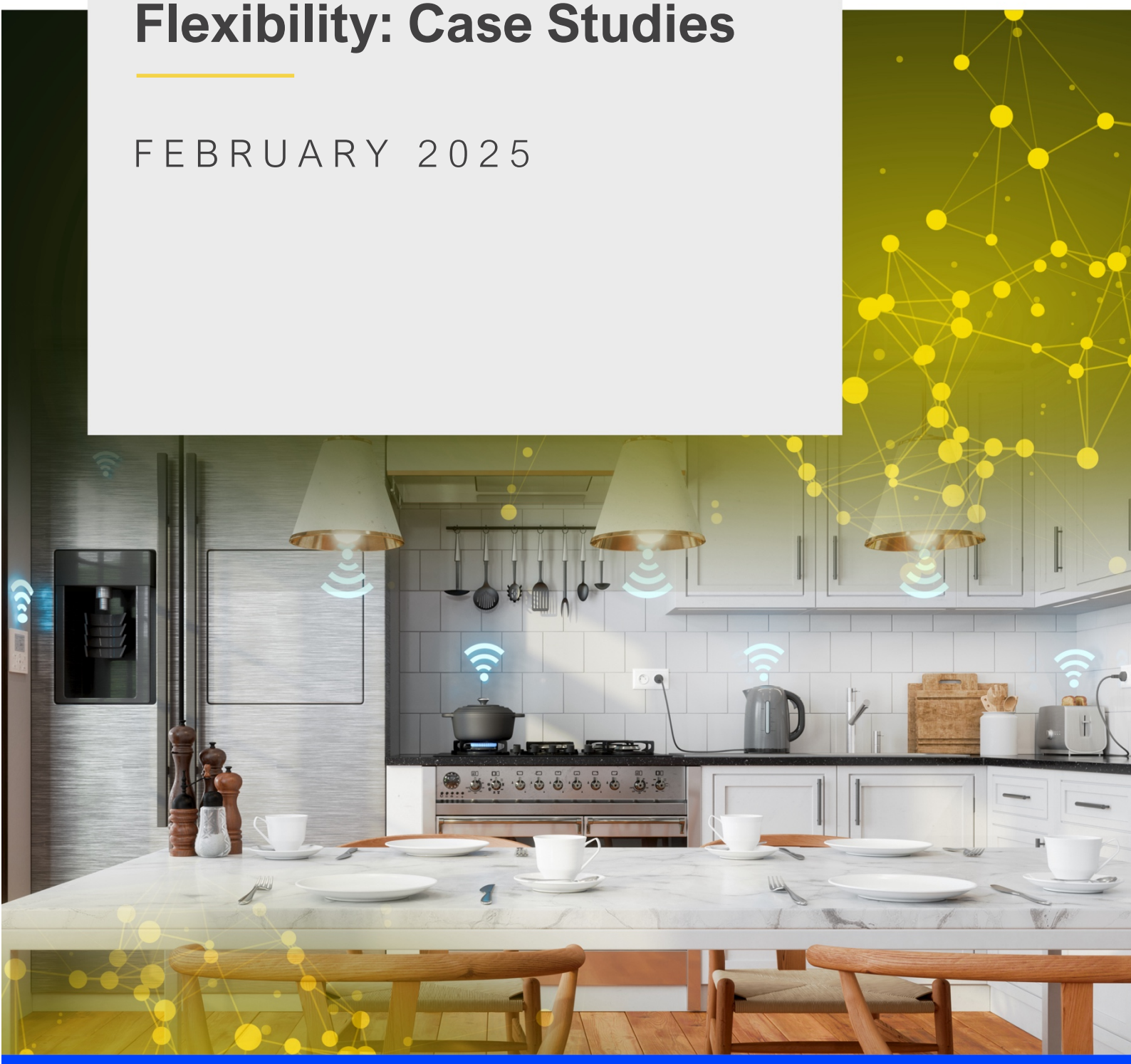
4E Efficient, Demand Flexible Networked Appliances EDNA

Product Policy Framework for Demand Side Flexibility: Case Studies

FEBRUARY 2025



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Further information on the 4E TCP is available from: **www.iea-4e.org**

The Efficient, Demand Flexible Networked Appliances Platform of 4E (EDNA) provides analysis and policy guidance to members and other governments aimed at improving the energy efficiency and demand flexibility of connected devices and networks.

Further information on EDNA is available from: **www.iea-4e.org/edna**

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Product Policy Framework for Demand Side Flexibility: Case Studies

Final report

Prepared for the 4E Technology Collaboration Program of the International Energy Agency

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Introduction

This report is a compilation of case studies mapping the status of residential product flexibility in seven jurisdictions using the EDNA *Product Policy Framework for Demand Side Flexibility*. The aim of the case studies was to test the effectiveness of the framework for mapping product policy and to collate approaches across a range of jurisdictions. The case studies did this by looking at both appliance flexibility standards (if any) and market access available to aggregated flexible appliances.

The case study countries and states chosen in consultation with EDNA were:

- Great Britain
- Australia
- New Zealand
- European Union (EU and Germany)
- USA (California, and Hawaii)

Case studies were conducted through desktop research and review of appropriate legislation, regulations and reports.

Consultation occurred with jurisdictional experts for Great Britain, California and Australian case studies. Jurisdictional experts were approached for information for the EU, New Zealand and Hawaii case studies, with no response received after multiple approaches.

Best efforts were made to obtain all required information to complete the case studies, however the research team recognises that additional sources may exist that were not accessed through desktop research.

Contents

1. Summary across case studies

The case studies found that **appliance flexibility standards** are at a very nascent stage, as summarised in Table 1. The only mandatory standards across the jurisdictions studied were for pool pumps in California; heat pumps, storage, EV charging and other devices over 4.2kW in Germany; and a crude demand response capability requirement for air conditioning devices under 19kW in South Australia.

Great Britain has the most advanced planning for appliance flexibility having developed a voluntary standard for energy smart appliances with mandatory implementation phases planned for 2026 and 2028.

Table 1: Comparison of appliance flexibility standards across case study jurisdictions

Jurisdiction	Current Standards	Coverage	Status	Major Requirements
Great Britain	PAS 1878:2021 Energy Smart Appliances	White goods, HVAC, storage, EV chargers	Voluntary, with mandatory phases planned for 2026 and 2028	Customer Energy Manager concept; OpenADR minimum requirement; Phase 1 (2026): Security/functionality; Phase 2 (2028): Technical standards
Australia	No national flexibility standards	Limited state requirements	Varies by state	SA: DR capability for air conditioners (July 2023); VIC: Timers on subsidized heat pump water systems (July 2024)
New Zealand	No mandatory flexibility standards	Energy efficiency only	Voluntary PAS for Smart Homes (2022)	Follows E3 program with Australia; No specific flexibility requirements
European Union	Code of Conduct for Energy Smart Appliances (V1.0)	White goods, HVAC including water heating	Voluntary, launched April 2024	Open standards for communication protocols; Machine-to-machine communication capability; Automatic consumption optimization; User permission requirements
Germany	Section 14a Energy Industry Act	Heat pumps, storage, EV charging >4.2kW	Mandatory for specified devices	Controllability for devices >4.2kW; Grid fee reduction incentives; Three module options for control
California	ENERGY STAR and Flexible Demand Appliance Standards (FDAS)	Pool pumps initially, expanding to other appliances	ENERGY STAR voluntary, FDAS mandatory under Senate Bill 49	Internet connectivity required; Cybersecurity requirements; Consumer protection elements; Default schedules for operation
Hawaii	No mandatory flexibility standards	DER only	Grid interconnection requirement only	Follows US ENERGY STAR program; IEEE 1547-2018 for DER connection to Hawaiian Electrity's grid

Market access for aggregated appliances is highly variable, as summarised in Table 2. Usually, access is defined for aggregated Distributed Energy Resources (DER) or 'flexibility' and in some

cases this is limited to relatively large minimum participation sizes of 1MW. Great Britain is the most advanced jurisdiction for market access, but in practice, participation comes from commercial and industrial (C&I) demand flexibility or batteries, rather than appliances.

Table 2: Comparison of market access for aggregated appliances across case study jurisdictions

Jurisdiction	Market Types	Minimum Size	Status	Market access details
Great Britain	Wholesale, Balancing, Distribution Flexibility	1MW for most markets, 0.1MW for wholesale, 50kW for distribution network flexibility	Active markets	Virtual Lead Parties (VLPs) can access most markets; 15 VLPs participating in the Balancing Mechanism currently; Distribution flexibility services had 2.4GW contracted for 2023-24; Demand Flexibility Service for winter peaks; Elexon as Market Facilitator from 2024
Australia (NEM)	Contingency, FCAS, Emergency Reserve, Demand Response Mechanism	1MW for most markets, 10MW for RERT	Active with reforms planned	Contingency FCAS markets (8 markets); Demand Response Mechanism (large C&I businesses only); Emergency reserve (RERT) procurement on 3 timeframes by the market operator; Distribution network support services (trials only); Wholesale energy markets (voluntary scheduling from late 2026);
New Zealand	Wholesale, Ancillary Services	1-10MW for DNL	Limited participation	Dispatch Notification Load for small aggregated resources; Difference Bids for baseline deviation; Fast and Sustained Instantaneous Reserve; Distribution flexibility in early stages
European Union	Wholesale, Balancing, Network Support	100kW from Jan 2024	Varies by member state	Legal framework established but implementation varies; Only France has independent aggregators with access to all markets; DSOs required to procure flexibility services. Demand response is available to small end-users in 22 out of 26 Member States, with independent aggregators recognised in the national legislation of 19 Member States.
Germany	Balancing Markets, limited wholesale market access	1MW for balancing services	Mixed access	Access to balancing markets (FCR, aFRR, mFRR); Limited wholesale market access;
California	Wholesale, Emergency Reserves	100kW (FERC Order 2222)	Four program options	Demand Side Grid Support Program: Emergency dispatch; Market-integrated demand response; Storage virtual power plant pilot; Emergency load flexibility VPP pilot (being introduced)
Hawaii	Utility Programs	No wholesale market	Three participation models	Direct pricing programs; Utility procurement through aggregators; Utility "Bring Your Own Device" programs; No wholesale market due to small system size

2. Great Britain

1.1. Appliance standards

Under The Smart Systems and Flexibility Plan 2021, Great Britain has funded the development of a voluntary standard PAS 1878:2021 for Energy smart appliances (ESAs)[1] that "are electrical consumer devices that are communications-enabled and capable of responding automatically to incentive signals (such as price) or other more direct control signals (such as specific instruction to operate at a given power at a certain time of day), by shifting or modulating their electricity consumption, storage, and/or production". "The ESA is a physical appliance, an edge processing device, making use of energy smart functionality and is sited on the consumer premises."

The standards requirements are summarised in the table below. Figure 1 is a diagram of the relationships between the components of the system. The standard includes the concept of a 'Customer Energy Manager' (CEM) which aligns with architectures in international standards (e.g. TC 23/ SC 23K). In PAS 1878, the CEM is defined as a 'logical entity, that can be physical or virtual, which deals with flexibility information and requests' and translates between the DSR Service Provider (DSRSP) and the ESA – effectively a gateway function. The interface A between the DSRSP and the ESA is specified to support the use of OpenADR as a minimum to enable interoperability. Other interfaces, such as interface B between the CEM and the ESA can be proprietary but cyber security requirements are specified.

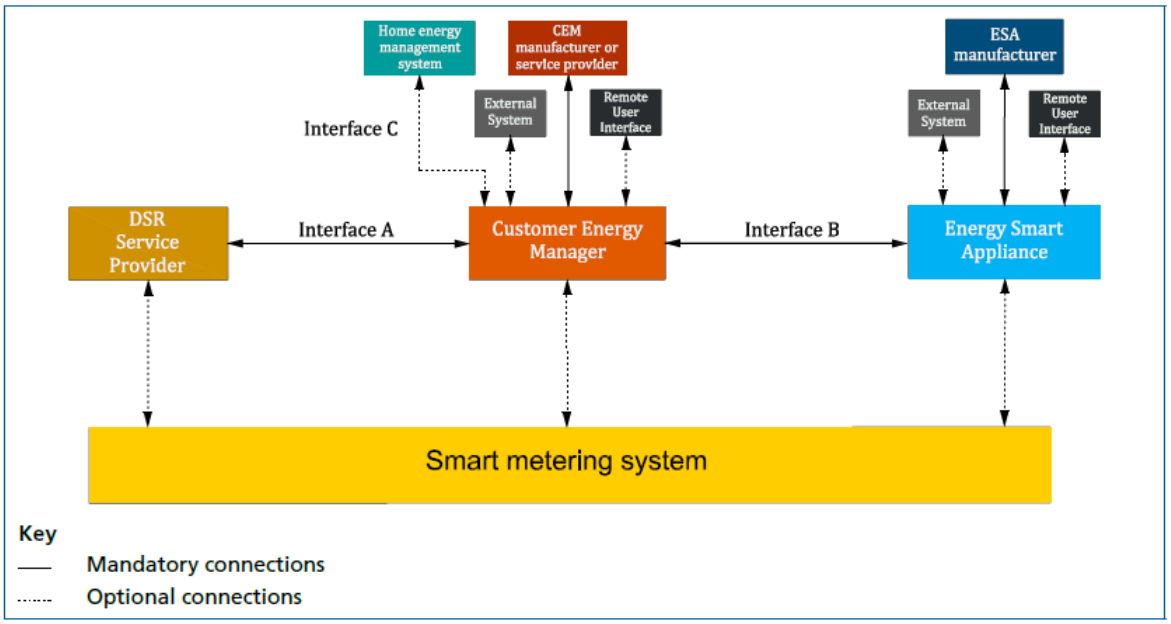

Figure 1: Representation of the communications interfaces of the ESA DSR systems architecture (PAS 1878:2021)

A hierarchy of DSR operation is defined, where consumer preferences have priority. In the 'Routine Mode' (Mode 1), the ESA controls electricity consumption according to the consumers wishes and any 'indirect' or 'implicit' DSR from incentives set in advance or other data. For example, a smart appliance may alter its routine power consumption based on other inputs, such as weather if it is a heating appliance. The inputs and how these calculate the routine mode operation is not specified in PAS 1878 and is left to innovation. In 'Response Mode' (Mode 2), the ESA controls electricity

[1] https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-1878-energy-smart-appliances-system-functionality-and-architecture/

consumption according to the consumers wishes and ‘direct’ or ‘explicit’ DSR, and involves response to flexibility requests made in real-time e.g. for frequency response. Consumer preferences also included in the operation of the ESA under both routine and response mode, and consumer override (Mode 3) is always available and given the highest priority.

PAS 1878 for appliances is accompanied by a grid-side standard PAS 1879 - Energy Smart Appliances - Demand Side Response Operation[2].

In the most recent consultation[3] (for which a Government response has not yet been published), the Government proposed Phase 1 regs in 2026 to ensure that devices with the greatest load potential meet minimum levels of security and functionality (for example by proposing to implement ETSI EN 303 645). This may include the following appliances: heat pumps, battery energy storage systems (BESS) and electric vehicle (EV) chargers.

The Government also proposed Phase 2 regs in 2028, which may include technical standards such as PAS 1878, but the Government has not yet confirmed if and how PAS 1878 will be used. What has been committed to,[4] is for the Department of Energy Security and Net Zero to sponsor the revision of PAS 1878 (PAS 1878:2025), building on the learnings from the Interoperable Demand Side Response innovation programme, which is building and testing the first ESAs and DSR systems against the PAS 1878 specification. [5]

The consultation proposes that ‘Cold appliances e.g. fridges, wet appliances e.g. washing machines, Heating Ventilation & Air Con appliances e.g. heat pumps, domestic battery energy storage systems, and electric vehicle charge points must provide two-way communication that allows them to receive and act upon price and other direct control signals, and at a minimum to send signals on the status of the device, whether it is responding to a signal or has ceased to do so.’

The consultation also proposes a staged approach to interoperability:

‘2026: Proposed as part of the first phase ESA regulations, devices must utilise an open standard communication protocol for the application interface.

2028: Second phase regulations will set out the minimum required communication protocol, which may be based on the revision of PAS 1878.’

In addition, it includes a proposal for mandating ETSI EN 303 645 The European Standard on connected device security for ESAs with the greatest potential for load control.[6]

It also proposes that ‘Electric heating appliances must provide a user interface (through any combination of an app, web portal or physical interface on the device or other)’ and that ‘Electric heating appliances, on set up, must have users set their heating preferences. DSR and Time of Use Tariff (TOUT) operations should be enabled by default and for operations, where appropriate, schedules should be pre-set to operate outside of peak hours (8am to 11am and 4pm to 10pm on weekdays), giving the user the opportunity to accept, remove or change those defaults.’

Note, however, for safety, 'Electric heating appliances must prioritise safe operation over responding to instructions (third party information or user input) where to do so would compromise device safety or result in a risk to the health or safety of the user.

Note: these plans were made under the previous British government, so are subject to change.

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[2] https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-1879-energy-smart-appliances-demand-side-response-operation/

[3] https://assets.publishing.service.gov.uk/media/6659f0147b792ffff71a8601/smart-secure-electricity-systems-2024-energy-smart-appliances-consultation.pdf

[4] https://www.gov.uk/government/consultations/delivering-a-smart-and-secure-electricity-system-implementation

[5] https://www.gov.uk/government/publications/interoperable-demand-side-response-programme-apply-for-stream-1-opportunities

[6] https://www.etsi.org/deliver/etsi_en/303600_303699/303645/03.01.03_60/en_303645v030103p.pdf

Major requirements in voluntary standard PAS 1878:2021 for Energy smart appliances (direct quotes from standard)

Communication	Interoperability	Measurement/sync	Security	Consumer override
'5.3 Operational Model ... The flow of information across the interfaces is divided into the following phases: 1. Consumer registration with DSRSP 2. CEM and ESA mutual authentication 3. Device registration of the CEM and the ESA with the DSRSP 4. Initialization 5. Normal operation (four CEM operating modes) 6. Exception conditions 7. De-registration' 5.3.2 CEM and ESA mutual authentication ... The CEM and ESA shall mutually authenticate using PKI. Once an authenticated connection is made between the two: a) the CEM shall provide an identification token to the Consumer (in the case of a remote CEM); or b) the CEM shall provide an identification token to the ESA via Interface B (in the case of a local CEM). The ESA shall send information including its manufacturer name, serial number, EUI-64, firmware version and firmware installation date to the CEM over Interface B.	'NOTE OpenADR has been selected as a candidate in this PAS and has been specified accordingly, but other possible candidates include the IEC 61850 series, BS IEC 62746-10-1: 2018, EEBus or the development of a new standard.' 'This PAS mandates that any implementation of Interface A shall support the use of OpenADR as described in this Annex and shall always revert to the use of OpenADR in order to guarantee interoperability. This PAS does not restrict the use of other protocols to implement Interface A and mandates that all such implementations shall meet the requirements of Clauses 5 and 6 of this PAS.	'An ESA shall be capable of measuring or calculating its power consumption/ production value in W or kW (e.g. by using an internal measuring approach or using a look-up table). An ESA shall be capable of measuring or calculating its Power consumption/ production values every 1 s. An ESA shall be capable of measuring or calculating its power consumption/ production values with an accuracy upper limit of 10% standard deviation error on reported power values.'	'System developers shall ensure that a high degree of cyber security is achieved between the CEM and ESA, at least as secure as in the illustrative examples below. NOTE At all times, the CA, DSRSP, CEM provider and ESA manufacturer should demonstrate that they are taking all reasonable measures and are following auditable internal security processes in order to ensure that sensitive and confidential information is not accessed by unauthorized parties, i.e. by implementing BS EN ISO/IEC 27000.'	The optional CEM or ESA remote user interface shall, as a minimum, provide access to information and controls required for the Consumer to engage in DSR services and allow the Consumer to provide their preferences for CEM or ESA operation and DSR service provision. The remote user interface shall give the consumer the ability to manually override, in real-time, current and planned DSR operations.' 5.3.5.2.4 Mode 3: Consumer override The ESA shall enter Mode 3 whenever it receives a manual override (i.e. modify, decline or cancel) from the Consumer. In Mode 3, the ESA shall allow the Consumer to override any Mode 1 (routine) or Mode 2 (response) operation at any time. This shall be in addition to any existing preferences set by the Consumer which are used in the construction of flexibility offering options for routine and response mode. The override shall be one of: a) modification of a planned flexibility offering or current flexibility option; or b) rejection of a requested operation; or c) cancellation of all routine and/or response mode operations for a specific interval; or d) cancellation of an ongoing routine or response mode operation. If the Consumer override involves a request rejection or event cancellation of a Mode 2 operation, the ESA shall send a "flexibility offer request rejected" or "cancel flexibility offer" (5.4.5.1.6) message to the DSRSP, via the CEM, and immediately revert to Mode 1 (Routine mode). The CEM shall authenticate and decrypt the "flexibility offer cancel" message received from the ESA over Interface B and, if authenticated and validated, shall both re-package the message, send to the DSRSP over Interface A and note that the ESA has transitioned to Mode 1. The CEM shall now include the ESA in any non-DSR HEMS operations as it sees fit. If the Consumer override involves a request rejection or event cancellation of a Mode 1 operation, the ESA shall send a "Mode 1 request rejected" or "Mode 1 operation cancelled" message to the CEM, (the format of these messages is beyond the scope of this PAS) and immediately revert to Mode 1 (Routine mode). The CEM shall authenticate and decrypt the "flexibility offer cancel" message received from the ESA over Interface B and, if authenticated and validated, shall note that the ESA has transitioned to Mode 1. The CEM shall now include the ESA in any non-DSR HEMS operations as it sees fit.

1.2. Appliance (device) participation in markets

In British energy market regulation, aggregators of Distributed Energy Resources (DER), including appliances, are known as Virtual Lead Parties (VLPs).[7]

VLPs can currently offer flexibility services on behalf of their customers in the following British markets:

1. the Balancing Mechanism,
2. frequency markets
3. the winter Demand Flexibility Service
4. distribution network (Distribution Service Operator or DSO) Flexibility Services, and into the Trans European Replacement Reserve Exchange – the TERRE project[8] (not detailed here as outside Great Britain).

From 7 November 2024, VLPs can also offer flexibility services to the wholesale market.

On 29 July 2024, Ofgem announced a one-stop shop Flexibility Market Asset Registration (FMAR) process for flexible consumer assets participating in local and national energy markets.[9]

In addition, Ofgem announced that Elexon will be the market facilitator delivery body[10] responsible for:

- reducing friction across DSO markets
- aligning transmission and distribution market arrangements, and
- developing local flexibility markets.

However, at present none of the VLPs (Aggregators) registered by ESO work involve the use of domestic appliances. Currently they all work with commercial and industrial loads or other business loads, e.g. air conditioning controlled through building management systems of hotels. There is very little domestic load controlled primarily because of the lack of interoperable standards for domestic appliances, which the PAS 1878 standardisation activities and associated innovation programmes are trying to address.

1. The Balancing Mechanism (BM)

This is the National Grid ESO's primary tool to balance supply and demand on grid. The BM is a continuously open online auction, with thousands of trades issued daily. Each trading period is 30 minutes long.

Balancing services now regularly exceed 50% of national demand. 15 VLPs have entered the British market since 2019, when entry to the BM began.

There are a number of system requirements before a unit can become active in the BM, to ensure they can communicate with the Electricity National Control Centre (ENCC). These systems are:

- Electronic Dispatch Logging (EDL)
- Electronic Data Transfer (EDT) or WA API (Wider Access Application Programming Interface - Combined EDL/EDT functionality)
- Control or System Telephony
- Operational Metering data provision

[7] https://www.neso.energy/document/161341/download
[8] https://www.entsoe.eu/network_codes/eb/terre/
[9] https://www.ofgem.gov.uk/press-release/ofgem-lays-groundwork-consumer-friendly-flexible-energy-use
[10] https://www.ofgem.gov.uk/decision/decision-market-facilitator-delivery-body

Once qualified, a VLP can register Secondary BM Units, a new type of BM Unit. Secondary BM Units allow the association of Metering System Identifier (MSID) Pairs that a VLP wishes to aggregate for the purposes of participating in TERRE and / or the BM.

Secondary BM Units have the following conditions:[11]

- the Secondary BM Unit does not comprise of CVA Metering System(s)
- the Secondary BM Unit may only comprise of half hourly SVA Metering System(s)
- the Secondary BM Unit does not comprise of SVA Metering Systems that are in more than one GSP Group
- the MSID Pairs within the Secondary BM Unit must have an import and may have an export.

2. Frequency markets

Frequency markets in Britain are in the process of changing but the minimum entry size is 1MW, from a single or from aggregated units. Currently under Firm Frequency Response (FFR) Static FFR will continue to be actively procured until replaced with a future enduring static product and Dynamic FFR is being phased out over the period FY23/24 replaced with new dynamic response services - Dynamic Containment (DC), Dynamic Moderation (DM) and Dynamic Regulation (DR). These are still being finalised but details as proposed are set out in the table below.[12]

3. The winter Demand Flexibility Service (DFS)

The DFS allows household participation via Registered Service Providers. The procurements rules for Registered Service Providers including registrations of DFS Units, half-hourly metering requirements, operational baselines, bidding processes, etc.[13]

4. Distribution network (DSO) Flexibility services

Distribution flexibility services are procured on an annual basis across four different types of service from aggregated distributed energy resources (DER), including smart appliances as shown in the table below.

Service parameters	SUSTAIN	SECURE	DYNAMIC	RESTORE
Minimum declarable capacity	50kW	50kW	50kW	50kW
Minimum utilisation	30 mins	30 mins	30 mins	30 mins
Utilisation notification period	Scheduled in advance	1 week in advance	Real time	Real time
Maximum ramping period	N/A	<15 mins	<2 mins	<2 mins
Availability agreement period	N/A	Contract stage	Contract stage	Contract stage
When required?	Scheduled forecast overload	Pre-fault / peak shaving	Network abnormality / planned outage	Network abnormality
Risk to network	Low	Medium	High	High
Utilisation certainty	High	High	Low	Low
Frequency of use	High	Medium	Low	Low

Figure 2: Flexibility service requirements (Electricity North West)[14]

[11] https://www.elexon.co.uk/about/roles/virtual-lead-party/
[12] https://www.nationalgrideso.com/industry-information/balancing-services/frequency-response-services/new-dynamic-services-dcdmdr
[13] https://www.neso.energy/document/286976/download
[14] https://www.enwl.co.uk/globalassets/future-energy/flexibility-hub/document-library/consultations/flexibility-services-consultation-2023.pdf

5. The wholesale market

On 6 October 2023, the regulator, Ofgem approved a modification to Britain's Balancing and Settlement Code (BSC) titled P415 'Facilitating access to wholesale markets for flexibility dispatched by Virtual Lead Parties (VLPs)'. Access to the wholesale market for flexibility dispatched VLPs will take effect from 7 November 2024. Under this new access, VLPs will be able to trade Deviation Volumes (a new type of settlement volume) which represent the difference between what is forecast to be consumed or generated and what was actually consumed or generated, where the difference can be attributed to VLP action. [15]

[15] https://www.ofgem.gov.uk/sites/default/files/2023-10/Ofgem%20decision%20P415%20%27Facilitating%20Access%20to%20Wholesale%20Markets%20for%20Flexibility%20Dispatched%20by%20VLPs_0.pdf

Great Britain electricity market requirements for aggregated device participation

Wholesale market (Day-ahead)	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
In 2023 a proposal was introduced to reduce the minimum bid to 50kW	Currently 0.1MW - 100kW in 'deviation volumes'			Short - 30 minutes	Long - day-ahead
Balancing Mechanism (managed by Elexon)	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
	1MW (minimum)	1MW (minimum)		Short - 30 minutes	Long - auction gate opens 60-90 mins before real time. During this window, market participants submit “bids” or “offers” into the BM
Firm Frequency Response (FFR):	**Power**			**Duration**	**Response time**
	Raise	***Lower***	***Hold***		
Static frequency response	1MW (minimum)	1MW (minimum)	No	Short - sustained for a further 30 minutes	Short - within 10 seconds of an event
Dynamic frequency response is a continuously provided service used to manage the normal second-by-second changes on the system					
Primary response	1MW (minimum)	1MW (minimum)	No	Short - sustained for a further 20 seconds	Short - within 10 seconds of an event
Secondary response	1MW (minimum)	1MW (minimum)	No	Short - sustained for a further 30 minutes	Short - within 30 seconds of an event
High frequency response	1MW (minimum)	1MW (minimum)	No	More than a day - sustained indefinitely	Short - within 10 seconds of an event
Frequency markets (new dynamic services proposed): Dynamic Containment (DC), Dynamic Moderation (DM), Dynamic Regulation (DR)	**Power**			**Duration**	**Response time**

	Raise	***Lower***	***Hold***		
Dynamic Containment (DC)	1MW (minimum)	1MW (minimum)	No	Short - 15 minutes	Very short - 0.5s
Dynamic Moderation (DM)	1MW (minimum)	1MW (minimum)	No	Short - 30 minutes	Very short - 0.5s
Dynamic Regulation (DR)	1MW (minimum)	1MW (minimum)	No	Short - 60 minutes	Short - 2s
Demand Flexibility Service (winter)	**Power**			**Duration**	**Response time**
		Lower			
		1MW (minimum) - 100MW (maximum)		Medium - 1 hour (usually)	Long - five days notice
DSO (distribution network) flexibility service - Sustain	**Power**			**Duration (minimum utilisation)**	**Response time**
	Raise	***Lower***	***Hold***		
Where scheduled forecast overload network constraint	50kW	50kW	No	Short - 30 minutes	Long - scheduled in advance
DSO flexibility service - Secure	**Power**			**Duration**	**Response time**
	Raise	***Lower***	***Hold***		
For pre-fault/peak shaving network constraint	50kW	50kW	No	Short - 30 minutes	Medium - 1 week in advance, but 15 minute ramping
DSO flexibility service - Dynamic	**Power**			**Duration**	**Response time**
Network abnormality/planned outage	***Raise***	***Lower***	***Hold***		
	50kW	50kW	No	Short - 30 minutes	Medium - less than 2 minutes maximum ramping period (for real-time response)
DSO flexibility service - Restore	**Power**			**Duration**	**Response time**
	Raise	***Lower***	***Hold***		
In response to network abnormality/unplanned outage	50kW	50kW	No	Short - 30 minutes	Medium - less than 2 minutes maximum ramping period (for real-time response)

3. Australia

3.1. Appliance standards

National energy efficiency standards

The Federal Greenhouse and Energy Minimum Standards (GEMS) legislation and program currently only covers energy efficiency. This is undertaken through Minimum Energy Performance Standards (MEPS) and requirements for Energy Rating Labels. However, there has been advocacy by the Institute for Energy Economics and Financial Analysis (IEEFA) for it to be expanded to include flexibility, especially for hot water[16] and reverse cycle air conditioning[17].

In November 2019 Australian Energy Ministers decided four domestic appliances sold in the country must support demand response (specifically, the AS4755 series of Australian Standards), including air conditioners (ACs), electric storage water heaters (resistive), pool pump controllers and electric vehicle (EV) charger/discharger units but this decision has not progressed to implementation (see below).

Australian Standard AS4755 is a technical standard developed for demand response capabilities in appliances. IEEFA has identified a series of ways in which the AS4755 does not contain the features of what should be contained in a modern standard.

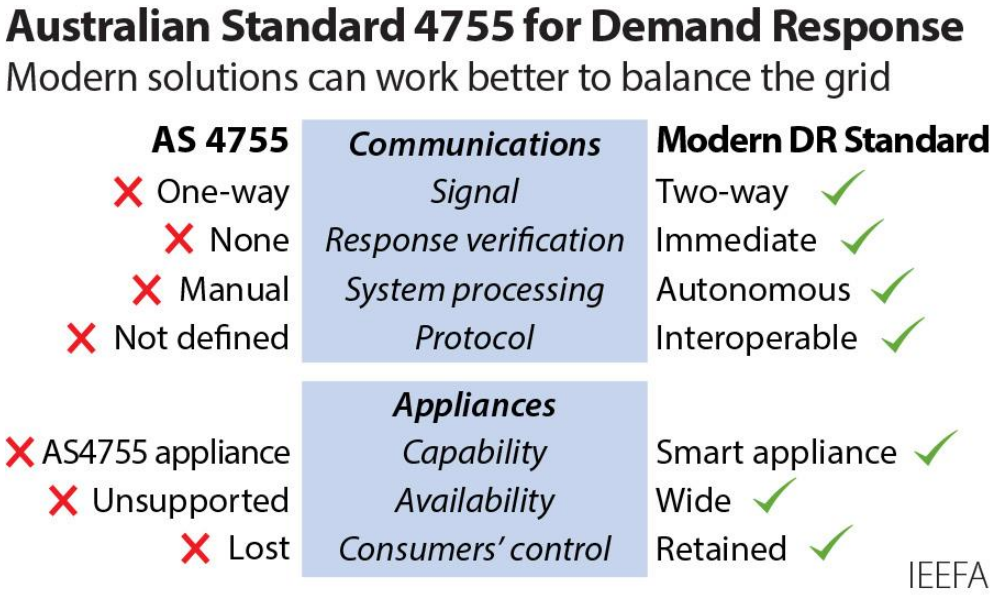


Figure 3: Summary of issues with AS4755[18]

The fundamental issues with the AS4755 series of standards are:

1. The interactions with other Australian policies and approaches to peak demand and minimum system load are unclear.
2. AS4755 is a very basic, out-dated approach to demand response.
3. The AS4755 series does not support interoperability.

There are alternative open interoperability international standards (e.g. IEEE2030.5) which overcome these issues. There are some state specific approaches to demand response for appliances across Australia, and this national case study has been extended with a consideration of sub-national standards below.

[16] https://ieefa.org/articles/big-shift-how-smart-hot-water-can-lighten-load-consumers-and-grid
[17] https://ieefa.org/articles/making-air-conditioners-smart-could-cut-household-energy-bills
[18] https://ieefa.org/articles/ieefa-enforcing-outdated-australian-only-demand-response-standard-not-consumers-long-term

South Australia

South Australia considered state-specific demand response requirements for swimming pool pump controllers, home chargers for electric vehicles, electric storage water heaters and air conditioners in 2021. So far, regulations have only been brought in for air conditioners.

Demand response capability requirements for installation of all air conditioning types (excluding evaporative, portable and close control air conditioners), up to a cooling capacity of 19kW inclusive have applied since 1 July 2023 under a Technical Regulator Guideline:[19]

'Air conditioners within the scope of this guideline shall comply with any of the following standards:

- AS/NZS 4755.3.1:2014; or
- AS/NZS 4755.2 (when published); or
- the equivalent of the superseded AS/NZS 4755.3.1.2012 (for a limited period until 1 July 2025 or 12 months after the publication of AS/NZS 4755.2, whichever is the later date).

These air conditioners are also required to comply with three [demand response modes] DRMs - DRM1, DRM2, DRM3. The Technical Regulator may add other standards in future revisions of this guideline.'

Draft DR AS 4755.3.1:2024 Part 3.1: Interaction of demand response enabling devices and electrical products—Operational instructions and connections for air conditioners (this Standard) was published on 12-08-2024. The draft standard is not publicly available and as it is proprietary, it must be purchased at considerable cost, creating a barrier to uptake.

In addition, connection of demand responsive HVAC, heat pump hot water system, pool pump or EV charger which complies with "AS/NZS 4755 or is otherwise approved by the Minister or their delegate" are recognised under the Retailer Energy Productivity Scheme (REPS), South Australia's white certificate energy efficiency scheme.

Victoria

Several Australian states offer a heat pump hot water system (HWS) subsidy, but Victoria is the only state to require any appliance flexibility requirements (a timer) to qualify for the subsidy. Under the Solar Victoria rebate (Solar Homes program)[20] from 1 July 2024, the list of eligible hot water products must have an end-user configurable integrated timer on the outside of the unit, or one that can be connected to a solar system to run the HWS during periods of solar generation. The timer requirement is intended to enable end-users to maximise self-consumption and align times of operation with their needs – which is a policy objective of the program.

Solar Victoria also *recommends* that the installed system should include an open communication protocol. While there is no definition provided, an open communication protocol is understood to mean it is possible to communicate with the device without using proprietary signals. In Australia, a Common Smart Inverter Profile (CSIP) has been developed as a standardised minimum communication protocol from Distribution Networks to Distributed Energy Resources (DER). This recommendation is an early signal to the market that Solar Victoria may introduce this as a mandatory requirement. If this recommendation progresses to a mandatory requirement, industry will be consulted on which protocol(s) are appropriate and achievable.

Note that in Victoria, distribution network companies also have the ability to use and control smart meters with controlled load.

[19] https://www.energymining.sa.gov.au/industry/energy-efficiency-and-productivity/air-conditioners-regulation-change
[20] https://www.solar.vic.gov.au/hot-water-rebate

Major requirements in AS4755

Communication	Interoperability	Measurement/sync	Security	Consumer override
One way	No requirement	No requirements	None	Unclear

3.2. Appliance (device) participation in markets

Virtual Power Plants (VPPs)/aggregated DER have the potential to participate in several Australian energy markets, including:

- The wholesale energy market (WEM) in the state of Western Australia and the wholesale demand response mechanism (WDRM) in the National Electricity Market, NEM (covering the eastern states, South Australia and Tasmania);
- Frequency Control and Ancillary Services (FCAS) markets in the NEM: aggregated DER can participate in contingency FCAS markets;
- The Reliability and Emergency Reserve Trader (RERT) in the NEM: RERT is demand response capacity contracted for emergency demand response. There may also be some DER in RERT contracts, but there is very little transparency around this; and
- distribution network support services (known in other jurisdictions as “flexibility”, “non-network” or “non-wires” services), among them thermal, voltage or peak-demand management.

From November 2026, aggregated DER will be able to be voluntarily scheduled and dispatched in the wholesale market but with a minimum 1MW bid size. This will include incentives for participation in the first five years. [21]

Wholesale market

Aggregated DER will be able to be voluntarily scheduled and dispatched in the wholesale market from 5 November 2026, with the tenders for early participation beginning in February 2027, following a final determination by the Australian Energy Market Commission (AEMC) on 19 December 2024.

This rule determination includes decisions to:

- Include a five-year incentive payment to drive participation in dispatch – conducted via tenders by the Australian Energy Market Operator (AEMO), and
- Introduce a monitoring and reporting functions to understand the forecasting challenges and errors from unscheduled price-responsive resources.

AEMO guidelines will establish the specific operational and technical requirements for participants.

Contingency FCAS

In the NEM there are eight contingency FCAS markets: to raise and lower frequency on a very fast (two-second), fast (six-second), slow (60-second) or delayed (five-minute) basis. Locally enabled market participants respond to frequency changes without a central command or instruction. Aggregated DER has been providing contingency FCAS for all eight services since VPP trials began in 2019.[22]

Aggregated DER is defined in the rules for the purposes of the wholesale demand response mechanism and FCAS as a ‘Wholesale Demand Response Unit (WDRU)’ which is ‘a single or an aggregation of demand-responsive, controllable market load connection point(s) within a NEM region. WDRUs need to be identified as eligible (a "qualifying load"), classified, scheduled, and dispatched’.

Requirements for participation in the FCAS markets are set out in the Market Ancillary Services Specification (MASS).

[21] Australian Energy Market Commission. (2024). Integrating price-responsive resources into the NEM. AEMC.
[22] https://ieefa.org/resources/what-state-virtual-power-plants-australia

Contingency FCAS are provided by technologies that can detect a Local Frequency deviation and respond in a manner that corrects System Frequency following a contingency event. FCAS Facilities may cease to provide Contingency FCAS once Frequency Recovery has occurred.

If AEMC finalises this 'scheduled lite' rule change, aggregated DER may be able to provide regulation FCAS which is delivered during each 5-minute trading interval.

Demand Response Mechanism

The wholesale demand response mechanism (WDR mechanism) is currently limited to large business customers (>100MWh or, in Victoria and South Australia, >160MWh and Tasmania, >150MWh) in compliance with a baseline methodology that requires a flat demand profile – see below. Aggregated household DER is not able to participate.

Small business customer NMIs can be classified and aggregated as WDRUs where it has a National Electricity Retail Rules (NERR 5(2)(a) agreement with its retailer to aggregate its premise loads. This has the effect of its total load corresponding to that of a large customer. As part of the application to classify/aggregate these small NMIs as WDRUs, AEMO requires a declaration confirming that a NERR 5(2)(a) agreement applies to them.

There is no lower size limit for individual loads within a WDR aggregation, so long as they are classed as 'large' customers (jurisdiction dependent). However, the dispatchable unit (either a single NMI or aggregation) must be a total of at least 1MW. This is because the dispatch engine (NEMDE) operates in integers.

There are mechanisms that can be used where facilities (generators or loads) are not sufficiently flexible to respond to 5-minute dispatch timeframes, including:

- Ramp rates
- Fast start inflexibility profile (FSIP) bidding
- Other bidding strategies, as determined by the DRSP.

RERT – Reliability and Emergency Reserve Trader

Reliability and Emergency Reserve Trader (RERT) is procured on three timeframes:[23]

- Long-notice situations where AEMO determines it has between 12 months and ten weeks of notice of a projected shortfall in reserves.
- Medium-notice situations where AEMO has between ten weeks and seven days of notice of a projected shortfall in reserves.
- Short-notice situations where AEMO has less than seven days of notice of a projected shortfall in reserves.

In addition, there are several criteria that AEMO will use to assess the reserve, these include:

- What is the availability of the reserve over the summer period
- Whether the reserve can be activated as a block of not less than 10MW
- Whether the reserve can be activated continuously for at least 30 minutes
- The potential reserve does not submit bids and offers into the National Electricity Market.

Because AEMO enters into commercial contracts for RERT, details of participating loads or generation are not available. However, households participated in the three year AEMO-ARENA demand response trials under the RERT[24] scheme including being paid to reduce their energy

[23] https://www.aemc.gov.au/sites/default/files/2020-08/Updated%20Amended%20Panel%20RERT%20Guidelines%20-%2018%20August%202020%20-%20Final%20for%20publication_0.pdf
[24] https://arena.gov.au/news/aemo-arena-demand-response/

use using smart thermostats in Victoria and South Australia.[25] A report on the trials concluded that ARENA's portfolio of demand response projects was effective in delivering and exceeding the trial's objective of 200MW of tested DR capacity for the RERT.[26]

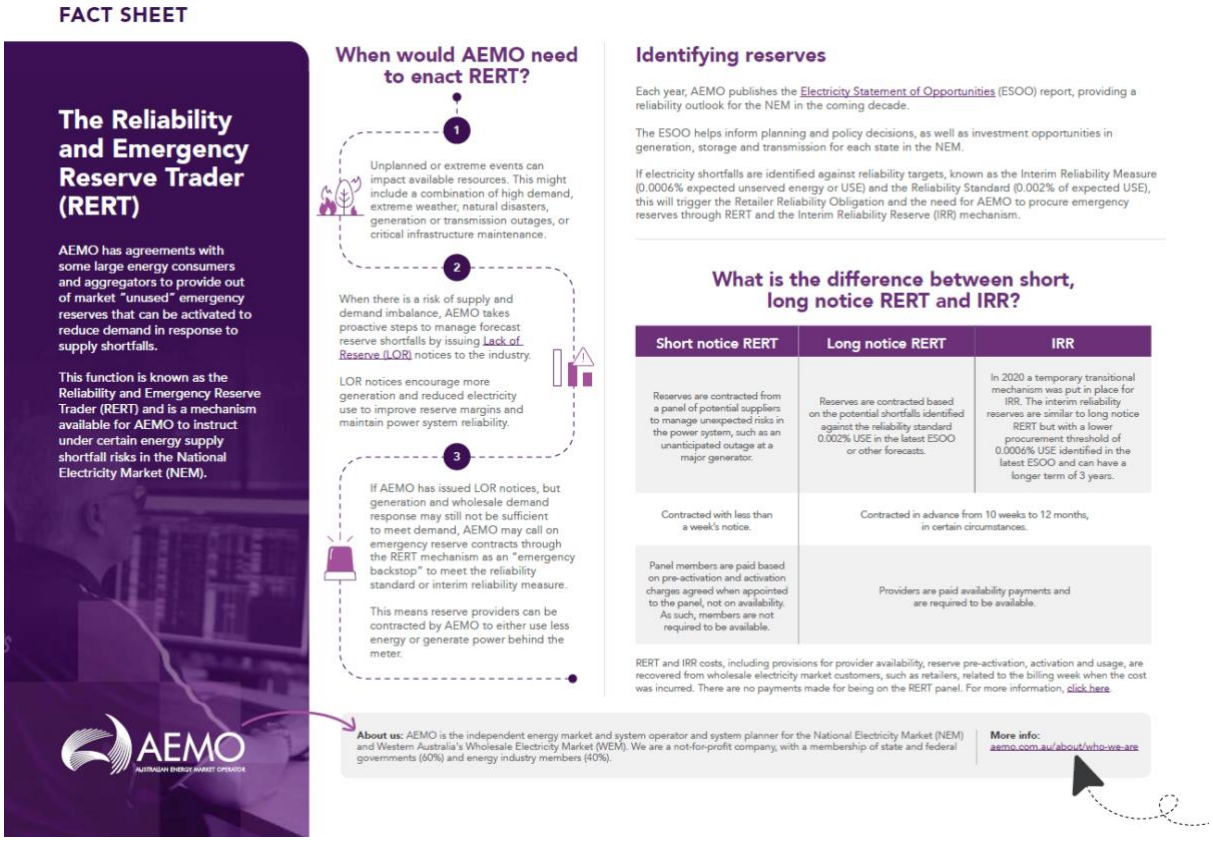


Figure 4: Fact sheet on the RERT from AEMO[27]

[25] https://arena.gov.au/blog/how-is-demand-response-working-in-australia/
[26] https://arena.gov.au/assets/2021/10/demand-response-short-notice-rert-trial-year-3-report.pdf
[27] https://wa.aemo.com.au/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert

Australia electricity market requirements for aggregated device participation

Wholesale market TBC	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
Scheduled from 5 November 2026	1MW (aggregated or singular)	No	No	5 minutes	TBD
Contingency FCAS	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
A term used to refer to very fast raise service, very fast lower services, fast raise service, fast lower service, slow raise service, slow lower service, delayed raise service and delayed lower service collectively.	1MW (aggregated or singular)	1MW (aggregated or singular)		FCAS Facilities may cease to provide Contingency FCAS once Frequency Recovery has occurred.	very fast (two-second), fast (six-second), slow (60-second) or delayed (five-minute)
Reliability and Emergency Reserve Trader (RERT)	**Power**			**Duration**	**Response time**
	Raise	***Lower***	***Hold***		
The Reliability and Emergency Reserve Trader (RERT) is a function conferred on AEMO to maintain power system reliability and system security during peak demand events using reserve contracts	10MW (can be aggregated)	10MW (can be aggregated)	No	30 minutes (minimum)	short notice (between three hours and seven days) and medium notice (between ten weeks and seven days) and long notice (more than 10 weeks) Note that length of dispatch and activation times can vary by contract

4. New Zealand

4.1. Appliance standards

Under the Equipment Energy Efficiency (E3) program, New Zealand and Australia regulate the energy efficiency of products in both countries. These regulations cover residential, commercial and industrial use for both labelling standards, Mandatory Energy Performance Labelling (MEPL) and appliance standards through the Minimum Energy Performance Standards (MEPS). In New Zealand, these regulations are made under the Energy Efficiency and Conservation Act 2000. However, none of these standards have any flexibility requirements.

Standards NZ produced a Publicly Available Specification (PAS) for Smart Homes in 2022[28]. It is intended to 'to guide electricity consumers, publicly facing businesses, and suppliers of Smart Home equipment and services to adopt a best practice approach on their journey to a New Zealand network of Smart Homes'.

This standard defines a smart home device as: *A device that can connect to a communications network (directly or through a hub or central interface) and be controlled remotely or set to be controlled automatically based on user preferences and sensor inputs. Smart home devices include (but are not limited to) demand response-enabled devices.*

The PAS does not 'not impose any requirements on sellers, importers, or manufacturers. However, it will introduce smart home technology to New Zealand consumers, providing information to help make household energy use smarter.'[29]

[28] https://www.standards.govt.nz/shop/snz-pas-60122022
[29] https://www.eeca.govt.nz/regulations/voluntary-guidance/publicly-available-specifications/guidance-for-smart-homes/

4.2. Appliance (device) participation in markets

In New Zealand (NZ) DERs can currently participate in wholesale electricity markets and the ancillary services markets.

The NZ Electricity Authority Te Mana Hiko (EATMH) undertook a consultation that closed in February 2023 on regulatory settings to support non-network solutions and flexibility services. The issues paper[30] released with this consultation noted that it was considering a review and update of Part 6 of the Electricity Authority's Code to 'enable the evolving capability of DER to deliver benefits to consumers' and 'support[s] flexibility markets and value stacking' but this has not yet occurred.

In May 2024, EATMH published draft guidance for distributor involvement in the flexibility services market but it contains no specifics on how or when distribution networks can procure flexibility services.[31]

Transpower is New Zealand's sole Transmission Owner and System Operator and has developed its own Distributed Energy Response Management System (DERMS) called FlexPoint. This is a software platform that allows DER providers to enrol and offer their distributed energy storage, distributed energy generation or demand response into the platform and for the operators to call on these resources when needed.[32]

In 2020 Transpower had 233 MW of demand response registered on its FlexPoint platform, including batteries, EV charging stations, and IOT devices.

New Zealand Wholesale Market

The wholesale market in NZ has three options for demand side participation, two of which allow for aggregated DER to participate – Dispatch Notification Load and Difference Bids. Dispatchable Demand does not include aggregated DER. The technical details are listed in Table 1.

Dispatch Notification Load (DNL)

Dispatch Notification Load (DNL) allows for smaller, more distributed generation or loads (typically between 1-10MW in total) to be aggregated or individually participate in the spot market. Dispatch notification is available to both generation and demand aggregators, allowing small scale resources to be aggregated behind a Grid Exit Point (GXP)[33]. Through this setup, DR and DER can participate in price discovery and receive dispatch signals, enabling them to optimise market pricing. Retailers and others can contract with load aggregators as a means of hedging against spot price fluctuations.

Difference Bids

Difference bids allow large consumers or aggregators to bid based on their difference from a baseline load rather than absolute consumption levels. A consumption level is set based on the historical usage patterns and consumers can submit their bids based on willingness to increase or decrease their consumption. This is a means for consumers and aggregators to signal their price sensitivity in the forecast schedules and assess the impact of their resources by comparing the non-responsive and price responsive schedule results. The difference bids are not binding and are not included in the dispatch schedules,

[30] https://www.ea.govt.nz/documents/1743/Issues-paper_-Updating-the-regulatory-settings-for-distribution-networks.pdf

[31] https://www.ea.govt.nz/documents/5009/Distributor_involvement_in_the_flexibility_services_market_-_draft_guidance.pdf

[32] https://www.transpower.co.nz/our-work/distributed-energy-resources/flexpoint

[33] GXP means any point of connection on the grid at which electricity predominantly flows out of the grid

Ancillary services

Aggregated DER can participate in the Fast Instantaneous Reserve (FIR), Sustained Instantaneous Reserve (SIR) ancillary services markets.

Fast Instantaneous Reserve (FIR) is designed to address the immediate drop in frequency that occurs during a significant grid event, such as a generator outage or sudden spike in demand. FIR acts as a "first line of defence" to stabilize the frequency until other reserves or grid resources can respond.

Sustained Instantaneous Reserve (SIR) provides ongoing support to maintain frequency after FIR has addressed the initial frequency decline. It ensures that grid frequency is stabilized until the system operator can activate more gradual balancing measures, like adjusting generation or bringing backup resources online.

The technical details of these services are given in the table on the following page.

Initiatives & trials

Flex Talk Project

The FlexTalk project, led by Electricity Engineers Association (EEA) in collaboration with Energy Efficiency and Conservation Authority (EECA) and industry partners, trialled the adoption of the OpenADR 2.0 protocol to establish interoperability between Distribution System Operators (DSOs) and flexibility providers. The current stage of the FlexTalk project[34] involves testing the functionality of 10 smart devices, and in 2025, it is planning a large-scale trial of in-home smart devices and consumer energy resources to manage flexibility on the electricity network.

[34] https://eea.co.nz/what-we-do/projects/flextalk/

NZ electricity market requirements for aggregated device participation

Wholesale market (Day-ahead)	Power			Duration (minimum)	Response time
	Raise	***Lower***	***Hold***		
Dispatchable Demand (Large consumers can offer to reduce their electricity consumption in the whole sale market	Minimum load reduction capability typically around 1MW			30 mins	Gate closure – 30 mins / 1 hour
Dispatch Notified Loads	Loads between 1 - 10MW			30 mins	Gate closure - 30 mins
Ancillary Service Participation	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
Fast Instantaneous Reserve (FIR)	No requirements identified.	No requirements identified.		Sustain for 60 sec	Fast (Within 6 seconds)
Sustained Instantaneous Reserve	No requirements identified.	No requirements identified.		Sustain for 15 minutes	Slow (Within 60 seconds)

5. European Union

5.1. Appliance standards

Two regulations govern energy appliances within the EU, the Energy Labelling Regulation 2017/1369,[35] and the Ecodesign for Sustainable Products Regulation (ESPR - Regulation (EU) 2024/1781)[36] that is replacing the Directive establishing a framework for the setting of ecodesign requirements for energy-related products (Directive 2009/125/EC). While the Ecodesign framework does not mention flexibility, Article 16 (d) of the Energy Labelling Regulation provides for a reference on the label for "energy smart" products, that is to say products that can provide flexibility[37]. The EU also has a voluntary code of conduct for energy smart appliances,[38] and market rules for energy system flexibility resources.[39]

Energy Labelling Regulation 2017/1369

This regulation sets a mandatory framework for energy consumption labelling of appliances. It applies to energy-related products placed on the market or put into service. It allows for a reference on the energy label for products that are energy smart, i.e. capable of automatically changing and optimizing their consumption patterns in response to external stimuli (Article 16(3)(d) [37]. It originally used letters A (most efficient) to G (least efficient), however in some cases market evolution or new ecodesign limits meant that in some cases bottom classes were left empty or that new upper classes had to be created (i.e. A+, A++, and A+++). Nevertheless, these labels are gradually being replaced by new rescaled labels that bring back the A to G scale, reflecting the state of the art.

Code of Conduct for Energy Smart Appliances

Version 1.0 of the code was launched on 23 April 2024, it promotes energy efficiency and interoperability among devices by encouraging manufacturers to design appliances that can communicate with each other, and with energy management systems. Energy smart appliances are defined as "products that provide energy flexibility being capable of automatically (by means of machine-to-machine communication) optimising their consumption patterns (e.g. time or profile) in response to external stimuli, based on user permission"[40]. This definition is in line with Article 16 (d) of the Energy Labelling Regulation.

A second phase of the code of conduct development started in September 2024. This aims to develop a common framework for the interoperability of energy smart appliances and explore the expansion of the code to include energy management systems (EMS), photovoltaic inverters (PVI), and electrical vehicle chargers (EVC). Currently, the Code of Conduct covers the following electrical appliances that have an energy label:

- White goods: washing machines, tumble driers, washer-driers, dishwashers
- Heating, ventilation and air conditioning (HVAC), including water heating.

[35] https://eur-lex.europa.eu/eli/reg/2017/1369/oj
[36] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781&qid=1719580391746
[37] "where appropriate, the inclusion of a reference in the label allowing customers to identify products that are energy smart, that is to say, capable of automatically changing and optimising their consumption patterns in response to external stimuli (such as signals from or via a central home energy managing system, price signals, direct control signals, local measurement) or capable of delivering other services which increase energy efficiency and the up-take of renewable energy, with the aim to improve the environmental impact of energy use over the whole energy system;"
[38] https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances#section-1479
[39] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401747
[40] https://ses.jrc.ec.europa.eu/sites/default/files/2024-10/1.2._overview_of_the_coc_v.1.0_accomplishments_and_challenges_dg_ener.pdf

	Flexible Start	Monitoring of Power Consumption	Limitation of Power Consumption	Incentive Table based Power Consumption Management	Manual operation
White goods					
• **washing machines, tumble driers, washer-driers, dishwashers**	M	O	O	n/a	M
Heating, cooling, and ventilation appliances					
• **heat pumps (delivering heat/cold through air or water)**	O	M	M	O	O
• **local space heaters**	O	M	M	O	O
• **water heaters**	O	M	M	O	O
• **ventilation**	n/a	M	O	O	O

M: mandatory; O: optional, n/a: not applicable

Table 1: Mapping of use cases to white foods and HVAC appliances that have an energy label (Source: EU[41])

As of October 2024, 11 manufacturers have signed to the Code of Conduct, including Arcelik, Daikin, Electrolux, Miele, Mitsubishi Electric, Panasonic, Viessmann and Qvantum Energy AB, among others.

[41] https://ses.jrc.ec.europa.eu/sites/default/files/2023-08/20230814_draft_of_the_testing_methodology_2.pdf

Major requirements in the Code of Conduct for Energy Smart Appliances (V1.0)

Communication	Interoperability	Measurement/sync	Security	Consumer override
The CoC is communication path agnostic	Development of a common interoperability framework is aim of the second phase of code development. In phase 1, manufacturers commit to ensure the implementation of the applicable use cases using the same information elements that refer to the common reference ontology (SAREF), and the implementation of interoperability profiles based on standardised open Application Programming Interface / open communication protocol to enable the information exchange for the applicable use cases	Information on the consumed energy, the current consumption, the voltage and the frequency may be offered by the ESA.	Apply state of the art and open security mechanisms for the open communication protocol used to: (1) secure the communication, (2) support the installation, administration and configuration (including the assignment of the system roles), (3) ensure proper authorisation for accessing the ESA, and (4) provide the control over the usage of private data, in accordance with the relevant EU legislation in force	The code defines ESAs as being capable of automatically optimising their consumption patterns in response to external stimuli, **based on user permission**[42].

[42] https://ses.jrc.ec.europa.eu/sites/default/files/2024-10/1.2._overview_of_the_coc_v.1.0_accomplishments_and_challenges_dg_ener.pdf

5.2. Appliance (device) participation in markets

Each Member State (MS) within the EU can set specific rules for their electricity markets, but they must comply with the requirements in the relevant Directives and Regulations to ensure standardisation across the Union, and facilitate cross-border participation in markets. The transposition of the Directives into national legislation in the MSs is ongoing. As of 2022, most of the MSs had already introduced a definition of an aggregator in the relevant legislation or regulation, but the secondary legislation and adaptation of market rules, procedures, responsibilities and business models for flexible demand/DR are yet to be drafted in many of them.

The main EU regulations covering demand response (DR) aggregation are detailed below.

2019 – The broader EU Clean Energy for All Europeans package included updates to provide a framework to foster grid flexibility, support consumer participation and ensure fair market access for both aggregators and traditional energy suppliers. Particularly through the following regulations:

- Internal market for electricity – Regulation (EU) 2019/943
- Common rules for the internal market for electricity - Directive (EU) 2019/944 – together define the main market-based principles and rules for the operation of electricity markets. They are important because the later states:
    - Article 15 Active customers
        - Member States shall ensure that final customers are entitled to act as active customers without being subject to disproportionate or discriminatory technical requirements, administrative requirements, procedures and charges, and to network charges that are not cost-reflective.
    - The Directive includes requirements on active customers and flexible demand, including that Member States shall ensure that active customers are:

(a) entitled to operate either directly or through aggregation;

…

(c) entitled to participate in flexibility schemes and energy efficiency schemes;

(f) financially responsible for the imbalances they cause in the electricity system; to that extent they shall be balance responsible parties or shall delegate their balancing responsibility […]

> ‘All customer groups (industrial, commercial and households) should have access to the electricity markets to trade their flexibility and self-generated electricity. *Customers should be allowed to make full use of the advantages of aggregation* of production and supply over larger regions and benefit from cross-border competition. Market participants engaged in aggregation are likely to play an important role as intermediaries between customer groups and the market. Member States should be free to choose the appropriate implementation model and approach to governance for independent aggregation while respecting the general principles set out in this Directive. … The chosen model should contain transparent and fair rules to allow independent aggregators to fulfil their roles as intermediaries and to ensure that the final customer adequately benefits from their activities. Products should be defined on all electricity markets, including ancillary services and capacity markets, so as to encourage the participation of demand response.’

In the Directive (EU) 2019/944, aggregation is defined as ‘*a function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in*

any electricity market', and an independent aggregator is defined as *a market participant engaged in aggregation who is not affiliated to the customer's supplier.*[43]

The Electricity Directive also recognises the right for market participants engaged in aggregation (including independent aggregators [IAs]) to enter electricity markets without the consent of other market participants. An *independent* aggregator (IA) operates independently of electricity suppliers, and can offer an alternative that empowers small users to understand the value of their flexibility better and engage in DR through all the options available to them. The new entity of the independent aggregator is enshrined by Article 17 of the EU Directive 2019/944.

The Electricity Directive requires "the fair participation of aggregators in all electricity markets and that transmission and distribution system operators treat aggregators equally with other market participants". Each EU member state would need to implement its own national regulatory frameworks to support independent aggregator implementation. Each of the electricity markets has its own rules, prices, and participants, and can offer different opportunities and challenges for aggregators.[44]

2023 – The Energy Efficiency Directive (EED) (EU/2023/1791) was adopted in September 2023 as a revision of EED 2012/27/EU defines the technical and contractual actions to support DR and includes provisions to enable its participation 'for trading energy, capacity, balancing and ancillary services in all timeframes, including forward, day-ahead and intra-day markets'(Annex XIII, Article 2)

2024 – On 13 June 2024 Regulation 2024/1747 and Directive 2024/1711 were adopted amending Regulation 2019/943 ('Electricity Regulation') and Directive 2019/944 ('Electricity Directive') in order to improve the Union's electricity market design. Amongst other changes, they reduced the reduced the minimum bid sizes from 500kW to 100kW, and, from 1 Jan 2026, reduced the intraday cross-zonal gate closure time from 60 mins to 30 mins before real time.

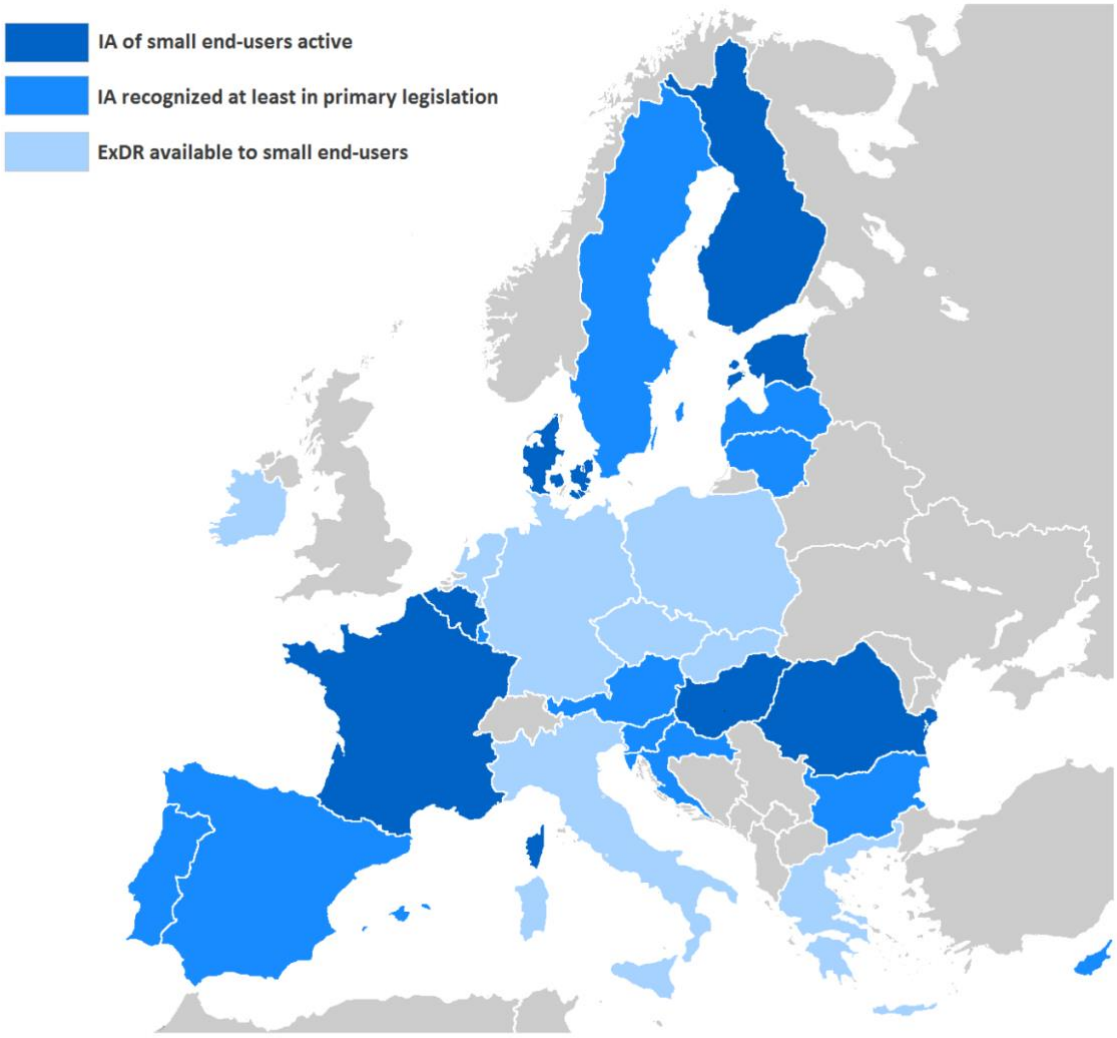
2025 – The Agency for the Cooperation of Energy Regulators (ACER) ACER will submit a new network code on demand connection proposal[45] to the European Commission by March 2025.

Current state of flexible demand in the EU

In 2022, Joint Research Centre (JRC) described the participation of large industrial and commercial facilities in DR as common business practice. The participation of small consumers was emerging, with varying levels of support across the EU[46]. DR was available to small end-users in 22 out of 26 MSs, with independent aggregators recognised in the national legislation of 19 Member States. However, even though the options and the pathways are available legally, the existence of independent aggregators of end-users that can participate in at least one electricity market can be found only in 7 MS: Belgium, Croatia, Denmark, Estonia, Finland, France, and Hungary, where the market is just emerging[47] (see Figure 5). France was described as the only country where independent aggregators of end-users have access to all markets. Wholesale market access is available to IA's only in France and Belgium.

Another review published in 2022 found that significant demand-side participation from independent aggregators was only occurring in France and, to some extent, Switzerland and Finland (https://pub.norden.org/nordicenergyresearch2022-04/#99954).

[43] Clean Energy Package (CEP) in Art. 2 (19) of the Directive (EU) 2019/944
[44] Maja Božičević Vrhovčak and Bruno Malbašić, "Unlocking the Value of Aggregated Demand Response: A Survey of European Electricity Markets," *Energies* 16, no. 17 (September 3, 2023): 6386, https://doi.org/10.3390/en16176386.
[45] https://www.acer.europa.eu/sites/default/files/documents/Official_documents/Public_consultations/PC_2024_E_07/ACER_revised_proposal_DR_NC_package.zip
[46] European Commission. Joint Research Centre., *Explicit Demand Response for Small End-Users and Independent Aggregators: Status, Context, Enablers and Barriers.* (LU: Publications Office, 2022), https://data.europa.eu/doi/10.2760/625919.
[47] European Commission. Joint Research Centre.



Source: JRC 2021

Figure 5: Status of explicit Demand Response and Independent Aggregators across the EU Member States in 2021 (source: JRC 2021)

Participation of Independent Aggregators (IAs) in energy markets varies across the EU. Summary of assessment of participation provided below.

Wholesale Market participation – Day-ahead markets (DAMs) and intra-day markets (IDMs)

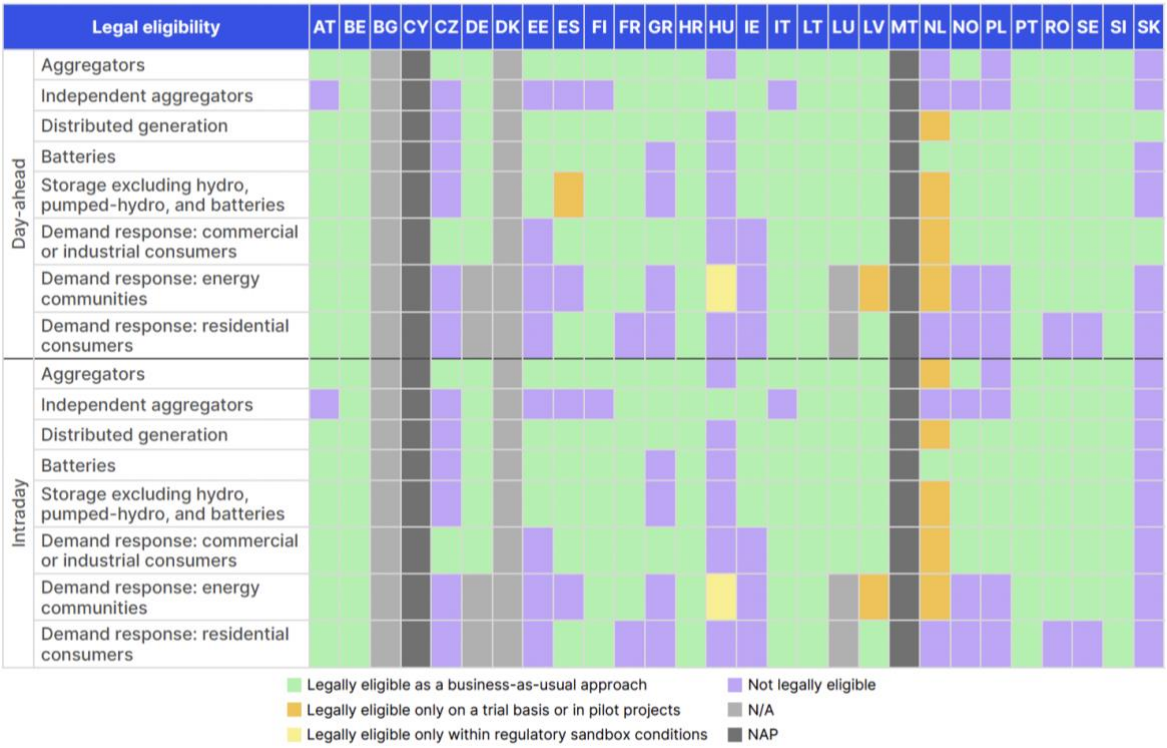
The legal eligibility of new actors and distributed energy resources to access day-ahead and intraday markets was reviewed in a report by ACER in 2022[48] (summarised in Table 3). This found, based on the information reported, that only Belgium, Croatia, Lithuania, Portugal, and Slovenia had fully opened these markets to all actors and distributed energy resources.

The most restrictive day-ahead and intraday markets in terms of legal eligibility were found in the Czech Republic, Hungary, and Slovakia.

[48] ACER, "Demand Response and Other Distributed Energy Resources: What Barriers Are Holding Them Back?," 2023, https://www.acer.europa.eu/sites/default/files/documents/Publications/ACER_MMR_2023_Barriers_to_demand_response.pdf.

Aggregators were still deprived from access in four Member States (of which the Netherlands was in testing phase), while independent aggregators do not have access in ten Member States.

Table 3: Legal eligibility of different distributed energy resources and new actors to access day-ahead and intraday markets per Member State - 31 December 2022 (ACER 2023)

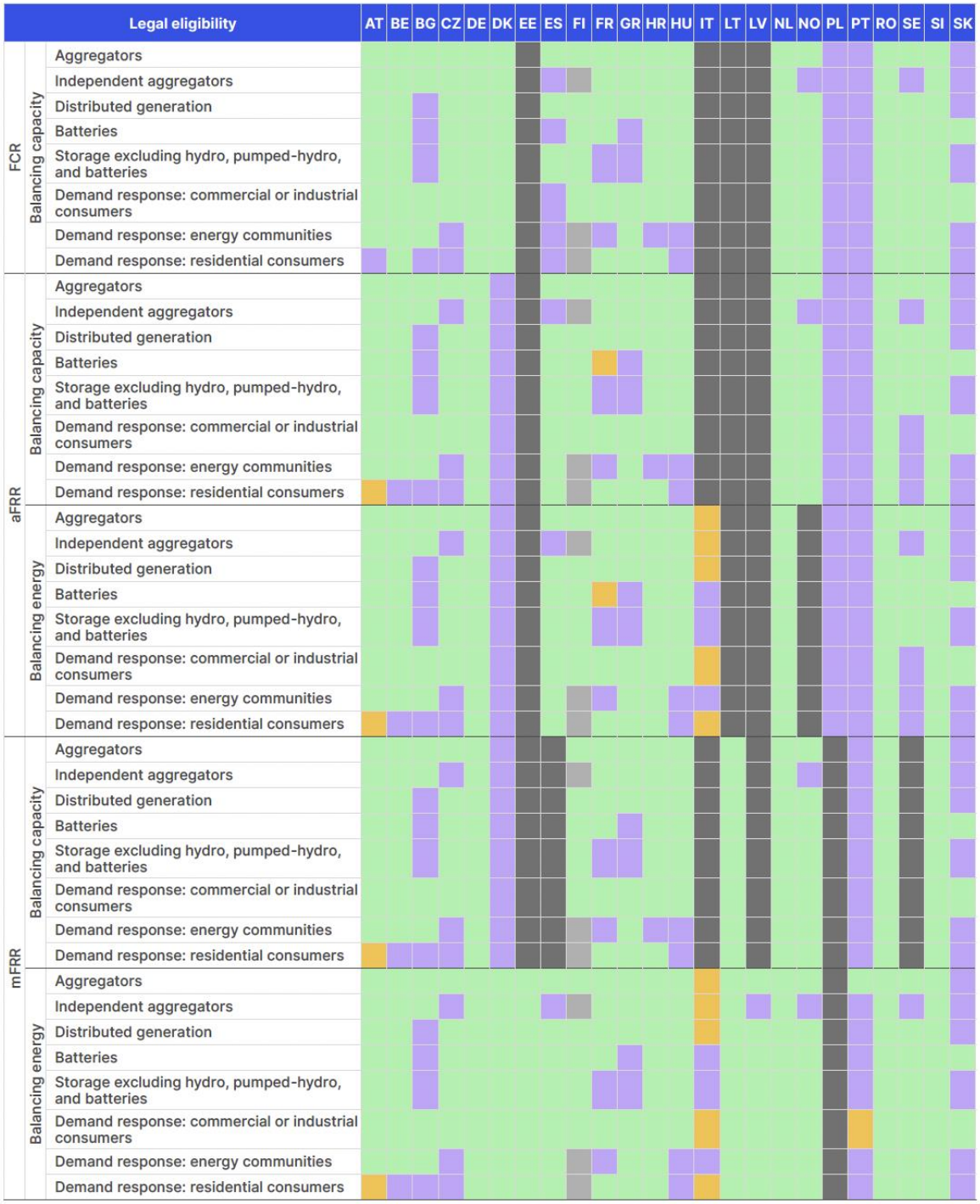


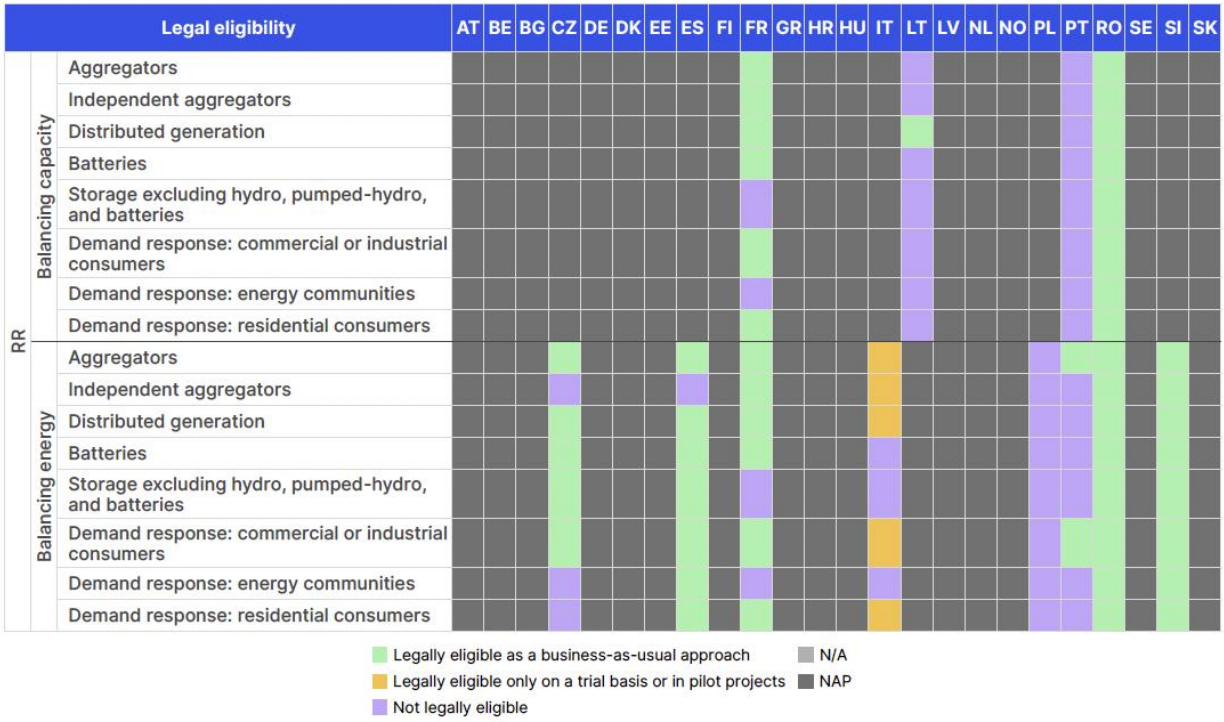
Balancing Markets

Table 4 shows the legal eligibility of new actors and DERs to offer different balancing products across the EU Member States in 2022[49]. Based on the information reported, only Germany, Estonia, the Netherlands, Romania, and Slovenia had fully opened all their balancing services. Denmark, Poland, Portugal and Slovakia allowed restricted access to balancing services, whilst in the majority of member states these markets were closed to varying degrees.

[49] ACER.

Table 4: Legal eligibility of different distributed energy resources and new actors to access balancing products per Member State - 31 December 2022 (ACER 2023) (Table across two pages)





Source: ACER based on NRA data.
Notes: (1) The table refers to legal eligibility to access local, specific or standard balancing products. (2) Not applicable to Cyprus and Malta since they do not have a liquid wholesale electricity market. (3) The table does not show Ireland since there is no clear translation of the EU balancing services to the IE-SEM due to the way that central dispatch has been implemented in Ireland. Nevertheless, all generators, battery energy storage systems, and demand-side units with capacity greater than 5 MW are mandated to make their capacity available to the TSO for balancing services and congestion management. (4) Luxembourg is integrated within the LFC perimeter of Amprion in the DE-LU bidding zone, hence German provisions apply. (5) In 2022 all distributed energy resources in Italy excluding energy communities, batteries, and other new storage solutions (e.g., compressed air energy, flywheels, hydrogen, etc.) were legally eligible to provide balancing energy in the framework of the national pilot projects 'Regolazione Secondaria' and 'UVAM'; however, they were not converted to the EU balancing energy platforms. This is expected to change from January 2025 when all types of distributed energy resources will be eligible to participate according to the regular regulatory framework. Since 2023, all energy storage solutions have become legally eligible to provide balancing energy individually.

Network Congestion management/Network support services

The legal eligibility of new actors and distributed energy resources to provide congestion management services for TSOs and DSOs in 2022 is shown in Table 5[50]. In the nineteen Member States where TSOs use some market-based or non-market-based mechanism for re-dispatching to tackle congestions in their transmission grid, only Belgium, Germany, France, Croatia, and the Netherlands have fully opened this service to all new actors and distributed energy resources.

DSOs implement some kind of congestion management measure in thirteen member states, i.e., market-based or non-market-based re-dispatching (also referred to as local markets), non-firm connection agreements or interruptible tariffs. Amongst these Member States, only Belgium (BE), Germany (DE), France (FR), Malta (MT), the Netherlands (NL), Sweden (SE) and Slovenia (SI) have fully opened this service to all new actors and distributed energy resources.

[50] ACER.

Table 5: Legal eligibility of different distributed energy resources and new actors to provide congestion management services for TSOs and DSOs per Member State - 31 December 2022 (ACER 2023)

EU electricity market requirements for aggregated device participation

Wholesale market (day-ahead)	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
On the day-ahead market energy is traded one day before real time,	0.1MW (minimum)	0.1MW (minimum)	No	Long (4 hours)	Long - day-ahead
Intra-day market	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
Energy trading that occurs on the same day as delivery	0.1MW (minimum)	0.1MW (minimum)	No	Short (15 minutes)	Medium (15 minutes ahead) (TBC)
Balancing services – Frequency balancing market	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
Frequency Containment Reserve (FCR) (Primary Reserve)	Details determined at the individual country level				
aFRR – automatic frequency restoration reserve (secondary reserve)					
mFRR – manual frequency restoration reserve (tertiary reserve)					
Network congestion management	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
Open to aggregated DER at the TSO level in Belgium, Germany, France, Croatia, and the Netherlands. At the DSO level in Belgium, Denmark, France, Malta, the Netherlands, Sweden and Slovenia	Details determined at the individual country level				

6. Germany

6.1. Appliance standards

As Germany is part of the EU, it follows their established appliance standards, including the Energy Labelling Regulation (EU) 2017/1369 and Ecodesign for Sustainable Products Regulation (ESPR - Regulation (EU) 2024/1781) that is replacing the Directive establishing a framework for the setting of ecodesign requirements for energy-related products (Directive 2009/125/EC). The EU also has a voluntary code of conduct for energy smart appliances introduced in April 2024 (and discussed in the EU case study). Germany also has their own national policies for energy appliance standards, including the German Energy Saving Ordinance (EnEV), and Blue Angel Label (Blauer Engel). Neither of these standards has any flexibility requirements.

A new regulation under Section 14a of the Energy Industry Act (EnWG)[51] for the management of 'controllable consumption equipment' such as heat pumps, battery storage and charging facilities for EVs came into force on 1 January 2024. The new regulation makes it possible for grid operators to temporarily reduce the output of (but not turn off) controllable energy-consuming assets to 4.2kW in the event of potential overloads. In return, consumers can benefit from a reduction in grid fees[52]. All newly installed stationary electrical heating, water heating and/or space heating or space cooling, as well as non-public electric vehicle charging are required to participate in consumption control if their grid connection capacity exceeds 4.2 kW, and a direct or indirect connection is made with the low voltage grid. Within a group of devices, the devices are added together. Therefore, even if there are five heat pumps installed in a building, each consuming less than 4.2kW, their consumption is added together. As a result, each device covered by §14a must be controllable, even if it consumes less than 4.2kW[53]. Incentives to provide the control ability to the grid operator are via three fee reduction options (modules) [54]:

- Module 1: Customers receive a flat-rate grid fee reduction. Depending on the grid area, it can amount to between €110 and €190 (gross) per year. Equivalent to 50-95% of the grid fee for the annual consumption of an electric car (approx. 2,500 kWh).
- Module 2: Customers can choose a percentage fee reduction (60%) on each kilowatt-hour drawn by the controllable consumer appliance. A separate meter is required for this option. This model can be combined with the levy exemption for heat electricity (CHP and offshore levy, EnFG levy exemption) and is therefore particularly suitable for heat pumps in many cases.
- Module 3: Grid operators are also obliged to offer Module 3. If desired, it will be possible from 1 January 2025 to combine Module 1 with Module 3, an incentive module with time-variable grid fees.

[51] https://www.bundesnetzagentur.de/DE/Beschlusskammern/1_GZ/BK6-GZ/2022/BK6-22-300/Beschluss/BK6-22-300_Beschluss_20231127.pdf?__blob=publicationFile&v=1
[52] https://www.gridx.ai/knowledge/paragraph-14a-enwg
[53] https://www.eebus.org/wp-content/uploads/2024/04/FAQs-%C2%A7-14a.pdf
[54] https://www.gridx.ai/knowledge/paragraph-14a-enwg

Major requirements in Section 14a of Energy Industry Act (Act in German, details source from EEBUS fact sheet[55])

Communication	Interoperability	Measurement/sync	Security	Consumer override
Only one-way communication required – "A device is paragraph 14a-compliant if it can be proven that it follows control signals."[56]	From the output of the control box (in the future also Smart meter gateway [SMGW] [grid connection point hub]) EEBUS[57] fulfills the requirements of BNetzA and BSI (German Federal Office for Information Security). In both regulations EEBUS is currently mentioned as the only example for a communication interface, which does not mean that other communication interfaces do not also fulfil the requirements.	Operators and device manufacturers must ensure and prove that control commands are successful – unclear if this is real time communication with the grid or just at the compliance/install phase?	Controllable devices must fulfil the IT security requirements of BNetzA regulation on § 14a and BSI Technical Guideline TR-03109-5 for CLS communication adapters.	No, grid operators are obliged to curtail consumption systems to prevent overloading of grid infrastructure. Consumers can utilise home energy management systems to harness the production of self-generated solar power to balance out the power supply despite operator throttling.
How the communication between the grid operator and the SMGW/control box works is decided by the metering point operator, who is responsible and installs the necessary technology.		The controllable device should apply the limit promptly: charging stations in seconds, heat pumps in minutes.		

[55] https://www.eebus.org/wp-content/uploads/2024/04/FAQs-%C2%A7-14a.pdf
[56] https://www.gridx.ai/blog/paragraph-14a-we-clarify-your-12-most-burning-questions
[57] EEBUS describes the communication interface (= application, transportation, communication) in order to allow for the interconnection between energy management relevant devices as well as corresponding control systems (https://www.eebus.org/what-is-eebus/)

6.2. Appliance (device) participation in markets

Within the EU, demand response (DR) aggregation is formally recognised and regulated through the following acts, Internal market for electricity – Regulation (EU) 2019/943, Common rules for the internal market for electricity - Directive (EU) 2019/944. Amendments were made to these in June 2024, with the adoption of Regulation 2024/1747 and Directive 2024/1711.

Each Member State (MS) within the EU can set specific rules for their electricity markets, however they must align with EU guidelines to ensure standardisation across the union, and facilitating cross-border participation in markets. As of 2021, Germany had not fully implemented these directives, and the independent aggregation of small end users was not described as active, however explicit demand response was available to small end users[58].

Within Germany, there are two major laws that are relevant for aggregators and DERs: the Energy Industry Act (EnWG), and the Renewable Energy Resource Act (EEG). Moreover, the two regulation authorities Federal Office for Information Security and the Federal Network Agency define the regulatory framework[59].

In Germany, as per EU directives, market participants engaged in aggregation, including independent aggregators (IAs), have the right to enter electricity markets without consent of other market participants. IA's can currently offer their services on the balancing markets:

Demand response is typically described as being explicit, or incentive driven, dispatchable flexibility which is committed and can be traded on different markets, or implicit, or price-based, which is the consumer's reaction to price signals. In Germany, residential users do not participate in explicit DR, and implicit DR is offered by some suppliers only[60] (as of 2022). The slow roll-out of smart meters across Germany has hindered the uptake of DR for residential users.

Balancing Market (FCR, mFRR and aFRR)

The non-discriminatory participation of all distributed energy resources is possible both individually and aggregated – with a 1MW minimum - in the following Balancing Markets in Germany[61].

- FCR (frequency containment Reserve),
- aFRR/mFRR (automatic/manual Frequency Restoration Reserve),
- RR (Replacement Reserve) - Some countries in continental Europe also procure replacement reserve (RR), but this is not used in Germany.

The German TSOs procure all control reserves (balancing capacity and balancing energy) commonly across their control areas and partly in cooperation with neighbouring countries (Austria, Belgium, Czech Republic, Denmark, France, the Netherlands, Slovenia, and Switzerland)[62]. Details of the balancing market in Germany -

[58] European Commission. Joint Research Centre., *Explicit Demand Response for Small End-Users and Independent Aggregators*.
[59] M Otte, J Kamsamrong, and S Lehnhoff, "How Can Aggregators Improve the TSO-DSO-Customer Coordination in Digitalised Power Systems?," 2024, https://www.iea-isgan.org/wp-content/uploads/2024/07/ISGAN_Aggregator_final.pdf.
[60] European Commission. Joint Research Centre., *Explicit Demand Response for Small End-Users and Independent Aggregators*.
[61] https://www.regelleistung.net/en-us/Market-information/Modalities-Legal-Framework
[62] Božičević Vrhovčak and Malbašić, "Unlocking the Value of Aggregated Demand Response."

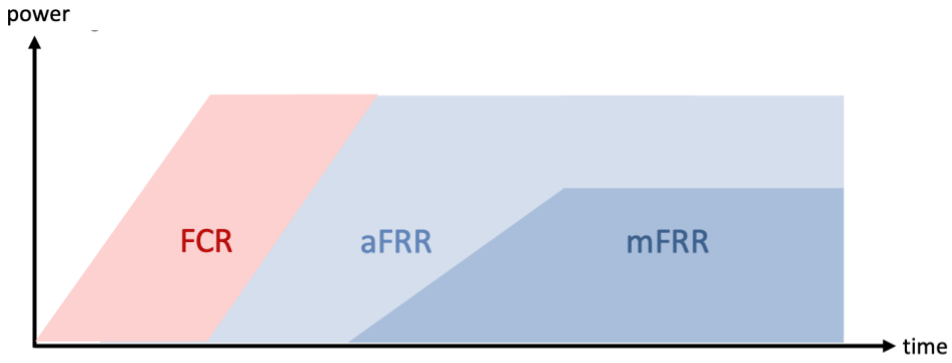


Figure 4.3: Three-stage balancing concept in Germany (schematic representation)

As of end of 2022, the prequalified capacity of distributed energy resources per balancing product in Germany was as follows:

- FCR – 800MW, or 12% of total prequalified balancing capacity (6,950MW).
- aFRR - ~750MW or 3% of total prequalified balancing capacity (23,400MW).
- mFRR - ~100MW or 1% of total prequalified balancing capacity (32,390MW).

The types of resources prequalified largely consists of distributed generation, commercial and industrial consumers and batteries, not residential appliances. At the end of 2022, residential consumers accounted for 0% of the prequalified DER for balancing product[63].

The development of the technical prerequisites for the use of DR for balancing markets and interruptible loads are not fully developed in Germany. They are currently developed at the TSO level, with TSOs working on adaptions of prequalification conditions to ensure that EVs can participate in balancing reserve markets. However, at the DSO level, the definition of technical prerequisites is still lacking. Due to the increasing share of electric vehicles, the definition of technical prerequisites at the DSO level is becoming increasingly necessary[64].

Wholesale Market (Day ahead and intra-day markets)

The non-discriminatory participation of all decentralised energy resources is effectively ensured, both individually and aggregated, in Day-ahead and Intraday Markets in Germany. However, there is still a requirement for aggregators to get permission of the supplier when aggregating and selling customer load flexibility to these markets.

Independent Aggregators – defined as a *market participant engaged in aggregation who is not affiliated to the customer's supplier* - currently do not have 'non-discriminatory participation' on the German wholesale market, or the capacity market, only the balancing market[65]. Limits to the participation are described as still being a major issue in Germany[66]. Access to the wholesale market is only available within the Balancing Responsible Party (BRP)[67] portfolio.[68]

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[63] ACER, "Demand Response and Other Distributed Energy Resources: What Barriers Are Holding Them Back?"
[64] European Commission. Joint Research Centre., *Explicit Demand Response for Small End-Users and Independent Aggregators*.
[65] European Commission. Joint Research Centre. *Local Electricity Flexibility Markets in Europe.* LU: Publications Office, 2022. https://data.europa.eu/doi/10.2760/9977.
[66] smartEN, "The Implementation of the Electricity Market Design 2022," 2022, https://smarten.eu/report-the-implementation-of-the-electricity-market-design-2022-smarten-monitoring-report/.
[67] A balance responsible party is a private legal entity that overlooks the balance of one or multiple access points to the transmission grid, they can *be a producer, a large user, an energy supplier or an energy trader.*
[68] (https://pub.norden.org/nordicenergyresearch2022-04/#99954)

Capacity mechanism

Germany has a winter, or grid, reserved for periods of high demand over winter, and a capacity reserve for extreme or unexpected situations.[69] The strategic reserve is open for DER participation in theory, but the product design makes this practically impossible[70]. The German mechanism stipulates that connections must be at the maximum voltage of the transmission system, and via not more than two voltage transformations, and only allows for aggregation of demand response units in minimum bid groups of at least 1 MW. This means that energy storage and renewable units smaller than 5 MW cannot effectively participate[71].

[69] https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2020/08/Meldung/direkt-account.html
[70] (https://pub.norden.org/nordicenergyresearch2022-04/#99954)
[71] ACER, "Demand Response and Other Distributed Energy Resources: What Barriers Are Holding Them Back?"

Germany electricity market requirements for aggregated device participation

Wholesale market (day-ahead)	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
Aggregated residential demand is not permitted in wholesale electricity markets, specifically the forward, day-ahead and intra-day markets. PV net metering, residential and PV<400kW are not currently allowed to participate in Intraday and Day-Ahead Markets.	- (0.5MW)	- (0.5MW)	-	- (15 minutes)	-
Intra-day market	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
As above – Not permitted	- (0.5MW)	- (0.5MW)	-	- (15 minutes)	-
Ancillary services – Frequency balancing market	**Power**			**Duration**	**Response time**
	Raise	***Lower***	***N/A***		
Frequency Containment Reserve (FCR) (Primary Reserve)	1MW (minimum)	1MW (minimum) (no specified, but appears to refer to up-regulating and down-regulating)	No	15 minutes	Short - 30 seconds
aFRR – automatic frequency restoration reserve (secondary reserve)	1MW (minimum)	1MW (minimum)	No	15 mins (aFRR Energy market) 4 hours (aFRR capacity market)	Medium – 5 minutes
mFRR – manual frequency restoration reserve (tertiary reserve)	1MW (minimum)	1MW (minimum)	No	0 mins (ramp up and down)	Medium – 15 minutes

7. United States – California

Following Senate Bill 846, the Californian Energy Commission has set a statewide goal of 7GW of load-shifting capacity by 2030. There are three categories of programs to achieve this goal – load-modifying (e.g. dynamic pricing), resource planning and procurement (e.g. a centralised, competitive market for procurement) and incremental and emergency (e.g. back-up generators). Flexible demand appliance standards are a component of load-modifying programs and aggregator participation are a component of resource planning and procurement programs.

7.1. Appliance standards

In California, the voluntary ENERGY STAR® program for efficient appliances (which includes criteria for 'connected' products, including air conditioners) has operated for several decades. Under the Energy Star program, the criteria stipulate that open standards shall be used for all communication layers. Meeting connected criteria is optional for all products where connectivity is not the primary driver of energy performance. However, it is required for connected thermostats and smart home systems to achieve ENERGY STAR certification. The EPA has included a subset of the capabilities below in the connected criteria for each product category[72].

Table 6: Connected criteria for each product category[73]

	Energy Consumption Reporting	Operational Status Reporting	Remote Management	Demand Response (DR)	Test Method to Confirm DR	Capabilities or DR Summary
Connected Thermostats				✓		✓
SHEMS	✓		✓	✓		✓
Lighting	✓	✓	✓			
Room Air Purifiers	✓	✓	✓			
Refrigerators & Freezers	✓	✓	✓	✓	✓	
Clothes Washers	✓	✓	✓	✓		
Clothes Dryers	✓	✓	✓	✓		
Dishwashers	✓	✓	✓	✓		
Room A/C	✓	✓	✓	✓	✓	
EVSE			✓	✓		
Pool Pumps	✓	✓	✓	✓	✓	
Water Heaters**	✓	✓		✓	✓	
Central A/Cs and Heat Pumps**	✓	✓		✓		
Ice Makers	✓*	✓*	✓*	✓		✓

** Products that meet the Smart Grid Interoperability Panel (SGIP) standards are understood to have incorporated energy consumption reporting, operational status reporting, and remote management into the foundation of their connectivity.*

*** Connected criteria are newly introduced to the ENERGY STAR specifications for water heaters and central A/Cs and heat pumps; the new connected criteria were finalized in Q2 of 2023.*

[72] Table last updated in 2020.
[73] https://www.energystar.gov/products/smart_home_tips/about_products_connected_functionality/connected_criteria_partners

Energy Star has requirements for Open Standards for all communications layers. The connected product Communication Link shall use Open Standards for all communication layers to enable functions listed in Remote Management and User Alerts. An Interface Control Document (ICD), Application Programming Interface (API), or other documentation shall be made available to interested parties that, at minimum, allows access to the functions listed in Remote Management and User Alerts.

These include standards that are:

1) Included in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards,6 and/or
2) Included in the National Institute of Standards and Technology (NIST) Smart Grid framework Tables 4.1 and 4.2,7 and/or
3) Adopted by the American National Standards Institute (ANSI) or another well-established international standards organization such as the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Institute of Electrical and Electronics Engineers (IEEE), or Internet Engineering Task Force (IETF).

Application Layer Communication Standards	Media/Network Layer Communication Standards
1. **Smart Energy Profile (SEP) 2.x, 1.x.**	1. **Wired Ethernet**
2. **OpenADR 2.0, 2.0A, 2.0B**	2. **Wi-Fi**
3. **CTA 2045A**	3. **Zigbee**
4. **6LoWPAN**	4. **HomePlug Green PHY**
5. **Z-Wave**	5. **6LoWPAN**
6. **ISO 15118**	6. **Z-Wave**
7. **OCPP 1.6,2.0**	

Figure 6:Standards options for application layer and media/network layer in Energy Star[74]

The California Energy Commission (CEC) is implementing **Flexible Demand Appliance Standards (FDAS)** on the basis of Senate Bill 49.[75] The Public Resources Code (Section 25402(f)(1)) directs the CEC to establish standards and labelling requirements “to facilitate the deployment of flexible demand technologies” to schedule, shift, or curtail the electrical demand. Senate Bill 49 requires the CEC to determine the technical feasibility and cost-effectiveness of a new FDAS and lists a range of criteria that must be considered (e.g. cybersecurity). The CEC must consult with the California Public Utilities Commission and load-serving entities to align the flexible demand appliance standards with demand response programs. As of January 1, 2021, the CEC must describe any actions it has taken following Senate Bill 49 in its biennial Integrated Energy Policy Report.

The first FDAS has been established for all pool controls sold, offered for sale rented or leased for use in California. The cost-benefit analysis found there was an incremental cost for customers of a pool control compliant with the FDAS of USD70 but a bill saving of USD1,131 over a 10-year lifetime. The FDAS requires the pool control to have a default operation schedule for cleaning between 9am – 3pm, internet connectivity, cybersecurity elements and consumer protection. The CEC notes this ‘establish(es) a framework for future demand flexibility standards for other appliances’ and the CEC expects to adopt one or two new standards each year for other devices.

The key elements are summarised in the table on the following page.

[74] https://www.energystar.gov/products/smart_home_tips/about_products_connected_functionality/connected_criteria_partners
[75] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49

Major requirements in Flexible Demand Appliance Standard Docket Number 20-FDAS-O1 (Pool controls)[76]

Communication	Interoperability	Measurement/sync	Security	Consumer override
A pool control must be a 'connected device' that can wirelessly communicate and is capable of receiving a signal from a 'modern digital network'.	Open-source communication standards have been required, but there is no common or integrated inter-operability protocol or standard.	No test method was specified to assess pool controls. The standards are verified by the CEC's enforcement unit using inspection of the pool control, associated packaging, and marketing materials. Future proposals may require the use of test standards or procedures to verify behaviour or performance. (Struven, p.20). There is a requirement for manufacturers to certify each model of appliance to the CEC's flexible appliance database.	The pool control FDAS standards requires compliance with the North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection standards.	Manufacturers are required to include a pre-programmed default operating schedule for pool cleaning between 9am – 3pm SB 49 requires consumers' consent to enable flexible demand functionality. The manufacturer must thoroughly explain the capabilities of the appliance and offer opt-in or opt-out choices to the end user.
The TCP/IP was selected as the base standard on the basis it is 'open source, interoperable, and widely accepted across nearly all internet devices'. TCP/IP and 'basic connectivity' was selected 'because it meets the needs to establish communication for pool control using the least burdensome approach' (Struven 2022: 22). The regulation does permit manufacturers to use OpenADR if they prefer. It was noted that 'many stakeholders' advocated for OpenADR and that the			The cyber-security standards include: • Device identification: unique identity for the connected device; • Device configuration: configuration of the software of the connected appliance shall be changed by authorized entities only	Customer and consumer consent provisions are set out in the Code of Regulations including: • providing information on the manufacturer's website of the device's flexible demand capabilities. • providing electronic consent functions, opt-in, or opt-out features for flexible demand capabilities required by this Article

[76] Struven, Nicholaus, Bruce Helft, Ho Hwang, and Sean Steffensen. 2022. *Analysis of Flexible Demand Standards for Pool Controls*. California Energy Commission. Publication Number: CEC-400-2023-001; Assembly Bill-205 , https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB205. ; California Code of regulations, Article 1, *Flexible Demand Appliance Standards*, https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I06016E70D23911EEB13EC5FE823ECF03&transitionType=Default&contextData=%28sc.Default%29#I9AB6EE40D23A11EE80D4B86A60AD7ACD.

standard ‘does not prescribe the use of a specific physical layer protocol or demand-response data model such as OpenADR, which may eventually support more progress in market developments’ (Struven 2022: 24).		• Data protection: customer data protection consistent with Federal and State laws. • Software upgrade: The device must be able to update to the latest available software version automatically. Updates must be delivered over a secure channel and not reduce the functionality of the device.	• obtaining consent prior to the collection of customer or consumer data. • providing information on the manufacturer's website describing the acceptable use policies of data collected by the device.

7.2. Appliance (device) participation in markets

The Demand Side Grid Support Program (DSGS) provides incentives for various types of demand response. The program, introduced in 2022 as part of the Strategic Reliability Reserve, has a total of 515 MW of capacity[77]. Currently, there is a budget of $202.5 million with incentive payments allocated on a 'first-come, first-served' basis. Eligible providers for the DGSG program are retailers, Federal power marketers and aggregators of customers registered with the publicly owned electric utility.

Under proposed changes by CEC to the Demand Side Grid Support (DSGS) program as of October 2024, there are three types of incentives with a new incentive (Option 4) being introduced:

Option 1: Emergency Dispatch: energy and standby payments to non-residential customers that reduce net load during program events. The energy payment incentive is $2/kWh and available during an Energy Emergency Alert, and the standby payment if $0.15/kWh. There is specified dispatch order from demand-response resources (including batteries), renewable and zero-emissions resources, near zero-emissions resources, biomethane and natural gas resources, conventional diesel and gas resources. In summer 2024, there were 8 enrolled providers with 33 participants and 144MW of enrolled capacity.[78]

Option 2: Market-Integrated Demand Response Incremental Capacity Pilot: a capacity payment for demand resources. The incentive payment varies by month and duration of incremental capacity relative to baseline and is triggered by CAISO market bidding and scheduling. In summer 2024, there were 5 enrolled providers with 230,220 participants and 132MW of enrolled capacity.[79]

Option 3: Market-Aware Storage Virtual Power Plant Pilot: capacity payment for behind-the-meter storage VPPs (which include stationary battery storage and vehicle-to-load and vehicle-to-grid providers). The aggregator needs to demonstrate they have remote control over the battery (e.g. API control) and provide hourly or sub-hourly charge and discharge data. It is a CAISO day-ahead market with locational marginal pricing. In summer 2024, there were 14 enrolled providers with 35,429 participants and 240MW of enrolled capacity.[80]

Option 4: Emergency Load Flexibility Virtual Power Plant Pilot: capacity payment for load reduction capacity by dispatchable VPPS with residential or C&I aggregated smart thermostat-controlled HVAC and electric hot water systems during program events. There is an up-front monthly capacity commitment with the incentive ($/kW) varying for each month.

[77] https://www.energy.ca.gov/news/2024-10/californias-demand-side-grid-support-program-grows-500-megawatts-capacity
[78] CEC (2024) Presentation slides for DSGS Program Staff Workshop held on October 18, 2024.
[79] CEC (2024) Presentation slides for DSGS Program Staff Workshop held on October 18, 2024.
[80] CEC (2024) Presentation slides for DSGS Program Staff Workshop held on October 18, 2024.

California: electricity market requirements for aggregated device participation[81]

Wholesale market	Power			Duration (minimum)	Response time
	Raise	***Lower***	***Hold***		
Option 2: Market-Integrated Demand Response Incremental Capacity Pilot	n/a	Each participant needs to specify the incremental capacity available. No specified limits. A weekly report summarising the expected energy (MWh) by resource must be submitted for each day and hour.	n/a	No specified limits	Each participant needs to specify the notice and ramp time for a program event. No specified limits
Option 3: Market-Aware Storage Virtual Power Plant Pilot	n/a The current minimum level for VPP provider is being increased from 100kW to 500 kW. Each participant needs to specify the incremental capacity (kW) available. The operational battery must be able to dispatch at least 1 kW for hours A monthly report summarising event characteristics (date, hours, MW discharge) must be submitted.		n/a	Each participant needs to specify the duration (hours) available. No specified limits. Incentives increase for resources with longer durations available.	Each participant needs to specify the notice and ramp time for a program event. No specified limits
Emergency	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
Option 1: Emergency Dispatch	n/a	Each participant needs to specify the minimum and maximum load reduction for a program event. No specified limits	n/a	No specified limits	Each participant needs to specify the notice and ramp time for a program event. No specified limits
Option 4: Emergency Load Flexibility VPP Pilot	n/a	The minimum level for the portfolio is 500 devices.		Events are triggered by the Emergency Energy Alert and have 2 core event hours and 2 shoulder hours.	

[81] Lyon, Erik, Guadalupe Corona, Brian Vollbrecht, and Syeda Nur E Saba. October 2024. *Proposed Draft Demand Side Grid Support Program Guidelines*, Fourth Edition, California Energy Commission. Publication Number: CEC-300-2024--D.

8. United States – Hawaii

8.1. Appliance standards

Hawaii minimum efficiency standards:

Hawaii has adopted minimum appliance efficiency standards incorporated in section 196-84 to the products such as computers and monitors, faucets, showerheads, high CRI fluorescent lamps, and spray sprinkler bodies. Minimum appliance efficiency standards also exist for portable electric spas, residential ventilating fans, toilets, urinals, and water coolers. Hawaii is also using Energy Star standards (voluntary standard for the energy efficient products) for the appliances such as water coolers.

Hawaiian Electric has adopted the IEEE 1547-2018 standard for customer energy resource (CER) systems to interconnect and operate within Hawaiian Electric's service territory. This standard establishes criteria and requirements for interconnection of distributed energy resources (DER) with electric power systems (EPS) and associated interfaces. The standard includes general interconnection technical specifications and performance requirements, reactive power capability and voltage/power control requirements, response to Area EPS abnormal conditions, power quality, islanding, DER on distribution secondary grid/area/street (grid) networks and spot networks, interoperability, information exchange, information models and protocols, test and verification requirements. Also, Hawaiian Electric will require additional certification requirements specified in SRD V2.0 that are necessary to support the safe and reliable operation of Hawaii's grids. These higher reliability requirements are required, in part, due to the high levels of legacy CER systems (mostly for the inverters).

Smart appliance standards:

After conducting thorough research, no mandatory smart appliance standards were found for the state of Hawaii.

While Hawaiian Electric was working with industry to implement OpenADR information exchange protocol,[82] the regulator has not mandated any specific communications standard.

As for other states of the US (see California case study), the voluntary ENERGY STAR® program for efficient appliances applies.[83] ENERGY STAR includes criteria for 'connected' products, including air conditioners.[84] Incentives Under the Inflation Under the Energy Star program, the criteria stipulate that open standards shall be used for all communication layers. Hawaii was one of the first states to deliver incentives under the Home Electrification and Appliance Rebates (HEAR)[85] Program (part of the recent Inflation Reduction Act initiatives), for relevant appliances such as residential air conditioning and hot water heat pumps. This rebate requires that these products are ENERGY STAR-certified.

[82] https://www.greentechmedia.com/articles/read/balancing-hawaiian-wind-power-with-demand-response
[83] https://www.energystar.gov/
[84] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf
[85] https://governor.hawaii.gov/main/lowering-costs-for-working-class-families-the-home-electrification-and-appliance-rebates-hear-program/

8.2. Appliance (device) participation in markets

As a series of relatively small islands (each managed by a single vertically integrated utility),[86] Hawaii's grid is not sufficiently "large and liquid enough to have a workable bid-based wholesale market".[87] As such, demand side resources are typically sought through centrally planned RFP aggregation processes, and most recently, direct customer engagement with the utility through CER programs. The capability of CER to deliver multiple grid services at the discretion of the utility is referred to as "Bundled Grid Services". The three types of customer participation are:

1. Pricing: Customers directly engage with the utility by adopting an innovative, *tailored DER pricing structure*.[88]
2. Utility Procurement: Customers engage through *contracts with aggregators* that are selected via competitive procurements run by the utility.
3. Utility Programs: Customers *directly engage with the utility* by enrolment in CER programs, such as new Bring Your Own Device (BYOD) Tariff.[89]

Options 2 and 3 are elaborated below.

Utility Procurement: Traditional 'utility procurement' Demand Response programs[90] have historically compensated customers via a bill credit, in exchange for their permission allowing the utility to directly control a device, and include:

- Commercial Industrial Direct Load Control: Involving monthly incentives for peak load reduction from behind-the-meter generators, pumps, HVAC, and water features such as in hotels and non-emergency lighting. A 'fast demand response' version also exists for a response with 10 minutes.[91]
- Small Business and Residential Direct Load Control: Involving monthly incentives or credits for grid services from water heaters and HVAC systems.

The new iteration of these aggregation programs is branded as Power Partnerships[92] and for residential customers are currently only open for water heaters, covering the following grid services:

- Capacity Reduction: reducing demand on the grid
- Capacity Build: increasing demand to balance grid loads.
- Fast Frequency Response (FFR): actions taken to stabilise system frequency in response to the sudden loss of generation or load.[93]

Utility Programs: There are three levels of the BYOD program planned: Level 1, Flexible User Dispatch; Level 2, Utility Dispatch; and Level 3, System Grid Services. Customer enrolment for Level 1 was launched on April 1, 2024, with Levels 2 and 3 to be launched later. Level 1 is currently restricted to customers with solar panels paired with batteries and involves a commitment from the

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[86] https://puc.hawaii.gov/energy/

[87] Kavulla, 2019. https://www.hawaiianelectric.com/documents/clean_energy_hawaii/grid_modernization/ards/03_rstreetinstitute_travis_kavulla.pdf

[88] Much of the regulatory focus on DER integration has been on Time of Use (TOU) pricing reforms, with a 'TOU rate study' launched in 2024 by the utility, Hawaiian Electric, with a view to rolling these out as standard for residential and commercial customer. While a Critical Peak Pricing has been discussed, rate schedule J suggests that this is only currently a peak demand charge, not requiring a real-time signalling from the utility.

[89] https://www.hawaiianelectric.com/documents/products_and_services/customer_renewable_programs/20210503_customer_energy_resources_for_hawaii.pdf

[90] Branded as EnergyScout, which is no longer open to new entrants: https://www.hawaiianelectric.com/products-and-services/customer-incentive-programs

[91] https://www.hawaiianelectric.com/products-and-services/customer-incentive-programs/fast-demand-response

[92] https://www.hawaiianelectric.com/products-and-services/customer-incentive-programs/power-partnership-programs

[93] https://www.hawaiianelectric.com/documents/products_and_services/customer_incentive_programs/202202_power_partnerships_programs.pdf

customer to allow control of the battery during a specified 2-hour period in the evening.[94] Details of each level are contained in the table below.

The advertised incentive mechanisms for customer participation are shown in Figure 7 below. These are translated into the case study template in the subsequent table.

Figure 7: Advertised incentive mechanisms for customer participation (Source: Hawaiian Electric)[95]

Programs	Power Partners	Bring Your Own Device	Fast DR	Battery Bonus	Energy Scout
Status	Active	Active	Active	Closed to new participants	Closed to new participants
Availability	Oahu and Maui County	Oahu, Maui County, and Hawaii Island	Oahu and Maui	Oahu and Maui	Oahu
Description	Partners enroll participants to deliver a contracted amount of grid services	Scheduled discharge of committed kW from batteries paired with solar	Reduces electricity usage during peak periods for Commercial & Industrial participants with 50kW+	Scheduled discharge of committed kW from batteries paired with solar	Temporarily reduces electricity usage during emergencies
Devices	Water heaters	Batteries	Generators	Batteries	Water heaters, air conditioners, generators
Grid Services Utilized	Capacity Reduction, Capacity Build, FFR	Capacity Reduction	Capacity Reduction	Capacity Reduction	Capacity Reduction, FFR

[94] Customers with batteries are being offered to transition from the Scheduled Dispatch Program (called the Battery Bonus, which offers a $5-per-kilowatt (kW) monthly peak capacity bill credit for exporting energy during the evening peak hours), to the BYOD program. For a comparison of the two options see: https://www.hawaiianelectric.com/documents/products_and_services/customer_renewable_programs/sre_byod_flyer.pdf and a generation transition diagram see: https://www.hawaiianelectric.com/products-and-services/smart-renewable-energy-programs.
[95] https://www.hawaiianelectric.com/products-and-services/customer-incentive-programs

Hawaii (US) electricity market requirements for aggregated device participation

Wholesale market	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***Hold***		
N/A (no wholesale market exists due to insufficient scale and liquidity in small islands)	-	-	-	-	-
Other grid-scale support – vertically integrated utility programs	**Power**			**Duration (minimum)**	**Response time**
	Raise	***Lower***	***N/A***		
BYOD: Level 1: Flexible User Dispatch (Currently batteries only)[96]	N/A	No kW minimum (direct agreement with utility)	No	Long (up to a day) [2 hours]	N/A (scheduled daily during evening peak; 365 events per year)
BYOD: Level 2: Utility Dispatch [Not yet launched]	N/A	No kW minimum (direct agreement with utility)	No	Medium (hour) [1 hour]	In response to utility events (day ahead notice, unless emergency–response time not stated; Up to 156 events per year)
BYOD: Level 3: System Grid Services Program [Not yet launched]	No kW minimum (direct agreement with utility)	No kW minimum (direct agreement with utility)	No	Long (up to a day) [2 hours]	In response to utility events (day ahead notice, unless emergency–response time not stated; Up to 365 events per year)
Other grid-scale support – vertically integrated utility procurement	**Power**			**Duration (minimum)**	**Response time**
Power Partners (residential and commercial aggregation incl. water heater and air conditioners)	Not stated	Not stated	No	Not stated	In response to utility events (day ahead notice, unless emergency–response time not stated; Up to 365 events per year)
Fast Demand Response[97] (C&I Sectors Only)	No	50 kW (minimum)	No	Medium (hour) [1 hour]	Medium (minutes) [<10 minutes; 40 events ($5/kW) or 80 events ($10/kW) per year]

[96] Additional devices may become eligible for this program
[97] https://www.hawaiianelectric.com/products-and-services/customer-incentive-programs/fast-demand-response