WPD INNOVATION
Transforming the electricity network

# Multi Asset Demand Execution (MADE)

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WESTERN POWER DISTRIBUTION
*Serving the Midlands, South West and Wales*

MADE

# Outline

- Innovation team introduction
- Project overview
- Work carried out
- Key learning
- Next steps

## WPD Innovation Team

# Our Innovation Strategy & Values

We are a team of engineers dedicated to implementing our Innovation Strategy


We identify problems, find solutions and trial them through our projects

**We aim to be a main contributor to decarbonisation**

**We are passionate about using our innovation funding the best way possible and providing value for money**

**We want to be working with the best people to achieve excellence together**

## WPD Innovation Team

# Our Commitments

- ✓ We are committed to overcoming the barriers to the energy transition.
  - ✓ We will continue to focus on finding novel ways of efficiently and effectively transforming our network.
    - ✓ We will continue to develop new technologies, commercial solutions and standards to make the most out of our existing network.
      - ✓ We will work with our communities to understand how best we can support our vulnerable customers and ensure that no one is disadvantaged.

WPD Innovation Team

# Our Priority Areas

WPD INNOVATION
Transforming the electricity network

- Decarbonisation and Net Zero
- Heat
- Transport
- Communities and Consumer Vulnerability
- Data

WPD Innovation Team

# Our Innovation Programme

DC Share

SHEDD

Harmonic Mitigation

ALARM

Net Zero South Wales

OpenLV

Presumed Open Data

PNPQA

MADE

PCB Sniffer

Virtual Monitoring Data

Wildlife Protection

OHL Power Pointer

Electric Nation - PoweredUp

EDGE-FCLi

Take Charge

EFFS

LTE| Connecting Futures

Virtual Statcom

Future Flex

IntraFlex

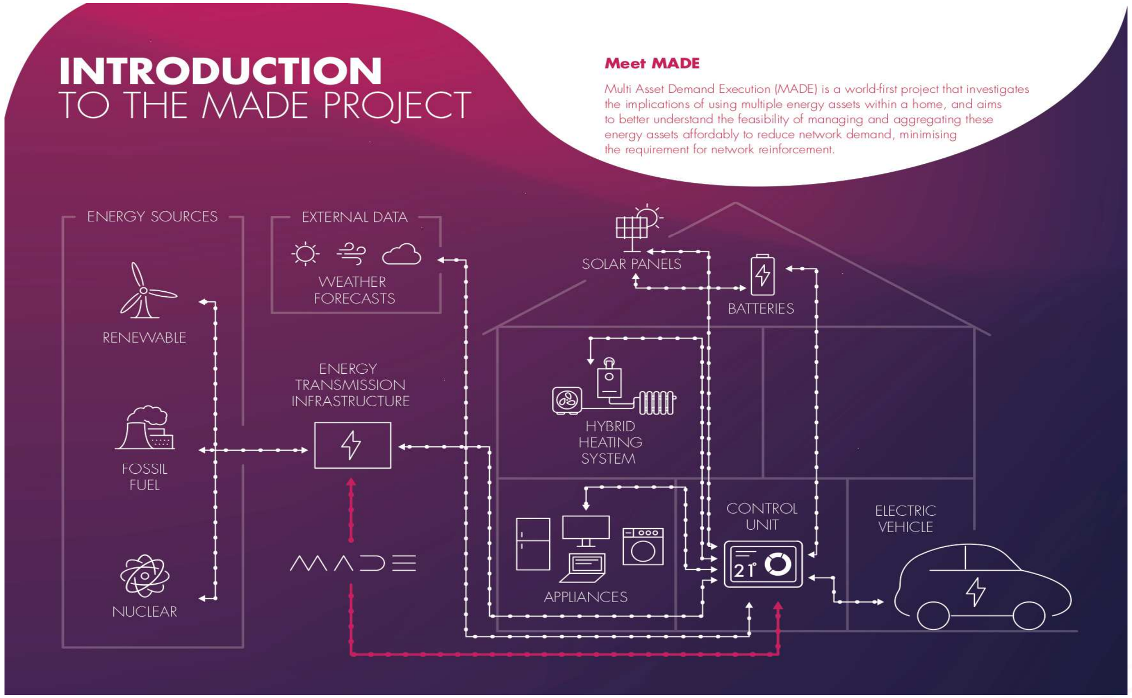
ARC Aid

Coordination of ANM & Markets

# MADE

FLEXIBLE, COORDINATED DOMESTIC HEAT,
POWER AND TRANSPORT

# MADE OVERVIEW



# £12BN TEN POINT PLAN FOR NET-ZERO TRANSITION

1. **Offshore wind: 40GW of offshore wind by 2030, supporting up to 60,000 jobs.**
2. **Hydrogen: £500m of investment to generate 5GW of low-carbon hydrogen production capacity by 2030, explore the use of hydrogen as a fuel for UK homes.**
3. **Nuclear: £525m to support up to 10,000 jobs and rollout small generation projects.**
4. **Electric vehicles: the ban on the sale of new petrol and diesel vehicles has been moved forwards to 2030, and £1.3bn is committed to charging infrastructure.**
5. Public transport: £5bn to be funnelled into cycling, walking, and low-carbon buses.
6. "Jet Zero" and greener maritime: funding to support low-carbon innovation, including £20m for maritime.
7. **Homes and public buildings: £1bn starting next year to improve energy efficiency in homes, schools and hospitals.**
8. Carbon capture: £1bn has been committed to target the removal of 10MT of carbon dioxide by 2030.
9. Nature: 30,000 hectares of trees planted annually. £5.2bn ring-fenced for flood defences.
10. Innovation and finance: supporting the development of new technologies in order to make the City of London the global centre of green finance.

## PROJECT OVERVIEW

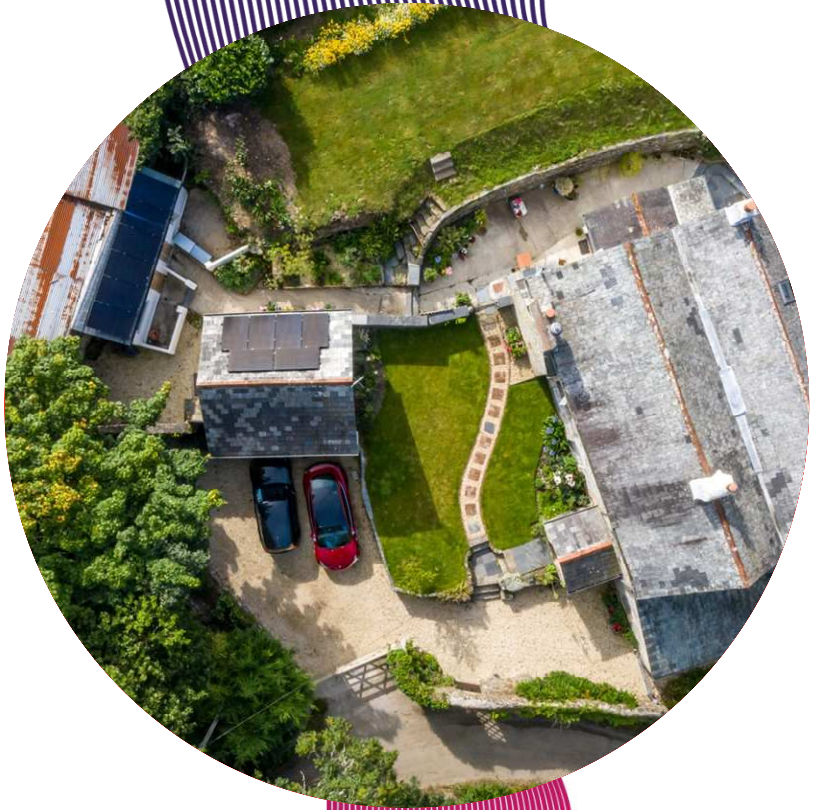
**MADE sets out to explore the implications for the electricity distribution network of homes having multiple low carbon assets, and the potential for reducing this impact through active control and coordination of these assets.**

To achieve net zero by 2050, it is likely that as we transition to reach this goal, a large proportion of UK homes will:

- Be heated by a **hybrid heat pump** (HHP)
- Have **solar photovoltaic** (PV) panels
- Have a **battery** system
- Drive an **electric vehicle** (EV) which can be charged via an EV charge point at home.

The project replicated this combination of assets within the home for the first time with smart controls, enabling all four technologies to be coordinated with each other.

The project explored how to optimise the combined flexibility from the assets to offer grid services and stay within any local grid constraints.



# PROJECT OBJECTIVES

**Based on the lessons learned from previous WPD Network Innovation trials, the following objectives were developed:**

1. Design and developed a domestic home flexibility model that considers multiple low carbon technologies and multi-vector flexibility for the GB energy system today.
2. Understand the interplay of residential solar PV generation, storage systems, hybrid heat pump systems and smart EV
3. Assess the whole-energy system benefits and carbon benefits of the MADE concept;
4. Understand the conflicts and synergies between local DSO and ESO services objectives;
5. Validate the modelled learning by completing 5-home, 12-month technology trial over a heating season.

# PROJECT OVERVIEW

The **Multi Asset Demand Execution (MADE)** project is a £1.6m Network Innovation Allowance project investigating the network, consumer and broader energy system implications of high-volume deployments of the combination of LCTs, including generation and storage.

WPD has collaborated with flexibility experts PassivSystems who have formed a project consortium with Everoze, Delta-EE, and Imperial College to deliver this ambitious project. The project consortium are all experts in their fields

**WPD**

- Distribution network requirements;
- Innovation strategy and leadership;
- Future low carbon technology planning and requirements;
- Flexibility platform design and drivers;
- Network intervention insight;

**Delta-EE**

- Whole-system assessment on the future GB electricity systems;
- Local distribution network modelling;
- DSO and ESO conflicts and synergies;
- Consumer propositions.

**PassivSystems**

- Project delivery;
- Project and field trial design;
- Home energy management system;
- Customer engagement, insight and interfaces;
- Demand side response and flexibility services;
- Home and LCT energy data;
- LCT controls;
- LCT control strategies.

**Imperial College London**

- Market research;
- Customer research;
- Distribution network modelling;
- Business models;
- Commercial propositions;
- Consumer propositions.

**Everoze**

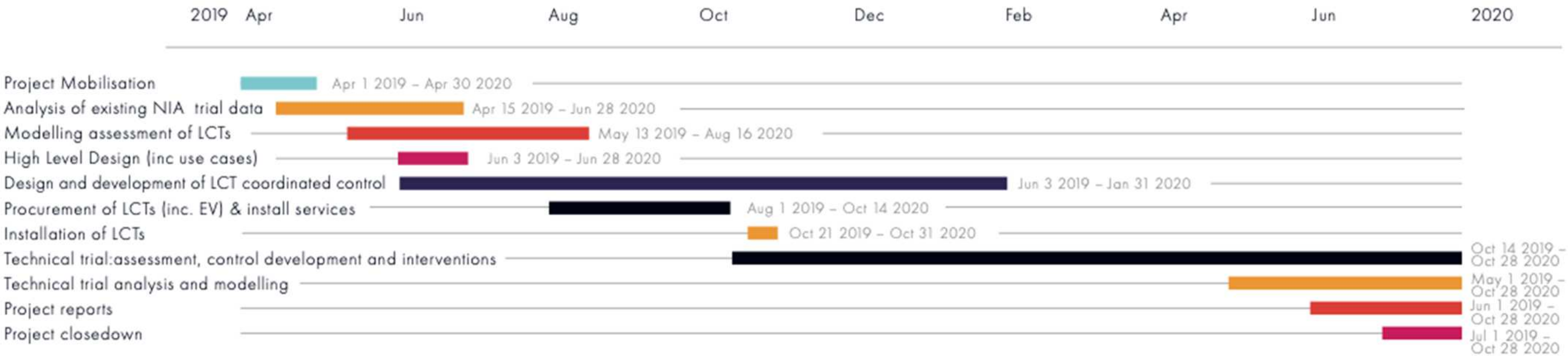
- Micro-economic energy modelling at domestic level;
- Inclusion of DSO services;
- Flexibility services;
- LCT data and analysis;

**Table 1** – Project partner overview

# PROJECT METHODOLOGY

**The project was designed and delivered under 6 work streams to produce a series of outputs. These were split into two general phases:**

1. Phase 1: Desktop analysis, network modelling and impact assessment.
2. Phase 2: 5-home technology trial (October 2019 and October 2020).



# COORDINATING MULTIPLE LCTS

**The low carbon technologies were controlled (where included in coordination) by PassivSystems' smart control system:**

- A smartphone App with which they specify their EV charging and thermal comfort requirements.
- Machine learning algorithms determine the thermal properties of the home and heating system.
- Predictive optimisation algorithms determine the best operational strategy for the assets.
- Control algorithms make real-time decisions to send commands to each asset:
    - Boiler operation;
    - Heat pump operation and demand level (target flow temperature);
    - Battery operation mode
    - EV charge point power limit.

# TECHNICAL FIELD TRIAL DESIGN

**The key aims of the technical trial were to:**

- Improve understanding of the real-world complexities of installing hybrid heat pumps, solar PV panels, batteries and electric vehicle (EV) chargers – with and without MADE concept.
- Demonstrate how coordinated control can be executed effectively within a real home and understand the benefits to the consumer;
- Collect data which can be used to validate the modelling results produced as part of the project.

**The technical trial was designed to answer the following research questions:**

- How does real-world overall household demand shape change depending on time-of-use tariffs, level of asset coordination and over the seasons?
- What happens to the peak demand as we move between each scenario?
- How can the demand shape be influenced by interventions?

# DEPLOYMENT SUMMARY

- 5 homes: 3 customer types and 4 house types.
- Gas grid connected and off-gas grid (LPG and Oil).
- 5 EVs: Varying driving patterns.
- **LCT application challenges.**

| 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 Motion32A | Nissan Leaf 40kWh |
| 4 | 9 kW Samsung ASHP | LPG system boiler | 3.78kWp | Sonnen hybrid 5kWh | New Motion32A | Tesla Model 3 75kWh |
| 5 | 9 kW Samsung ASHP | Oil system boiler | 4.41kWp | Sonnen hybrid 5kWh | Alfen 32A | Nissan Leaf 40kWh |

# TECHNICAL FIELD TRIAL APPROACH

**An increase in the number of assets optimised together in a coordinated way:**

- Phase 1: Baseline (Heat pump and solar coordination only);
- Phase 2: Heat pump, solar and battery coordination;
- Phase 3: Full coordination including EV;
- Phase 4: Summertime operation.

**Contrasting dimensions simultaneously:**

- Level of asset coordination;
- Time of use tariffs;
- Seasonality;
- Interventions.

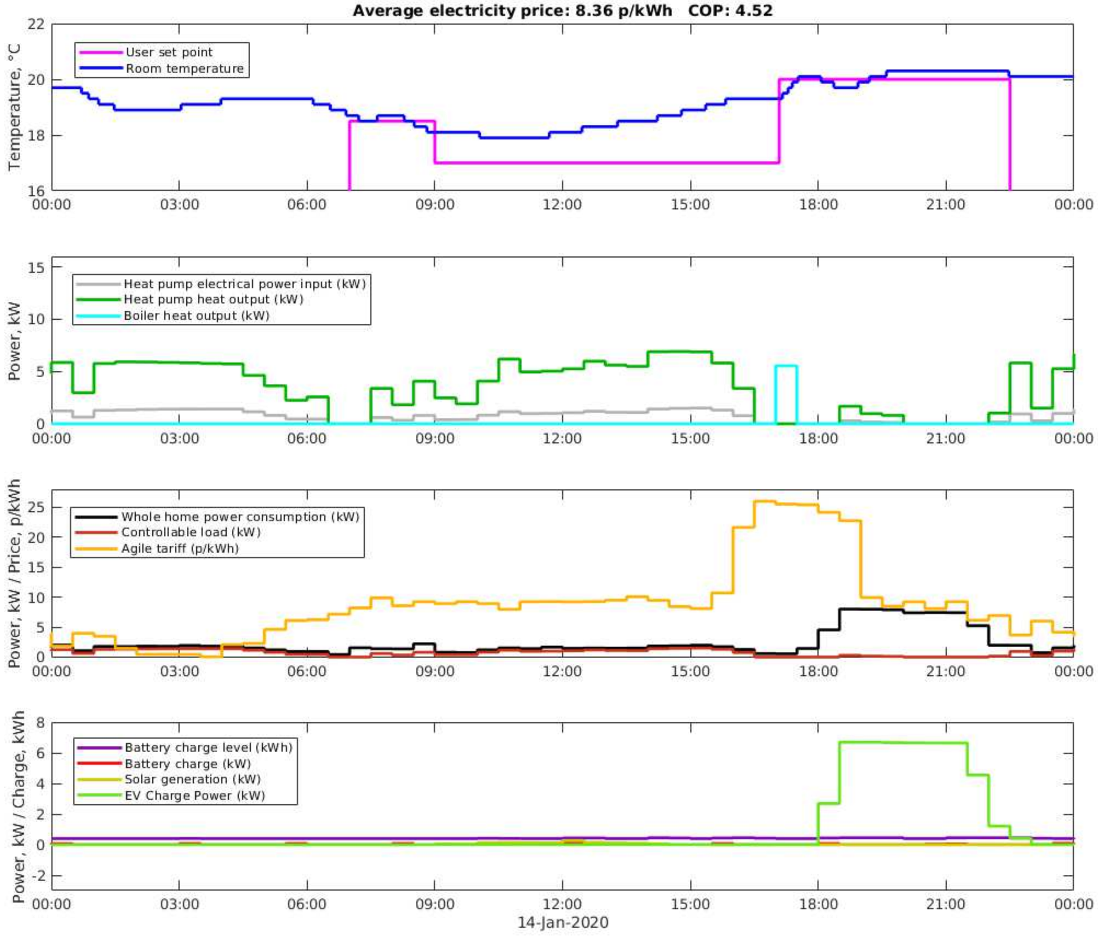
| Month | Oct 19 | Nov 19 | Dec 19 | | Jan 20 | Feb 20 | Mar 20 | Apr 20 | May 20 | Jun 20 | Jul 20 | Aug 20 | Sep 20 | Oct 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | Phase 1 | | | Christmas period | Phase 2 | | Phase 3 | | Phase 4 | | | | Phase 5 | |
| Tariff | Flat Rate | Economy 7 | Octopus Agile | | Octopus Agile | Octopus Go | Octopus Agile | | Octopus Agile | | Octopus Go | Octopus Agile | Flat Rate | Octopus Agile |
| Hybrid heat pump | Self-optimised against tariff | | | | Coordinated optimisation: hybrid heat pump + solar battery | | Coordinated optimisation: hybrid heat pump + solar + battery + EV smart charging | | | | | Coordinated optimisation: hybrid heat pump + solar + battery + EV smart charging + hot water | | |
| Solar PV Battery | Automatic PV self-consumption and discharge | | | | | | | | | | | | | |
| Electric Vehicle | User behaviour | | Charging deferral tests | | Midnight charge deferral | Turn up and turn down | | | | | | | | |
| Hot water | User behaviour | | | | User behaviour | | | | | | | | | |
| Local grid interventions | | | | | | | Peak reduction and local grid signals | Secure and dynamic | | Secure, dynamic and turn-up | | Secure, dynamic and optional downward flexibility management (ODFM) | | |

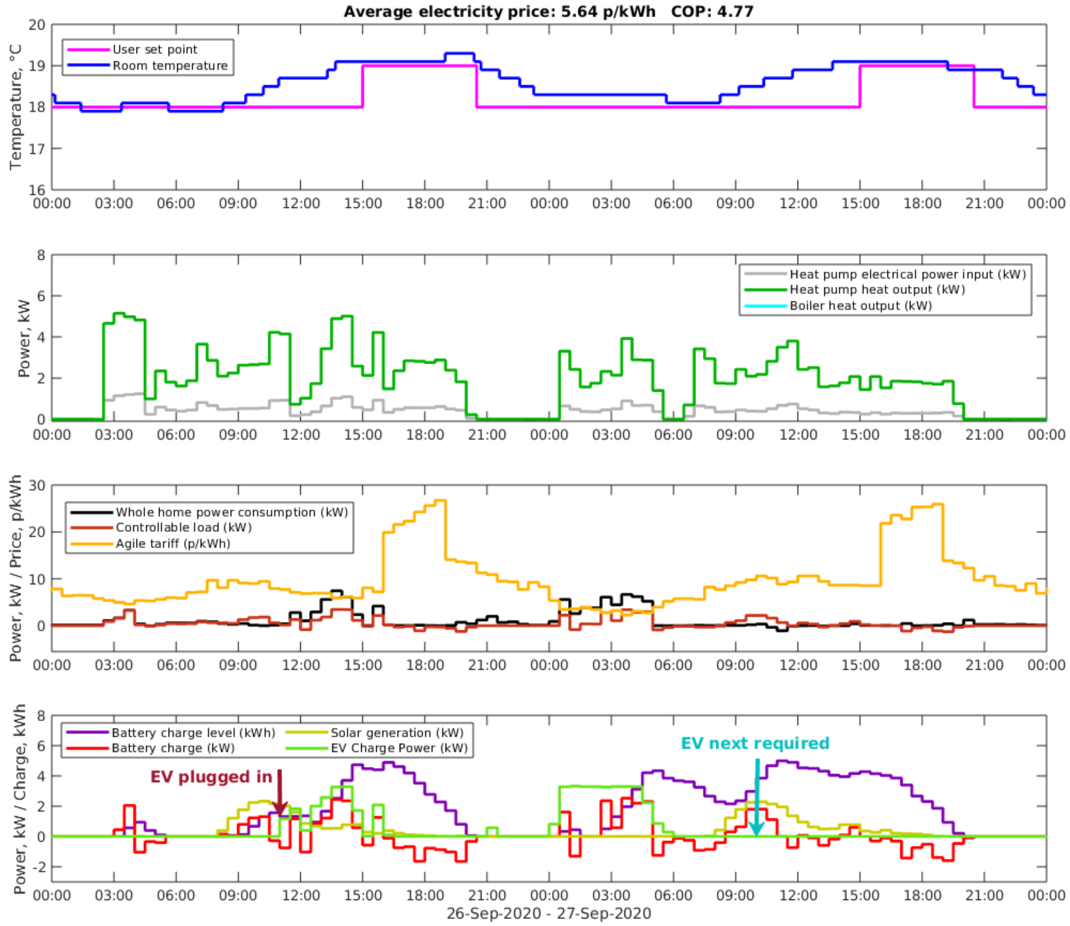
## SELECTED ENERGY TARIFFS

**The project used four tariffs to trial virtually:**

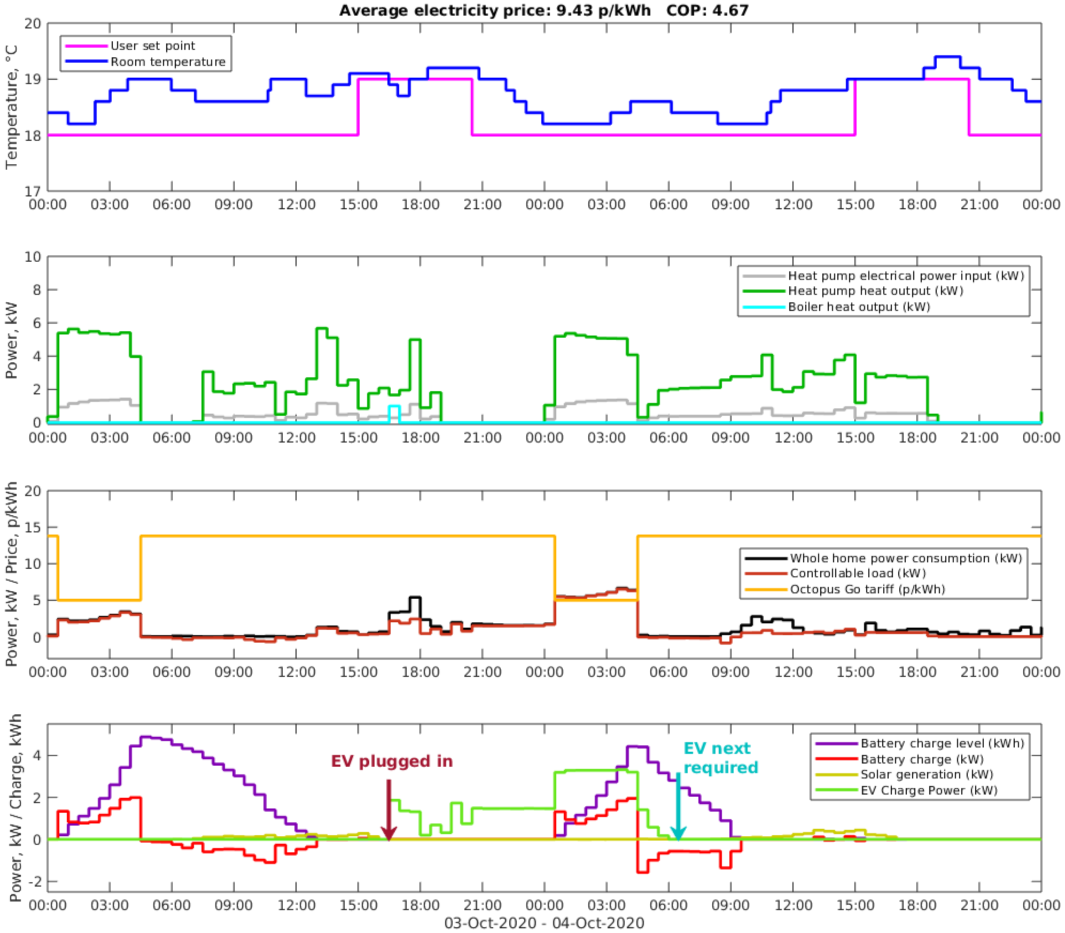
- **Flat tariff:** This provided a good initial baseline as it represents today's home.
- **Economy 7 tariff:** A tariff with a cheap night-time rate (00:00 - 07:00) provided a straightforward example of a ToU tariff. It is widely deployed today, particularly among EV owners.
- **Octopus Go:** An electricity 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 outside of these hours.
- **Octopus Agile tariff:** This is a half-hourly tariff where prices are published day-ahead. It provided a great representation of the needs of the network, combining electricity market prices (national influence) with early evening DUoS charges (local influence).

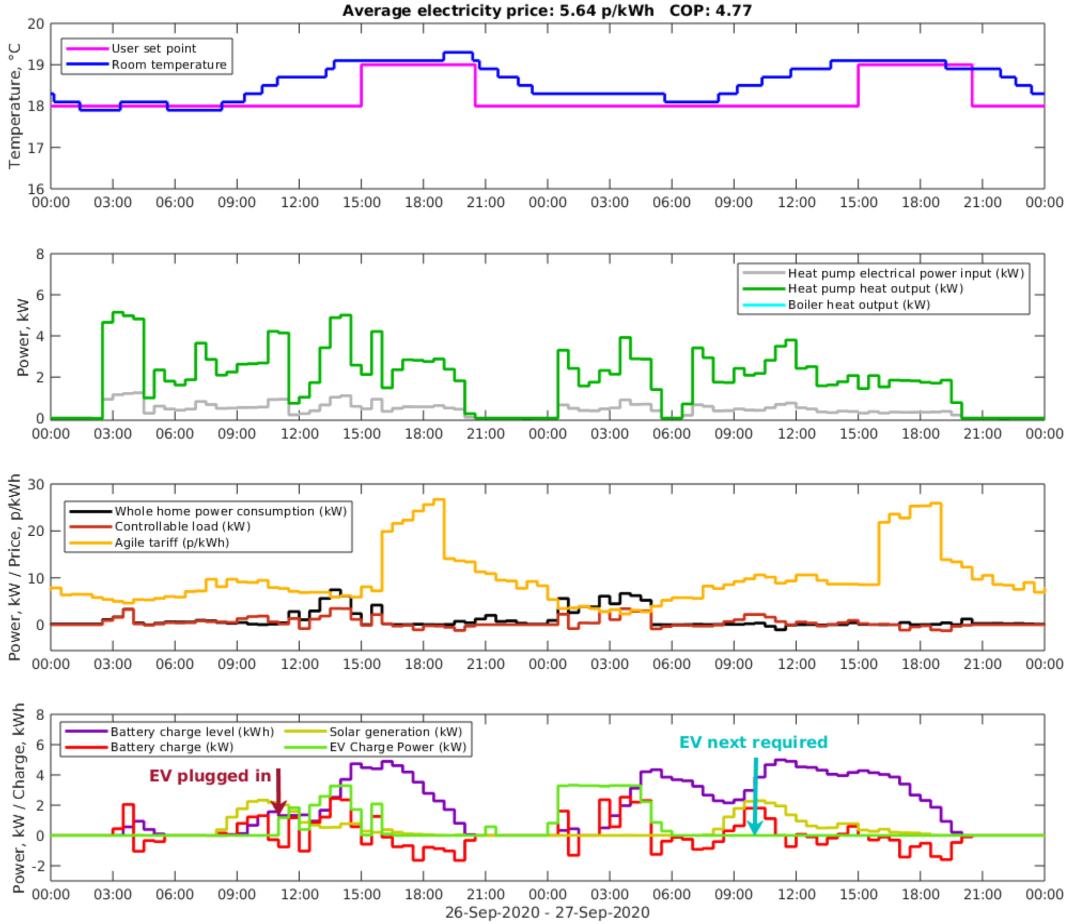
# FIELD TRIAL RESULTS: STANDARD VS COORDINATED CONTROL



# FIELD TRIAL RESULTS: TARIFFS - OCTOPUS AGILE VS OCTOPUS GO



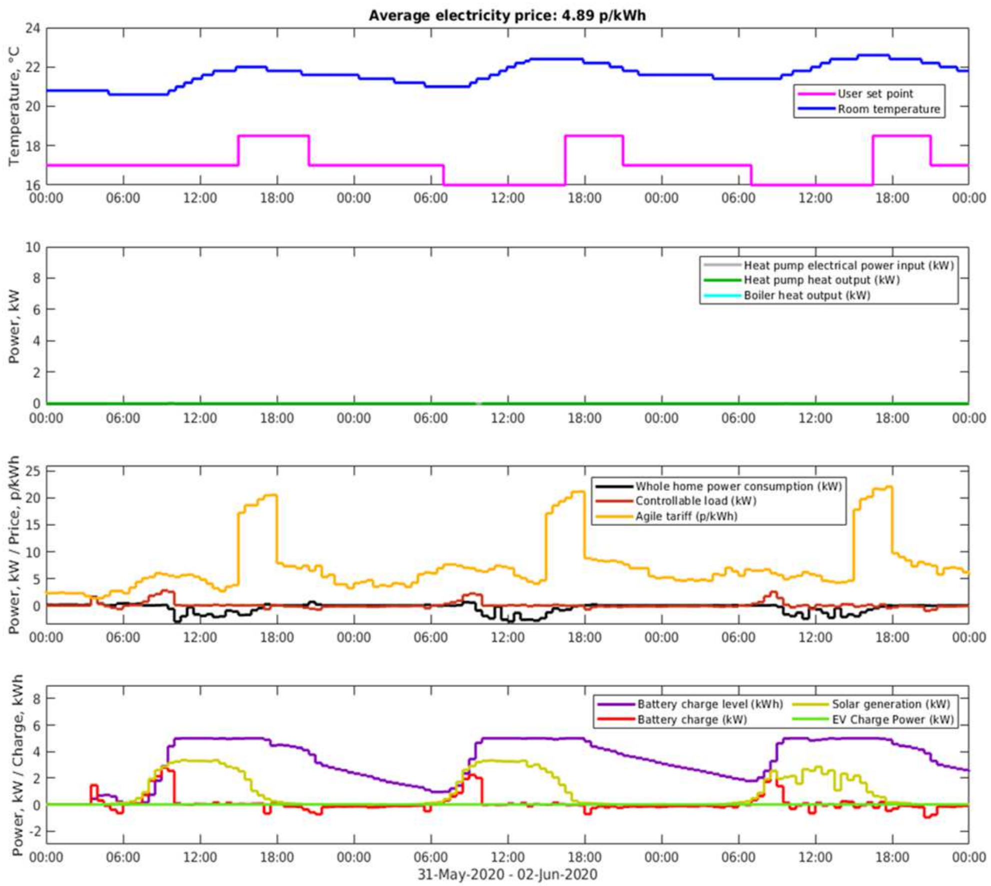
# FIELD TRIAL RESULTS: PHASE 4 - SUMMERTIME – OCTOPUS AGILE

- There is no heating demand. The home stays well above setpoint without the need for use of the heat pump or boiler.

- High solar PV generation has moved the system back from two cycles a day (observed previously) to one cycle a day, as the system recognises that free solar is advantageous over cheap night-time electricity rates.

- The household imports only 4.76kWh of electricity over the three-day period, but exports 34.8kWh of electricity in the same period. The percentage of household electricity consumption supplied by solar PV generation (and subsequent battery discharge) was as follows:

  - Day 1: 79%
  - Day 2: 90%
  - Day 3: 95%



# FIELD TRIAL RESULTS: FLEXIBLE POWER - SECURE

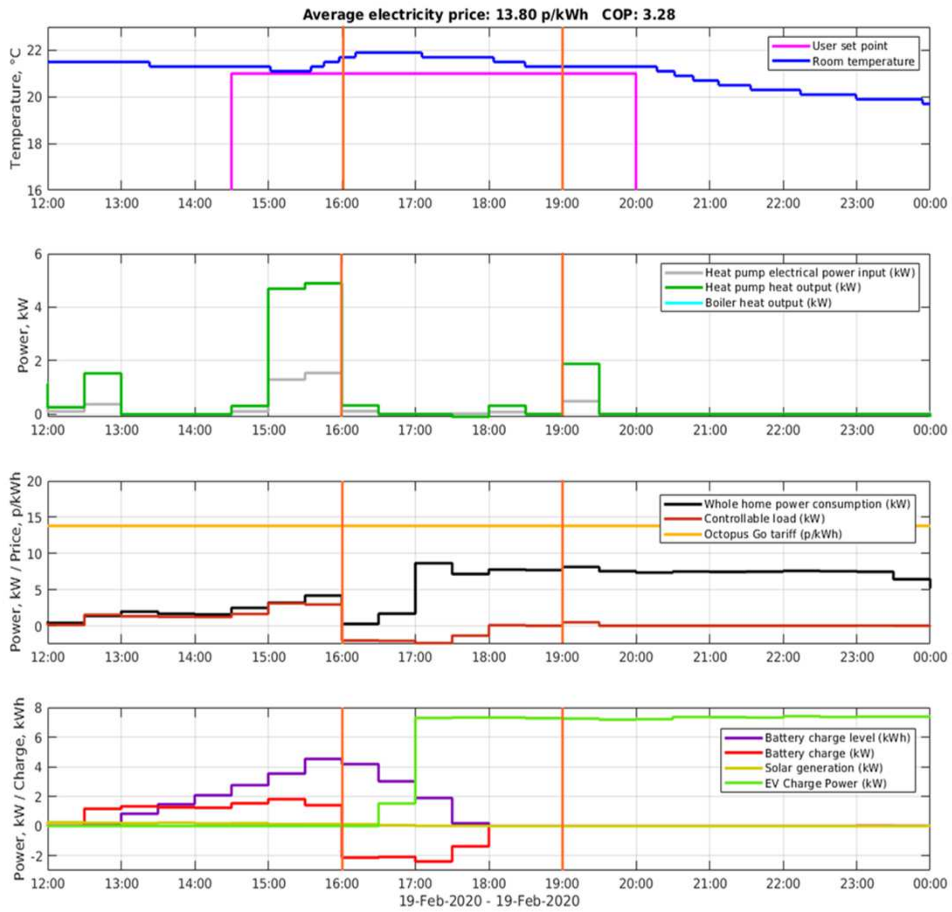
**The project carried out interventions to explore the flexibility of the system to respond to the needs of the network (beyond the baseline response represented by the ToU tariff).**

Interventions were carried out to emulate the mechanisms currently offered by Western Power Distribution in Flexible Power:

- **Secure**: where an advance commitment is given to reduce power for particular windows in time.
- **Dynamic**: where an availability window is agreed in advance, and on the day 15 minutes notice is given for a demand reduction.

The aim was to understand the flexibility and responsivity of the multi-asset systems against these mechanisms.

The graph shows an example of a Secure intervention scheduled for 4-7pm, where assets have a chance to store energy in advance.



# DIGITAL TWIN: FIELD TRIAL DATA SIMULATED

**This section presents the results of using a digital twin of one of the MADE homes to investigate the benefits of asset coordination.**

Comparative evaluations were made of householder running costs at different levels of asset coordination (which is not directly possible in the field trial as each home and each day is different).

- Baseline: heat pump coordinated with PV
- Phase 2: battery coordination added
- Phase 3: EV coordination added

The EV is assumed to be plugged in at 18:00 and require a full charge by 07:00 the following morning. Charge strategies:

- Uncontrolled charging: as soon as EV is plugged in
- “Smart” EV charging: delayed to midnight
- Phase 3: tariff-optimised and coordinated with other assets

This comparison was done for the Octopus Agile tariff.

The table below shows total electricity cost (£) over a two-day period, under each of the control strategies, in three different seasonal scenarios:

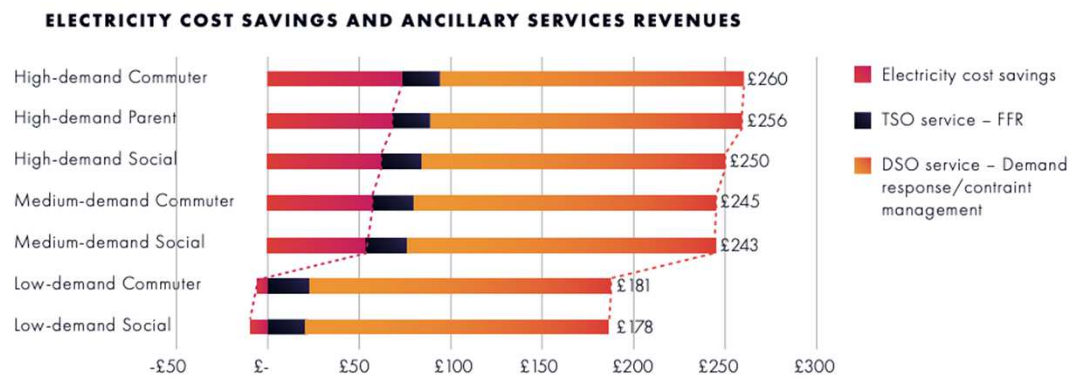
| | **Winter** | **March** | **Summer** |
|---|---|---|---|
| **Baseline Control** | 8.76 | 5.82 | 4.21 |
| **Baseline Control, Smart EV Charging** | 6.92 | 4.09 | 3.21 |
| **Phase 2 Control** | 8.00 | 5.26 | 4.05 |
| **Phase 2 Control, Smart EV Charging** | 6.21 | 3.95 | 3.12 |
| **Phase 3 Control** | 5.95 | 3.72 | 2.92 |

# DOMESTIC HOME-LEVEL FLEXIBLITY MODELLING

**Coordinated control has a notable value opportunity, with a value of up to £260 per annum per household.**

**The key conclusions regarding electricity cost savings from Everoze's techno-economic modelling are as follows:**

- Value from peak shifting is sensitive to consumer type;
- Value from peak shifting is tempered by additional energy imports for ancillary services;
- Low demand/EV utilisation customer types are only attractive for DSO services;
- DSO services form a key part of the value stack, but are subject to large variance in value depending on the local network constraints and service need;
- Coordinated FLEX can help maximise value from DSO service opportunities; &
- FFR is a less attractive value proposition.



# DOMESTIC HOME-LEVEL FLEXIBLITY MODELLING: VALIDATED

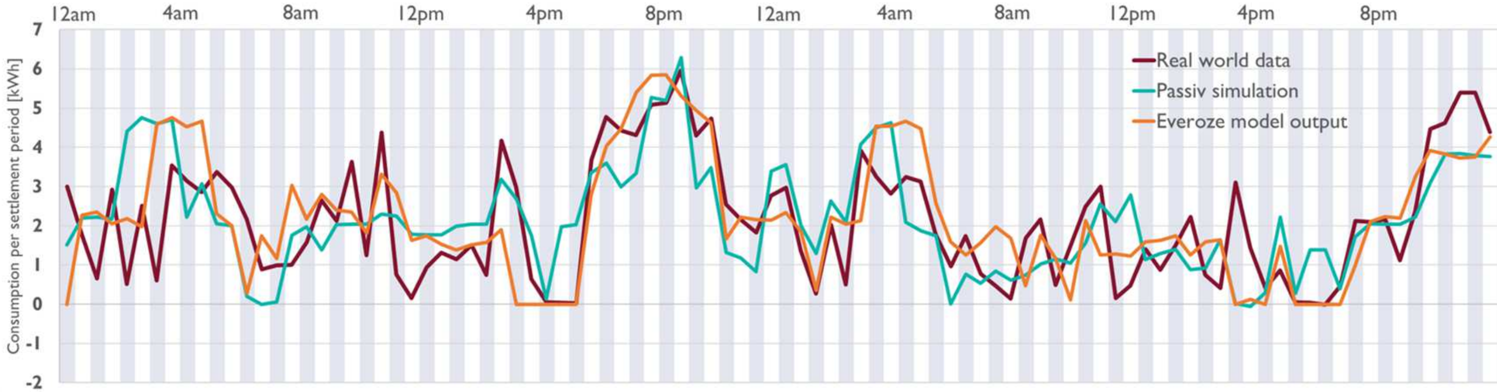
**WINTER: Key differences attributed to**

i) Differences in modelled ASHP behavior.
ii) Perfect foresight assumed in Everoze modelling for home consumption and solar PV generation.
iii) Minimum spread considered in the Everoze modelling.
iv) Bug in the real-world set-up for battery charging/discharging.

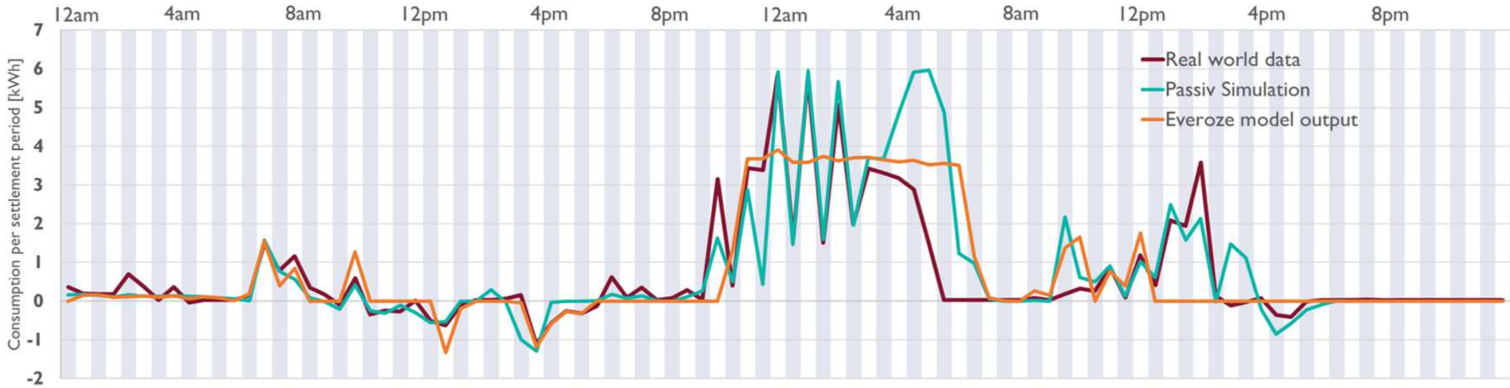
**SUMMER: Key differences attributed to**

i) Battery cycling to capture small changes in the tariff during the night.
ii) Uncertainty in the knowledge of actual EV state of charge prior to charging.

Winter scenario



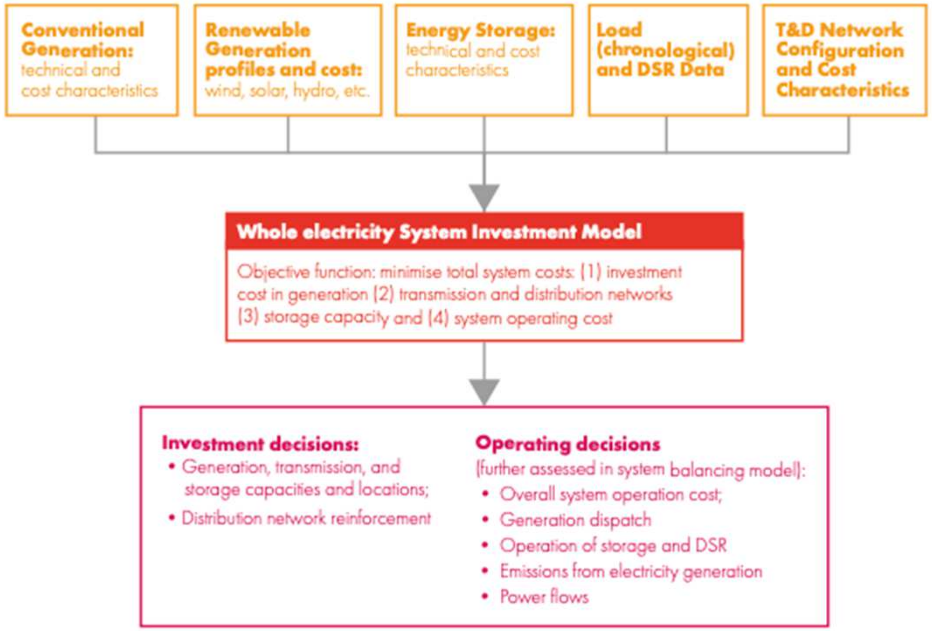

Summer scenario



# WHOLE-SYSTEM MODELLING FROM IMPERIAL COLLEGE

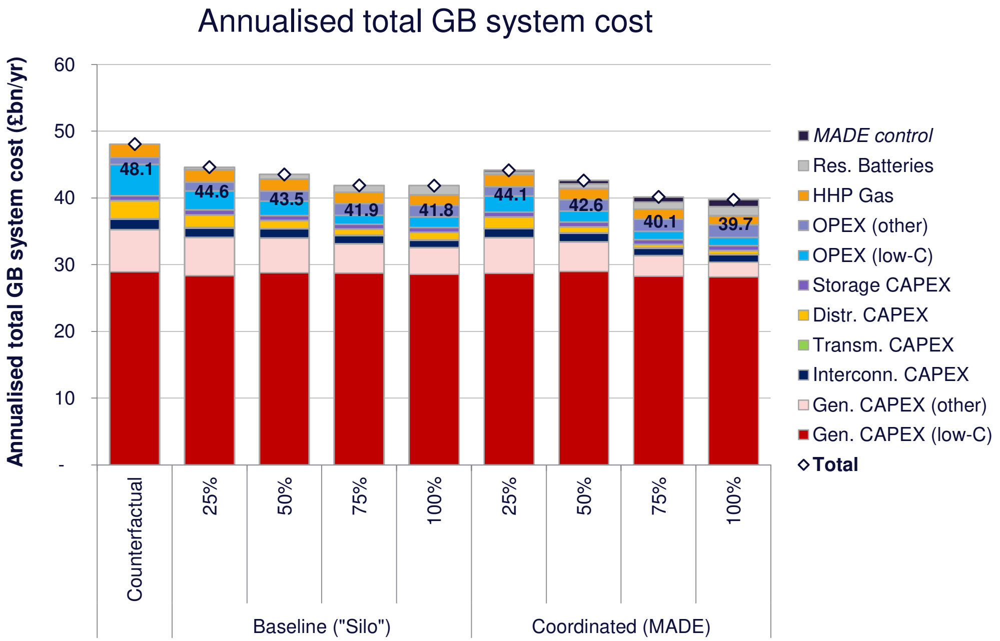
**Modelling assumptions:**

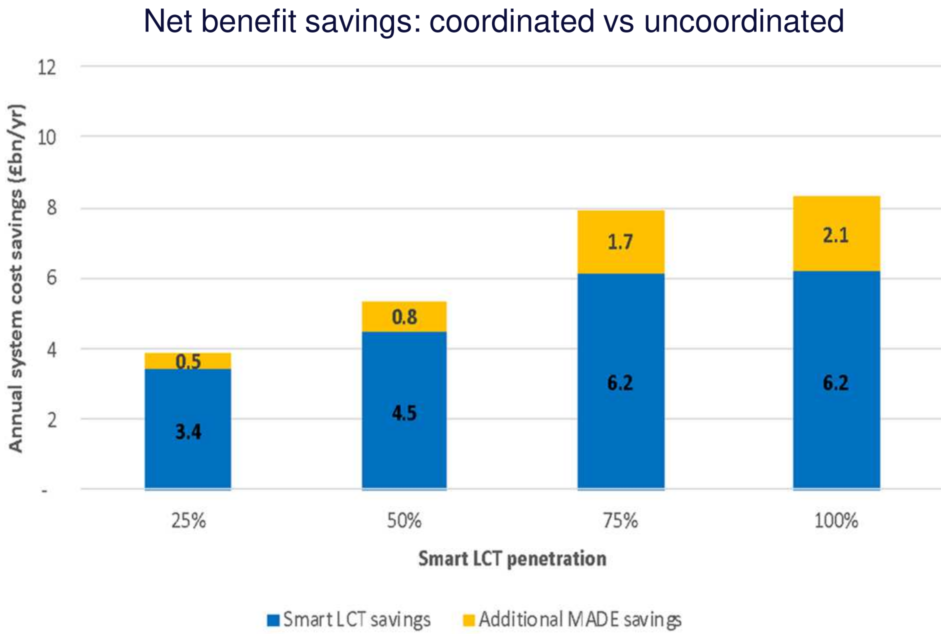
- 25%, 50%, 75% and 100% (relative to the number of eligible households);
- 14.748 million (of 28.535) detached, semi-detached houses and bungalows;
- Excludes terraced houses and flats;
- Total annual cost of MADE control: £70.1;
- A blend of renewables;
- Carbon capture;
- Hydrogen;
- Nuclear;
- 50 gCO2/kWh target;
- 20% population domestic flexibility.



# WHOLE-SYSTEM MODELLING: RESULTS

**The analysis by Imperial College has shown that there is significant potential for distributed flexibility to deliver whole-system cost savings with over £8.3bn/yr. net value provided in 2035.**

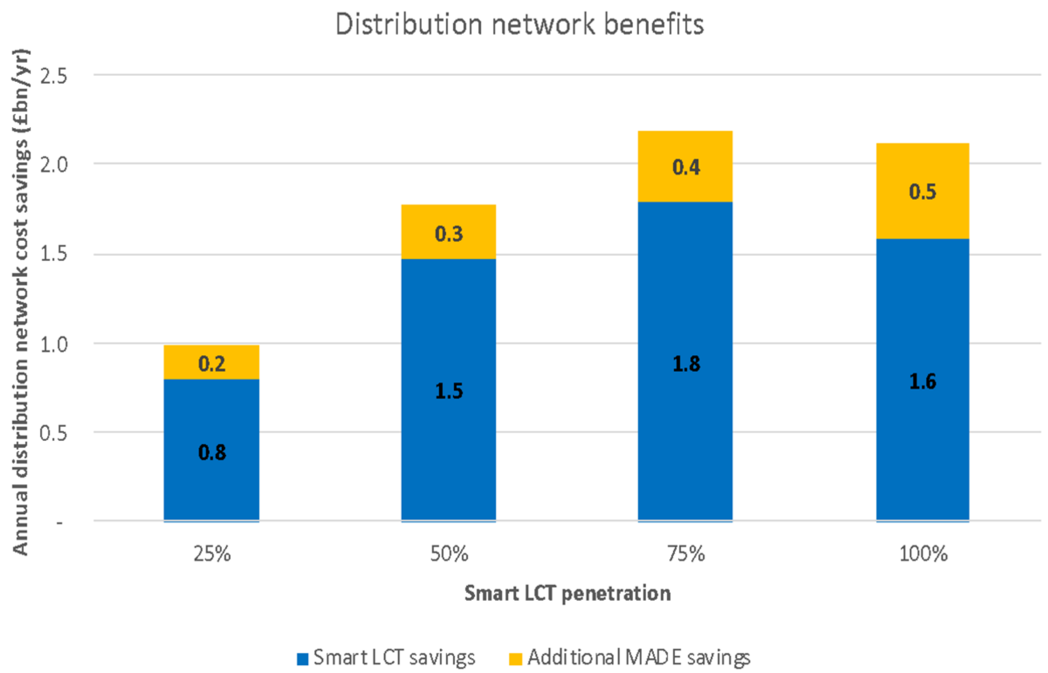


# LOCAL DISTRIBUTION BENEFITS RESULTS

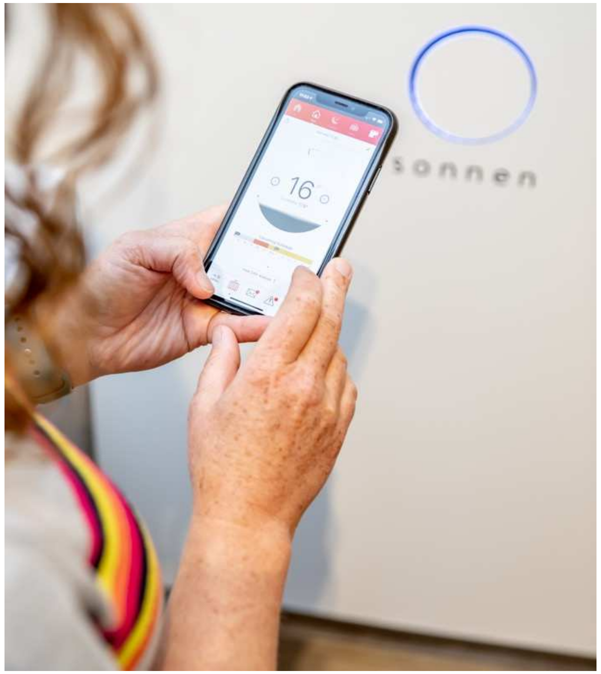
**Significant potential for distributed flexibility to deliver distribution network cost savings across different voltage levels and asset types, which can reach £200m to £500m of avoided annualised reinforcement cost in the longer term.**

Distribution net benefit savings: coordinated vs uncoordinated



# CUSTOMER PROPOSITION DEVELOPMENT

1. All inclusive
2. Buying enhanced control
3. Minimising peak demand



# CONCLUSION

**Aggregated, optimised low carbon technologies :**

- The greater the level of coordination between the low carbon technologies, the greater the savings in consumer electricity costs.
- Time-varying tariffs can offer significant running cost benefits to consumers with MADE assets, particularly where the battery and heat pump can be coordinated to store energy in the right balance between the battery and the thermal fabric of the building and making the right decisions about waiting for available PV generation.
- Even slight variations in tariff can introduce demand peaks, for example due to batteries delivering arbitrage.
- Smart controls can effectively deliver both Secure and Dynamic Flexible Power services using the MADE assets, by pre-charging both the battery and the home in advance of the availability window.

# CONCLUSION

**Consumer benefits from smartly coordinated LCTs**

- Coordinated control provides a notable value opportunity, of up to £260 per annum, per household.

**Local network benefits from aggregated, reactive LCTs**

- Analysis has shown that there is significant potential for distributed flexibility to deliver distribution network cost savings across different voltage levels and asset types, reaching £200m to £500m of avoided annualised reinforcement cost
- Distribution networks can utilise the MADE concept by limiting loads to 33% of the 14 kW fuse limit .
- The MADE concept offers material peak load shifting potential for the distribution network of between 35% and 40% reduction in peak loads on the network

## CONCLUSION

### Whole-system network benefits from peak load shifting

- Whole-system case studies run by Imperial College demonstrate that there are opportunities to deliver significant cost savings between £500m and £2.1bn per year.
- Imperial College quantified marginal system benefits per customer. As the system becomes more flexible the marginal value of more flexibility decreases. Near 100% penetration net benefits drop to close to zero.

# POLICY AND MARKET RECOMMENDATIONS

1. Further access to Time of Use Tariffs
2. LCT interoperability standards
3. Clear incentives for the adoption of LCTs
4. Clear economic and investable business models

## NEXT STEPS AND OPPORTUNITIES

**The MADE project has successfully achieved its core objectives. As we have gathered more learning about the feasibility of such controls a number of potential follow up opportunities have been identified.**

- Large scale trial of optimised LCTs and coordinated control.
- Exploring the potential of the next generation of heat pumps, storage heaters, V2G charge points.
- Leaving no customers behind.
- Improving our understanding of connected LCTs
- LCT forecast tool
- Review the connection process for domestic LCTs.
- Support Ofgem and BEIS market, regulatory and policy recommendations.

# QUESTIONS

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