Cornwall Local Energy Market

LEM Residential Technical Executive Summary

Cornwall Local Energy Market, Centrica plc

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Introduction

This document is an Executive Summary of the technical findings from the Cornwall Local Energy Market [LEM] residential workstream. This document provides a summary of the following documents;

1. The analysis of site performance, as presented in the document titled *"LEM Residential Fleet Self-Consumption Summary Report".*
2. The assessment of BESS utilisation and optimisation/VPP dispatch headroom as presented in the document titled *"LEM Residential BESS Utilisation Summary Report".*
3. The description of system performance monitoring datapoints, and associated data coverage summary, as captured in the document titled *"LEM Residential Data Dictionary*"
4. The description of metadata datapoints, and associated metadata coverage summary, as captured in the document titled *"LEM Residential MetaData Summary Report*"

The following dataset are referenced:

- Site definition captured in "t_sites.csv"
- Independent Monitoring System 1-minute data captured in "t_ims1m.csv.bz2"
- Independent Monitoring System 1-second data captured in "t_ims1s.csv.bz2"
- Sonnen Battery Diagnostic System 1-minute data captured in "t_msb1m.csv.bz2"
- Weather Forecast data captured in "t_weatherforecasts.csv.bz2"
- Production & Consumption data captured in "t_prodconsforecasts.csv.bz2"
- Tables of daily data coverage per database table captured in *"LEM Resi Data Coverage PUBLIC.xlsx"*
- Tables of MetaData captured in *"LEM Resi MetaData Tables.xlsx"*

In addition to the documents summarised in this document, the following may be of interest:

1. The residential participants selection methodology captured in the document titled *"Selecting participating properties – methodology and outcome*"
2. LEM Residential Participant Event presentation titled *"LEM Residential Dissemination Event Feb 2020_FINAL_v2.pptx"* as presented on 11th February 2020
3. The description of energy data available from the consumer focussed MySonnenBatterie portal in the document titled "App & Meter Guidance for Cornwall LEM Residential Project Participants"
4. The discussion of CO_2-equiavelent [CO_2e] savings for flexibility assets, such as Battery Energy Storage Systems [BESS] discussed in the document titled "Accounting for GHG Abatement in the Cornwall LEM Project"

LEM Residential Fleet Self-Consumption Summary Report

The economic and environmental performance of BESS was compared to a baseline of the dwelling only and the estimated performance of the dwelling with installed PV only. Electricity consumption of the participating dwellings ranged from c2 to c20MWh and electricity billing costs were estimated to range from c£250 to £3,050pa. Three different capacities of BESS were installed in dwellings, and it was observed that those dwellings with higher electricity consumption generally had higher capacity BESS systems. This was not a universal truth as installation decisions were made on consumer estimated bills, which were found to be unreliable.

Electricity bill savings accrued from reduced grid import in dwellings with installed PV only ranged from £50 to £310 and export revenue using an assumed tariff of £0.055/kWh ranged from £50 to £220. The total value of the PV only deployment ranged from £100 to £430, generating dwelling emissions savings of 0.38 - 1.22 TCO_2e pa based on an annual system average grid emission factor.

The incremental value created by adding BESS caused by further reducing grid import to meet demand ranged from £75 to £300 and the combined PV&BESS deployment resulted in savings that ranged from £150-£550pa. However, BESS also reduced grid export resulting in an associated lost income to the dwelling of £50-£140pa. This lost export income reduced the incremental "Total Value" provided by BESS to £25-£160pa. Clearly, there will be dwellings where the deployment of BESS does not make economic sense.

To assist with performance assessment of the PV&BESS solutions, two KPI's were derived from the electricity import and export data; namely production deficit (BESS discharge + Grid import) and production surplus (BESS charge + grid export). The ratio of production surplus to production deficit was highly correlated with the residual grid import required by the dwelling. As this ratio increased, grid import fell following a power law relationship. The volume of grid export was also impacted by the BESS capacity, as might be expected. However, the trend was not absolute, it being disrupted by intra-day consumption behaviour. In this manner a dwelling with continuous daytime occupancy could reduce grid export of a dwelling of similar production and consumption, higher BESS capacity but no weekday, daytime occupancy.

BESS round trip efficiency (RTE) was influenced by annual consumption. As this figure fell below 4,000kWh pa, BESS RTE tended to fall below 70%. The average RTE of the fleet was found to be 70.3% (ranging from 50-81%), with this average figure being significantly lower than the manufacturer's estimates. RTE was heavily influenced by the charge/discharge power levels, with lower power levels on discharge prevalent in low consumption dwellings.

Dwelling could loosely be clustered by production and consumption levels, with respect to total savings from BESS & PV. Dwellings with PV production below 2400kWh pa typically returned the lowest total value (<£250). Dwelling with production greater than 3400kWh pa and consumption greater than 4000kWh typically retuned the highest value (>£400) with other dwellings placed in-between these two clusters. It was possible to predict with good accuracy the total value of the BESS & PV solution using the equation; $TV_{P\&BESS} = 0.052 * P^{0.0935} * C^{0.141}$. The subsequent linear relationship between forecasted and estimated $TV_{P\&BESS}$ had a coefficient of determination [R^2] value of 0.99 indicating a high degree of fit. Errors in the forecast tended to occur in the middle cluster of dwellings where the influence of inter-day behaviour was less swamped by either low/high production or high consumption.

Residential energy demand is influenced by seasonal, daily and stochastic variation. Seasonal and daily variations can be heavily influenced by external weather conditions, day of the week and habitual practices that might be inferred from household meta-data. However, the presence of a stochastic element makes prediction of inter-day consumption patterns that might influence BESS performance difficult and as a consequence only weak predictor variables were found. A larger dataset would be required to allow better characterisation of demand patterns and their subsequent influence on BESS performance in self-consumption operating mode.

LEM Residential BESS Utilisation Summary Report

The BESS Utilisation summary report quantified the energy utilisation of BESS at each participating site in the LEM residential trial when operated in self-consumption control mode. This also allowed the headroom capacity, not utilised for self-consumption to be quantified. A methodology was developed for assigning economic value to this headroom using arbitrage based on a published, dynamic, half-hourly data-set of time of use tariffs for the operating period. The impact of varying how BESS capacity that was apportioned between self-consumption and arbitrage was then explored to understand its impact on BESS economics. The extent to which an economic or operational performance case could be made for increasing BESS capacity at each site was investigated alongside comparison with an alternative option of deploying a community-scale BESS. The impact of these on individual dwelling CO_2e emissions was also considered.

The energy utilisation of BESS systems deployed in the LEM trial, when operated using a self-consumption control signal, returned a fleet average of 63%, ranging from 33%-90%. Energy utilisation for a given site can be approximated using estimates of Production Surplus and Production Deficit. Significant stranded capacity is therefore present in almost all sites with commensurate impact on BESS economics. Power utilisation, defined as the average power level when charging or discharging divided by BESS rated power was found to be significantly lower than energy utilisation, with fleet averages of 26% and 17% for charge and discharge respectively. Round Trip Efficiency (RTE) was found to be influenced by charge and discharge power utilisation. This is expected and is consistent with part-load efficiency curves that occur in any electronics that have been designed to meet rated power capacity.

A methodology was proposed for investigating headroom using confidence intervals that allowed quantification uncertainty to be evaluated by time of day, between seasons (winter, summer, shoulder), and within each season. This was also able to explore the proportion of BESS energy capacity that has to be reserved to achieve maximum available self-consumption and how this can be traded to provide additional headroom for monetisation.

A generic arbitrage approach was defined that used up-to 3 shifting events between 2 charge and 2 discharge time windows within each day. This illustrated how multi-objective BESS operation can increase BESS utilisation through multiple dispatch events within each day, whilst delivering economically optimal level of self-consumption. Using annual average time of use arbitrage values of £3/MWh to £87/MWh (per each shifting event), the headroom could be monetised to improve Total Value by 50%+ versus self-consumption, without appreciable detriment to self-consumption value. Further study is required to ascribe value to a definite contracting structure or trading approach, and to optimise reduced self-consumption vs increased trading; but the initial results suggest that more value can be unlocked.

The potential for increasing the BESS capacity over the value installed in the LEM trial was evaluated for 2 generic capacity upgrade scenarios; +2.5kWh per site (increases fleet capacity by 39%) and +5kWh per site (increases fleet capacity by

78%). Under self-consumption control, only a small proportion of this additional capacity is utilised and no commercial case can be made what so ever to justify the increase. Even when the capacity is monetised as headroom using the arbitrage procedure previously described still produced simple payback periods for the additional capacity that would exceed probably lifetime of systems.

A more persuasive economic case can be made for replacing discrete dwelling BESS with a community-scale system driven by the economies of scale that can be derived from load diversity. Using the confidence limit approach, it was found that a 10% reduction in BESS capacity (with commensurate impact on capital costs) would have <1% reduction on self-consumption value (this relates specifically to the 100-site fleet from these trials; a larger fleet could unlock greater potential for economies of scale). The impact on project economics may be significant, especially when considering the project mobilisation and ongoing support costs, as many 100's or 1000's of sites could be reduced to a single site. Further study is required to optimise any such sizing decisions against loss in headroom and any associated monetisation opportunities.

The impact of BESS on CO_2-equivalent footprint of the dwelling was found to be negative when compared to PV only technology deployment using a simplistic basis of displacing average grid emissions because of round trip efficiency (RTE) of the battery). In a similar vein to Time of Use tariffs, the opportunity for CO_2e arbitrage was explored, but the results clearly demonstrated that such arbitrage is of limited value, and insufficient to outweigh the losses attributable to the current fleet-average RTE of 70%.

Self-consumption operation and headroom dispatch opportunities could be leveraged to address network capacity and generation reliability constraints, allowing zero carbon renewables to be connected (or avoid constraint). When the charging electricity has a CO_2e intensity of zero, the round-trip efficiency is irrelevant from a CO_2e savings perspective; instead, the BESS should be credited with the annual generation that it enables to be connected to the network, and the attendant displacement of marginal generation (usually at grid emission factors 2-3x higher than current grid average). This aligns with the Green House Gas [GHG] savings methodology for flexibility assets (which applies to CO_2e) discussed in a related LEM publication[1].

It is worth noting that increased RTE is still an important aspiration, as it reduces losses and hence operational and embodied costs (financial, CO_2e and materials) that are associated with generation and network.

LEM Residential MetaData Summary Report

This document summarises the metadata datasets available across the fleet, where the distribution of properties in the fleet is described using pertinent combinations of metadata. The limited correlation demonstrated in the results highlights the difficulty in using metadata to predict consumption, and makes the case for easy access to historic metering data.

A Data Dictionary describes the purpose of each column of each dataset, and the coverage of each metadata dataset is described; all datasets cover less than 100% of the fleet.

Household electrical consumption and Solar PV production data collected during the trial is compared with the data and estimates collected/made during questionnaires, surveys & design, in order to assess the effectiveness of Sizing Assumptions. The results reinforce the value of metering data and of effective survey to predict solar PV production.

LEM Residential Data Dictionary

This document summarises the measurement and forecast datasets available for BESS, Solar PV, consumption and grid supply. A Data Dictionary describes the purpose of each column of each dataset, with associated code to recreate the tables in a PostgreSQL database. The Data Coverage Summary section, the coverage of datasets across the fleet of 100 sites is summarised, with coverage of 12-19 months ending on 31st March 2020.

[1] "Accounting for GHG Abatement in the Cornwall LEM Project", D. Parish, Centrica PLC, Cornwall Local Energy Market project, 26/10/2020