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Modelling Results

Project MADE: Domestic FLEX Opportunity Assessment

FINAL

PassivSystems

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Project MADE: Modelling Results

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Prepared by	Nithin Rajavelu
Checked by	Bob Hodgetts
Approved by	Felicity Jones

This document has been prepared and is issued by Everoze Partners Limited to the named Client in accordance with the contract dated 11/04/2019, which governs how and by whom this report should be read and used.

Issues C, D and E are updates to the issue B (dated 9 October 2019) to include some additional work on validation of the model with real world data. The updates include the addition of Section 5 and associated updates to the table of contents and executive summary. No changes have been made to other sections of the report.

EXECUTIVE SUMMARY (1/4) – APPROACH

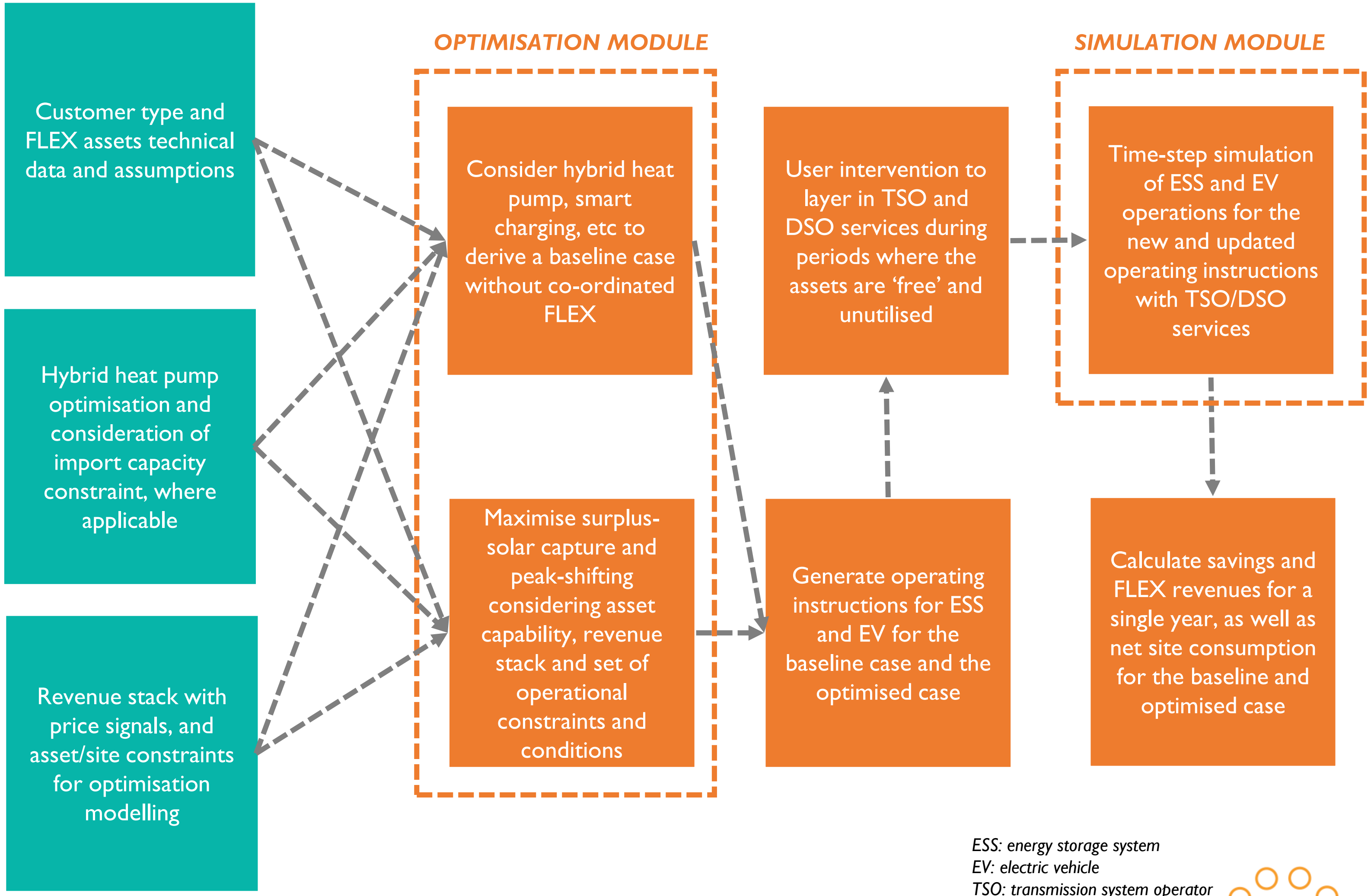
This report is a deliverable under the Multi-Asset Demand Execution (MADE) project. Everoze has undertaken techno-economic modelling to evaluate the benefits of multi-asset co-ordinated delivery of flexibility (FLEX) at an individual domestic property level.

Everoze's modelling evaluates seven customer types and electric vehicle use case combinations. Everoze's modelling is undertaken over a single year. Core data sources for delivering this modelling include empirical trials of domestic EV, domestic solar, and domestic hybrid heat pumps.

Multiple low carbon technologies are assumed to be within each home. These are:

- Solar PV
- Electric vehicle (EV) with bi-directional chargers
- Stationary storage
- Hybrid heating systems

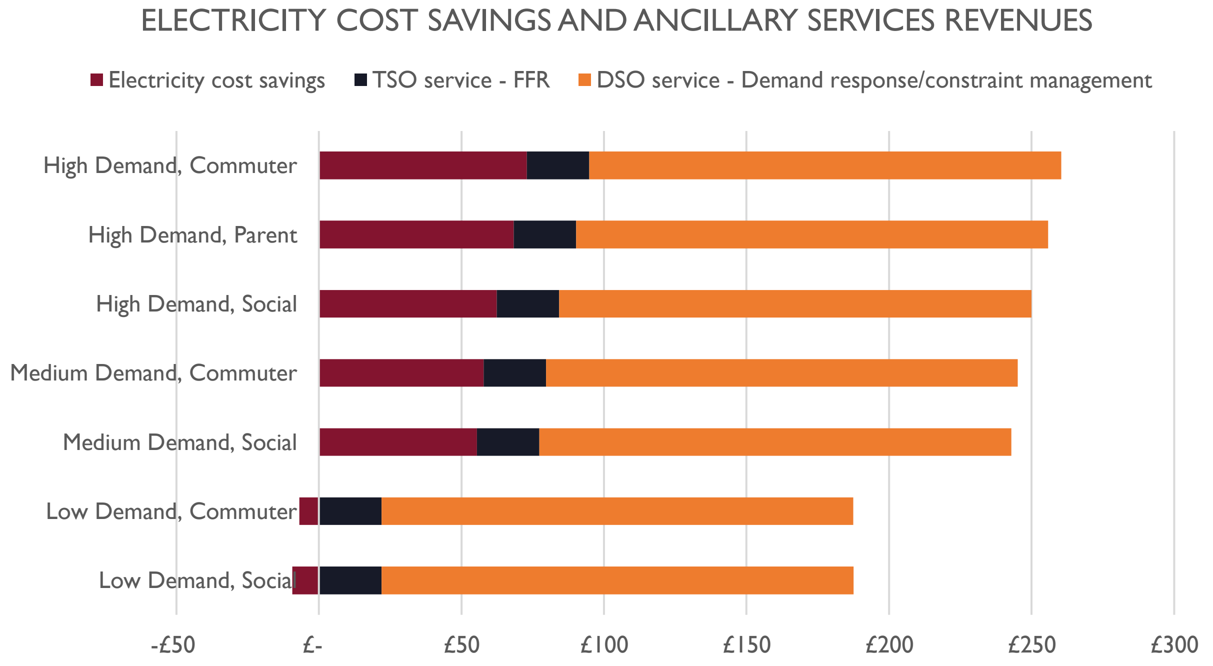
Everoze's model architecture is shown to the right.

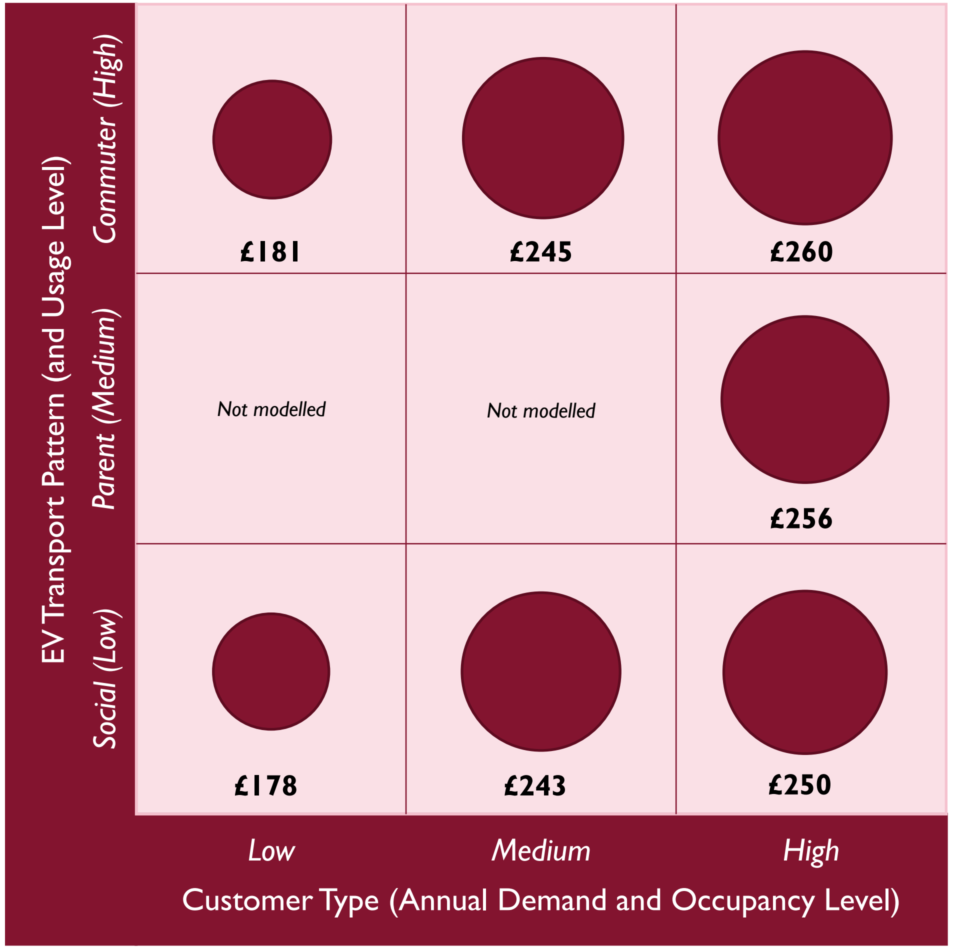


ESS: energy storage system
EV: electric vehicle
TSO: transmission system operator
DSO: distribution system operator

EXECUTIVE SUMMARY (2/4) – RESULTS

The estimated FLEX value (£/household/year) accrued under best conditions is shown in the two charts. Modelled benefits or 'value' from providing FLEX are calculated as the savings in electricity costs and revenues from ancillary services, less any cost of additional electricity imports. This excludes asset capital or operating costs and so 'value' as used in this report does not imply life-cycle value.





***The estimated values are based on a 'best conditions' assumption**: the property being located in an area of local network constraints where high value DSO services are available, as well as a 100% foresight assumption and 100% asset availability with no aggregation discounting considered. As such the results lie in the upper range of what may be achievable.*

The modelling considered a smart charging regime as a baseline and so the estimated benefits are not materially sensitive to EV transport patterns.

EXECUTIVE SUMMARY (3/4) – CONCLUSIONS

Key findings are as follows.

ELECTRICITY COST SAVINGS

- **Value from peak shifting is sensitive to consumer type:** Based on current wholesale cost profiles and network charges, savings from peak shifting is a smaller component of the overall value stack compared to ancillary services revenues. The property demand and consumption patterns, as well as surplus solar available at the property, have a high degree of sensitivity on cost savings that can be achieved.
- **Value from peak shifting is tempered by additional energy imports for ancillary services:** The additional energy cost for providing ancillary services has a material effect of reducing the savings in energy costs from peak shifting. In some cases this can be higher than the annual savings in energy costs.
- **Low demand/EV utilisation customer types are only attractive for DSO services:** The value opportunity from peak shifting and smart charging is low for customer types with low demand and low EV utilisation levels, and the value stack is heavily reliant on DSO services. For such customer types, if DSO service opportunities are not available, then there is little benefit from co-ordinated FLEX at the household level. Moreover, if the EV is available for most of the time during the evening peak period, then with the EV by itself performing peak-shifting, an ESS would not be needed for such Low Demand consumer types (unless DSO services are available and pursued).

ANCILLARY SERVICES

- **Value from DSO services can be lucrative but is extremely location sensitive:** DSO services form a key part of the value stack, but are subject to large variance in value depending the local network constraints and service need. WPD's SECURE service offers better value over the year compared to the DYNAMIC service; although the latter has a higher utilisation tariff, the likelihood of utilisation is lower. The right kind of DSO service opportunities appropriate for the domestic portfolio would need to be pursued. If otherwise, revenues from DSO services are not attractive.
- **Co-ordinated FLEX can help maximise value from DSO service opportunities:** A household or a portfolio being able to offer a higher volume with co-ordinated and combined FLEX from the suite of ESS and EV available would be able to maximise value.
- **FFR is a less attractive value proposition:** FFR is a small portion of the value stack, and so may not be worth pursuing given metering, testing and associated administration costs unless the entry requirements are streamlined.

MODEL VALIDATION Real world data recorded at homes using PassivSystems optimisation and coordinated control and PassivSystems simulations of those homes have been compared with Everoze modelling. The validation primarily covered the ability of the model to capture the usage and co-ordination of the heatpump, stationary storage and EV charging. The results demonstrated Everoze modelling captures the main trends well and the differences can be explained due to the known variation in the modelling approach. This also identifies potential areas of improvement for PassivSystems' simulation modelling and co-ordinated control solutions for real world applications.

EXECUTIVE SUMMARY (4/4) – CONCLUSIONS

ECONOMIC BENEFITS

[for ASSET OWNER, AGGREGATOR, PROPERTY OCCUPANT]

£260 p.a.

Domestic FLEX is a notable value opportunity – up to £260 p.a. per household may be possible under best conditions.

- **Select customers strategically:** There is significant variance in potential value from domestic FLEX across different customer type / EV use case combinations, with some customer types offering a higher value opportunity to maximise FLEX benefits over others. Targeting the right kind of consumers in the right postcode with the desired energy and EV use behaviour would be key to maximise value.
- **Small clustered portfolios:** Route-to-market for domestic DSR is expected to be through aggregation. Larger portfolios will need to be clustered into smaller subgroups (properties within a specific postcode) to target hyper-local DSO services.
- **Understanding local DSO service opportunities:** Constraint management and demand response service needs for the DSO varies across the network, and impact on DSO revenues is high if the right service opportunities are not pursued.
- **Early mover advantage:** Ongoing regulatory reform on network charges, and anticipated downward pressure on future DSO tariffs means an uncertain outlook on future revenues. Fast movers capitalising on the current opportunities available may benefit in the long run.

NETWORK BENEFITS

[for DSO]

35-40%

Domestic FLEX offers material peak load shifting potential for the DSO – between 35-40% reduction in peak loads on the network compared to the Baseline Case *(based on half-hourly data)*.

- **Incentivise optimisation of EV charging times:** Although the recent Department of Transport's EV Smart Charging consultation prescribes a default smart charging mode, this is not mandated for domestic charge-points and can be manually over-ridden. There is significant benefit to the network from optimising EV charging times and rates of charging, however, existing time-of-use network charges are not visible at the household level so don't provide a strong price signal to incentivise this behaviour, which is at risk of being weakened further through the ongoing network charging reforms.
- **Portfolio co-ordination approach delivers value:** Co-ordinated FLEX between LCT assets at a single property level is demonstrated to be able to provide value to the DSO through peak-load reduction and demand response for constraint management. There is however the risk of individual users optimising their consumption behaviour to the same price signals creating new peaks on the network. There is currently no price signal that incentivises portfolio co-ordinated FLEX to deliver network benefits. Co-ordinated FLEX at a portfolio level is one solution to deliver the desired outcome for the DSO.

CONTENTS

1 APPROACH

- Context
- Household definition
- Core approach
- Model architecture

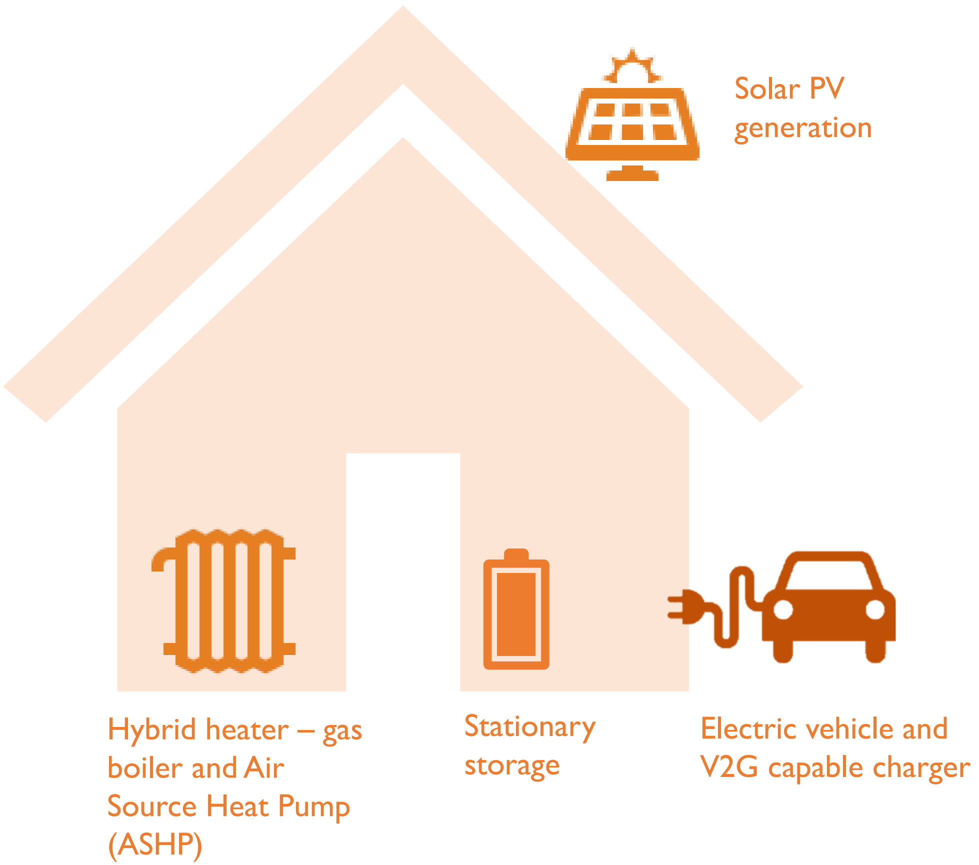
CONTEXT

Electrification of the heat and transport sector presents a significant challenge for Distribution System Operators (DSO) to accommodate disruptive demand technologies on the existing distribution network. Distributed hyper-local assets, including those available at a home-level, will be a key part of the solution to address these challenges.

Everoze has undertaken techno-economic modelling to evaluate the feasibility and benefits of multi-asset co-ordinated delivery of flexibility (FLEX) at a domestic property level. This work was completed as part of WPD's NIA-funded Multi-Asset Demand Execution (MADE) project.

Everoze's modelling focus is at a single residential property level, considering various flexible Low Carbon Technologies (LCTs) such as solar PV, electric vehicle (EV) with bi-directional chargers, stationary storage and hybrid heating systems. Modelling was completed for various property types and this report presents key findings from the feasibility assessment.

Everoze's modelling objective is to evaluate the economic benefits of providing FLEX at a residential property level. Delta-ee, one of the project participants retained by WPD and PassivSystems, shall be undertaking feeder-level modelling using outputs from Everoze modelling to evaluate the impacts on the network.



HOUSEHOLD DEFINITION (1/2) – CUSTOMER TYPES

A big driver of the multi-asset FLEX modelling outcome is the household type which drives the electrical and heating demand and consumption pattern, and associated factors such as property occupancy patterns, thermal efficiency of the property, EV use and transport pattern, and FLEX assets available at the property.

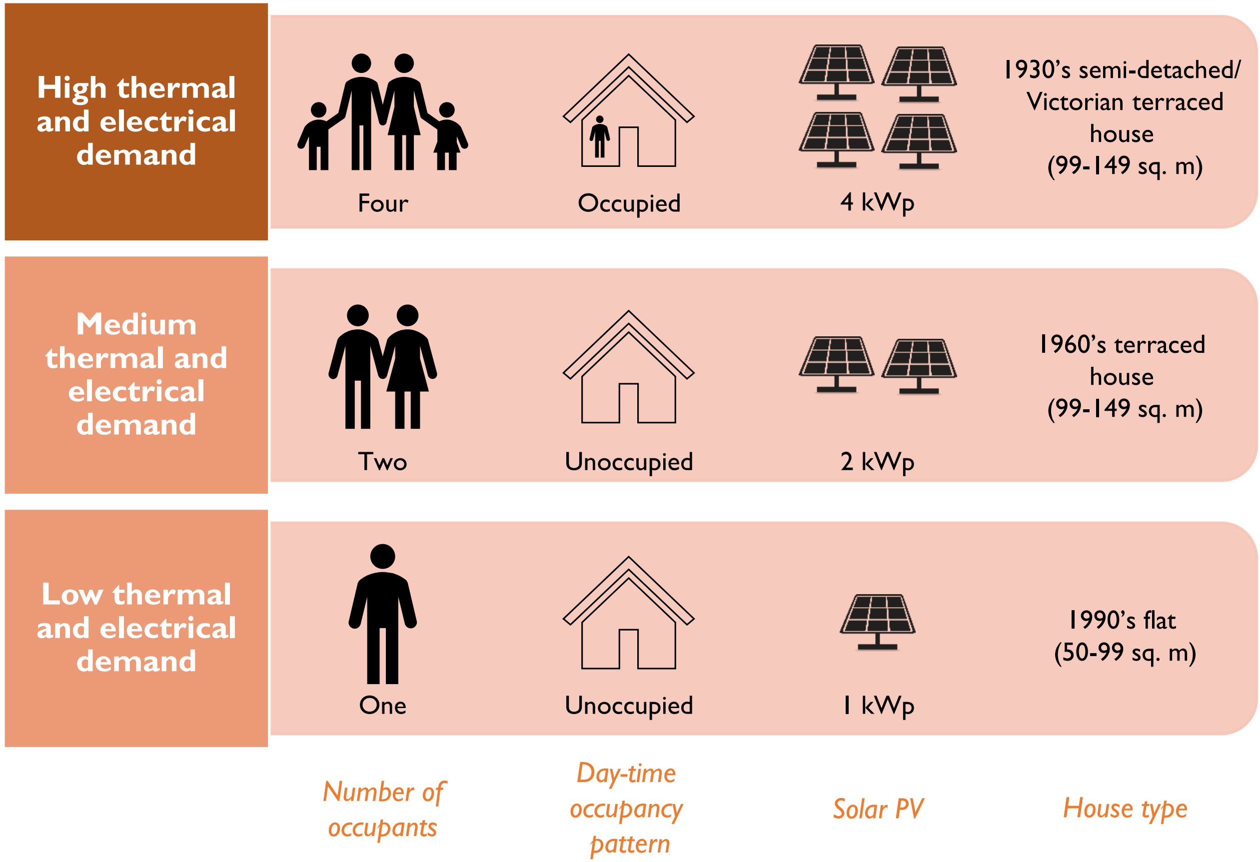
Although in the real world the combination of these factors can provide a large number of possible customer typology with various sub-types, for modelling purposes, a pragmatic set of representative customer types and EV transport patterns have been considered.

Following discussions with PassivSystems and Delta-ee, three base customer types defined by the type of property and household make-up have been considered[1]:

- High thermal and electrical demand – characterised by a 99-149 sq.m 1930's semi-detached or Victorian terraced house; household of four, two adults and two children
- Medium thermal and electrical demand – characterised by a 99-149 sq.m 1960's terraced house; household of two with no children
- Low thermal and electrical demand – characterised by a 50-99 sq.m flat constructed post-1990; single non-retired occupant

The age of the property (ie., thermal efficiency) and the day-time occupancy pattern have a large impact on the property's heating demand pattern as well as the non-heating electrical loads during the day.

The defined customer types provide a sample selection of customer types capturing variation in both the magnitude of demand (SCALE), as well as the timing of demand (SHAPE).



Low Carbon Future Assumption
Along with roof-top solar PV, all properties are assumed to have a hybrid heating system, a stationary storage asset and an EV with bi-directional charger

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1 – Delta-ee's Customer Segmentation note, May 2019

HOUSEHOLD DEFINITION (2/2) – EV TRANSPORT PATTERN

The Office for Low Emission Vehicles (OLEV) Electric Charge Point Analysis (2017 Domestics)[2] notes EV charging behaviour to be a mixture of shorter day-time charging and longer overnight charging. Although the data shows plug-in between 4-7pm and plug-out between 7-9am to be popular times for EV charging, there is greater variation of plug-in and plug-out times across the wider data set coupled with a large variation in energy drawn for EV charging.

Therefore, differences in EV transport and charging patterns will have a large bearing on the FLEX modelling outcome. To evaluate the relative scale of impact on the modelling outcome, three EV use cases and transport patterns with different intensity of EV use have been considered:

- Commuter use case with heavy EV usage – weekday commute to work, and weekend visits to friends and family
- Parent use case with moderate EV usage – parent with school runs in the morning with high-intensity social use multiple times during the day
- Social use case with occasional low-intensity EV use – three to four times a week (one to two evenings).

The base customer types and the EV transport patterns were used to inform the seven modelling cases considered by Everoze. These modelling cases provide a reasonable set of representative cases for Delta-ee to undertake its feeder-level modelling.

Property consumption data, heating pattern data, EV transport pattern data, etc were obtained from different sources and were matched to the customer types and modelling cases considered to inform the input data used in the modelling. The modelling assumptions and data sources are described further in Chapter 3.

		Commuter	Parent	Social
High thermal and electrical demand	Four	✓	✓	✓
Medium thermal and electrical demand	Two	✓	–	✓
Low thermal and electrical demand	One	✓	–	✓

The Parent EV use case is only used for the High demand customer type as that is the only customer type with children.

2 – *Department for Transport, Electrical Chargepoint Analysis 2017: Domestics, 13 December 2018*

CORE APPROACH (1/3) – LOW CARBON TECHNOLOGY ASSETS

For each of the seven modelling cases, the household is assumed to have a number of Low Carbon Technology (LCT) assets which can be controlled to provide FLEX. Other than the solar PV installed capacity, the same asset size and technical capability is used across the seven modelling cases.

The technical capability of the LCTs is interlaced with the relevant price signals to make an economic decision for providing FLEX. Although the mix of LCTs available at the property assumes a low carbon future, the price signals are based on current year levels.

It is envisioned that route-to-market is achieved through aggregation, with the LCTs at a residential level aggregated across a number of properties to form a portfolio of LCTs. Everoze has not considered possible regulatory barriers for domestic DSR as part of this work, and for modelling purposes, Everoze has assumed that provision of ancillary services using domestic DSR is possible from a regulatory perspective. In reality, an aggregator will take a portion of the revenue generated from providing FLEX. Everoze modelling is focused on estimating the total value achievable from providing FLEX and so, sharing of value between stakeholders is not considered. Also, Everoze has assumed no aggregator discounting of volumes in its modelling.

For modelling purposes, Everoze has assumed perfect forecasting accuracy in property consumption pattern, solar generation pattern and EV transport pattern. A more detailed record of assumptions on the LCTs and the price signals used in the modelling is included in Chapter 3.

'value' of FLEX: *Everoze modelling is undertaken over a single year and modelled benefits or 'value' from providing FLEX is calculated as the savings in electricity costs and revenues from ancillary services, less any cost of additional electricity imports. This does not include asset capital or operating costs and so 'value' as used in this report does not imply life-cycle value.*

ROOFTOP SOLAR PV

- 4, 2, or 1 kWp DC depending on customer type
- Same solar generation pattern across the seven modelling cases

HYBRID HEAT PUMP

- 2 kW air-source heat pump (AHSP) with a gas boiler
- Can switch between ASHP and the gas boiler to serve heating loads depending on which is cheaper

STATIONARY STORAGE (energy storage system – ESS)

- 10 kWh battery and 3.3 kW inverter
- Can perform peak-shifting using surplus solar or pre-charging during night-time to capture a targeted price spread

ELECTRIC VEHICLE

- 33 kWh battery and 7 kW bi-directional charger
- Can defer charging time and regulate charging power
- Can provide ancillary services when available/connected

CORE APPROACH (2/3) – DEFINITION OF BASELINE

MODELLING SCENARIOS

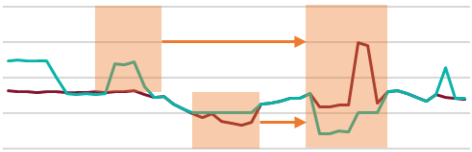
Two different modelling scenarios were considered for each customer type-EV use case combination:

1. **Baseline Case** which includes a selection of Low Carbon Technology assets with no coordinated FLEX provision
2. **Optimised Case** with the Low Carbon Technology assets operating in a coordinated manner (at a residential level) for FLEX provision.

	Solar	Heat pump	Battery	EV
BASELINE CASE	Included, installed kWp based on customer type	Included, ASHP loads optimised against price signals	Included, load-shifting using surplus solar	Included – unidirectional charger with smart charging
OPTIMISED CASE	Included, installed kWp based on customer type	Included, ASHP loads optimised against price signals	Included, load-shifting using surplus solar and pre-charging as well as ancillary service provision	Included – bidirectional charger with smart charging as well as V2H/V2G service provision

CORE APPROACH (3/3) – REVENUE OPPORTUNITIES

PEAK SHIFTING

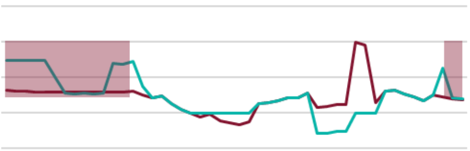


Surplus solar generation during the day is used to charge the ESS and EV (when available), which is then discharged during the evening peak demand period to reduce peak charges and reduce impact of peak-time loads on the network. If surplus solar generation is not sufficient to meet the evening peak demand volume, the ESS and EV pre-charge when the energy price is low (*e.g. night time*) to top-up the balance volume for peak shifting.

Value accrued from peak shifting is the spread between the peak-time charge (*Sell action*) and the cost of energy for charging the ESS/EV net of energy losses (*Buy action*). A target spread of £10p /kWh is assumed in the modelling – peak shifting is only performed for that day if the buy-sell spread is more than 10p/kWh.

If additional surplus solar over that needed for peak-time loads is available during the day, this is used by the ESS to shift loads during the off-peak hours. The aforementioned economic decision driver is not applied in this instance.

FIRM FREQUENCY RESPONSE (FFR)



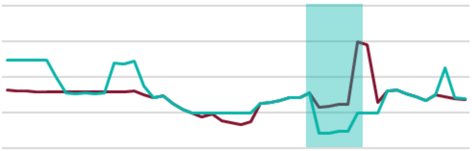
Night-time FFR for FFR availability windows 1 and 2 (11pm-7am) outside of summer months (May-Aug) is assumed as part of the revenue stack.

Weekly FFR auctions are considered in the modelling in line with the ongoing FFR auction trials; a success rate of 75% is assumed.

An FFR tariff of £5/MW/hour is assumed – this is based on the clearing prices in the recent weekly FFR auctions.

A 3 kW service volume is assumed. As noted previously, route-to-market is expected to be through aggregation to meet the minimum volume requirements.

DSO SERVICES



DSO services are procured by WPD to manage constraints caused by a variety of reasons across its network (*ie. overloads under peak demand conditions, overloads during summer outage season*).

The seasonal, day-of-week and time-of-day need for demand response required by WPD varies across its Constraint Management Zones (CMZs) depending on the needs of the local network, which also informs the type of service procured by the DSO. WPD currently procures two products across its CMZs:

1. SECURE – week-ahead notification of a scheduled demand turn-down or generation turn-up
2. DYNAMIC – week-ahead notification of availability to provide demand turn-down or generation turn-up, with a close to real-time notification to provide response

Given the local nature of DSO service requirements, it is not possible to make a generalised assumption on the service profile for use in the revenue stack. To accommodate the variability in network constraint and service need across WPD's South Wales DSO region, a few scenarios with different DSO service stacks have been considered in the modelling.

One of these scenarios is considered for the base modelling for the seven modelling cases, with the assumption that the property is located in a part of the network where the system need is represented by this scenario. The remaining scenarios are considered in the sensitivity analyses.

These scenarios and other modelling assumptions (tender success rate, tariff, service volume, etc) are described in Chapter 3.

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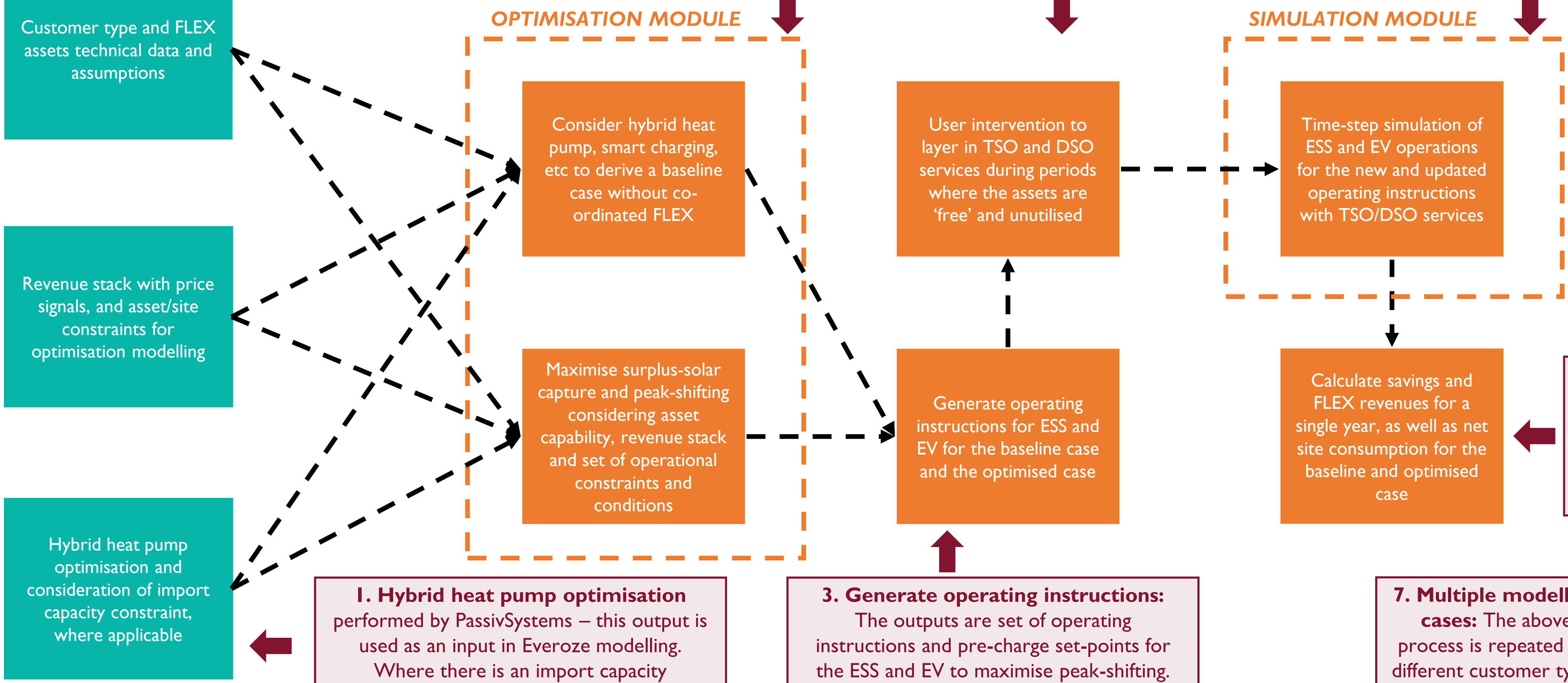
MODEL ARCHITECTURE (1/2) – OVERVIEW

2. ESS and EV optimisation to maximise surplus-solar capture with night-time pre-charging to discharge during evening peak period, taking into account the relevant price signals and targeted minimum spread, whilst considering smart-charging to minimise impact of EV charging on the network.

4. Set-up revenue stack: Outputs generated from the Optimisation Module are reviewed to consider different options for providing TSO/DSO services, considering timing of asset availability, EV transport pattern, as well as additional ESS/EV pre-charging or recharging needs.

5. Simulation modelling: The updated set of ESS and EV operating instructions are used to perform a time-step simulation for a full year, which also provides the net site consumption profile following delivery of FLEX.



6. Value accrual: The net savings in energy costs from peak-shifting as well as revenues from TSO and DSO services are calculated.

1. Hybrid heat pump optimisation performed by PassivSystems – this output is used as an input in Everoze modelling. Where there is an import capacity constraint, the ASHP loads are reduced to switch heat delivery over to the gas boiler.

3. Generate operating instructions: The outputs are set of operating instructions and pre-charge set-points for the ESS and EV to maximise peak-shifting. This also identifies when the ESS and EV are idle and free to perform other services.

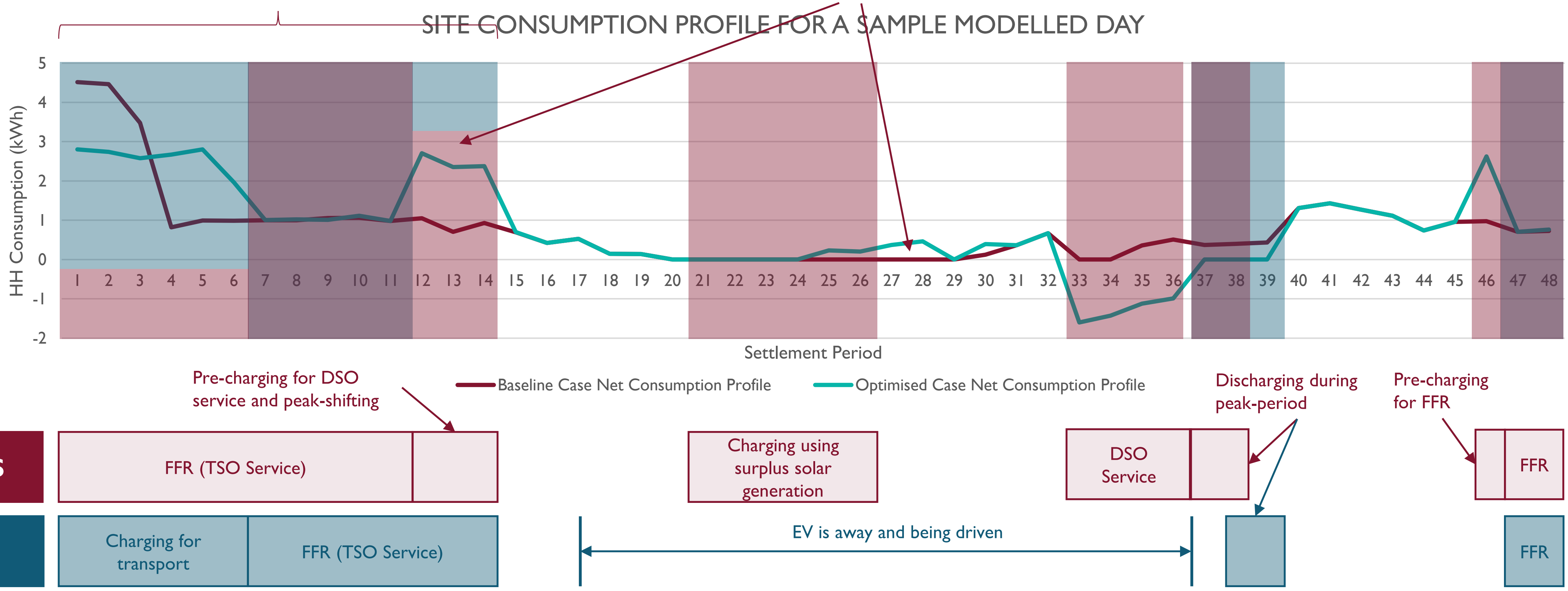
7. Multiple modelling cases: The above process is repeated for different customer types and modelling cases considered.

MODEL ARCHITECTURE (2/2) – ILLUSTRATION

From SP47 the previous day, ESS and EV are providing FFR in a co-ordinated manner by sharing the FFR delivery volume between each other. When either of the assets is otherwise occupied (such as EV being charged for transport and the ESS pre-charging), the other asset provides the full volume of FFR required.

The ESS charges using the surplus solar generation during the day which is used for providing FLEX (peak-shifting or DSO service). The ESS 'tops-up' any balance volume not met by the surplus solar by pre-charging ahead of time during the night and also limit off-peak hour load shifting to maximise FLEX delivery.

The ESS delivers the required DSO Service volume during the two-hour period from SP33 to SP36. When the EV returns at this time, the ESS and EV together discharge during the remainder of the peak-period to perform peak-shifting in a co-ordinated manner such that the site loads are zero during this period, The ESS runs out of charge during SP38 and the EV meets the remaining FLEX need for SP39 by itself

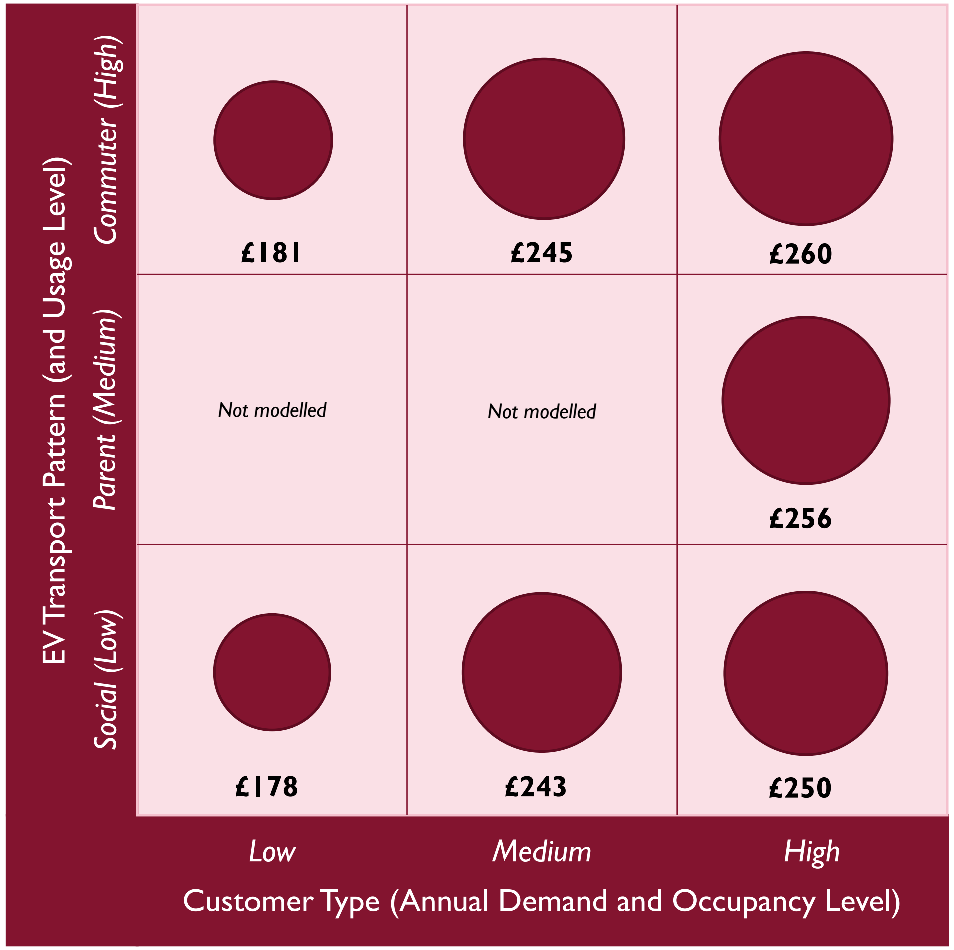


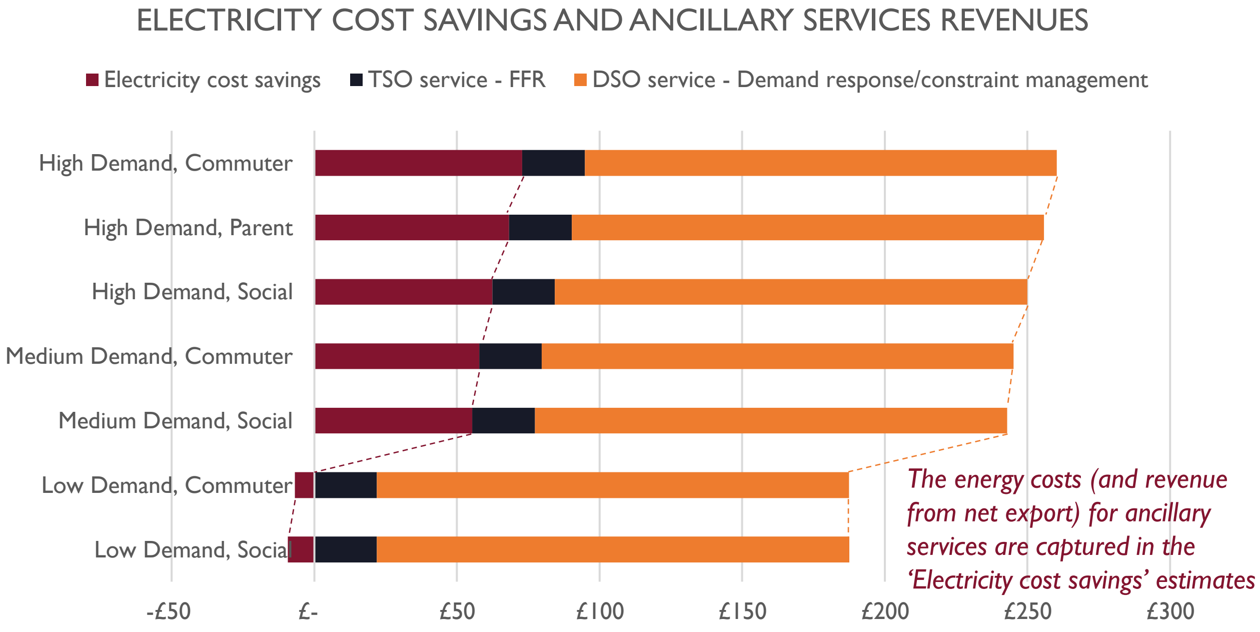
2 RESULTS

- Economics
- Load profiles
- Scenario modelling

ECONOMICS

The estimated FLEX value (£/household/year) accrued for the seven customer types and EV use case combinations is summarised here, including a breakdown of the value stack for each of the modelling cases.





ELECTRICITY COST SAVINGS

- Large variation in potential value in energy cost savings across the modelling cases – primarily driven by difference in evening peak-time consumption volume and surplus solar available at the property
- In the long-term, this component of the value stack is subject to regulatory reform (e.g., *Targeted Charging Review and Forward-looking Charges Review*)

ANCILLARY SERVICES

- DSO revenues form a key part of the value stack – there is a high degree of variability associated with these revenues (*depending on the type of service, temporal and special variation in system need and service requirement*) with no long-term revenue assurance.
- TSO revenues form a small proportion of the value stack

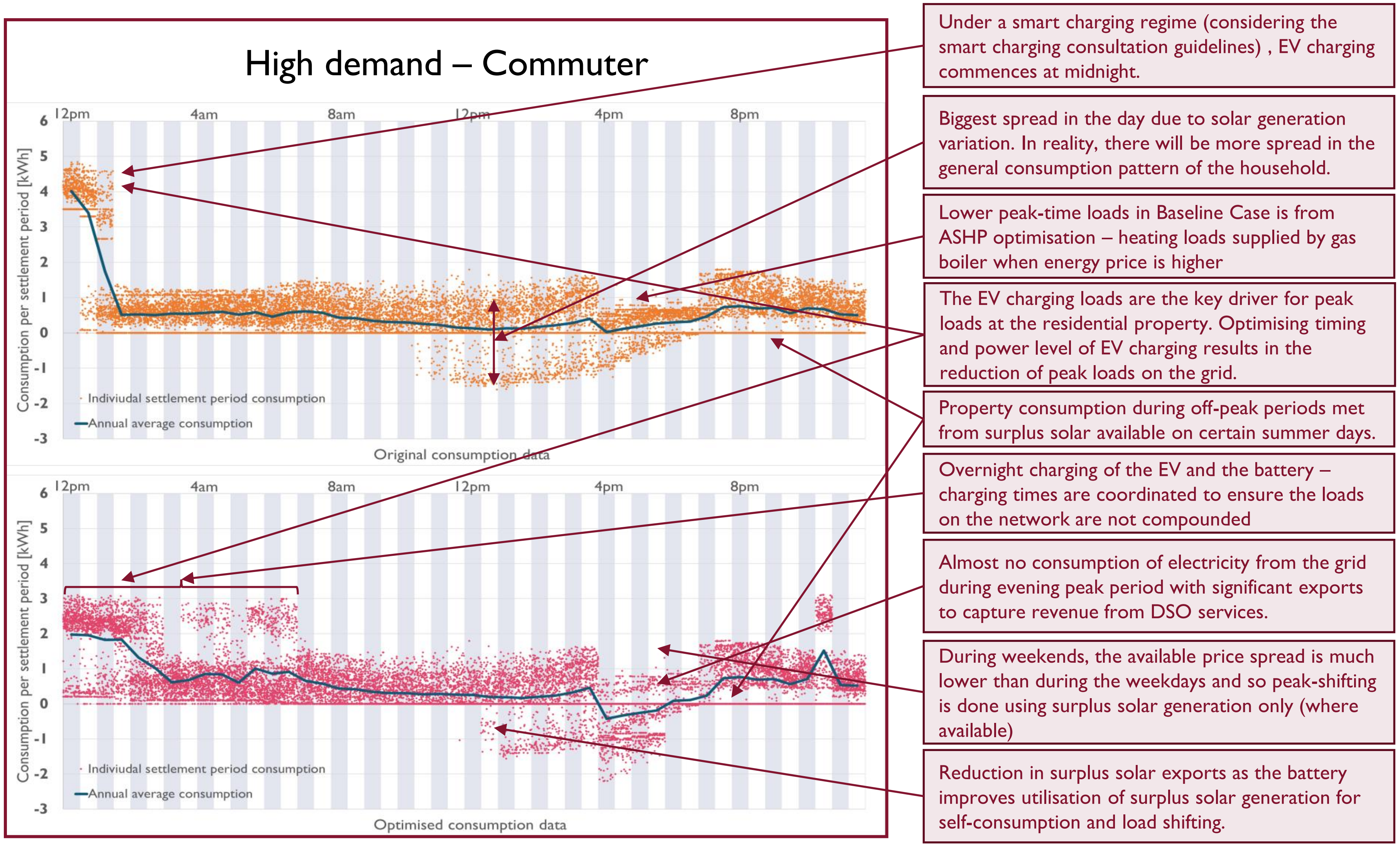
LOAD PROFILES (1/4)

The graphs present the net consumption data for each modelling case. There are two graphs per modelling case – the Baseline Case and the Optimised Case.

The individual data points represent all the 30-minute settlement periods over the year modelled. Plotting the individual data points together with the annual average profile demonstrates the upper and lower limits of consumption in a settlement period as well as the spread of data points between the limits. Negative data points indicate when the property is a net exporter of electricity for that settlement period (attributable to solar generation exceeding the consumption needs of the household or where the battery and/or EV are providing ancillary services).

The input profiles were characterised by 24 usage consumption profiles (two per month – one for weekdays and another for weekend days). The variation from day to day is driven by the source data used for the solar generation and heating demand.

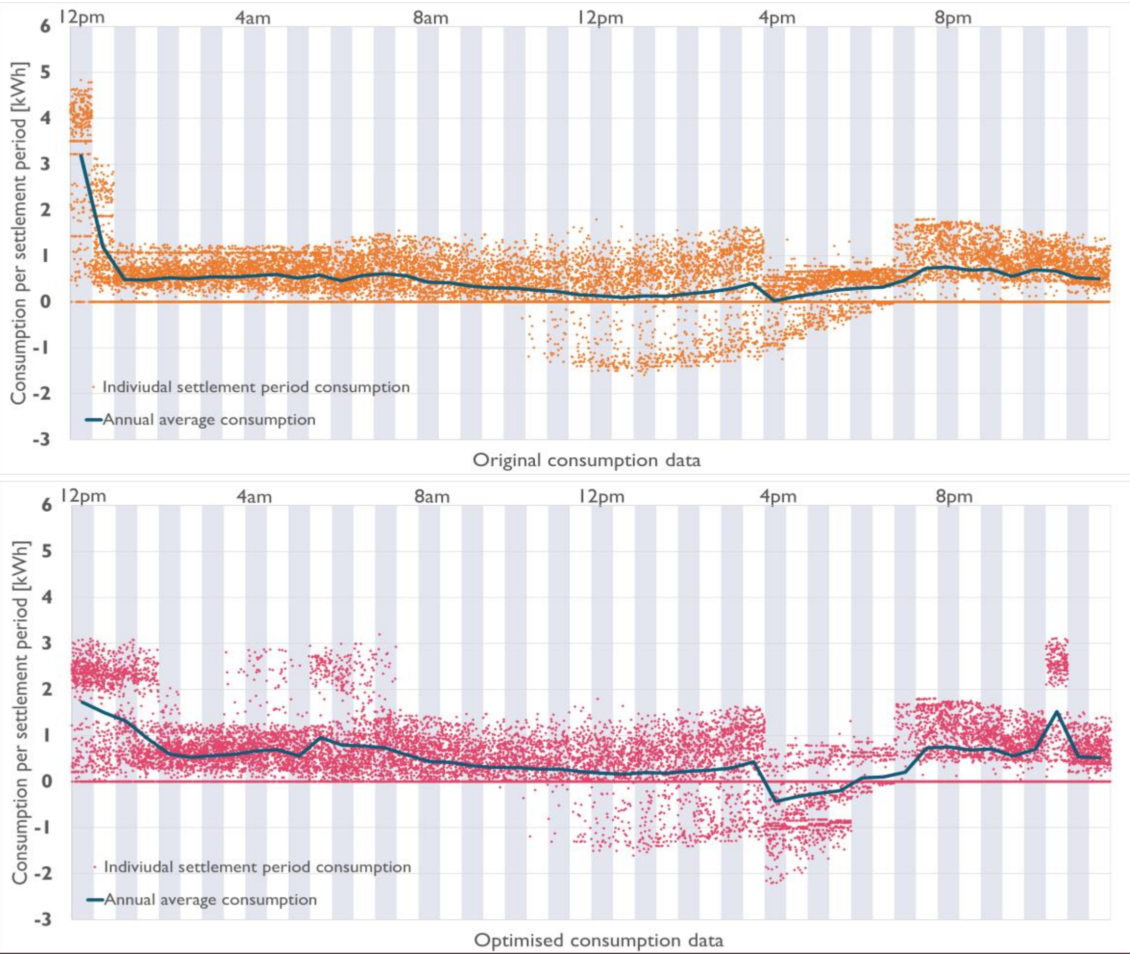
The source data is described further in Chapter 3.



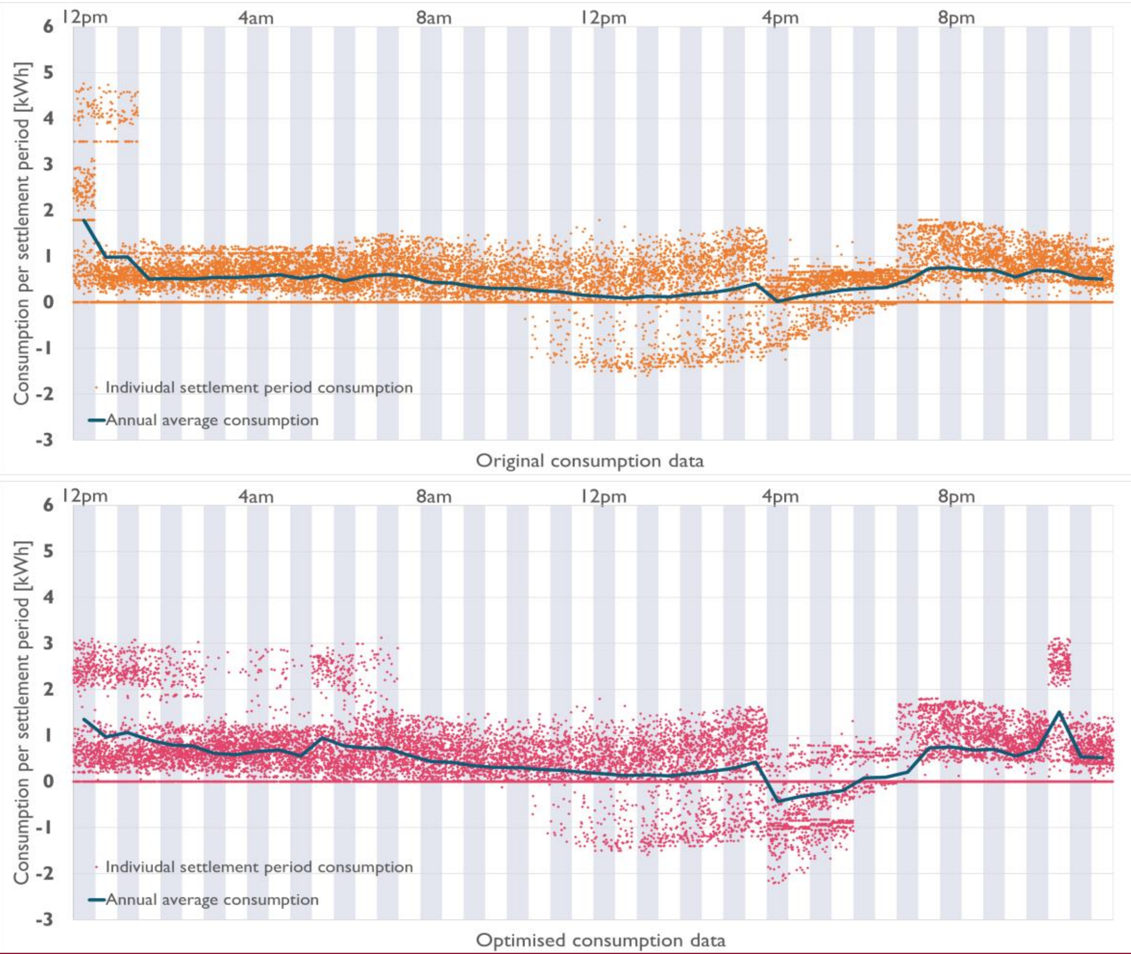
Note on the graph data: The individual settlement period consumption values are randomly spread across the settlement period they fall in so the data appear more spread in the horizontal axis than in reality. This has been done to provide a better visualisation of the data so they are not all aligned in narrow lines in the middle of the settlement period.

LOAD PROFILES (2/4)

High demand – Parent



High demand – Social



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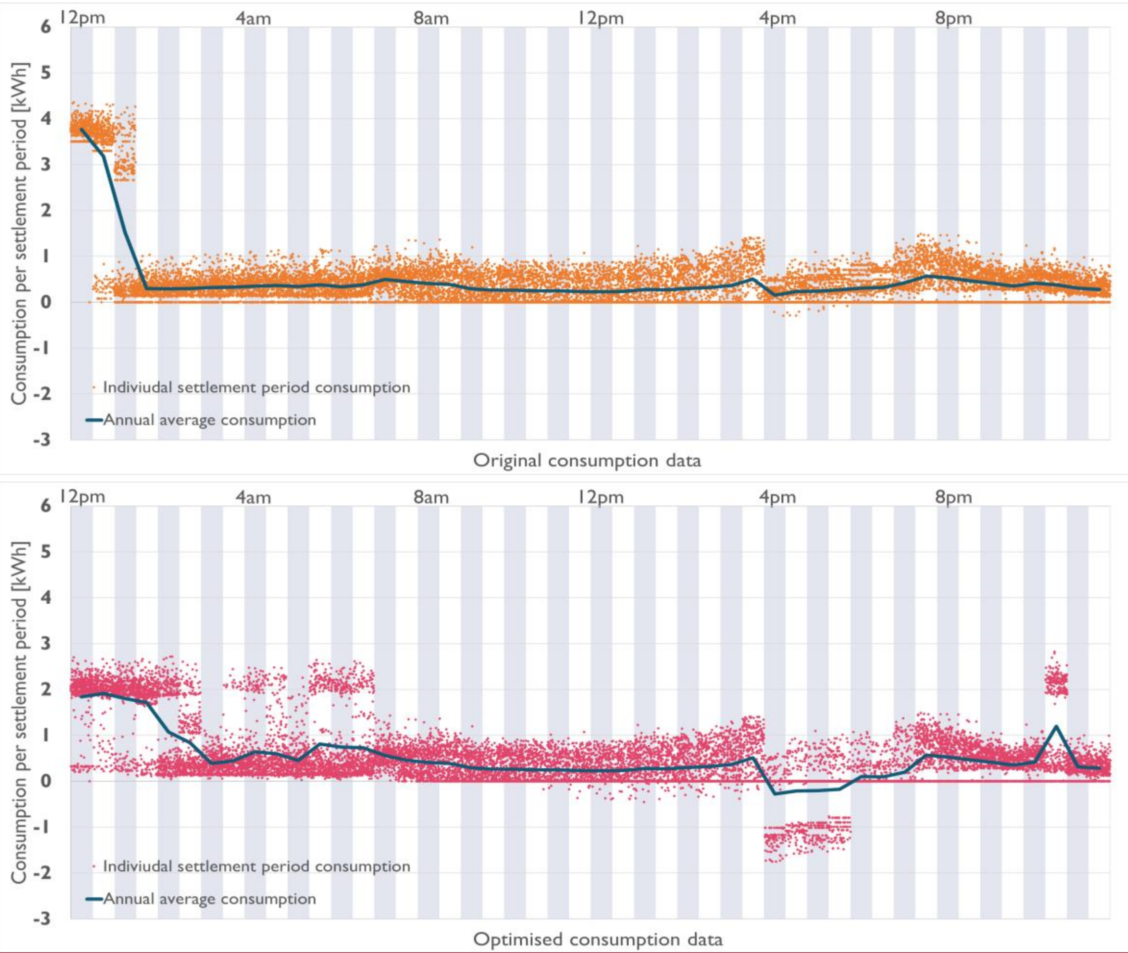
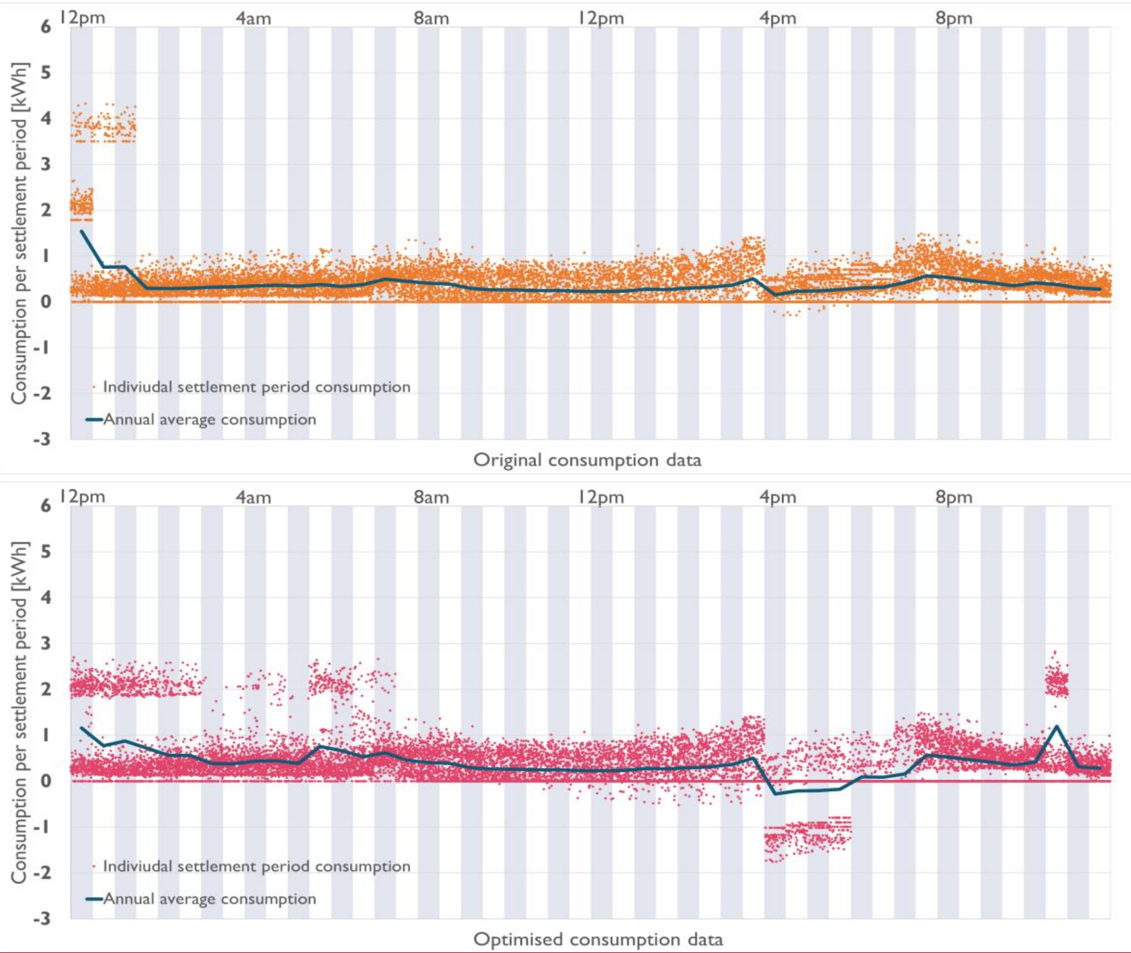
LOAD PROFILES (3/4)

Medium demand – Commuter

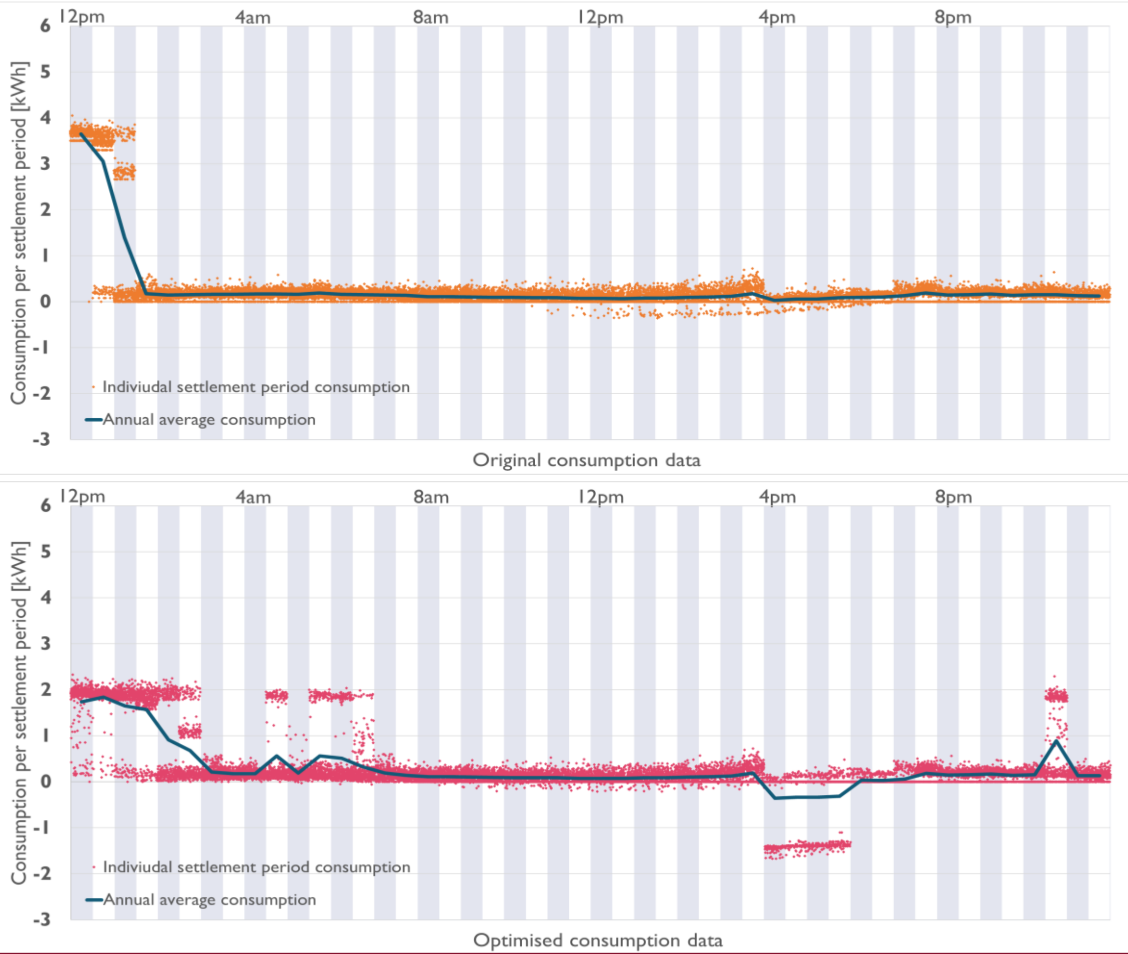


Medium demand – Social

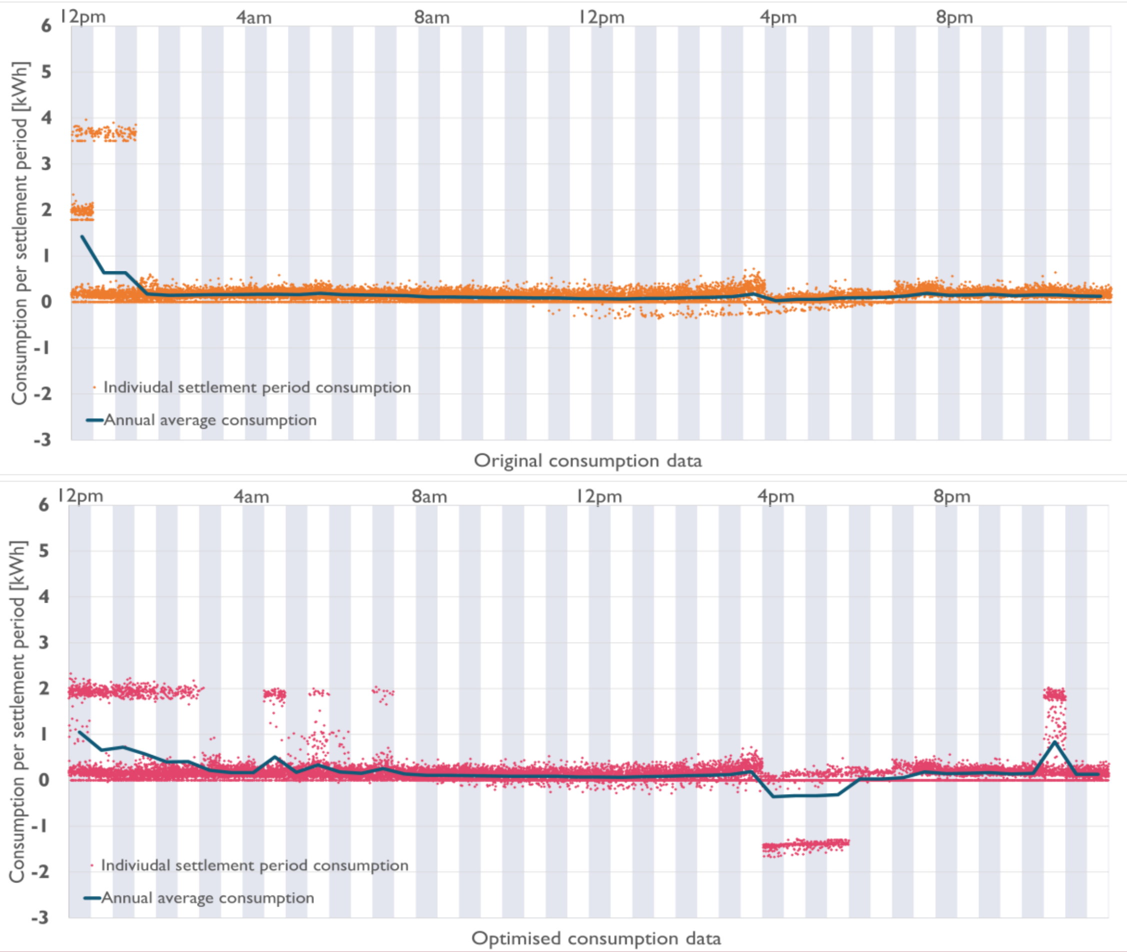


LOAD PROFILES (4/4)

Low demand – Commuter



Low demand – Social



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SCENARIO MODELLING RESULTS – GENERAL (1/2)

The seven modelling cases considered in the feasibility assessment provide a snapshot across a broad variety of customer types. The LCTs, the revenue stack and other inputs considered in the modelling have been assumed to be consistent across the seven modelling cases to present a consistent base for comparison between the modelling cases.

Modelling has been completed for a number of alternative input combinations to test for sensitivity of various factors on the estimated value accrued. The tables presented here show the various sensitivity scenarios considered, with the impact on the modelled value of FLEX (annual energy cost savings plus revenues from TSO and DSO services) shown in percentage. The reference case considered is the High Demand customer type with the Commuter EV use case.

Case 1: ESS energy capacity *(compared to 10 kWh)*		
Change	**Impact**	**Comments**
5 kWh	-26%	ESS is undersized for the DSO service stack considered in the reference case. EV is not always available during the DSO service period for this EV transport pattern and so does not compensate for the ESS's shortfall in service delivery
6.75 kWh	-12%	ESS is sized minimally to cover the 2-hour service delivery requirement for DSO services. The ESS is not large enough to meet the rest of the peak-time loads during days when DSO services are delivered.
7.5 kWh	-7%	The ESS is not large enough to fully meet the peak-time loads during days when DSO services are delivered.
12.5 kWh	+1%	No notable benefit of having a larger energy capacity for the ESS.
15 kWh	+2%	
Expected impact on other modelled cases		*Impact expected to be reduced for EV transport patterns where the EV is available during peak-time / DSO service delivery*

Case 2: Property import / export limit *(compared to 14 kW)*		
Change	**Impact**	**Comments**
10 kW	0%	No change from reference case
5 kW	-1%	Site peak loads limited to 5 kW (22% less than the reference case) whilst maintaining similar levels of value compared to the reference case on annual savings
Expected impact on other modelled cases		*Similar*

Case 3: No ancillary services		
Change	**Impact**	**Comments**
ESS and EV perform peak-shifting only	-59%	DSO revenues are a big part of the value stack and so revenues are significantly affected
Expected impact on other modelled cases		*Higher where value in peak-shifting is lower*

SCENARIO MODELLING RESULTS – GENERAL (2/2)

Case 4: No V2G/V2H for EV – EV is operated to a smart charging regime		
Change	**Impact**	**Comments**
ESS performs peak-shifting and provides TSO/DSO services	-1%	Fewer FFR availability periods due to EV not providing this service when the ESS is otherwise occupied (ie., pre-charging during the night). FFR revenues are a small proportion of total value and so impact is minor. Also, impact is tempered as EV does not play a big role in provision of DSO services for this EV use case/transport pattern.
Expected impact on other modelled cases		*Higher for a larger DSO service volume where this is possible*

Case 5: No ESS in the house		
Change	**Impact**	**Comments**
EV performs peak-shifting and provides TSO/DSO services	-81%	Significant drop in value as vast majority of value for this Customer type-EV use case combination is accrued by the ESS. Also difference between these two scenarios is minor as EV has little role in providing DSO services for this EV use case and the value from FFR services is low.
No ancillary services for EV, only peak-shifting	-85%	
Expected impact on other modelled cases		*Reduced for EV transport patterns where EV is available during peak-time / DSO service periods*

Case 6: Unmanaged 'dumb' charging regime for the EV		
Change	**Impact**	**Comments**
The baseline reference is the EV operated to an unmanaged charging regime	+97%	Energy bill savings is significantly improved if the baseline reference is unmanaged EV charging – this illustrates that there is significant value from managing EV charging times as has been demonstrated through other innovation projects and trials
Expected impact on other modelled cases		*Higher where value in peak-shifting is lower, varies depending on EV transport and charging pattern*

Case 7: Varying network charges		
Change	**Impact**	**Comments**
West Midlands DUoS/TNUoS charges (low charges)	-2%	Lower savings in electricity costs from lower DUoS charges marginally offset by lower energy costs for ancillary services. Electricity cost savings is ~8% less than the reference case.
South West DUoS/TNUoS charges (high charges)	+5%	Higher savings in electricity costs from higher DUoS and TNUoS charges for the South West DNO zone. Electricity cost savings are ~19% higher than the ref. case
DUoS charges reform – charges reduced by 1.254p per kWh[1]	+2%	Negligible effect as the differential in green/amber/red zone charges is still the same. Minor positive as energy cost of round-trip efficiency losses are lower
No CM supplier charges in import tariff	-9%	Lower savings expected if CM supplier charges are no longer charged on winter evening peak-time consumption
Expected impact on other modelled cases		*Broadly similar level of impact on electricity costs expected, however the percent-level impact on overall value is expected to be lower*

1 – Demand residual component in WPD South Wales DUoS charges for 2020/21. A reduction of 1.343p per kWh (2019/20 charges) is assumed for the months of Jan-Mar

SCENARIO MODELLING RESULTS – DSO SERVICES

As noted previously, there is a high degree of variability in DSO revenues depending on the type of service, temporal and special variation in system need and service requirement. A number of DSO service stack definitions have been developed considering various scenarios for system need. One of these nine DSO service stacks has been used in the base modelling for the seven modelling cases. The remaining eight DSO service stacks, as well as other factors impacting the estimated value, have been modelled against a reference case to test for sensitivity on the DSO revenues.

The tables presented here show the various sensitivity scenarios considered, with the impact on the modelled value of FLEX (from DSO services excluding annual energy cost savings and TSO services) shown in percentage. The reference case considered is the High Demand customer type with the Social EV use case – this use case has the least EV utilisation level for transport needs.

Case 8: Contract service volume *(compared to 3 kW)*

Change	Impact	Comments
5 kW	+67%	Higher energy costs and so the annual energy cost savings will be lower than the reference case
7.5 kW	+150%	Annual energy cost is higher than the baseline case due to increased energy imports to meet DSO service needs

Case 9: Weekly tender success probability *(compared to 75%)*

Change	Impact	Comments
50% success probability	-33%	As DSO service subscription increases, this has an impact on likelihood of being able to secure a DSO service contract
25% success probability	-67%	

Case 10: Service tariff

Change	Impact	Comments
50% reduction	-50%	As market liquidity improves, a competitive procurement framework will be implemented which will have a downward pressure on the tariffs

Case 11: Days of week for service need *(compared to 5 weekdays only)*

Change	Impact	Comments
3 days (M/T/W) or (T/W/F)	-40%	Days of week for which demand response service is needed varies across CMZs and also changes depending on the month/season
7 days (incl. wknds)	+40%	

Case 12: Alternative DSO service stacks[1] *(compared to SECURE (W) Profile 1 'Narrow')*

Change	Impact	Comments
SECURE Profile 1 'Narrow' - Summer and Winter - Summer only	 +113%[2] +7%[2]	Equal amount of DSO service revenues from Summer and Winter season for service stack assumed. Depending on seasonal changes in property consumption patterns and EV transport patterns, a seasonal revenue strategy could be employed to optimise value accrual
DYNAMIC Profile 1 'Narrow' - Summer and Winter - Summer only - Winter only	 +77% -11% -17%	Although the utilisation payments for the DYNAMIC service is higher than the tariff (availability + utilisation) for the SECURE service over a single day, due to likelihood of EV of not being dispatched on some days, overall the SECURE service is more lucrative than the DYNAMIC service for a similar service profile
DYNAMIC Profile 1 'Wide' - Summer and Winter - Summer only - Winter only	 -70% -94% -80%	20% utilisation probability resulting in low utilisation payments. Also, the availability tariff for the DYNAMIC service (for the low utilisation probability) is not high enough to incentivise pursuing this service stack

1 – S – Summer season; W – Winter season   *2 – Seasonal difference in modelling results is from how DSO service weeks overlapping months are treated in the modelling*

3 CONCLUSIONS

- Findings
- Recommendations
- Further research

FINDINGS

ELECTRICITY COST SAVINGS

- **Value from peak shifting is sensitive to consumer type:** Based on current wholesale cost profiles and network charges, savings from peak shifting is a smaller component of the overall value stack compared to ancillary services revenues. The property demand and consumption patterns, as well as surplus solar available at the property, have a high degree of sensitivity on cost savings that can be achieved.
- **Value from peak shifting tempered by additional energy imports for ancillary services:** The additional energy cost for providing ancillary services has a material effect of reducing the savings in energy costs from peak shifting. In some cases this can be higher than the annual savings in energy costs.
- **Low demand/EV utilisation customer types are only attractive for DSO services:** The value opportunity from peak shifting and smart charging is low for customer types with low demand and low EV utilisation levels, and the value stack is heavily reliant on DSO services. For such customer types, if DSO service opportunities are not available, then there is little benefit from co-ordinated FLEX at the household level. Moreover, if the EV is available for most of the time during the evening peak period, then with the EV by itself performing peak-shifting, an ESS would not be needed for such Low Demand consumer types (unless DSO services are available and pursued).

LOAD REDUCTION AT HOUSEHOLD LEVEL

- **Large untapped benefit to the DSO from domestic FLEX:** Loads can be limited to ~33% of the 14 kW fuse limit at a property level without compromising household consumption behaviour and savings that can be achieved (based on half-hourly average loads). There is a notable potential for using residential consumers to manage peak loads on the network.

ANCILLARY SERVICES

- **Value from DSO services can be lucrative but is extremely location sensitive:** DSO services form a key part of the value stack, but are subject to large variance in value depending the local network constraints and service need. WPD's SECURE service offers better value over the year compared to the DYNAMIC service; although the latter has a higher utilisation tariff, the likelihood of utilisation is lower. The right kind of DSO service opportunities appropriate for the domestic portfolio would need to be pursued. If otherwise, revenues from DSO services are not attractive.
- **Co-ordinated FLEX can help maximise value from DSO service opportunities:** A household or a portfolio being able to offer a higher volume with co-ordinated and combined FLEX from the suite of ESS and EV available would be able to maximise value.
- **FFR is a less attractive value proposition:** FFR is a small portion of the value stack, and so may not be worth pursuing given metering, testing and associated administration costs unless the entry requirements are streamlined.

BATTERY SIZING

- **Not more than 3 hour energy capacity duration:** A battery with energy capacity duration longer than ~3 hours does not offer any notable increased benefit for domestic FLEX at the property level (unless a service duration longer than 2 hours is sought by the DSO).
- **Optimise battery energy capacity to reduce CAPEX:** A battery with a smaller energy capacity duration can be used if EV utilisation is low and is available more often during times when FLEX is provided (peak-shifting and DSO services).
- **Inverter power driven by ancillary service volume:** The DSO service volume that can be offered is a key driver for selecting the power rating of the battery inverter beyond the minimum level required for peak-shifting.

RECOMMENDATIONS

ECONOMIC BENEFITS

[for ASSET OWNER, AGGREGATOR, PROPERTY OCCUPANT]

£260 p.a.

Domestic FLEX is a notable value opportunity – up to £260 p.a. per household may be possible under best conditions.

- **Select customers strategically:** There is significant variance in potential value from domestic FLEX across different customer type / EV use case combinations, with some customer types offering a higher value opportunity to maximise FLEX benefits over others. Targeting the right kind of consumers in the right postcode with the desired energy and EV use behaviour would be key to maximise value.
- **Small clustered portfolios:** Route-to-market for domestic DSR is expected to be through aggregation. Larger portfolios will need to be clustered into smaller subgroups (properties within a specific postcode) to target hyper-local DSO services.
- **Understanding local DSO service opportunities:** Constraint management and demand response service needs for the DSO varies across the network, and impact on DSO revenues is high if the right service opportunities are not pursued.
- **Early mover advantage:** Ongoing regulatory reform on network charges, and anticipated downward pressure on future DSO tariffs means an uncertain outlook on future revenues. Fast movers capitalising on the current opportunities available will benefit in the long run.

NETWORK BENEFITS

[for DSO]

35-40%

Domestic FLEX offers material peak load shifting potential for the DSO – between 35-40% reduction in peak loads on the network compared to the Baseline Case *(based on half-hourly data)*.

- **Incentivise optimisation of EV charging times:** Although the recent Department of Transport's EV Smart Charging consultation prescribes a default smart charging mode, this is not mandated for domestic charge-points and can be manually over-ridden. There is significant benefit to the network from optimising EV charging times and rates of charging, however, existing time-of-use network charges are not visible at the household level so don't provide a strong price signal to incentivise this behaviour, which is at risk of being weakened further through the ongoing network charging reforms.
- **Portfolio co-ordination approach delivers value:** Co-ordinated FLEX between LCT assets at a single property level is demonstrated to be able to provide value to the DSO through peak-load reduction and demand response for constraint management. There is however the risk of individual users optimising their consumption behaviour to the same price signals creating new peaks on the network. There is currently no price signal that incentivises portfolio co-ordinated FLEX to deliver network benefits. Co-ordinated FLEX at a portfolio level is one solution to deliver the desired outcome for the DSO.

FURTHER RESEARCH

The technoeconomic modelling suggests a need for subsequent research/action in the following areas.

1. **Develop model to adopt stochastic portfolio view.** Everoze's approach under the MADE project has been to model value at an individual household level. The next step is to adopt a probabilistic portfolio approach to ensure optimal asset dispatch and manage uncertainties.

2. **Validate and elaborate model through real world trials.** The model should be refined, developed and challenged based on empirical data from trials of households with multi-LCT systems installed. For instance, it would be important to probe energy service and mobility requirements in greater detail.

3. **Ensure real life trial collates higher resolution temporal data:** Current modelling is based on half-hourly metered data. This averaging has the effect of dampening short-duration peaks within the half-hourly period. It is recommended to secure meter data at a more granular temporal resolution to reach a more accurate view on the extent to which domestic FLEX can reduce peak loads on the network.

4. **Develop model to assess project internal rate of return (IRR) not just value.** Everoze's approach has excluded asset capital or operating costs and so 'value' as used in this report does not imply life-cycle value. The next recommended step is to create a rounded economic perspective inclusive of capex and all opex. This will then determine the overall economic viability of domestic flex to provide DSO and other services.

5. **Streamline TSO requirements to ensure participation is worthwhile.** TSO services are shown to deliver a relatively small contribution towards the overall value stack. As a result, if domestic FLEX participates in providing these TSO services, it is particularly important that metering, testing and other administrative requirements are streamlined, to make participation worth it.

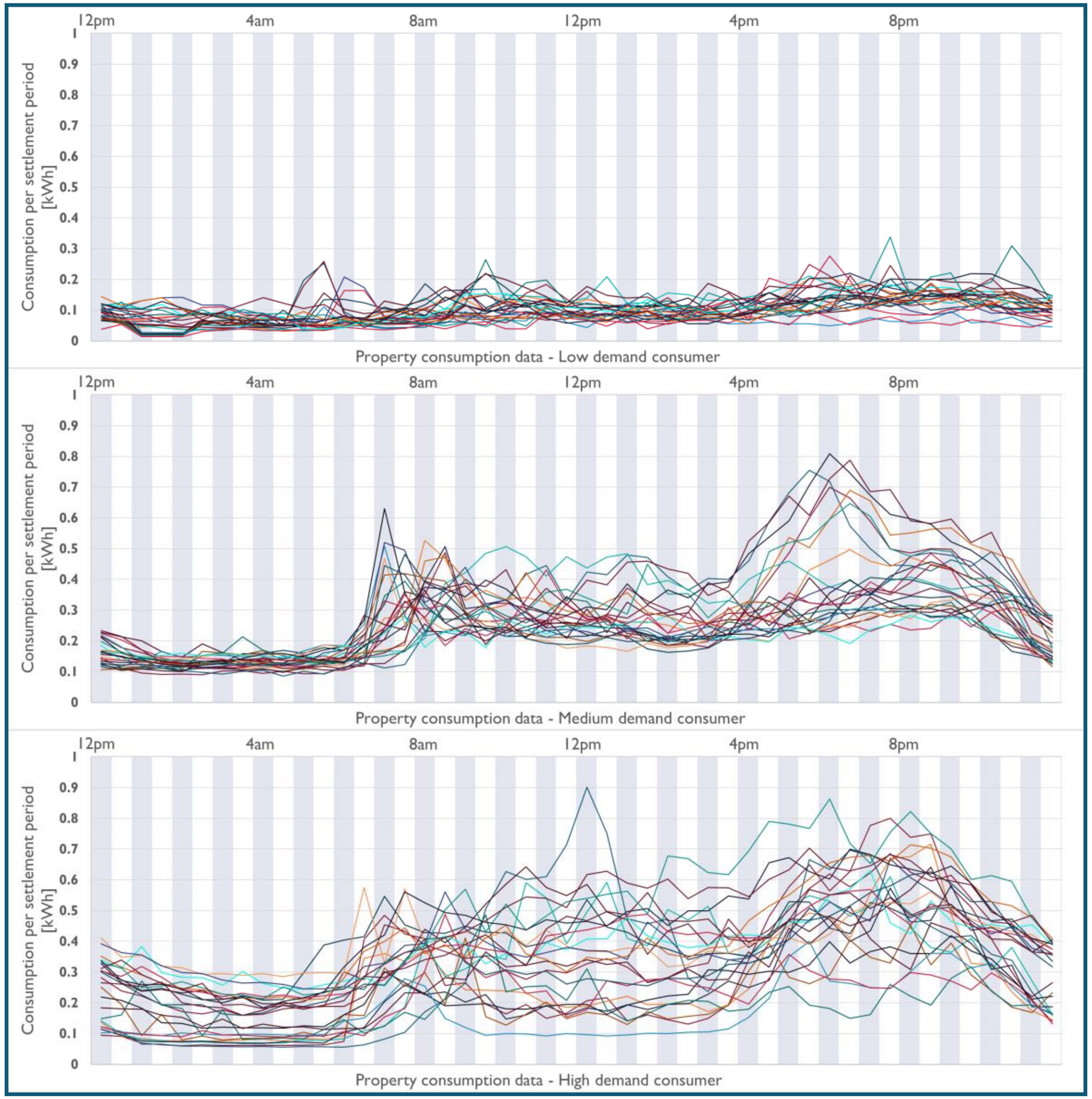
6. **Assess predictability of consumer behaviour further.** Everoze's approach assumes perfect foresight of consumer behaviour, and thus represents an upper bound on value that can be captured. A later model iteration could be developed which addresses uncertainties in this area.

7. **Review value stack again as DSO services transition towards a competitive tender.** At present, WPD is setting prices for its DSO services. When WPD transitions to competitive tender, it is possible that price reduction will be experienced; this might then amend Everoze's findings.

8. **Address the regulatory barriers to providing domestic FLEX.** Everoze has assumed that markets are open to domestic FLEX without friction. This is an oversimplification; regulatory barriers should be explored and addressed.

4 ASSUMPTIONS

CONSUMER LOAD PROFILES



The graphs show the consumer load data used in the modelling for each customer type as provided by Delta-ee. The data does not included any electric heating loads.

The consumer load data are drawn from the 'Powering the Nation' dataset and are provided as a representative weekday and weekend for each month of the year, yielding 24 usage consumption patterns for each customer type. These 24 representative consumption patterns are used to generate a half-hourly consumption pattern for a full year for use in the modelling. The total annual consumption (excluding space heating loads) for these consumers are as follows:

- Low heating and electrical demand: 1,731 kWh per year
- Medium heating and electrical demand: 4,602 kWh per year
- High heating and electrical demand: 5,678 kWh per year

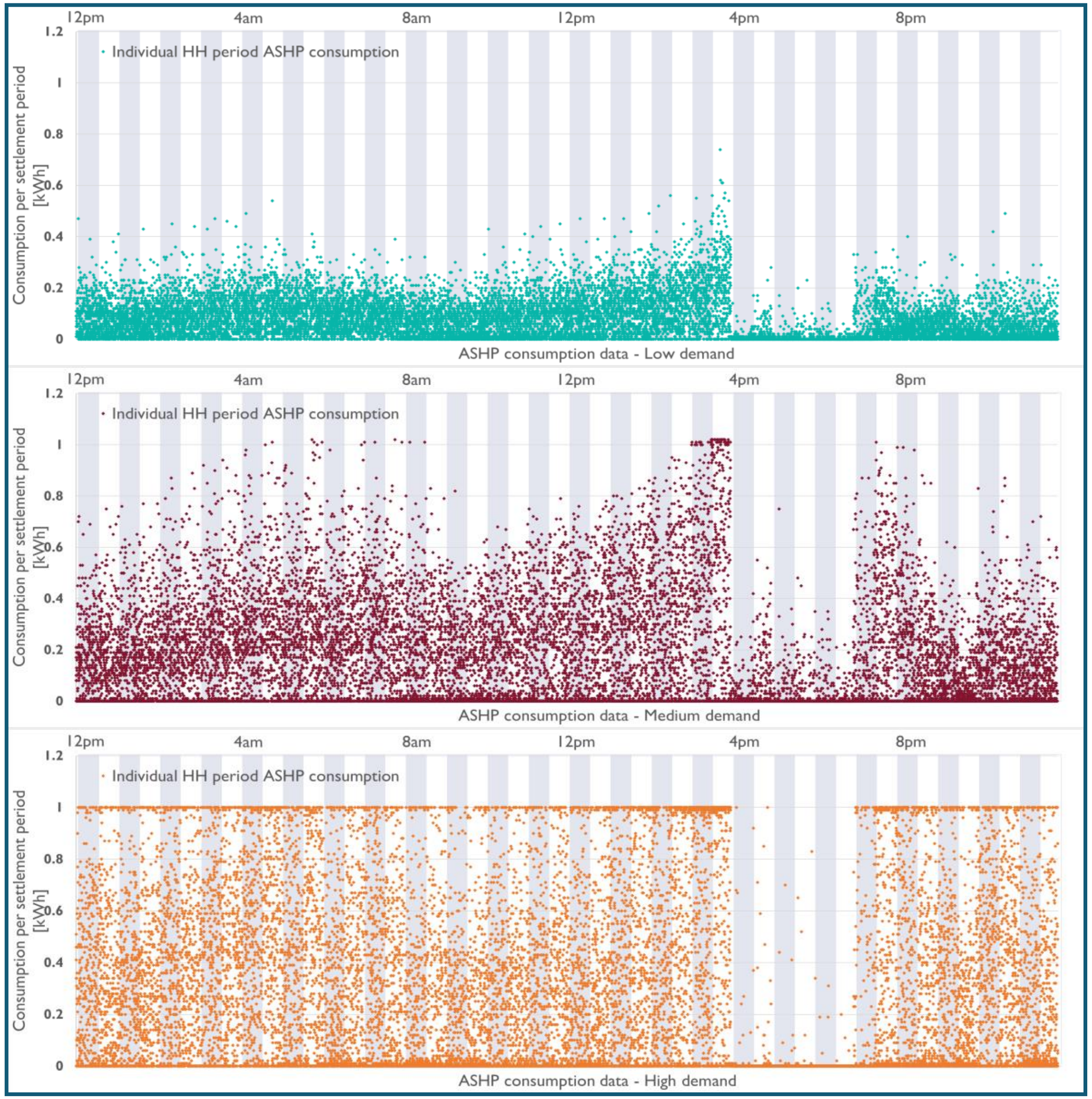
Delta-ee has identified the following limitations in using the 'Powering the Nation' dataset:

- Although the dataset includes 250 homes, only 30 homes were monitored for a full year with the rest of the homes monitored for between 1 to 2.5 months. This had resulted in anomalous step-changes in the consumption profile from month to month due to unrepresentative homes being included in the dataset for some months and not others. Delta-ee has performed some data processing to remove consideration of such unrepresentative properties.

- Due to data protection considerations, the dataset does not allow fewer than four homes to be viewed to present an average sample. Delta-ee has considered as small a sample as possible for the customer types to minimise 'peak flattening' due to averaging across a sample dataset.

Nevertheless, the dataset is deemed to be of sufficient quality for the purposes of feasibility modelling.

ASHP LOAD PROFILES



The graphs show the ASHP electrical load data used in the modelling for each customer type. These data are an output from the hybrid heating system optimisation completed by PassivSystems based on 2018 heating profile data for a selection of homes from the Freedom Project.

Data for 10 homes were provided, and following discussions with PassivSystems, the following homes were used for the three customer types:

- Low heating demand: Home #10; 1,360 kWh per year (ASHP) and 9 kWh per year (gas boiler)
- Medium heating demand: Home #01; 3,065 kWh per year (ASHP) and 186 kWh per year (gas boiler)
- High heating demand: Home #05 (with an altered home occupancy schedule assuming day-time occupancy); 5,400 kWh per year (ASHP) and 392 kWh per year (gas boiler)

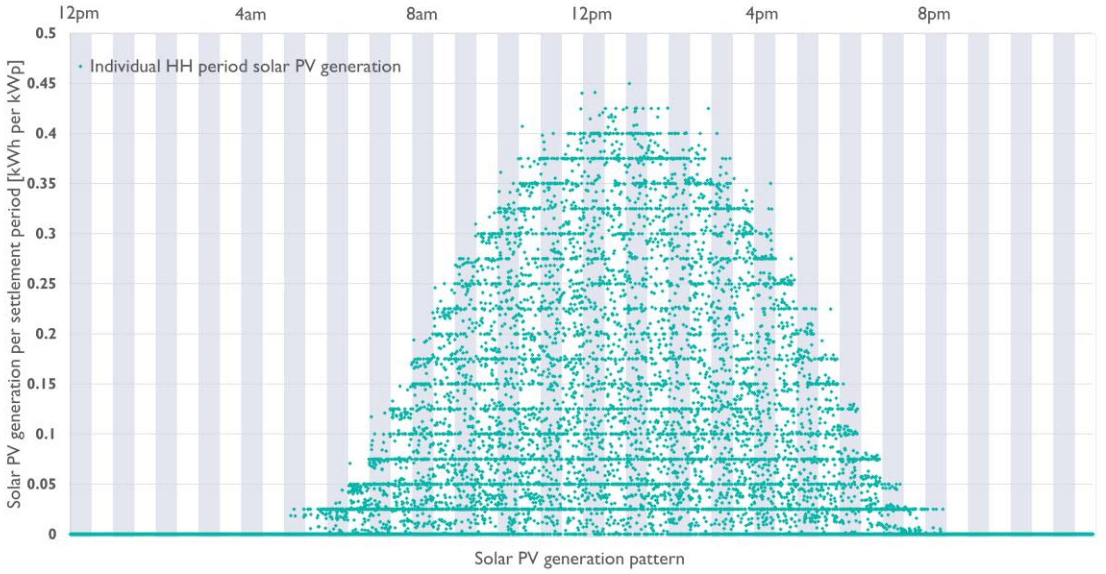
The data from the three homes considered for modelling are for different heat pump manufacturers – Mastertherm, Samsung and Daikin.

The hybrid heating system optimisation was performed against half-hourly electricity price based on the cost of energy data (as described in a subsequent slide). The data shows little ASHP operation during the evening peak periods where the cost of energy is high.

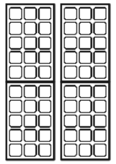
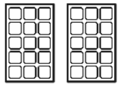
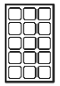
Where there is a limit on import capacity for ASHP operation, the ASHP loads are replaced with gas boiler to deliver an equivalent amount of heat output. The replacement gas cost is calculated assuming a gas price of 7.22p per kWh and a boiler efficiency of 85%.

Note on the graph data: The individual settlement period consumption values are randomly spread across the settlement period they fall in so the data appear more spread in the horizontal axis than in reality. This has been done to provide a better visualisation of the data so they are not all aligned in narrow lines in the middle of the settlement period.

SOLAR PV AND GENERATION PROFILE



Installed solar PV capacity per customer type:

High thermal and electrical demand	*Medium thermal and electrical demand*	*Low thermal and electrical demand*
 4 kW	 2 kW	 1 kW

Clip-arts used courtesy of Delta-ee's Customer Segmentation note, May 2019

The graph shows the solar PV generation pattern used in the modelling. The data shows the generation measured on the AC side of the inverter. A normalised generation pattern was used in the modelling and the solar PV generation for each customer type was scaled depending on the installed solar PV capacity specific to that customer type.

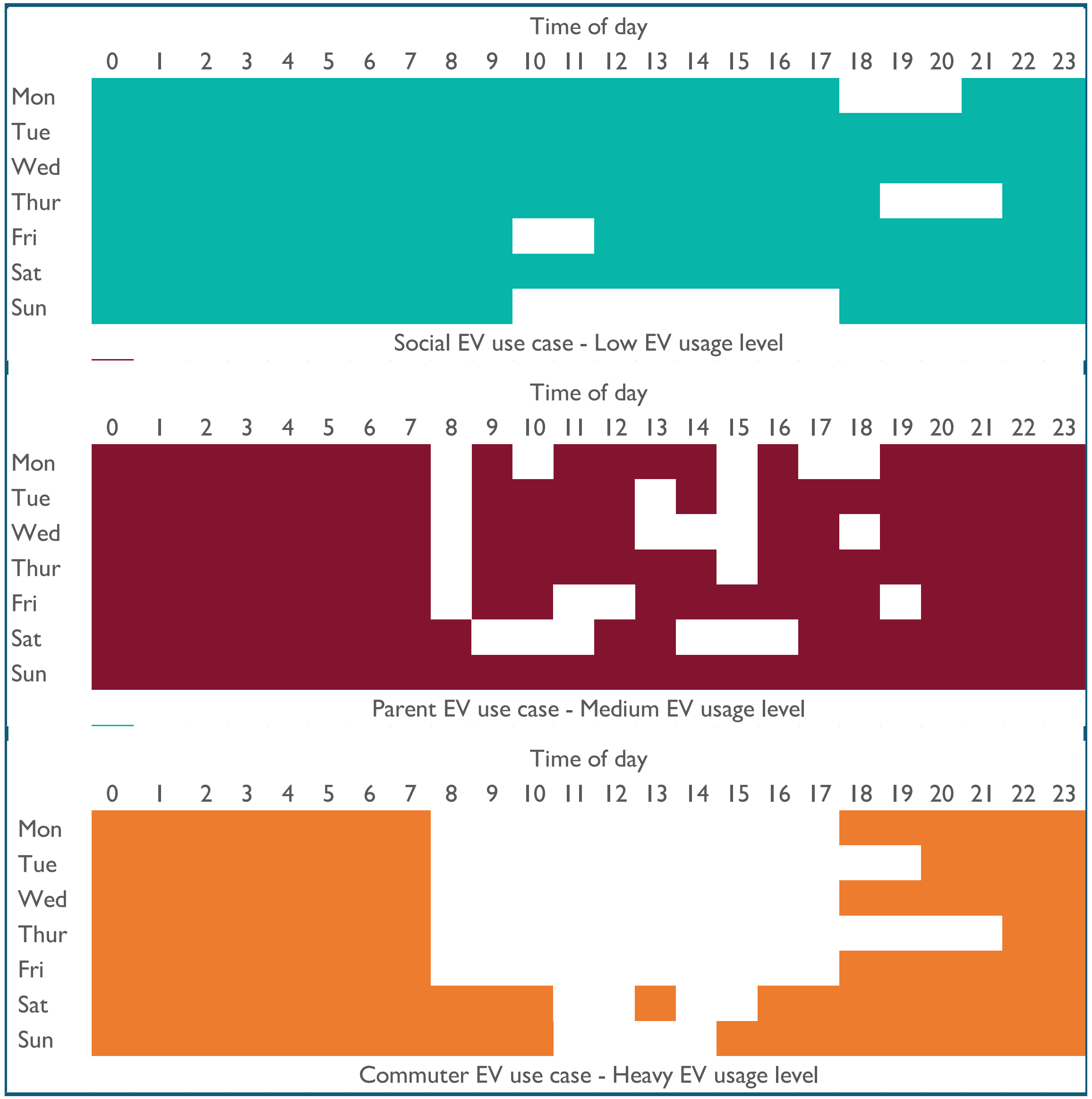
The normalised generation pattern data is sourced from the 2018 solar PV generation data provided by PassivSystems for a selection of 16 homes in the South Wales region. These properties have different installed capacities (1-4 kWp), azimuth orientation and tilt angles. These properties have capacity factors ranging between 6%-12%.

The generation profile for Home #06 (2 kWp installed capacity, 180 degree azimuth orientation and 35 degree tilt angle) was normalised against the installed solar PV capacity to generate the normalised generation pattern in kWh per kWp installed capacity. This property has a capacity factor of 11% which is in line with the typical level expected for a roof-top solar installation.

The data set had a number of half-hourly settlement periods where no data were recorded, more for some homes than others. Home #06 had 18 such records, largely towards the end of the generation period during the day and so did not materially affect the generation pattern. Everoze has assumed the generation to be zero during such affected periods. Given the small number of affected half-hourly periods for the assumed data set and the timing of the affected records, this does not materially affect the modelling results.

Note on the graph data: The individual settlement period consumption values are randomly spread across the settlement period they fall in so the data appear more spread in the horizontal axis than in reality. This has been done to provide a better visualisation of the data so they are not all aligned in narrow lines in the middle of the settlement period.

EV TRANPORT PATTERN (1/2)



The images show the EV transport pattern used in the modelling for each customer type as provided by Delta-ee. Delta-ee has noted that the transport patterns are informed by National Transport Statistics (2018 update) as well as BEIS CP data. Similar to the customer load data, the transport pattern data are provided as a representative weekday and weekend profile, which is then applied across the full year for modelling.

The shaded areas represent times when the EV is available on the driveway / is not being used, and unshaded areas represent times when the EV is being used for transport. Everoze has assumed that when the EV is available on the driveway, it is also connected to the EV charger. The charging pattern considered is a smart charging strategy.

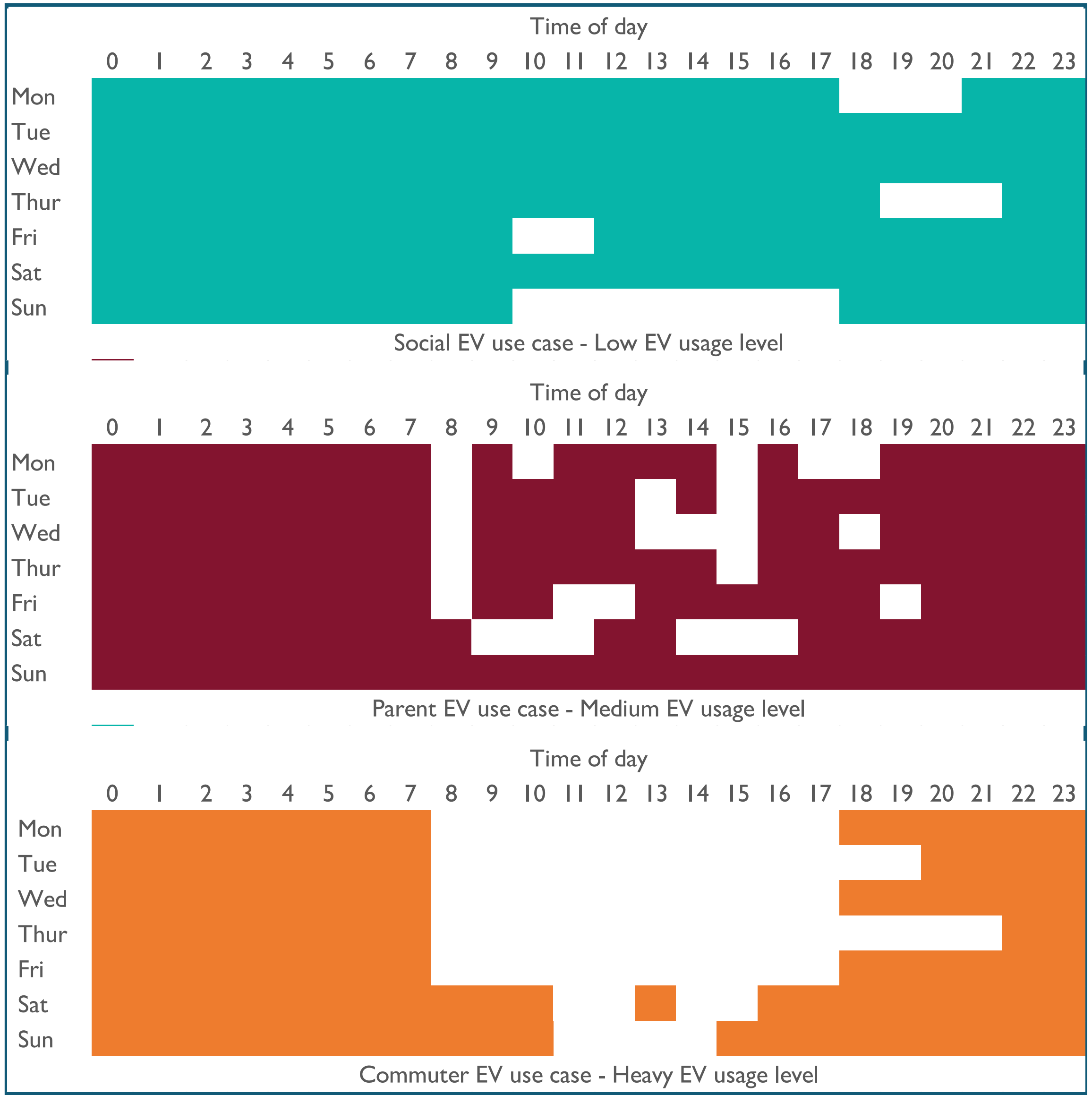
The images show the EV availability in one-hour windows, and the time of day shown is the time at the start of the corresponding one-hour block.

Three transport patterns with corresponding levels of EV usage are considered to provide a representative spread of the customer types:

- Commuter with high EV utilisation – Weekday commute to work, and weekend visits to friends and family
- Parent with moderate EV utilisation – Parent with school run, high-intensity social use multiple times during the day
- Social with low EV usage – Low-intensity utilisation – three to four times a week (one to two evenings)

The mileage assumptions and EV state of charge assumptions used in the modelling are shown on the next page.

EV TRANPORT PATTERN (2/2)



The table below shows the mileage assumptions and EV state of charge assumptions used in the modelling, which has been informed by Delta-ee's customer research undertaken as part of the MADE Project.

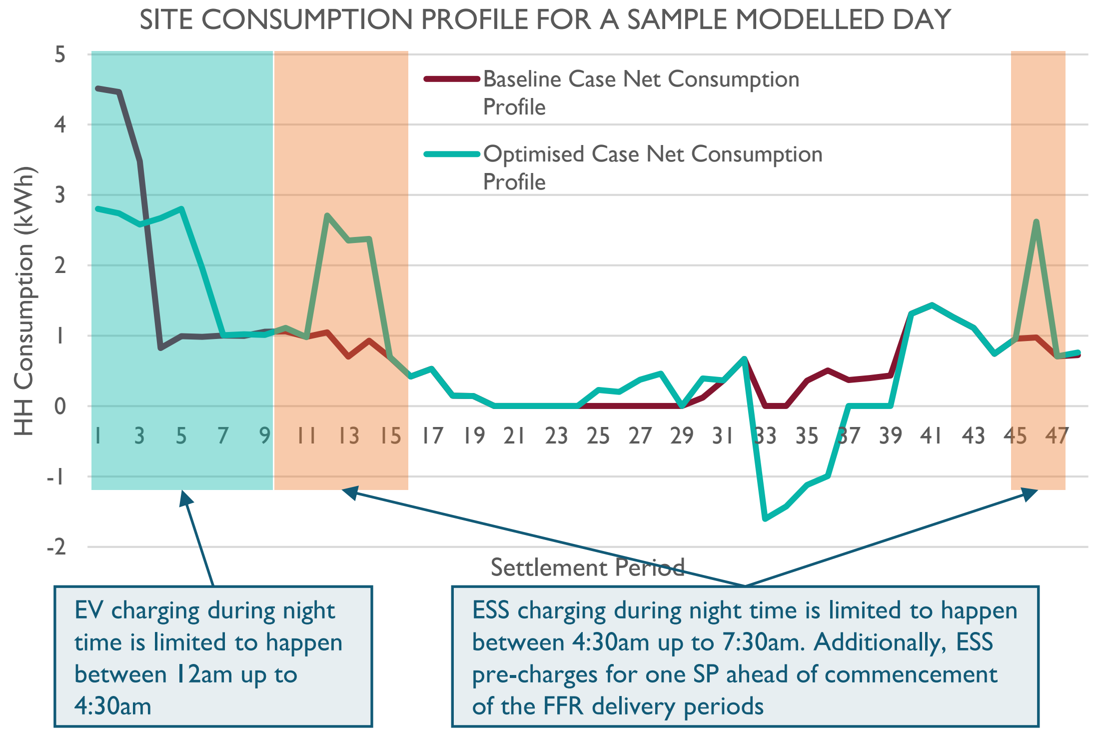
	Social	Parent	Commuter
Monday	7.12 miles *for social/evening activity*	5 mile *school run*, 14.24 miles *for visits to the shops, and other activities*	25 mile *commute*
Tuesday	-	5 mile *school run*, 7.12 miles *for visits to the shops, and other activities*	25 mile *commute*, 10 miles *for other social/evening activity*
Wednesday	-	5 mile *school run*, 10.68 miles *for visits to the shops, and other activities*	25 mile *commute*
Thursday	7.12 miles *for social/evening activity*	5 mile *school run*	25 mile *commute*, 10 miles *for other social/evening activity*
Friday	7.12 miles *for mid-day visit to the shops*	5 mile *school run*, 14.24 miles *for visits to the shops, and other activities*	25 mile *commute*
Saturday	-	14.24 miles *for Saturday activities with the children*	13 miles *for shopping and Saturday afternoon activity*
Sunday	40 miles *for visit to friends and family*	-	40 miles *for visit to friends and family*

A mileage efficiency of 4 miles per kWh has been assumed as advised by Delta-ee. No seasonal variation in efficiency (taking into account effect of hot/cold ambient temperatures on EV battery efficiency) has been considered in the modelling.

It has been assumed that the EV is charged up to 100% state of charge for the start of the following day.

TECHNICAL ASSUMPTIONS FOR EV AND ESS (1/2)

	Stationary Storage (ESS)	Electric Vehicle (EV)
Usable energy capacity	10 kWh	33 kWh
Rated power	3.3 kW (inverter power, AC)	7 kW (charger power, AC)
Allowed state of charge range	5% to 100% of usable energy capacity	20% to 100% of usable energy capacity
Round-trip efficiency	88%	85%



The technical parameters of the stationary storage (ESS) asset and the EV used for modelling are shown in the table here. The energy capacity and rated power of the ESS assumed are based on a commercially available Sonnen battery[1]. The EV battery usable capacity and charger power assumed are based on the largest model of cars in the Electric Nation data set.

Everoze has assumed a floor limit for the ESS and EV, state of charge below which the battery is not discharged for FLEX. This is to preserve battery life, and in the case of the EV, to maintain a 'buffer' charge level at all times for short trips.

Everoze has not considered any limitation of charging power for the EV at higher levels of state of charge. In reality, it would be expected that at higher levels of EV battery charge levels, say beyond 80% state of charge, the EV would be charging at a reduced power level (operating in constant voltage charging mode). This variable charging power at higher state of charge levels has not been considered in the Everoze modelling. As a result, it may be the case that the EV is under charge mode for longer and therefore is available for fewer HH settlement periods during the night time for provision of other services (such as FFR – provided in a co-ordinated manner with the ESS).

For the optimised case, with a view to minimising the impact of EV charging loads on the network, Everoze has assumed a 50% de-rating on the EV charging power to consider a managed 'smart charging' scenario. This means the EV will be in charging mode for more HH settlement periods compared to the base case, however the impact of EV charging loads on the network is vastly reduced.

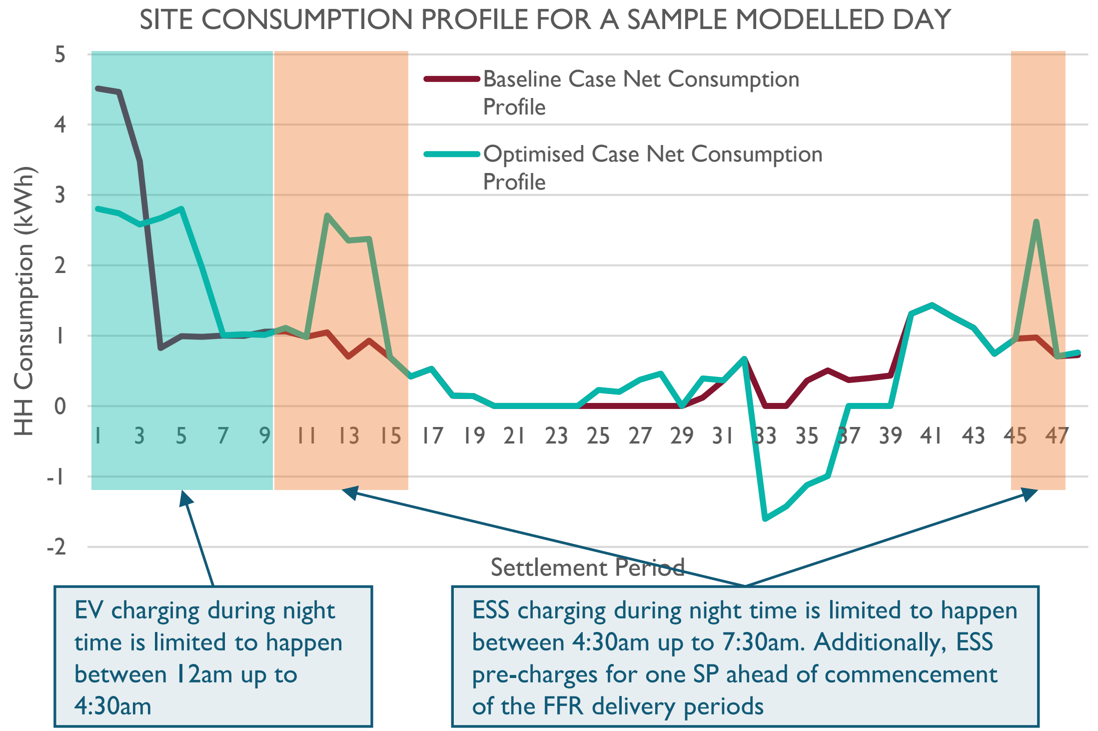
The ESS and EV round-trip efficiency assumptions are informed by Everoze experience. No asset downtime assumptions have been used, and the ESS and EV (when connected) are considered to be fully available during the year.

everoze

1 – https://sonnenbatterie.co.uk/sonnenbatterie/

TECHNICAL ASSUMPTIONS FOR EV AND ESS (2/2)

	Stationary Storage (ESS)	Electric Vehicle (EV)
Usable energy capacity	10 kWh	33 kWh
Rated power	3.3 kW (inverter power, AC)	7 kW (charger power, AC)
Allowed state of charge range	5% to 100% of usable energy capacity	20% to 100% of usable energy capacity
Round-trip efficiency	88%	85%



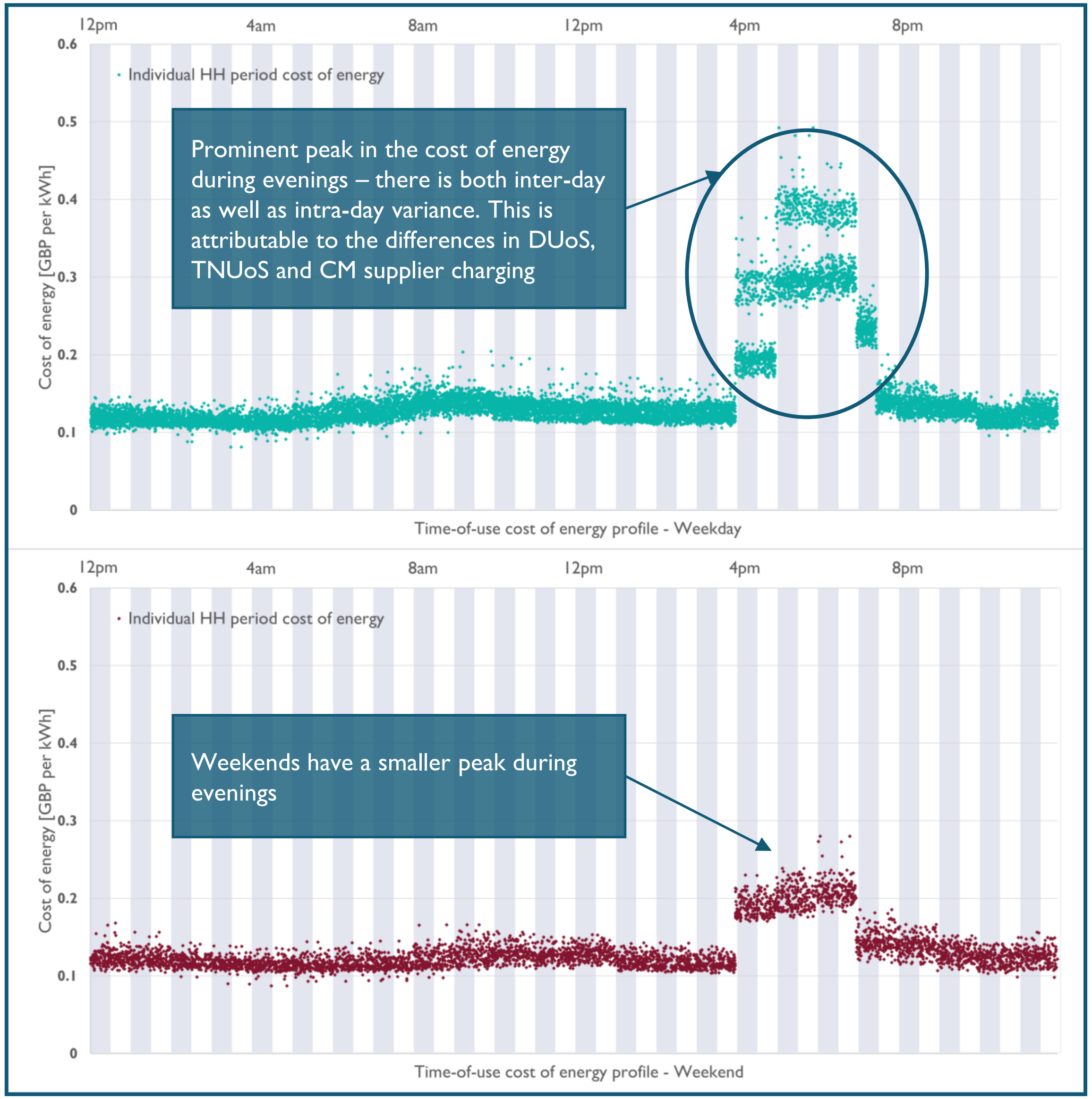
The Electric Vehicle Smart Charging[1] consultation published in July 2019 sets out a few proposed operational requirements for system security reasons. A summary of the requirement as set out in the consultation paper is included in *italics* with Everoze comment on modelling assumption in non-italicised text:

1. *Randomised delay of up to 10 minutes on charge-points which can be overridden if providing ancillary services such as FFR* – as the modelling resolution is 30-minute periods, this randomised delay function has not been considered in the modelling
2. *Minimum charging current/power when vehicle is connected to charge-point and is charging, except for when the EV is providing V2G services* – a minimum charging power is not considered in the modelling
3. *Default installation mode (not mandated, with manual override) for home charge-points where charging is delayed until a specific off-peak time (say midnight to 6am)* – this has been considered in the modelling where EV charging (for transport needs and for FLEX) is not done before 12am

Additionally, time windows for ESS and EV charging have been considered in the optimisation modelling such that the ESS and EV are not set to charge at the same time therefore avoiding the impact of cumulative charging loads on the network. The time period limits considered are shown on the graph to the left.

1 – Department for Transport, Electric Vehicle Smart Charging consultation, July 2019

COST OF ENERGY



The cost of energy (ie., the wholesale energy price plus network charges plus non-energy charges) is used as the price signal for the customer energy cost. A half-hourly timeseries for a full year has been used in the modelling, and is made up of the following components:

- Wholesale market price: the 2018 hourly day-ahead price obtained from publicly available sources
- DUoS charges: charges for LV Network Domestic tariff class from the most recent WPD South Wales charging statements (April 2020 – March 2021) has been assumed. To capture the change in DUoS charges in a given calendar year (as DUoS charging year commencing in April), the 2019/20 charges for Jan-Mar and the 2020/21 charges for Apr-Dec have been assumed.
- TNUoS charges: published NHH tariffs for the South Wales TSO charging zone has been used. Similar to the approach taken for the DUoS charges, to capture the change in tariffs from April in a given calendar year, the published 2019/20 charges for Jan-Mar and the NGESO forecast for 2020/21 for Apr-Dec have been assumed.
- BSUoS: From NGESO published charges for 2018 (for each HH settlement period)
- CM supplier costs: Assumption of an operational/settlement costs rate of £0.03/MWh and CM supplier charge of £89.87.MWh (for winter evening peak only).
- Other costs, renewables levies, VAT – Assumption based on Eurostat data provided by Delta-ee. The values for the customer demand band 'TOT_KWH' has been used.

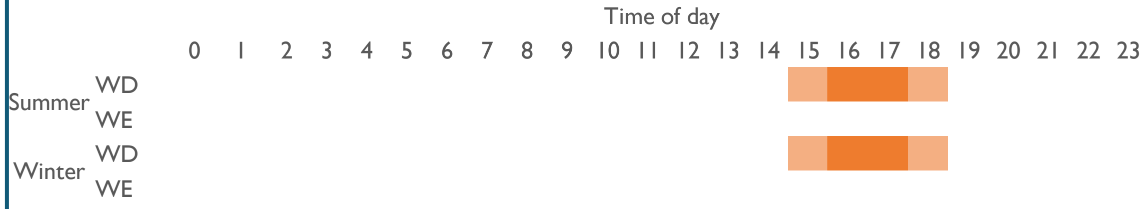
For energy export, it is assumed a tariff similar to the 'Octopus Agile' tariff is available for the property. The value of export (surplus solar generation and ESS/EV net export to the grid) is therefore assumed to be the wholesale energy price.

Note on the graph data: The individual settlement period consumption values are randomly spread across the settlement period they fall in so the data appear more spread in the horizontal axis than in reality. This has been done to provide a better visualisation of the data so they are not all aligned in narrow lines in the middle of the settlement period.

DSO SERVICES (1/2)

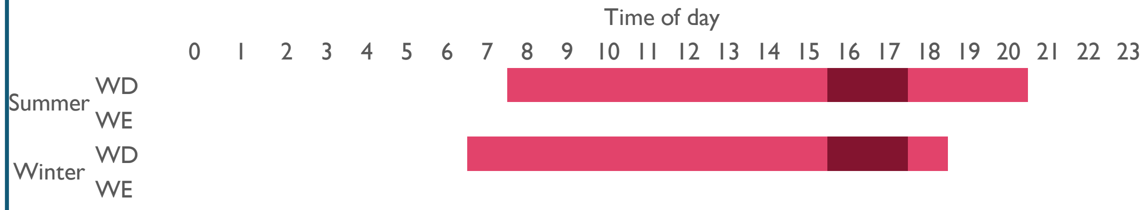
SYSTEM NEED AND SERVICE PROFILES

These system need profiles have been developed based on the DSO service need identified in WPD's 2019 Phase 1 ITT for demand response services across the various CMZs, and the same has been discussed with WPD to confirm they are sensible assumptions for developing scenarios.



Profile 1 ('Narrow') - Summer and Winter

Constraint and system need across all months for the respective season: Summer – May to Oct (3:30pm to 7pm), and Winter – Nov to Apr (3:30pm to 7pm). This is only during weekdays. WPD advise that the SECURE service will typically be contracted for this type of system need, but also notes that the DYNAMIC service may be contracted in some instances.



Profile 2 ('Wide') - Summer and Winter

Constraint and system need across specific months during the respective season: Summer – May and June (8am to 9pm), and Winter – Nov to Feb (7am to 7pm). This is only during weekdays. WPD advise that the DYNAMIC service will typically be contracted for this type of system need.

For both profile types noted above, services would be contracted for Summer and Winter season separately, and not all CMZs will have a requirement during both Summer and Winter seasons.

DSO services are hyper-local and WPD's requirements for demand response across its Constraint Management Zones (CMZs) vary i) seasonally / months of the year, ii) day of the week, and iii) time of the day. Therefore it is not reasonable to assume a 'generic' service profile for modelling purposes as the network need varies from location to location.

To accommodate the variability in network constraint and service need across WPD's South Wales region, Everoze has defined a few system need profiles with WPD's inputs. Depending on the network need, WPD either procures the SECURE service or the DYNAMIC service. Considering the four system need profiles (one per season), Everoze has drawn a number of DSO service stack scenarios as described below:

#	System need scenario	Season	DSO Service	Tender success rate[1]	Utilisation probability rate[1]
1		Summer and Winter			
2	Profile 1 'Narrow'	Summer only	SECURE	75%	N/A
3		Winter only			
4		Summer and Winter			
5	Profile 1 'Narrow'	Summer only	DYNAMIC	75%	80%
6		Winter only			
7		Summer and Winter			20%
8	Profile 2 'Wide'	Summer only	DYNAMIC	75%	5%
9		Winter only			20%

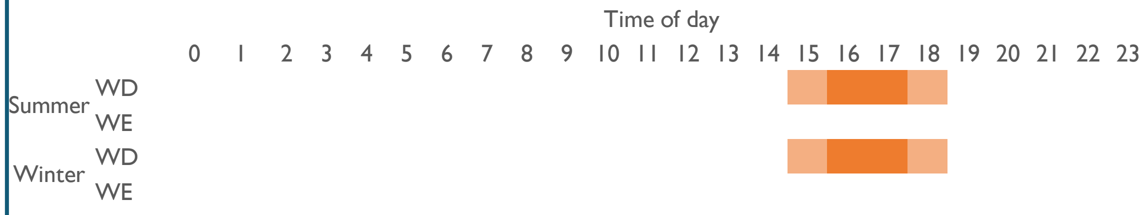
Scenario #3 is considered in the main seven modelling cases. The other scenarios #1, #2 and #4 to #9 have been considered in the sensitivity analysis for a specific reference case.

1 – Probability assumptions used are informed through discussions with WPD

DSO SERVICES (2/2)

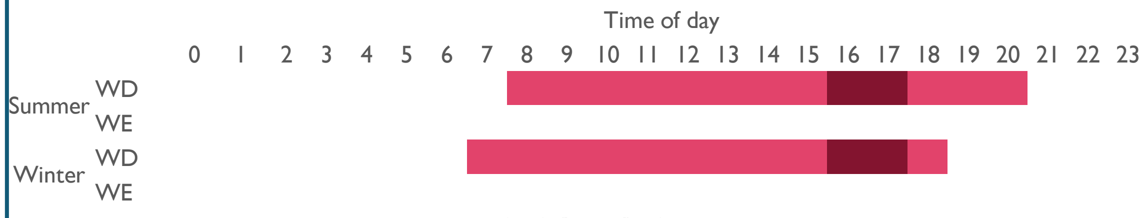
SYSTEM NEED AND SERVICE PROFILES

These system need profiles have been developed based on the DSO service need identified in WPD's 2019 Phase 1 ITT for demand response services across the various CMZs, and the same has been discussed with WPD to confirm they are sensible assumptions for developing scenarios.



Profile 1 ('Narrow') - Summer and Winter

Constraint and system need across all months for the respective season: Summer – May to Oct (3:30pm to 7pm), and Winter – Nov to Apr (3:30pm to 7pm). This is only during weekdays. WPD advise that the SECURE service will typically be contracted for this type of system need, but also notes that the DYNAMIC service may be contracted in some instances.



Profile 2 ('Wide') - Summer and Winter

Constraint and system need across specific months during the respective season: Summer – May and June (8am to 9pm), and Winter – Nov to Feb (7am to 7pm). This is only during weekdays. WPD advise that the DYNAMIC service will typically be contracted for this type of system need.

For both profile types noted above, services would be contracted for Summer and Winter season separately, and not all CMZs will have a requirement during both Summer and Winter seasons.

A minimum 2 hour service delivery is required by WPD for demand response, and for modelling purposes, Everoze has assumed the assets to provide FLEX response for no more than this minimum 2 hour requirement.

For each of the DSO service stack scenarios, Everoze has assumed that the site will be dispatched for demand response during 4pm to 6pm coinciding with periods where the network loads are highest. A contract service volume of 3 kW is assumed for the DSO service stacks.

WPD pays an availability payment and a utilisation payment for the DSO demand response services. The tariffs are currently set by WPD – the following tariff assumptions are used in the modelling (as discussed with WPD):

Service	Scheduling / Arming fee	Utilisation fee
SECURE	£125 per MW per hour	£175 per MWh
DYNAMIC	£5 per MW per hour	£300 per MWh

Everoze has made the following assumptions with respect to contracting for the SECURE and DYNAMIC services

- SECURE: It is assumed that service availability is declared and is scheduled by WPD for the two hour period noted above. Availability payments are made for this two hour period with utilisation payments made for the energy volume provided during the contracted period.
- DYNAMIC: It is assumed that service availability is declared and the site is armed by WPD over the full period of service need. DSO dispatch instruction is assumed to be received during the two hour period noted above. Availability payments are made for the full period of service need, with utilisation payments made for the energy volume provided during the 2-hour dispatch period.

5 VALIDATION

REAL WORLD DATA

PassivSystems has gathered real word data from a number of homes operating under PassivSystems live coordinated control solution using their optimisation algorithms which quantitatively determine the optimum strategy for asset operations. A selection of this data has been provided to Everoze. PassivSystems has also undertaken simulation modelling for these homes for the period considered and has provided the outputs of their simulation for comparison. Everoze has undertaken a validation exercise comparing the Everoze modelling outputs for the specific home for the period considered with the real world data as well as PassivSystems simulations.

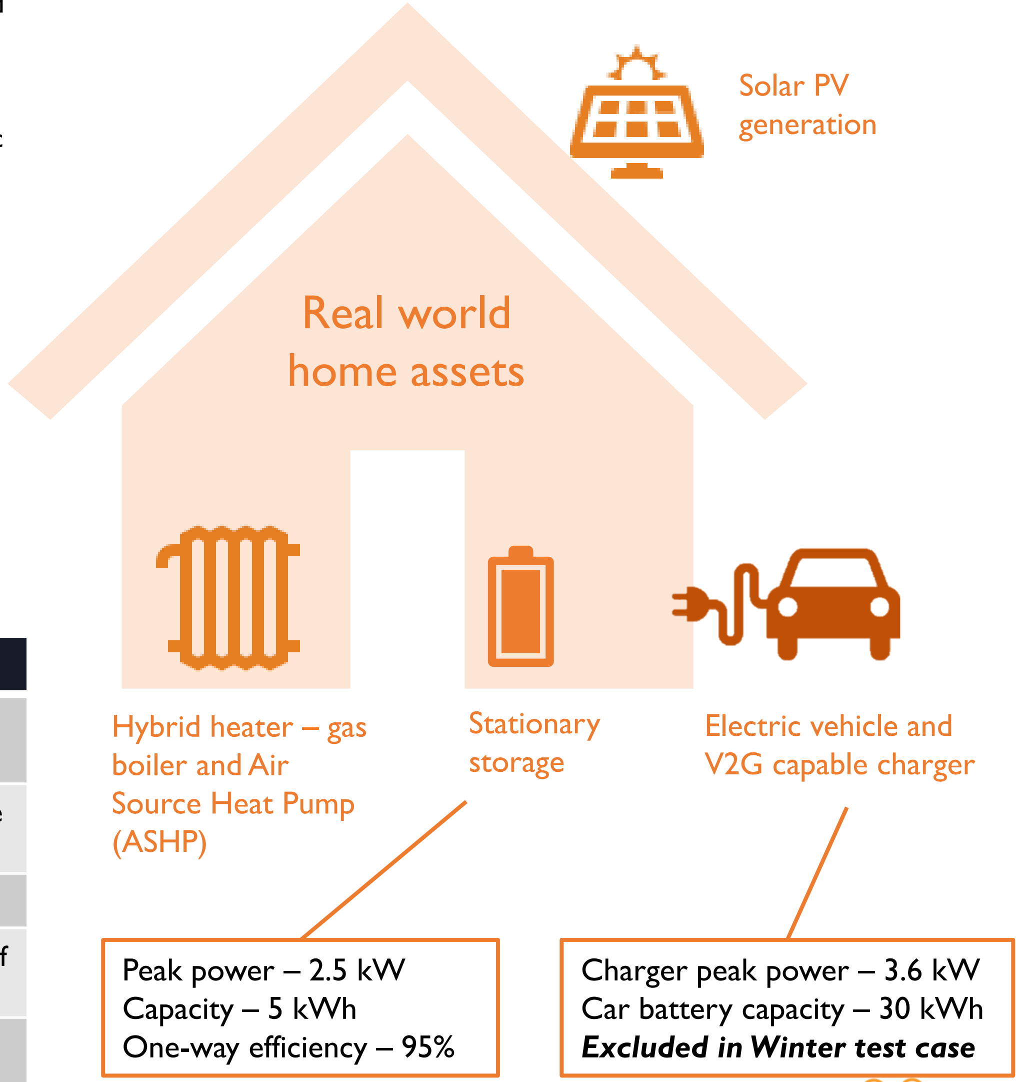
PassivSystems has supplied data representing Home 1 for the following periods:

- A 2-day period from 11th February 2020 representing a sample Winter season period
- A 2-day period from 20th June 2020 representing a sample Summer season period

The key capability of the Everoze modelling that is being validated is the ability to simulate the co-ordinated control and optimisation of the home consumption using the suite of low carbon assets at the home. Therefore the DSO and TSO services are excluded from the validation exercise as they are not relevant to the core capabilities being tested here.

The key input data supplied by PassivSystems are summarised graphically on the following slide, with the following characteristics as noted below. Similar to the original modelling, the optimised ASHP data used in the modelling was provided by PassivSystems.

	Winter test case	Summer test case
Heating	Active with no use of the gas boiler	Inactive as no heating required for summer season
Solar PV	Low generation	High generation beyond baseload during the day (surplus solar)
Stationary storage	Fully active	Fully active
Electric vehicle	Not present	Plugged in at 8:30pm on Day 1 with c.10% of charge remaining
General base consumption	Averaging 0.5 kWh per settlement period with a peak energy demand of 2.4 kWh	Averaging 0.25 kWh per settlement period with a peak energy demand of 1.4 kWh



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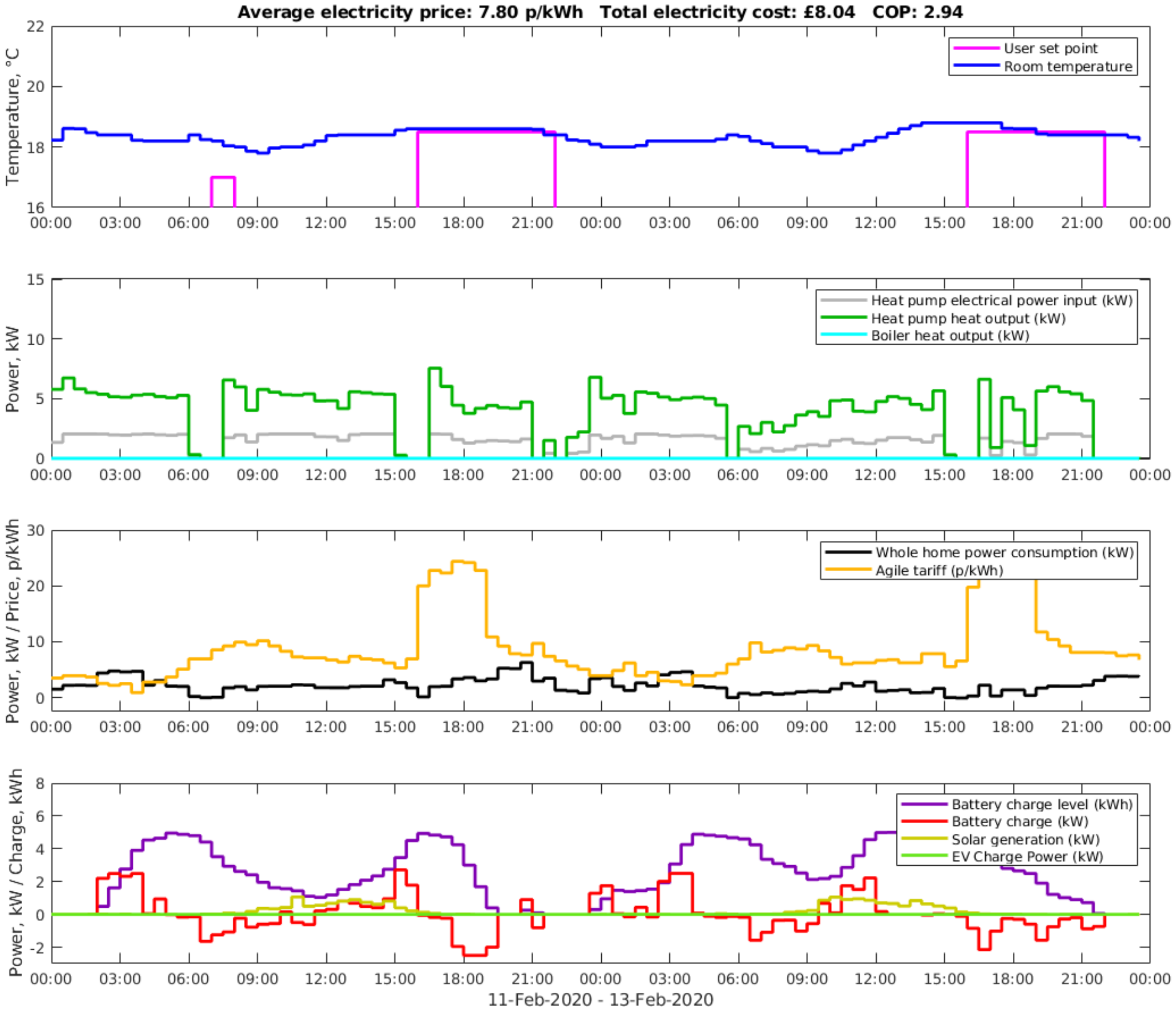
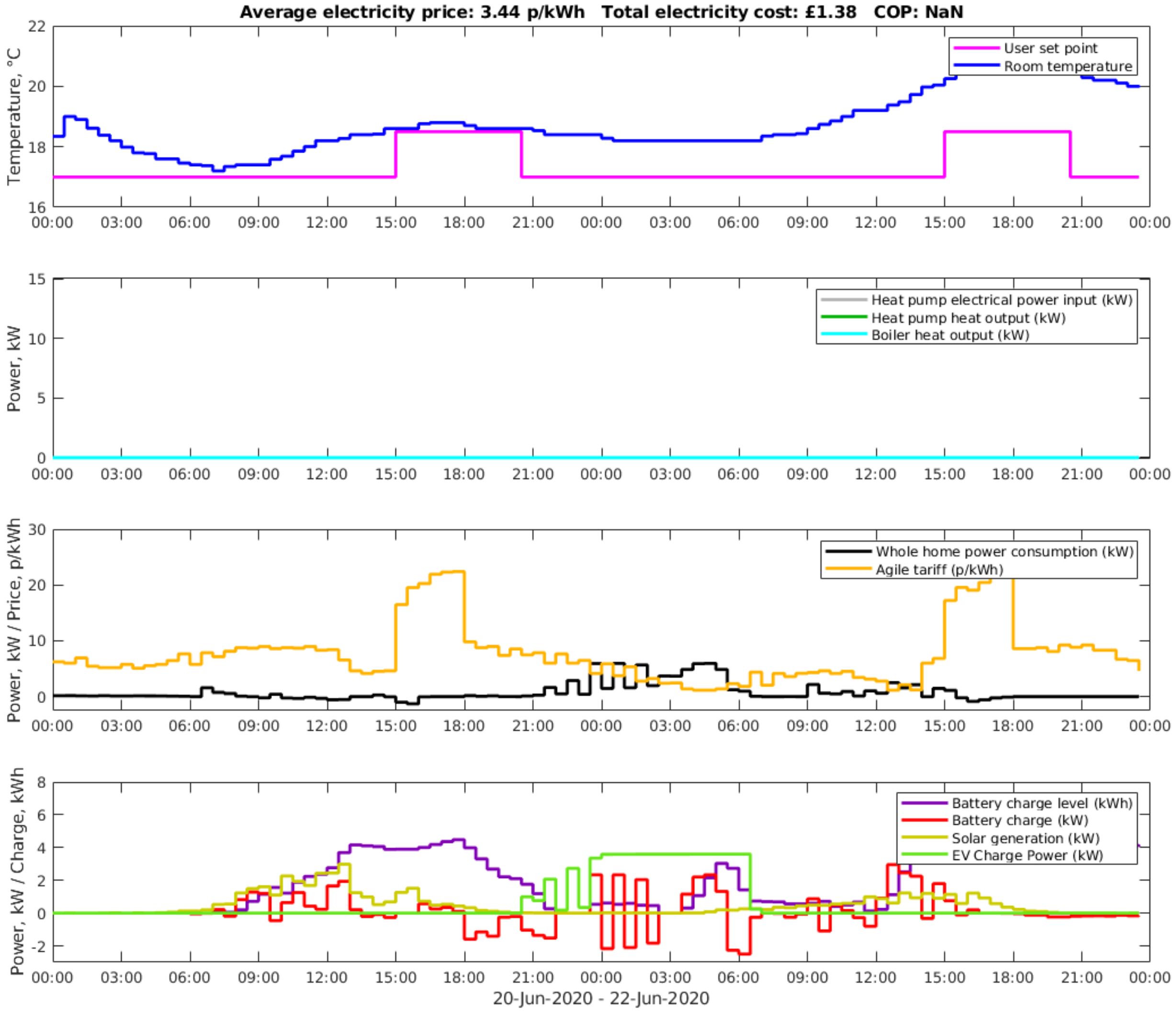
INPUT DATA

Winter test case



Summer test case

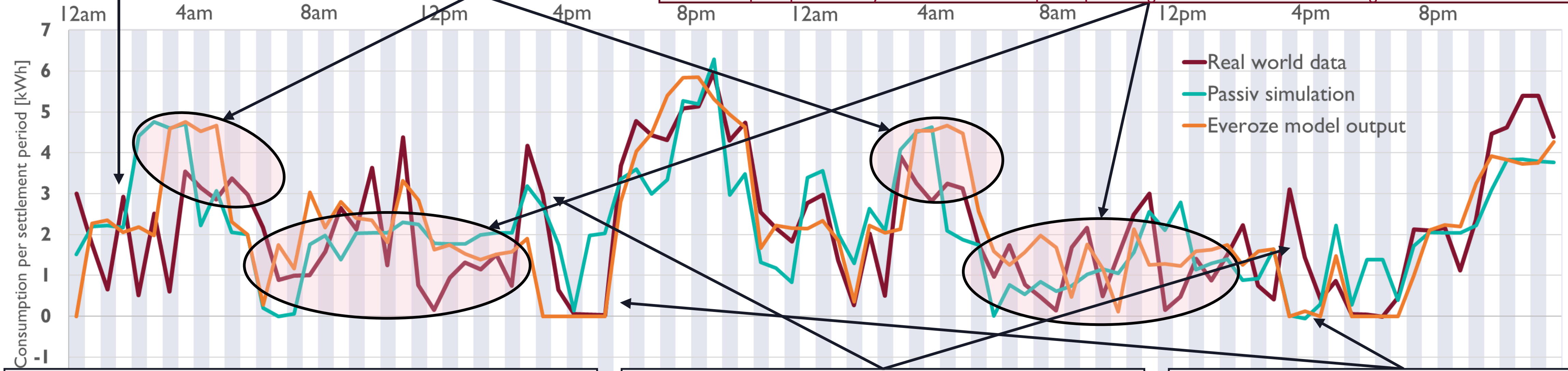


WINTER TEST CASE

PassivSystems advised there was a bug in the initial set-up which caused the stationary storage to charge and discharge in alternating settlement periods.

The battery is pre-charged overnight when the energy price is low. There is some minor difference in timing of charging in day 1 but this difference is minor.

In the real world case, the battery is discharged during the day-time when the energy price is marginally higher than the night time charging price. Everoze modelling does not perform this day-time discharge for the battery. This is due to a minimum target price spread considered as an economic decision driver for the battery to perform load-shifting. An assumed marginal cost of degradation for the battery is used as this minimum target price spread. This means load-shifting in Everoze modelling is limited to peak-periods only where the achieved price spread is greater than this minimum target value considered.



There are underlying differences between the modelling and real world data due to differing assumptions for the Air Source Heat Pump behaviour. The ASHP is optimised with all the assets in the real world case, but this was not possible for the modelling due to the approach adopted where Everoze modelling uses PassivSystems' ASHP optimisation as a modelling input. This difference leads to a different profile for ASHP usage and also some changes to the use of the stationary storage as it is generally more efficiently to store energy in the battery than in the thermal fabric of the home.

The PassivSystem simulation and real world data show an increase in consumption ahead of the peak period – from discussion with PassivSystems, this is understood to be due to forecasting error where solar generation during this period was over forecasted and the battery was instructed to capture this surplus solar generation. Everoze modelling considers the actual solar generation with 100% foresight, and so does not consider the impact of forecasting inaccuracies.

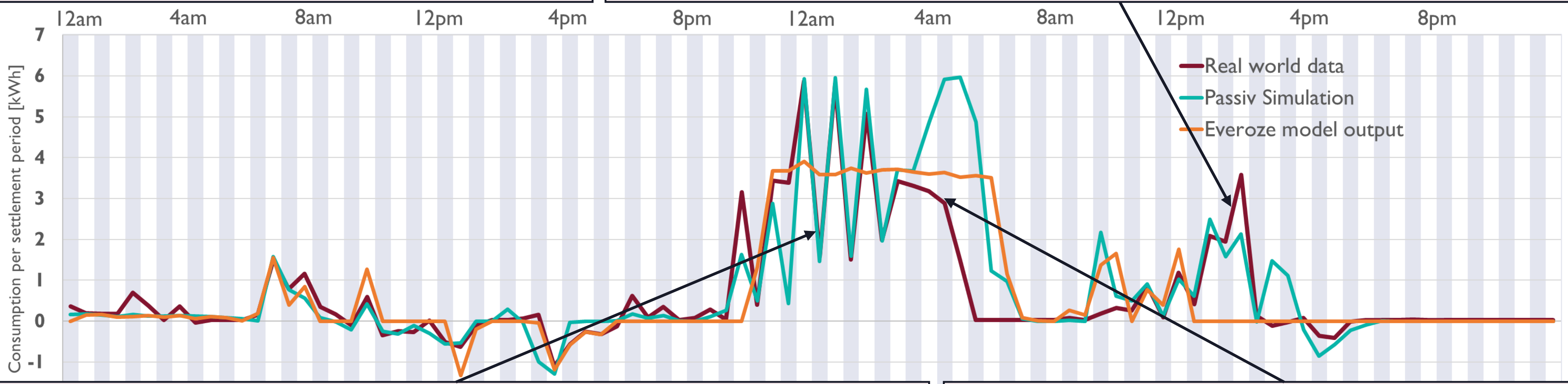
All profiles show a reduction in energy consumption during the evening peak. Everoze modelling has zeroed this from the start of the peak period by using pre-charged energy in the stationary storage with perfect foresight of peak-shifting demand required. However, the battery runs out of charge and/or the inverter capacity is not big enough to fully offset the household demand during the entirety of the evening peak period.

Conclusions: The modelling, simulation and real world data largely follow similar trends with differences attributed to i) differences in modelled ASHP behaviour, ii) perfect foresight assumed in Everoze modelling for home consumption and solar PV generation, iii) minimum spread considered in the Everoze modelling, and iv) bug in the real world set-up for battery charging/discharging. Points 1 and 2 identify areas of improvement for the modelling undertaken, and point 3 is a recommendation for PassivSystems to consider in its optimisation solutions. Overall, the real world outcomes for this test case show the Everoze modelling reasonably reflects the utilisation of the stationary storage asset.

SUMMER TEST CASE

Generally, the consumption from the grid for the home is very low during the day as there is a lot of solar generation during this period which offsets household demand and the surplus generation is used to pre-charge the stationary storage ready for when solar generation drops in the evening.

This peak in the real world data and PassivSystems simulation does not appear in the Everoze modelling outcomes as the modelling assumes perfect foresight of household demand and solar PV generation. So the model accurately estimates the amount of stationary storage charge needed to fully offset peak time loads, and this being met from capturing surplus solar PV generation only and not requiring any other pre-charging from the grid. Also, the model discharges the remaining surplus solar captured to reduce home consumption to zero for the rest of the day as much as is possible.



In the real world case the stationary storage exhibits behaviour of alternating charging and discharging during alternating 30 minute settlement periods during the night. PassivSystems has described that this is due to the battery charging during low electrical price settlement periods and then discharging during the next higher cost settlement periods to reduce import costs. The price differential captured in this night-time arbitrage/load-shifting is minimal. As described in the previous slide, Everoze modelling does not consider this night-time arbitrage when the price spread is minimal. An assumed marginal cost of degradation is used as a minimum target threshold to reduce battery cycling for minimal gains. There is therefore a minor difference in approach which creates this difference in outcomes.

There is a significant period of prolonged high consumption due to the EV being charged during the night time. There is difference in the charge duration between the cases due to differences in the amount of charge required for the EV. Everoze modelling is done based on the manual user input which is observed to be incorrect in this instance, as the EV charging requirement in the real world data is notably less than that estimated in the modelling. Everoze model assumes perfect knowledge of the EV battery state of charge when plugged in whereas in reality this is a manual user import which is not always accurate.

Conclusions: The three data sets follow each other closer than the winter case, with the key differences attributed to i) battery cycling to capture small changes in the tariff during the night, and ii) uncertainty in the knowledge of actual EV state of charge prior to charging. The good conformance is likely to be due to a combination of no ASHP usage and generally good alignment of stationary storage utilisation between the data sets. Overall, the real world outcomes for this test case show the sophistication of the PassivSystems optimisation and coordinated control capability and that the Everoze modelling reasonably reflects the utilisation of the stationary storage asset and EV charging.

nithin.rajavelu@everoze.com

everoze.com

@everozepartners

everoze

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