Trilemma Consulting
Delivering Technology Innovation with Insight

Cornwall Local Energy Market Residential Project

A Whistle-stop Tour

Knowledge Exchange and Stakeholder Sign-off Event

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Residential Project Workstreams

Selection	• Vendors & technologies: Considered BESS, smart storage heating and EV charging • Participants: Web Questionnaire, Desktop & Physical Surveys • Systems: PV Design & BESS Sizing
Installation & Support	• Installed 100 BESS: 54 dc-coupled (new PV) & 46 ac-coupled (existing PV) • Installed independent monitoring system [IMS] (grid, BESS, PV & Major Loads) • Regular quality assurance of BESS, PV & IMS operation
Integration	• Supported development & test of Sonnen's Virtual Power Plant [VPP] platform • Integrated Sonnen VPP with Centrica's in-house aggregation platform • Independent Monitoring System to support flexibility trading decisions & FFR pre-qualification
Testing	• Dominated by un-restricted Self-Consumption operation • Delivered flexibility as contracted via LEM Platform • National Grid FFR pre-qualification and pilot delivery
Reporting & Analysis	• Site-specific Participant Annual Savings Report • Participant Event • Studies on performance, sizing & headroom

Publications Available Soon

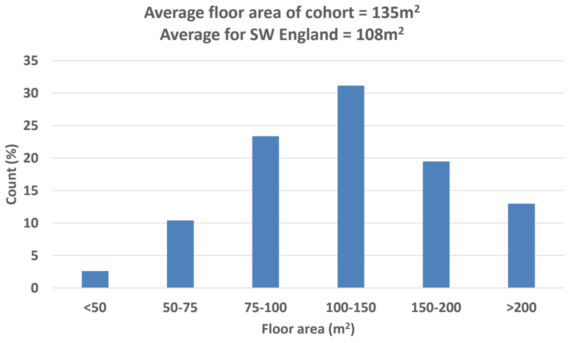
- **LEM Residential Fleet Self-Consumption Summary Report:** Analysis of baseline, PV-only and BESS+PV system performance
- **LEM Residential BESS Utilisation Summary Report:** BESS utilisation and VPP dispatch headroom under various sizing scenarios, with associated cost and CO_2 impacts
- **LEM Residential Data Dictionary:** Description of system performance monitoring datapoints, and associated data coverage summary
- **LEM Residential MetaData Summary Report:** Description of metadata datapoints, and associated metadata coverage summary
- **Public-domain Datasets:** System Performance and Site Metadata

Today’s Whistle-stop Tour

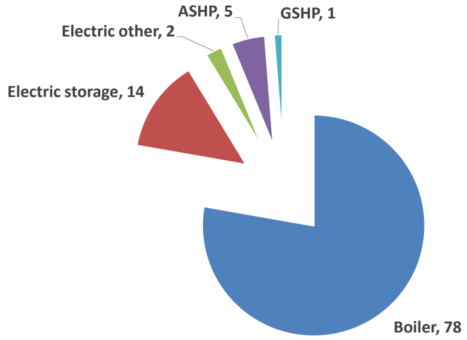
- Meet the LEM Residential Fleet
- Learning 1: The Role of Smart Metering
- Learning 2: Options to Improve Financial Returns of BESS
- Learning 3: CO_2 savings from residential BESS: a VPP perspective
- Conclusions

Meet the LEM Residential Fleet

Meet our Participants – a diverse bunch!



Floor area distribution



Heating system type

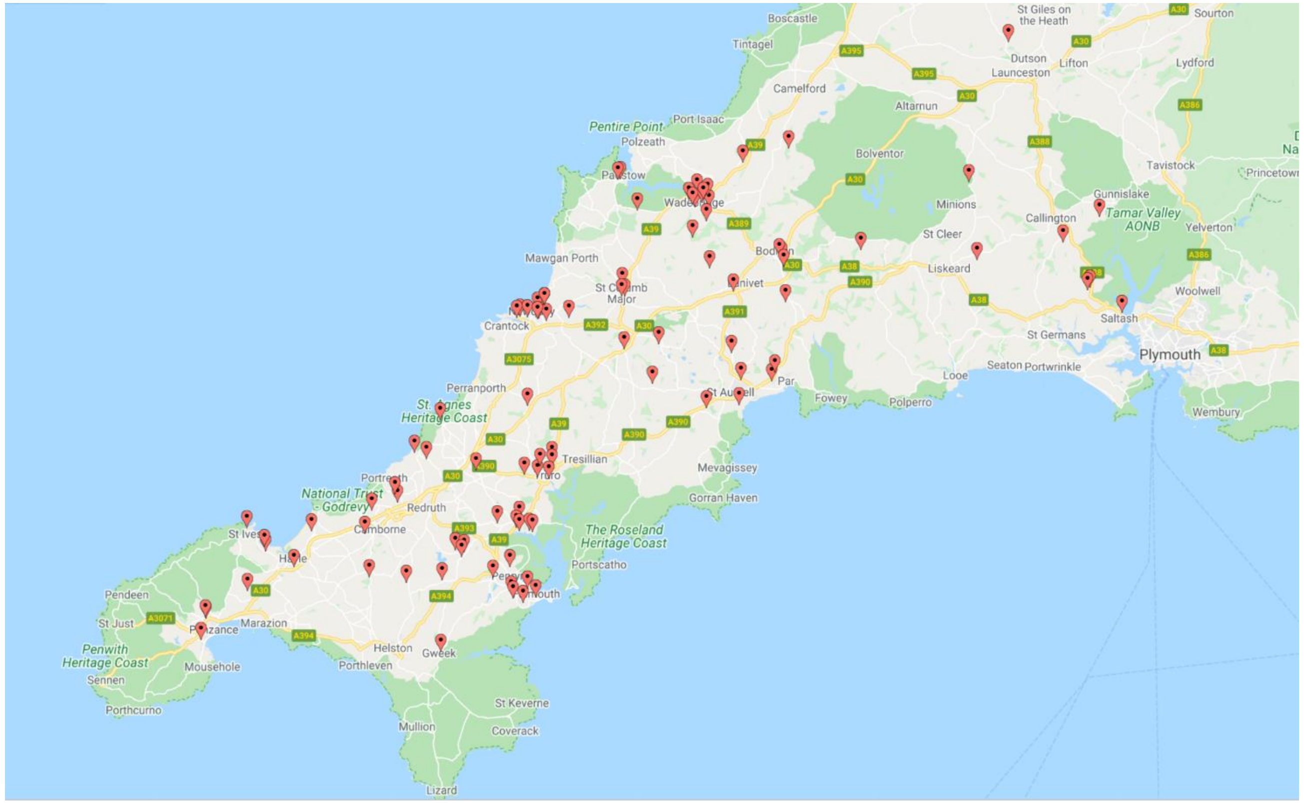
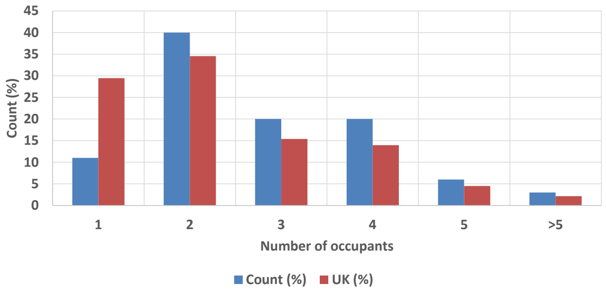
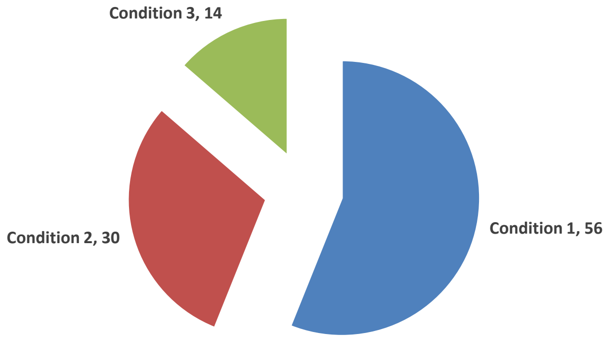


Figure 1: Locational map of participating dwellings



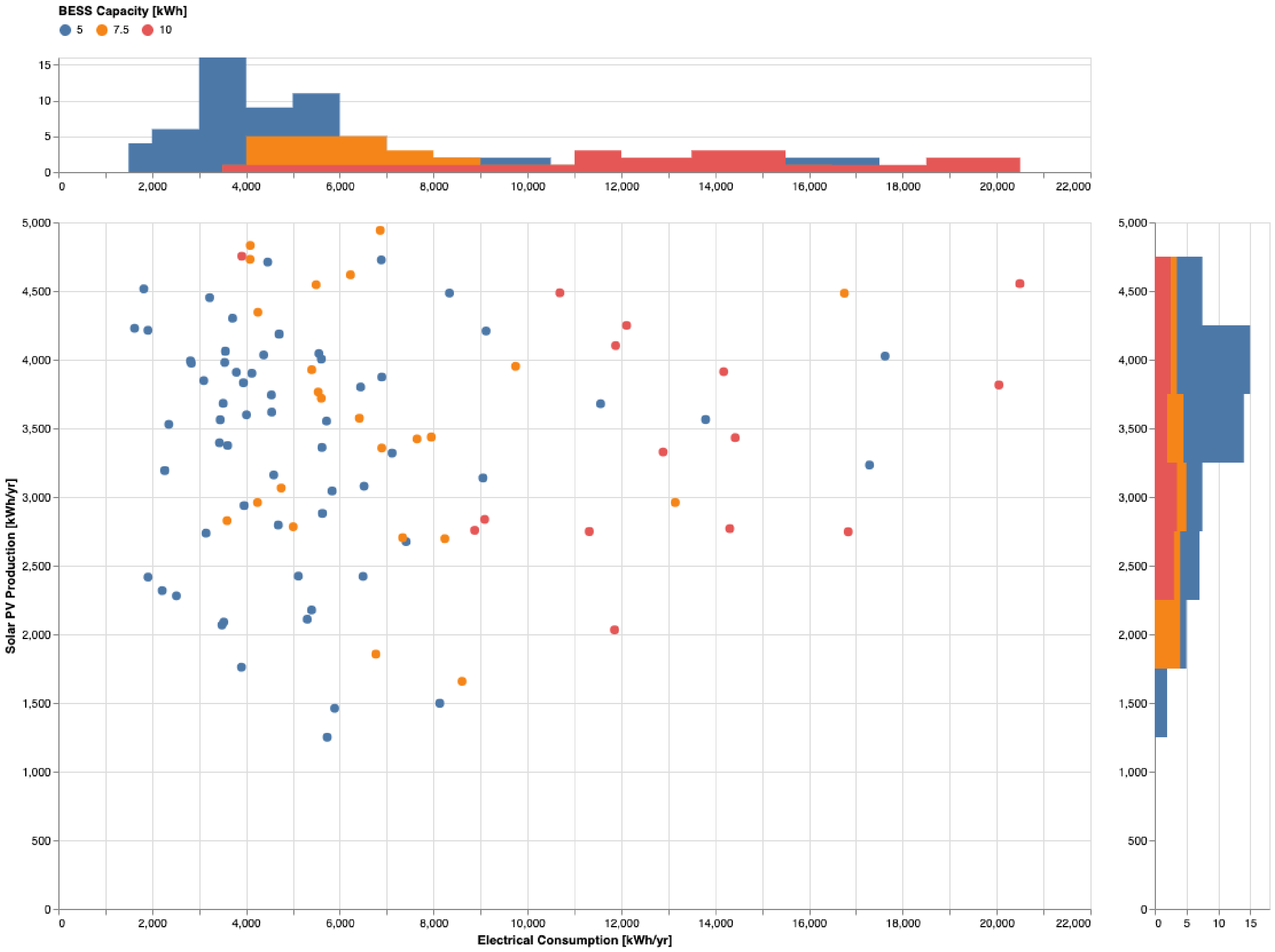
No of occupants per dwelling



Daily occupancy pattern

- Diverse Building Sizes & Heating Systems
- Dispersed installations
- Range of household sizes & Occupancy Patterns

Wide spectrum of Annual Consumption & Generation



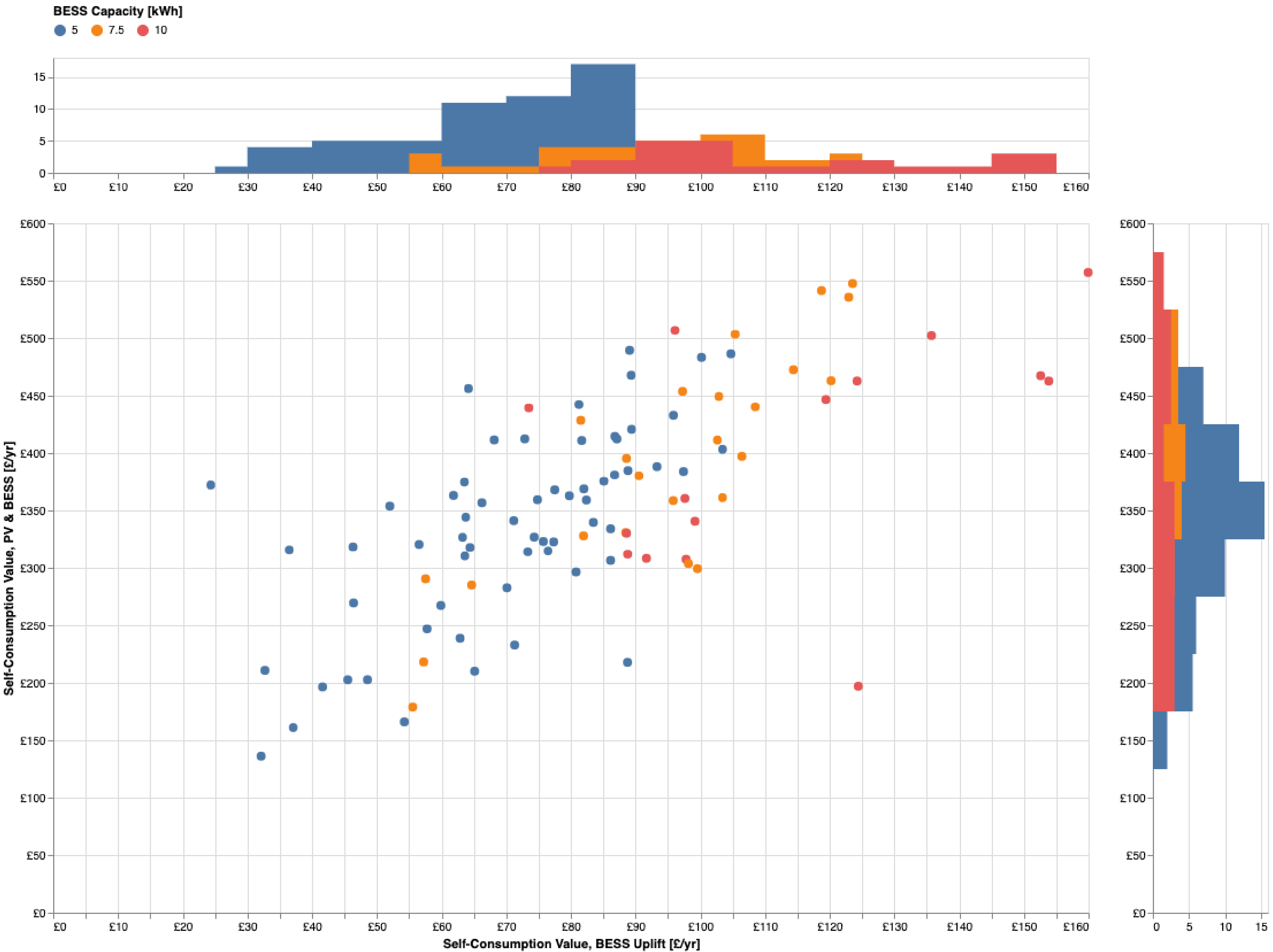
- 6 groups in the fleet, by BESS Type & Capacity
  - ac or dc-coupled
  - 5, 7.5 or 10kWh

Type	5kWh	7.5kWh	10kWh
ac	31	7	8
dc	30	17	7

- Significant spread in annual consumption & production in each group

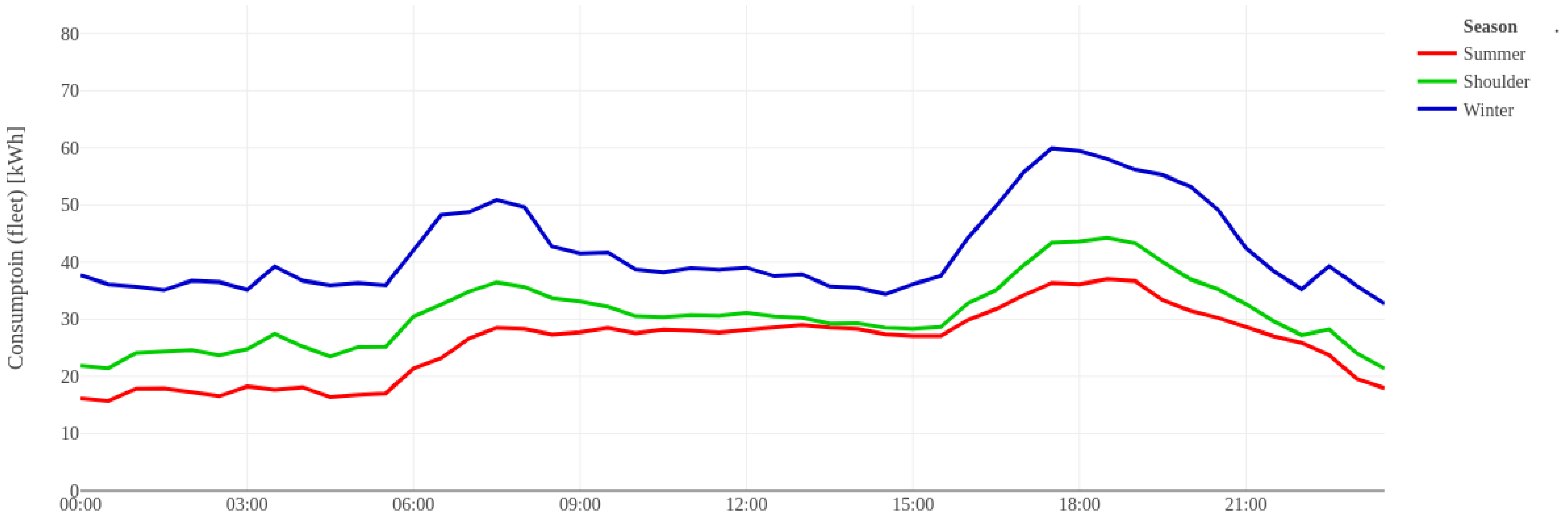
Learning 1: The Role of Smart Metering

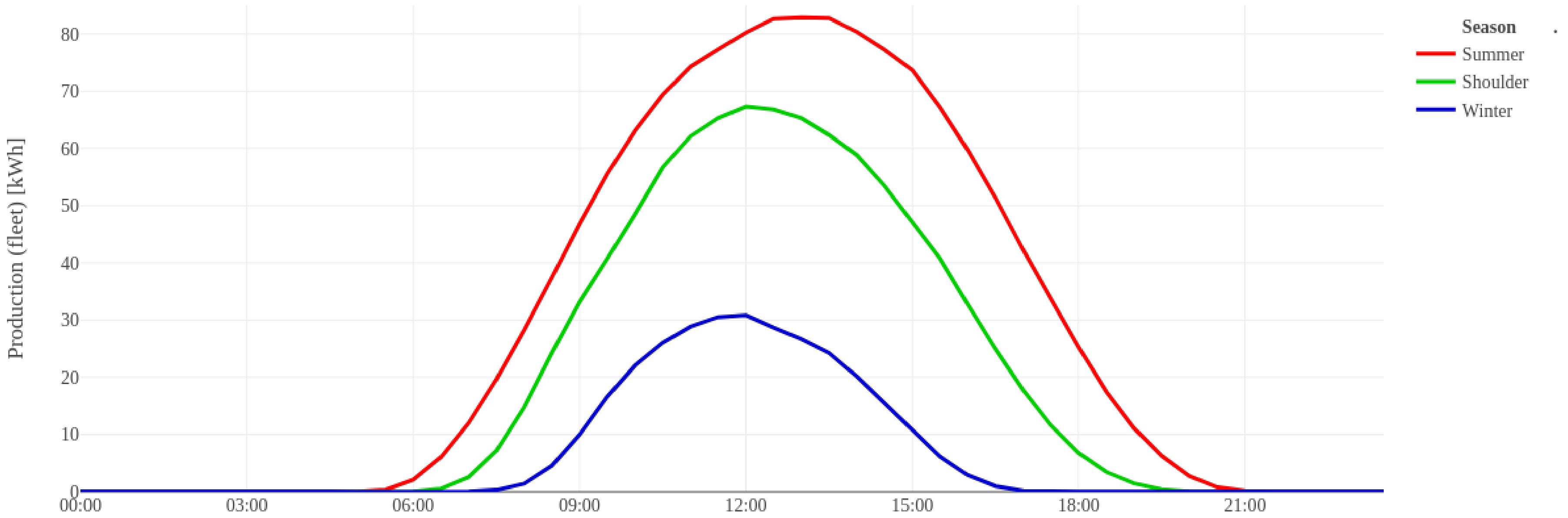
Total Financial Value from self-consumption



- Total Financial Value from Self-Consumption:
  - Import avoidance
  - Export income
- Value Driven by:
  - Production
  - Consumption
  - Profiles, not annual values
- Incremental Value of BESS
  - Increased import avoidance
  - Reduced Export income
- Marginal Benefit unless you monetise headroom via:
  - Time-of-Use arbitrage
  - Trading & Grid Services

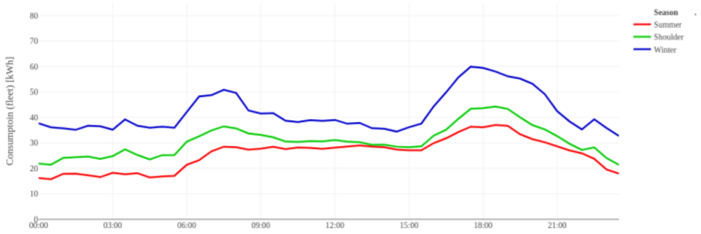
Seasonal Average Production & Consumption





- Annual data hides
  - Variation by Season
  - Variation by HH
- Predicting BESS utilisation is difficult
  - Limited effectiveness of sizing calculations
  - Uncertain savings
  - Low confidence in available Headroom (for trading/flex)

Understanding Production Surplus & Production Deficit

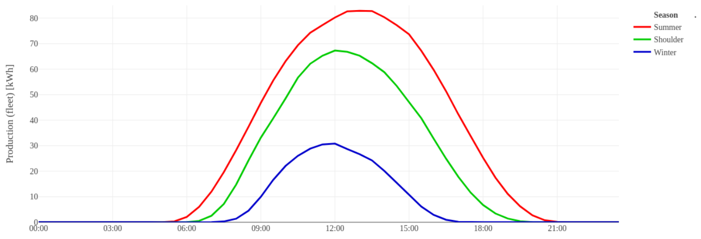


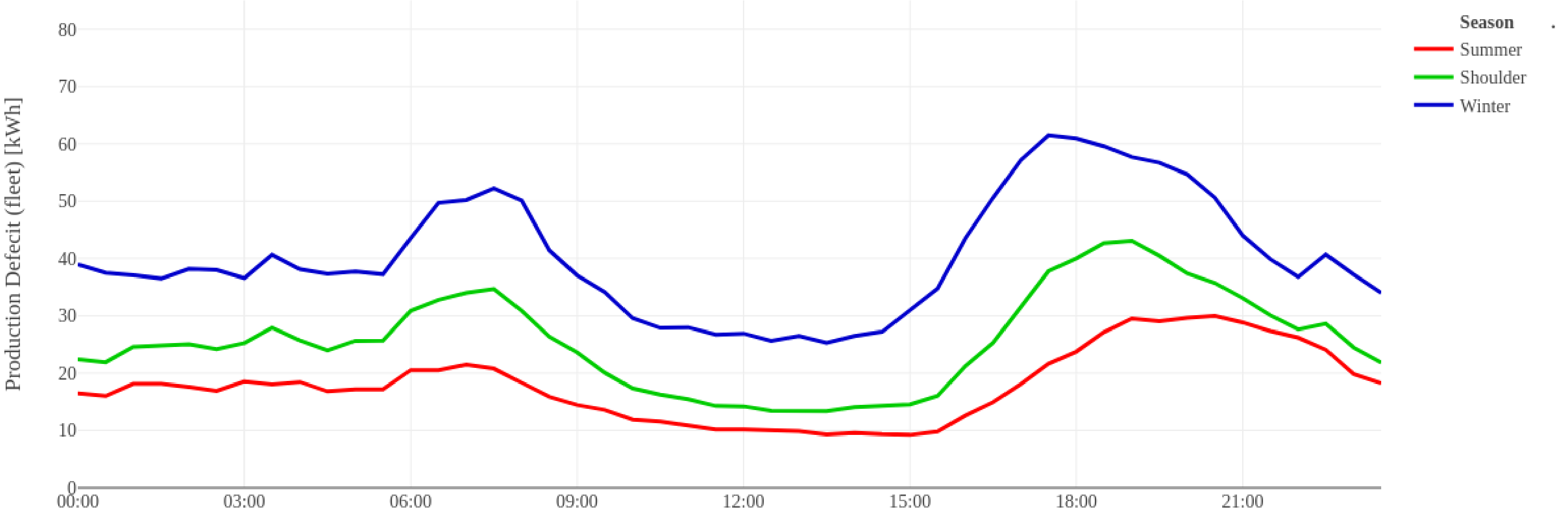
Production Surplus

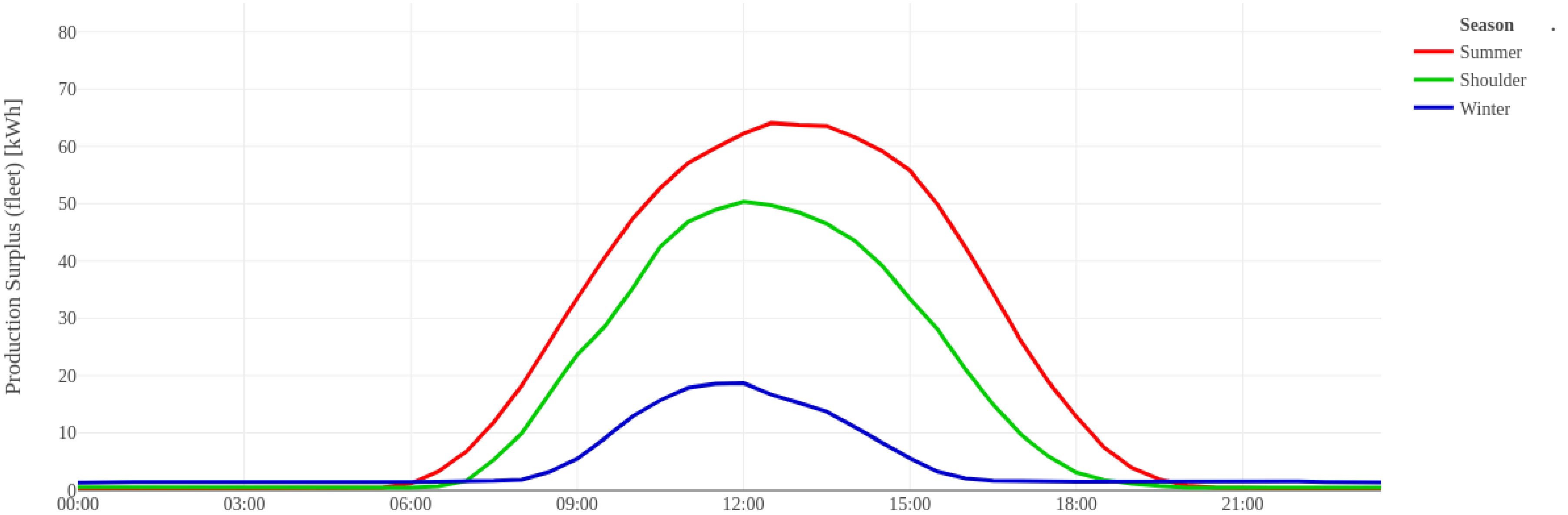
Production not instantly consumed on-site

Production Deficit

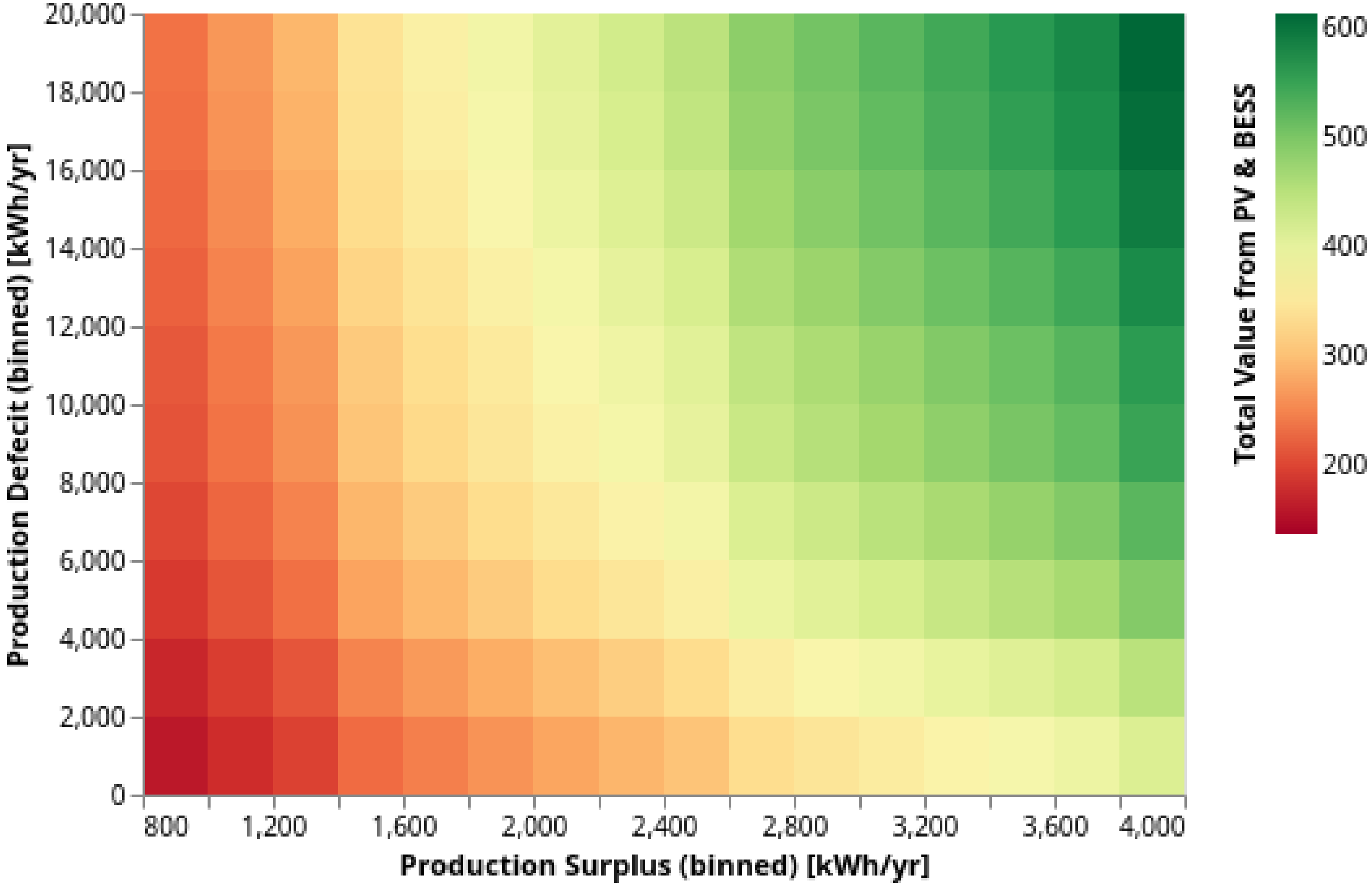
Consumption not instantly met by on-site production







Improving Value Prediction with Smart Meter Data



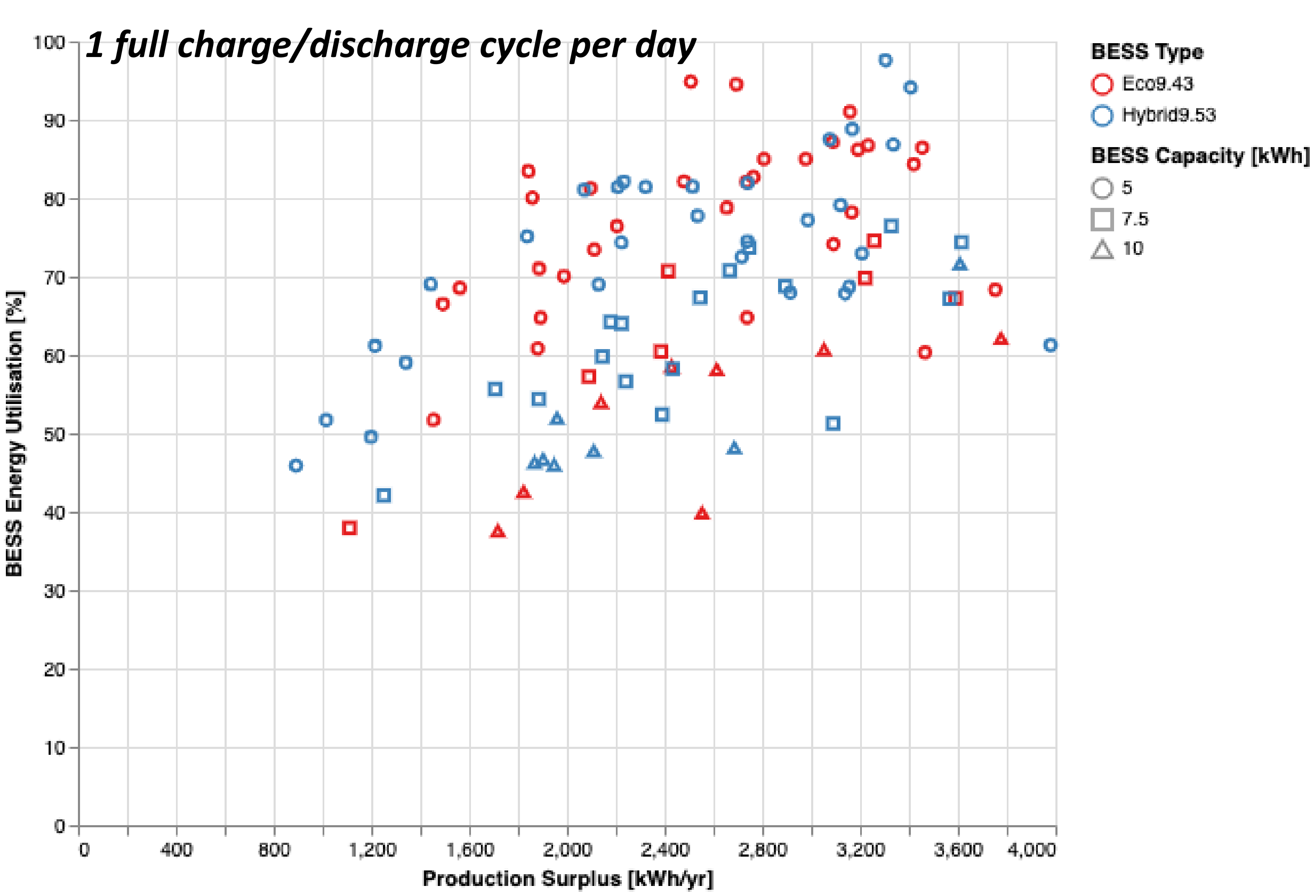
- Example uses half-hourly data
- Calculate production surplus/deficit every 30minutes
- Limited by the performance characteristics & BESS sizing of the training datasets
- Does not rely upon the "average" load shapes from the consumption & production training datasets
- Further improve accuracy with time-of-use tariffs or other price signals

Advantages of Smart Metering

- Data Availability pre-deployment could aid several stakeholders:
  - Savings prediction for consumer (from self-consumption and/or trading)
  - Assessment of headroom value for a Virtual Power Plant operator
  - Effective sizing algorithms; reduce CAPEX & improve RoI for asset owners
- Integration with BESS - avoiding duplicate metering - could improve the customer experience, and reduce costs:
  - Reduce hardware & install cost
  - Minimising physical footprint & installation disruption
  - Reduce installation or commissioning errors
  - Transparency of energy flows for billing & trading settlement
  - Minimise data collection costs

Learning 2: Options to Improve Financial Returns of BESS

Low BESS energy utilisation limits financial returns



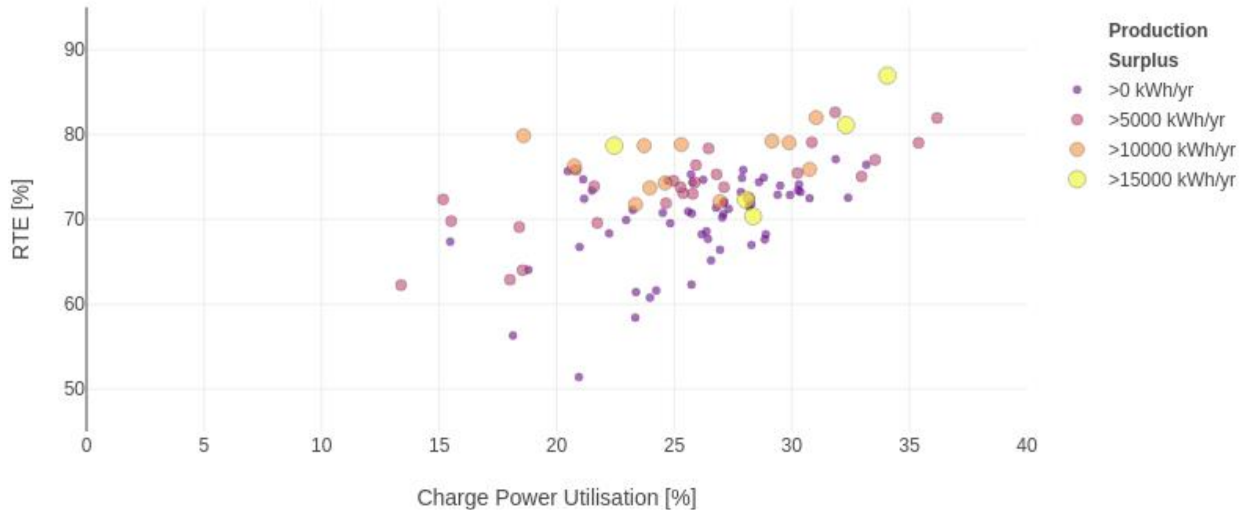
- Annual average: 0.4-1 full charge cycle equivalents per day
- Warranties could support >more than 1 cycle/day
- Driven by lack of production surplus
- Production surplus limited by Solar PV capacity
- Even with larger Solar PV, eventual Production Deficit will limit BESS Utilisation

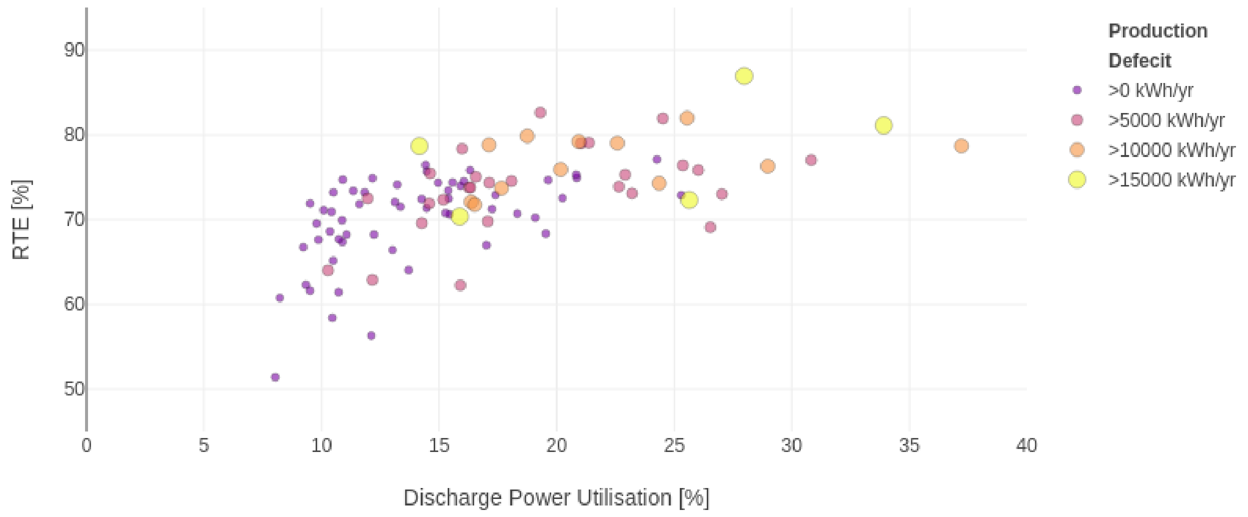
How do we limit Round Trip losses?

- Round Trip Efficiency [RTE]
  - Ratio of Discharge Energy to Charge Energy
  - Fleet Average was 70.3%
- Losses are primarily driven by the operating profile:
  - Parasitic Loads: control systems, user displays, metering, communications
  - Charging Losses: driven by varying Production Surplus
  - Discharging Losses: driven by Production Deficit / Consumption

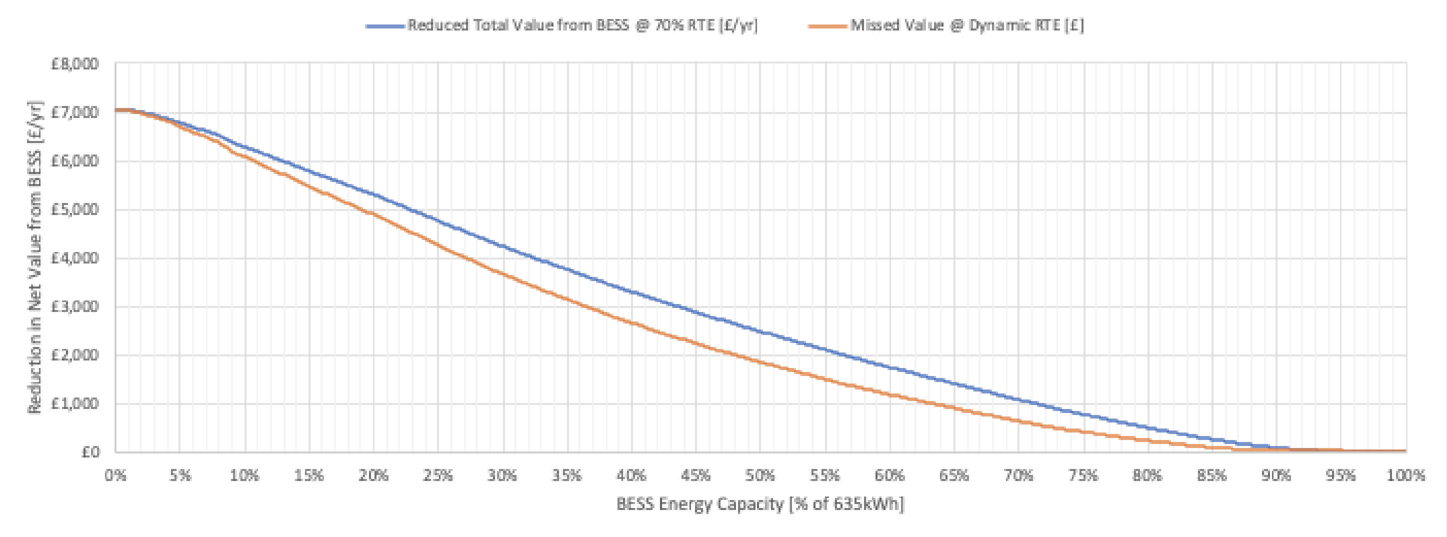
Options to improve returns:

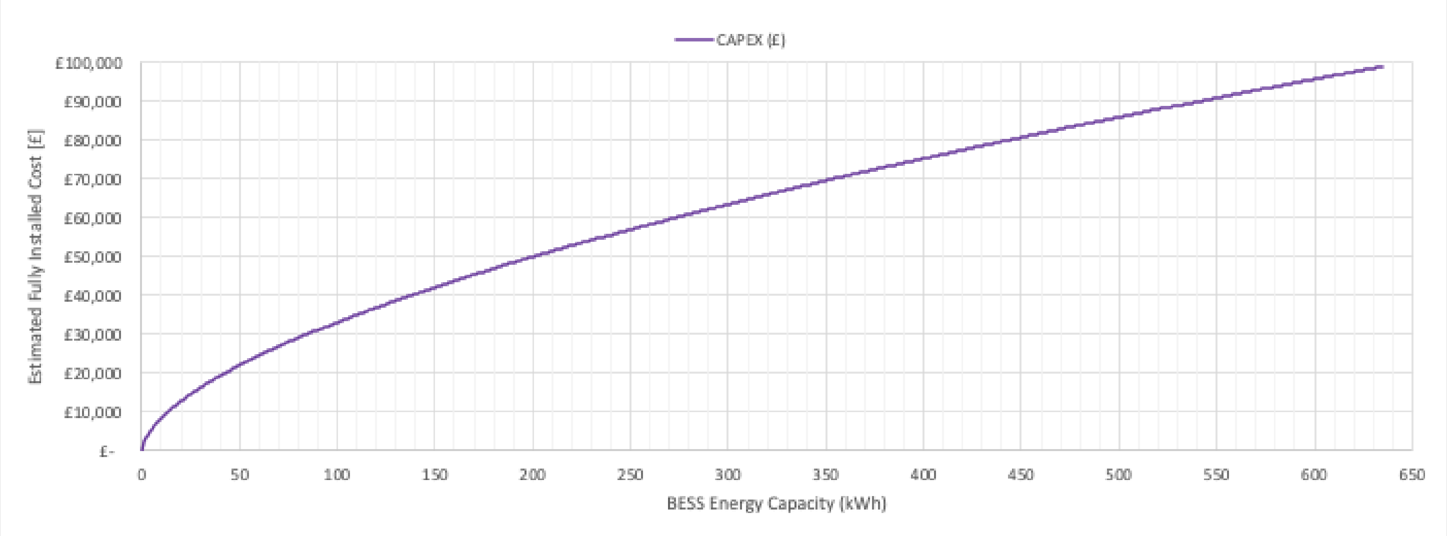
- Product development to reduce CAPEX & increase RTE; *which comes with monetary & time costs*
- Reduce sizing of dwelling-scale BESS; *limit headroom earnings with minor impact on CAPEX*
- Aggressive headroom trading; *headroom value needs to outweigh impacts on BESS cycling & lifetime*
- Community-Scale BESS to leverage diversity whilst reducing CAPEX; *regulatory hurdles*





Community-scale BESS: The trade off

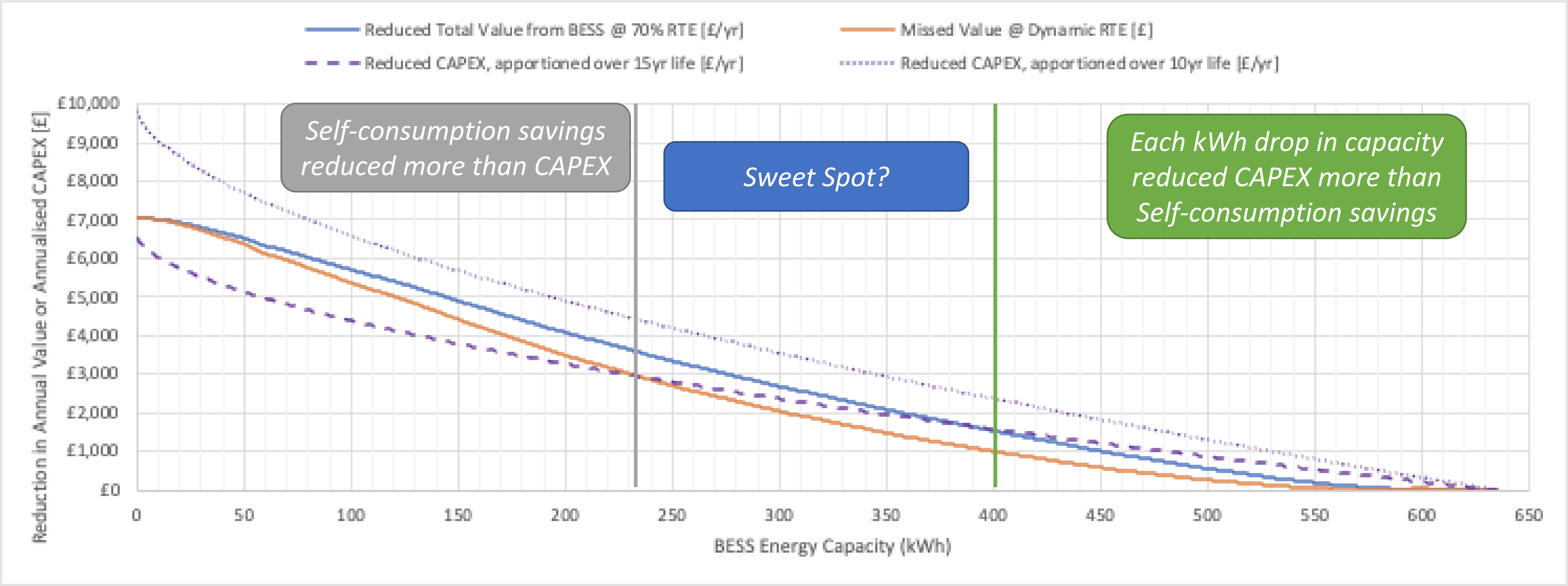




- Why downsize?
  - Increase BESS Utilisation
  - Improved RTE
  - Reduced CAPEX

BESS Resizing Factor	Energy Capacity [kWh]	Net Value	
		70% RTE	Dyn. RTE
100%	635	-	-
90%	572	£80	£20
80%	508	£500	£230
70%	445	£1,060	£630
60%	381	£1,740	£1,180
50%	318	£2,470	£1,840

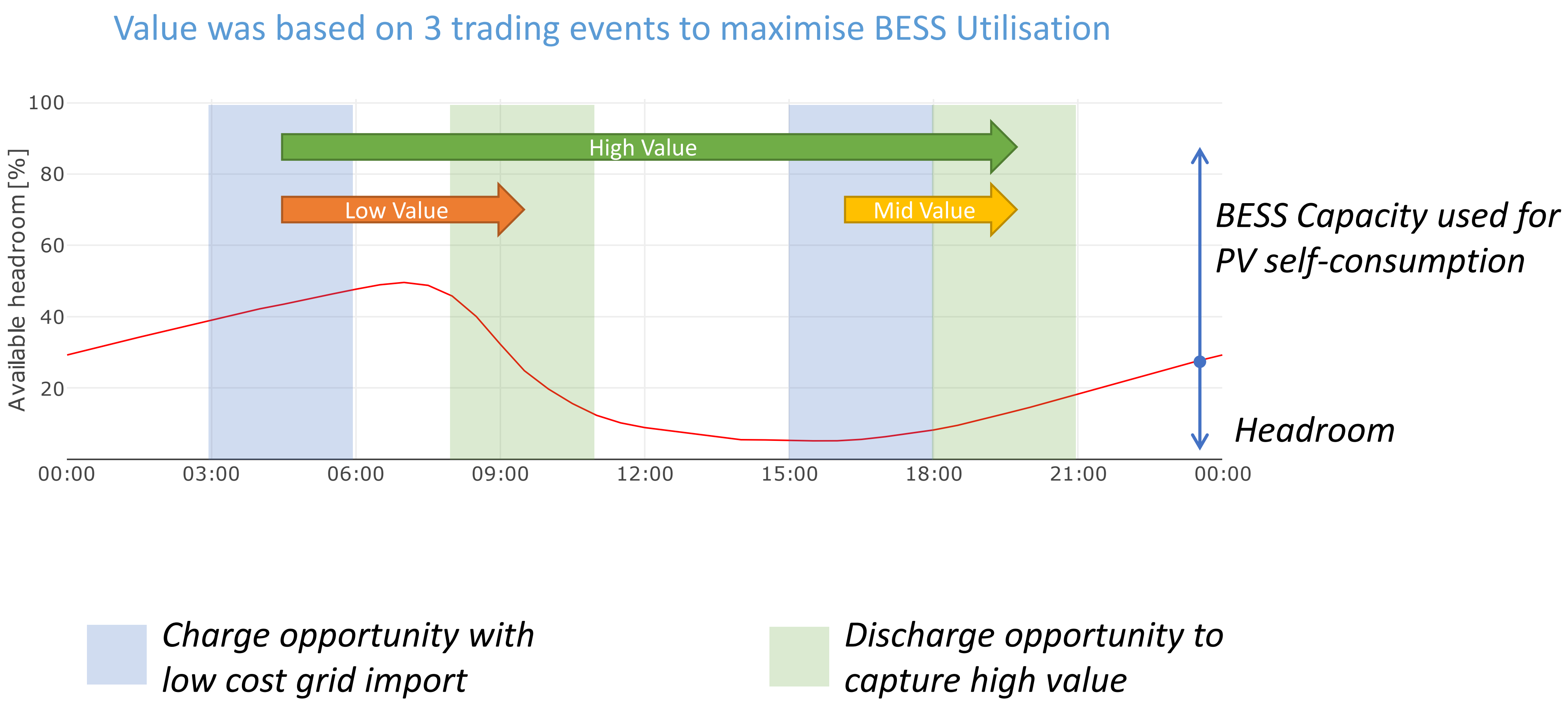
Community-scale BESS: Is there a sweet-spot?



Key Challenges:

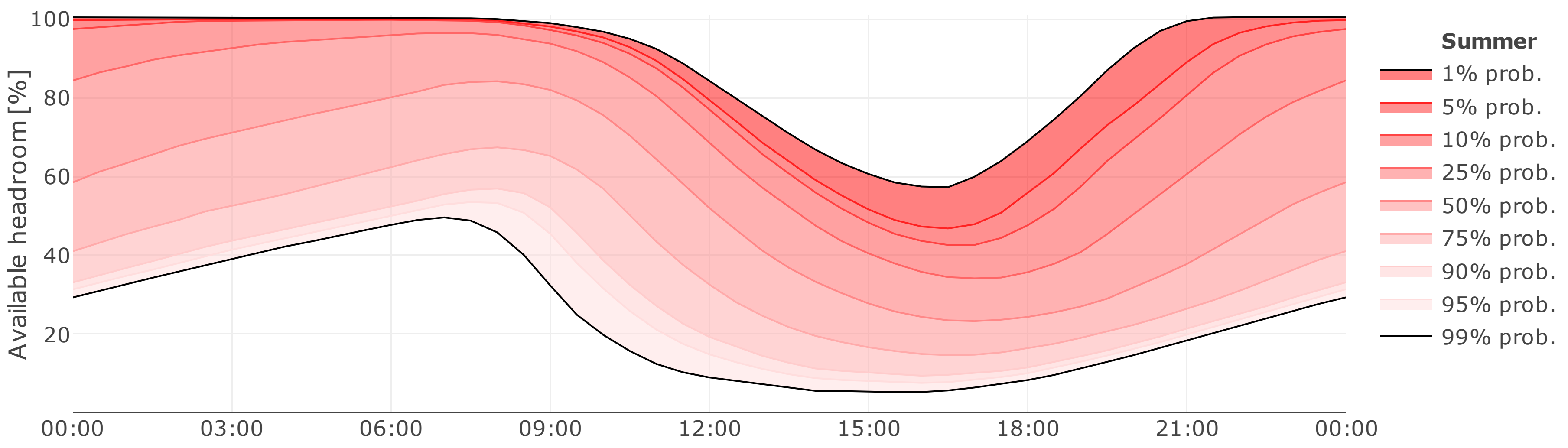
- Reduced Self-Consumption savings
- Reduced headroom for trading
- Regulatory hurdles

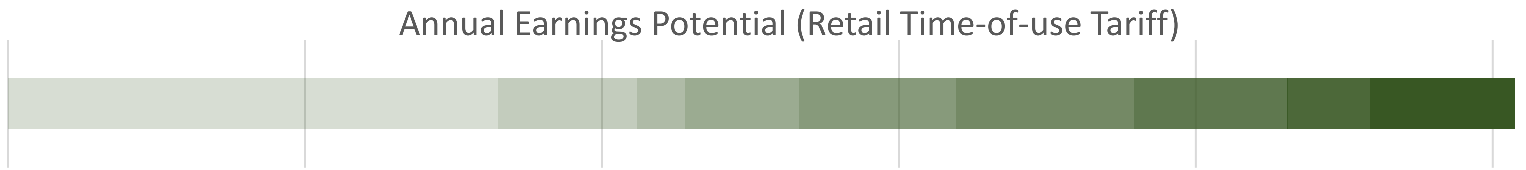
Leveraging Headroom to increase BESS Utilisation



Headroom: Confidence Level

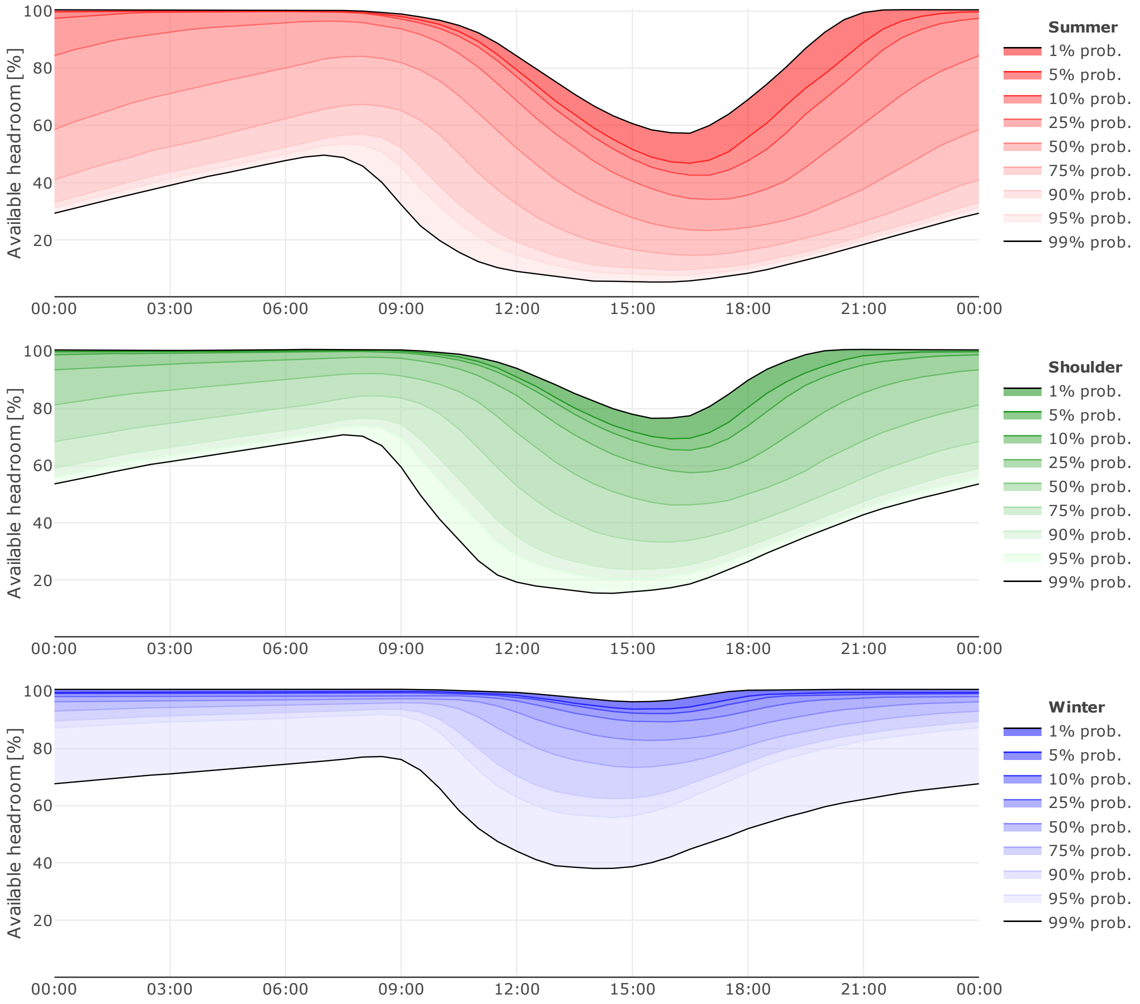
- Use confidence limits to determine the probability of headroom being available at different periods during the day
- Compute your trading value, here based on ToU arbitrage based on different confidence levels



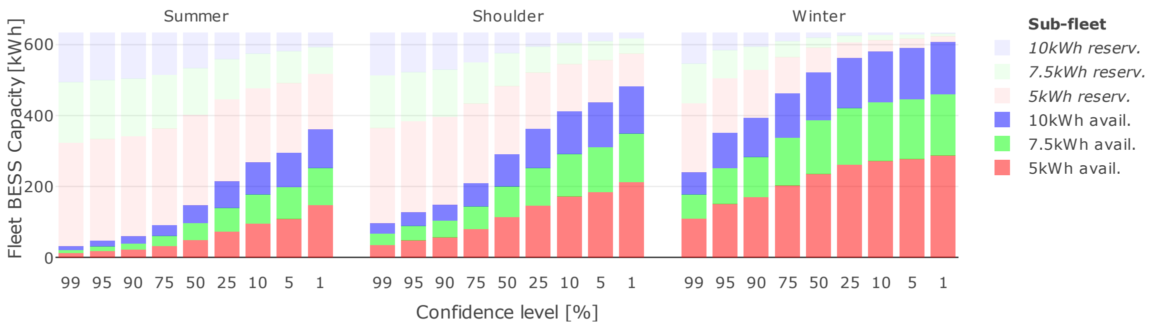


Annual Earnings (£/kWh Capacity)	£0	£5.00	£10.00	£15.00	£20.00	£25.00
Annual Earnings (5kWh batt.)	£0	£25.00	£50.00	£75.00	£100.00	£125.00
Annual Earnings (7.5kWh batt.)	£0	£37.50	£75.00	£112.50	£150.00	£187.50
Annual Earnings (10kWh batt.)	£0	£50.00	£100.00	£150.00	£200.00	£250.00

To unlock Headroom, aggregation is needed

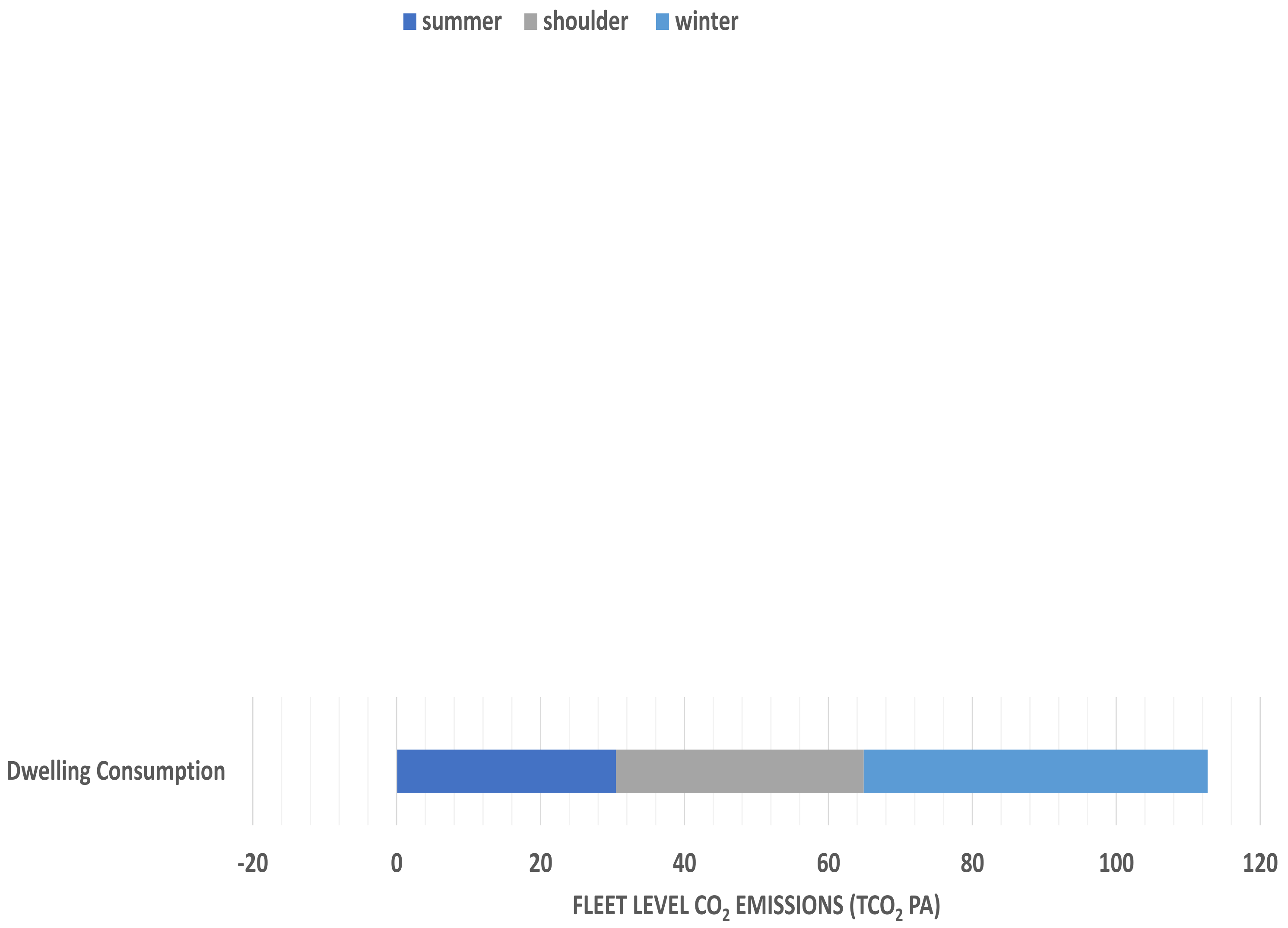


- The headroom profile significantly varies by season; a wide range of trading options may be required
- Using this confidence limit approach, it is possible to allow for significant self-consumption to occur whilst reserving significant capacity for arbitrage/services



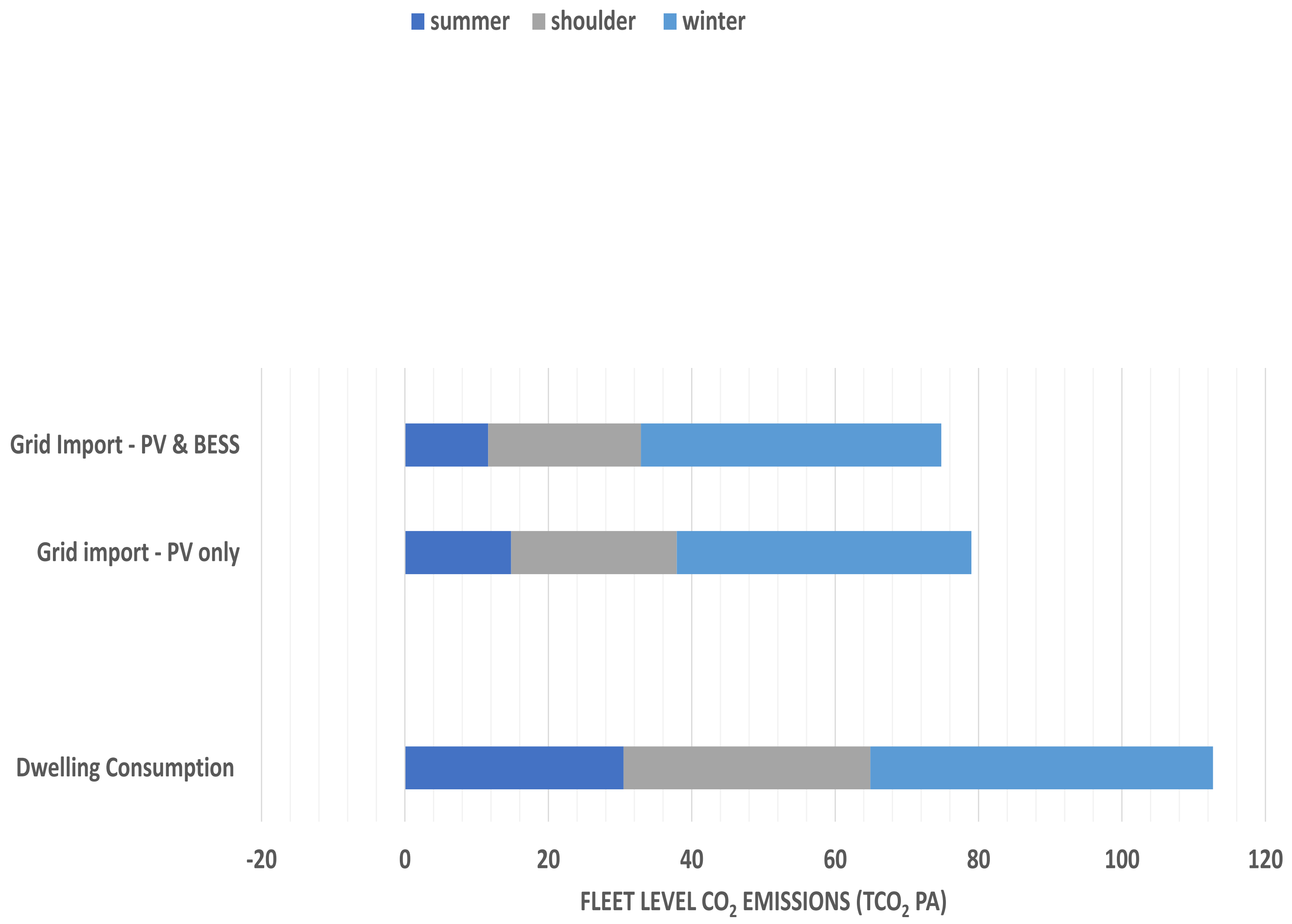
Learning 3: CO_2 savings from residential BESS: a VPP perspective

Fleet level CO_2 emission saving



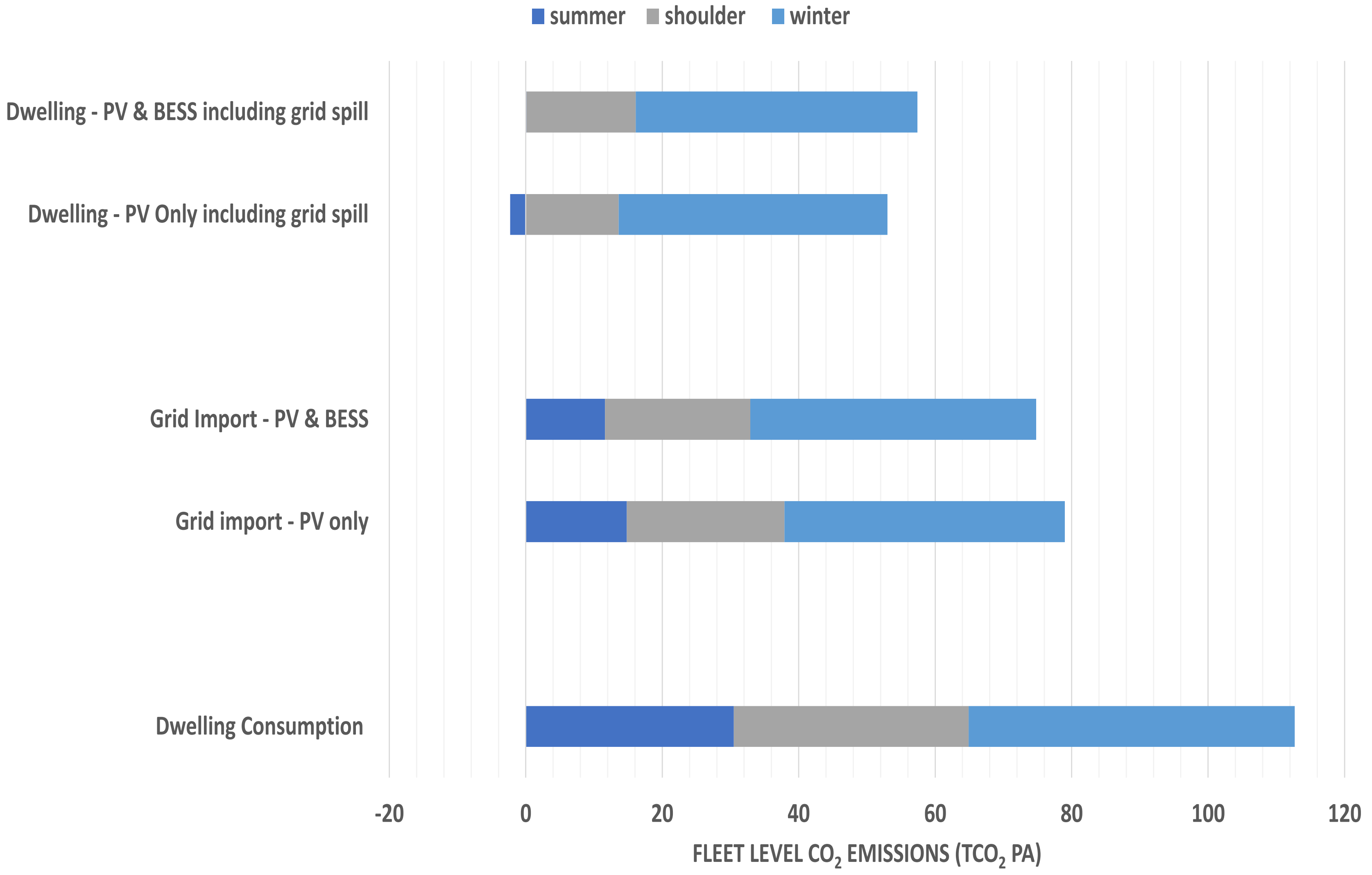
- Compute CO_2 emissions using 12 month data at 30 minute temporal precision.
- Use National Grid half-hourly GEF for period of analysis https://carbonintensity.org.uk/

Fleet level CO_2 emission saving



- Fleet CO_2 emissions attributable to grid import fall by c22% by the provision of PV and fall by c30% by the provision of PV&BESS

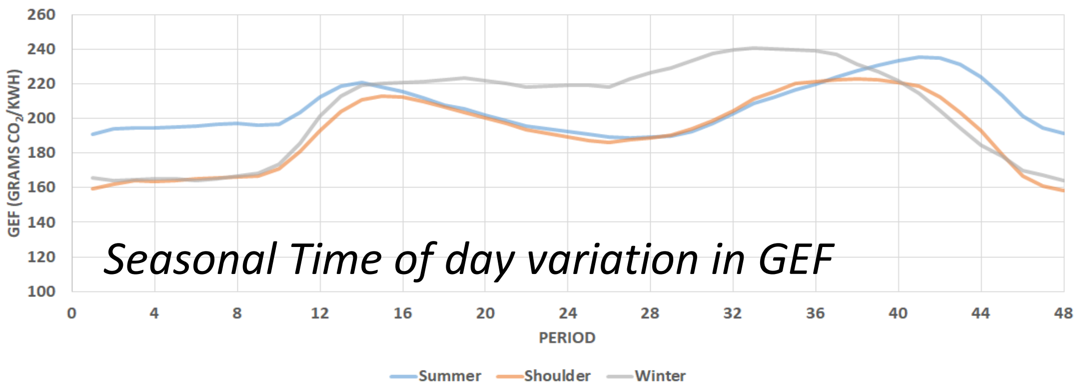
Fleet level CO_2 emission saving



- If net fleet emissions are computed, BESS increases emissions, because of energy losses (RTE = c70%)
- PV only reduction is c52% cf PV& BESS of c48%
- Dwelling CO_2 emission as computed using a SAP/EPC type approach are disadvantaged by BESS addition

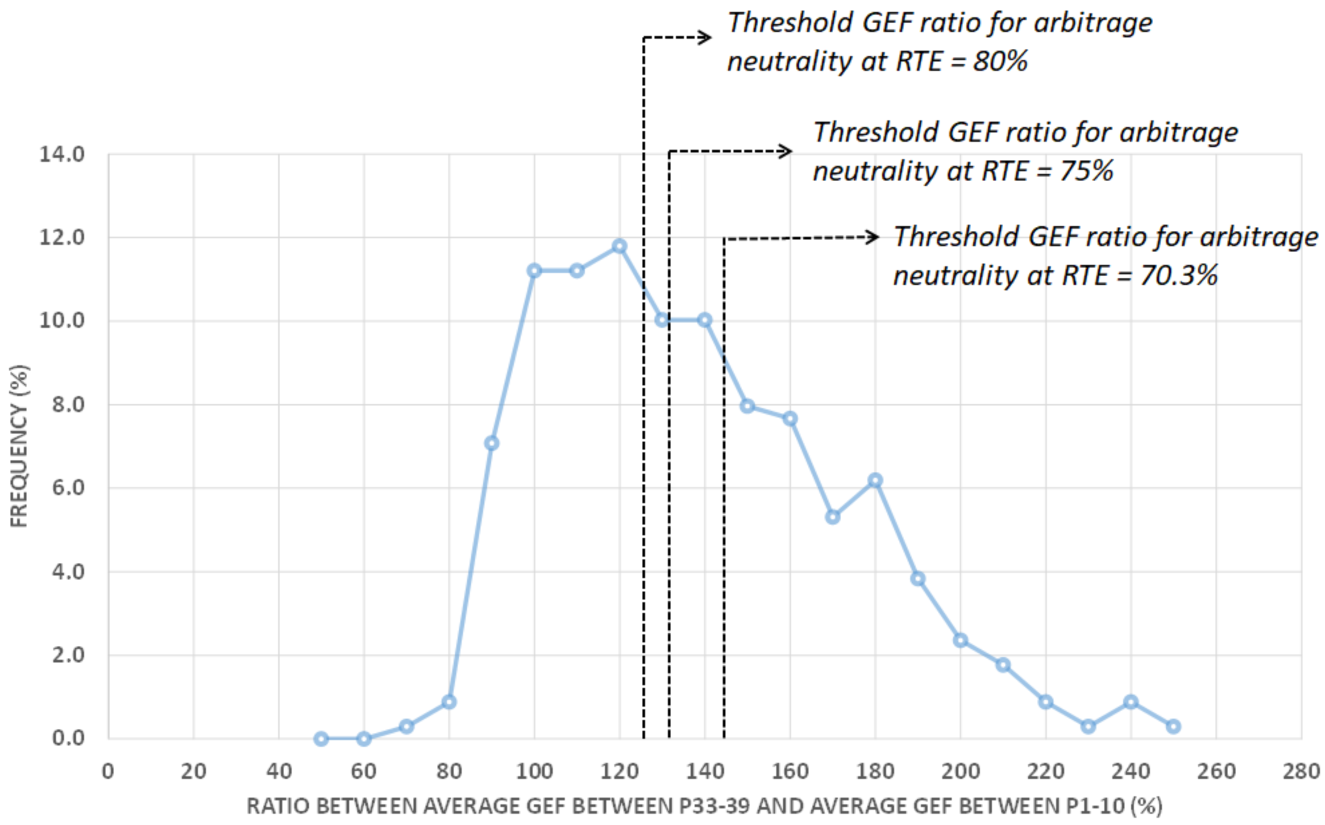
Time-of-Use CO_2 arbitrage

It is possible to evaluate the impact of 'CO_2 arbitrage', where charging at night at low GEF offsets import at evening during high GEF



- Have to question the validity of this type of carbon accounting for flexibility assets
- Emission savings is not at the level of the dwelling but rather at the level of grid
- Flexibility is permits access of VRE and reduced deployment of fossil fuel peaking plant
- System average GEF, even if time of use is perhaps not the best accounting metric

The number of days pa where CO_2 differential night to peak is large enough to overcome RTE losses is limited



Conclusions

Conclusions

- Combined self-consumption & trading revenue from behind the meter, residential BESS generates c£160-£200 pa on capital costs that are about 30x this value
    - Self-consumption only delivers £25-160 per year of net savings within the home

- Based on capital, efficiencies and utilisation, community-scale seems to make more sense than individual dwelling BESS
    - Individual dwelling may allow increased consumer participation and may deliver hyper localised flexibility

- Grid independence may be a key motivation for participants but it is neither tenable nor the purpose of the technology
    - Without high BESS utilisation, return of investment (financial or other embodied costs) is limited
    - Education and transparency are critical

- Access to temporally precise data (e.g. half-hourly Smart Meter data) is key to unlocking more optimal sizing, control options and understanding multiple intra-day trading/flex opportunities

- Revised carbon accounting methodologies are required that reflect how flexibility aids the low carbon transition