CrowdFlex: Alpha

December 2022

D5.1 - High Level functional specification for technologies to be deployed in CrowdFlex Trial sufficient to deliver "trial-services"

Strategic Innovation Fund

ESO

ESO

Contents

1 Objectives and approach

The objective of WP5 is to outline the functional requirements of the ESO and DSO services chosen in D4.1, and match these with the capabilities of the technologies currently being considered in CrowdFlex. The outcome is to finalise which technologies are most suited to which services, and what derogations or adjustments to business-as-usual (BAU) will be needed to complete the trial effectively.

The services being considered are:

System operator	Trial service	Service type	Dispatch vectors
ESO	Balancing Mechanism	“Real-time”	Automated
ESO	Thermal Constraint Management	Day-ahead	Manual or automated
ESO	Demand Flexibility Service	Day-ahead	Manual or automated
DSO	Sustain	Scheduled	Manual or automated
DSO	Secure	Day-ahead	Manual or automated

We are assessing Electric Vehicles (EVs), electrified heating systems, and white goods for participation in these services. Firstly, we will discuss the technological performance criteria of the ESO & DSO services; these may include metering, dispatch, and visibility, amongst others. We then describe the technological capabilities of EVs, electrified heating systems, and white goods. This will be in terms of the communications requirements needed, but also how their capabilities match up with the chosen services in terms of the technological performance criteria. Finally, we conclude the scope of technologies most suited for trial in CrowdFlex, and which adjustments to BAU need to be made.

2 Technical performance criteria of ESO trial services

2.1 Energy balancing via the Balancing Mechanism

Balancing Mechanism Units (BMUs) must meet two types of metering requirements for participation in the Balancing Mechanism (BM). Metering for settlement purposes and operational metering. Metering for **settlement** purposes is necessary to allow Elexon to undertake the accurate calculation of volumes necessary to produce BM unit cashflows, non-delivery charges, and imbalance cashflows, amongst others. **Operational** metering is required for the ESO control room to have real-time visibility of assets participating in the BM, but also provides better system modelling for the ESO. Historically, the requirements for metering have focussed on single large assets, as these have provided the bulk of balancing actions.

An agreed framework for cost effective metering of lower power assets to participate in the BM is not yet available. Recent developments towards creating this framework include modification P375[1] of the Balancing and Settlement Code (BSC), allowing for the settlement of secondary BMUs behind the site boundary point (i.e., asset level metering). There have also been developments to update operational metering for aggregated small assets (Section 2.1.2); however, these have not yet been implemented.

2.1.1 Settlement metering

The regulations for settlement metering are published by Elexon and were developed with Ofgem approval. As such, they are extremely rigorous and would require a derogation if CrowdFlex needed to navigate around them. The first barrier with settlement metering is that BMUs must be half-hourly (HH) settled to participate in the BM. Domestic consumers are overwhelmingly not HH settled, even when they are HH metered via smart meters. While the Market-wide Half Hourly Settlement (MHHS) Programme is currently working on reforming the market to shift all consumers onto HH settlement[2], this programme does not aim to reach completion until 2025. Therefore, HH settlement presents a clear barrier for entry for a CrowdFlex Trial beginning in Winter 2023. As such, any CrowdFlex Trial that aims to enter domestic assets into the BM will require a derogation from Ofgem to enable non-HH settled assets to participate alongside other BMUs in the BM. The details of this derogation are laid out in Section 4.4.

Metering for settlement is outlined in Codes of Practice (CoP) 1-11. These outline the accuracy, equipment and other criteria that meters need to fulfil. Relevant to domestic assets are Code of Practice 10[3] (CoP10) and Code of Practice 11[4] (CoP11).

- CoP10 defines the requirements of metering via low voltage circuits for boundary meters, thus relevant to household smart meters used in a CrowdFlex trial.
- CoP11 defines the requirements for the metering of assets behind a boundary meter. This is relevant for potential asset-level metering in a CrowdFlex trial.

CoP10 states that the accuracy required for boundary meters is defined by the Electricity Act 1989[5]. Outstations (equipment which receives and stores data from a meter for the purpose of transfer of that metering data) must comply with The Measuring Instruments Regulations 2016[6] (UK implementation of MID 2014/32/EU). SMETS 2 (Smart Metering Equipment Technical Specifications) smart meters do not require approval under BSCP601 “Metering Protocol Approval and Compliance Testing”, as their data format and protocol already fulfil these requirements[7]. SMETS2 meters fulfil the main requirements outlined in CoP10, yet a few additional requirements still need to be met in order to be HH settled[8]. Relevant to domestic contexts, these include displaying import and export kVArh, data storage requirements, time keeping and monitoring requirements, and others. As SMETS2 meters are currently being used for domestic metering, it can be

[1] Elexon, P375 ‘Settlement of Secondary BM Units using metering behind the site Boundary Point’, Accessed Nov 2022.
[2] Elexon, Market-wide Half Hourly Settlement, Accessed Nov 2022.
[3] Elexon, Code of Practice 10: The Metering of Energy via Low Voltage Circuits for Settlement Purposes, Accessed Nov 2022.
[4] Elexon, Code of Practice 11: Code of Practice for the Metering of Balancing Services Assets for Settlement Purposes, Accessed Nov 2022.
[5] Electricity Act 1989, Accessed Nov 2022.
[6] The Measuring Instruments Regulations 2016, Accessed Nov 2022.
[7] Elexon, Removing SMETS compliant Meters from the scope of BSCP601, Accessed Nov 2022.
[8] Elexon, BSC Codes of Practice and Smart Meters, Accessed Nov 2022.

assumed their accuracy fulfils the requirements set out in the Electricity Act 1989. The accuracy error permitted for single phase whole current boundary meters is: **±1.9%**[9].

CoP11 defines accuracy in two ways: metering accuracy, and metering equipment criteria. Both imply metering accuracies and therefore overlap. CoP11 outlines requirements for metering equipment within a Secondary BMU which is located behind a Boundary Point Metering System(s). There are five Asset Metering Types with varying requirements; domestic assets fall into **Type 5** – metering (embedded within equipment for energy transfers with a maximum demand of up to (and including) 100kW). The limits of error permitted for a Type 5 meter are **+2.5% to -3.5%**.

As such, SMETS2 smart meters and domestic asset meters are generally well suited to meet the settlement metering criteria imposed on them in the BSC. The primary barrier to entry that must be overcome is therefore that the need to be HH settled is yet to be rolled out for domestic customers.

2.1.2 Operational metering

Operational metering requirements are currently written for the metering of individual large-scale assets, i.e., >1MW assets, three orders of magnitude (1,000 times) greater than the focus of CrowdFlex (kW ranges). This poses a problem for domestic assets as there is a costly burden to provide compliant metering solutions across potentially hundreds or thousands of sites. As a result, the Power Responsive workgroup, which includes representatives from ESO, among other industry experts, is currently developing proposals to define operational metering on a portfolio basis for use in small-scale aggregated BMUs. Such proposals would be well suited for domestic flexibility. Operational metering requirements suggested by Power Responsive[10] include the overall accuracy of the aggregated unit, the frequency of data refresh of the aggregated unit and the associated latency. The proposed operational metering requirements for portfolios of domestic flexibility are defined in Table 1. This proposal has yet to be implemented operationally. Therefore, if CrowdFlex were to pilot it in a trial, it would require an agreement with National Grid ESO. Given, the reduction in data processing that the submission of domestic flexibility as aggregated BM units would provide the ESO, it is recommended that CrowdFlex pursue this approach in a trial via an aggregator.

Table 1: Existing BM operational metering standards and proposed standards for aggregated units.

Service Name	Aggregated unit size	Accuracy	Read Frequency	Latency	Resolution
Balancing Mechanism (current)[11]	>1MW	+/-1.0%	Once per second	≤5 seconds	3 decimal places (d.p.)
Aggregated BM units (proposed)[10]	>1MW & ≤10MW	+/-1.5%	Once per second	≤5 seconds	3 d.p.
Aggregated BM units (proposed)[10]	>10MW & ≤100MW	+/-1.0%	Once per second	≤5 seconds	3 d.p.

Even with this proposal for asset portfolios, while asset level operational metering is not required, the aggregate requirements will still need data fed by the assets. To achieve read frequency and latency standards, compliant meters will be required. These are more sophisticated than the meters currently installed in domestic contexts (Section 4.2.1). It is recognised by the Power Responsive workgroup that this may present similar barriers for domestic flexibility, as domestic asset and boundary point metering might not have the capabilities to meet these requirements, particularly the read frequency. Navigating the requirements of operational metering so that domestic metering is compliant should be less strenuous than settlement metering, as operational metering is defined by ESO, rather than Elexon. Any adjustment to operational metering would have to be agreed in a bilateral agreement with ESO, which for domestic assets would be the

[9] Schedule 3, The Meters (Certification) Regulations 1998, Accessed Nov 2022.
[10] National Grid ESO, Operational Metering Working Group Summary Session 2, Accessed Nov 2022.
[11] National Grid ESO, Technical Appendix (Appendix F5, Schedule 2) of Bilateral Connection Agreements, Accessed Nov 2022.

Bilateral Embedded Generator Agreement (BEGA)[12]. This would reflect the need for less stringent metering requirements of read frequency and implementing the submission of aggregated operational data. Even if operational data requirements are relaxed, the high frequency of real-time data submission will create a cost burden to the aggregator. The minimum BMU size is 1MW, which may include thousands of assets/households to aggregate into a single operational data stream, requiring significant computation. This cost is unlikely to be prohibitive, but more work is required to calculate the exact cost associated with aggregation and issuing dispatch instructions.

2.2 Thermal Constraint Management via a Day Ahead Service

2.2.1 Criteria for Thermal Constraint Management

A Day Ahead Thermal Constraint Management "trial service" would be a trial designed by CrowdFlex. Its aim would be to understand the potential for domestic flexibility to mitigate the curtailment of renewables and redispatch of thermal generation to resolve constraints via manual and automated response, dispatched a Day Ahead of delivery. As such, the technical performance criteria for participation could be designed with domestic assets in mind to ensure they could participate. Based on previous work completed by the ESO and DSOs to design flexibility products for domestic assets (e.g., the Demand Flexibility Service and Sustain-H), half-hourly metering is the best approach to make as many domestic consumers as possible eligible for the service. This is because SMETS2 meters are HH metered by default. Therefore, additional customer permission is not required for meter data at a more granular level. As with other services such as Sustain-H, asset level metering should also be included to allow for greater eligibility of domestic consumers.

However, there are some specific factors to Thermal Constraint Management on the transmission network, raised by SMEs within ESO, that require consideration. Most important of these is visibility of the location of assets providing the service. The location of flexibility for Thermal Constraint Management is vital for two reasons:

- ESO need to ensure that when they dispatch assets to turn up/down demand they are on the right side of the constraint for the action, so that counterproductive actions are not called.
- ESO need to ensure that dispatching assets to turn up demand behind an export constraint does not cause further and new constraints behind the original constraint they were trying to manage.

Therefore, the service provider/aggregator of domestic flexibility will be required to aggregate at a GSP level to participate effectively in a Thermal Constraint Management service; this is far more granular than previous ESO domestic services (such as the Demand Flexibility Service, which is aggregated at a national level). This would require the flexibility provider to know the MPANs (Meter Point Administration Numbers) or the location (e.g., postcode) of the customer providing flexibility mapped onto the GSP. Nevertheless, aside from the level of aggregation required for a Day-Ahead Thermal Constraint Management service, the other requirements of such a service can be closely related to the Demand Flexibility Service, ESO's operational Day-Ahead service.

2.2.2 Demand Flexibility Service

As per the Demand Flexibility Service (DFS) Participation Guidance Document[13], to participate in the DFS, DFS Participants need to meet the following criteria:

- Be half-hourly metered, can be either half-hourly settled, or non-half-hourly settled,
- MPANs cannot be allocated to more than one Registered DFS Participant,
- Cannot form part of a BMU except a Supplier Base BMU,
- Cannot be providing any other ESO Balancing Service (including having a Capacity Market Agreement) or any similar service to any third party,
- Must be able to respond for a minimum of 30 minutes,
- 1 MW minimum DFS Unit size, up to 100 MW maximum DFS Unit size. Parties can register multiple units,

[12] National Grid ESO, Understanding Your NGESO Contract Offer, 2020.
[13] National Grid ESO, Demand Flexibility Service Participation Guidance Document V.4, 2022.

- Be able to respond to an instruction for day-ahead delivery,
- DFS Units can be aggregated on a national basis.

The DFS was designed with domestic flexibility in mind as the aim is to allow the ESO to access additional flexibility when national demand is at its highest. As such, the DFS should not present any key barriers for the entry of domestic flexibility in CrowdFlex and, alongside the Domestic Reserve Scarcity Trial (DRST), should be the basis of Day-ahead services trialled in CrowdFlex.

Figure 1 illustrates the timeline for the DFS dispatch process. Beginning with a weekly forecast of demand from DFS participants, the ESO will publish whether a DFS call is anticipated a Day-Ahead of delivery and confirm its requirement later in the day. Such a call can then be accepted by DFS Participants, who update their forecasts for the DFS period based on their expected response and then execute the delivery of demand turn down in real-time. Based on the consumption of participants in the DFS delivery period, participants are rewarded in a post-event settlement.

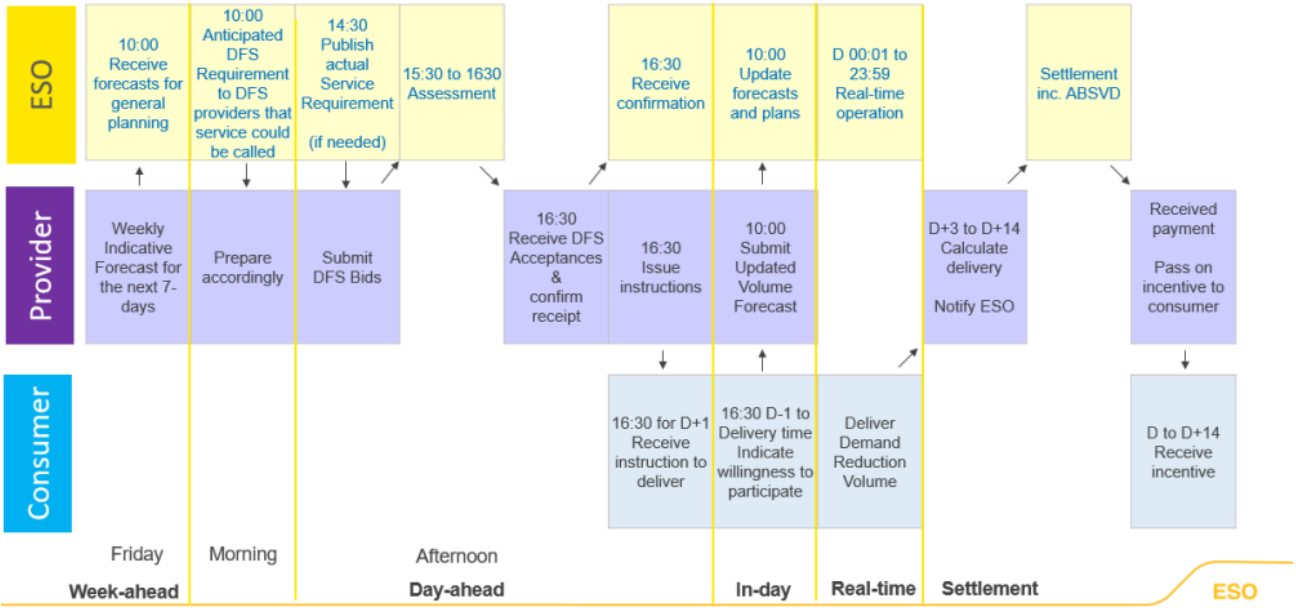

Figure 1: Timeline of the weekly process for the Demand Flexibility Service[13].

Such a process could be repeated for CrowdFlex Day-Ahead "trial services" such as a Thermal Constraint Management Service. There are, however, a few conditions for the DFS that CrowdFlex must be aware of and understand how they might impact CrowdFlex "trial services". They are:

- Participants must be half-hourly metered in order to properly assess delivery.
- Participants must be metered at MPAN (i.e., boundary meter) level. Therefore, at present, asset metering for the DFS is not possible for domestic assets. We would recommend that new iterations of the DFS service include asset level metering to enable greater participation of different customers.
- Participants cannot be providing any other ESO Balancing Services or be part of a BMU. CrowdFlex hopes to enter domestic assets into the BM and understand how this could stack with other services. Therefore, CrowdFlex would need an exemption from this criterion to stack energy balancing in the BM with the DFS.
- DFS Units can be aggregated nationally in the DFS. However, CrowdFlex will want to explore locationally dependent ESO services that will have to be aggregated to a more granular level, i.e., GSP/GSP Group.

3 Technical performance criteria of DSO trial services

3.1 Constraint management with Sustain-H

Sustain-H, like DFS, is a flexibility service designed with domestic flexibility in mind. Therefore, it's technical requirements for participation were specified based on the capabilities of domestic meters and assets. The requirement for metering for Sustain-H is for half-hourly resolution; however, flexibility providers are encouraged to submit data at higher resolutions where possible[14]. Sustain-H is agnostic to the level at which domestic flexibility is metered, accepting both asset-level and boundary metering.

- Boundary metered homes can submit the flexibility achieved from both their Low Carbon Technologies (LCTs) and whitegoods. This data can be submitted based on SMETS smart meter data.
- Asset-level metering only applies to the flexible response from the specific LCT metered. It is worth noting that NGED state "Asset-level metering does not provide a whole home view and so is less valuable to the DSO."[14]

Generally, Sustain-H accepts metering that is complaint with the PAS 1878 standard for energy smart appliances. Data is submitted to the DSO as an aggregated portfolio within each CMZ, and therefore the assets in each CMZ should be aggregated by the flexibility provider ahead of the submission each calendar month. NGED are considering options to improve the quality of data submitted for participation in Sustain-H. This includes incentives for higher resolution data and for data completeness.

As DSO services are only required on certain parts of the distribution network designated Constraint Management Zones (CMZs), Sustain-H is extremely location specific, and hence will require the flexibility provider to declare the location of participants down to High Voltage (HV) or in some case Low Voltage level.

3.2 Alternative to LMAs with Secure

Secure is another pre-existing DSO product like Sustain. However, unlike Sustain, which is a scheduled service, Secure is dispatched a Day Ahead of time based on distribution network constraint forecasts. Nevertheless, the reporting measures for Secure with SSEN appear to be similar to those of Sustain. As per the Flexibility Services Agreement document[15], Secure has half hourly performance metering that is submitted, like Sustain, each calendar month. Settlement is made based on this data. Requirements on accuracy state that metering is "with sufficient accuracy to enable the Company to monitor the provision of Flexibility Services". Therefore, it appears that PAS 1878 standards for energy smart appliances should be compliant with Secure when domestic assets are aggregated in a portfolio. Dispatch instructions are issued via the Flexible Power API[16]. Therefore, broadband/4G connected devices can be dispatched to provide flexibility when called upon.

Given this service is Day-ahead in nature, it could be applicable for both automated and manual assets. Therefore, it should be available for both dispatch vectors, encouraging automated assets to randomise their consumption time within a 24h period to introduce diversity in consumption onto the network and for manual response to shift their demand out of the peak period to further reduce demand.

As with Sustain-H, as a DSO service, Secure will be location specific at HV substation level and hence will require the flexibility provider to declare the location of participants down to HV level.

[14] Everoze, Sustain-H: Product Road Map, 2021.
[15] SSEN, Flexibility Services Agreement, Accessed Nov 2022.
[16] Flexible Power Participant API, Accessed Nov 2022.

4 High-level functional specification for CrowdFlex technologies

4.1 High-level schematic of communication capabilities required

4.1.1 Context

The provision of ESO and DSO flexibility services relies on the communication and performance metering between different technologies and parties involved. CrowdFlex is considering three domestic technology types to include in its trial:

1. Electric vehicles (EVs),
2. Electric heating (potentially heat pumps and resistance/storage heaters), and
3. White goods.

And two methods of dispatching these technology types:

- Manual.
- Automated.

In order to comply with the dispatch times set out for the “trial services” in D4.1 we have recommended that the “real-time” services focus on automated assets while “Day Ahead” or prescheduled services include both manual and automated response. By automation we mean the ability to dispatch or control a DSR asset (including but not restricted to an EV charger or a heat pump) via external signals, within some boundary of action such as a time-period or state-of-charge window, or flexibility on internal heated temperature. More generally, electrical assets that can share data, be pre-programmed, automated, or are broadband/4G connected and can be instructed by external signals via an API are referred to as “smart” assets, and it is all of these “smart” devices that we refer to.

In the future, as more LCTs are installed in households with “smart” capabilities, it will become easier to automate domestic flexibility by dispatching smart assets, i.e., instructing an asset to produce a demand response without involving the consumer (other than operating within the consumers pre-set limits and/or a manual override). Automating domestic flexibility could be an extremely powerful tool for increasing participation in domestic flexibility given the fast response time to a dispatch instruction it provides. However, the uptake of smart technology in the home is nascent, with the exception of EV charging and electric heat, where smart technology is more common. Therefore, CrowdFlex should also consider the manual provision of domestic flexibility using white goods as a resource that is available today, and at a much larger scale.

Installation of further hardware during a large-scale trial will lead to significant costs, be invasive for trial participants, and involve burdensome administration. As such it should generally be avoided. It is therefore important to assess the technologies currently available that will allow for participation in flexibility services. Furthermore, due to the existing high expenditure on the rollout of domestic smart meters in the UK, it is not advisable to develop domestic flexibility services that require further installations or replacement of metering equipment.

At a high level, the information signals from the ESO or DSO need to arrive at a household and instruct a change in electricity use, executed by either manual consumption change or automated dispatch. The change will need to be recorded and verification sent back to the ESO or DSO. In practice this will be done through an aggregator/aggregation service. The aggregators must therefore be able to combine and apply primacy rules to different ESO, DSO and market signals, and send a demand side response (DSR) signal to domestic assets to turn up or down. In the diagrams below, different scenarios are outlined that depict the flow of information required for a specific technology to participate in flexibility services.

4.1.2 Whole house

At its most simple, all electric devices in a household can be manually controlled. All that is required for participation is to be able to receive DSR signals from the aggregator and verify the response. Receiving the signal can be through several mechanisms such as text, app, or email. Verification of the response can be done using the household boundary smart meter. This approach is appropriate for a range of scheduled (e.g., services like Sustain-H, or static ToU tariffs) or day-ahead services (e.g., Thermal Constraint Management or the DFS). The change in demand is delivered through manual actions by the occupants, or via timers set up by the household.

SMETS1 and SMETS2 certified smart meters are required to meter such flexible responses as non-smart assets that encompass the whole house's demand need a smart meter to record and share consumption data with the aggregator. Smart meters do not require a local internet connection via the homes broadband, but can communicate to the Data Communications Company (DCC) directly using radio or the cellular network. The DCC handles smart meter data in the UK and passes this on to the relevant parties. For manual, scheduled, and day-ahead type services, using a boundary smart meter is suitable for use in CrowdFlex. The demand of the whole home is monitored, providing more value to the ESO or DSO service. Any technology can be metered for settlement in this way. Therefore, it can, for example, include electrified heating systems that only have simple thermostat timers.

Using manual meters would be technically feasible by completing pre- and post-event readings. We do not recommend this for any CrowdFlex trial. Such reading would add a massive burden to participants. It is more difficult for a supplier or aggregator to administer such a system, and large volumes of readings may overwhelm submission portals (as has happened for suppliers' websites when rates increased in 2022). Additionally, the smart meter rollout is expected to be completed by 2025[17], further reducing the incentive to set up such a system. Many pre-paid meters are also smart[18]. Currently there are already 14m homes with smart meters installed in the UK[19].

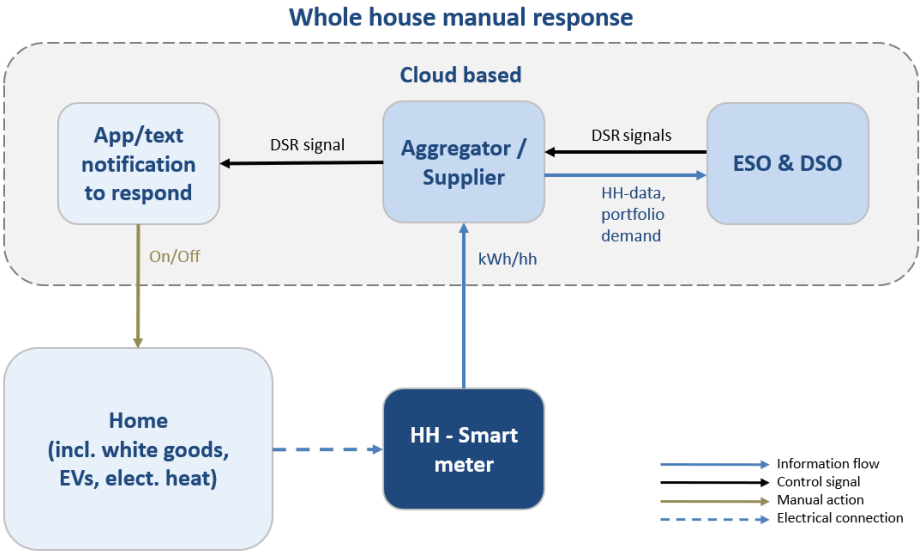

Figure 2: Whole house manual response communications

[17] DCC, DCC Business & Development Plan 2022/23, Accessed Dec 2022.
[18] https://www.smart-energy.com/industry-sectors/smart-meters/prepayment-metering-appears-on-the-rise-in-britain/#:~:text=Smart%20metering&text=By%20the%20end%20of%202021,meters%20operating%20in%20prepayment%20mode, Accessed Jan 2022.
[19] DCC, Network Data Dashboard, Accessed Dec 2022.

4.1.3 EVs

For scheduled services, EV charging can be programmed by the EV owner to charge or not charge during specific hours. This could also be done for day-ahead services. Currently, “smart” EV charging is either controlled via the EV charge point (EVCP), or directly through the EV. Using the EVCP approach, the EVCP can communicate with the charge point operator (CPO), which may act as an aggregator, via 4G or a home broadband connection. This provides for low latency communications between the EVCP and the aggregator, allowing for participation in “real-time” services such as the BM. Day-ahead and “real-time” services can be automated by communication between the aggregator and the EVCP via API. This allows for more efficient use of flexibility capacity and reduces the need for EV owner involvement. When EV charging is controlled directly through the EV, no smart EVCP is required. The EV is equipped to be able to communicate its charging status to the OEM/aggregator via 4G or home broadband. The outcome is the same, except that the EV charging status, including state-of-charge (SoC) is directly communicated through the EV rather than the EVCP.

When EVs are controlled by the EVCP, the EV SoC must either be manually entered into the charging app, or automatically via an API set up by the EVCP company. If an API is not set-up, a barrier to full automation is created. SoC is an important piece of information for EV flexibility, as it allows aggregators to know how much time is needed to fully charge the EV when it is plugged in. The amount of flexibility available depends on how much the charging time can be moved around when the EV is plugged in. Other information such as power consumption and plug-in times can be recorded and communicated through the EVCP to the aggregator, allowing for good visibility of availability of the EV portfolio.

An EV charging aggregator with good visibility of the EV portfolio can then accurately forecast flexibility capacity to the ESO and DSOs, allowing for efficient dispatch of flexibility for day-ahead and “real-time” services via API signals. Good visibility also provides benefits to scheduled services, as their impact can be more accurately forecast throughout the year.

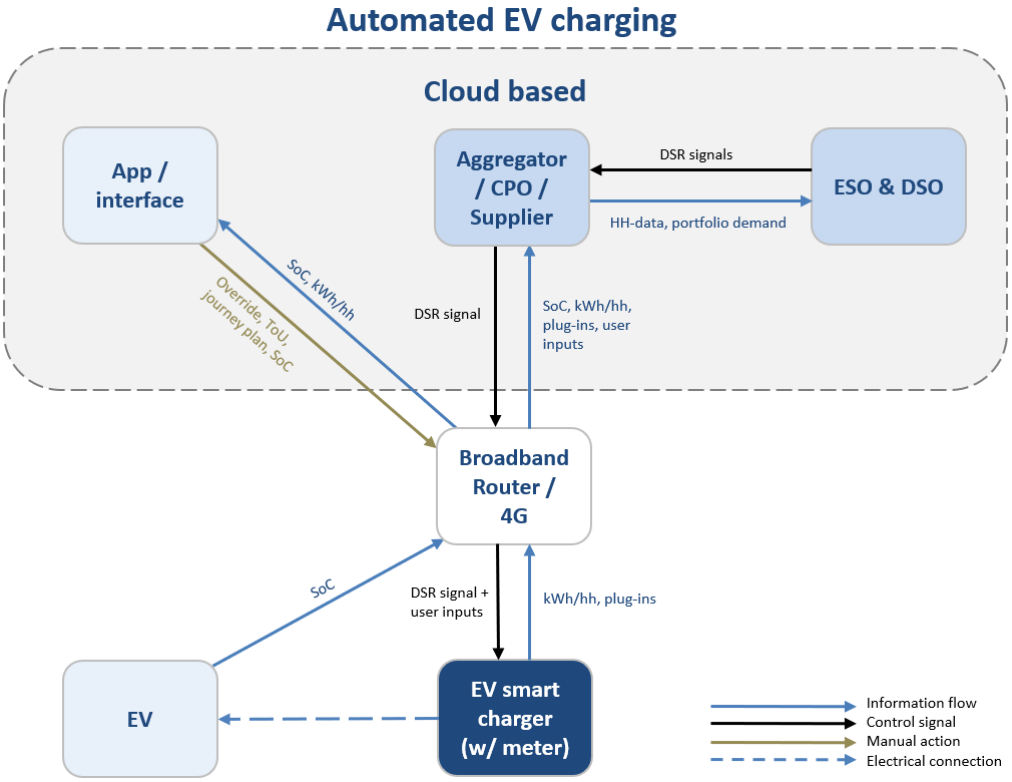

Figure 3: EV charging communications using an EV smart charger

4.1.4 Electrified heat

Electrified heat proves more complex than most other technologies. Different forms of heat pumps or resistive heaters, with or without storage, exist in the market today. This creates complexity in the aggregation of heating systems as there is a multitude of OEMs with different specifications and communications capabilities. For scheduled services, heating systems can be programmed for specific hours. This could also be done for day-ahead services; however, automation would be preferred to increase participation amongst less engaged consumers.

The heating systems targeted in CrowdFlex should include those with 4G or broadband connectivity to which DSR signals can be dispatched via API. Systems with communications-ready hardware should be included in CrowdFlex, as installing further equipment will be costly and invasive to households. The heat systems that already have the communications capabilities for external control via aggregator API may require firmware updates to enable such functionality. With direct visibility of the heating system, including power consumption, temperature, and heating patterns, the aggregator can forecast flexibility within a heating system and efficiently dispatch automated, day-ahead, and “real-time” services via API.

Older resistive heating systems may also include connectivity via radio teleswitching (RTS). These have traditionally been accessed directly by DSOs to improve diversity in load managed areas (LMAs). RTS systems may not be able to be dispatched via API given that they may not have broadband/4G capabilities. As modern aggregators dispatch flexibility based on 4G/broadband connections rather than this legacy connectivity approach, it is unlikely that CrowdFlex will be able to dispatch such legacy storage heaters without the installation of additional communication hardware. As this is likely to be prohibitively expensive, the relative prevalence of these RTS systems represents a key risk to CrowdFlex, especially when deploying the LMA-Secure service.

Some current heat-pump models do not measure their power consumption to accuracies needed for domestic flexibility. A DSR controller that can meter the power consumption of the heating system will therefore be required if asset level metering is being used. The DSR controller must also be able to measure the temperature of the home, by accessing the heating system thermostat, or by separate thermostat. This is to ensure that any DSR actions do not drop the temperature below reasonable comfort levels. Heating systems that require further installation of hardware, such as external DSR controllers, thermostats, or meters will, however, not be included in CrowdFlex as installing hardware will be too costly and invasive to households.

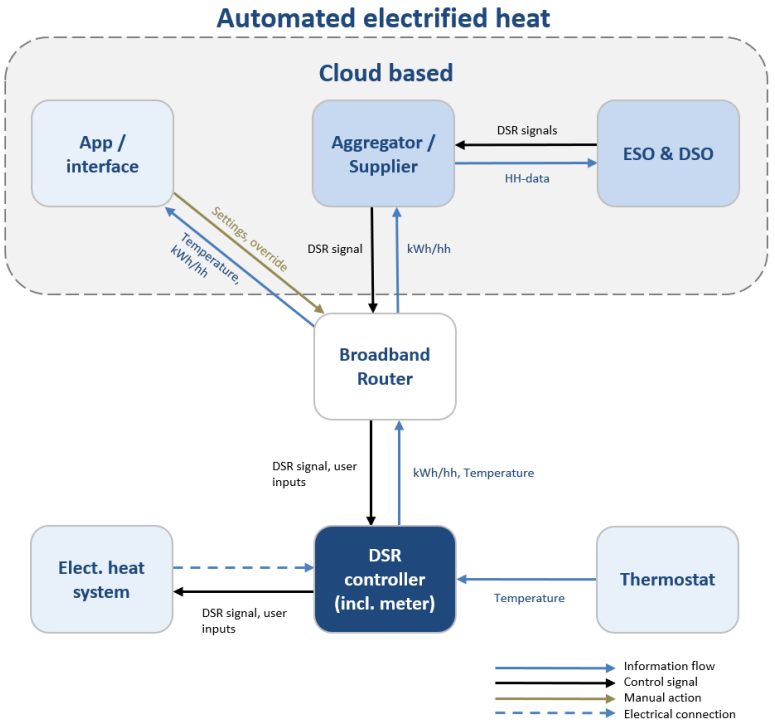

Figure 4: Electrified heating system communications

4.1.5 White goods

Most current white goods do not come with any smart functionality. However, white goods can gain some smart functionalities when used with smart plugs. However, these provide limited functionality as smart plugs can only affect the demand of goods that are “always on”, such as fridges and freezers. Smart plugs would not be able to schedule activities such as washing machine runs, as these would simply go into standby when the smart plug switches on. Currently, smart plugs with timers would provide the greatest functionality, as they can be “set-and-forget” to, for example, scheduled services, but are inherently limited to “always on” goods.

Full automation could be achieved using smart white goods with built-in communications. These would include programming of washing machine cycles, not possible with smart plugs. The rollout of such devices is limited, so will not be included in CrowdFlex. An aggregator DSR signal sent to a smart white good or smart plug will require the development of a communications protocol to allow the smart devices to communicate with the aggregator, most likely an API.

For CrowdFlex, we suggest including whitegoods for scheduled and day-ahead type services. This is because the rollout of smart white goods is limited. Participants could be encouraged to install smart-plugs to enable timers on goods. As such, this scenario will be similar to the “Whole house” scenario (Section 4.1.2), as both will be metered using a boundary meter.

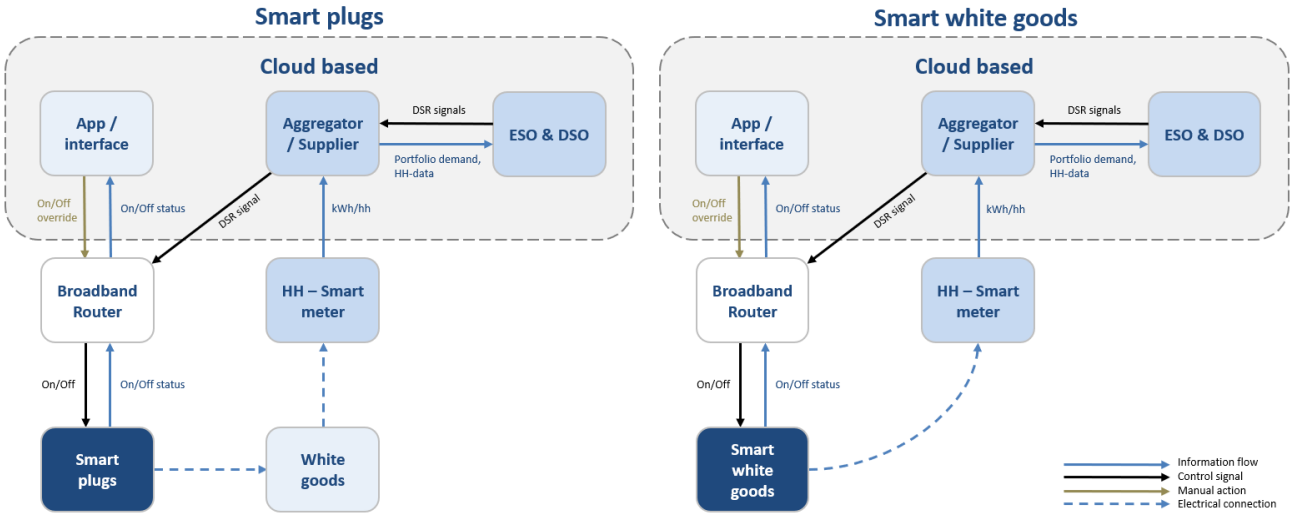

Figure 5: White goods communications

4.2 High-level capabilities of each technology

4.2.1 Capabilities of technologies for ESO and DSO services

The “trial services” laid out in D4.1 will be suitable for different technologies included in the scope of CrowdFlex based largely on the timescales associated with the service’s dispatch. “Real-time” services such as participating in the Balancing Mechanism require different capabilities than scheduled and day-ahead services.

For CrowdFlex, we therefore recommend only including technologies that can be fully automated for “real-time” services in our real-time services trials (i.e., participation in the Balancing Mechanism). It is not practical to expect residential customers to respond to real-time DR actions without automation. To respond to DR events in “real-time”, technologies need to be able to connect and receive “real-time” instructions from the ESO/DSO, via an aggregator API. The automation of white goods is currently very limited, thus removing their suitability from real-time services. We include any manual actions to be synonymous with white goods in this table (e.g., electrified heaters set with using thermostats/timers), as we are not including smart white goods in the scope of the trial. This is in effect similar to the “whole house” scenario discussed in Section 4.1.2.

For other scheduled services, we recommend all technologies be permitted to take part.

Table 2: Technologies suitable for ESO & DSO services

Technology	Dispatch method	“Real-time” Balancing Mechanism	Day-ahead thermal constraint management	Day-ahead DFS	Scheduled DSO Sustain	Day-ahead DSO Secure
EV	Automated	✓	✓	✓	✓	✓
Elect. heat	Automated	✓	✓	✓	✓	✓
White goods	Manual	X	✓	✓	✓	✓

There are two types of metering relevant to domestic flexibility:

- Boundary metering using smart meters (SMETS1 or SMETS2).
- Asset level metering.

For existing day-ahead and scheduled services (e.g., DFS, DSO Sustain, and DSO Secure), half-hourly data for settlement is sufficient. This can be delivered via asset or boundary level metering (via smart meters). However, it is worth noting that system operators procuring these services have indicated that sub half-hourly data would be beneficial for visibility (e.g., NGED with DSO Sustain-H). Participating in the BM includes additional operational metering requirements (Section 2.1.2) such that the control room can have “real-time” visibility of balancing actions.

Table 3 shows the capabilities of using boundary metering (smart meters) or asset meters to provide operational metering in the BM. These show that accuracy requirements can generally be fulfilled if units are aggregated, thus reducing overall errors to within the limits (Section 4.2.2). However, the read frequency and latency requirements would not met, and will require the discretion of the ESO to allow participation. Data on heating system capabilities has not been made available.

Table 3: Potential metering capabilities for different technologies recommended for the Balancing Mechanism trials

Technology	Accuracy	Read Frequency	Latency
Smart meter	1%[20]	10-20 seconds[21]	~13 seconds[22]
EV (asset metered)	±2%[23]	1 minute[23]	< 5 seconds[23]
Heat (asset metered)	N/A	N/A	N/A

To participate in the Balancing Mechanism, real-time instructions need to be executed at portfolio level, within an acceptable time (response rate). The asset also needs to fulfil the request for the instructed amount of time (DR event period). The control room considers different ramp rates of available technologies when accepting Bid/Offer pairs to suit the current balancing need. Table 4 illustrates that the response times for dispatchable domestic assets are on the order of seconds for EVs and minutes for Heat and therefore, their ramp rates are not prohibitive for participation in the BM.

Table 4: DR response capability for the Balancing Mechanism

Technology	Response time	DR event period turn up[24]	DR event period turn down[24]
EV	Instant – turn down[23] < 30 secs – turn up[23]	4 hours[25]	4 hours[25]
Heat (without storage)	~2 minutes[26]	1-2 hours[27]	1-2 hours[27]
Heat (with storage)	~2 minutes[26]	4-6 hours[27]	4-6 hours[27]

4.2.2 Role of aggregation

The sections above identify the gap between the capabilities of residential meters, and the requirements of the services CrowdFlex wishes to demonstrate, particularly the BM. Two specifications that represent particularly onerous/costly barriers for operational metering are 1) the acceptable level of accuracy of metered energy demand, and 2) the requirement for 1Hz frequency of measurements. CrowdFlex is exploring an alternative approach: to meet these requirements at an aggregate level by using statistical methods. This will require flexibility from ESO to accept these methods of improving operational metering data through aggregation.

Meter accuracy: The acceptable level of accuracy of SMETS meters is lower than the current requirements for operational metering in the BM. However, if the reason for each meter's inaccuracy is due (primarily) to a random variable (such as component tolerances during manufacture), then the accuracies of all meters would follow a statistical distribution (such as a normal distribution). The aggregated accuracy of any group of meters will approach the mean of that distribution. In other words, the accuracy improves as the group of

[20] Aclara, SGM1400-B Series Single Phase SMETS2, Accessed Nov 2022.
[21] Bulb, Using your Secure SMETS1 In-Home Display (IHD), Accessed Nov 2022.
[22] Data Communications Company, DCC Performance Measurement Methodology, Accessed Nov 2022.
[23] Ohme, EV charging provider. Response time to turn down can be instantaneous, however turn up response time depends on the EV protocols.
[24] DR event period of individual assets can be increased by "group switching", extending the overall DR event period.
[25] CrowdFlex Phase 1, underlying data.
[26] Data from DSR heat-pump trial, other heating systems may vary. NEDO, Smart Community Demonstration Project in Greater Manchester, Accessed Nov 2022.
[27] J. Hong et al., Assessing heat pumps as flexible load, Accessed Nov 2022.

meters increases. Even if the standard deviation of the accuracy of each meter is 2.5%, even with group sizes on the order of 100, an accuracy of better than 1% can be expected. This result depends on the source of inaccuracy not being systematic in origin, and so CrowdFlex will review shortlisted meters to determine if manufacturers can provide evidence to support this approach to achieving high accuracy readings across a portfolio.

Measurement frequency: measuring individual asset demand at 1-second intervals will generate very large datasets, which could give rise to data storage, latency and transfer failure issues. An alternative approach is to choose a lower frequency for measurements in the household (1-minute intervals for example). Across a group of assets, the start-stop timestamps of these 1-minute readings should not be coincident, rather they should be staggered. For example, in a group of 60 assets, the first would issue data at time 1 second and 61 seconds etc., the second would issue data at time 2 and 62 etc. When added together by the aggregator, the resulting signal would vary at 1 second resolution. For groups of any size, the start timestamp would simply be randomly assigned between 1-59. While this is not identical to adding together 1-second interval data, FutureFlex[28] has shown that any discrepancy reduces as the size of the group increases. As this is a good balance between accuracy and cost impact, CrowdFlex will pursue this approach to meeting the specification.

4.3 Confirmation of technologies in scope

4.3.1 Flexible assets in scope

The ESO and DSO services included in the scope of CrowdFlex include:

- Scheduled,
- Day-ahead, and,
- “Real-time” services.

To access domestic flexibility, both **manual** and **automated** dispatch can be used; however:

- The installation of additional metering hardware to allow technologies to participate in flexibility services will be too costly at a large-scale, involve high levels of administration, and will be intrusive to households.
- Only technologies that already have “smart” communications will be able to participate in automated dispatch services.

Scheduled services can be dispatched fully manually, or using smart EV charging schedules on EVs, heating systems, and white goods. Day-ahead services can also be dispatched fully manually in the same way. However, EVs and electrified heating systems that are communications capable can also be dispatched using APIs from an aggregator. “Real-time” services require low-latency response times, thus only EVs and communications capable electrified heating systems can participate. White goods are included for scheduled and day-ahead services, and we will not target “smart” white goods as the rollout of these is limited. Participants could be encouraged to use smart plugs to set timers on white goods.

Table 5: Technologies suitable for different service types in CrowdFlex

Service type	Dispatch vector	Suitable technologies
Scheduled	Manual	EV, Electrified heat, White goods
Day-ahead	Manual or automated	EV, Electrified heat, White goods
“Real-time”	Automated	EV, Electrified heat

[28] Everoze, Aggregated datasets – third party & sustain-h datasets analysis, Accessed Nov 2022.

4.3.2 Metering in scope

As laid out in section 4.1 and 4.2, it is possible to meter domestic consumption, and hence demand response, at either an asset level or a boundary (house) level. For all “trial services” we do not wish to exclude either asset or boundary metering from the trial as supporting a choice of metering approaches will enable more flexibility providers to become involved in the project, improving participation as the outputs from CrowdFlex become commercial / Business-as-usual. For example, should asset meters be excluded from the trial, then only suppliers (with access to smart meter data) could be flexibility providers in CrowdFlex, excluding alternative providers of flexibility (such as CPOs). For manual/scheduled services, there should not be any significant barriers for entry for either boundary or asset meters as half-hourly settlement metering will likely be sufficient in all of the services that we are trialling. Metering “real-time” dispatched assets becomes more complicated both in terms of settlement and operational metering.

For settlement metering, while both the boundary and asset meters involved in CrowdFlex conform with their respective requirements laid out in the BSC, domestic properties are not half hourly settled. This is currently the primary barrier to entry for aggregated domestic assets into the BM, as with regards to the more detailed requirements:

- Boundary or whole house metering is possible with a SMETS2 smart meter and meets the vast majority of the settlement requirements associated with CoP10 requirements.
- Asset metering only applies to domestic assets that come with such capabilities. However, the majority of smart assets, specifically EVs and electric heat, have such capabilities. For BM participation, asset meters must be broadly in line with CoP11 requirements.

Neither SMETS2 smart meters nor EV or electrified heating asset meters are likely to meet the rigorous operational metering requirements. The key concern for domestic meters is that the 1Hz read frequency requirement exceeds what domestic meters are configured to report.

Aside from these concerns not meeting specifications, there are other risks specific to either of the metering approaches:

- For SMETS2 smart meters this includes:
  - Limiting the role of the flexibility provider to parties that have access to smart meter data (i.e., the electricity supplier),
  - Potentially requiring consumer consent to increase the read frequency of smart meter data.
- For asset meters this includes:
  - Only providing visibility of individual domestic assets rather than at a household level, restricting the assets that can provide flexibility to the metered assets rather than any flexible device in the household,
  - Ensuring asset operators are not incentivised to programme perverse baselines to manipulate the flexibility that they are able to provide and boost revenues at the expense of the system and consumer.

However, these risks are not prohibitive and are outweighed by the benefit of including multiple options for aggregators/flexibility providers to meter assets in CrowdFlex.

4.4 Derogations & bilateral agreements required

4.4.1 Derogations

Given that the only existing service/market that we plan to enter that is not designed for domestic flexibility is the Balancing Mechanism, the derogations required for CrowdFlex focus on ensuring domestic assets can participate. The derogations involve removing the need for BMUs to be located at HH settled sites. This follows a similar derogation acquired by the Centrica trial Sandbox, that wishes for domestic storage heaters to enter the BM. Their derogation addresses:

> *BSC Section K (Classification and Registration of Metering Systems and BM Units) to enable the utilisation of assets located on non-HH-settled sites in a Secondary Balancing Mechanism Unit,*

and from provisions in BSC Section S (Supplier Volume Allocations – SVA), and BSC Procedure 503 (HH Data Aggregation for SVA Metering Systems).[29]

CrowdFlex will have to replicate such a derogation to enable domestic assets to participate in the BM. As SMETS2 smart meters fulfil all other CoP10 requirements, no further derogation is expected for boundary metering. Flexibility providers controlling assets (e.g., CPOs) will need to confirm if their assets align with CoP11 requirements. However, from initial conversations and a review of the CoP11 requirements, we do not foresee the need for any further major derogations to enable participation, similar to the Sandbox trial. Further derogations may be necessary to enable CrowdFlex to explore the statistical nature of domestic flexibility in the Balancing Mechanism, but that is out of scope for this work package.

4.4.2 Bilateral agreements

As the operational metering requirements are set by ESO, rather than Ofgem, a derogation is not required to remove the barriers that currently would prohibit domestic participation. Such a divergence from the standard operational metering requirements for the BM would have to be agreed with ESO through the Bilateral agreement, as mentioned in Section 2.1.2. The ESO have some discretion on these standards outside of code obligations, and this is what is currently being reviewed in Power Responsive. The key changes to the standard requirements would include either:

- Enabling small assets to provide operational data as an aggregated portfolio, leading to efficiencies in both portfolio accuracy and read frequency reporting as outlined in Section 4.2.2.
- Loosening the requirements for small assets around accuracy, read frequency, and latency to enable domestic assets to meet the requirements for operational reporting without new and expensive metering equipment.

Future work on CrowdFlex should feed into these discussions so that the operational requirements for domestic assets are not prohibitive, while maintaining the standards and visibility required in the Control Room. Enabling assets to report as an aggregated portfolio would initially appear to be the most efficient method to achieving this. However, this must be worked through with the ESO to ensure such an approach can deliver energy balancing to the high standard required.

[29] Ofgem, Sandbox derogation from the Balancing and Settlement Code, Accessed Dec 2022.

5 Summary and recommendations

5.1 Technical performance criteria of services

Participation in the **Balancing Mechanism** requires "real-time" response to dispatch instructions, therefore it will be limited to automated domestic assets in CrowdFlex. Participation includes rigorous **settlement** and **operational metering** requirements.

- **Settlement metering** is carried out by Elexon; they require for all BMUs to be HH settled and comply with CoP10 (for boundary meters) and CoP11 (for asset meters).
- **Operational metering** requirements are defined by ESO, agreed with a BM participant in a bilateral agreement. The standard operational metering requirements for the BM are extremely challenging for domestic assets to fulfil. Power Responsive are working to implement the submission of aggregated data for BMUs comprising of many small assets (e.g., domestic assets) to alleviate some of these challenges (e.g., accuracy). However, challenges around read frequency persist.

Participation criteria for Thermal Constraint Management would be less stringent as we recommend that it should be a Day-Ahead Service. Therefore, settlement and operational metering would be carried out following each dispatch event and could be limited to half-hourly metering. However, as a regional service, flexibility providers would be obliged to report the GSP of their assets ahead of being allowed to participate.

The ESO **Demand Flexibility Service** has already been launched, and CrowdFlex plans to allow its trial members to still participate in this service. The main requirement of participation is to use HH boundary metering, and not participate in other ESO balancing services such as the BM. As such, we recommend that participation in the DFS would include a recommendation that new iterations of the service would allow for stacking of services such as those covered by CrowdFlex, as well as asset level metering.

The DSO services, **Sustain-H** and **Secure**, are pre-scheduled and Day-Ahead dispatched respectively. Therefore, they can include both automated and manual response and be HH-metered (providing the metering is PAS 1878 compliant). As DSO services are only required on certain parts of the distribution network, these services are extremely location specific, and hence will require the flexibility provider to declare the location of participants down to HV or in some case LV level.

5.2 Capabilities of technologies to participate in "trial services"

The following **technologies are in scope** for the various "trial services" set out in D4:

Technology	Dispatch method	Balancing Mechanism	Thermal Constraint Management	Demand Flexibility Service	DSO Sustain	DSO Secure
EV	Automated	✓	✓	✓	✓	✓
Elect. heat	Automated	✓	✓	✓	✓	✓
White goods	Manual	X	✓	✓	✓	✓

To ensure that domestic flexibility produces a response that can be confidently measured by the ESO and DSOs procuring flexibility services, **domestic flexibility in CrowdFlex should be tested and reported on a portfolio level by an aggregator**. The requirements of this portfolio may vary in number of customers and location, dependent on the specific needs of the "trial service".

5.3 Capabilities of asset metering

Both **asset and boundary (house) metering are in scope** for CrowdFlex. Based on the data collected on the capabilities of metering available in the home (SMETS smart meters and EVCP asset meters), household boundary and asset meters should fulfil the vast majority of the requirements for settlement

metering laid out in CoP10 and CoP11 respectively. The main derogation that will be required will be to enable non-HH metered assets (all domestic assets) to participate in the BM.

There is a **clear gap between the capabilities of domestic meters and the operational metering requirements of the BM**. This can either be solved through amending the requirements with a bilateral agreement with the ESO or by meeting these requirements using statistical methods through aggregation.

For the **other "trial services"**, SMETS smart meters and asset meters **should be compliant**.

5.4 Derogations and bilateral agreements

CrowdFlex will require a derogation to enable **non-HH metered assets to participate in the BM**.

As SMETS2 **smart meters fulfil all other CoP10 requirements**, no further derogation is expected for boundary metering. Flexibility providers metering assets (e.g., CPOs) will **need to confirm if their assets align with CoP11 requirements**. If they do not, a derogation will be necessary.

The key amendments to the bilateral agreement on the standard requirements of operational metering in the BM must include either:

- allowing for **improvement of operational data using statistical methods in aggregation,** or
- **loosening the requirements for small assets** around accuracy to enable domestic assets to meet the requirements for operational reporting, without new and expensive metering equipment.