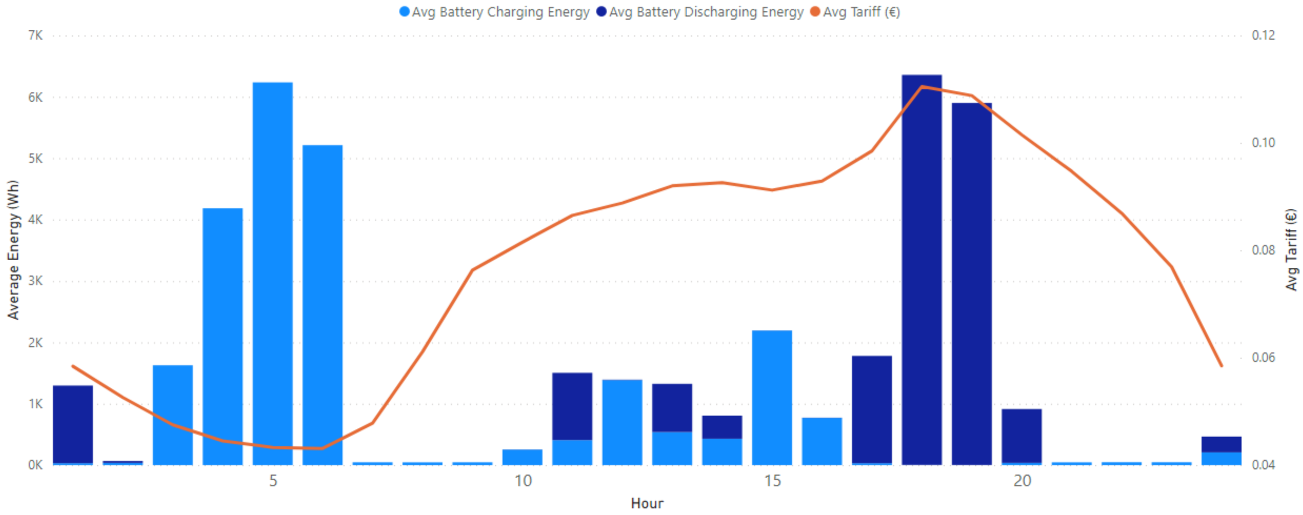


FIGURE 30 SCENARIO 2 / SECURE – AMBASSADOR BATTERY ENERGY STORAGE SYSTEM OPERATION

It demonstrates how the system charged the batteries during the lowest price periods while discharging when price was highest, with small amounts of energy spilled to the grid during discharging as shown in Figure 31. Its charge/discharge profile is substantially different to the previous use case that required energy discharge for the morning peak where the Scenario 2 use case demonstrates that it retained as much stored energy as possible for the highest price period at the evening peak. As with the previous tests, some excess energy fed into the grid as battery discharging occurred and is shown in Figure 31.

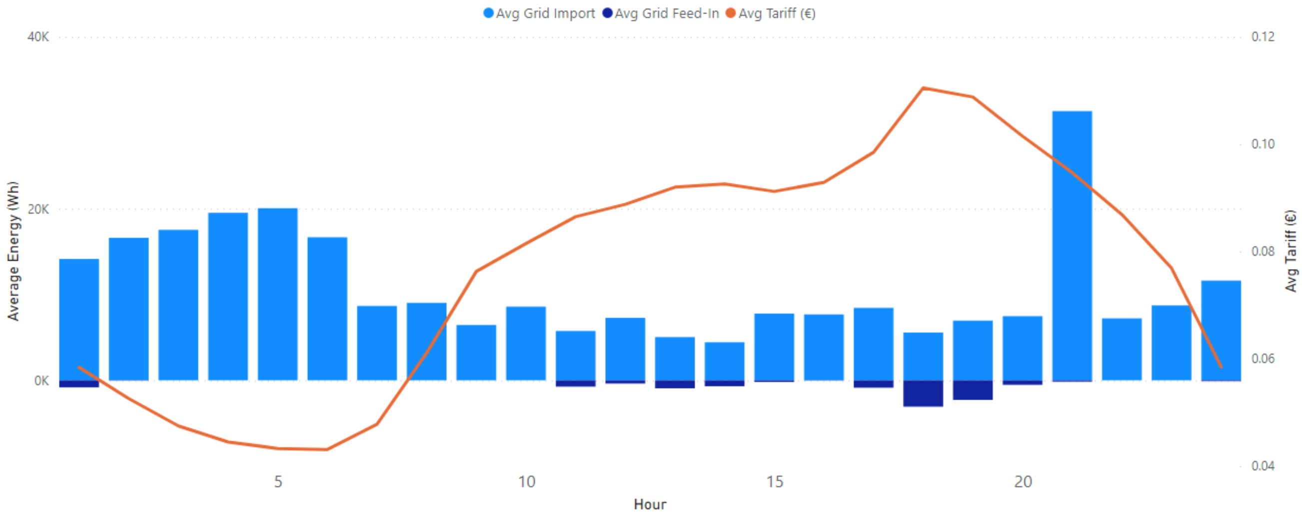


FIGURE 31 SCENARIO 2 / SECURE – GRID IMPORT & GRID FEED-IN

Considering that the balancing of battery discharge to meet the energy consumption of the properties was based on forecasted data from the GreenCom Networks algorithms, it performed well, with energy spilled to the grid being relatively minor.

Heat Pumps

The aggregated energy consumption of the heat pumps at the ambassador properties for hot water heating is shown in Figure 32. The detail of the heat pump response at each property to the pricing data is masked because of the differing hot water needs at each of the properties but an increase in energy consumption is observed between 2AM to 5 AM in line with the lower derived tariff pricing signal fed to the GreenCom Networks system.

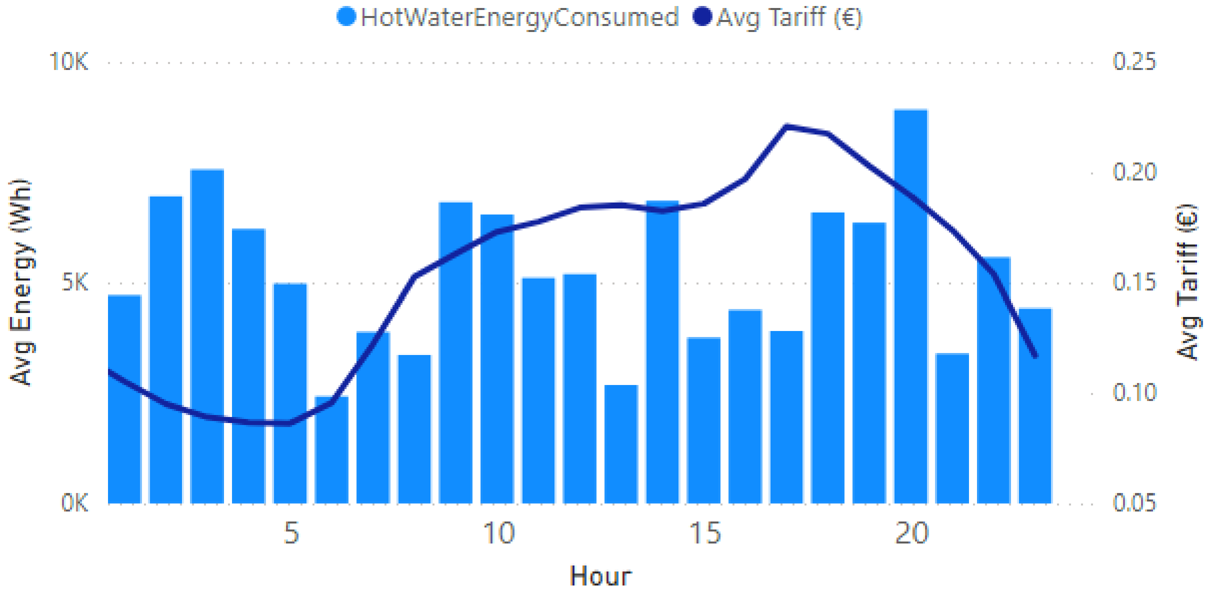


FIGURE 32 SCENARIO 2 / SECURE – AVERAGE AMBASSADOR HOT WATER ENERGY CONSUMPTION

However, Figure 33 shows the hot water energy consumption for a single site and it becomes much clearer that the increase in energy consumption for hot water heating is, as expected, in line with the lowest price period where hot water heating was commanded on, in the economic interests of the customer. Hot water energy consumption at other times of the day reflects the property's use of hot water, which for this household necessitated a large amount of water heating around 8 PM.

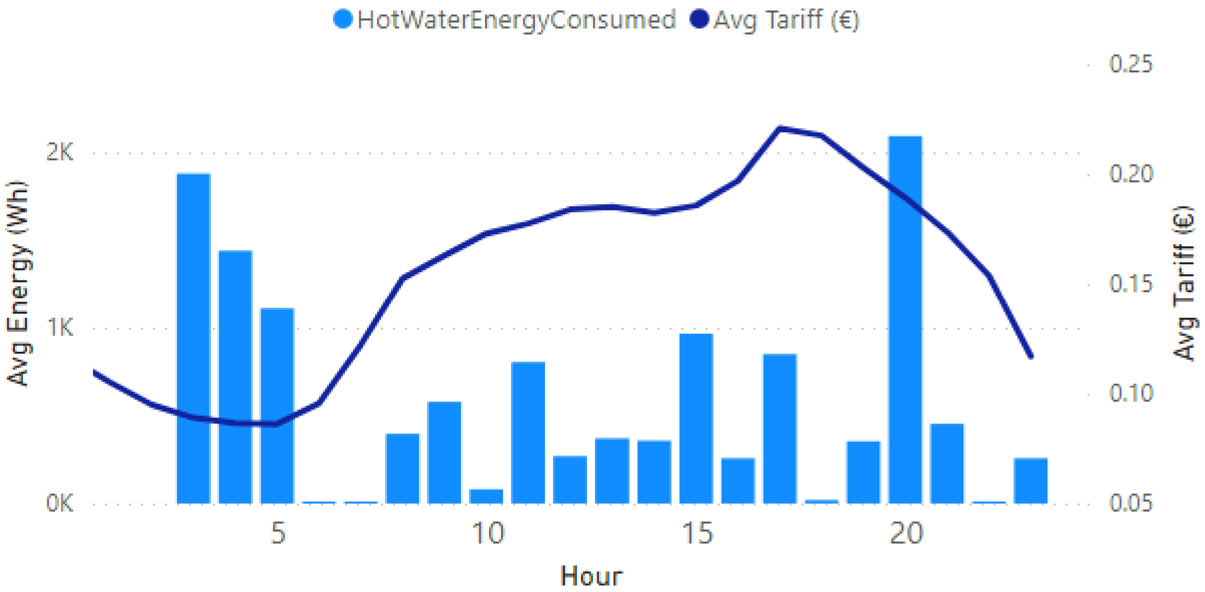


FIGURE 33 SCENARIO 2 / SECURE – ESB_017 HOT WATER ENERGY CONSUMPTION

Machine Learning

One of the key learnings from the results of this use case is the sensitivity and adaptability of the GreenCom Networks optimisation algorithms to simulated input pricing and the capability of the residential batteries to respond accordingly to the control set points, in the absence of user interaction.

Figure 34 demonstrates the differences in the pricing profiles for each day between the 18th of December 2021 and the 22nd of December 2021. It is noticeable that the peak price tends to occur during the typical evening peak and as such the discharged energy from the battery system is highest during this period each day.

The battery charging behaviour is very interesting and the timing of it clearly moves in respect of the provided pricing information. The slight peaks and troughs in the tariff pricing make for interesting charging and discharging behaviour with some days, in particular the 21st of December, showing substantial charging occurring in advance of a sharp rise in price over the evening peak.

Where energy is discharged earlier in the day, the level of recharge from solar is minimal as expected, with the tests being conducted in mid-December when solar PV generation is typically much lower due to winter conditions and less daylight hours.

The GreenCom Networks algorithms managed the charging and discharging pattern each day in line with the input pricing data and the forecasted energy consumption in the home. In some cases, the magnitude of power discharge also varied to provide a higher power, shorter discharge of energy or a lower power, longer discharge of energy depending on the price profile for that day. One example of good forecasting is from the 22nd of December where no energy is discharged from the batteries during the day to ensure the maximum energy was available when a sustained period of high price took effect around 6 PM. The battery discharged as much energy for as long as possible during this period to maximise the notional savings for the customer.

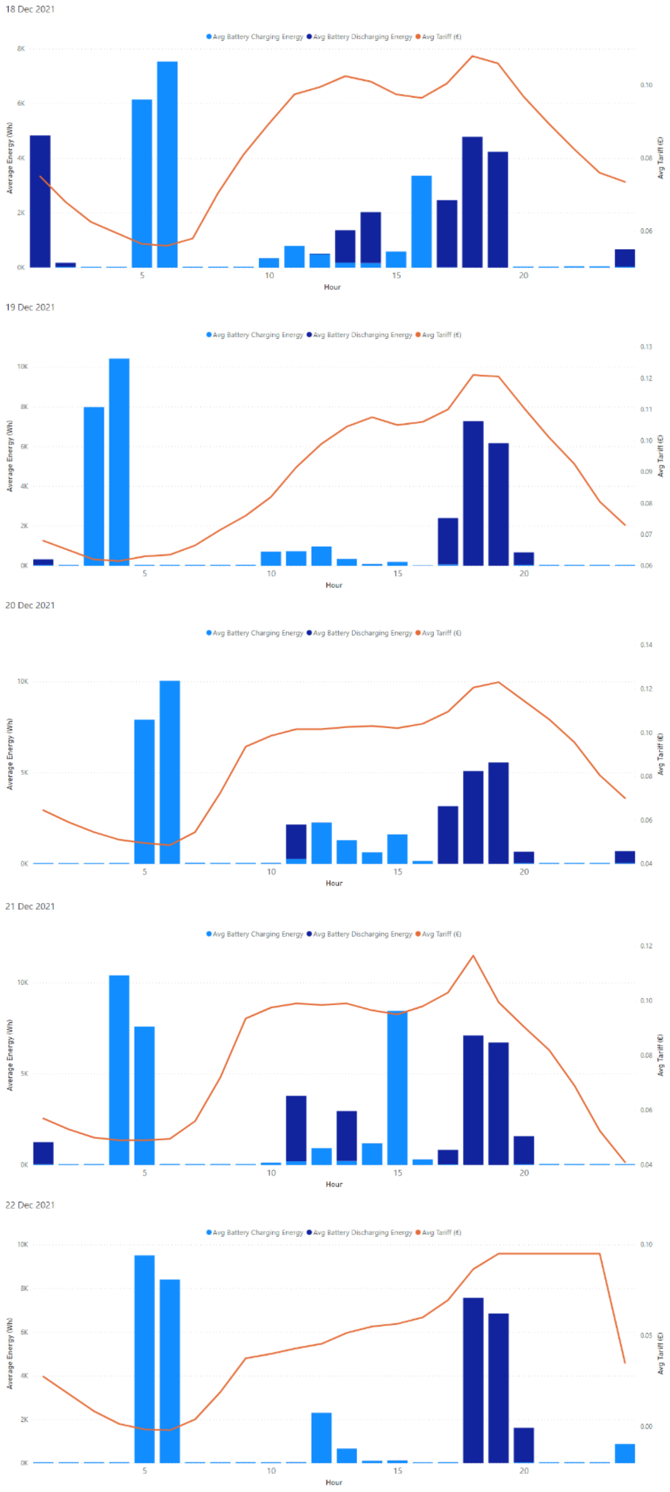


FIGURE 34 SCENARIO 2 / SECURE – PRICING PROFILE VARIABILITY

Summary

The Scenario 2 Secure use case demonstrated that clean energy enabling technologies and home energy management solutions can align and optimise their operation in response to dynamic inputs, be they price based, as was the case for the Dingle Project, or otherwise. The tests have shown that even with day-ahead pricing data, the GreenCom Networks optimisation algorithm and the clean energy enabling technologies can adapt their behaviour in the economic interests of the customer and would be able to do likewise if fed with other input signals. The UK market is seeing manufacturers of clean energy enabling technologies, embed within their product, the capability to align operation with certain dynamic supplier tariffs, thereby offering potential economic benefits to those electricity consumers.

This agility, when coupled with the potential of energy storage, demonstrates that mechanisms do exist whereby domestic battery energy storage systems could also be controlled to provide savings to the customers and energy services to the grid.

4.1.6.3 Scenario 3 / Manual Demand Response

The outcomes observed in the Sustain and Secure use case tests described in Sections 4.1.5.3.1 and 4.1.5.3.2, in terms of the role, capability and performance of residential-sited clean energy enabling technologies in providing automated demand response services to the network operator, will be significantly influenced by product manufacturer and home energy management optimisation systems, energy supplier tariffs and consumers' lifestyles. Scenario 3 on the other hand, as described in Section 4.1.5.3.3, was designed as a manual event, activated by a utilisation call from the grid operator or utility, and was designed such that it would take priority over other baseline optimisations that might already be running at customer properties. These manual utilisation calls provided the greatest and most impactful response, in terms of demand reduction and power injection at residential properties from energy storage and consequential support to the local network, but the availability of that response was difficult to predict due to the non-fixed nature of some of the clean energy enabling assets providing it.

For example, EV charging load could only be reduced if vehicles were charging at the time of the utilisation call and similarly, energy could only be discharged through V2G if the respective vehicles were connected. The response of the domestic battery energy storage systems was more reliable, in part due to its fixed nature, but the available energy in the batteries was heavily influenced by the energy usage behaviours and lifestyles of the respective properties and that meant little, or no energy was available from the battery systems at some participating properties during certain times.

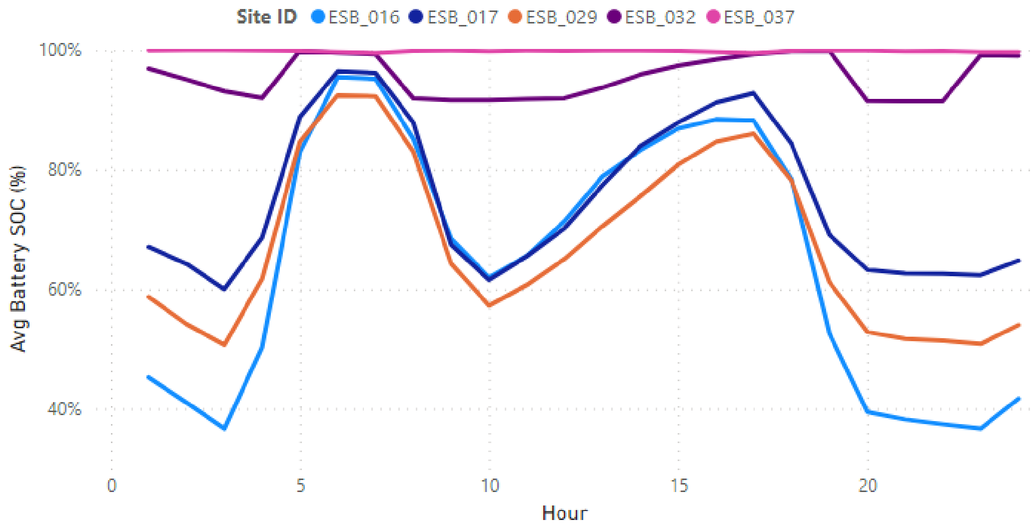


FIGURE 35 AVERAGE HOURLY AMBASSADOR BATTERY STATE OF CHARGE

Figure 35 shows the variation in the average hourly state of charge of the battery energy storage systems at the ambassador properties during the period between the 8th of November 2021 and the

2nd of December 2021 when the Scenario 1 use case was running. It shows how some batteries were leveraged much more than others and that was driven by several factors including the level of demand in the properties, solar energy generation at each site and the available excess used for charging. Note that there was an issue at ESB_037, over this period, where optimisation controls were not being actioned by the battery energy storage system and so the battery remained at 100% state of charge.

This plot also indicated those sites which were poised to provide the greatest response, depending on the time of day, if issued with a utilisation call under Scenario 3. If the battery state of charge was low when instructed to discharge, the discharge power was reduced and in some cases no power discharge was possible. Throughout the testing period, utilisation calls were completed across a range of times of day and with different groups of sites to better understand the impacts that time of day, participant behaviours and technology limitations, had on the level of demand response provided. Most Scenario 3 tests were conducted without providing advance notice to the participating households while a small number of tests were scheduled with the participants with the aim of maximising the demand response provided.

4.1.6.3.1 ORGANISED TEST – 21ST DECEMBER 2021

A large, coordinated test was scheduled with all participants in mid-December 2021. All 15 participants were requested to have their EVs connected to the chargers from 10 PM on the 20th of December 2021 and a manual utilisation call with a 15min duration was initiated just after midnight at 12:09 AM on the 21st of December.

Prior to the utilisation call, all sites were confirmed as having their EV connected however, several EVs were already fully charged and thus no charging was underway at those properties at the time of the utilisation call. There are several possible reasons for this including conflicting schedules between the Wallbox charging app and the GreenCom Networks schedule or the vehicles only needing small amounts of charge and having already reached 100% SoC. EV charging was actively underway at 7 of 15 properties incorporating 1 of 5 ambassador sites, 1 of 5 regular EV sites and 5 of 5 V2G EV sites. The stacked plot in Figure 36 shows the combined reduction of approximately 40 kW of EV charging demand from the 7 sites which were available to provide this form of demand reduction.

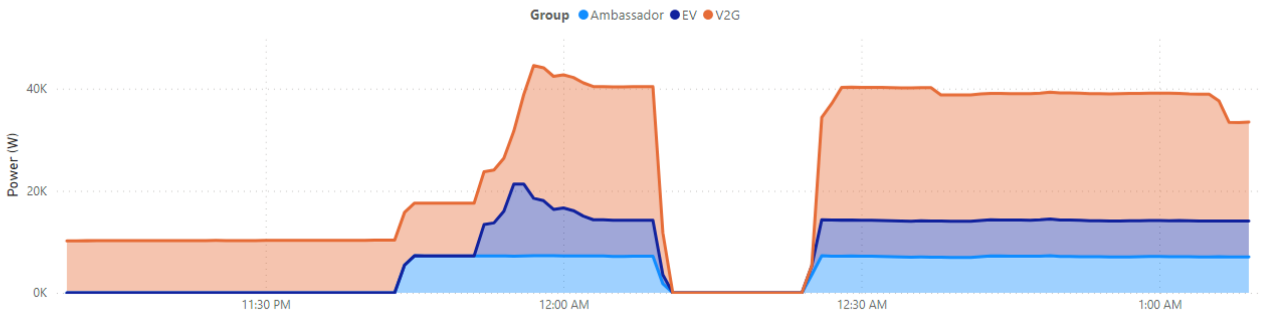


FIGURE 36 EV CHARGING DEMAND REDUCTION DURING ORGANISED SCENARIO 3 TEST

Along with the demand reduction from EV charging, there was a small amount, approximately 1-2 kW, of additional demand reduced during the test from the heat pumps at the ambassador properties. The stacked plot in Figure 37 shows that the magnitude of the heat pump response pales in comparison to what was provided through the suspension of EV charging.

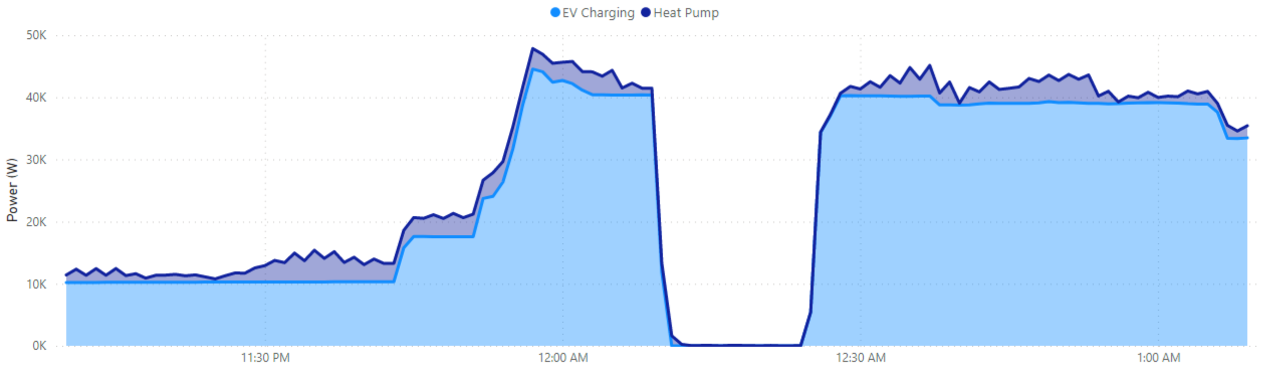


FIGURE 37 EV CHARGING & HEAT PUMP DEMAND REDUCTION DURING ORGANISED SCENARIO 3 TEST

At the time of the coordinated utilisation call, all sites were running the Scenario 2 use case and consequently the battery energy storage systems at the ambassador properties were already discharging some energy and some sites had no stored energy available. However, upon receipt of the utilisation call, the sites with available energy increased their power discharge to its maximum as expected, albeit the combined response from the batteries was relatively small. Figure 36 previously highlighted the reduction in charging from the EV and V2G sites but in addition, all 5 V2G sites also started to discharge energy. When the level of discharge from the V2G units had reached its maximum output after approximately 5 mins, almost 25 kW of power was exported to the grid across the 5 locations as shown in Figure 38.

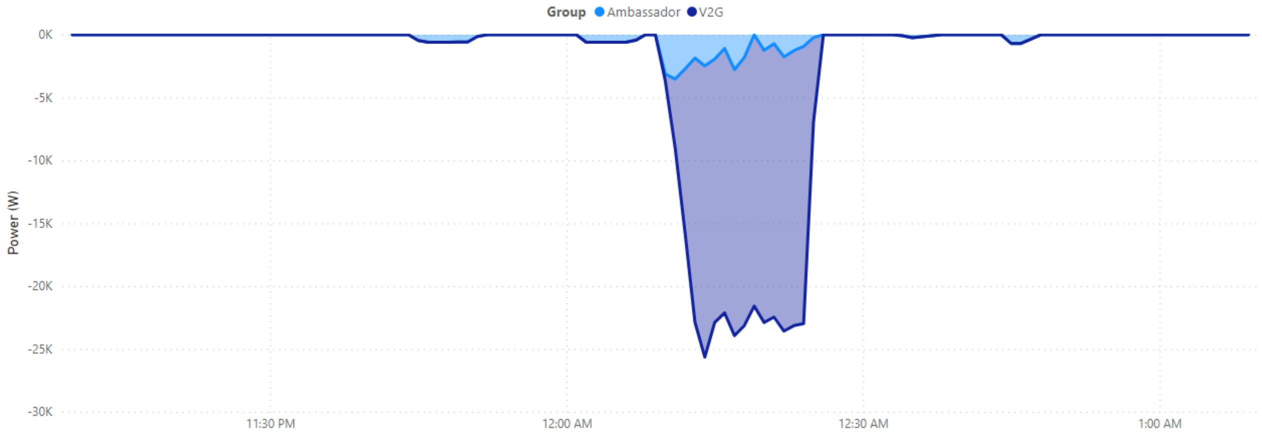


FIGURE 38 GRID FEED-IN DURING ORGANISED SCENARIO 3 TEST

Figure 38 clearly demonstrates that most of the grid support was provided from the V2G sites with a small contribution from the batteries at some of the ambassador locations. Immediately prior to the utilisation call, there was an aggregated total demand of approximately 75 kW across the 15 sites where controllable clean energy technologies were installed. Figure 39 shows that during the test, the aggregated level of demand across the sites dropped to between 6-9 kW once the V2G units reached their maximum export. This resulted in an overall nett demand reduction of approximately 65-70 kW on the Dingle Peninsula during the 15min test. On conclusion of the utilisation call at 12:24 AM, all suspended EV charging resumed, and the aggregated demand across the sites returned to the pre-test level of 75 kW.

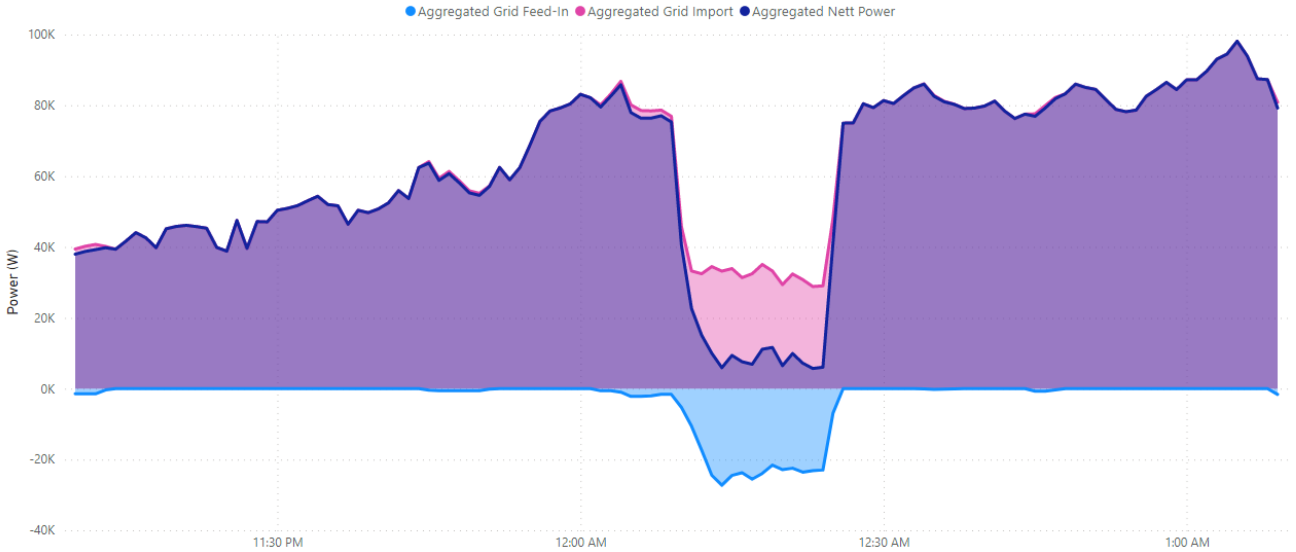


FIGURE 39 AGGREGATED GRID IMPORT & FEED-IN DURING ORGANISED SCENARIO 3 TEST

While the test did not achieve its maximum impact in terms of kilowatt reduction based on the overall capacity of all installed clean energy enabling technologies, it still demonstrated the huge potential in this type of service into the future. The outcome of the test reinforced several key points including understanding of the impact of competing algorithms and optimisations and the challenges of using EV charging for demand reduction. In this case, the already active Scenario 2 optimisation severely limited the available energy in the battery energy storage systems and reduced its impact during the test. As seen from previous use cases, the reduction in demand from heat pumps is minimal but they did provide a level of demand response support as intended.

EV charging and particularly V2G is shown as having had the biggest impact during this test with all 5 V2G sites performing perfectly. However, this represents an unrealistic scenario whereby all V2G-enabled EVs were connected and charging at the time of the utilisation call. In reality, customer lifestyles and behaviours mean that cars may not be connected to the chargers at certain times. This unpredictability or unreliability in EV charging as a source of demand reduction is reflected in the performance of the EV charging at the 5 ambassador and 5 EV champions where only 2 of 10 locations were charging at the time of the utilisation call and therefore in a position to provide demand reduction. This is despite all vehicles being connected to their respective chargers.

4.1.6.3.2 AD HOC V2G TEST

The ability to specify particular sites to respond to the utilisation call was something that was tested on many occasions and one example is when it was used to command the 5 V2G sites to provide demand response for a 15min period on the 2nd of December 2021.

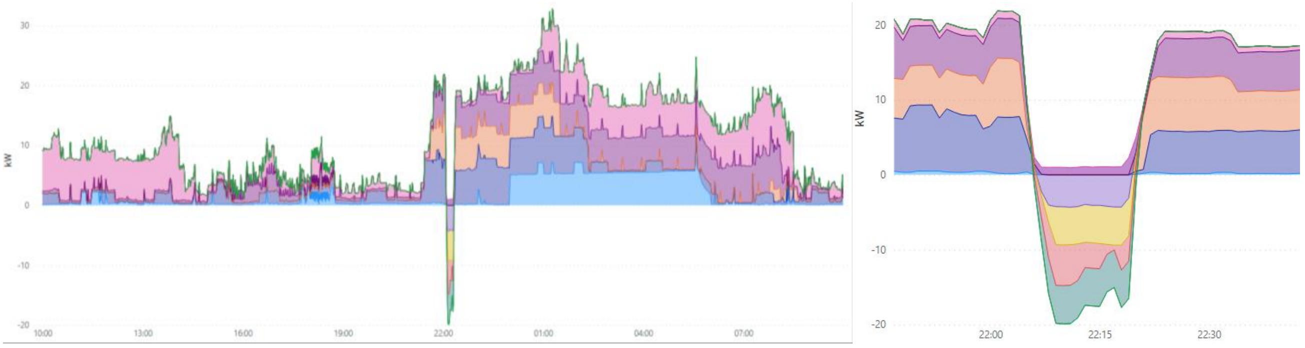


FIGURE 40 V2G SCENARIO 3 TEST - 2ND DECEMBER 2021

Figure 40 shows the power consumption for each of the 5 V2G properties from 10 AM on 2nd December 2021 to 10 AM on the 3rd of December. Clearly visible at 10:05 PM is the impact of the Scenario 3 test on the aggregated demand and grid feed-in. From the plot it is evident that EV charging commenced at 3 of the 5 sites around 9:30 PM with a total demand of approximately 20 kW at the time the utilisation call was issued.

On receipt of the call, the 3 EVs that were charging ceased charging within 1min and proceeded to start to discharge energy from the vehicles. 1 site either had no EV present at the property, or it was not connected to the charger while the other site was connected but had not been charging. On receipt of the instruction, it started to discharge as expected and after approximately 5min, all 4 discharging units reached their maximum output and together were exporting approximately 20 kW to the grid across the 4 locations. This was a nett change of approximately 35-40 kW on the peninsula during this test. The output varied over the duration of the test due to changing demand at one location and on conclusion of the utilisation call at 10:21 PM, the pre-test status resumed with charging recommencing at 3 locations and the 4th location returning to standby.

This test demonstrated both the capability of V2G in providing demand response and support to the grid, and the potential for future flexibility service providers to target response from specific registered locations or technologies. The capability is very powerful provided the availability of the service can be determined and relied upon. Depending on the lifestyles and behaviours of the customers, the likelihood of the vehicles being present and connected to the V2G chargers is something that can vary significantly from one property to the next. This issue was magnified with such a small number of participating sites.

4.1.6.3.3 AD HOC TEST – 27TH OCTOBER 2021

A utilisation call was issued to the 5 ambassador properties at 08:30 AM on the 27th of October 2021. At the time of the utilisation call, there was negligible heat pump energy consumption and no EV charging taking place as shown in Figure 41.

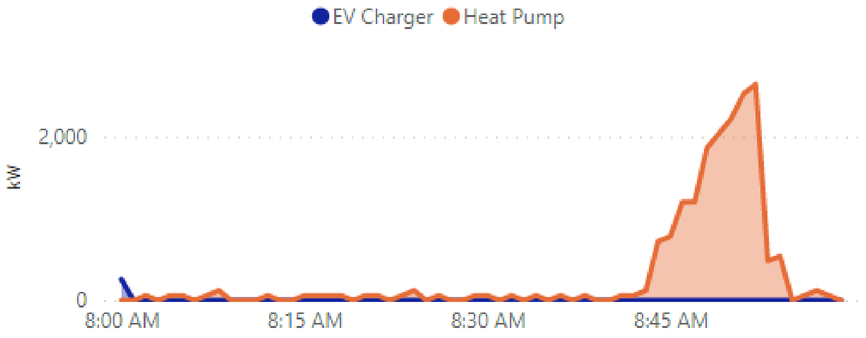


FIGURE 41 EV CHARGER & HEAT PUMP – SCENARIO 3 TEST 27TH OCTOBER 2021

Upon receipt of the call, the battery energy storage systems at 4 of the 5 ambassador sites started to discharge at their maximum capability of approximately 2.5 kW to provide a total of just under 10 kW as shown in Figure 42. The battery at one location did not respond due to a communications issue with the system following an earlier power outage in the area.

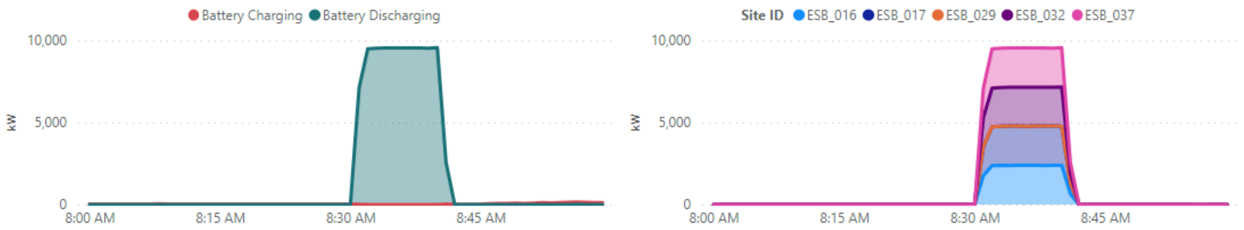


FIGURE 42 BATTERY ENERGY STORAGE SYSTEM RESPONSE - SCENARIO 3 TEST 27TH OCTOBER 2021

Figure 43 shows the reduction in aggregated demand across the 5 sites. There was no reduction in demand at site ESB_029. The plot also shows the aggregated nett power when a combined grid feed-in of almost 8 kW is included.

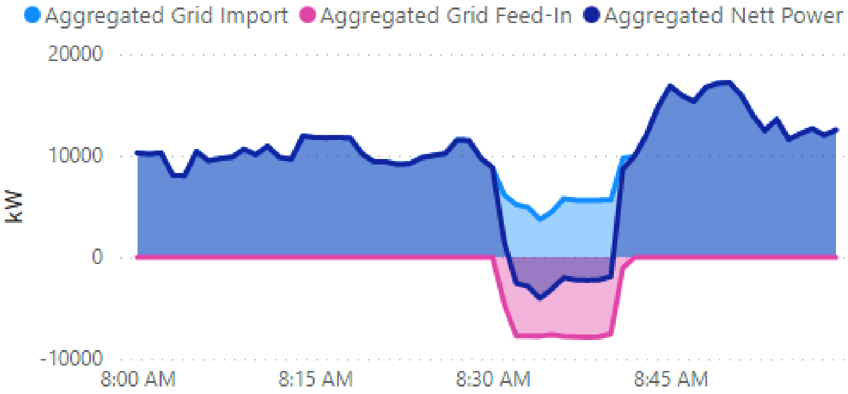


FIGURE 43 SCENARIO 3 TEST 27TH OCTOBER 2021 GRID IMPORT & FEED-IN

The level of grid feed-in was sufficient at one location (purple trace) to cause a reverse power flow at one of the transformers as shown in Figure 44 while the impact of the demand reduction due to the discharge from the battery energy storage systems is also visible in the aggregated transformer data in Figure 45. The variation in the load on the transformers in Figure 45 is due to the energy usage of other customers connected at each of those transformers.

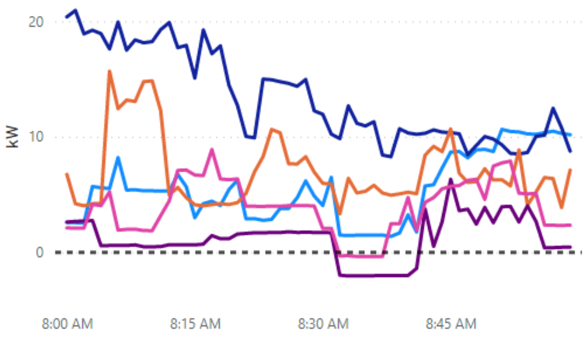


FIGURE 44 TRANSFORMER LOADINGS

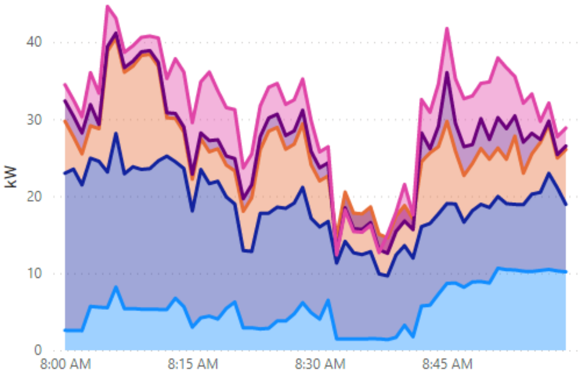


FIGURE 45 AGGREGATED TRANSFORMER LOADING

4.1.6.3.4 AD HOC TEST – 14TH DECEMBER 2021

Figure 46 demonstrates the response of ambassador site ESB-032 to a utilisation call on the 14th of December 2021. No EV charging was in progress at the time of the utilisation call while the heat pump was consuming approximately 1.3 kW.

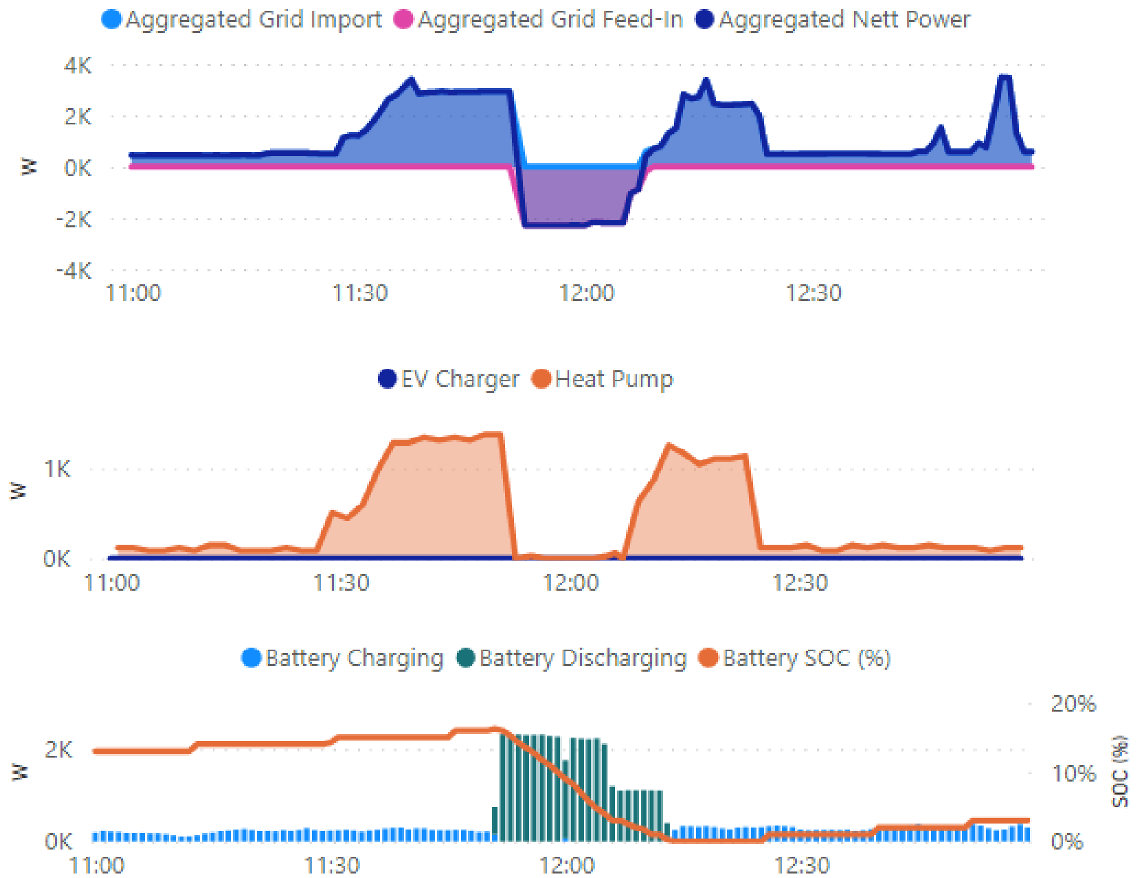


Figure 46 Scenario 3 Test 14th December 2021 - Site ESB_032

On receipt of the utilisation call at 11:52, the heat pump switched off for the duration of the 15min test while the battery energy storage system started to discharge energy. The battery discharged close to its maximum capability for the duration of the 15 min test before reducing its power output at the end of the utilisation call and continuing to discharge in line with the scenario1 optimisation schedule that was running prior to this ad-hoc, manual demand response test. The state of charge of the battery energy storage system was 16% at the start of the Scenario 3 test when the utilisation call was initiated, and it reduced to 3% by the conclusion of the call at 12:07 PM.

A nett change of approximately 4 kW was achieved throughout the duration of this test and it demonstrated that the combination of the demand reduction from the heat pump coupled with the battery energy storage system can represent a substantial level of demand reduction and support to the local electricity grid.

4.2 Challenges

The delivery of the technical solution to enable the customer flexibility tests was challenging. However, the challenges that arose during the tests were much more significant and impactful to the potential viability of such services being relied upon by grid operators into the future.

When operating in a residential setting and in particular rural areas, the robustness of the communications networks is a particular concern. During the 8 months from the initial activation of the field gateways in the home, until they were decommissioned in January 2022, there were several communications outages from both cellular and broadband providers. Some outages persisted for up to 48 hours during which time all remote communications, monitoring and control was lost with the affected properties. This is a vital link in the chain for the reliability and control of energy services and unfortunately, there is very limited, cost-effective measures that can be put in place to fully mitigate against these issues. Adding additional redundancy adds extra cost to a solution and service that already struggles with viability to begin with.

The Dingle Project aimed to recreate a realistic, future scenario whereby active energy citizens and prosumers could leverage clean energy technologies they may have or may install in their homes for the provision of energy services. As such, the project aimed to leverage the standard installations for the trial test bed and not falsely bolster weak points in communications by specifying and hard wiring all assets. It is most likely that many of the clean energy enabling technologies will communicate with the home local area network (LAN) and the internet via a wireless Wi-Fi connection. Some assets may be hard wired with ethernet connections, but these are likely to be in the minority. Throughout the Dingle Project some households experienced issues with Wi-Fi connectivity and signal strength, particularly with some of the installed assets like the EV chargers which are installed external to the building. In these cases, low cost Wi-Fi extenders were installed to increase the range of the Wi-Fi network with mixed results. However, for some households, due to the fabric of their construction, they still encountered some connectivity issues which did impact on the operation of and the results of the trials.

Another challenge that appeared during the trials related to some of the energy saving habits that certain participating customers had. For example, following the installation of the field gateways and indeed the EV chargers, it was observed that some sites and devices would go offline each night and upon investigation it was found that the customers would manually turn off switches, sockets and the EV charger isolator switch with the intention of saving energy from these devices being left on standby. Other gateway outages were also experienced through accidental disconnections when customers may have plugged out the power adaptor for the gateway when requiring a socket for another domestic appliance. These issues were resolved through discussions with the relevant customers and bringing to their attention the importance of leaving the gateway device and the installed clean energy enabling technologies always powered up.

The power of the GreenCom Networks gateway device lies with its vast library of device drivers and software integrations. However, these drivers and integrations are developed to leverage data and interfaces from the corresponding clean energy enabling assets they interface with. Should the asset manufacturers change firmware or interface parameters then it often breaks the GreenCom Networks driver, forcing redevelopment and testing works. This issue was experienced on the Dingle Project with buggy firmware versions deployed by some manufacturers of the installed assets, and which took some time to resolve. In most cases, GreenCom Networks were quickly able to develop and redeploy a modified driver to the relevant field gateways, but in other instances where the bugs were fundamental to the integration, the link to the assets was unavailable until the manufacturer published new firmware and it was applied to the relevant assets. Without common interfaces and protocols for the monitoring and control of clean energy technologies, this issue will continue and is becoming worse as more and more manufacturers of assets enter this space requiring companies like GreenCom Networks to continually expand their driver and integration libraries.

With all data collection and operational tools from GreenCom Networks delivered through the Software as a Service (SaaS) model, the reliance on the availability of the cloud provider is paramount. Some minor, short duration outages were experienced during the Dingle Project but were primarily due to small issues encountered when GreenCom Networks were migrating services from one cloud provider to another. However, the impact of these short outages highlights the importance of cloud service availability and will be key for flexibility service providers to consider in the future when contracting with utilities for energy services where non delivery of services may incur penalties.

4.3 Vehicle-to-Grid

Vehicle-to-grid (V2G) is a technology that enables energy to be taken out of the battery in the connected electric vehicle. The charging becomes bidirectional, meaning power can be sent from the home into the vehicle or from the vehicle back into the home and potentially back to the electricity grid. There are often other terms used such as vehicle-to-everything (V2X), vehicle-to-home (V2H) or vehicle-to-building (V2B). These are used depending on whether the energy is only used within the home or if it is to be exported to the grid and provides an energy service to the grid operators.

The Dingle Project saw the first residential scale vehicle-to-grid electric vehicle chargers installed in Ireland. The Quasar units manufactured by Wallbox Chargers are a bidirectional direct current (DC) charger suitable for home installation. They have a maximum alternating current (AC) rating of 32 A but were limited to 25 A for installation in line with microgeneration thresholds [22] in Ireland. The devices comply with I.S. EN 50549-1 [23] and were installed in line with the I.S. 10101:2020 [24] National Rules for Electrical Installations.

FIGURE 47 WALLBOX QUASAR VEHICLE TO GRID CHARGER INSTALLATION

At the time of installation, Vehicle to Home (V2H) capability was not available on the Quasar units but subsequent firmware versions now support this capability which unlocks greater potential for the end customers [25]. A specific model of energy meter is required to be installed to enable this capability.

The capability of V2G is impressive and will come more to the fore over the coming few years as charger manufacturers provide units compatible with the Combined Charging System (CCS) combo plugs. This is likely to open V2G capability up to more electric vehicles provided the vehicle manufacturers support V2G/V2H and maintain existing warranties. Currently it is prohibitively expensive to consider a V2G charger over a regular smart charger, but it is expected this technology will become more common as the unit costs come down.

When compared to current battery energy storage systems which are often installed along with solar PV, the V2G capability is far superior in terms of the volume of energy storage and the inverter discharge ratings and herein lies a new challenge for ESB Networks. Accommodating such technologies at scale will present a new challenge and issues such as voltage and network capacity will have to be considered carefully. The use of V2G for grid services has the potential to be very valuable to grid operators in the future but its success will be determined by the forecasting and availability telemetry because of it being a mobile energy store rather than one which is fixed and permanently connected.

The pace of research and development is fast and Wallbox has already announced its second generation Quasar 2 bidirectional charger in the US [26]. This new model is expected to support the CCS-combo plugs along with a blackout mode which Wallbox say will allow customers to use their vehicle as an emergency generator during instances of power outages. While it may be some time before it is available in Europe and has the appropriate grid code compliance certification, it demonstrates the continuing development in this technology.

Through the Dingle Project, ESB Networks sought to understand the impact of such chargers on the electricity network and the potential energy services that they could offer into the future. The scenario 3 use case as described in Section 4.1.5.3.3 utilised the maximum capability of the Quasar V2G charger. In cases where a vehicle is charging when a utilisation call is received, the GreenCom Networks gateway in the property instructs the charger via Modbus TCP to cease charging and commence discharging at its maximum capability of 25 A. This scenario achieves the largest nett impact on the electricity grid as the Quasar unit goes from 25 A consuming to 25 A discharging. Section 0 outlines the results of the various tests conducted but other interesting observations were made during those tests.

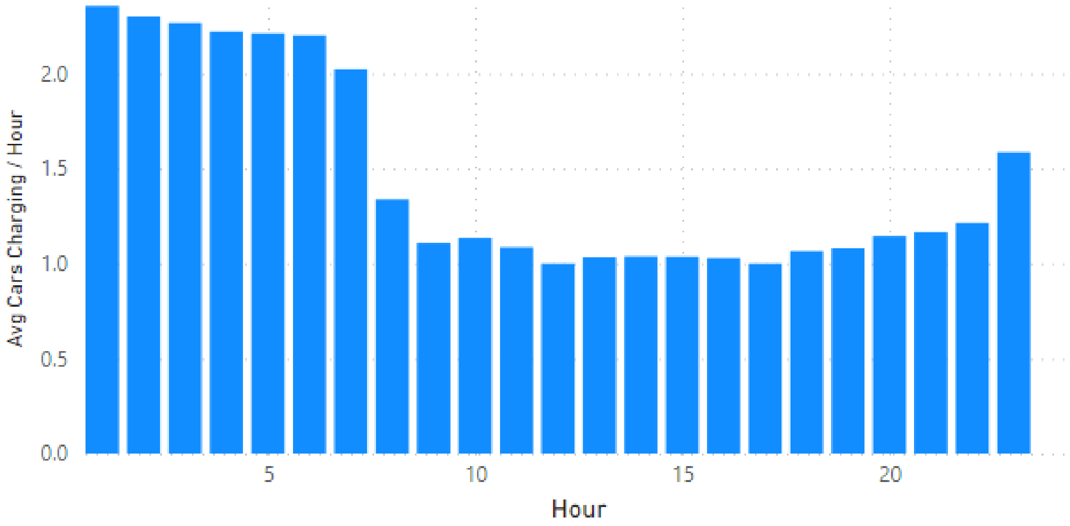


FIGURE 48 V2G HOURLY CHARGING ACTIVITY

Figure 48 shows the that on average between the 1st of October 2021 until 19th of January 2022, there were approximately 50% of the V2G compatible EVs connected and charging between midnight and 7am while there was typically just 20% connected and charging at other times during the day. It is no surprise to see that most of the charging is completed during the night rate hours of 11 PM to 8 AM Coordinated Universal Time (UTC) when suppliers in Ireland typically offer lower unit rates for electricity consumption.

Another notable observation from a network's perspective is the impact on the voltage at the customers connection point. While there were limited discharge events with the V2G units during the pilot, there appears to be a correlation between the voltage at the connection point of the property to the grid, and the charging or discharging power of the V2G charger.

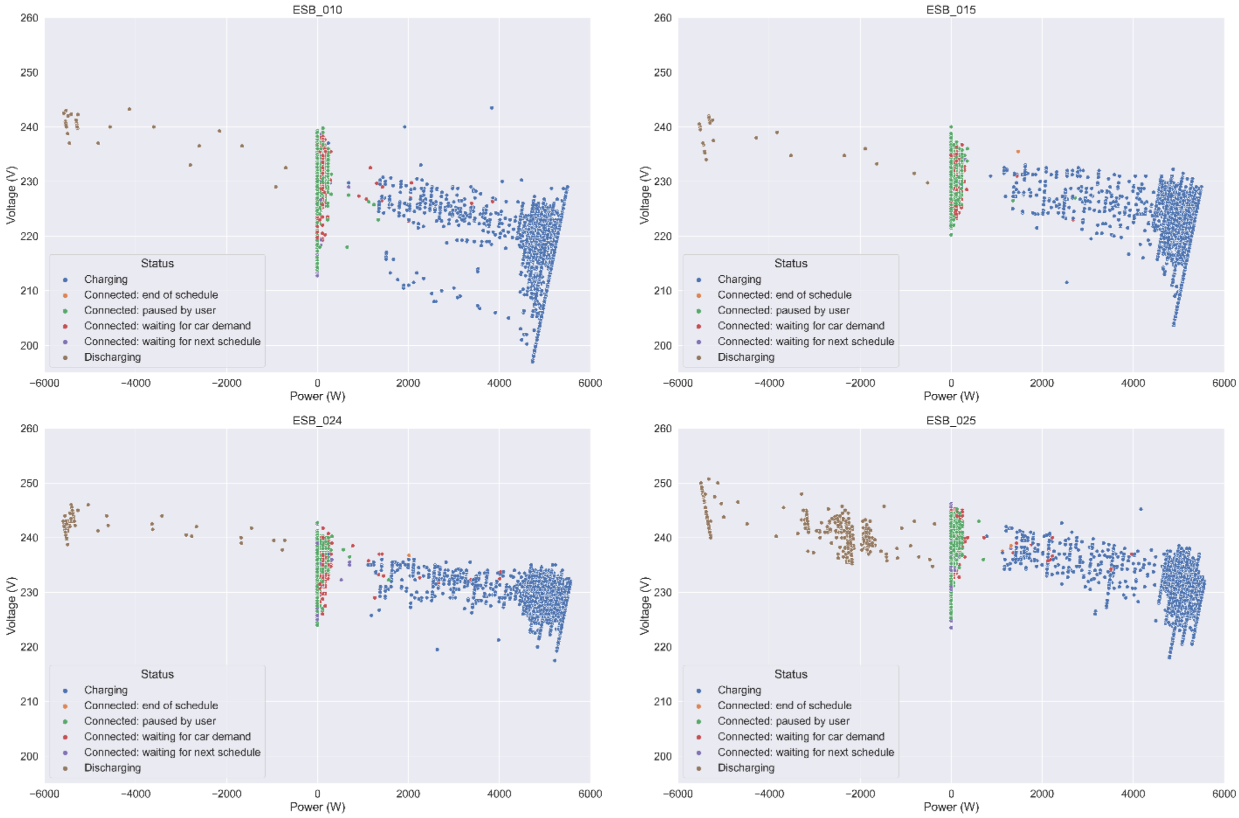


FIGURE 49 V2G CHARGING/DISCHARGING VS. GRID CONNECTION POINT VOLTAGE

As shown in Figure 49, the greater the power being discharged from the connected EV (negative), the higher the connection point voltage observed and conversely the greater the power when charging (positive), the lower the observed connection point voltage is.

Sites ESB_010 and ESB_015 are installed on a rural 10 kV feeder from Dingle 38 kV substation with each site located near the end of a branch off that feeder while sites ESB_024 and ESB_025 are located at the end of separate 20 kV feeders that are fed from the Inch and Camp 38 kV substations. This information provides additional context to the lower voltages observed at sites ESB_010 and ESB_015 which suffers historically with voltage issues. The upgrading of the Dingle 10 kV network to 20 kV is planned to take place over the next few years and will substantially help to resolve these issues. Where voltage drop during charging is less of an issue on the 20 kV feeder, the voltage rise during discharging raises another potential issue especially if mass deployment of V2G capability was to materialise in future.

4.4 Low Voltage Mapping, Modelling & Monitoring

This section outlines the activities undertaken to physically map and monitor the Low Voltage (LV) network on the Dingle Peninsula and how that data was leveraged to develop an integrated MV-LV model for software simulations to assess the impacts of increasing clean energy enabling technologies on the distribution network.

4.4.1 LV Mapping

The LV mapping pilot allowed ESB Networks assess whether a national programme of LV mapping is feasible from both a cost and delivery perspective. The pilot concluded in February 2020 and the findings fed into the Operations submission for PR5 (Price Review 5) to the Commission for Regulation of Utilities (CRU). The works required the capture, storage, and transfer of accurate LV network data to ESB Networks' graphical information system (GIS) from G/Technology and included both Overhead (OH) and Underground (UG) networks.

The works were procured via mini-tender under an existing framework contract and the pilot resulted in an increase of 33% in the volume of LV poles and an increase of 11% in mini-pillars recorded on ESB Networks' GIS system within the Dingle area. Figure 50 provides an example for a section of the distribution network GIS map before and after the LV mapping process was completed. The MV network is represented in green, the additional LV network is shown in blue, and the additional underground LV network is represented in black. The dashed representation of the network in Figure 50 indicates single-phase network while the three-phase network is represented by solid lines.

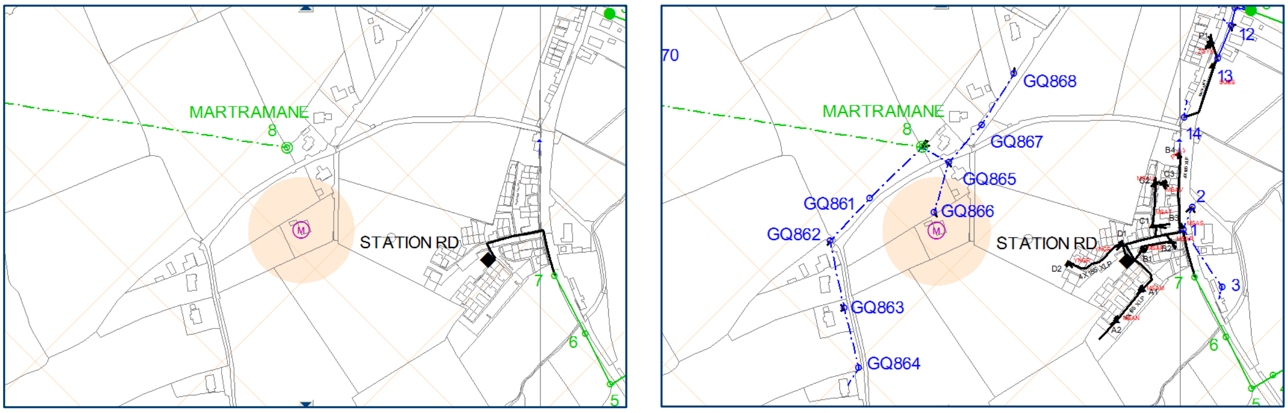


FIGURE 50 GIS NETWORK MAP BEFORE & AFTER LV MAPPING PILOT

Important learnings from the pilot included a better understanding of the time and resources to undertake the task and to transfer the data accurately to ESB Networks' GIS system. Furthermore, the pilot recommended that mapping should be prioritised in areas where electrification of heat and transport is expected first and that there is a need to integrate a future national mapping programme with other existing or planned work programmes. The learnings from the pilot were shared with the wider business and several recommendations were made with regard to training, job aids, processes and procedures.

ESB Networks' National Networks Local Connections programme is currently working towards a target of 50% mapping / modelling visibility of the network by the year 2025 and is seeking to develop accurate maps and models of the LV network using an innovative approach that combines data analytics with field spot checks to validate the model [27]. This innovative pilot will demonstrate an alternative approach to the resource intensive pilot conducted by the Dingle Project. The NNLC pilots will also further the testing of cable location, phase and feeder identification units.

4.4.2 LV Monitoring

To have an active, real-time view of the LV network, the installation of LV monitors on ground mounted and pole mounted MV/LV substations was required. Over 30 LV monitors were deployed as part of ESB Networks' Dingle Project and the preceding StoreNet project on the Dingle Peninsula.

The deployed monitors were powered from the LV side of the MV-LV transformers where they also measured voltage and current. The devices also reported active, reactive, and apparent power along with frequency and harmonic measurements every minute, to a centralised cloud database. For further information on the ICT infrastructure to support the LV monitoring, see the SERVO Close Out report [28].

Not all MV-LV transformers in Dingle were monitored as part of the project and selection was based upon several criteria include the technology types in the participating customer homes and the trials in which they were involved in. Monitors were installed at the transformers feeding all ambassador properties while others were distributed across participants taking part in the Solar and EV trials with additional emphasis placed on those with the V2G enabled chargers and vehicles.

Reliability of data collection was a challenge throughout the pilot with cellular communications being particularly troublesome. A number of cellular communications outages were experienced during 2021, some of which affected data collection for multiple days. Whilst the monitoring devices have onboard buffers, the buffer capacity had been filled on several locations resulting in loss of data. Backfilling of stored, buffered data was also problematic in locations with low signal strength as the devices struggled to transmit all data to the storage database. Should these monitoring devices feed information to real-time operational systems in the future, communication issues would have a much greater impact.

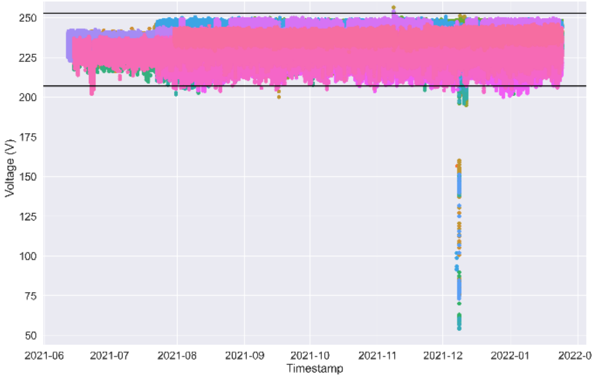


FIGURE 51 CONNECTION POINT VOLTAGE ACROSS ALL PARTICIPATING SITES

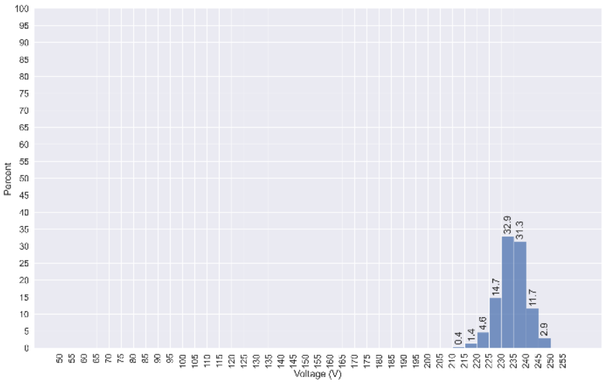


FIGURE 52 VOLTAGE DISTRIBUTION HISTOGRAM FOR ALL PARTICIPATING SITES

The data from the installed monitors enabled the visualisation and analysis of the flexibility tests and their impact on the electricity network in the local area. Accurate voltage measurements at over 30 points across multiple 10 and 20 kV MV feeders gave an insight into the challenges on the Dingle Peninsula in maintaining the voltage within the contractual limits with our customers as shown in Figure 51. Instances of low voltage were observed on the western extremities of the network at times of high demand while instances of high voltage were experienced in Dingle town during times of low demand and especially where the monitoring device was located electrically close to Dingle 38 kV substation. Figure 52 provides a histogram showing the spread of voltages recorded between late June 2021 and mid-January 2022.

Several stakeholder visits were conducted in person on the peninsula in late 2021 and early 2022 to disseminate and share the learnings from the Dingle Project. Each of these visits included a trip to an ambassador property where a live demo of the customer flexibility demand response test (See Section 4.1.5.3.3 for more detail) was conducted.

Attendees were able to visually see the impact of the test at the nearby MV-LV transformer in real-time. Figure 53 shows that the EV was initially connected and charging initiated at 12:06 before the demand response scenario was activated at 12:24 causing the EV charger to suspend charging, the heat pump to turn off and the battery energy storage system to discharge at its maximum rating. At 12:34 the demand response utilisation call is finished and EV charging recommences, the heat pump is turned back on, and the battery energy storage system returns to normal. Following the test, the load on the transformer varies and increases slightly and this is typical of a small increase in energy consumption around lunch time.

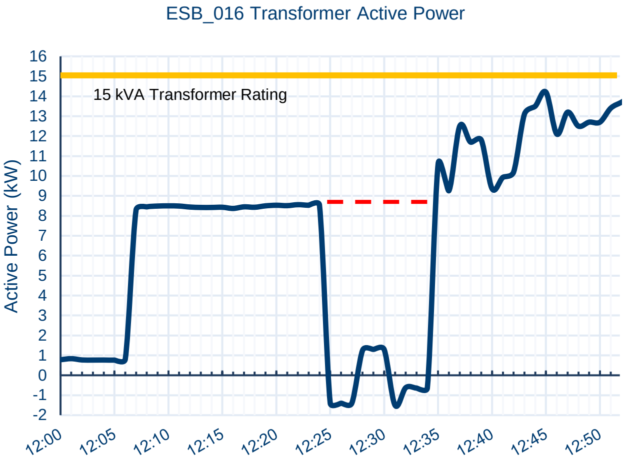


FIGURE 53 LV MONITOR DATA DURING DEMAND RESPONSE TEST

Figure 53 provides an example of the LV monitor data and represents the active power flowing through the transformer before, during and after the demand response test. The discharging of the battery energy storage system is enough at times during this test to meet the needs of the participating household and export power to the grid, but also to meet the power requirements for the other houses fed by this transformer and export the excess up onto the MV network as shown by the negative power flow in Figure 53.

It was clear from the Dingle Project that as the electrification of heat and transport continues to gather pace, additional monitoring will aid in the delivery of reinforcement works but monitoring will be a necessary pre-requisite for any form of flexibility services or congestion management at the LV level. The experiences of the LV monitors deployed on the Dingle Project will also help inform future LV monitoring programmes conducted by ESB Networks including the NNLC programme.

4.4.3 LV Modelling

With a fully mapped LV and MV network for the Dingle peninsula available in ESB Networks' GIS system, it was originally planned to build upon this data and develop an integrated MV-LV electrical model suitable for running various simulations and studies.

This work package proved to be much more challenging that envisaged. The MV planning division within ESB Networks currently uses the Synergi Electric software package from DNV [29] for distribution planning and renewable connection studies. However, after early discussions with the network planning division, it was decided that a different application may be better suited to achieve an integrated MV and LV model.

MaREI is the SFI Research Centre for Energy, Climate and Marine research and innovation co-ordinated by the Environmental Research Institute (ERI) at University College Cork. Members of MaREI's social science division were already involved in the Active Energy Citizen workstream of the Dingle Project and an opportunity came along for a collaboration on the LV modelling works through MaREI's participation in the CREDENCE project [30].

A scope of work was agreed between ESB Networks and MaREI to take a converted and validated MV model of the Dingle Peninsula and integrate a portion of the LV network from the mapping data such that studies could be performed to assess the impact of distributed energy resources and clean energy enabling technologies on the distribution network.

MaREI used an opensource simulation tool called OpenDSS [31] which was developed by the Electric Power Research Institute (EPRI). The Ballyferriter area of the Dingle Peninsula was chosen as the portion of LV network to be incorporated into the integrated model. This area was chosen due to its electrical topology and the presence of multiple LV monitors in the area to aid with model verification.

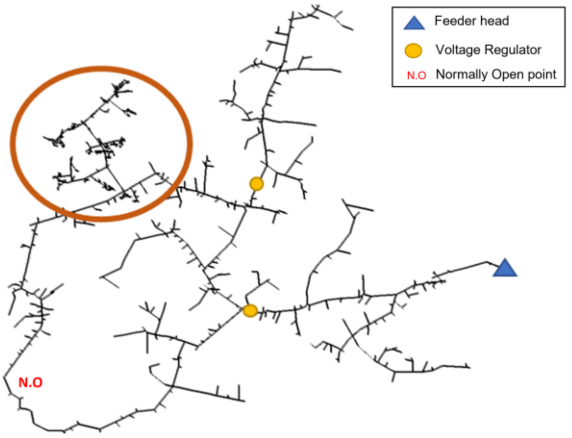


FIGURE 54 OPENDSS MODEL OF DINGLE MV-LV NETWORK

A technical paper was submitted to IEEE Transactions on Power Systems following the works completed in collaboration with the Dingle Project. The paper presented a methodology for large-scale MV-LV integrated network model building, scenario determination and analysis for distribution networks. A pre-print copy of the paper is available [32]. The submission was peer reviewed by four international expert reviewers who all recognised the merit and applicability of the work in the paper, but the consensus view was that it did not contain enough novelty and contribution beyond the current state of the art in the scientific literature to merit publication in this venue. The paper will be revised in due course and resubmitted to IEEE Systems Journal for review and consideration.

Some of the challenges encounter during the works included some inconsistencies in the technical data for LV conductors held by ESB Networks. Other items that made the development of an electrical model rather difficult included instances of missing phasing information, some isolated mini pillars with no connections to the ground mounted substations, instances of missing conductor types along with missing or incorrect customer referencing at some transformers. These works highlighted the need for and importance of ensuring accurate records are kept in relation to the LV network as planning, operating, and maintaining the LV network will become much more important over the next decade. The learnings gained during the LV modelling collaboration will be helpful as ESB Networks and the National Networks Local Connections programme undertake further, deeper LV-MV integration as new operational tools are procured and developed to manage a more active electricity network into the future.

4.5 Non-Flexibility Learnings & Insights

The Dingle Project set out in part to study the impact of EV charging and EV charging behaviours on the electricity network and to do that effectively, real customers with different lifestyles, needs and driving requirements were needed. The project provided 15 households with an EV for a 1 year period. The data from the vehicles was used to provide more context and understanding to the charging behaviours observed at the home chargers but it also provided some interesting insights into the applicability of EVs available on the market in 2021 and 2022. An additional 2 EVs were made available on a managed basis to members of the community to increase the awareness of the EV trial and provide others with the experience of electrified motoring.

4.5.1 Electric Vehicles and Charging

It was found that users of the EVs overcame any range anxiety issues very early on and within weeks, several users were completing daily distances in excess of 500 km. There appeared to be a consistent trajectory of increasing confidence in the use of the vehicles throughout the early months of the EV trial and as the summer period arrived, it coincided with reduced national travel restrictions associated with the COVID-19 pandemic, and enabled customers to undertake longer journeys throughout Ireland. Figure 55 shows the greatest single week for distance covered by the fleet of EVs was in week 47 of 2021 when more than 11,600 km were travelled.

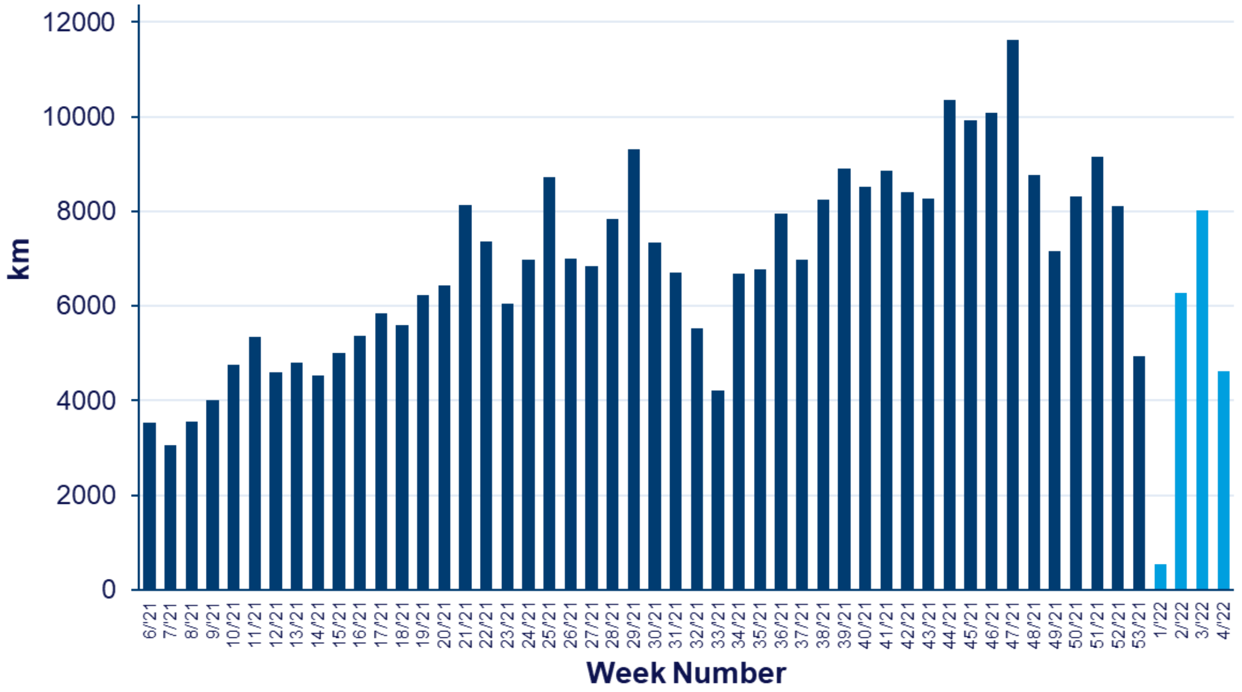


FIGURE 55 TOTAL WEEKLY DISTANCE COMPLETED

Having 365 days of driving completed by the 15 project ambassadors and EV champions provided 5,475 samples of which less than 0.5% travelled greater than 396 km in a single day with 95% of daily distances completed being under 195 km. This data is presented in Figure 56. This demonstrates that the EVs available on the market in 2021 and 2022, as used in the Dingle Project's EV trial, with a typical driving range of more than 400 km, are suitable for most people regardless of whether their location is urban or rural. Home charging is also sufficient for most of the charging needs and maximises the savings per km for the customers.

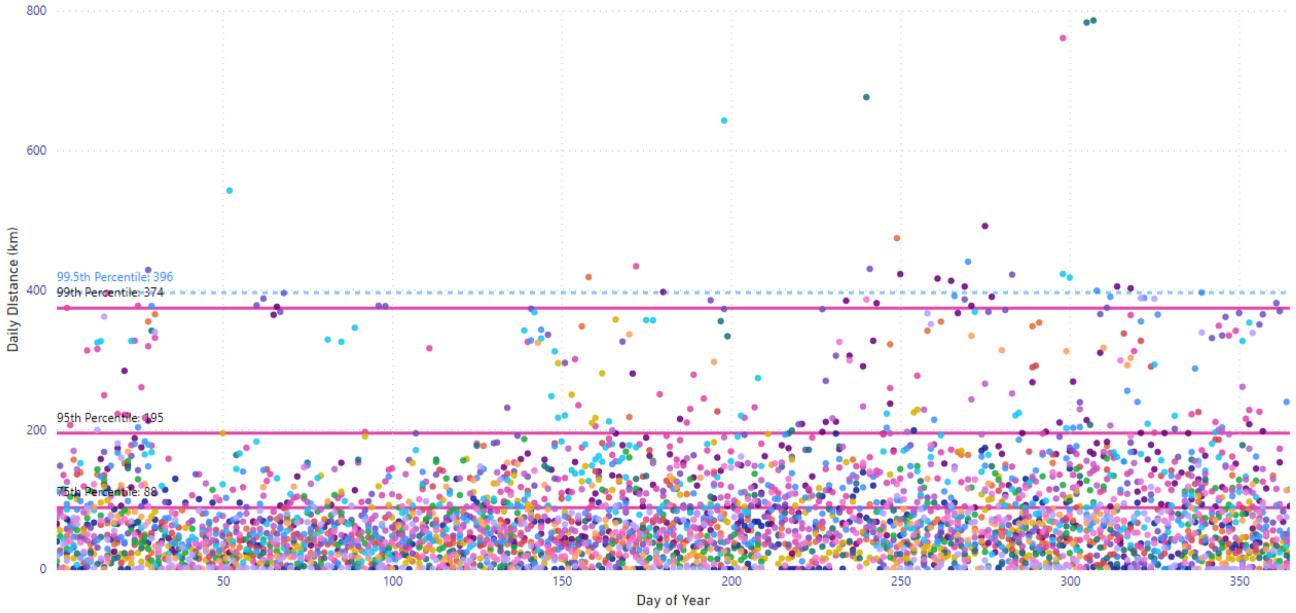


FIGURE 56 DAILY EV DISTANCES COMPLETED BY ALL EVS

In total over 59.3 megawatt hours (MWh) of charging was completed by the home chargers of the participating homes spread across more than 2,100 individual charging sessions. While more than 331,900 km were completed in total by the fleet of 15 EVs throughout the year, some customers really maximised the use of the EVs with almost a quarter of the users completing in excess of 30,000 km in the year as shown in Figure 57 below. The two shared EVs completed a total of 30,300 km over the course of the 12 month trial period.

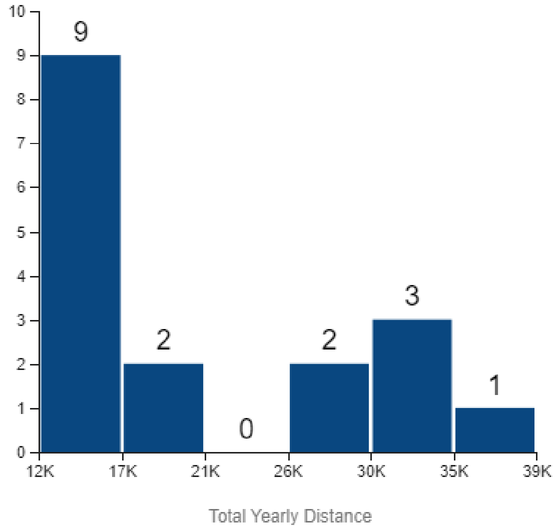


FIGURE 57 TOTAL YEARLY DISTANCE COMPLETED

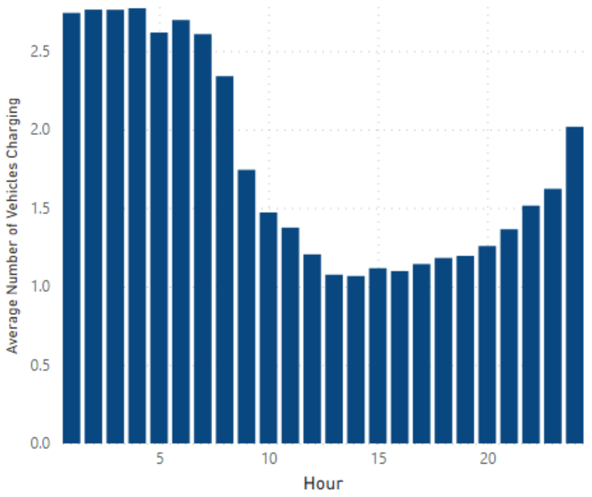


FIGURE 58 AVERAGE EVS CHARGING PER HOUR THROUGHOUT TRIAL

Throughout the customer flexibility trials it was noted that as customers became increasingly dependent on their electric vehicle, there was a growing anxiety regarding the autonomous and remote control of their EV charger. Instead of range anxiety, a form of charger anxiety crept in whereby customers were worried that their EV might not have been fully charged for them when they needed it. This was made worse by the fact that most of the charging took place in the early hours of the morning, as shown in Figure 58, when customers would typically be asleep, and it would not be practical for them to monitor if charging commenced as expected.

In a similar vein, many customers noted that they did not have range anxiety when undertaking long journeys but instead stressed about the availability and reliability of the charge points at their planned stops.

4.5.2 Heat Pump Performance & Energy Usage

The abundance of data from the heat pumps installed as part of the ambassador programme, has provided several interesting insights. Each of the installed heat pumps had dedicated heat and energy meters installed which provided accurate data on the electrical energy consumed and the heat energy produced. As outlined in the introduction, the electrification of heat is anticipated to grow rapidly over the next decade as the country strives to meet the CAP targets through electrification of heat and the decarbonisation of electricity generation. While heat pumps do consume a considerable amount of energy, they are an efficient means of heating your home and your hot water provided you can retain the heat in your building and hot water tanks.

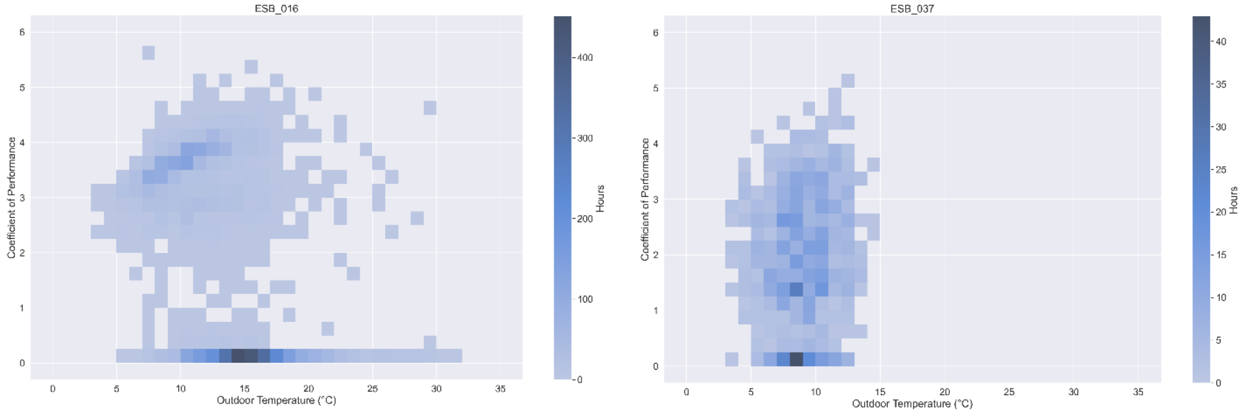


FIGURE 59 HEAT PUMP COEFFICIENT OF PERFORMANCE VS. OUTDOOR TEMPERATURE

Figure 59 shows the Coefficient of Performance (COP) for 2 of the ambassador properties plotted against the outdoor temperature. The darker areas of the heatmap represents a greater number of hours throughout the period at the corresponding temperature and COP value. The plot on the left has data for site ESB_016 for the period June 2021 to January 2022. The heat pump appears to consistently maintain a heat output between 2-4 times the electrical power input across the temperature range. The plot on the right reflects the months of December 2021 and January 2022 at site ESB_037, where the heat output is primarily between 1.5-3 times the electrical power input across the temperature range. The slightly lower COP value at site ESB_037 could be due to several factors including cooler outdoor temperatures, a different house type and a lower BER rating as it had not undergone a deep retrofit.

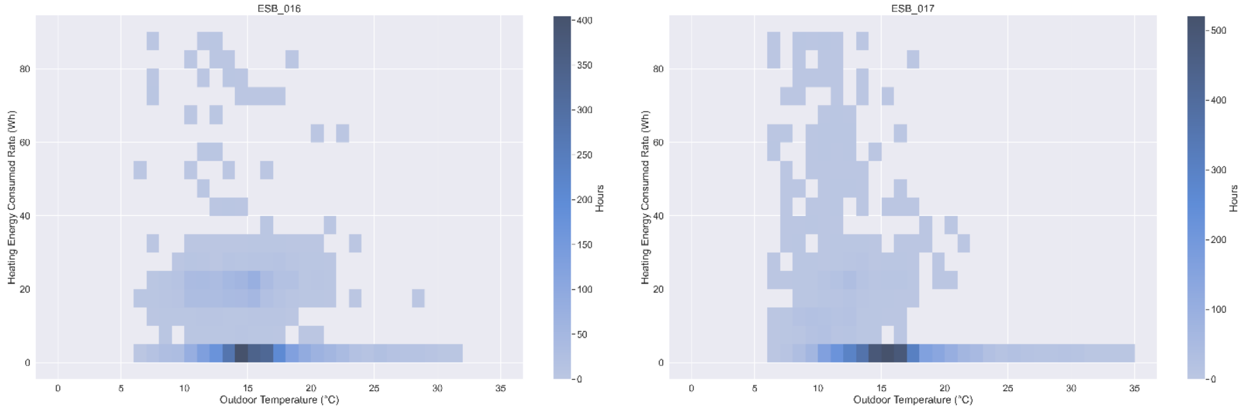


FIGURE 60 SPACE HEATING ENERGY CONSUMED VS. OUTDOOR TEMPERATURE

Similarly, it is interesting to observe how electrical energy consumed by the heat pump for space heating varies with outdoor temperature. One notable observation from Figure 60 is the amount of time, denoted by the darker areas, where the heat pump is shown to be consuming very little energy even with colder outdoor temperatures. This reflects the benefits of effective building insulation and air tightness, and it also shows that minimal space heating is required when outdoor temperatures are at or above 18-19 degrees Celsius.

While energy usage associated with space heating appears low, Figure 61 gives a typical example of the quantity of energy consumed by the heat pump per month for both space and water heating at one location for a 12 month period. This data is from a single storey bungalow property which underwent a deep retrofit resulting in a Building Energy Rating (BER) of A2 and shows the seasonal differences in energy consumption throughout 2021. Energy usage during the summer months is primarily water heating.

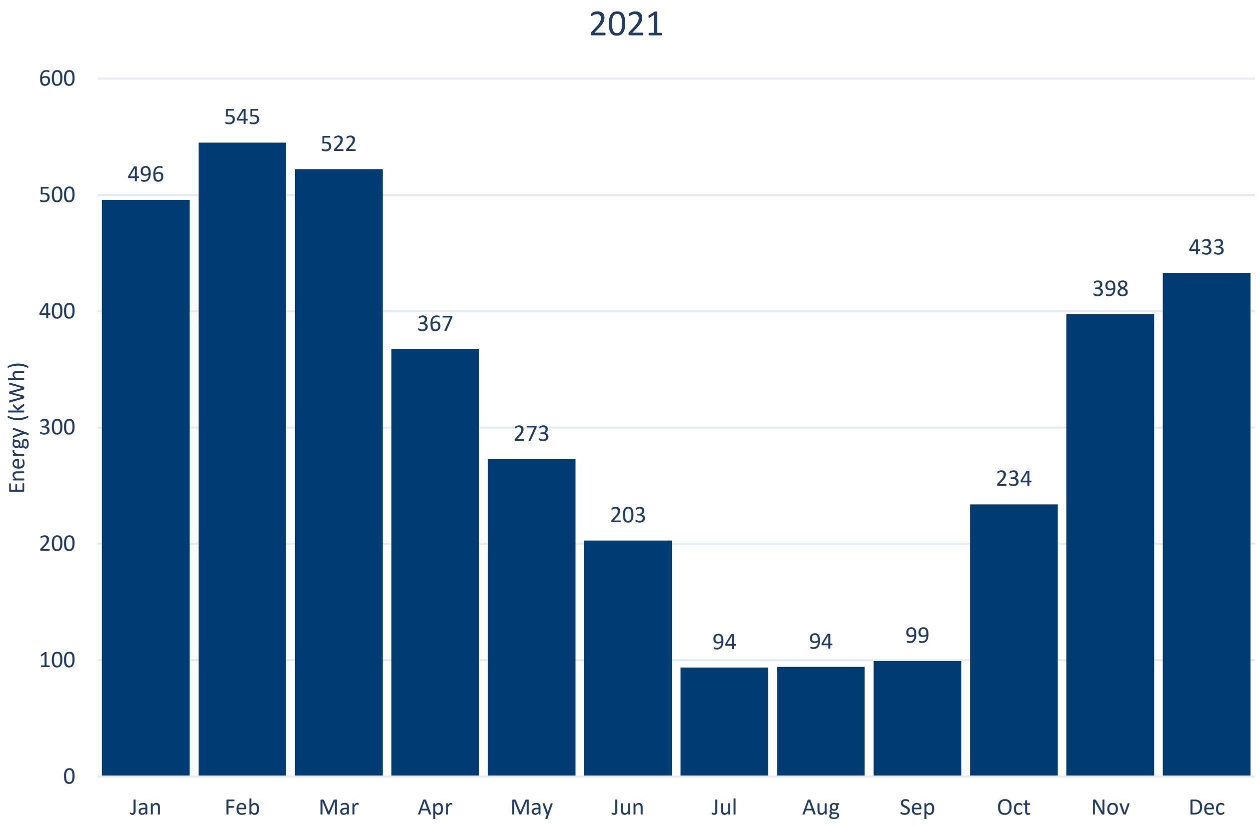


FIGURE 61 EXAMPLE YEARLY HEAT PUMP CONSUMPTION (ESB_016)

5 Conclusions

The Dingle Project customer flexibility tests demonstrated the capability of the GreenCom Networks platform to control the clean energy enabling technologies for home energy optimisation and to provide various flexible energy services to the grid while the capabilities of residential battery energy storage systems, heat pumps, EV charging and V2G technologies were also assessed in this context.

Both scenario 1 and 2 use cases highlighted that while demand reduction was possible and achieved during the morning and evening peaks, through control signals issued to technologies in the home, the scale of this controlled demand flexibility was limited due to the behavioural effect of pre-existing energy supplier tariffs which by their design encourage large discretionary loads, primarily EV charging, to ordinarily take place at off-peak periods when tariffs are lower. It is expected that the deployment of smart metering, when coupled with more refined energy supplier tariffs, will continue to drive and encourage sustained energy usage behaviours towards low tariff periods, in particular for EV charging and potentially domestic hot water heating. i.e., night-time, when the wholesale price for electricity is typically lowest.

These consumer behaviours and regular patterns of electricity usage, explored under Scenario 1, can be supported by rudimentary technologies such as timeclocks or simple scheduling software, whether in the clean energy enabling technologies themselves or in other in-home systems, without the need for deployment of separate and dedicated demand side management technologies.

While the scenario 1 & 2 use cases demonstrated the potential for demand from clean energy enabling technologies to align with incentivised periods, they also highlighted the possibility of challenges to the network operator associated with new peaks in demand aligned with, and driven by new energy supplier off-peak tariffs, separate to the traditional morning and evening demand peaks on the grid. For example, as more electric vehicles are purchased across society as anticipated under the Climate Action Plan 2021 [4], it is to be expected that charging will be concurrent and primarily take place at home chargers at the most economic times. Should electrified heating be layered on top of this EV charging load, the challenge for the network operator will be amplified, potentially requiring the diversity rules, currently applied in planning the network, to be revised. Such a revision to the After Diversity Maximum Demand (ADMD) rules would require cater for both new transformer installations and new customer connections to existing transformers, however, the greatest challenge is likely to be on pre-existing areas of the network, which were designed to a lower ADMD standard and have not had new customer connections or network upgrades in the past 5 to 6 years or more.

Scenario 1 focused on the potential of the control technology and mathematical algorithms, influenced by a fictitious, regular, block-shaped tariff, to move clean energy enabling demand such as EV charging and domestic hot water heating into regular, cyclical patterns during off-peak periods, and in that way manage their impact on the local network on a sustainable basis.

Scenario 2 explored the responsiveness of the same suite of clean energy enabling technologies using the same control technology and algorithms, albeit influenced in this case by a more agile and dynamic tariff than that used in Scenario 1 and notified within a shorter, day-ahead time period. Scenario 2 also examined the potential for the network impact of these same discretionary loads to be minimised, closer to real time.

Scenario 2 demonstrated that the clean energy enabling technologies can be controlled to be responsive, on a day-ahead horizon basis to potential scenarios, while at the same time being optimised to collectively operate in the best economic interests of the electricity consumer, within those overarching horizon control boundaries. While rudimentary controllers, such as analogue time clocks or simple scheduling software in the clean energy enabling technologies themselves, coupled with energy supplier tariffs, could drive and give effect to the outcomes desired under Scenario 1, it is considered that more dynamic control will be necessary to achieve the responsiveness as desired under Scenario 2. In addition, where optimisation of the operation of multiple technologies is required, any enduring solution will need to incorporate the necessary controlling software and algorithms. As clean energy enabling technologies mature further, it is anticipated that manufacturers will embed this control and optimisation capability into their products and support alignment with dynamic or agile energy supplier tariffs, to maximise benefits for electricity consumers.

The scenario 3 use case demonstrated the capability for manual demand response to be used to the advantage of grid operators and it is likely such services may become more mainstream in the coming years as flexibility service providers branch out into the residential market. Several key learnings were gained through the tests on the Dingle Project including the impact of other home energy optimisations, or flexibility services being provided under scenario 1 or 2, on the availability of technologies to respond to utilisation calls under scenario 3. Where electricity consumers offer to provide a stack of flexibility services, for example scenario 1 or 2 and scenario 3 services, it may be necessary to set limits and thresholds on the operation of clean energy enabling technologies under either scenario 1 or 2 such that some availability is retained for service provision under scenario 3. Managing the multiplicity of services being offered by individual consumers will be complex.

It was shown that energy storage from domestic battery energy storage systems and V2G provided the greatest response under the tests conducted. However, in much the same way as real-world supplier tariffs influenced the flexibility potential of EV charging load under scenario 1 and 2, the potential availability and response of battery technologies under scenario 3 may require future evaluation in a real-world scenario where more dynamic supplier tariffs and home energy optimisation are in effect. Customer behaviours and lifestyles have a huge impact on the provision of flexible energy services from both EV charging and V2G due to their mobile nature. Response from these technologies is not available when the vehicles are either not charging or not connected to the chargers, meaning a limited response may be available during the day.

It is expected that, in the absence of all clean energy enabling technologies being provided by the same manufacturer, or to minimise the number of separate control signals being issued to multiple technologies at the same location, that some form of grid edge, in-premises technology may be required to enable this manual demand response.

While V2G chargers are more expensive than more standard / non-V2G chargers at present, should V2G technology become more available and mainstream, whether through stand-alone charging technology or in electric vehicles themselves, there is the potential that synchronised discharging could cause some voltage challenges in particular areas of the LV network depending on location and the network topology. However, the application of V2G capability in a commercial fleet scenario, where the nature of that business supports it, is something that could potentially be valuable to grid operators but also raises new challenges in terms of the existing electrical connections to those facilities. In any case, the effectiveness of V2G to respond to manual demand response utilisation calls will depend on the coincidence of those events with the availability of V2G, whether at residential settings or fleet depots.

Utilisation of domestic customer flexibility as a non-wires alternative (NWA) to network reinforcement is technically feasible, but the suitability of its application is dependent on a few key points. ESB Networks' guide to non-wires alternatives to network development [33] outlines a reasonableness test that considers potential NWA options based on timeline, technical, economic and feasibility criteria. One point that is particularly relevant to residential customer flexibility as an NWA, is the risk that further load growth could quickly make the NWA option ineffective. This is more likely on smaller transformers such as a 15 kVA transformer where a single 7 kW EV charger could account for over 40% of the transformer capacity. Furthermore, for smaller transformer sizes where there are less customers, the deferral period coupled with the costs of implementing the NWA option may no longer be the least cost, technically advantageous option when compared with the cost and longer term benefit of the physical reinforcement. It is considered that domestic customer flexibility may be more suited as an NWA at transformers with larger numbers of customers, such as in urban areas, where the solution will have a greater longevity and the physical reinforcement alternatives are both expensive and difficult to deliver.

In parallel with the customer flexibility trial, ESB Networks in collaboration with MaREI, explored the value of initiatives like the Dingle Project ambassador programme in activating energy citizenship at a community level. As part of its direct engagement with the project ambassadors, ESB Networks sought to understand whether individuals would be willing to cede control of clean energy enabling technologies at their properties to a third party on a limited basis. Reluctance was expressed regarding ceding control over EV charging and to a lesser degree in relation to discharge of the residential battery, whose role in the optimisation of energy footprint at the property was less understood by the participants. This engagement took place in the absence of any financial incentives applying to the ambassadors during times of flexibility provision, and as such the role of financial incentives in encouraging future participation in flexibility schemes could not be determined.

While not part of the flexibility trial, the data from the EV trial also demonstrated that EVs, with a range typical of modern electric vehicles, can work in rural areas for most people where charging is predominately completed at home. The trial found that on average, users only travelled more than 195 km in a single day, on 18 days across the year. Furthermore, it was observed from the trial that instances where the total distance driven per day exceeded 396 km, and where recharging of the vehicle at another charging facility was required, accounted for only one or two occasions per year for each customer, further supporting the suitability of electric vehicles for people residing in rural communities.

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Appendix 1 – Availability of Project Data

All technical data recorded from the clean energy enabling assets and sensors installed in the participating properties is available on request. Please email innovationfeedback@esbnetworks.ie with your name, contact details and intended use of the data. ESB Networks will review your request and respond at our earliest convenience.