WPD INNOVATION

MADE

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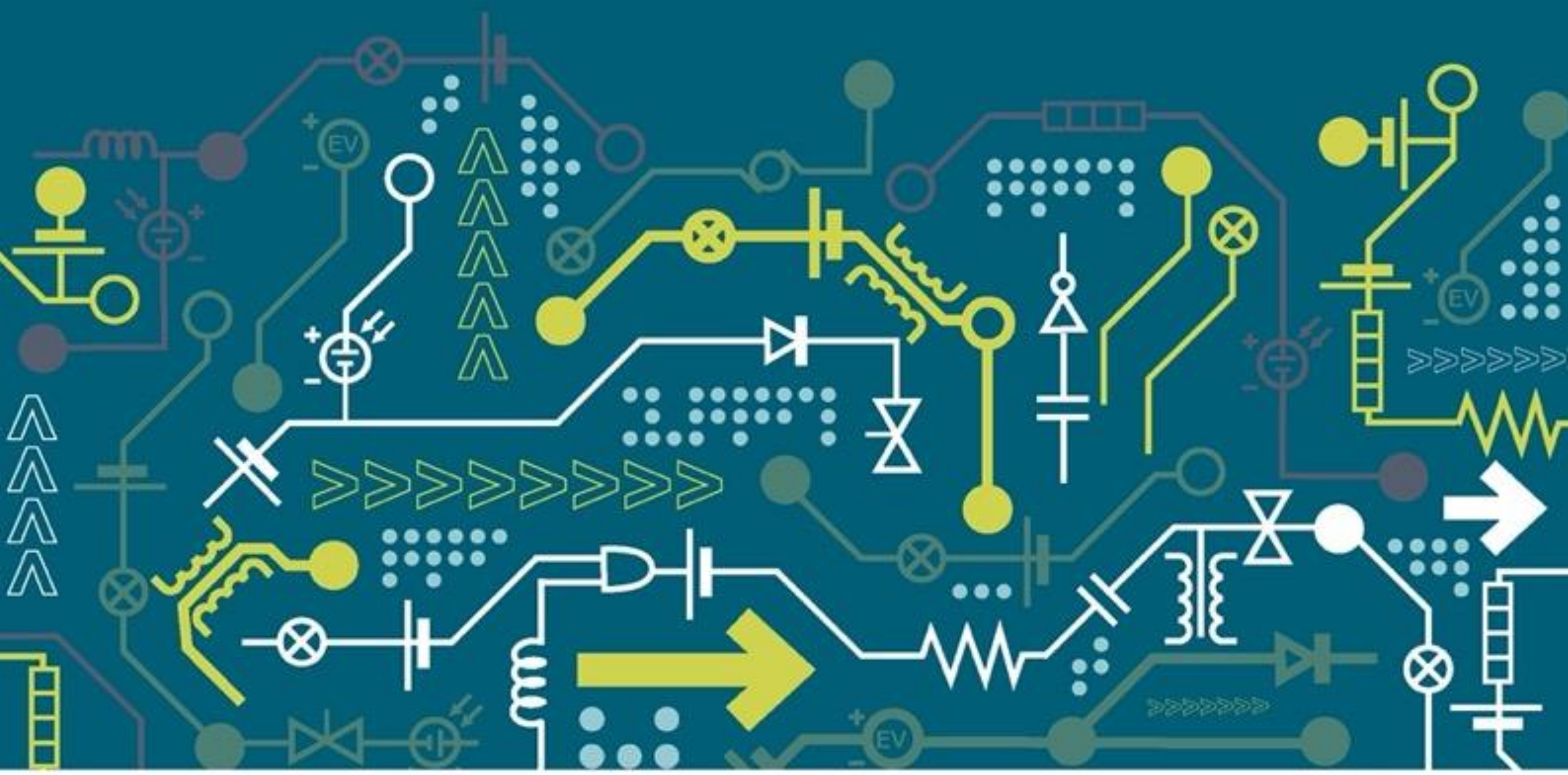
SIX MONTHLY PROGRESS REPORT
REPORTING PERIOD: OCT 2019 – MAR 2020



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Name	Role
Tom Veli	Author
Matt Watson	Reviewer
Jon Berry	Approver

Contact Details

Email

wpdinnovation@westernpower.co.uk

Postal

Innovation Team
Western Power Distribution
Pegasus Business Park
Herald Way
Castle Donington
Derbyshire
DE74 2TU

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1 Executive Summary

The Multi Asset Demand Execution (MADE) project is funded through Ofgem's Network Innovation Allowance (NIA). MADE was registered in March 2019 and will be complete by October 2020.

The MADE project investigates the network, consumer and broader energy system implications of high-volume deployments of the combination of:

- Domestic Electric Vehicle (EV) charging;
- Hybrid heating systems (domestic gas boiler and air-source heat pump) or Heat Pump (HP) heating systems; and
- Solar photovoltaic (PV) generation and battery storage.

The research objective is to better understand the feasibility of managing and aggregating multiple Low Carbon Technology (LCT) assets affordably through the use of advanced algorithms to unlock value from energy markets.

MADE is a £1.6m project, delivered by PassivSystems with a five-home technology trial in based in South Wales and the South West.

This report details progress of the project, focusing on the last six months, October 2019 to March 2020.

1.1 Business Case

Previous Distribution Network Operator (DNO) trials[1] have highlighted the significant potential value of flexibility from LCT loads (My Electric Avenue highlighted up to £2.2bn of reinforcement avoidance by 2050 and Freedom highlighted £300 million of reinforcement deferral in South Wales alone by 2050). This trial will evaluate the potential interactions between the various value streams to understand the total savings possible.

Based on a future homeowner that has a conventional heat pump and a conventional EV charger, PassivSystems estimate that one LV (Low Voltage) feeder (at a cost of approximately £40k) would be required for every four homes, a cost of £9,279 per home.

As shown in the trials mentioned above, this cost can be reduced significantly though the use of inherent asset flexibility (smart EV charging & hybrid heating systems). By utilising this flexibility, PassivSystems estimate that one feeder would be required for every 14 homes, at a cost of 2,900 per home.

An integrated optimised approach with supplemented PV and battery storage (the MADE method) could produce significant savings, PassivSystems estimates that one feeder would be required for every 39 homes, at a cost of £1,531 per home. This would help reduce network reinforcements; in addition, a hybrid solution can also respond to constraint signals and prevent Distribution Use of System (DUoS) charges.

Financial benefit = base cost – method cost.

Financial benefit = £2,900 - 1,531 = £ 1,369 per household.

Whilst the speed of deployment will vary on a regional basis, the deployment of LCTs is expected to grow significantly across GB. As such the learning will be replicable across all GB.

To achieve the optimised control of LCTs, new hardware and software is required. With economies of scale, the hardware cost to roll out an automated multiple asset control that will integrate with the

[1] For Example Electric Nation (http://www.westernpower.co.uk/projects/electric-nation), Sola Bristol (https://www.westernpower.co.uk/projects/sola-bristol), Freedom (https://www.westernpower.co.uk/projects/freedom) & My Electric Avenue (www.myelectricavenue.info).

majority of LCTs will be £100. In addition, an annual service fee of £30 - £50 will maintain and continually optimise to market conditions. This equates to a Net Present Value (NPV) of approx. £500 - 756 over a 25-year lifetime. However, these costs will provide significant additional benefits beyond DNO reinforcement avoidance which should help cover a significant portion of the costs.

1.2 Project Progress

This is the second progress report. It covers progress from October 2019 to the end of April 2020.

The desktop data analysis and modelling work packages (between April 2019 and September 2019) indicated significant benefits of coordinated LCT control and as a result the project has moved to technical feasibility stage. A 5-home field trial is in progress, testing live coordinated control. The following has been completed to enable the delivery of technical trial:

- High level software design for coordinated control;
- Field trial technical specification - design and installation of multiple LCTs with coordinated control;
- Coordinated LCT control strategy – optimise LCTs to collaborate with one and other while considering variable tariffs, the local network, customer type, house type, generation availability and weather;
- The software development of the coordinated control and algorithms;
- Field trial plan – detailing hardware and software implementation into actual homes;
- Intervention plan - detailing the experiments to be executed over the trial period;
- The procurement and installation of LCTs; and
- Customer satisfaction and initial feedback survey.

The trial has completed two phases and is halfway through phase three. Phase three and four are due to completed by July 2020.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The MADE Project Review Group meets on a bi-annual basis. The role of the Project Review Group is to:

- Ensure the project is aligned with organisational strategy;
- Ensure the project makes good use of assets;
- Assist with resolving strategic level issues and risks;
- Approve or reject changes to the project with a high impact on timelines and budget;
- Assess project progress and report on project to senior management and higher authorities;
- Provide advice and guidance on business issues facing the project;
- Use influence and authority to assist the project in achieving its outcomes;
- Review and approve final project deliverables; and
- Perform reviews at agreed stage boundaries.

1.3.2 Project Resource

Using existing relationships from the Freedom project, we have formed a project team led by PassivSystems to deliver the MADE project. This includes: Wales and West Utilities, Imperial College, Everoze and Delta EE.

The project partners are all experts in their field and are managed by PassivSystems. Everoze, Imperial College London and Delta EE act as subcontractors to PassivSystems, whilst Wales and West Utilities act as an advisor.

PassivSystems - Project management, home energy management system, PV optimisation and demand aggregation modelling.

Wales & West Utilities - Gas distribution network requirements, measurement and modelling.

Everoze – micro-economic energy modelling, commercial modelling.

Imperial College – Data analysis and a whole-system assessment on the future GB electricity systems.

Delta-EE – Customer research and Business Modelling.

1.4 Procurement

There were no additional contracts placed within this reporting period.

During the initial reporting period contracts were placed with PassivSystems for the delivery of the project. PassivSystems have in turn placed contracts with the partners acting as subcontractors.

1.5 Project Risks

A proactive role in ensuring effective risk management for MADE is taken. This ensures that processes have been put in place to review whether risks still exist, whether new risks have arisen, whether the likelihood and impact of risks have changed, reporting of significant changes that will affect risk priorities and deliver assurance of the effectiveness of control.

Contained within Section **Error! Reference source not found.** of this report are the current top risks ssociated with successfully delivering MADE as captured in our Risk Register. Section 7.2 provides an update on the most prominent risks identified in the previous reporting period. The project has had a total of 35 risks logged and there are currently 18 live project risks.

1.6 Project Learning and Dissemination

Project lessons learned and what worked well are captured throughout the project lifecycle. These are captured through a series of on-going reviews with stakeholders and project team members and will be shared in lessons learned workshops at the end of the project. These are reported in Section **Error! eference source not found.** of this report.

The Project has been disseminated by WPD via a webinar and at Balancing ACT and presented the project on 12 different occasions between October 2019 and the end of March 2020. The aim is to create learning opportunities for many key external stakeholders, particularly the wider DNO community, electricity suppliers, charitable bodies, and third sector organisations. Below is a list of events:

- Quarterly project briefings to BEIS Science & Innovation and Heat Policy Teams;
- BEIS consultation for EVs;
- BEIS consultation for heat;
- Briefing to BEIS delegation in Wales;
- International Energy Agency – Flexible Energy System – Paris;
- Policy UK event;
- Westminster Forum event;
- Energy Networks Association event;
- Welsh Government decarbonisation of heat event;

- Bridgend Borough Council;
- Energy Systems Catapult: Decarbonising Heat - Understanding how to increase the appeal and performance of the electrification of heat; and
- UK Committee on Climate Change quarterly update

The project was referenced in the EnergyUK**;** Barriers to Flexibility Delivering the potential benefits of a smart flexible energy system in the transition to net zero report.

2 Project Manager's Report

2.1 Project Background

Following the publication of the Committee on Climate Change (CCC) report promoting hybrid heating systems as a "low regret" option, we need to consider the network implications of CCC's call for ten million hybrid heating system installations across GB by 2035. Many of these installations will be in homes that have also adopted EVs. Understanding the interplay between these two primary drivers of electrification is essential to plan future network developments. The third factor that the project will explore is the impact of domestic solar PV and storage installations on these. During the same timescale as hybrids and EVs are being adopted, solar PV costs will fall to a level that makes subsidy free installation an economic reality for homes that wish to save on the cost of their grid supplied electricity.

Several innovation trials have highlighted the possibilities for individual LCTs to provide flexibility: EV - Electric Nation[2], HP - Freedom[3], PV and Storage - Sola Bristol[4]. However, each of these investigations has looked at a single technology type in isolation. Currently we do not have sufficient understandings on how such systems may interact and whether the flexibility is complementary, optimal, or counter-acting.

The research objective is to better understand the feasibility of managing and aggregating multiple energy assets (EV, hybrid heating system and solar PV) affordably through the use of advanced algorithms to unlock value from energy markets. Through customer research we will also evaluate consumer trust in new technology that is taking greater levels of EV charging, heating system control, and design appropriate user interfaces and information systems to help drive adoption.

Based on the lessons learned from previous NIA trials MADE will carry out micro-economic and system-level analysis to extrapolate previous trial findings in order to:

- Build a microeconomic model for domestic multi-asset, multi-vector flexibility for GB today, this will: Identify the most attractive customer types; Identify the high potential service stacks; Quantify the value (£); Include a particular focus on Distribution System Operator (DSO) services;

- Understand how the combined operation of residential solar PV generation, heat pump systems and smart EV charging may provide benefits to the consumer;

- Assess the whole-energy system benefits (including network infrastructure) and carbon benefits of large-scale deployment of the MADE concept;

- Consider conflicts and synergies between local community and national level objectives, in the context of the flexibility enabled by the MADE concept; and

[2] The Electric Nation project aimed to enable DNOs to identify which parts of their network are likely to be affected by EV uptake, and whether EV demand control services are a cost effective solution to avoiding or deferring reinforcement on vulnerable parts of their networks. The project has deployed Smart Chargers to understand how and when people charge their EV's, and has trialled solutions such as smart charging and Time of Use tariffs. The results from these trials were used to develop a network assessment tool to predict where plug-in electric vehicle uptake may cause network problems.
[3] FREEDOM, in partnership with Wales and West Utilities installed 75 hybrid heat pumps within domestic properties in South Wales. The hybrid heat pumps used electricity when there was sufficient capacity on the system to do so and switched to gas at the point the capacity on the electricity system had been reached. This project demonstrated the value of a hybrid solution to avoid the need to reinforce the electricity network whilst supporting a significant decarbonisation.
[4] The Sola Bristol installed 2kW of battery storage in domestic lofts alongside PV solar panels. The PV panels were directly connected to the battery to store excess solar energy. Five commercial buildings were also tested. The project highlighted the

- Estimate consumer benefits of the MADE concept and inform the design of the market framework that would enable consumer to access the revenues that reflect the benefits delivered.

A five-home technology trial in South Wales and the South West will be used to validate the modelled learning.

The proposed project runs for 19 months and has been broken down into six work packages.

Work Package 1: Project Management
PassivSystems will complete the project management for the duration of the project to deliver the system design, development and technical feasibility installation. The project management will use PassivSystems' project management processes and will oversee the flow of development work through PassivSystems' agile Kanban processes.

Work Package 2: Problem definition, approach and trial design
The project delivers the consolidation of existing information across partners, development of the customer, DNO, local network and national network proposition, a documented set of use cases, establishing data protection and data management protocols.

Work Package 3: Modelling: Consumer, Micro-Economic, Local and National GB Network
PassivSystems will produce a high-level control strategy, simulate the MADE concept (desktop exercise) and collaborate with Imperial College and Everoze to model the local network, national network and the microeconomics. All partners will apply advanced big-data techniques to analyse and quantify the success of different approaches, considering demographic parameters, consumer flexibility, different loading conditions, different generation periods, time of application of different prices etc. The system-wide benefits of a large-scale rollout of the MADE concept, considering both local and national level infrastructure will be assessed. This will be enabled by advanced modelling approaches developed by Imperial College, that identify system solutions that deliver secure and cost-efficient energy supply while respecting national decarbonisation targets.

Work Package 4: ASHP/EV/PV Control & Aggregation Solution
PassivSystems will design and develop its smart control to enable optimisation (by cost or carbon) of the EV charge point, the electric heating asset and the rooftop PV generation. They will include the PassivEnergy platform that aggregates demand across households and enables the demand flexibility to be traded with energy markets including the DSO. PassivSystems will develop its existing aggregation platform to ensure each vehicle has enough charge for the next trip (based on consumer preferences) before calculating how much remaining capacity to sell to grid and/or support domestic heating (via heat pump, hybrid heating system, or hot water tank immersion). The controls will also manage the heat and transport assets and maximise the self-consumption of rooftop solar PV through a coordinated control strategy.

Work Package 5: Technology Feasibility Trial (maximum of five homes)
PassivSystems will deliver a five-home technology trial; the field trial will test the technology deliverables and gather data on consumer EV charge and energy system outcomes.

Work Package 6: Technology, Customer and Network Analysis – Dissemination
The project partners will deliver an interim and final report on consumer, energy system and business model outcomes. PassivSystems will be responsible for sharing the findings of MADE publically during and after the project is complete.

2.2 Project Progress

2.2.1 Work Package 1: Project Management

Progress within this reporting period
This work package runs for the duration of the project and looks to ensure the project is running smoothly and is progressing adequately. This also looks to track and manage risks to maximise the change of successful delivery. Key elements of this are mentioned in Sections 3-7.

Next steps
This work package will continue for the duration of the project.

2.2.2 Work Package 2: Problem definition, approach and trial design

This Work Package was completed in the first reporting period.

2.2.3 Work Package 3: Modelling: Consumer, Micro-Economic, Local and National GB

This Work Package was completed in the first reporting period.

2.2.4 Work Package 4: ASHP/EV/PV Control & Aggregation Solution

Progress within this reporting period
With accordance to the project plan, all R&D and development activities for optimised LCTs, coordinated control and aggregation solutions were completed in February 2020. The final update was remotely pushed to the customers in-home Passiv Hub that which controls the LCTs. Below are some example screen shots of the PassivLiving that the consumer uses to input their heating schedule requirements and EV charging requirements:

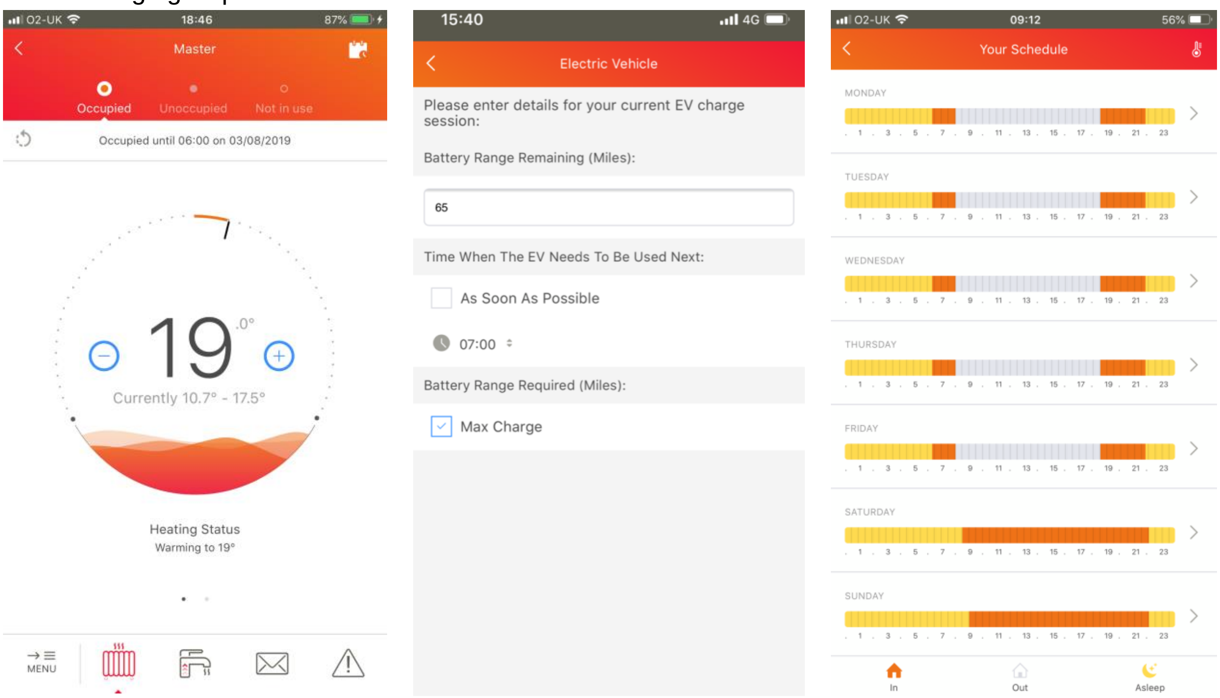

Figure 2-1: Example MADE Project Smart App Controls

In addition to development activities, PassivSystems R&D team has completed algorithms to support the optimisation of the Low Carbon Technologies under a coordinated strategy. This included:

- Developing simple battery controller for ToU import & export tariffs;
- Developing simple immersion heater controller for ToU tariffs;
- Support for using the heat pump to store heat in the hot water tank;
- Expanded tariff support to encompass export tariffs;
- Developing multi-asset optimisation algorithm for HHP & PV & Battery; and
- Developing multi-asset optimisation algorithm for HHP & PV & Battery & EV.

Next steps

PassivSystems has completed the control development, however, will complete any refinement work based on the trial learnings following interventions. PassivSystems is completing interventions on the 5 trial homes, they review the results on a weekly basis and fortnightly with WPD.

2.2.5 Work Package 5: Technology Feasibility Trial (maximum of five homes)

Progress within this reporting period

Work package 5 has been the core part of the MADE project between October 2019 and March 2020. A 5-home technology trial is in progress and is due to be completed in September 2020 and will be used to validate the modelled learning. Below is a summary of the installations completed in each of the trial homes that are being used for the field trial.

Table 2-1: Equipment at trial homes

Home	Heat pump	Fossil boiler	PV array	Battery	EV Charger	EV
1	5kW Samsung ASHP	LPG Combi	4.41kWp	Sonnen hybrid 5kWh	New Motion 32A	Nissan Leaf 30kWh
2	8kW MasterTherm ASHP	Gas system boiler	3.46kWp	Sonnen hybrid 5kWh	Alfen 32A	Hyundai Kona 64kWh
3	22kW MasterTherm GSHP	Oil system boiler	4.41kWp	Sonnen hybrid 5kWh	New Motion 32A	Nissan Leaf 40kWh
4	9 kW Samsung ASHP	LPG system boiler	3.78kWp	Sonnen hybrid 5kWh	New Motion 32A	Tesla Model 3 75kWh
5	9 kW Samsung ASHP	Oil system boiler	4.41kWp	Sonnen hybrid 5kWh	Alfen 32A	Nissan Leaf 40kWh

Figure 2-2: Example installation images.

The field trial has been divided up into four phases, as outlined in Figure 2-3 which shows a summary of the trial plan. These four phases are as follows:

- Phase 1: Baseline - The focus was on gathering baseline data about household and asset electrical demand with the assets largely uncoordinated and hoped to capture some of the problematic scenarios caused by assets operating independently and synchronizing their activities on tariff transitions;

- Phase 2: In-home asset coordination - This phase involved automatic coordination of the operation of the hybrid heat pump with the battery and solar generation. It also included integrated control of the EV charge point (although largely manually driven);

- Phase 3: Full coordination including EV - This phase involved fully optimised integration of the EV charge point along with the other assets; and

- Phase 4: Summertime - The last phase of the project explores the transition of the multi-asset system through late spring into summer as the availability of solar PV generation starts to dominate the picture.

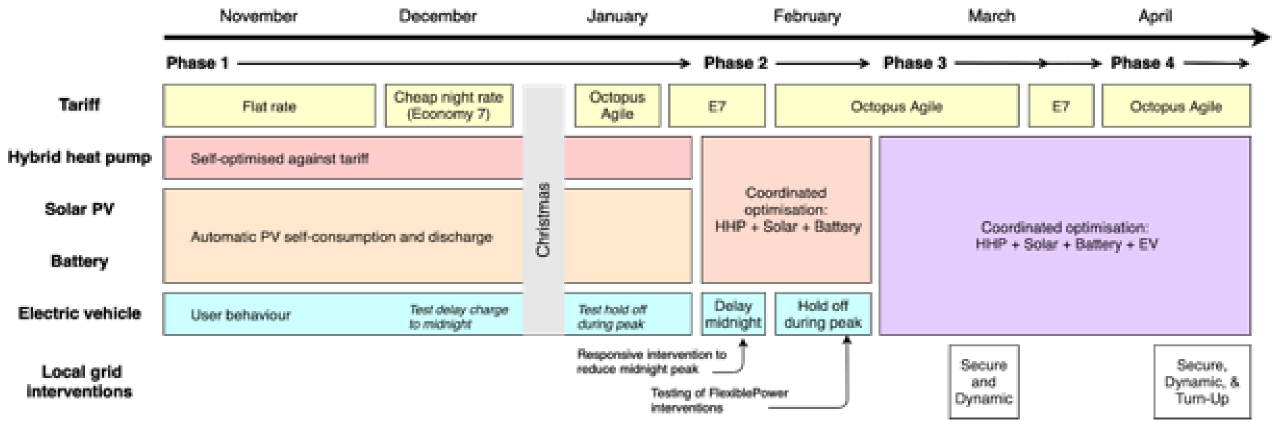

Figure 2-3: Field Trial Intervention Phases.

To date the project has explored a number of contrasting dimensions simultaneously:

- **Time of use tariffs** which provide the first level of demand shaping through a straightforward mechanism which exists in today's market and rewards the consumer directly. We have tested three tariff patterns: (a) flat rate tariffs as a baseline, (b) cheap night-time tariffs like Economy 7 and (c) the Octopus Agile, which captures the major national-scale and distribution-scale drivers;

- **Level of asset coordination**: the field trial is now in phase 3 and gradually expanded the number of assets whose operation is coordinated by our optimisation algorithms;

- **Seasonality**: the interplay of the assets changes significantly over the seasons: in winter, heating is dominant over PV generation, but vice versa in summer; and

- **Interventions** to explore the flexibility of the system to respond to local network needs.

The results presented in this section are related to phase 1 and early phase 2 results and is structured as follows:

- Baseline operation;
- Asset coordination - Hybrid heating system, battery and solar;
    - LCT behaviour with Octopus GO Tariff
    - LCT behaviour with Octopus Agile Tariff
- Electric vehicle charging integration; and
- Customer satisfaction and LCT feedback survey and interviews.

Baseline operation

Phase one of the trial focussed on gathering baseline data about the household and asset demand. During this phase, the energy assets within the home were largely uncoordinated. The control strategy for each asset during the baseline phase was as follows:

- **Hybrid heating system:** use was optimised against the tariff, but with no awareness of solar, battery availability or EV demand. The hybrid heat pump controls were configured with a high price for the fossil fuel boiler in order to reflect the future scenario of substantial decarbonisation, which enabled a high proportion of the heat demand to be provided by the heat pump. This is in line with the baseline case considered in the Domestic Level Techno-economic Modelling performed by Everoze under MADE;

- **Battery:** controlled by Sonnen's internal "automatic" control algorithm which charges the battery when there is excess solar and discharges when there is net demand from the home. The battery will therefore react to heat pump consumption but cannot distinguish this from another household demand. This is in line with the baseline case considered in the Domestic Level Techno-economic Modelling performed by Everoze under MADE; and

- **EV:** During this phase, no EV optimisation was performed. The charge point was used as and when the householder decided to charge. This allowed insight to be gained into typical plug in times.

Figure 2-4 shows typical baseline operation for a MADE home. The following can be observed from this figure:

- Thermal comfort is maintained throughout the day. Both the heat pump and boiler are used to meet heat demand, with the heat pump utilised over the majority of the day with support from the boiler when required;

- There is negligible solar in December. Thus, the battery, which as outlined above is being controlled by Sonnen's "automatic" control algorithm, is not utilised at all; and

- There is high electricity demand from the home during the evening. This is largely driven by the occurrence of an EV charge session, with the heat pump also operating during this time in addition to an increase in baseload electricity consumption.

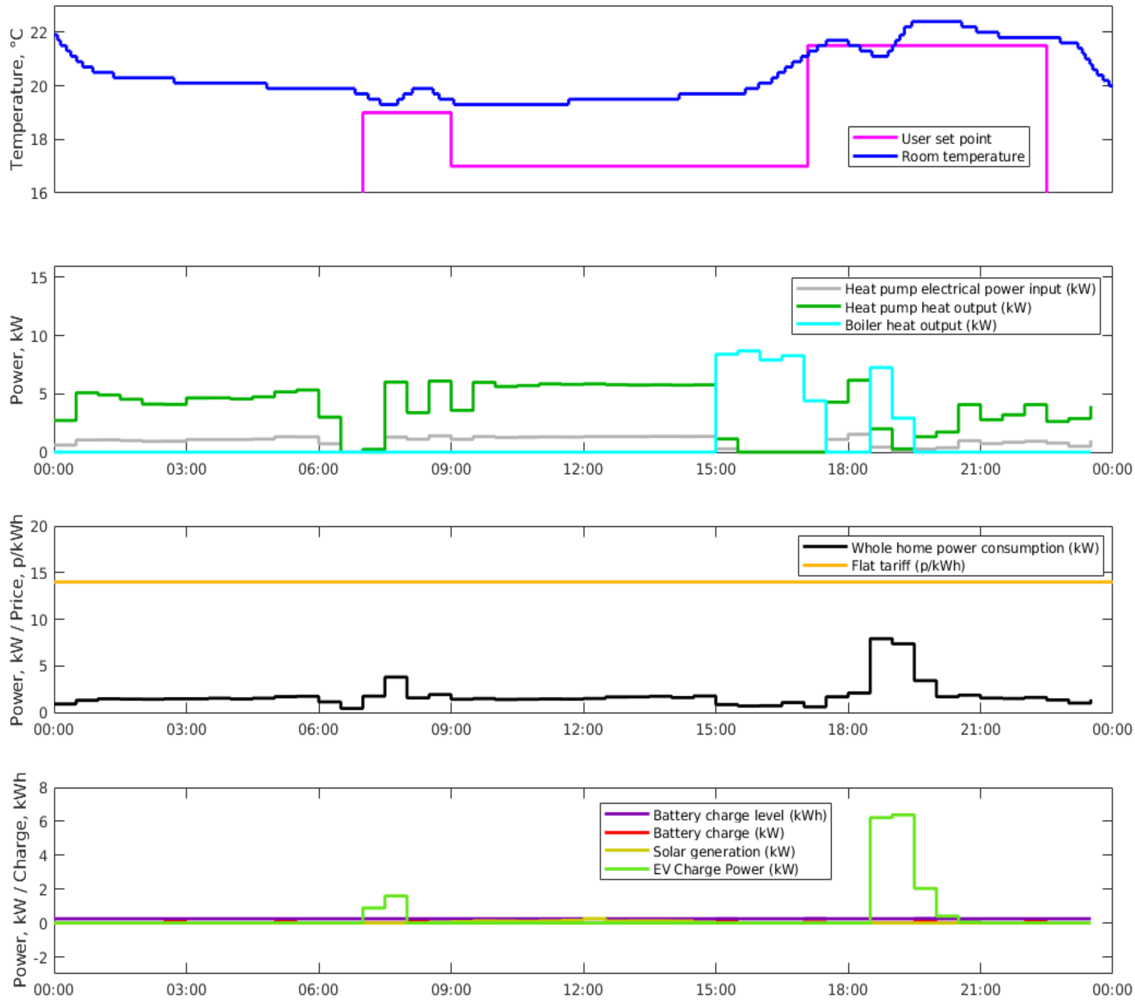

Figure 2-4 - Baseline operation (Home 5, 11/12/2019)

Since there was no control strategy implemented on the EV charging during the baseline phase, conclusions can be drawn on typical EV charging times in the absence of any control. Figure 2-5 shows the average EV charge power across the day for the MADE homes. It can be observed from this figure that the EV's in this field trial were most commonly charging over the early evening peak. This is in line with findings from previous projects such as Electric Nation.

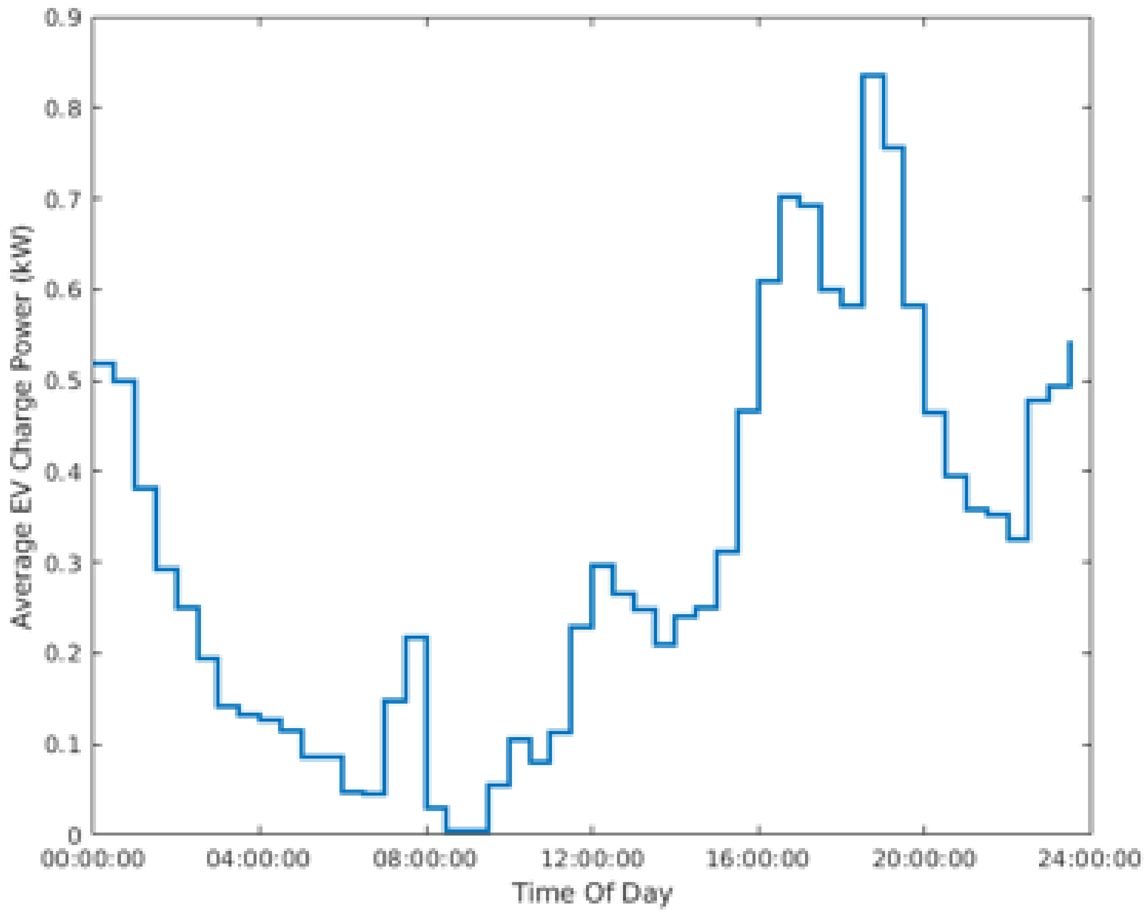

Figure 2-5 - Average EV charge power across the day for the MADE homes (Homes 2,3,4 & 5, 01/12/2019 - 15/01/2020. Note that Home 1 was not included in this analysis since the charge point was installed at a later date.)

Asset coordination - Hybrid heating system, battery and solar

Phase two of the trial involved automatic coordination of the operation of the hybrid heat pump with the battery and solar generation. It also included control of the EV charge point, although through this phase this was largely manually driven. The control strategy for each asset during phase two was as follows:

- **Hybrid heating system:** use was optimised against the tariff, coordinated with solar generation and battery availability, but no awareness of EV demand. The hybrid heat pump controls were configured with a high price for the fossil fuel boiler in order to reflect the future scenario of substantial decarbonisation, which enabled a high proportion of the heat demand to be provided by the heat pump;
- **Battery:** controlled via a combination of Passiv's battery control algorithm and Sonnen's internal "automatic" control algorithm, with Passiv's algorithm deciding when to switch between control strategies. During this phase, the battery was optimised against the tariff, coordinated with both solar generation and hybrid heat pump use as well as baseload electricity demand. This enabled load shifting through pre-charging the battery during cheap tariff periods; and
- **EV:** During this phase, EV control was largely manual driven.

During this phase, homes were optimised to two different tariffs:

- **Octopus Go:** an electricity tariff designed with EV users in mind. It offers an off-peak unit price of 5p/kWh between 12:30am and 4:30am, with a peak unit price of between 13-14p/kWh (13.8p/kWh for the MADE trial) outside of these hours; and

- **Octopus Agile:** an electricity tariff with half-hourly energy prices tied to wholesale prices and updated daily. This captures the major national-scale and distribution-scale drivers.

Octopus Go Tariff

Figure 2-6shows typical operation under the coordinated control strategy implemented in phase two of the trial, under the Octopus Go tariff. The following can be observed from the figure:

- The home is pre-heated with cheap electricity during the off-peak tariff period. Thermal comfort is maintained and met entirely by the heat pump over the window shown. Here the average heat pump coefficient of performance (COP) was 3.22;
- One battery cycle per day is observed. The battery charges over the cheap tariff period and then discharges following the return to the peak tariff rate;
- Minimal solar is observed in February; and
- There is high household consumption during the cheap tariff periods, with heat pump use and battery charging maximised during this time. The average price of electricity paid over this three-day window was 10.5p/kWh.

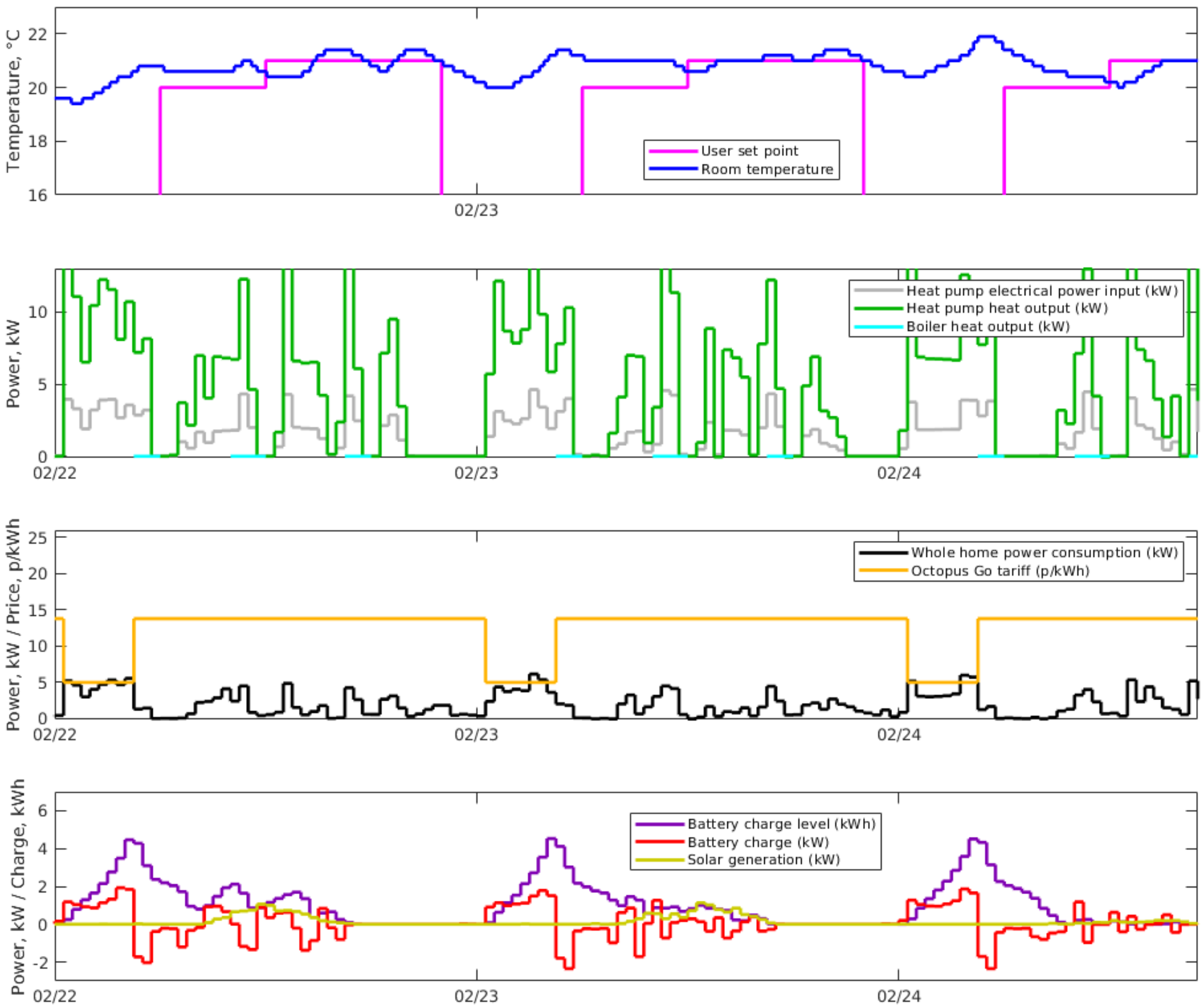

Figure 2-6 - Coordinated control on the Octopus Go tariff (Home 05, 22/02/2020 - 24/02/2020)

Agile Tariff

Figure 2-7 shows typical operation under the coordinated control strategy implemented in phase two of the trial, under the Octopus Agile tariff. The following can be observed from the figure:

- The home is pre-heated with cheap electricity during the off-peak tariff period. Thermal comfort is maintained and met mainly by the heat pump over the window shown, with support from the boiler to meet short notice requests for heat.
- Two battery cycles per day are observed. The first cycle involves the battery charging up with very cheap overnight electricity which is then discharged over the late morning. The second cycle occurs in order to avoid peak electricity prices. The battery charges up prior to the peak agile tariff period (typically 16:00 - 19:00), and discharges during this expensive period. This observation of two battery cycles per day is interesting project learning given that most domestic batteries are currently designed with an expectation of one battery cycle per day. Battery arbitrage can also be observed, particularly overnight on the 10th February, where the battery exploits varying electricity prices, charging when cheap and discharging to meet home consumption when expensive.
- Household consumption is reduced almost entirely during the agile peak tariff period (typically 16:00 - 19:00).

Figure 2-7 - Coordinated control on the Octopus Agile tariff (Home 05, 08/02/2020 - 10/02/2020)

Electric vehicle charging integration

EV charging control was first implemented during phase two of the trial, with control being largely manual driven during this stage of the project. Phase three of the trial then moved to fully optimised integration of the EV charge point along with the other assets. The control strategy for each asset during phase three was as follows:

- **Hybrid heating system:** use was optimised against the tariff, coordinated with solar generation and battery availability as well as EV demand. The hybrid heat pump controls were configured with a high price for the fossil fuel boiler in order to reflect the future scenario of substantial decarbonisation, which enabled a high proportion of the heat demand to be provided by the heat pump;

- **Battery:** controlled via a combination of Passiv's battery control algorithm and Sonnen's internal "automatic" control algorithm, with Passiv's algorithm deciding when to switch between control strategies. During this phase, the battery was optimised against the tariff, coordinated with both solar generation and hybrid heat pump use as well as EV and baseload electricity demand. This enabled load shifting through pre-charging the battery during cheap tariff periods; and

- **EV:** During this phase, EV charging control was fully automated. Charging was controlled using Passiv's EV control algorithm, based on user information inputted via the Passiv app. EV users were asked to enter the current state of charge of their vehicle, the desired state of charge, and the time they required it to be charged by. Based on this information, the EV was then charged at the most beneficial time, coordinated with all other energy assets in the home to minimise consumer costs whilst also honouring any constraints that may be in place.

This section of the report presents results regarding EV charging from both phase two and phase three of the field trial.

EV charging optimisation against tariff

Prior to coordinating the EV charge point with the other energy assets within the home, interventions were performed in order to align charging with cheap tariff periods. Figure 2-8 demonstrates EV charging being managed against the Octopus Go tariff. The householder plugged in their EV at 21:00, and at 21:30 a request was sent to the EV charge point to delay charging until the Octopus Go tariff became cheap at 00:30. The bulk of the charging thus took place during this cheap period, with a saving of £1.29 achieved compared to if no intervention had been applied. The length of time between plug in and the command to restrict charging would in practice tend to be much shorter than the half an hour demonstrated here, however this scenario allows for clear indication of plug in time and the period over which EV charge is being constrained to be displayed on the graph

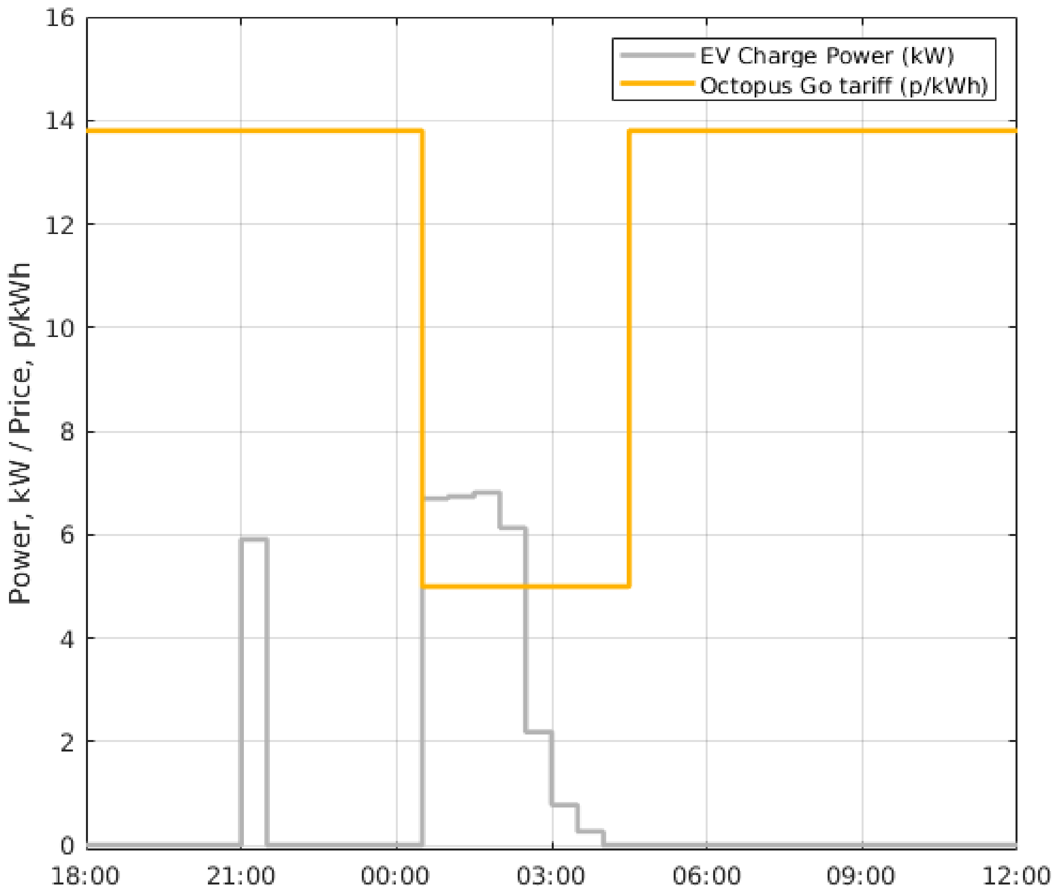

Figure 2-8 - Delayed EV charging on Octopus Go tariff (Home 3)

Figure 2-9 demonstrates EV charging being managed against the Octopus Agile tariff. Charging is constrained over the peak agile tariff period, and the electric vehicle resumes charging at full power at 19:00, once the peak tariff period has passed. This results in a total saving of £2.79 compared to if no intervention had been applied. It should be noted that the intervention displayed in Figure 2-9 involved a Tesla. One key project finding from MADE has been the discovery that Tesla's enter a "sleep mode" if charging is entirely restricted and subsequently stop responding to any further chargepoint power increases, thus charging can never be resumed. Experimentation has occurred under the MADE project to deduce the minimum value to which Tesla charging can be restricted, whilst preventing the vehicle from entering "sleep mode". This minimum value has been discovered to be 6A (~1.4kW). It can be seen from Figure 2-9 that during the peak agile tariff period, charging has not been stopped entirely, but instead restricted to this minimum value of 6A.

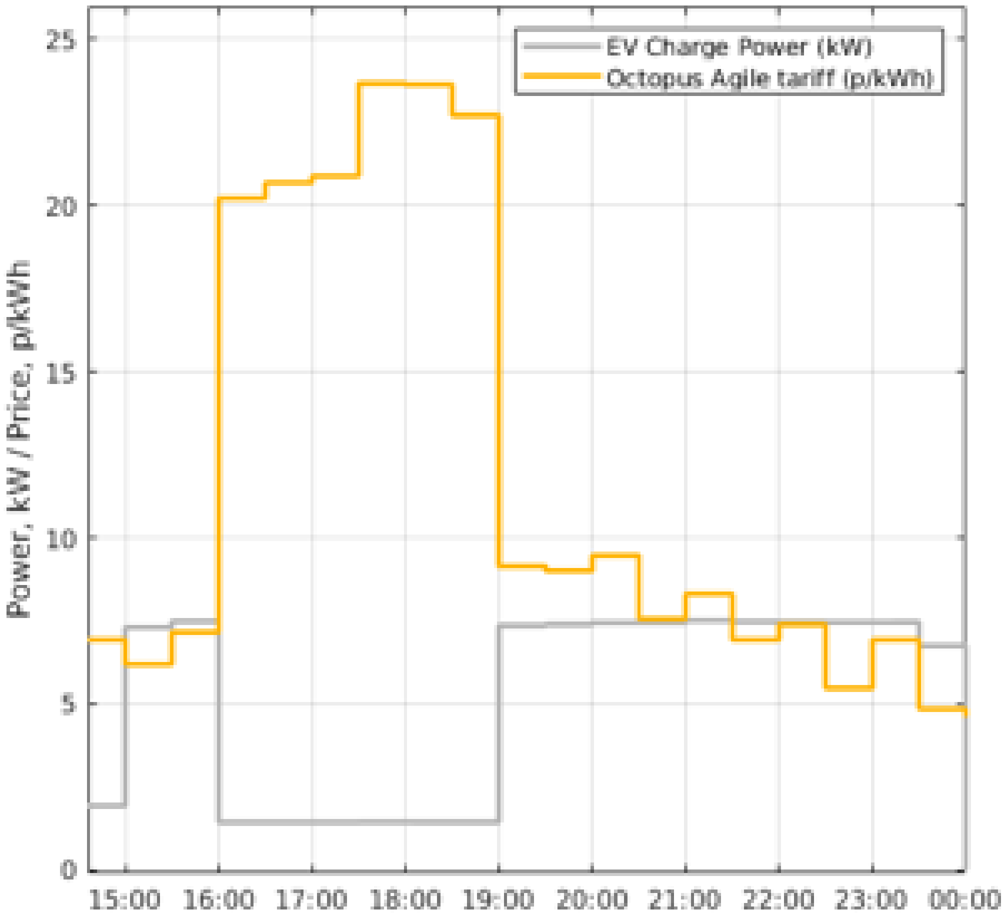

Figure 2-9 - Constraining EV charging on Octopus Agile tariff (Home 4)

Customer satisfaction and LCT feedback survey and interviews

Part of Work Package 5 the Project Partners agreed on the following learning objectives at different times throughout the trial. A combination of in-depth interviews and surveys are to be utilised at various stages of the trial in order to assess customer experiences and perceptions of LCTs with integrated control throughout.

Below provides an interim update on the research undertaken at various stages of the trial with the exceptions of the post-heating survey, interviews and post-trial survey which will follow after the trials have been completed.

Table 2-2: Customer surveys

Research objectives	Status
Pre-trial – Survey 1 and interview 1: ▪ Understanding existing consumer perception and expectations of LCTs. ▪ Identifying potential barriers and concerns about LCTs. ▪ Identifying potential attractions of LCTs and willingness to pay for additional benefits. ▪ Outcome: de-risks and helps to ensure success of controls strategy, customer targeting, customer proposition & trial design.	Complete
During trial – Survey 1 and interview 1: ▪ Assessing the installation and commissioning process and lessons learnt. ▪ Reviewing in-use performance of integrated LCT control with optimisation and whether this meets expectations and requirements. What could be improved? ▪ Assessing the user experience of the smart control user interfaces and evaluate potential improvements.	Complete

Post-trial – Survey 2 and interview 2: ▪ Identifying the successes and failures of the trial to feed into future systems design. ▪ Clarifying the requirements of customers and what the market needs to offer. ▪ Assessing barriers to large-scale deployment and recommending how issues can be addressed.	April and May 2020
Post-project – Survey 3 • Trial participant satisfaction survey. • Future project improvements.	June 2020

Below is a summary of key learnings from survey 1 and interview 1:

- **Shifting customers away from conventional fossil fuels to LCTs will be a challenge - customers are overwhelmingly positive about their existing fossil fuel assets:** In order for customers to engage with LCTs it must be able to compete on the priority areas of running costs, reliability and comfort. When combined with low LCT awareness the scale of the challenge is clear. There is a real need for education among customers, and installers (who largely hold the customer relationship). A near term option could be to target environmentally conscious homeowners, who are more likely to be motivated to reduce their carbon footprint as a basis for building expertise and customer momentum.
  Recommendation: trusted advisor role needs to be filled to engage customers and installers; off-gas homes should be an initial target.

- **The technology has been proven – customers were overwhelmingly positive about the LCTs:** The trial has proven that both the installation of LCTs with 3rd party controls, and the long-term use and operation of LCTs in a variety of house types and customer types is possible. The LCT with optimised controls largely met the comfort and reliability challenge, and all customers were satisfied. The most satisfied customers experienced a high-quality customer journey throughout, from the information at pre-trial, to the installation and follow ups. This highlights how important it is to get the customer journey right. Bundling with smart controls also proved popular and can support increased customer engagement and confidence.
  Recommendation: Offer end-to-end LCT service, from pre-install to aftersales support to ensure customer 'peace of mind'. Bundling with smart controls should be standard.

- **Financial criteria are a key priority for customers - innovative business models will be needed for market creation –** participants were drawn to the trial because they would get free LCTs, but also because they believed they would save money on their energy bill (even though this was not a stated aim of the trial). Energy prices today make this difficult, and we know up-front costs are typically higher for LCTs than conventional fossil fuel equivalent replacements so the market will need to address these challenges to capture customer attention.
  Recommendation: Consider the potential of LCT for free models, leasing, or other innovative financial models.

- **There is an opportunity around DSR which needs further exploration:** The trial participants in this research demonstrated a high level of interest in future DSR propositions, although it is clear that many struggle to understand the concept, so there is an education piece here too. However, once explained, respondents were open to DSR. With the right incentives in place DSR could offer significant network benefits and support the creation of innovative energy tariffs – that in turn could support LCT uptake if it provides the running cost saving customers require in order to invest.
  Recommendation: Explore potential DSR opportunity with further research and consider what sort of incentives or tariffs it could support.

Next steps

PassivSystems is to complete phase 3 and commence phase 4 interventions with the trial homes. A full analysis will be completed by the end of May 2020.

Survey 2 and interview 2 will be completed by May 2020.
Following the completion of the Work Package 5, PassivSystems will distribute Low Carbon Technology (LCT) data, home load profiles and maximum demand profiles with the project partners to conduct in depth network and technology analysis.

2.2.6 Work Package 6: Technology, Customer and Network Analysis – Dissemination

Progress within this reporting period

The project is currently at technical trial phase and the partners are collating the results. A data analysis plan and modelling methodology has been drafted which details what data is required and appropriate modelling to best demonstrate the MADE concept.

Next steps

The project partners will start to share the interim results from the technical field trial over the next reporting period.

Formal modelling with analysis using the LCT performance and coordinated LCT load profile data will be completed over the next reporting period. The modelling and analysis will assess the benefits and impact coordinated LCT control for the following.

- Whole-energy-system;
- National network;
- Local network; and
- Home/customer.

The partners will start to collaborate to produce a proposition framework for each area listed above to unlock and drive the potential of coordinated LCT controls.

3 Progress Against Budget

The project has progressed well against the budget and is currently tracking a slightly lower spend than expected. Table 3-1 summarises the details of the progress that has been made with respect to the project budget.

Table 3-1: Project finances

Spend Area	Budget (£k)	Expected Spend to Date (£k)	Actual Spend to Date (£k)	Variance to expected (£k)	Variance to expected %
WPD Project Management	£81,221	£46,094[1]	£39,486	£6,608[2]	-14%
PassivSystems costs	£1,357,000	£1,148,136	£1,146,520	£1,616	0%
Contingency	£116,825	£0	£0	£0	0%
TOTAL	**£1,555,046**	**£1,161,502**	**£1,186,006**	£3,259	1%

Comments around variance

1. The total expected spend was re-baselined to £62,430 following lower than expected resource usage in the initial stages of the project.
2. Less resource has been required than allowed for to date on the project.

4 Progress Towards Success Criteria

Good progress has been made on the Success Criteria within this reporting period, with the data coming from the trial feeding into their progress. Table 4-1 presents the progress towards the project objectives as documented in the MADE Project Registration and PEA document.

Table 4-1: Progress towards project objectives

Objectives	Status
Use the ability of managing multiple energy assets (EVs, hybrid heating systems and solar PV) to switch between gas and electric load to provide fuel arbitrage and highly flexible demand response services.	**In progress:** This has been shown within the trial to date. This will be further refined in the next reporting period.
Demonstrate the potential consumer, network, carbon and energy system benefits of large-scale deployment of in-home multi-energy assets with an aggregated demand response control system.	**In progress:** Initial modelling has shown the value. This will be re-run following the trial.
Gain insights into the means of balancing the interests of the consumer, supplier, and network operators when seeking to derive value from the demand flexibility.	**In progress:** Initial modelling has given an initial view. This is being evaluated in the trial.

Table 4-2presents the progress towards the success criteria as documented in the MADE Project Registration and PEA document.

Table 4-2: Progress towards success criteria

Success Criteria	Status
A detailed understanding of technical feasibility of asset coordination (supported by a report and operational data).	**In progress:** an interim field trial analysis report has been produced which highlights initial coordinated results. A final field trial analysis report will be produced at the end of May 2020 and updated in September 2020.
A detailed customer proposition for the MADE concept.	**Complete:** the business modelling work in the previous reporting period has highlighted the potential propositions for customers.
A detailed understanding of the customer benefits of the MADE concept (supported by a report and operational data).	**In progress:** the micro-economic model and analysis conducted by Everoze highlights the customer benefits of the project.
A detailed understanding of the impact of coordinated asset control on the distribution network (supported by a report and operational data).	**In progress:** field trial data is currently being collated, the data will be formatted, and profiles will be produced and issued to Imperial College to conduct distribution modelling.
A detailed understanding of the whole system benefits of coordinated asset control on the distribution network (supported by a report).	**In progress:** field trial data is currently being collated, the data will be formatted, and profiles will be produced and issued to Imperial College to conduct distribution modelling.
Dissemination of key results, findings and learning to policy makers, regulators, network operators and suppliers.	**In progress:** WPD, PassivSystems and the project partners have presented at 12 events and the project has been referenced in two publications.

5 Learning Outcomes

Within the project to date we have created the following learning:

- Following a technical review of LCTs the project identified additional control capabilities. As a result, the proposed coordinated control baseline has been revised and Everoze and Imperial recalibrated their models to understand the impact;
- LCTs can operate differently when optimised and can deliver requirements tailored to consumer tariffs (e.g. flat, ToU);
- PassivSystems coordinated controls are capable of responding to negative pricing under octopus agile;
- Tesla model 3 currently does not allow for cold start smart charging due to its sleep mode. This is a manufacture issue that they are looking to address and is currently causing issues for smart charging providers;
- There could be a requirement for coordinated control within the home following learnings from the field trial interventions. This is due to the example where both a Sonnen battery and the EV was charging the customer installation tripped out;
- Occasionally the battery charge/discharge dropping to zero for short periods despite requests not to, therefore, cannot solely depend on this LCT;
- Shifting customers away from conventional fossil fuels to LCTs will be a challenge - customers are overwhelmingly positive about their existing fossil fuel assets; and
- Early field trial results suggest that LCT coordinated control can relieve strain on the local network and can potentially take homes off grid at peak times.

6 Intellectual Property Rights

Table 6-1 presents a complete list of all IPR generated within the reporting period from all project partners. The IP register is reviewed on a quarterly basis.

Table 6-1: IPR generated within this project reporting period

IPR	Category	Owner
Field trial plan	Relevant Foreground	PassivSystems
Technical specification	Relevant Foreground	PassivSystems
Software high level design	Relevant Foreground	PassivSystems
Customer engagement report	Relevant Foreground	PassivSystems
Interim trial results report	Relevant Foreground	PassivSystems

7 Risk Management Current Risks

Our risk management objectives are to:

- Ensure that risk management is clearly and consistently integrated into the project management activities and evidenced through the project documentation;
- Comply with WPDs risk management processes and any governance requirements as specified by Ofgem; and
- Anticipate and respond to changing project requirements.

These objectives will be achieved by:

- Defining the roles, responsibilities and reporting lines within the Project Delivery Team for risk management;
- Including risk management issues when writing reports and considering decisions;
- Maintaining a risk register;
- Communicating risks and ensuring suitable training and supervision is provided;
- Preparing mitigation action plans;
- Preparing contingency action plans; and
- Monitoring and updating of risks and the risk controls.

7.1 Current Risks

The MADE risk register is a live document and is updated regularly. There are currently 18 live project related risks. Mitigation action plans are identified when raising a risk and the appropriate steps then taken to ensure risks do not become issues wherever possible. In Table 7-1, we give details of our top five current risks by category. For each of these risks, a mitigation action plan has been identified and the progress of these are tracked and reported.

Table 7-1: Top five current risks (by rating)

Details of the Risk	Risk Rating	Mitigation Action Plan	Progress
Participants request to leave the trial early	Major	Clear focus on customer needs. Clear customer engagement plan	PassivSystems customer support is adhering to the customer engagement plan. Completing weekly engagement activities with the trial participants.
COVID 19 related risk	Major	Detailed is captured in a specific COVID-19 RAID log	We are currently reviewing specific Covid-19 risks on a daily basis.
The trial interventions by PassivSystems may increase the customer's bills. There is the possibility that the controls may have bugs and effect the homeowner's usage.	Moderate	A well-defined engagement plan.	Updating the trial participants with their energy use.
Customers interfere with controls	Moderate	A well-defined engagement plan. This will include clear instructions on what should and should not be adjusted.	Customer engagement activities and daily data monitoring.
Loss of data through	Moderate	A well-defined engagement	Daily data checks and

customer disconnection of broadband		plan. This will include clear instructions on what should and should not be adjusted.	intervention reviews.

Table 7-2 provides a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the projects' risks.

Table 7-2: Graphical view of Risk Register

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	**0**	**0**	**0**	**0**	**0**
	More likely to occur than not/Likely to be near future (16-20)	**0**	**0**	**0**	**0**	**0**
	50/50 chance of occurring/Mid to short term (11-15)	**0**	**0**	**0**	**2**	**0**
	Less likely to occur/Mid to long term (6-10)	**0**	**6**	**6**	**0**	**0**
	Very unlikely to occur/Far in the future (1-5)	**0**	**2**	**0**	**2**	**0**
		1. Insignificant changes, re-planning may be required	2. Small Delay, small increased cost but absorbable	3. Delay, increased cost in excess of tolerance	4. Substantial Delay, key deliverables not met, significant increase in time/cost	5. Inability to deliver, business case/objective not viable
		Impact				

	Minor	Moderate	Major	Severe	
Legend	**8**	**8**	**2**	**0**	**No of instances**
Total	**18**				No of live risks

Figure 7-1 provides an overview of the risks by category, minor, moderate, major and severe. This information is used to understand the complete risk level of the project.

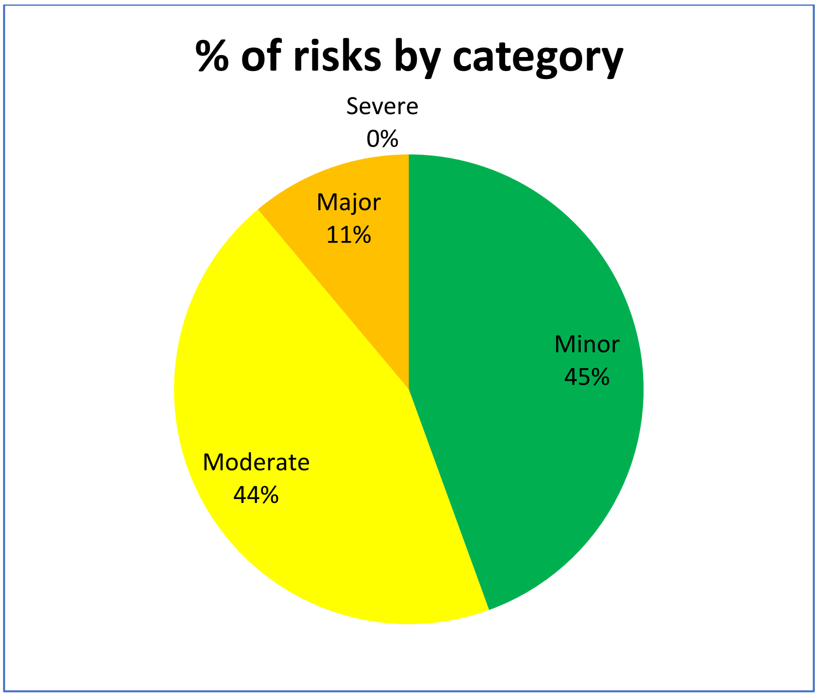

Figure 7-1: Percentage of Risk by category

7.2 Update for risks previously identified

Descriptions of the most significant risks, identified in the previous six monthly progress report are provided in Table 7-3 with updates on their current risk status.

Table 7-3: Risks identified in the previous progress report

Details of the Risk	Previous Risk Rating	Current Risk Rating	Mitigation Action Plan	Progress
Load shifting causing low charge EV/discomfort/overheating/confusion	Major	Moderate	Detailed testing as part of design	Risk has decreased, as experience and customer feedback has been gathered. This includes the addition of maximum temperature set-points following feedback on pre-heating.
Unknown capabilities and functionality of EVs, charge points and PV invertors resulting in not being able have the desired	Major	Closed	Testing, detailed specification and communication	The risk has now closed as the trial development has now concluded

control functionality. If the functionality does not meet the product specification could result in not being able to design automated control.				
Unable to recruit 5 trial homes in time to hit the critical heating season.	Major	Closed	A well-defined engagement plan.	The risk is now closed following the completion of the recruitment phase
On-boarding of customers is more arduous than expected	Major	Closed	Adequate budget and support for on boarding	The risk is now closed following the completion of the recruitment phase
Customers interfere with controls	Moderate		A well-defined engagement plan. This will include clear instructions on what should and should not be adjusted.	Customer engagement activities and daily data monitoring.

8 Consistency with Project Registration Document

The scale, cost and timeframe of the project has remained consistent with the registration document, a copy of which can be found here.

9 Accuracy Assurance Statement

This report has been prepared by the PassivSystems MADE Project Manager (Tom Veli), reviewed by the WPD Project Manager (Matt Watson), and approved by the Innovation Team Manager (Jon Berry).

All efforts have been made to ensure that the information contained within this report is accurate. WPD confirms that this report has been produced, reviewed and approved following our quality assurance process for external documents and reports.

10 Glossary

Abbreviation	Term
BAU	Business as usual
BEIS	Department for Business, Energy and Industrial Strategy
CCC	Committee on Climate Change
DNO	Distribution Network Operator
DSO	Distribution System Operator
DUoS	Distribution Use of System
EV	Electric Vehicle
GB	Great Britain
HHP	Hybrid Heat Pump
HP	Heat Pump
HV	High Voltage
IPR	Intellectual Property Register
LCT	Low Carbon Technologies
LRE	Load Related Expenditure
LV	Low Voltage
MADE	Multi Asset Demand Execution
NIA	Network Innovation Allowance
NPV	Net Present Value
PV	Photovoltaic
V2G	Vehicle to Grid
WeSIM	Whole-electricity Scenario Investment Model
WPD	Western Power Distribution

Western Power Distribution (East Midlands) plc, No2366923
Western Power Distribution (West Midlands) plc, No3600574
Western Power Distribution (South West) plc, No2366894
Western Power Distribution (South Wales) plc, No2366985
Registered in England and Wales
Registered Office: Avonbank, Feeder Road, Bristol BS2 0TB

wpdinnovation@westernpower.co.uk
www.westernpower.co.uk/innovation

@wpduk