

Roadmap for Consumer Devices to Participate in Demand Flexibility

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The Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP), has been supporting governments to co-ordinate effective energy efficiency policies since 2008.

Fourteen countries and one region have joined together under the 4E TCP platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However, the 4E TCP is more than a forum for sharing information: it pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Members of 4E find this an efficient use of scarce funds, which results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions.

The 4E TCP is established under the auspices of the International Energy Agency (IEA) as a functionally and legally autonomous body.

Current members of 4E TCP are: Australia, Austria, Canada, China, Denmark, the European Commission, France, Japan, Korea, Netherlands, New Zealand, Switzerland, Sweden, UK and USA.

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



The EDNA Annex (Electronic Devices and Networks Annex) of the 4E TCP is focussed on a horizontal subset of energy using equipment and systems - those which are able to be connected via a communications network. The objective of EDNA is to provide technical analysis and policy guidance to members and other governments aimed at improving the energy efficiency of connected devices and the systems in which they operate.

EDNA is focussed on the energy consumption of network connected devices, on the increased energy consumption that results from devices becoming network connected, and on system energy efficiency: the optimal operation of systems of devices to save energy (aka intelligent efficiency) including providing other energy benefits such as demand response.

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

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Roadmap for Consumer Devices to Participate in Demand Flexibility

Prepared for:

**The Electronic Devices & Networks Annex of
the IEA 4E Technology Collaboration
Programme**



Prepared by:
Valerie Nubbe
Mansi Thakkar
Alejandro Valdez
Judith Reich
William Goetzler

Guidehouse Inc.

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guidehouse.com

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Table of Contents

1. Introduction to Demand Flexibility	1
1.1 Evolution of Demand Response	3
1.2 Trends in Residential Demand Response and Demand Flexibility.....	7
1.2.1 Residential Demand Response	7
1.2.2 Residential Demand Flexibility	8
2. Key Demand Flexibility Technologies	11
2.1 Smart Metering Infrastructure.....	11
2.2 Smart Home Technologies.....	11
2.2.1 Smart Thermostats for HVAC Systems	13
2.2.2 Connected Water Heaters.....	13
2.2.3 Smart Appliances	13
2.2.4 Connected Lighting	14
2.2.5 Battery Storage	14
2.2.6 Electric Vehicles.....	14
3. International Status of Demand Flexibility.....	15
3.1 Europe	15
3.1.1 Austria	17
3.1.2 Belgium	17
3.1.3 Denmark	18
3.1.4 Finland	18
3.1.5 France	18
3.1.6 Germany	19
3.1.7 Republic of Ireland	19
3.1.8 Italy	20
3.1.9 Netherlands	20
3.1.10 Poland	20
3.1.11 Portugal	21
3.1.12 Spain	21
3.1.13 Sweden	21
3.1.14 Switzerland	22
3.1.15 United Kingdom (UK)	22
3.2 Asia Pacific	22
3.2.1 Australia	23
3.2.2 China	23
3.2.3 Japan	24
3.2.4 New Zealand.....	25
3.2.5 Singapore	25
3.2.6 South Korea.....	26
3.3 North America.....	26

3.3.1 Canada	26
3.3.2 United States	27
4. Demand Flexibility Programmes	29
4.1 Automated Demand Response	29
4.1.1 US, Duke Energy Florida, EnergyWise Home	29
4.1.2 US, ComEd and Nest Thermostat	29
4.1.3 US, Pacific Northwest, Connected Water Heaters	30
4.2 DER Aggregation	30
4.2.1 US, Southern Company: Smart Neighborhood	31
4.2.2 US, Sacramento Municipal Utility District: 2500 R Midtown	31
4.2.3 US and Japan, Maui Electric Company: Jumpstart Maui	32
4.2.4 US, Southern California Edison: Preferred Resources Pilot	33
4.2.5 Finland, Fortum Spring: Virtual Power Plant	34
4.2.6 Australia: Tesla Virtual Power Plant	35
5. Demand Flexibility Challenges and Recommendations	36
5.1 Market and Programme Implementation Challenges and Recommendations	36
5.1.1 Market Requirements	36
5.1.2 Customer Incentives	37
5.1.3 Customer Awareness and Satisfaction	38
5.2 Technology Challenges and Recommendations	38
5.2.1 System Integration	39
5.2.2 Cybersecurity	39
5.2.3 Interoperability and Communication	40
5.2.4 Complexity and Usability	41
5.2.5 High Cost	41
5.3 Policy Challenges and Recommendations	42
5.3.1 Adopting Regulations	42
5.3.2 Developing Standards and Frameworks	43
6. Roadmap Guide	44
6.1 Introduction	44
6.2 Roadmap Process	45
6.2.1 Phase 1: Planning and Preparation	46
6.2.2 Phase 2: Visioning	49
6.2.3 Phase 3: Roadmap Development	51
6.2.4 Phase 4: Monitoring and Revision	55

List of Figures

Figure 1-1. Net Electricity Generation of Renewables	1
Figure 1-2. Demand Flexibility Load Profiles	2
Figure 1-3. Evolution of Demand Response.....	3
Figure 1-4. Demand Response Classifications.....	4
Figure 1-5. Global Residential Demand Response Capacity	8
Figure 1-6. Grid-Interactive Residential Building	9
Figure 1-7. Residential Virtual Power Plant Capacity	10
Figure 2-1. Annual Smart Home Devices Global Shipments	12
Figure 3-1. Development Status of Aggregated Demand Response in Europe in 2017.....	16
Figure 3-2. 2018 US Enrolled Demand Response Capacity (MW)	28
Figure 4-1. Example DER Aggregation Programmes in the US.....	31
Figure 4-2. Preferred Resource Portfolio by Resource	34
Figure 6-1. Roadmap Process Phases.....	45
Figure 6-2. Stakeholder Involvement Strategy	49
Figure 6-3. Demand Flexibility Goal Development Guidance	53

List of Tables

Table 1-1. Common Types of Demand Response Programmes	6
Table 6-1. Key Stakeholder Organisations	48
Table 6-2. Summary of Key Challenges.....	51
Table 6-3. Initiative and Action Items Recommendations	54

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Acronyms and Abbreviations

ADR	Automated demand response
AMI	Advanced metering infrastructure
BYOD	Bring your own device
CHP	Combined heat and power
DERMS	Distributed energy resource management system
DERs	Distributed energy resources
DR	Demand response
EDNA	Electronic Devices and Networks Annex
EIA	Energy Information Administration
EU	European Union
EV	Electric vehicle
GEB	Grid-interactive efficient building
GW	Gigawatt
HEMS	Home energy management system
HVAC	Heating, ventilation, and air conditioning
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IESO	Independent Electricity System Operator
IoT	Internet of things
kW	Kilowatt
MECO	Maui Electric Company
MW	Megawatt
NGO	Non-governmental organisation
NREL	National Renewable Energy Laboratory
PG&E	Pacific Gas and Electric

PV	Photovoltaic
SCE	Southern California Edison
SEPA	Smart Electric Power Alliance
T&D	Transmission and distribution
TCP	Technology Collaboration Programme
UK	United Kingdom
US	United States
VRE	Variable renewable energy

Glossary of Terms

Note: Definitions listed here are for the purposes of the EDNA IEA 4E TCP report series on connected devices. Definitions may differ in other contexts or reports.

Balance Responsible Party	Market participant responsible for mitigating imbalances in the electricity market.
Demand Aggregator	Third party entity that provides demand flexibility by combining multiple consumer loads, typically using communication networks and automated control technologies.
Demand Flexibility	Changes in electricity usage by end-use customers from their normal consumption patterns in response to changing market conditions, especially changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.
Demand Response	A change in electric power demand in response to grid systems needs and/or market conditions.
Demand Response Capacity	The total maximum demand reduction available for participation in demand response programmes, including both dispatchable and non-dispatchable demand response.
Deregulated Electricity Markets	Market structure in which market participants other than utilities are permitted to own power plants and transmission lines to sell wholesale electricity to retail energy suppliers.
Distributed Energy Resources	A demand-side resource that can provide demand flexibility.
Load Modulating	Balancing power supply/demand or reactive power draw/supply to provide fast response ancillary services. ¹
Load Shedding	Reducing electricity demand for a short time period in response to a peak or emergency event. ²
Load Shifting	Changing the timing of electricity demand to minimise/avoid peak periods or shifting electricity use to align with cheap wholesale electricity prices or high VRE generation periods. ³
Peak Demand	The highest electric power demand over a specified time period (typically daily).
Regulated Electricity Markets	Market structure in which a utility/energy company owns the entire electricity system (infrastructure and transmission) and generates and sells all electricity to customers.

¹ US Department of Energy. 'Grid-Interactive Efficient Buildings (GEB): Overview of Research Challenges and Gaps.' Nov. 2019 <https://www1.eere.energy.gov/buildings/pdfs/75470.pdf> (US DOE, 'GEB: Overview of Research Challenges and Gaps.')

² *Ibid.*

³ *Ibid.*

Background

The Electronic Devices and Networks Annex (EDNA) is an initiative of the International Energy Agency's (IEA) 4E Technology Collaboration Programme (TCP), which promotes energy efficiency as the key to ensuring safe, reliable, affordable and sustainable energy systems. EDNA specifically focuses on network connected electronic devices and equipment. The objective of EDNA is to: 'provide technical analysis and policy guidance to members and other governments aimed at improving the energy efficiency of connected devices and the systems in which they operate.' The three key areas of focus for EDNA are 1) energy consumption of network connected devices, 2) the increased energy consumption that results from devices becoming network connected, and 3) the optimal operation of systems of devices to save energy including other energy benefits such as demand flexibility.

This EDNA report, 'Roadmap for Consumer Devices to Participate in Demand Flexibility' is the second in a series of three reports written by Guidehouse for EDNA. The report, 'Policy Guidance for Smart, Energy-Saving Consumer Devices',⁴ provides considerations for policy makers to encourage 'smart' consumer devices which save energy and provide demand flexibility. This report provides a roadmap that lays out specific steps needed to achieve widespread demand flexibility of consumer devices in the residential sector. Finally, the third report, 'Energy Applications within IoT and Digitalisation Strategies',⁵ provides guidance for developing Internet of Things (IoT) and digitalisation strategies for enhancing energy efficiency (including demand flexibility).

The purpose of this report is to provide technical assistance and policy guidance to support national or regional government organisations, utilities, and/or energy regulatory bodies in developing a roadmap for residential demand flexibility. The IEA definition of a roadmap is 'a specialised type of strategic plan that outlines activities an organisation can undertake over specified time frames to achieve stated goals and outcomes.'⁶ An effective roadmap will engage stakeholders and responsible members in creating the plan and build consensus in the goals and priorities of the roadmap. This report is presented in six chapters:

- **Chapter 1 (Introduction to Demand Flexibility)** provides background on demand response and the benefits and trends in demand flexibility.
- **Chapter 2 (Key Demand Flexibility Technologies)** provides information on how demand flexibility is implemented and what technologies have the greatest flexibility potential.
- **Chapter 3 (International Status of Demand Flexibility)** includes a literature review of the status of demand flexibility markets and policies in 23 countries across Europe, North America, and Asia Pacific.
- **Chapter 4 (Demand Flexibility Programmes)** summarises examples of key successful automated demand response and distributed energy resource (DER) aggregation programmes in place today.

⁴ 4E Electronic Devices & Networks Annex, EDNA, Publications, 'Policy Guidance for Smart, Energy-Saving Consumer Devices,' <https://edna.iea-4e.org/library>

⁵ 4E Electronic Devices & Networks Annex, EDNA, Publications, 'Energy Applications within IoT and Digitalisation Strategies,' <https://edna.iea-4e.org/library>

⁶ IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

- **Chapter 5 (Demand Flexibility Challenges and Recommendations)** provides an overview of challenges and barriers hindering the implementation of demand flexibility and recommendations for overcoming these barriers.
- **Chapter 6 (Roadmap Guide)** provides guidance including detailed steps for achieving widespread residential demand flexibility based on the current status of demand flexibility.

1. Introduction to Demand Flexibility

As more countries, states/provinces, and utilities commit to decarbonisation goals and prices for renewable energy sources continue to fall, proliferation of variable renewable energy (VRE) sources is likely. The United States (US) Energy Information Administration (EIA) projects that renewable energy will provide almost half of world electricity by 2050, with wind and solar accounting for over 70% of this capacity (see Figure 1-1).⁷ In fact, wind and solar are currently the fastest growing electricity generation resources.⁸ In addition, utilities are also dealing with increasing demand, driven by electrification of the transportation and industrial sectors, as well as space heating/water heating in buildings and increased penetration of air conditioning.

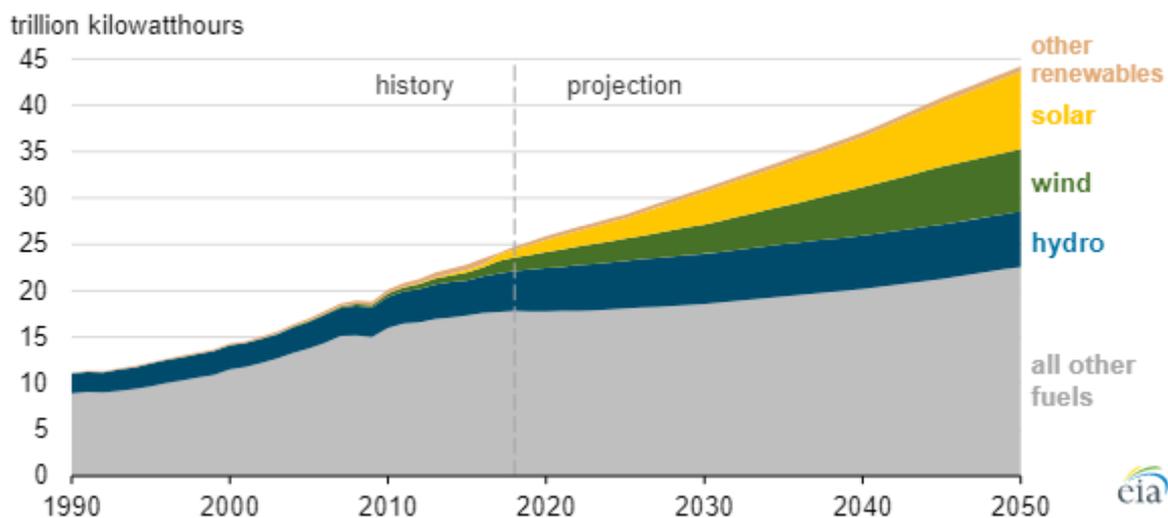


Figure 1-1. Net Electricity Generation of Renewables

Source: US Energy Information Administration International Energy Outlook

Behind-the-meter solutions, including energy efficiency and demand response, have been key resources for utilities to help avoid costly new generation and transmission and distribution (T&D) upgrades and reduce peak demand. Dynamically matching electricity supply and demand, however, has traditionally come from supply-side entities such as adjusting output of controllable power plants. Demand flexibility is an emerging and underutilised resource to optimise electricity use on the demand-side, particularly in buildings, that can also provide these balancing services.

Demand flexibility expands upon the capabilities of traditional demand response to shed, shift, or modulate electricity loads in response to real-time grid systems needs and/or market conditions using communication networks and automated control technologies. Figure 1-2 shows the resulting building load profiles from these three demand flexibility capabilities. These types of demand flexibility are defined as follows:

⁷ US EIA. 'Today in Energy: EIA projects that renewables will provide nearly half of world electricity by 2050.' October 2019. <https://www.eia.gov/todayinenergy/detail.php?id=41533>

⁸ US EIA. 'International Energy Outlook.' 2019. Table H10 and H19. https://www.eia.gov/outlooks/ieo/tables_ref.php

- **Load shedding:** reducing electricity demand for a short time period in response to a peak or emergency event.⁹
- **Load shifting:** changing the timing of electricity demand to minimise/avoid peak periods or shift electricity use to align with cheap wholesale electricity prices or high VRE generation periods.¹⁰
- **Modulating:** balancing power supply/demand or reactive power draw/supply to provide fast response ancillary services including frequency regulation, voltage support,¹¹ load following reserves, *etc.*¹²

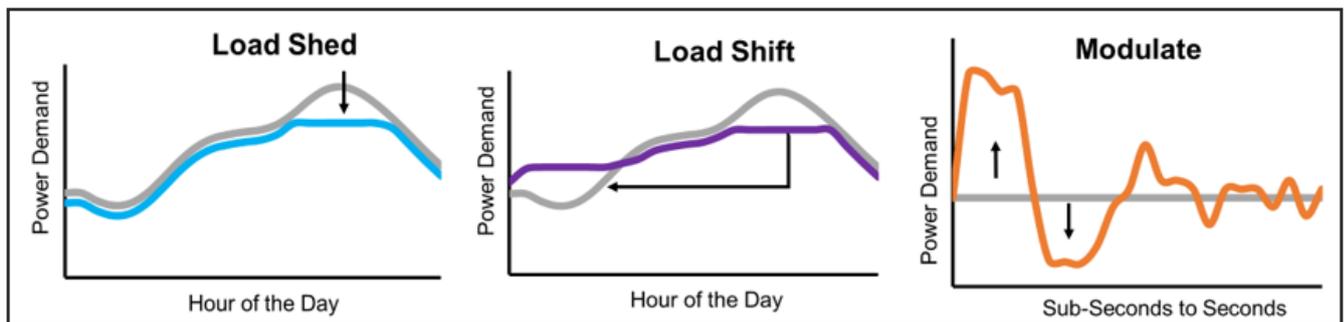


Figure 1-2. Demand Flexibility Load Profiles

Source: Adapted from US Department of Energy¹³

Utilities may utilise demand flexibility to satisfy the local needs of the grid such as shaving peak demand, integrating renewables, or increasing grid reliability. Building owners may participate in demand flexibility programmes to lower utility bills or to receive rebates or award payments. Demand flexibility also produces quantifiable value to the utility system, customers/building owners, and society including:

- Reduced operation and maintenance costs,
- Reduced generation costs,
- Reduced T&D costs,
- Increased system resilience,
- Improved power quality, and
- Reduced emissions/environmental impacts.¹⁴

⁹ US Department of Energy. 'Grid-Interactive Efficient Buildings: Overview of Research Challenges and Gaps.' Nov. 2019 <https://www1.eere.energy.gov/buildings/pdfs/75470.pdf> (US DOE, 'GEB: Overview of Research Challenges and Gaps.')

¹⁰ *Ibid.*

¹¹ Voltage support is provided by equipment capable of producing or absorbing reactive power to help maintain power system voltage within acceptable limits.

¹² US DOE, 'GEB: Overview of Research Challenges and Gaps.'

¹³ *Ibid.*

¹⁴ *Ibid.*

1.1 Evolution of Demand Response

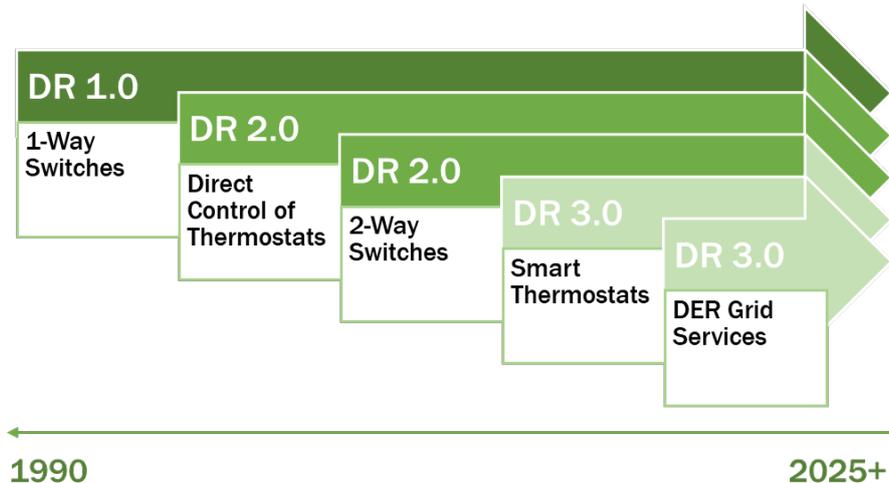


Figure 1-3. Evolution of Demand Response

Sources: US Department of Energy¹⁵ and Smart Electric Power Alliance¹⁶

Figure 1-3 above shows the evolution of demand response. Demand response 1.0 (DR 1.0) began in the 1990s as interruptible tariffs in which utilities contacted large commercial and industrial customers directly to request them to manually reduce energy consumption. DR 1.0 also included load control devices on residential water heaters and air conditioners. DR 1.0 was generally used to curtail demand during periods of high wholesale power prices or when there was a shortfall in generation capacity.^{17, 18}

In the 2000s, demand response 2.0 (DR 2.0) emerged to include increasing usage of two-way communication devices including switches and programmable communicating thermostats. This led to increased participation in wholesale markets and ancillary services such as frequency and voltage support. It also allowed for increased measurement and verification.^{19, 20}

Today, advanced communication and controls have allowed demand response to evolve from an *ad hoc* service to an autonomous function which dynamically changes load in response to changing electricity prices and grid system needs (*i.e.*, demand flexibility). Demand response 3.0 (DR 3.0), or demand flexibility, is seen as a component of the larger field of distributed energy resources (DERs), including distributed solar photovoltaic (PV), electric vehicles (EVs), and energy storage. This allows buildings to provide a wide array of benefits to the grid including renewable energy integration, voltage control, and localised distribution system congestion management.^{21, 22, 23} As will be discussed in Chapter 2, smart

¹⁵ *Ibid.*

¹⁶ Smart Electric Power Alliance. '2017 Utility Demand Response Market Snapshot.' 2017.

¹⁷ Peak Load Management Alliance (PLMA). 'Evolution of Demand Response in the United States Electricity Industry.' 2017. <https://www.peakload.org/assets/dr-dialogue/Evolution-of-DR-White-Paper.pdf>

¹⁸ US DOE, 'GEB: Overview of Research Challenges and Gaps.'

¹⁹ Peak Load Management Alliance (PLMA). 'Evolution of Demand Response in the United States Electricity Industry.' 2017. <https://www.peakload.org/assets/dr-dialogue/Evolution-of-DR-White-Paper.pdf>

²⁰ US DOE, 'GEB: Overview of Research Challenges and Gaps.'

²¹ Peak Load Management Alliance (PLMA). 'Evolution of Demand Response in the United States Electricity Industry.' 2017. <https://www.peakload.org/assets/dr-dialogue/Evolution-of-DR-White-Paper.pdf>

²² US DOE, 'GEB: Overview of Research Challenges and Gaps.'

²³ Smart Electric Power Alliance. '2017 Utility Demand Response Market Snapshot.' 2017.

metering infrastructure, energy management devices (smart thermostats, home energy management systems (HEMS), etc.), and connected devices are key to enabling this autonomous function in homes.

All demand response programmes fall into two classifications based on who has the authority to modify the building load: dispatchable (or incentive-based) and non-dispatchable (or price-based), as shown in Figure 1-4. In dispatchable or incentive-based demand response, customers receive incentives for reducing loads in response to prompts from the utility or grid operator.²⁴ Demand flexibility falls within dispatchable demand response which generally relies on two-way communication and control technologies. In non-dispatchable demand response or price-based programmes, customers decide to reduce consumption (or not) based on the cost of electricity which changes based on supply and demand.²⁵ This includes pre-set time-of-use pricing, dynamic real-time pricing, and critical peak-pricing. As non-dispatchable programmes allow customer control there is less certainty in what the outcome will be for utilities.²⁶

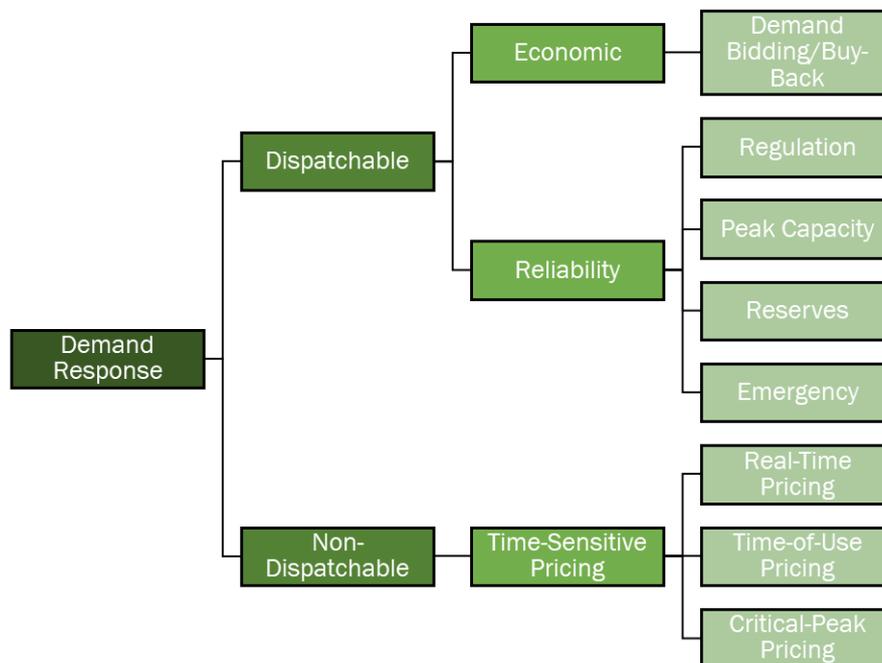


Figure 1-4. Demand Response Classifications

Source: Adapted from North American Electric Reliability Corporation (NERC).²⁷

Demand response product and services vary between utilities and grid operators, but generally fall into four main categories:

1. **Energy:** demand response used to reduce demand during a peak event to reduce operating cost and utilise lowest-cost generation resources.
2. **Capacity:** demand response used to deliver capacity to avoid or delay the need for new generation capacity.

²⁴ US DOE, 'GEB: Overview of Research Challenges and Gaps.'

²⁵ *Ibid.*

²⁶ CGI, Inc. 'The Demand Response Paradox.' The World of Demand Response: White Paper Series. 2016.

²⁷ NERC, '2011 Demand Response Availability Report.' 2013.

<http://www.nerc.com/docs/pc/dadswg/2011%20DADS%20Report.pdf>

3. **Reserves:** demand response used to shift demand to meet system reliability standards or in response to an unexpected generation or grid failure.
4. **Regulation:** demand response used to increase or decrease load to regulate system frequency and/or voltage.²⁸

There are a variety of demand response programme designs that may be used based on what the goal of the demand response programme is and what demand response product is being procured. For example, demand response could be used to: shave peak demand, shift electricity use to align with periods of high variable renewable generation, provide grid reliability, and/or provide energy reserves.²⁹

Table 1-1 provides a summary of the most common types of demand response programme designs today including typical participants, programme purpose, and avoided costs to utilities/grid operators. As the focus of this report is on residential devices, the demand response programmes covered in the report will be smart thermostats, direct load control, and DERs.

²⁸ NERC, '2011 Demand Response Availability Report.' 2013.

<http://www.nerc.com/docs/pc/dadswq/2011%20DADS%20Report.pdf>

²⁹ Open ADR Alliance. 'OpenADR 2.0 Demand Response Program Implementation Guide.' 2016.

Table 1-1. Common Types of Demand Response Programmes

Source: Adapted from Open ADR Alliance³⁰

Demand Response Programme	Description	Target Participants	Purpose	Avoided Costs
Critical Peak Pricing	<ul style="list-style-type: none"> When utilities/operators observe or anticipate high wholesale market prices or power system emergency conditions, they may call critical events during which the electricity prices are substantially raised. 	<ul style="list-style-type: none"> Residential Commercial Industrial 	<ul style="list-style-type: none"> Peak reduction 	<ul style="list-style-type: none"> Reduced generation capital costs Reduced energy costs
Capacity Bidding Programme	<ul style="list-style-type: none"> This is used to obtain load shed or shift capacity when utilities/operators observe or anticipate high wholesale market prices, power system emergency conditions, or as part of normal energy resource utilisation by calling demand response events. 	<ul style="list-style-type: none"> Demand aggregators Self-regulated commercial and industrial 	<ul style="list-style-type: none"> Peak reduction Emergency reserves Ensure resource adequacy 	<ul style="list-style-type: none"> Reduced generation capital costs Reduced energy costs
Smart Thermostat Programme/Direct Load Control	<ul style="list-style-type: none"> When utilities/operators observe or anticipate high wholesale market prices or power system emergency conditions, they remotely control a customer's electrical equipment to reduce demand. 	<ul style="list-style-type: none"> Residential Small commercial 	<ul style="list-style-type: none"> Peak reduction Emergency reserves 	<ul style="list-style-type: none"> Reduced generation capital costs Reduced energy costs
Fast DR Dispatch/Ancillary Services Programme	<ul style="list-style-type: none"> This is used by utilities/operators to obtain pre-committed load response in real-time (seconds to minutes) when they observe conditions that require immediate action to maintain the stability and integrity of the grid. 	<ul style="list-style-type: none"> Large commercial & industrial (with 100 to 500 kW loads) Demand aggregators 	<ul style="list-style-type: none"> Grid reliability Power quality³¹ 	<ul style="list-style-type: none"> Reduced operation and maintenance costs
EV DR Programme	<ul style="list-style-type: none"> The cost of charging EVs is modified to cause consumers to shift consumption patterns. 	<ul style="list-style-type: none"> Public and household EV chargers 	<ul style="list-style-type: none"> Peak reduction 	<ul style="list-style-type: none"> Reduced generation capital costs Reduced energy costs
DER DR Programme	<ul style="list-style-type: none"> Customers with distributed generation and storage can store excess energy when electricity prices are low to utilise when electricity prices are high. 	<ul style="list-style-type: none"> Customers with energy storage and distributed generation technologies 	<ul style="list-style-type: none"> Distributed generation integration Load following reserves 	<ul style="list-style-type: none"> Reduced generation capital costs Reduced energy costs

³⁰ Open ADR Alliance. 'OpenADR 2.0 Demand Response Program Implementation Guide.' 2016.

³¹ Including frequency regulation and voltage control.

1.2 Trends in Residential Demand Response and Demand Flexibility

1.2.1 Residential Demand Response

Though certain forms of demand response have been in place in the US for several decades, global expansion in Europe and Asia Pacific began more recently.³² Residential demand response is also nascent or non-existent in many countries, as larger commercial and industrial customers are often the focus of early demand response programmes. However, recent technology innovations and rapid adoption of smart home technologies, energy management software, and smart grid technologies are paving the way for residential demand response adoption.³³ Further, the need for demand-side flexibility with increasing variable renewable energy penetration and electrification is a key driver. Implementation of residential demand response programmes is also becoming easier through the integration of previously isolated demand-side management programmes (efficiency, demand response, DERs) as well as the emergence of new third-party administrators (demand aggregators, retail energy suppliers, *etc.*).³⁴

Estimates show that global residential demand response capacity was expected to reach 14 gigawatts (GW) in 2019 with rapid expansion expected over the next decade (47 GW by the end of 2028).³⁵ The current capacity and growth projections are dominated by North America, the majority of which comes from the US.³⁶ The European residential demand response market is also projected to expand rapidly, though current capacities vary greatly by country. The United Kingdom (UK) and Finland both utilise aggregated residential demand response loads in their ancillary and capacity markets, and France recently opened its markets to aggregators too. Australia currently leads Asia Pacific in residential demand response participation with the recent addition of 10 pilot projects that partially target residential customers including battery storage, rooftop solar, and smart thermostat programmes.³⁷ A more in-depth analysis of European, North American, and Asia Pacific countries' residential demand response status is available in Chapter 3.

³² Navigant Research: Mehrhoff, J. and Feldman, B. 'Market Data: Residential Demand Response.' 2019. (Navigant Research, 'Market Data: Residential DR.')

³³ *Ibid.*

³⁴ *Ibid.*

³⁵ *Ibid.*

³⁶ *Ibid.*

³⁷ *Ibid.*

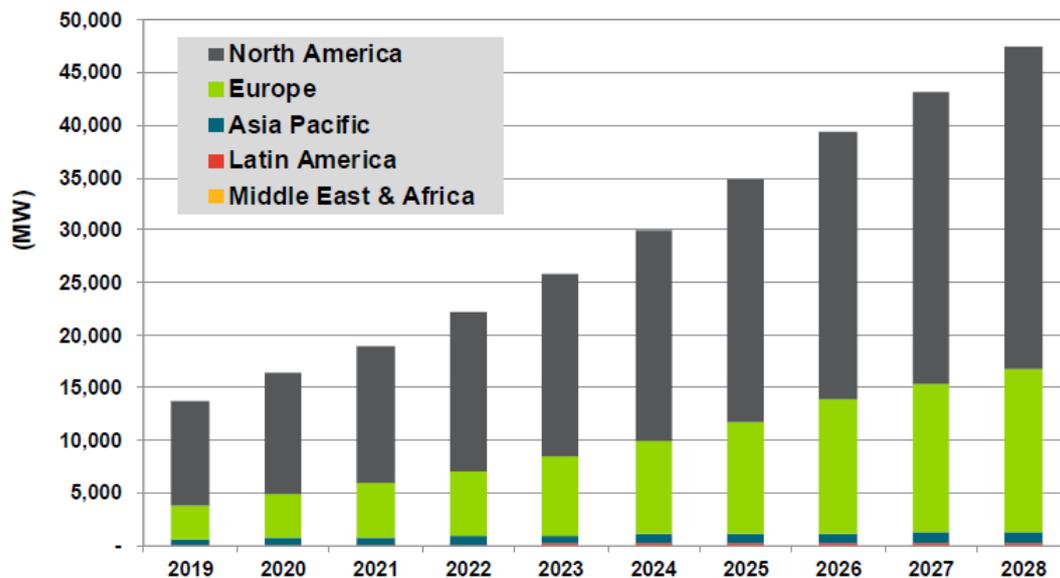


Figure 1-5. Global Residential Demand Response Capacity

Source: Navigant Research³⁸

1.2.2 Residential Demand Flexibility

Residential demand response was historically used primarily during emergency or peak events, but new opportunities are emerging. As discussed previously, demand response is evolving to become part of the broader DER landscape, which provides flexibility to the grid. Similar to residential demand response, the growth of demand flexibility is also driven by increased adoption and innovations in smart home technologies, energy management software, and smart grid technologies. These new technologies allow demand flexibility to be used for load shifting for peak reduction or renewable integration.³⁹ In addition, some ancillary services that demand flexibility can participate in are emerging/expanding in response to increased variable renewable generation coming online,⁴⁰ including:

- **Frequency regulation:** helps to regulate system frequency within acceptable limits by rapidly increasing/decreasing loads within seconds.
- **Voltage control:** helps to maintain voltages within acceptable limits and enables the system to respond to both contingencies and shifts in generation and demand.⁴¹
- **Load following reserves:** provides minute-to-minute balancing during normal system conditions.⁴²

³⁸ Navigant Research, 'Market Data: Residential DR.'

³⁹ *Ibid.*

⁴⁰ Navigant Research: Asmus, P. and Labastida, R. 'Market Data: Virtual Power Plants.' 2019. (Navigant Research, 'Market Data: VPP.'

⁴¹ 'Ancillary Services.' *Greening the Grid*. <https://greeningthegrid.org/integration-in-depth/ancillary-services>

⁴² *Ibid.*

- **Replacement reserves:** provides contingency reserves to help restore system balance with slower response time.⁴³

Integrating and aggregating demand flexibility resources (demand response, distributed generation, storage, and EVs) with software and smart grid technologies can allow them to act as a virtual power plant. These virtual power plants are transforming power grids from a traditional one-way power system to distributed, two-way power flows (*i.e.*, from consumers to ‘prosumers’).⁴⁴ An example grid-interactive residential building serving as a virtual power plant is shown in Figure 1-6. This home utilises a suite of distributed generation, energy storage, connected/efficient technologies, and energy management software (within a HEMS) to optimise energy use based on grid needs, price signals, weather patterns, available onsite energy, and occupants’ needs/preferences.

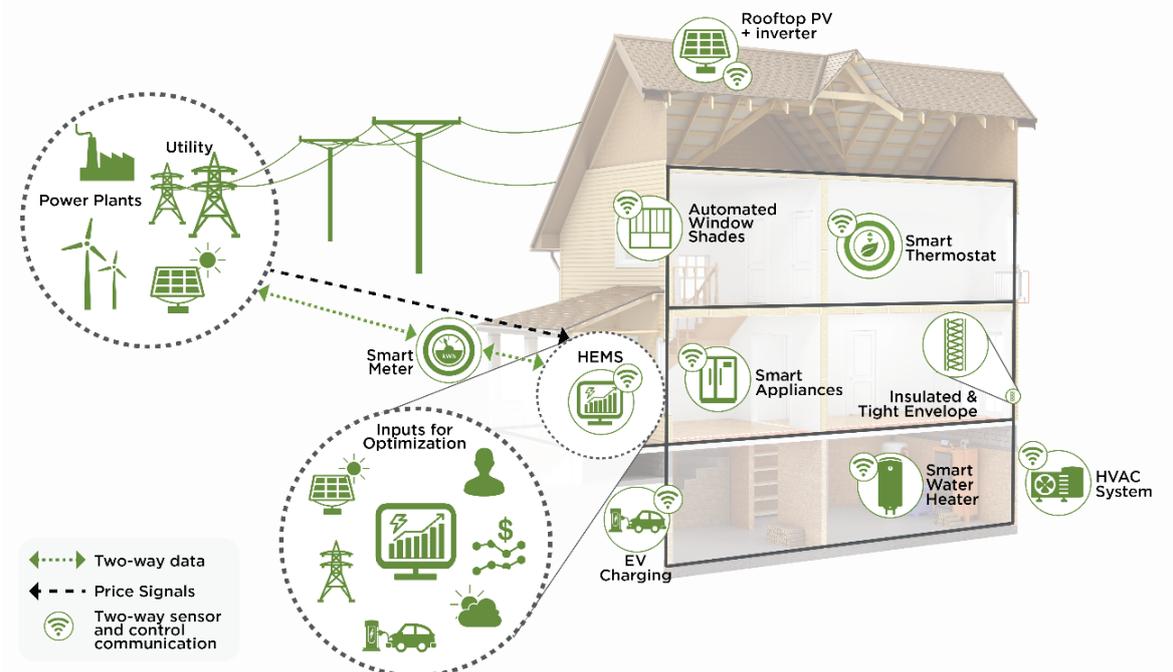


Figure 1-6. Grid-Interactive Residential Building

Source: Navigant Consulting, Inc. n/k/a/ Guidehouse Inc.

In 2019, the total residential virtual power plant capacity was 1.4 GW which is expected to increase to 9.9 GW by 2028.⁴⁵ As shown in Figure 1-7, Europe currently leads the way in residential virtual power plant capacity, followed by Asia Pacific, and then North America. The US, Germany, UK, Australia, and Japan are key drivers in the global capacity and growth potential in this space. The US currently leads in overall demand flexibility capacity with strong growth potential in energy storage and EVs capacity.⁴⁶ Although the US also has substantial residential demand response capacity, much of this capacity is still non-

⁴³ Lawrence Berkeley National Lab, Heffner, G., Goldmand, C., Kirby, B., and Kintner-Meyer, M. ‘Loads Providing Ancillary Services: Review of International Experience.’ 2007. https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Loads_providing_Ancillary_Services_main_report_62701.pdf

⁴⁴ Navigant Research: Lawrence, M. and Vrins, J. ‘Energy Cloud 4.0: Capturing Business Value through Disruptive Energy Platforms.’ 2018.

⁴⁵ Navigant Research, ‘Market Data: VPP.’

⁴⁶ *Ibid.*

automated and is not included in demand flexibility capacity.⁴⁷ Germany leads in global distributed generation capacity and the UK also contributes greatly to Europe’s total virtual power plant capacity and growth potential.⁴⁸ Australia and Japan are expected to see the highest growth rates in virtual power plant capacity over the next decade (2019-2028) at 39% and 36%, respectively.⁴⁹

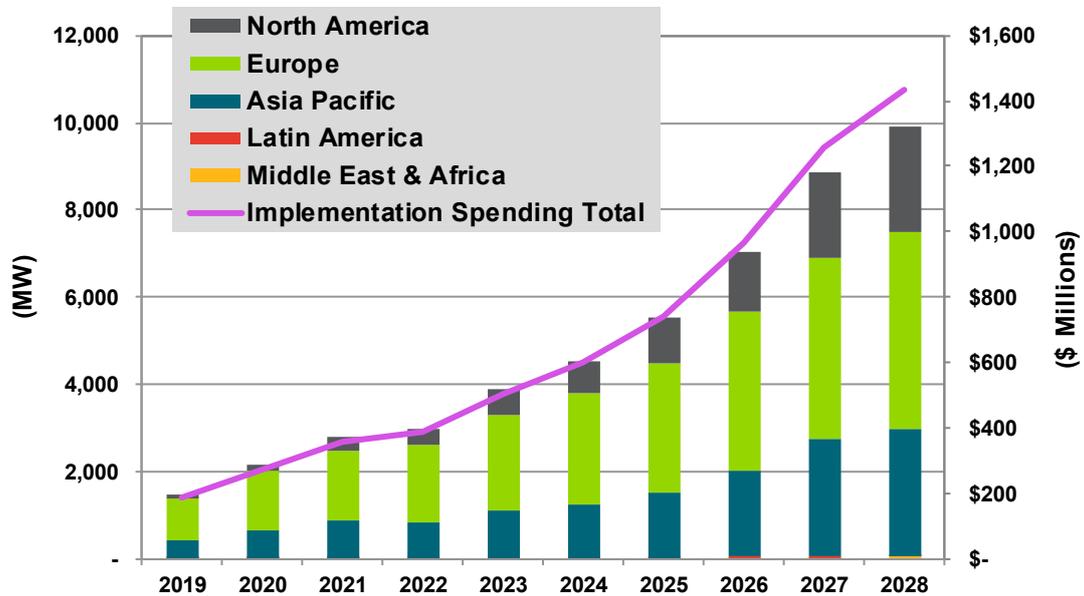


Figure 1-7. Residential Virtual Power Plant Capacity

Source: Navigant Research⁵⁰

⁴⁷ *Ibid.*

⁴⁸ *Ibid.*

⁴⁹ *Ibid.*

⁵⁰ *Ibid.*

2. Key Demand Flexibility Technologies

In addition to market and programme requirements, two-way communication and automated control technologies are needed to implement demand flexibility. Two-way communication capability allows utility/programme administrators to send signals to initiate a load change in response to real-time grid needs (emergency or peak event, frequency regulation, *etc.*) or a change in wholesale electricity prices and to verify that the load change occurred. Automated controls react to these signals to provide the requested load change from connected devices, such as a change in set-point temperatures for thermostat devices, dimming of lighting systems, or switching electricity use to on-site battery storage. Energy management software platforms are also key to enabling smart home device communication and integration.

Smart metering infrastructure helps enable demand flexibility by facilitating grid-to-device communication in homes and capturing granular data on energy loads. In the residential sector, two-way communication and/or automated control is also enabled through smart thermostats or smart home hubs/energy management systems. Common end-use technologies used to provide demand flexibility include space heating/cooling, water heating, smart appliances, battery storage, and EV charging. These key technologies are discussed in more detail in the following sections.

2.1 Smart Metering Infrastructure

Smart meters are defined as electric meters that are capable of computing and data storage to enable frequent energy readings (minutes to 1 hour) and two-way communication between the meter and the utility.⁵¹ Smart meters provide granular data analytics and communication capability that can enable demand flexibility, though it is not necessarily a requirement. The growth of the smart meter market has been driven by the need for DER integration and optimisation, increased grid reliability, and enhanced control of electricity usage for utilities and customers. Smart metering infrastructure allows utilities to collect and utilise data to better manage power supply and demand and help integrate grid-scale variable renewable generation.⁵²

The global smart meter market is rapidly evolving as penetration rates grow in emerging areas and second-generation smart meters are adopted in more mature markets. The total number of installed smart meters in the world is expected to double from 2017 to 2024, from 665 million to 1.2 billion.⁵³ The smart meter penetration in a country/region can help estimate the demand flexibility potential in existence. Overall, smart meter penetration is expected to rise steadily in both emerging and developed markets globally.

2.2 Smart Home Technologies

In addition to smart metering infrastructure, the growth in smart home technologies is a key driver for residential demand flexibility deployment. Many smart home technologies can provide the two-way communication and/or automated control capabilities needed to implement demand flexibility. Beyond demand flexibility, smart home technologies also

⁵¹ Navigant Research, Kelly, M. and Elberg, R. 'Global AMI Tracker 2019.' 2019. (Navigant Research, 'Global AMI Tacker 2019.')

⁵² Menonna, F. and Holden, C. 'WoodMac: Smart Meter Installations to Surge Globally Over Next 5 Years.' *GreenTech Media*. July 2019. <https://www.greentechmedia.com/articles/read/advanced-metering-infrastructure-to-double-by-2024>

⁵³ Wood Mackenzie. 'AMI Global Forecast 2019-2024: H1 2019.' 2019.

provide increased comfort, enhanced control, and energy savings to consumers. Smart thermostats and smart HEMS are key communication/control devices that have substantial demand flexibility potential. Over the next decade (2019-2028), smart home shipments are expected to increase from 100 million to 900 million as shown in Figure 2-1.⁵⁴ Among all smart home technologies, smart thermostats, solar PV, energy storage, EV chargers, smart meters, smart appliances, smart plugs, and connected lighting could all be grid-connected providing demand flexibility potential. IEA estimates that by 2040, 1 billion households and 11 billion smart/connected devices could actively be participating in demand flexibility, providing 185 GW of capacity.⁵⁵

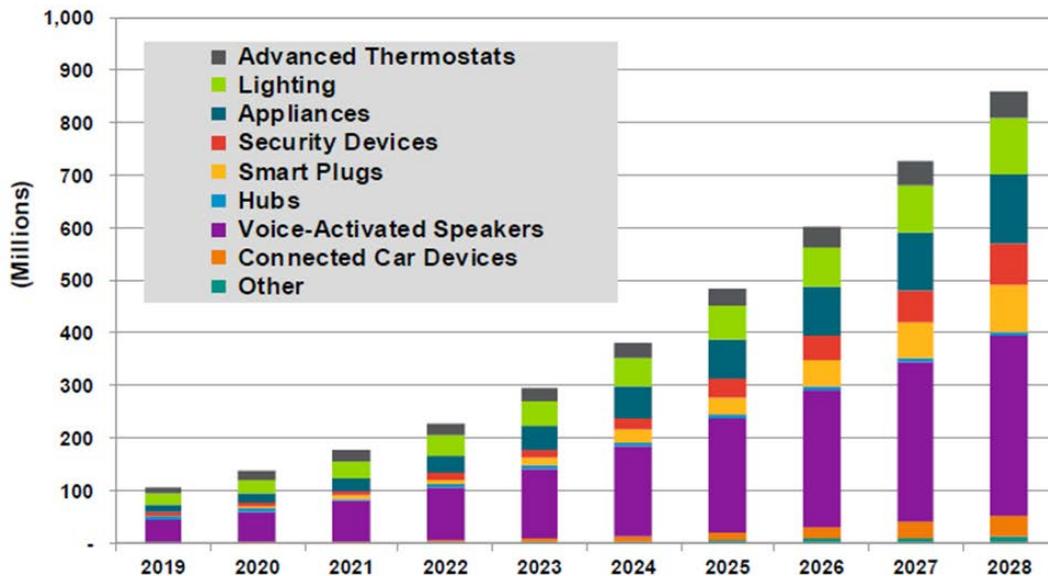


Figure 2-1. Annual Smart Home Devices Global Shipments

Source: Navigant Research⁵⁶

Though a variety of building end-uses are technically capable of providing demand flexibility with the addition of controls/smart plugs, many technologies face implementation challenges. First, residential customers are less likely to participate in demand flexibility programmes involving technologies that could potentially be disruptive to comfort or productivity. Second, smaller building loads have less overall load-shifting potential, making them unfavourable for utility programmes. Third, the high cost and security concerns around connected technologies has led to slower adoption in the residential sector.

The 'bring your own device' (BYOD) demand response programme design is becoming increasingly popular in the residential sector. This programme design allows customers to purchase their own grid-responsive device (from a pre-approved list) to participate in a demand response programme managed by their utility, energy supplier, or a demand aggregator.⁵⁷ In exchange for enrolling in the programme, customers typically receive a rebate, award, or payment for participating in demand response events. The vast majority of these programmes to date have used smart thermostats, though demand flexibility

⁵⁴ Navigant Research: Leuschner, P. and Strother, N. 'The Smart Home Overview.' 2019.

⁵⁵ IEA, 'Digitalization & Energy.' 2017. <https://www.iea.org/reports/digitalisation-and-energy>

⁵⁶ Navigant Research: Leuschner, P. and Strother, N. 'The Smart Home Overview.' 2019.

⁵⁷ Navigant Research: Feldman, B., Strother, N., Mehrhoff, J., and Taylor, R. 'Bring Your Own Device DSM Programs for Utilities and Retail Energy Suppliers.' 2018. (Navigant Research, 'BYOD DSM Programs for Utilities and Retail Energy Suppliers.')

opportunities are also emerging for connected water heaters, smart appliances, connected lighting, battery storage, and EVs.

2.2.1 Smart Thermostats for HVAC Systems

Smart thermostats can be used to control energy use in heating, ventilation, and air conditioning (HVAC) systems to provide demand flexibility. They are advantageous to other connected technologies as they are relatively inexpensive and offer the ability to add advanced controls to simple HVAC systems. Smart thermostat programmes are by far the most common residential demand response programme globally and make up the most devices in utility BYOD programmes. Smart thermostat programmes are typically used for load shifting either to reduce peak (through pre-heating/pre-cooling strategies) or for emergency demand response events by adjusting thermostat setpoints.

In 2018, approximately 37 million connected and smart thermostats⁵⁸ were installed globally, and this is expected to grow to 168 million by 2025.⁵⁹ The smart thermostat market growth can be attributed to utility incentive programmes as well as the additional features of remote control and potential energy savings.

2.2.2 Connected Water Heaters

Water heaters are well suited to provide demand flexibility because of their thermal storage capacity, allowing them to be turned off during a grid event or their energy use to be modulated to provide ancillary services. Because residential water heaters are well suited to store heat (thermal insulation, specific heat of water, *etc.*), demand flexibility services can be provided without impacting the hot water supply to consumers. Connected water heater programmes are becoming increasingly popular for residential demand flexibility. They can be used for load shifting by pre-heating water during off-peak periods to enable no power draw during peak events.⁶⁰ They could also potentially shed load during emergency events. Electric resistance water heater and heat pump water heaters can also provide frequency regulation services (when aggregated), but because water heating power consumption is generally not constant throughout the day in homes, this service could only be provided intermittently.⁶¹

2.2.3 Smart Appliances

Smart (or connected) appliances are a broad category including refrigerators/freezers, clothes washers, clothes dryers, and dishwashers with grid-interactive capability. The ability of smart appliances to provide demand flexibility is more limited than smart thermostats and battery storage as they are intermittently used and relatively smaller loads. In addition, adoption of these technologies is limited, because they are considered premium products with prohibitively high costs for many residential customers. Accordingly, smart appliances are not commonly used in demand flexibility programmes today, but potential exists. Smart dishwashers, clothes washers, and clothes dryers can provide load shifting through delayed

⁵⁸ Connected thermostats include two-way communication and control and smart thermostats include the same capability with enhanced data analytics and optimisation capabilities.

⁵⁹ Navigant Research, 'BYOD DSM Programs for Utilities and Retail Energy Suppliers.'

⁶⁰ US Department of Energy, 'Grid-Interactive Efficient Buildings Technical Report Series: HVAC; Water Heating; Appliances; and Refrigeration.' Nov. 2019. <https://www1.eere.energy.gov/buildings/pdfs/75473.pdf> (US DOE, 'GEB Technical Report Series: HVAC, Water Heating; Appliances.')

⁶¹ *Ibid.*

start controls during peak times or emergency events.⁶² Smart clothes dryers can also potentially modulate heating systems to provide fast response ancillary services (frequency regulation).⁶³ Smart refrigerators/freezers can provide load shifting through adjusting set point temperatures, though this is limited as maintaining constant temperatures is often necessary to prevent food spoilage.⁶⁴

2.2.4 Connected Lighting

Connected lighting for the residential sector consists of an LED lamp with network communication and remote-control capability, often including dimmability and colour tunability. Connected lighting can provide demand flexibility by shedding loads through dimming during peak times or emergency events. However, the ability for connected lighting to provide demand flexibility in residential buildings is limited because they are relatively smaller loads with no energy storage capability (no load shifting ability). Connected LED lamps would also need to be integrated into a lighting system to provide meaningful value, which is not commonly done in residential buildings. Further, dimming is limited to levels that are not disruptive to occupant productivity, comfort, and safety. Accordingly, connected lighting is not commonly used in residential demand flexibility programmes, but some potential exists.

2.2.5 Battery Storage

Smart home battery storage can serve as a valuable asset to the grid, particularly in regions with high VRE generation. In BYOD programmes, customers can enrol their battery to either dispatch stored electricity to the grid or shift electricity use to avoid peak demand or during an emergency event. They could also potentially participate in fast response ancillary service markets through aggregators (frequency regulation, voltage support, load-following reserves). Battery recharging could be aligned with off-peak hours (low cost electricity) or periods of high VRE generation. Battery storage can be an even more valuable asset to the grid when coupled with onsite distributed generation (*i.e.*, solar PV) as batteries could recharge without utilizing grid electricity. The primary drivers for the growth of residential energy storage is the use of battery backup generation during power outages, especially during natural disasters. Additional market drivers include the use of batteries with distributed generation, declining battery prices, and the increased opportunities for energy market participation.⁶⁵

2.2.6 Electric Vehicles

Connected EV chargers can provide load shifting ability to the grid by staggering charging to reduce or avoid peaks. The EV batteries themselves can also offer energy storage capabilities such as dispatching stored energy to the grid or modulating charging to provide fast response ancillary services (frequency regulation, voltage support, load following reserves). However, the demand flexibility potential for EVs is also limited, primarily by the slow adoption of EVs. Adoption of EVs faces market barriers including prohibitively high costs for many customers, lack of charging infrastructure, and consumer preferences, among others. However, the rapidly declining costs of batteries and government incentives of EVs offered in many countries/states/provinces have been key drivers for the EV market.

⁶² US DOE, 'GEB Technical Report Series: HVAC, Water Heating; Appliances.'

⁶³ *Ibid.*

⁶⁴ *Ibid.*

⁶⁵ Navigant Research: Rodriguez, R. and Eller, A. 'Residential Energy Storage.' 2019.

3. International Status of Demand Flexibility

In addition to the technological capabilities and infrastructure needed for demand flexibility, establishing demand response markets, residential programmes, policies, and demand aggregators is also necessary to implement demand flexibility for consumer devices. This chapter provides a summary of the current status of demand response markets, regulatory frameworks, policies, and programmes throughout the world, covering regional trends and a total of 23 countries across Europe, North America, and Asia Pacific. All countries examined in this section have already made some progress in implementing, developing, or exploring the potential of demand response, though no country has achieved widespread demand flexibility in the residential sector. In general, this chapter focuses on dispatchable (incentive-based) demand response which enables demand flexibility. This chapter provides a snapshot of the progress that has been made in each country, gaps, and the potential for growth in demand flexibility in the residential sector. The current development status of demand response in each country will strongly influence the roadmapping process, as outlined in Chapter 6.

3.1 Europe

Demand flexibility in Europe is primarily driven by the increasing penetration of VRE. The European Union (EU) has set ambitious climate goals to achieve by 2030 including: 40% reduction in greenhouse gas emissions, 32% share for renewable energy in electricity, and 32.5% improvement in energy efficiency.⁶⁶

Europe as a whole currently leads the global market in demand flexibility capacity with the UK and France representing the largest markets.⁶⁷ In 2019, Europe comprised 53% of global virtual power plant capacity⁶⁸ and 24% of global residential demand response capacity.⁶⁹ Overall, Europe has seen significant progress in establishing demand flexibility including opening and expanding markets, increasing the role for demand aggregators, and making market product requirements more accessible to customers.⁷⁰ However, the demand response markets in the EU are still fragmented, and the status of demand flexibility varies substantially by country, as shown in Figure 3-1.

⁶⁶ European Commission. '2030 Climate and Energy Framework.' https://ec.europa.eu/clima/policies/strategies/2030_en

⁶⁷ Navigant Research, 'Market Data: VPP.'

⁶⁸ *Ibid.*

⁶⁹ Navigant Research, 'Market Data: Residential DR.'

⁷⁰ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.' 2017. <https://www.smartenergydemandcoalition.org/wp-content/uploads/2017/04/SEDC-Explicit-Demand-Response-in-Europe-Mapping-the-Markets-2017.pdf> (Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.')

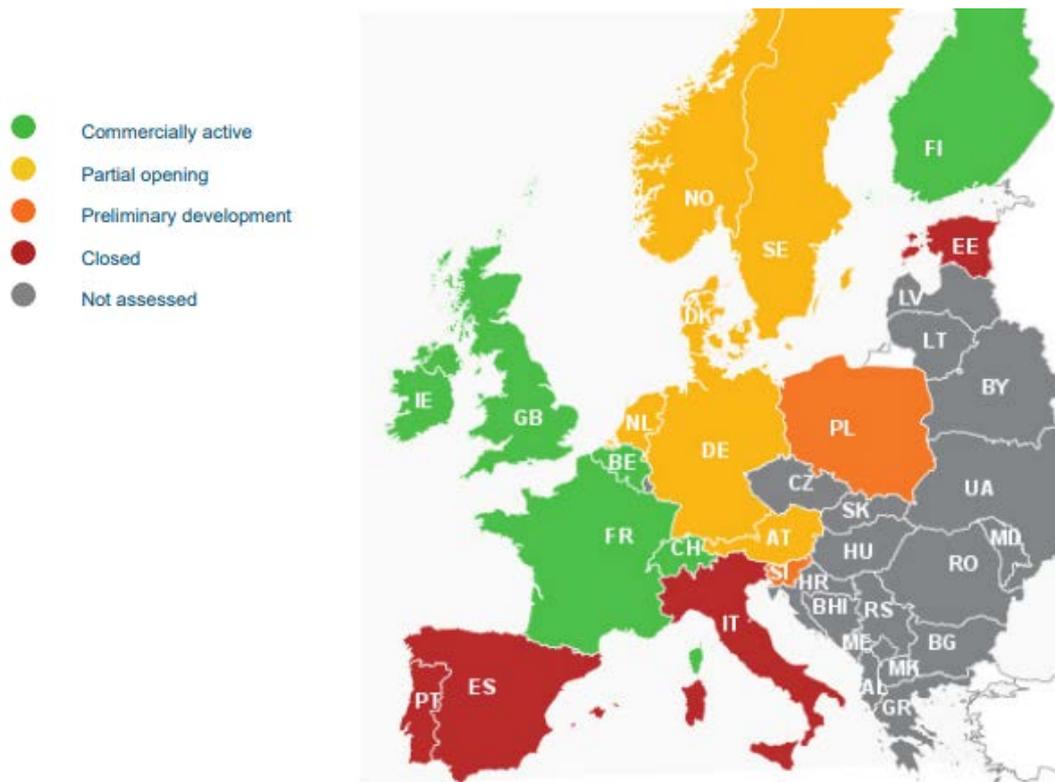


Figure 3-1. Development Status of Aggregated Demand Response in Europe in 2017

Key: Countries coloured in green have active participation from aggregators in demand response markets; countries in yellow have open markets with regulatory barriers which hinder participation in demand response markets by aggregators; countries in orange have made little regulatory developments to allow aggregated demand response participation; and countries coloured in red do not allow aggregated demand flexibility in their markets.

Source: Smart Energy Demand Coalition (2017)⁷¹

The European Commission made an important step toward establishing widespread demand flexibility in publishing the 2019 directive and regulation on common rules for the internal market for electricity as part of the Clean Energy for All Europeans package designed to help achieve renewable energy goals.⁷² The newly established rules enable participation of distributed generation, energy storage, and aggregated demand response in electricity markets and brought harmonised rules for capacity mechanisms.⁷³ Key highlights from the directive regarding demand response/demand flexibility are:

- 'Member States and regulatory authorities should facilitate cross-border access for new suppliers of electricity from different energy sources as well as for new providers of generation, energy storage and demand response.'⁷⁴
- 'All consumers should be able to benefit from directly participating in the market, in particular by adjusting their consumption according to market signals and, in return,

⁷¹ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁷² Available online here: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0944&from=EN>

⁷³ European Commission. 'Clean Energy for All Europeans: Commission welcomes European Parliament's adoption of new electricity market design proposals.' 2019. https://ec.europa.eu/commission/presscorner/detail/en/IP_19_1836 (European Commission, 'Clean Energy for all Europeans.')

⁷⁴ *Ibid.*

benefiting from lower electricity prices or other incentive payments. Consumers should have the possibility of participating in all forms of demand response.⁷⁵

- 'Products should be defined on all electricity markets, including ancillary services and capacity markets, so as to encourage the participation of demand response.'⁷⁶
- 'Consumers should be able to consume, to store and to sell self-generated electricity to the market and to participate in all electricity markets by providing flexibility to the system, for instance through energy storage, such as storage using EVs, through demand response or through energy efficiency schemes.'⁷⁷

3.1.1 Austria

In 2014, Austria passed several amendments which helped ease demand response aggregation and opened balancing markets to demand response.⁷⁸ The frequency containment reserve is also open to demand response, while wholesale and capacity markets are not.⁷⁹ There are also barriers to entry for aggregators such as the requirement that inform and contract with the balancing responsible party/retailer to use demand response for balancing markets. In general, Austria has made some progress in implementing demand response, but participation is still low as the business case in Austria is weak. Aggregators only use customers with large flexible loads or backup generators for demand flexibility (industrial and large commercial customers).⁸⁰ More work is needed to address barriers and increase participation of demand flexibility. Further, smart meter penetration in Austria is lagging other countries, at only 12% in 2018.⁸¹

3.1.2 Belgium

In recent years Belgium has implemented measures to open their ancillary services to demand response and independent aggregators, including a new framework allowing aggregators to sign contracts for ancillary services with the grid operator.⁸² However, the secondary reserve, wholesale market, and distributed network services are not open to demand response.⁸³ More work is needed to increase demand flexibility participation. Currently residential customers have no way of participating in demand flexibility either directly or through an aggregator.⁸⁴ Adoption of smart meters in Belgium has also been slow, though they are beginning to roll out smart meter deployment projects, such as the one project planning to deploy 1.3 million smart meters by the end of 2020.⁸⁵

⁷⁵ European Commission, 'Clean Energy for all Europeans.'

⁷⁶ *Ibid.*

⁷⁷ *Ibid.*

⁷⁸ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁷⁹ *Ibid.*

⁸⁰ *Ibid.*

⁸¹ European Commission DG Energy, 'European smart metering Benchmark.' 2019. <https://www.vert.lt/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf>

⁸² Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.' 2019. http://geography.exeter.ac.uk/media/universityofexeter/schoolofgeography/images/researchgroups/epg/Barriers_to_Independent_Aggregators_in_Europe.pdf (Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.')

⁸³ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁸⁴ Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.'

⁸⁵ Navigant Research, 'Global AMI Tacker 2019.'

3.1.3 Denmark

Demand response participation has been very low in Denmark historically as there is not a significant need for flexibility or additional capacity. The ancillary markets and wholesale markets are technically open to demand response participation, but there is little incentive for participation as payments are too low.⁸⁶ In addition, there are no independent aggregators in Denmark because of the way the relationship is defined for aggregators and balance responsible parties (*i.e.* requiring bilateral contracts). Many service and product markets are also oriented toward generation sources as opposed to demand response such as 10 MW capacity requirements.⁸⁷ Recently Denmark published the Markedsmodel 2.0 with included recommendation for reform to enable greater flexibility.⁸⁸

3.1.4 Finland

Finland relies heavily on inflexible generation sources (nuclear and hydro) and intermittent VRE, justifying the need for demand response.⁸⁹ Finland has a relatively established demand response regulatory framework which allows independent aggregators to participate in markets, though limitations exist (*i.e.*, aggregators can only participate in certain reserve markets).⁹⁰ In fact, Finland was one of the first European nations to utilise aggregated residential demand flexibility in ancillary markets.⁹¹ Minimum capacity requirements also limit full participation in the demand response markets. Though overall, Finland has established favourable markets and business models for residential demand flexibility. Further, Finland has reached nearly 100% penetration of smart meters.⁹²

Finland is also active in establishing demand flexibility pilot programmes. For example, some energy companies (Fingrid and Helen) have tested the participation of independent aggregators in balancing power markets.⁹³ Some energy companies are also actively looking at residential loads, such as space heating and water heating, to establish virtual power plants.⁹⁴ The energy company Fortum also developed 1 MW virtual power plant using control of residential water heaters (see Section 4.2 for more information).⁹⁵

3.1.5 France

France was an early adopter of demand response in Europe. In 2007, pilot programmes were used to allow aggregated residential demand flexibility to participate in the balancing mechanism.⁹⁶ France was also the first country in the EU to open both ancillary services and wholesale markets to demand aggregators, in part because of the regulated and standardised relationship between demand aggregators and balance responsible parties since 2013.⁹⁷ Currently, electricity markets in France are favourable to aggregated demand

⁸⁶ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁸⁷ *Ibid.*

⁸⁸ Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.'

⁸⁹ Mendes, G., Matos, L., Honkapuro, S. and Klein, L. 'Comparison of Opportunities and Challenges in Demand Response Pilots in Finland and Portugal.' June 2018. DOI: 10.1109/EEM.2018.8469894 (Mendes *et al.*, 'Comparison of Opportunities and Challenges in Demand Response Pilots in Finland and Portugal.')

⁹⁰ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁹¹ Navigant Research, 'Market Data: Residential DR.'

⁹² European Commission DG Energy. 'European smart metering Benchmark.' 2019. <https://www.vert.lt/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf>

⁹³ Mendes *et al.*, 'Comparison of Opportunities and Challenges in Demand Response Pilots in Finland and Portugal.'

⁹⁴ *Ibid.*

⁹⁵ *Ibid.*

⁹⁶ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁹⁷ Navigant Research, 'Market Data: Residential DR.'

response participation as participation is allowed in balancing mechanism, ancillary markets, intraday and day ahead markets, and the capacity mechanism.⁹⁸ There are also several pilot projects assessing demand response/flexibility for congestion management.⁹⁹

Accordingly, France currently leads Europe in residential demand response capacity.¹⁰⁰ Further, the outlook for residential demand flexibility in France is good considering the expected smart meter penetration of 95% expected by the end of 2020,¹⁰¹ and growth in connected residential technologies. However, there are some potential limitations including the minimum participation requirements for reserves that are not favourable to demand response.¹⁰²

3.1.6 Germany

Germany is internationally recognised for its decarbonisation goals and renewable energy policies, achieving 35% of electricity generation from renewable sources in 2018, with 25% coming from intermittent solar and wind.¹⁰³ Demand flexibility is key to assisting in VRE integration in the grid as more renewables come online. However, policy and market barriers exist that limit the full potential of demand flexibility from being realised. For one, Germany does not have a national smart meter deployment plan in place. Only large customers (average annual consumption >10,000 kWh) are required to have smart meters; though this is expected to be lowered to 6,000 kWh in 2020, it still will not apply to most residential customers.¹⁰⁴ In addition, the German market regulation creates barriers to implementing demand response including by retailers and independent aggregators.¹⁰⁵ The major market barriers include: several markets closed to demand response, lack of incentives for demand flexibility participation, stringent requirements for balancing reserves, and a lack of standardised role for independent aggregators.¹⁰⁶ However, balancing and ancillary markets are open to demand response participation.

The German Federal Ministry for Economic Affairs and Energy is actively working on addressing the market barriers through a series of measures aimed to facilitate participation of demand side resources in wholesale and balancing markets.¹⁰⁷ Among measures in place, they are working to allow demand response to participate in balancing markets and to standardise the relationship between service companies, utilities, and balance responsible parties.¹⁰⁸

3.1.7 Republic of Ireland

Demand response in Ireland has grown more prevalent in recent years. Further, the need for demand flexibility is expanding as Ireland has set a target of 40% of electricity generation from renewable sources by the end of 2020, with a large portion of this expected to come

⁹⁸ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

⁹⁹ Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.'

¹⁰⁰ Navigant Research, 'Market Data: Residential DR.'

¹⁰¹ 'Smart meters 101: France's Linky electricity meters.' Dec. 2018. <https://www.smart-energy.com/features-analysis/smart-meters-101-frances-linky-electricity-meters/>

¹⁰² Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹⁰³ 'Germany's energy consumption and power mix in charts.' Oct. 2019.

<https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts>

¹⁰⁴ Navigant Research, 'Global AMI Tacker 2019.'

¹⁰⁵ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹⁰⁶ *Ibid.*

¹⁰⁷ Stede, Jan. 'Demand Response in Germany: Technical Potential, Benefits and Regulatory Challenges.' 2016.

https://www.diw.de/documents/publikationen/73/diw_01.c.532827.de/DIW_Roundup_96_en.pdf

¹⁰⁸ *Ibid.*

from variable wind generation. Ireland has also made efforts to open their markets to demand side resources recently. Currently, balancing and ancillary markets and wholesale markets are open to both demand response and independent aggregators.¹⁰⁹ In the future, demand flexibility could play a bigger role in congestion management through distribution network services. Smart meter penetration is also on the rise in Ireland, with 2.3 million installations expected by 2024,¹¹⁰ increasing the potential for demand flexibility.

3.1.8 Italy

Until very recently, demand response in Italy was limited to interruptible tariffs requiring a minimum of 1 MW for participation. Further, this programme was rarely used in past years. Aggregation was also not allowed in any key markets, and all flexibility needs came from supply-side entities. However, in 2017, Italy began implementing a plan to open balancing markets to demand flexibility, distributed generation, and energy storage resources.¹¹¹ Italy is also working on second-generation upgrades to their smart metering infrastructure.¹¹²

3.1.9 Netherlands

Currently there is around 1.5 GW of demand response capacity in the Netherlands.¹¹³ Demand response in the Netherlands occurs through price-based programmes and through participation in balancing and ancillary services.¹¹⁴ Aggregators may participate in demand response, but they primarily rely on large commercial and industrial customers such as greenhouses, hospitals, and industrial plants.¹¹⁵ Aggregators are also constrained by the obligation to have a pre-set agreement with the balancing responsible party/retailer.¹¹⁶ Emergency services also require 2 MW capacity for participation. Overall, demand flexibility is limited in the Netherlands. However, potential exists with efforts to improve smart metering infrastructure; in 2018, reports showed a smart meter penetration around 50% with the goal of 80% by the end of 2020.¹¹⁷

3.1.10 Poland

Demand response in Poland is generally nascent. Though balancing markets were opened to demand response in 2014, the stringent requirements for demand response participation has led to slow adoption. In recent years there has been a slight increase in demand response capacity at around 200 MW in 2017. The grid operator in Poland does curtail loads of large commercial and industrial customers in emergency situations. Currently there is no role for independent aggregators or residential customers to participate in demand response markets. In addition, ancillary markets are not open to demand response. As many power plants in Poland are located in the south, the transmission network is at risk for congestion. Demand flexibility could potentially be used to mitigate these issues.¹¹⁸

¹⁰⁹ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹¹⁰ Hayes, Barry. 'Smart electricity meters are coming so what can we expect?' April 2018.

<https://www.rte.ie/brainstorm/2018/04/10/953366-smart-electricity-meters-are-coming-so-what-can-we-expect/>

¹¹¹ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹¹² Navigant Research, 'Global AMI Tacker 2019.'

¹¹³ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹¹⁴ *Ibid.*

¹¹⁵ *Ibid.*

¹¹⁶ *Ibid.*

¹¹⁷ European Commission DG Energy. 'European smart metering Benchmark.' 2019. <https://www.vert.lt/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf>

¹¹⁸ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

3.1.11 Portugal

Demand response in Portugal today is limited interruptible tariffs in the industrial sector are used for customers with demand above 4 megawatts (MW).¹¹⁹ In addition, though these programmes are in place they are seldom used by system operators.¹²⁰ Aggregated demand response is not currently accepted as a resource in Portugal.¹²¹ However, the increased penetration of VRE on the grid, namely wind power, has underscored the need for demand flexibility in the country.¹²² In response, a number of pilot programmes were put in place in Portugal in recent years (2016-2019), including HVAC controls and industrial load controls, but none in the residential sector.¹²³ Portugal also plans to deploy 6 million smart meters by 2020.¹²⁴

3.1.12 Spain

Demand response in Spain is limited to interruptible tariffs in the industrial sector. Aggregated demand response is also not allowed in any markets including balancing, ancillary services, wholesales, or capacity. However, some smart grid pilot programmes are emerging that allow demand flexibility to be used in congestion management. In general, Spain currently relies on flexible supply-side entities (hydro and gas) for their flexibility needs. Spain is also beginning to explore opening services and markets to demand flexibility.¹²⁵ Spain has also reached high penetration of smart meters (over 90%).¹²⁶

3.1.13 Sweden

Though demand flexibility and aggregation are allowed in wholesale and balancing/ancillary services, participation has been limited. Most flexibility in Sweden has historically come from supply-side entities including hydropower plants. Regulatory and market changes are needed to increase participation of demand response flexibility. First, in the demand capacity markets, the minimum capacity sizes are adapted to large bids, making it difficult for smaller bids to compete. Second, today it is unclear whether an aggregator needs to be independent and under what conditions they will operate. However, this is expected to be resolved during 2020. More work is also needed to define the role of independent aggregators in balancing markets.¹²⁷

Demand flexibility is primarily implemented through industrial customers though some commercial projects utilise residential loads such as heat pumps. Sweden was one of the first countries in Europe to reach 100% smart meter penetration,¹²⁸ but demand flexibility has not yet reached its full potential. The second generation of smart metering will be rolled out in the near future.

Sweden recently experienced capacity shortage in distribution networks which has become a problem in some of the largest urban areas. Thus, it is expected that the exploration of

¹¹⁹ Mendes *et al.*, 'Comparison of Opportunities and Challenges in Demand Response Pilots in Finland and Portugal.'

¹²⁰ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹²¹ Mendes *et al.*, 'Comparison of Opportunities and Challenges in Demand Response Pilots in Finland and Portugal.'

¹²² *Ibid.*

¹²³ *Ibid.*

¹²⁴ Navigant Research, 'Global AMI Tacker 2019.'

¹²⁵ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹²⁶ Simon, F. 'Smart meter woes hold back digitalisation of EU power sector.' *Euractiv*. Jan. 2019.

<https://www.euractiv.com/section/energy/news/smart-meter-woes-hold-back-digitalisation-of-eu-power-sector/>

¹²⁷ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹²⁸ European Commission DG Energy. 'European smart metering Benchmark.' 2019. <https://www.vert.it/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf>

demand flexibility solutions will increase. There are several projects underway that aim to develop different capacity mechanisms but mainly on the supply side. Demand flexibility could play a role in congestion management too; some pilots such as Smart Grid Gotland have explored this.¹²⁹

3.1.14 Switzerland

In 2013, Switzerland made major progress in demand flexibility by opening balancing and ancillary markets up to demand aggregators.¹³⁰ Demand side resources provide around 3 MW of primary and 10 MW of secondary resources currently.¹³¹ Some independent aggregators are currently participating in balancing markets. However, under current market design, demand response has limited financial value which has stifled adoption. In addition, demand response is not open in the wholesale market; and they do not have a capacity mechanism. There are a few pilot programmes looking at congestion management from demand response.¹³² A recent revision of the Electricity Supply Act assigns ownership of demand flexibility to the end user. This means that the end user can decide how and to whom they wish to market their demand flexibility (e.g. to a distributor, transmission system operator, aggregator, etc.) and that this party must pay for the service (except in the event of a grid hazard).

Market challenges include no tariff-incentives in balancing markets and lack of price-based demand response signals. The Switzerland generation sources primarily consist of nuclear and hydropower, though as resources shift to include more VRE this may increase the need for demand flexibility to provide ancillary services.

3.1.15 United Kingdom (UK)

The UK holds the second largest residential demand response capacity in Europe,¹³³ and it was the first nation to open several of its markets to residential consumer participation.¹³⁴ Almost all ancillary and balancing services and capacity markets are open to demand response and independent aggregators. However, the balancing mechanism and wholesale markets are closed to aggregators. Despite the market maturity in the UK, participation of demand flexibility has been low. When introduced in 2014, the capacity mechanism did not allow demand-side resources to compete equally with generation resources, but significant progress has been made since to increase demand response capacity.¹³⁵ National Grid also launched the Power Responsiveness project to encourage demand flexibility participation in markets, focused on the commercial and industrial sector.¹³⁶

3.2 Asia Pacific

Demand flexibility and demand response in Asia Pacific is nascent but growing rapidly. In 2019, Asia Pacific comprised 26% of global virtual power plant capacity.¹³⁷ Japan, Australia,

¹²⁹ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹³⁰ Bray R. and Woodman, B. 'Barriers to Independent Aggregators in Europe.'

¹³¹ *Ibid.*

¹³² *Ibid.*

¹³³ Navigant Research, 'Market Data: Residential DR.'

¹³⁴ Smart Energy Demand Coalition, 'Explicit Demand Response in Europe: Mapping the Markets 2017.'

¹³⁵ *Ibid.*

¹³⁶ *Ibid.*

¹³⁷ Navigant Research: Asmus, P. and Labastida, R. 'Market Data: Virtual Power Plants.' 2019.

New Zealand, and Singapore are leading the way in the region. The recent efforts toward deregulation of electricity markets in these countries has been a strong driver, allowing for increased market competition.¹³⁸ Currently, many countries in Asia Pacific are still in the process of testing and piloting demand response and flexibility programmes. Though demand response today is primarily used for emergency services in these countries, growth is expected for ancillary service markets and price-based demand response.¹³⁹

However, residential demand response comprises a small portion of the overall demand response market in Asia Pacific.¹⁴⁰ In 2019, Asia Pacific comprised only 4% of global residential demand response capacity.¹⁴¹ Australia has led in residential demand response participation. A key driver in the residential sector is the increasing penetration of smart meters and distributed energy resources such as solar PV and energy storage¹⁴²

3.2.1 Australia

Extreme heat waves in recent years in Australia have led to issues in power reliability. The need for demand response led to the emergence of pilot programmes in Australia.¹⁴³ Pilot programmes in Victoria, South Australia, and New South Wales are testing emergency and peak reduction demand response programmes with large commercial and industrial customers. Research has shown that demand response has the potential to reduce peak demand in Australia by 10%.¹⁴⁴ In 2017, demand response also expanded to provide balancing services including frequency response.¹⁴⁵

Unlike most of Asia Pacific, Australia has also made progress in residential demand response. In 2019, their estimated residential demand response capacity was 579 MW.¹⁴⁶ Residential demand response began as direct load control switches, but they are currently exploring demand flexibility through several pilot programmes targeting connected devices.¹⁴⁷ Further, they have made substantial progress in developing virtual power plant pilots utilizing rooftop solar and batteries in thousands of homes. More details on these pilots is available in Section 4.1.

3.2.2 China

Demand response in China has lagged North America and Europe, despite being a huge market for renewable generation and smart grid technologies. Overall demand response has been fragmented and adoption has been slow. Demand response began in China in 1998

¹³⁸ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?' July 2018. <https://ww2.frost.com/frost-perspectives/asia-pacific-region-demand-response-ready/> (Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?')

¹³⁹ PR Newswire. 'Asia-Pacific Demand Response Market Gets a Boost in the Residential Segment from Smart Meter Rollouts, finds Frost & Sullivan.' Aug. 2018. New Provided by Frost & Sullivan. <https://www.prnewswire.com/in/news-releases/asia-pacific-demand-response-market-gets-a-boost-in-the-residential-segment-from-smart-meter-rollouts-finds-frost-sullivan-691856471.html> (PR Newswire, 'Market Gets a Boost in the Residential Segment from Smart Meter Rollouts, finds Frost & Sullivan.')

¹⁴⁰ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁴¹ Navigant Research, 'Market Data: Residential DR.'

¹⁴² Navigant Research, 'Global AMI Tacker 2019.'

¹⁴³ Navigant Research, 'Market Data: DR C&I.'

¹⁴⁴ Denis, A. 'Managing Demand Can Save Two Power Stations' Worth of Energy at Peak Times.' *The Conversation*. May 2017. <https://theconversation.com/managing-demand-can-save-two-power-stations-worth-of-energy-at-peak-times-78173>

¹⁴⁵ Navigant Research, 'Market Data: DR C&I.'

¹⁴⁶ Navigant Research, 'Market Data: Residential DR.'

¹⁴⁷ *Ibid.*

with the establishment of the Demand Response Management Center.¹⁴⁸ Early demand response measures included time-of-use pricing, interruptible loads, and energy storage.¹⁴⁹ Additional pilot demand response programmes began as early as 2002 in Jiangsu, testing out interruptible tariffs, voluntary load shifting, and energy storage devices.¹⁵⁰ From 2013-2015, pilots were also conducted in four cities to test demand response programme designs for industrial and commercial customers only.¹⁵¹ In 2012, China launched its first smart grid automated demand response programme with a partnership with Honeywell using controls in commercial, government, and industrial facilities.¹⁵²

Residential demand response has essentially been non-existent in China, but substantial potential exists. China also represents the largest smart meter market globally, finishing a nationwide rollout of 500 million in 2017.¹⁵³ It is currently moving toward second-generation upgrades.¹⁵⁴

3.2.3 Japan

Demand response started in Japan around 2011 after the tsunami eliminated a portion of its nuclear generation capacity.¹⁵⁵ Demand response activity began to expand more rapidly following the deregulation of electricity markets in 2016. In 2017, Japan opened a new demand response market called NegaWatt to help with reliability during severe weather conditions and to reduce procurement costs.¹⁵⁶ This new market is intended to demonstrate how demand response can be used for reliability in Japan including for emergency events, frequency regulation, and peak reduction capacity.¹⁵⁷

In 2017, Japan had the second highest demand response capacity in Asia Pacific, at 958 MW, coming from four electric companies.¹⁵⁸ However, this is comprised of commercial and industrial customers only. By 2020, the ancillary services market is expected to be open to demand response and aggregators, creating significant new opportunities.¹⁵⁹ Rapid growth in demand response and flexibility is expected. By 2025, Japan is projected to have the highest demand response capacity in Asia Pacific at 20 GW.¹⁶⁰

The recent growth in demand response in Japan has been driven by the recent deregulation of energy markets, adoption of smart metering infrastructure and DERs, and energy efficiency targets (it aims to reduce its energy intensity by 30% from 2012 baseline).¹⁶¹ Japan is in the process of implementing a nationwide smart meter rollout involving 10 utilities.¹⁶² Japan also has a significant emerging market in virtual power plants reaching

¹⁴⁸ Hale, E.; Bird, L.; Padmanabhan, R.; and Volpi, C. 'Potential Roles for Demand Response in High-Growth Electric Systems with Increasing Shares of Renewable Generation.' 2018. <https://www.nrel.gov/docs/fy19osti/70630.pdf> (Hale *et al.*, 'Potential Roles for DR in High-Growth Electric Systems with Increasing Shares of Renewable Generation.')

¹⁴⁹ Hale *et al.*, 'Potential Roles for DR in High-Growth Electric Systems with Increasing Shares of Renewable Generation.'

¹⁵⁰ *Ibid.*

¹⁵¹ *Ibid.*

¹⁵² Parker, A. 'Honeywell and TEDA Launch China's First Demand Response Project Under Us-China Smart Grid Cooperative.' 2012. <https://buildingsolutions.honeywell.com/en-US/newsevents/resources/Publications/honeywell-hbs-teda-us-china-smart%20grid-press-release-2012.pdf>

¹⁵³ Navigant Research, 'Global AMI Tacker 2019.'

¹⁵⁴ *Ibid.*

¹⁵⁵ Navigant Research: Feldman, B and Asmus, P. 'Market Data: Demand Response for C&I.' 2018. (Navigant Research, 'Market Data: DR C&I.')

¹⁵⁶ Navigant Research, 'Market Data: DR C&I.'

¹⁵⁷ *Ibid.*

¹⁵⁸ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁵⁹ *Ibid.*

¹⁶⁰ PR Newswire, 'Market Gets a Boost in the Residential Segment from Smart Meter Rollouts, finds Frost & Sullivan.'

¹⁶¹ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁶² Navigant Research, 'Global AMI Tacker 2019.'

capacity of 16.3 MW in 2019.¹⁶³ However, significant work is needed to expand demand response into the residential sector.

3.2.4 New Zealand

Demand response programmes exist in New Zealand, providing capacity reserves and T&D cost deferral (for example ripple control of hot water cylinders started in the 1950's to reduce residential peak demand).¹⁶⁴ Transpower is the electric power system operator in the country which has made progress in establishing demand response in New Zealand. Transpower began demand response tests and pilots around 2007 with little participation.¹⁶⁵ In 2011, they began scaling their demand response programmes through a Demand Response Management System for industrial and commercial customers, which allowed them to automate communication and coordination, in order to create grid maintenance and upgrade windows.¹⁶⁶ They are currently working on a new demand response programme aimed to reduce peak demand. The key customers are hospitals and campuses with backup generation and large industrial customers.¹⁶⁷

Although pilots are in progress, there are no residential demand flexibility programmes in New Zealand, although the Energy Efficiency and Conservation Authority (EECA) has created a cross-government group to investigate the barriers to creation of demand flexibility market (different agencies regulate different parts of the electricity supply chain).

3.2.5 Singapore

Singapore has been moving towards a deregulated electricity market since 2003 with the establishment of National Electricity Market of Singapore.¹⁶⁸ This has been a key driver for capacity demand response in the country. Currently Singapore has the largest demand response market in Southeast Asia, though demand response has been limited to commercial and industrial sectors only.¹⁶⁹ In 2017, 7.2 MW of aggregated commercial and industrial demand response capacity participated in markets.¹⁷⁰ Interruptible loads through aggregators is a popular form of demand response utilised in Singapore.¹⁷¹ In 2016, Singapore launched the OptiWatt programme to test the efficacy and feasibility of demand response, but again this programme was focused on commercial and industrial sectors. In the residential space, customers can participate through price-based demand response only.¹⁷²

¹⁶³ Navigant Research, 'Market Data: VPP.'

¹⁶⁴ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁶⁵ Transpower. 'Demand Response: The journey so far.' Accessed Dec. 2019. <https://www.transpower.co.nz/keeping-you-connected/demand-response/demand-response-journey-so-far>

¹⁶⁶ *Ibid.*

¹⁶⁷ *Ibid.*

¹⁶⁸ Loi, T. S. A. and Jindal, G. 'Electricity market deregulation in Singapore – Initial assessment of wholesale prices.' April 2019. *Energy Policy*. Vol. 127, pp. 1-10. <https://doi.org/10.1016/j.enpol.2018.11.043>

¹⁶⁹ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁷⁰ *Ibid.*

¹⁷¹ *Ibid.*

¹⁷² Energy Market Authority. 'Demand Side Management What is Demand-side Management (DSM)?' Accessed Dec. 2019. https://www.ema.gov.sg/Demand_Side_Management.aspx

3.2.6 South Korea

In 2017, South Korea had the largest demand response capacity in Asia Pacific at 3.9 GW,¹⁷³ projected to reach 13 GW by 2025.¹⁷⁴ Demand response is currently open in all balancing service markets, and the primary markets are day ahead economic demand response and hour ahead reliability demand response. However, progress to date has been limited to the commercial and industrial.¹⁷⁵ South Korea has also made significant progress in establishing smart meter infrastructure, currently working on a nationwide rollout of 22 million smart meters with a goal of 100% penetration by the end of 2020.¹⁷⁶ In general, South Korea shows significant untapped potential in residential demand flexibility.

3.3 North America

North America leads globally in residential demand response capacity, comprising 72% of total global capacity in 2019.¹⁷⁷ However, North America lags Europe in developing more automated demand flexibility. In Europe, most of the demand response is used for integrating renewables and providing ancillary services while in North America, residential demand response is still dominated by behavioural programmes, one-way switches and controls, and other non-automated demand response. In 2019, North America comprised only 18% of virtual power plant capacity in the world.¹⁷⁸ The vast majority of demand response and demand flexibility capacity in North America can be attributed to the US where demand response has been established for several decades. Trends in North America show demand flexibility expanding to utilise connected consumer devices and provide ancillary services to integrate VRE. Many successful pilot programmes are in existence throughout North America today, but efforts are still needed to expand and scale these projects to larger capacities.

3.3.1 Canada

In 2019, the residential demand response capacity in Canada was about 497 MW or 5% of total North American capacity.¹⁷⁹ Similar to the US, Canada has fragmented electricity markets and power system operators consisting of regulated and deregulated provinces. Demand response participation also varies by province but is generally still nascent. Ontario has seen the greatest development in demand response in Canada, with limited capacity in British Columbia, Alberta, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island.¹⁸⁰ In Ontario, the Independent Electricity System Operator (IESO) has been working to evolve their demand response to auctions in various electricity markets, with the first demand response auction taking place in 2015.¹⁸¹ IESO has also been active in developing demand response pilot programmes.

¹⁷³ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁷⁴ PR Newswire, 'Market Gets a Boost in the Residential Segment from Smart Meter Rollouts, finds Frost & Sullivan.'

¹⁷⁵ Frost & Sullivan, 'Is the Asia-Pacific Region Demand Response Ready?'

¹⁷⁶ Navigant Research, 'Global AMI Tacker 2019.'

¹⁷⁷ Navigant Research, 'Market Data: Residential DR.'

¹⁷⁸ Navigant Research, 'Market Data: VPP.'

¹⁷⁹ Navigant Research, 'Market Data: Residential DR.'

¹⁸⁰ Mars Market Insights. 'Market Information Report: Canada.' October 2018.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/761224/Canada_Report_v3.pdf

¹⁸¹ Independent Electricity System Operator. 'Markets and Related Programs: Demand Response Pilot.' Accessed Dec. 2019. <http://www.ieso.ca/en/Sector-Participants/Market-Operations/Markets-and-Related-Programs/Demand-Response-Pilot>

Electricity generation from wind power has been one of the fastest growing resource in Canada.¹⁸² In provinces with high penetration of wind generation (*i.e.*, Ontario, Nova Scotia, and Alberta) there is an increased need for demand flexibility relative to provinces dominated by hydro power (Quebec and British Columbia). Canada has also made significant progress toward smart grid development, including the installation of smart metering infrastructure (approximately 84% penetration in 2018), charging stations, and EVs.¹⁸³ Overall, Canada has substantial untapped potential for demand flexibility, but work is needed to expand existing programmes and grow demand response into new provinces.

3.3.2 United States

Residential demand response has been utilised in the US for over three decades. The US also leads all other nations in residential demand response in terms of capacity, enrolled sites, spending, and revenue.¹⁸⁴ However, much of this demand response capacity does not fall within the automated definition of demand flexibility. In 2019, the US alone comprised about 69% of residential demand response capacity¹⁸⁵ and 17% of total virtual power plant capacity in the world.¹⁸⁶

In the US, the purpose of demand response has historically been for peak demand management, emergency services, and deferring generation/T&D capacity. The recent growth in VRE has led to an increase in the ancillary service markets including frequency regulation and load following reserves. The US EIA projects that wind and solar will be the fastest growing electricity generation sources in the US.¹⁸⁷ Further, despite the US planned withdrawal from the Paris climate agreement, there are still significant commitments to reduce emissions at the subnational level: 22 states, 550 cities, and 900 companies with operations in the US have made commitments to lower greenhouse gas emissions.¹⁸⁸ State regulations in particular are pushing utilities to deploy more energy efficiency, demand response, and integrated DER programmes.

The US has fragmented electricity markets and power system operators comprised of some regulated and some deregulated regions and states. Accordingly, demand response capacity in the US also varies significantly by state and region, as shown in Figure 3-2. In addition, most demand response in the US is focused on commercial and industrial customers. Residential demand response comprised approximately 36% of total demand response enrolled capacity in the US in 2018.¹⁸⁹ According to a survey of 190 utilities, this residential demand response enrolled capacity in the US consisted of air conditioning switches (4.5 GW), thermostats (1 GW), water heaters (0.6 GW), behaviour programmes (0.5), and other miscellaneous programmes (0.5 GW) in 2018.¹⁹⁰

¹⁸² Natural Resources Canada. 'Renewable Energy Facts.' Accessed Dec. 2019. <https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/renewable-energy-facts/20069#L1>

¹⁸³ Mars Market Insights. 'Market Information Report: Canada.' October 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/761224/Canada_Report_v3.pdf

¹⁸⁴ Navigant Research, 'Market Data: Residential DR.'

¹⁸⁵ *Ibid.*

¹⁸⁶ Navigant Research, 'Market Data: VPP.'

¹⁸⁷ US EIA. 'EIA forecasts renewables will be fastest growing source of electricity generation.' Jan. 2019.

<https://www.eia.gov/todayinenergy/detail.php?id=38053>

¹⁸⁸ Climate Action Tracker. 'USA Country Summary.' Accessed Dec. 2019. <https://climateactiontracker.org/countries/usa/>

¹⁸⁹ Smart Electric Power Alliance. '2019 Utility Demand Response Market Snapshot.' 2019. Available online:

<https://sepapower.org/resource/2019-utility-demand-response-market-snapshot/> (SEPA, '2019 Utility Demand Response Market Snapshot.')

¹⁹⁰ *Ibid.*

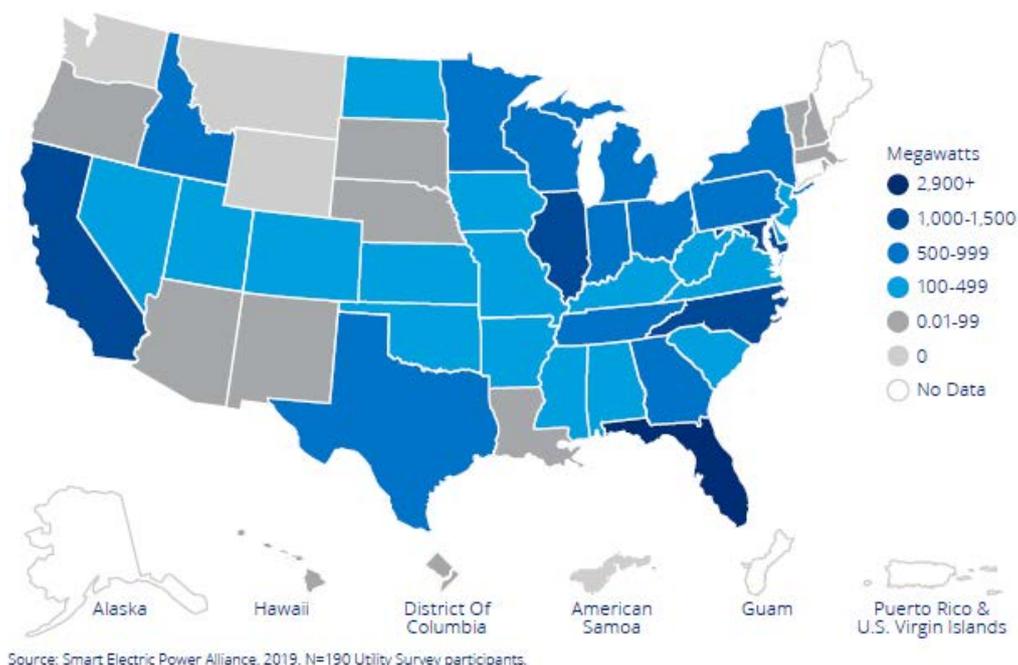


Figure 3-2. 2018 US Enrolled Demand Response Capacity (MW)

Source: SEPA 2019 Utility Demand Response Market Snapshot¹⁹¹

Demand flexibility is a growing trend in the US. The current demand flexibility capacity in the US is about 59 GW, or about 7% of peak demand.¹⁹² The growth of smart/connected home technologies and smart metering in the US are key drivers for demand flexibility in the residential sector. Estimates show that 36% of households in the US in 2019 owned a remotely monitored internet-connected device in their home, with smart thermostats ranking as the most common device.¹⁹³ Smart meter installations are also growing rapidly, reaching over 50% penetration in 2017.¹⁹⁴

Many pilot programmes in residential demand flexibility are in place in the US, but more work is needed to expand and scale these programmes to reach the full demand flexibility potential in the US. Most residential demand flexibility pilot programmes utilise smart thermostats, connected water heaters, and energy storage (batteries/EVs). An overview of key successful residential demand flexibility programmes in the US is available in Chapter 4.1.

¹⁹¹ Available online: <https://sepapower.org/resource/2019-utility-demand-response-market-snapshot/>

¹⁹² The Brattle Group. 'The National Potential for Load Flexibility.' 2019.

https://brattlefiles.blob.core.windows.net/files/16639_national_potential_for_load_flexibility_-_final.pdf

¹⁹³ Park Associates contribution to: Smart Electric Power Alliance. '2019 Utility Demand Response Market Snapshot.' 2019.

Available online: <https://sepapower.org/resource/2019-utility-demand-response-market-snapshot/>

¹⁹⁴ Navigant Research, 'Global AMI Tacker 2019.'

4. Demand Flexibility Programmes

Residential demand flexibility programmes generally consist of automated demand response (ADR) and DER aggregation projects. ADR programmes provide an incentive for customers to install connected and smart technologies that are capable of shedding, shifting, and/or modulating energy use in response to signals. DER aggregation projects go beyond the capabilities of ADR to serve as a virtual power plant for utilities. To date, demand flexibility and virtual power plant programmes have consisted of smaller utility programmes and pilots. More work is needed to expand these programmes to larger capacities to see greater grid benefits. This chapter provides an overview of ADR and DER aggregation pilots.

4.1 Automated Demand Response

ADR is more established and prevalent than DER aggregation, currently. In the residential sector, these programmes consist typically of technologies such as smart thermostats, connected water heaters, batteries, and/or smart appliances. A common programme design is the BYOD model (discussed in Section 2.2). Demand aggregators are often used in the residential space to aggregate smaller loads to be able to provide more impactful load shifting to the grid. This section highlights a few successful residential ADR programmes, though many more successful programmes have been implemented worldwide.

4.1.1 US, Duke Energy Florida, EnergyWise Home

Duke Energy in Florida began the EnergyWise programme in 2015 when the utility transitioned from one-way demand response to two-way Wi-Fi and cellular direct load control switches utilizing the IntelliSOURCE Demand Response Management System which includes variable and geographic load control and real-time asset and inventory management.¹⁹⁵ This programme boasts 418,000 participating customers and 550,000 direct load control switches with a total demand response capacity of 653 MW.¹⁹⁶ It utilises heating and cooling systems, electric water heaters, and pool pumps to avoid peak demand automatically, normally calling on water heaters, then pool pumps.¹⁹⁷ This programme has proven to effectively and frequently utilise these technologies in real-time, controlling water heaters more than 140 times per year. In 2016, it was recognised by the Peak Load Management Alliance as a programme Pacesetter for their industry-leading applied technology innovation.¹⁹⁸

4.1.2 US, ComEd and Nest Thermostat

Commonwealth Edison (ComEd) in Illinois partnered with Nest Thermostat to offer the Bring Your Own Thermostat programme starting in 2014 to implement air conditioner cycling.¹⁹⁹ By 2018, they had 18,000 customers participating in the programme.²⁰⁰ In this programme, ComEd offers a \$100 rebate in exchange for buying a thermostat and participating in the

¹⁹⁵ Peak Load Management Alliance. 'Duke Energy Florida's Award-Winning Initiative.' Accessed Dec. 2019. <https://www.peakload.org/DukeFla> (PLMA, 'Duke Energy Florida's Award-Winning Initiative.')

¹⁹⁶ *Ibid.*

¹⁹⁷ Clearly Energy. 'Residential Demand Response Programs.' Accessed Dec. 2019. <https://www.clearlyenergy.com/residential-demand-response-programs>

¹⁹⁸ PLMA, 'Duke Energy Florida's Award-Winning Initiative.'

¹⁹⁹ Peak Load Management Alliance. 'The Future of Utility 'Bring Your Own Thermostat' Programs.' 2018. <https://www.peakload.org/assets/Groupsdocs/PractitionerPerspectives-UtilityBYOTPrograms-March2018.pdf> (PLMA, 'The Future of Utility BYOT Programs.')

²⁰⁰ PLMA, 'The Future of Utility BYOT Programs.'

programme.²⁰¹ ComEd utilises these thermostats during peak events by adjusting setpoints automatically. The programme has been successful in reducing peaks according to load profile data; the smart thermostats have proven to offer comparable or even higher energy savings results than direct load control switches on air conditioning systems.²⁰²

4.1.3 US, Pacific Northwest, Connected Water Heaters

Bonneville Power Administration, Portland General Electric, and the Northwest Energy Efficiency Alliance collaborated in the US Pacific Northwest to develop the largest smart water heater demand response pilot programme. The programme involved multiple demand response events every day with a total of over 600 events in 220 days.²⁰³ The intention of the pilot was to run a test to collect data including load shifting performance and utilise this to calculate the potential of a large-scale project in the future. The pilot also attempted to show that load shifting through connected water heaters could be effective without impacting customers' lifestyles. The analysis showed promising results. First, 80% of customers were very satisfied with the programme and 94% would be very likely/somewhat likely to join a similar programme in the future.²⁰⁴ Also, the analysis projected (assuming a 26.5% participation rate) that by 2039 the programme would create the equivalent of a 301 MW peaking plant and 340 to 800 MWh of battery storage equivalence depending on time of day and year.²⁰⁵

4.2 DER Aggregation

DER aggregation programmes are more nascent than ADR programmes as they generally require more complex grid-interactivity and integration. These projects often include batteries, EVs, and rooftop solar PV in addition to connected consumer devices. The US, Japan, Finland, and Australia, among others, have seen successful pilot programmes. In the US in 2018, there were around 23 DER aggregation pilots beginning as early as 2009 according to a study from the National Renewable Energy Laboratory (NREL).²⁰⁶ Figure 4-1 shows the types of DERs used in DER aggregation programmes in the US. This section highlights examples of successful DER aggregation programmes from recent years.

²⁰¹ *Ibid.*

²⁰² *Ibid.*

²⁰³ Bonneville Power Administration. 'CTA-2045 Water Heater Demonstration Report Including A Business Case for CTA-2045 Market Transformation.' Nov. 2018. https://www.bpa.gov/EE/Technology/demand-response/Documents/20181118_CTA-2045_Final_Report.pdf

²⁰⁴ *Ibid.*

²⁰⁵ *Ibid.*

²⁰⁶ Cook, J.; Ardani, K.; O'Shaughnessy, E.; Smith, B.; and Margolis, R. 'Expanding PV Value: Lessons Learned from Utility-led Distributed Energy Resource Aggregation in the United States.' *National Renewable Energy Laboratory*. 2018. <https://www.nrel.gov/docs/fy19osti/71984.pdf> (Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.')

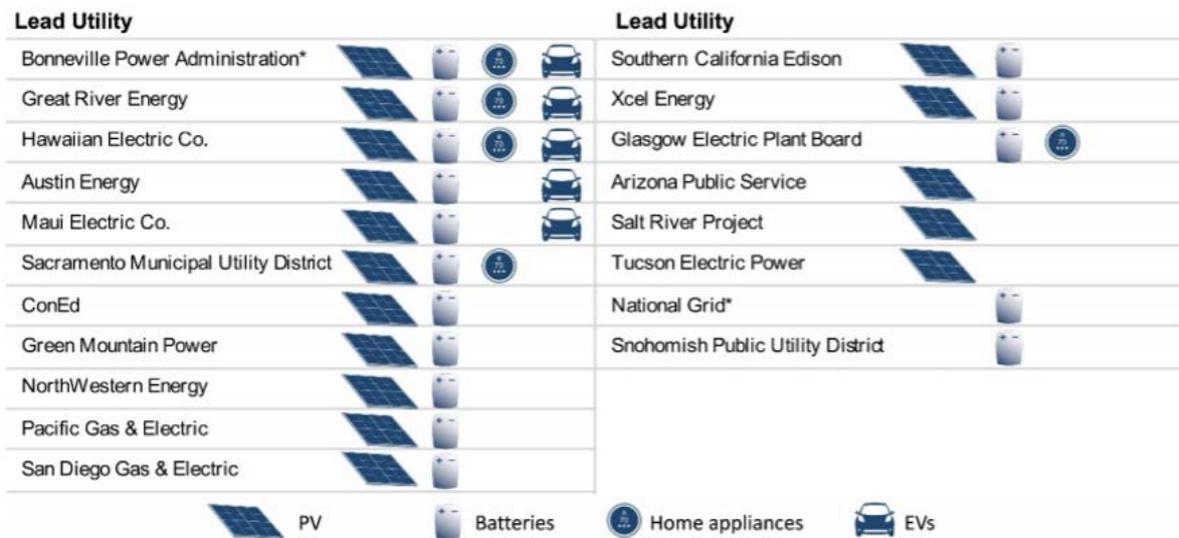


Figure 4-1. Example DER Aggregation Programmes in the US

Source: Adapted from NREL (2018)²⁰⁷

4.2.1 US, Southern Company: Smart Neighborhood

Alabama Power partnered with Southern Company, Oak Ridge National Laboratory, and Electric Power Research Institute to develop the Smart Neighborhood project in Birmingham, Alabama. This neighbourhood consists of 62 homes equipped with efficient and smart home technologies integrated into a microgrid powering the entire community.²⁰⁸ The microgrid (consisting of a solar array, battery storage system, and a natural gas back-up generator) controls the smart home technologies to support grid resilience and reliability through novel control strategies aimed at optimizing energy use while maintaining occupant comfort.²⁰⁹ Technologies used include a smart home system with connected heat pump HVAC, smart water heaters, connected lighting, and smart appliances (refrigerator, dishwashers, etc.). These homes are also rated to be 35% more efficient than a standard home built in Alabama.²¹⁰ Though the project is still in progress, preliminary results have been positive. Results show that these houses consume an average of 44% less energy than comparable new homes in Birmingham and have reduced winter peak demand by 34%.²¹¹

4.2.2 US, Sacramento Municipal Utility District: 2500 R Midtown

The Sacramento Municipal Utility District launched a DER project in 2014 on 34 single-family homes. Each home was equipped with a rooftop solar PV array, a lithium-ion battery, a smart thermostat, and a smart plug used to control appliances. The purpose of this pilot project was to test the ability of the houses to serve as a virtual power plant providing: load aggregation with a group of homes, load shifting and shedding at peak times, providing backup power during emergency grid events, solar PV firming (mitigating rapid output

²⁰⁷ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²⁰⁸ US DOE, 'GEB: Overview of Research Challenges and Gaps.'

²⁰⁹ *Ibid.*

²¹⁰ Fischbach, A. 'Alabama Power Builds Smart Neighborhood of the Future.' Nov. 2019. <https://www.tdworld.com/grid-innovations/smart-grid/media-gallery/20971954/alabama-power-builds-smart-neighborhood-of-the-future>

²¹¹ US DOE, 'GEB: Overview of Research Challenges and Gaps.'

changes with the battery), and regulation (using solar PV and batteries to respond to regulation pulse signals).²¹²

The project was successfully able to demonstrate the ability of these DERs to provide all these services. Ten of the homes also volunteered to participate in time-of-use electricity pricing (non-dispatchable DR) to shift loads during peak periods on a daily basis. The load shifting provided an average reduction of 2.66 kW per house per day by utilizing the solar PV and battery (93%), smart thermostat (7%), and smart plugs (<1%).²¹³ However, they found that the smart thermostats and smart plugs provided considerably less value than the solar PV and battery DERs as the thermostat load shifting performance was inconsistent and the smart plug loads were small. The integration of DERs and distributed energy resource management system (DERMS) platforms was a major challenge; they found it was difficult to identify cost-effective methods to integrate and exchange data between the utility and third-party platforms.²¹⁴ Though, ultimately successful, the DERMS development and integration with DERS was costly and time-consuming, underscoring the need for open communication platforms.

4.2.3 US and Japan, Maui Electric Company: Jumpstart Maui

The Maui Electric Company (MECO) partnered with the Hawaiian Electric Company for the five-year Jumpstart Maui programme (2011-2016) to help mitigate grid challenges associated with increased penetration of distributed solar PV and EVs on the island of Maui. The project also involved collaboration with New Energy and Industrial Technology Development Organization (NEDO) of Japan to help develop a smart community.²¹⁵ The goal of the project was to create a virtual power plant that would manage power quality, provide customers with increased control over energy consumption, help to integrate high penetration of renewables in the grid, and maximise renewable energy consumption.²¹⁶ Hawaii also recently implemented an ambitious renewable portfolio standard goal of 100% by 2040, underscoring the need for this demonstration project.²¹⁷ Over the duration of the two-phase project, 530 residents and businesses participated.²¹⁸

The project involved a broad scope of technologies performing various grid functions including distributed solar PV, home lithium-ion batteries, EVs, solar inverters, and connected electric water heaters. MECO also partnered with the software company Hitachi to develop a DERMS to manage and control the DERs.²¹⁹ The batteries and EVs were dispatched to the grid in response to signals and load forecast from MECO, and the solar PV and inverters were used from ancillary services in response to voltage signals.²²⁰ The electric water heaters were directly controlled loads that helped maximise use of renewable generation and reduce system grid peak demand.²²¹

The project was successfully able to demonstrate the use of DER aggregation to provide a variety of grid services. Batteries were used to provide frequency response; EVs (charging

²¹² Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²¹³ *Ibid.*

²¹⁴ *Ibid.*

²¹⁵ Irie, H. 'Japan - US Collaborative Smart Grid Demonstration Project in Maui Island of Hawaii State: A case study.' 2017. <https://www.nedo.go.jp/content/100864936.pdf> (Irie, H. 'Japan - US Collaborative Smart Grid Demonstration Project in Maui Island of Hawaii State: A case study.')

²¹⁶ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²¹⁷ *Ibid.*

²¹⁸ 'JUMPSmart Maui Announces Successful Completion of Project.' May 2017. *MauiNow*.

<https://mauiNOW.com/2017/05/05/jumpsmartmaui-announces-successful-completion-of-project/>

²¹⁹ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²²⁰ *Ibid.*

²²¹ Irie, H. 'Japan - US Collaborative Smart Grid Demonstration Project in Maui Island of Hawaii State: A case study.'

and discharging) and water heaters were used to maximise renewable generation consumption and reducing peak demand; and solar inverters were used to provide voltage support.²²² The greatest overall potential came from the EVs' capability to maximise renewable energy consumption through charging to consume excess electricity from wind and solar. The EVs also provided a maximum of 3 kW of peak load reduction through discharged electricity.²²³

Though successful, this programme faced implementation challenges. First, acquiring customers to participate in demand flexibility services was a challenge for the programme, especially because many customers preferred the excess solar PV generation be used for net metering. Second, implementing smart meter inverters for voltage support was difficult because the Underwriters Laboratories standard had not been published yet, meaning there was no established guidelines for construction.²²⁴ In addition, relying heavily on residential EVs created challenges such as not always being connected to the grid when needed or already having full charge capacity when excess solar PV generation was available.

4.2.4 US, Southern California Edison: Preferred Resources Pilot

In 2013, Southern California Edison (SCE) began developing the Preferred Resources Pilot to utilise aggregated DERs to meet the capacity needs with a forecasted peak load growth in Orange County of 141 MW.²²⁵ The project involved the use of a variety of clean energy resources – energy efficiency, demand response, energy storage, distributed solar, and combined heat and power (CHP). In 2019, they completed the DER sourcing phase of the project, reaching the capacity needs required. They expect that a 200 MW aggregated DER portfolio will be available to serve the region's peak needs by 2021.²²⁶ The current portfolio makeup is shown in Figure 4-2.

²²² Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²²³ *Ibid.*

²²⁴ *Ibid.*

²²⁵ Southern California Edison. 'Preferred Resources Pilot: Lessons Learned About DER Sourcing and Deployment.' August 2019. https://www.sce.com/sites/default/files/inline-files/2019_PR_P AnnualReport.pdf (SCE, 'Preferred Resources Pilot: Lessons Learned About DER Sourcing and Deployment.')

²²⁶ *Ibid.*

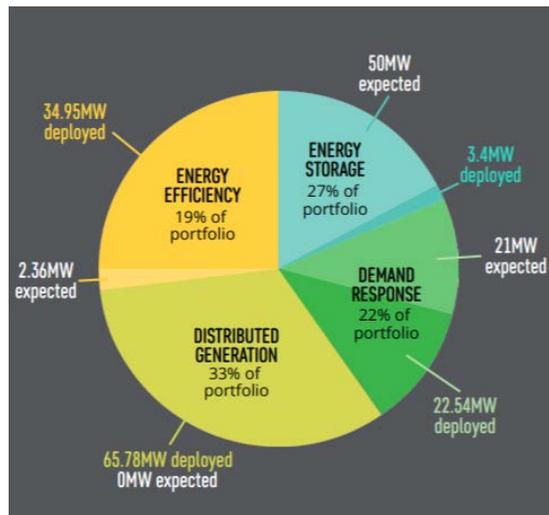


Figure 4-2. Preferred Resource Portfolio by Resource

Source: Southern California Edison (2019)²²⁷

In the summer of 2018, SCE measured the effectiveness of the DERs in providing peak reduction, measured as a ratio of measured level reduction to DER capacity deployed during the highest peak hour of demand in 2018.²²⁸ The results showed an average effectiveness of 68% with the highest effectiveness ratings of 71%, 70%, and 69% coming from solar PV, CHP, and energy storage, respectively.²²⁹ Energy efficiency and demand response performed more modestly at 59% and 54%.²³⁰ The results in 2018 underscored the need for having a diverse mix of resource types to manage peak load growth as no one resource type has all the requirements needed to meet their grid needs.

SCE has also experienced issues developing a DERMS and communicating with DERs, reporting that it was a time and resource intensive project. SCE is currently using a test DERMS but expects to adopt a full DERMS before the project's conclusion.²³¹ It expects that the publication of the Institute of Electrical and Electronics Engineers (IEEE) 2030.5-2018 Standard for Smart Energy Profile Application Protocol (supporting communication between the utility and DERs) will help address these communication challenges that they faced.²³²

4.2.5 Finland, Fortum Spring: Virtual Power Plant

In 2016, Fortum, a major energy company in Finland, launched a small pilot programme consisting of 70 aggregated, connected water heaters in single-family homes creating a 100 kW virtual power plant.²³³ This virtual power plant was the first of its kind in Finland to participate in maintaining system power balance.²³⁴ Since 2016, the pilot programme has expanded to create a 1 MW virtual power plant utilizing a network of over 1,000 residential

²²⁷ SCE, 'Preferred Resources Pilot: Lessons Learned About DER Sourcing and Deployment.'

²²⁸ *Ibid.*

²²⁹ *Ibid.*

²³⁰ *Ibid.*

²³¹ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

²³² *Ibid.*

²³³ Fortum Corporations, 'Fortum and a group of households participate together in the balancing power market in an virtual power plant experiment first of its kind.' March 2016. <https://www.fortum.com/media/2016/03/fortum-and-group-households-participate-together-balancing-power-market-virtual-power-plant-experiment-first-of-its-kind>

²³⁴ *Ibid.*

water heaters which actively participate in balancing markets.²³⁵ This is currently the largest operating virtual power plant in the Nordics.²³⁶ As of January 2020, 1,990 water heaters are participating in the programme which have been used for balancing services over 21 thousand times since 2017.²³⁷

4.2.6 Australia: Tesla Virtual Power Plant

In 2018, South Australia announced plans to create the world's largest virtual power plant utilizing a network of 50,000 home solar systems backed up by Tesla Powerwall batteries.²³⁸ The project involves installing a 5kW solar panel system and 13.5kWh Tesla Powerwall 2 batteries in each household at no charge to consumers. Once complete, the project will boast a capacity of 250 MW of solar power and 650 MWh of energy storage, making it the largest virtual power plant in the world.²³⁹ The goals of the project are to: reduce electricity rates for customers, increase grid stability and resilience against power outages, and increase penetration of renewables.²⁴⁰ The project began with a smaller trial of 1,100 public houses in South Australia in 2019.

Though still in the early phases of the project, initial results have been promising. The first phase has shown reduction in electricity rates of more than 20% for participating households.²⁴¹ The virtual power plant was also successfully used to provide grid stability when a coal plant in Queensland went offline and reduced system supply by 748 MW in October 2019.²⁴²

²³⁵ Fortum Corporations, 'A thousand Fortum customers' homes form a one-megawatt virtual battery,' Jan 2018.

<https://www.fortum.com/media/2018/01/thousand-fortum-customers-homes-form-one-megawatt-virtual-battery>

²³⁶ Fortum Corporations, 'Building a Virtual Battery with Our Customers.' Accessed Dec. 2019.

<https://www.fortum.com/products-and-services/smart-energy-solutions/virtual-battery-spring>

²³⁷ Fortum Corporation, 'Environmental Report.' Accessed Jan. 2020. <https://energianseuranta.fortum.fi/report>

²³⁸ Bevege, A. 'South Australia promises world's largest virtual power plant.' Feb. 2018. *Reuters*.

<https://www.reuters.com/article/us-australia-power-tesla/south-australia-promises-worlds-largest-virtual-power-plant-idUSKBN1FO02G>

²³⁹ Maloney, P. 'Tesla to outfit 50K Australian homes with solar+storage for 250 MW virtual power plant.' Feb. 2018. *Utility Dive*.

<https://www.utilitydive.com/news/tesla-to-outfit-50k-australian-homes-with-solar-storage-for-250-mw-virtual/516352/>

²⁴⁰ Government of South Australia. 'South Australia's Virtual Power Plant.' Accessed Dec. 2019.

<https://virtualpowerplant.sa.gov.au/>

²⁴¹ Lambert, F. 'Tesla virtual power plant in Australia reduces electricity rate by 'more than 20%', moving to phase 3.' *Electrek*.

July 2019. <https://electrek.co/2019/07/26/tesla-virtual-power-plant-australia-savings-phase-3/>

²⁴² Walton, R. 'Tesla's Australian virtual power plant propped up grid during coal outage.' *Utility Dive*. Dec. 2019.

<https://www.utilitydive.com/news/teslas-australian-virtual-power-plant-propped-up-grid-during-coal-outage/568812/>

5. Demand Flexibility Challenges and Recommendations

Though some initial progress has been made in developing demand flexibility programmes and pilots, much work is needed to reach widespread adoption. Policy-makers and programme administrators will need to overcome challenges and barriers to implementing widescale residential demand flexibility. These barriers can be broadly categorised as market challenges, technology challenges, and policy challenges. The barriers and recommendations discussed in this section are intended to be general and apply to most regions of the world. Pilot programmes should be used to help identify more regional specific barriers and policy needs.

5.1 Market and Programme Implementation Challenges and Recommendations

Market challenges exist on both the programme implementation side and the customer participation side. A summary of some of these challenges and recommendations is provided in the following sections.

5.1.1 Market Requirements

5.1.1.1 Challenges

DER aggregation programmes/virtual power plants are dependent on the existence of structured markets for revenue. Aggregators are only able to participate in markets if the regulations and incentive structures allow them to. This alone makes DER aggregation in regulated electricity markets less viable if not impossible. Further, in many unregulated electricity markets, there are still substantial implementation barriers. In general, markets for demand flexibility are immature and highly variable by region. In many cases, the absence of markets and incentives (reducing barriers, *etc.*) for participating is the greatest implementation barrier to demand flexibility as connected technology adoption and advanced metering infrastructure adoption has already seen significant growth.

In some countries, there are a limited number of electricity markets in existence and/or open to independent aggregators and demand response. Balancing and ancillary services and congestion management are emerging markets around the world, but development of these markets has been slow. In addition, product requirements for some market services make it difficult for residential demand aggregators to participate (*i.e.*, capacity requirements). Some countries/regions also require demand aggregators to make bilateral agreements with the supplier to sell demand flexibility. Finally, lack of financial incentives for aggregators are a substantial barrier in some markets. If the payments for bidding into markets are too low relative to the incurred costs, aggregators have no incentive to participate.

5.1.1.2 Recommendations

First, electricity markets should be liberalised and open to demand flexibility and independent aggregators. Many countries/regions also need to work to develop and open new ancillary services aimed at renewable energy integration such as frequency response, voltage support, load following reserves, and replacement reserves. Market design for increased flexibility includes sub-hourly dispatch periods, hourly or daily performance commitment periods, and inclusion of all demand-side resources in all markets (commercial,

residential, and industrial).²⁴³ Beyond simply opening markets, independent aggregators and consumers must also be incentivised to participate. Barriers to providing flexibility such as strict bilateral contract requirements with suppliers or minimum capacity requirements should be removed.

Ultimately, top-down policies are needed to incentivise the use of demand flexibility by system operators and to develop independent demand aggregators (where they are not already in existence).²⁴⁴ Policies could include demand response minimum capacity requirements and requirements for increased financial incentives/payments for flexibility participation in markets. This may first require quantifying the current and projected future system needs for demand flexibility capacity.

5.1.2 Customer Incentives

5.1.2.1 Challenges

Customer participation in demand flexibility programmes requires establishing financial incentives that can promote the adoption of the necessary technologies (batteries, smart thermostats, *etc.*) and the participation in the demand response events/services. From the customer perspective, programme participation may require a large capital investment for the equipment necessary and could be a time-consuming process. In addition, providing demand flexibility from certain connected technologies may require customers to deal with decreased comfort (dimmed lighting, changing temperature setpoints) and/or minor inconveniences (delayed start on appliances). Accordingly, it is important to provide customers with a clear business case for participating in the programme. Some programmes to date have shown that customers have a lack of clear information about what financial incentives are available and whether the benefits outweigh the costs.²⁴⁵

5.1.2.2 Recommendations

Creating the right incentives (specific to the region) is vital to encouraging customer participation in the programmes. Some pilots provide the equipment needed to the customer outright (at no cost to the customer) while others may offer a partial/full rebate in exchange for participating in the programme. Other programmes provide payments or bill reductions in exchange for automatically controlling their batteries, thermostats, controls, and/or equipment or participating in peak demand events. Determining the optimal incentive structure for the programmes is dependent on regional differences and differences in the programme design and goals. Market research, evaluations, and testing can help determine incentive structures for a programme design including surveys of potential customers and pilot studies designed to test various incentive structures.

²⁴³ Dragoon, K. and Papaefthymiou, G. 'Power System Flexibility Strategic Roadmap: Preparing power systems to supply reliable power from variable renewable energy sources.' Ecofys by order of European Copper Institute, 2015. http://www.flinkenergy.com/resources/strategic_flexibility_roadmap-final-20150915.pdf

²⁴⁴ *Ibid.*

²⁴⁵ European Smart Grids Task Force. 'Demand Side Flexibility: Perceived Barriers and Proposed Recommendations.' 2019. https://ec.europa.eu/energy/sites/ener/files/documents/eg3_final_report_demand_side_flexibility_2019.04.15.pdf

5.1.3 Customer Awareness and Satisfaction

5.1.3.1 Challenges

In addition to the financial incentives provided, customer acquisition and retention in demand flexibility programmes depends on 1) their awareness of the programme, and 2) the satisfaction in their participation. First, customer acquisition requires the programme administrators to educate the target population of the programme on the potential benefits of demand flexibility. Customer retention then requires the administrators to creatively engage and incentivise customers to remain in the programme.

In the vast majority of demand response and flexibility programmes (aside from some default time-of-use pricing structures), customers must opt-in to the programmes. When developing these programmes in new markets/regions especially, this is a significant challenge as baseline awareness of demand flexibility will be low. Customers, particularly in the residential sector, may be reluctant to agree to participate in a programme that allows utilities to have direct control of their home's technologies. Further, as residential loads are generally smaller, participation from thousands of customers is necessary to provide meaningful grid services.

Maintaining customer participation in these programmes is also challenging. Demand flexibility must be implemented without substantially impacting occupant comfort and convenience. Customers are unlikely to remain in a programme if providing the flexibility services was inconvenient for them and/or if they are unsatisfied with the incentives they receive.

5.1.3.2 Recommendations

First, substantial investments in marketing will help increase initial awareness in the programmes and increase participation. In general, programmes offering rebates or free equipment (such as smart thermostats or controls or water heaters) have seen great success. During the programme, customer support through technical assistance and additional financial incentives is beneficial. Customer support is especially important in programmes with new technologies and software systems that could have issues. In addition, collecting data and communicating savings can help to show customers that their initial investment is paying off. For new programmes, customer satisfaction surveys can also help determine areas for improvement to help retain customers.

In general, more research is needed to understand the occupant comfort impacts from various technologies providing demand flexibility. However, technologies with energy storage capabilities (thermal storage and electrochemical) , such as water heaters, batteries/EVs, and HVAC systems coupled with efficient building envelopes, are better suited to shift and modulate energy consumption.

5.2 Technology Challenges and Recommendations

Demand flexibility requires technologies with two-way communication and control capabilities, and software systems are needed to aggregate and manage these technologies. In general, these technologies are in existence today; however, technology challenges remain that impact programme implementation and technology adoption including: system integration, interoperability/communication, cybersecurity, complexity/usability, and high costs.

5.2.1 System Integration

5.2.1.1 Challenges

Managing DERs from a central system has been cited by programme administrations as the primary technology challenge.²⁴⁶ DERMS can help optimise and integrate DERs into the grid. The development of a DERMS is necessary to scale DER aggregation programmes and optimise the use of multiple DERs for grid services beyond simple peak management.²⁴⁷ The DERMS platform allows utilities to send signals to the DERs and control them and/or request the service from an independent aggregator.²⁴⁸ Independent aggregators often develop their own DERMS platforms to autonomously manage and control DERs in response to utility requests. However, DERMS are still in their infancy so developing a platform can be costly and time-consuming. In addition, some utilities have struggled to determine cost-effective pathways to manage integration and data exchange between utilities and demand aggregators.²⁴⁹

5.2.1.2 Recommendations

DERMS platforms have never been used in wide-scale programmes. More work is needed to adopt standardised DERMS communication protocols and operational practices. The IEEE recently established the Standard for Smart Energy Profile Application Protocol for communication between the DERs, aggregators, and utilities which is expected to help address communication challenges around DERMS and increase cost-effectiveness.²⁵⁰ Widespread adoption of similar communication standards can help reduce the complexity and cost of implementing a DERMS platform.

Some utilities, such as Pacific Gas and Electric (PG&E) in California, have demonstrated the benefits of using DERMS to aggregate DERs with shared characteristics into groups.²⁵¹ PG&E used these groups to more effectively utilise the DERs for regional specific challenges and certain grid services.²⁵² This functionality could be beneficial in scaling DER aggregation programmes to larger markets.

5.2.2 Cybersecurity

5.2.2.1 Challenges

Cybersecurity is a challenge facing all internet-connected technologies. Cybersecurity is defined as ‘the process of enabling appropriate confidentiality of information, integrity of that information and the devices on which it resides, and availability of devices and information when needed.’²⁵³ Cybersecurity is necessary to protect data privacy. One connected device could potentially provide backdoor access to other systems connected on the same network (*i.e.*, IT systems).²⁵⁴ Cyberattacks on connected devices have also demonstrated the ability

²⁴⁶ Perry, C.; Bastian, H.; York, D. ‘Grid-Interactive Efficient Building Utility Programs: State of the Market.’ Oct. 2019. American Council for an Energy Efficient Economy White Paper. <https://aceee.org/sites/default/files/gebs-103019.pdf>

²⁴⁷ Cook et. al, ‘Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.’

²⁴⁸ *Ibid.*

²⁴⁹ *Ibid.*

²⁵⁰ *Ibid.*

²⁵¹ *Ibid.*

²⁵² *Ibid.*

²⁵³ US Department of Energy. ‘Grid-Interactive Efficient Buildings Technical Report Series: Lighting and Electronics.’ Nov. 2019. <https://www1.eere.energy.gov/buildings/pdfs/75475.pdf> (US DOE, ‘GEB Technical Report Series: Lighting and Electronics.’)

²⁵⁴ *Ibid.*

to serve as an access point to the electric grid and to damage targeted hardware equipment.²⁵⁵

Further, consumers have become increasingly cautious of adopting technologies that they believe could compromise their privacy or data security. End-to-end data security is needed to ensure both network reliability and consumer confidence in smart home technologies. This means security measures must be implemented at all levels: individual devices, energy management systems, DERMS, and the grid.²⁵⁶

5.2.2.2 Recommendations

The technical capabilities to provide cybersecurity in smart home equipment (*i.e.*, software and network equipment) are in existence today. However, more work is needed to increase the adoption of secure system architectures and cybersecurity best practices.²⁵⁷ In 2019, the European Telecommunication Standards Institute released a standard for cybersecurity in consumer IoT devices which provides manufacturers with guidance on developing cybersecure products.²⁵⁸ Additional work is needed to develop cybersecurity testing standards and methods to evaluate cyber vulnerabilities.

5.2.3 Interoperability and Communication

5.2.3.1 Challenges

Interoperability is defined as ‘the ability of devices or software systems to reliably and consistently exchange data.’²⁵⁹ Interoperability is needed to effectively and securely exchange data between DER devices, applications, and management systems. Demand flexibility relies on a suite of technologies from many different industries and manufacturers (batteries, EVs, solar PV, controls, smart thermostats, HVAC systems, water heaters, software, *etc.*) who often develop their own communication protocols and proprietary software. Accordingly, the DER/smart home technology market is fragmented, and developing and adopting common interoperable platforms and communication protocols remains a significant challenge today.

Telecommunication consists of a hierarchy of communication protocols operating at different levels: physical layers at the bottom (*i.e.*, Bluetooth, Wi-Fi), network layers in the middle (*i.e.*, Transmission Control Protocol, Internet Protocol), and application layers at the top (*i.e.*, BACnet).²⁶⁰ Interoperability is needed both within a level and all layers below for effective telecommunication.²⁶¹

5.2.3.2 Recommendations

A common and widely adopted standard for device communication including physical ports and protocols could enable increased adoption of smart home technologies/DERs. A communications standard would enable increased communication between devices and

²⁵⁵ *Ibid.*

²⁵⁶ *Ibid.*

²⁵⁷ *Ibid.*

²⁵⁸ European Telecommunication Standards Institute. ‘Cyber Security for Consumer Internet of Things.’ 2019.

https://www.etsi.org/deliver/etsi_ts/103600_103699/103645/01_01_01_60/ts_103645v010101p.pdf

²⁵⁹ US DOE, ‘GEB Technical Report Series: Lighting and Electronics.’

²⁶⁰ *Ibid.*

²⁶¹ *Ibid.*

allow consumers/aggregators to more easily integrate and aggregate equipment into demand flexibility markets. Currently, several industry organisations are working to support increased interoperability at smart home device level (Wi-Fi, Bluetooth, *etc.*) through common communication protocols and established standards, including the Open Connectivity Foundation, the TALQ Consortium, oneM2M, Bluetooth special interest group, the Industrial Internet Consortium, and the Zigbee Alliance.²⁶²

5.2.4 Complexity and Usability

5.2.4.1 Challenges

Connected/smart home technologies with capabilities such as two-way communication, controls, data analytics, and user interfaces are innately more complex than non-connected technologies. These technologies often include advanced features such as sensors, controllers, software, touchscreens, displays, and/or cameras. These advanced capabilities and features may make it more difficult and costly to install, configure, operate, and maintain this equipment. Further, consumers lacking technology expertise may avoid purchasing these more complex technologies. Manufacturers should play a key role in increasing the usability of connected/smart technologies.

5.2.4.2 Recommendations

When developing connected/smart home technologies, it is vital to balance the need for advanced capabilities and complexity so that technologies can provide the intended services (demand flexibility, energy savings, advanced control, *etc.*) without requiring significant technical expertise to install, configure, and operate them. Manufacturers should focus on developing connected devices and systems with streamlined or automated installation/configuration and predictive maintenance features. Smart home technologies should be designed to promote plug-and-play functionality, which uses wireless connectivity to automatically discover the equipment (avoiding physical configuration needs). In addition, manufacturers can streamline the installation and configuration process by providing software-based tools and documentation. Further, providing customer support for operation and maintenance of the technologies during the lifetime of the equipment can ease consumer concerns with complexity.

5.2.5 High Cost

5.2.5.1 Challenges

The greatest technology adoption barrier is the high cost for demand flexibility technologies such as batteries, rooftop solar PV, smart thermostats, and smart/connected water heaters/appliances. As mentioned previously, demand flexibility requires two-way communication, controls, and energy management software, which increases the cost of the technologies to consumers. Further, many grid-interactive technologies are coupled with other premium features (touchscreens, sensors, *etc.*) that increase the cost. These premium products may have prohibitively high costs for many residential consumers who cannot justify the long payback periods. More progress is needed to make smart home technologies

²⁶² US DOE, 'GEB Technical Report Series: Lighting and Electronics.'

accessible to a larger portion of the population to make widespread demand flexibility a reality.

5.2.5.2 Recommendations

Research and development are needed to improve manufacturing processes to lower capital costs of the equipment and/or to utilise existing manufacturing equipment.²⁶³ In addition, these connected technologies need to be compatible with scalable manufacturing to increase production without increasing capital costs.²⁶⁴ Utilities/programme administrators often use rebates to help reduce the cost of smart home equipment (smart thermostats, water heater controls, *etc.*) to consumers in exchange for participating in their demand flexibility programme. In addition, federal/regional policy makers utilise tax credits or subsidies to encourage adoption of higher cost technologies, such as efficiency upgrades or EVs. Such programmes have been successful in increasing adoption of the technologies and increasing participation in the programmes.

5.3 Policy Challenges and Recommendations

Technological and market developments in demand flexibility are not enough to reach widespread demand flexibility. Government organisations, programme administrators, standards bodies, and other industry players must work to develop new regulations and standards to help support demand flexibility programmes. Delayed action could stifle the propagation of demand flexibility beyond the smaller pilots in place today.

5.3.1 Adopting Regulations

5.3.1.1 Challenges

Adopting new regulations is generally a time-consuming process, lagging the rapid technological development in DERs and smart home technologies. Utilities must work with regulators and local governments to develop and implement new programmes, such as demand flexibility. In addition, independent aggregators may also be required to go through a regulatory approval process with both the utility and the local regulator to review proposals and/or legal documents before implementing a programme.²⁶⁵

5.3.1.2 Recommendations

Increased collaboration between regulators and utilities can help expedite the programme development process. A survey of utilities and programme administrators suggests that top-down policy mandates from governments/regulators can also support utilities in the development of new flexibility programmes.²⁶⁶ Integrating requirements for demand flexibility in utilities' system and resource planning could also be beneficial.²⁶⁷

²⁶³ US DOE, 'GEB Technical Report Series: Lighting and Electronics.'

²⁶⁴ *Ibid.*

²⁶⁵ Navigant Research, 'Market Data: Residential DR.'

²⁶⁶ Perry, C.; Bastian, H.; York, D. 'Grid-Interactive Efficient Building Utility Programs: State of the Market.' Oct. 2019. American Council for an Energy Efficient Economy White Paper. <https://aceee.org/sites/default/files/gebs-103019.pdf>

²⁶⁷ *Ibid.*

5.3.2 Developing Standards and Frameworks

5.3.2.1 Challenges

Developing and adopting standards and frameworks with industry input can be a time-consuming and intensive process, especially in emerging industries. However, establishing both technology and market standards and frameworks will go a long way in easing the development and implementation of demand flexibility programmes. As discussed previously in Sections 5.2.2 and 5.2.3, establishing communication and interoperability standards are key for both DERs/smart home technologies and DERMS platforms. On the market side, regional differences and ambiguities in the role of demand aggregators is a remaining barrier.

5.3.2.2 Recommendations

Policy makers should adopt standards for common communication around DERs and DERMS platforms. Some initial progress has been made in this. The Smart Electric Power Alliance (SEPA) is advocating currently for a plug-and-play standard for DERs such as smart water heaters and batteries to communicate with the grid.²⁶⁸ IEEE recently established the Standard for Smart Energy Profile Application Protocol for communication between the DERs, aggregators, and utilities which is expected to help address communication challenges around DERMS.²⁶⁹

In addition, a standardised framework for roles and responsibilities of demand aggregators in relation to utilities/energy companies and balance responsible parties is needed. In the end, policy makers should determine who is responsible for customer acquisition, controlling the DERs and connected devices, and operating the DERMS platform, among others.

²⁶⁸ *Ibid.*

²⁶⁹ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

6. Roadmap Guide

6.1 Introduction

IEA defines a roadmap as a ‘a strategic plan that describes the steps an organisation needs to take to achieve stated outcomes and goals.’²⁷⁰ An effective roadmap should include action items, near-term and long-term goals, priorities, and metrics and methods for tracking progress.²⁷¹ There are many types of roadmaps an organisation may use to achieve their goals including technology, visions, strategies, and business development, among others. This roadmap guide generally falls within the technology roadmap category as the focus here is the deployment of connected devices and DERs in the residential sector to participate in demand flexibility markets. The audience for a technology roadmap such as this one is focused on national governmental energy/environmental organisations, state/provincial energy policy makers, energy companies/utilities, electric system operators, and other relevant stakeholders in demand flexibility including laboratories and non-governmental organisations (NGOs) involved in research and advocacy.

Developing a technology roadmap can be a long and arduous process, often taking between 6 months and 18 months.²⁷² Before proceeding with the development of a demand flexibility roadmap, an initial assessment should be done to determine if the roadmap would be valuable and necessary for the country/region.²⁷³ The evaluation should look further at the current development status of demand response and demand flexibility in the country/region and the status of connected consumer devices and DERs in the residential sector. In addition, other prerequisites and factors for consideration in developing a demand flexibility roadmap include funding availability, resource constraints, stakeholder interest and buy-in, and methods for collecting data for tracking progress.

In general, the 23 countries identified in Chapter 3 have made some progress toward developing demand response, electricity markets, and/or advanced metering infrastructure. Hence, these countries along with many sub-national energy organisations within them could potentially benefit from developing a demand flexibility roadmap utilizing this guide. These 23 countries, however, vary greatly in their current development status, ranging from only limited availability of industrial non-automated demand response to numerous ADR and DER aggregation programmes in place already. This status has substantial impact on the roadmap development process and final product.

Section 6.2 provides concrete steps for policy makers to follow in developing a technology roadmap for consumer devices to participate in demand flexibility. This roadmap highlights differences in the process based on the development status of demand flexibility. In addition, other factors to consider for tailoring the roadmap to the needs of each country/region are outlined in this section.

²⁷⁰ IEA. ‘Energy Technology Roadmaps: A Guide to Development and Implementation.’ 2014.

²⁷¹ *Ibid.*

²⁷² *Ibid.*

²⁷³ *Ibid.*

6.2 Roadmap Process

Roadmapping should be a continuously evolving process consisting of the creation of the roadmap, implementation of the action plan, monitoring of goals, and revising the roadmap. This process, equally as important as the roadmap itself, is intended to engage key stakeholders and build consensus, ultimately ensuring that the demand flexibility vision is achieved.²⁷⁴

Generally, the development of a demand flexibility roadmap should follow four phases: 1) Planning and Preparation, 2) Visioning, 3) Roadmap Development, and 4) Monitoring and Revising (see Figure 6-1).²⁷⁵ The initial planning phase helps to establish a starting point for the roadmap based on what activity and progress has already been made. Then, a group of key stakeholders with interest and defined roles in implementing demand flexibility are convened to provide expertise and develop consensus. Next, with input from the stakeholder working group, the demand flexibility vision is created, representing the long-term goals and outcomes for achieving widespread adoption of residential demand flexibility. In Phase 3, the roadmap document is created including identifying region-specific challenges and barriers, goals and metrics for addressing the challenges, and key initiatives and action items to meet the established goals. Finally, data collection and analyses are used to measure progress toward the goals and revise the goals once progress has been made. These four phases are broken down further in Sections 6.2.1 to 6.2.4.

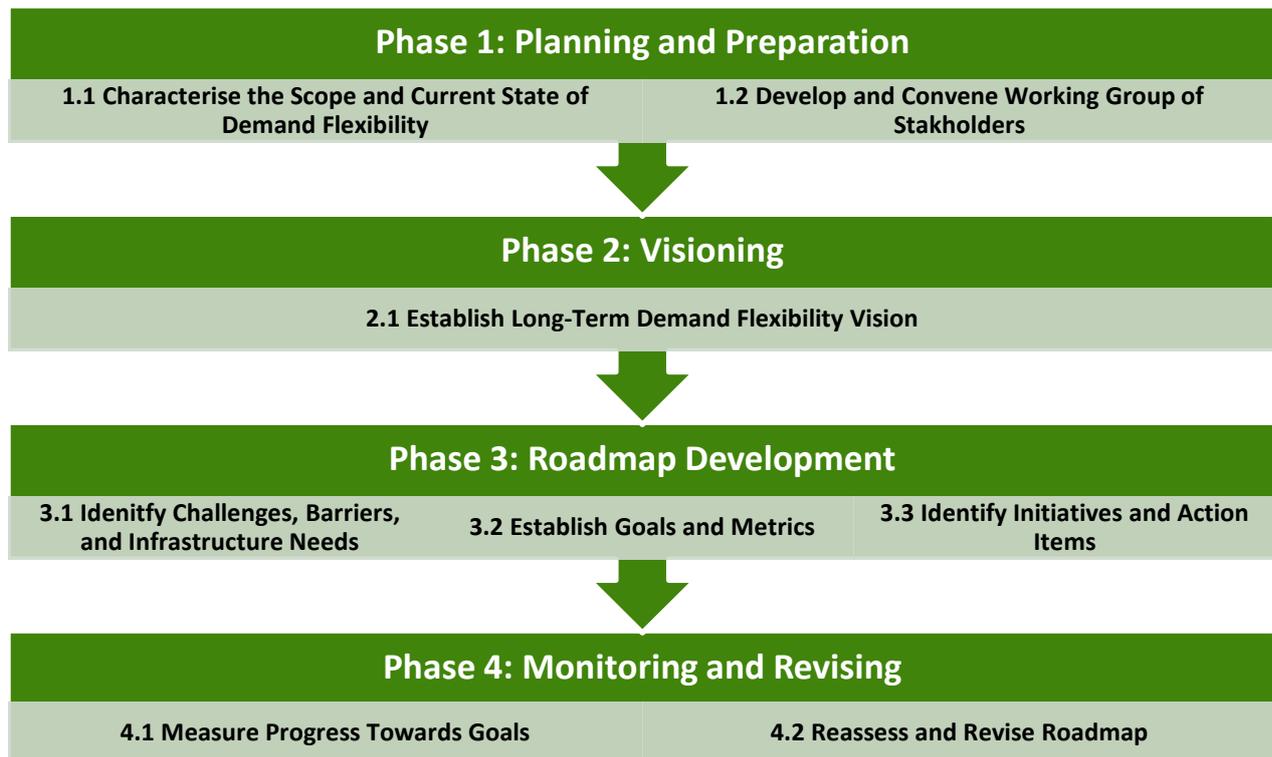


Figure 6-1. Roadmap Process Phases

Source: Adapted from IEA²⁷⁶

²⁷⁴ IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

²⁷⁵ Adapted from: IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

²⁷⁶ IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

For the purposes of this roadmap guide, some relevant roadmapping steps are defined separately for each of the three groups of countries/regions, based on the development status of demand response and flexibility in the region. While not every country and region will map neatly to these three groups, the intention is to provide more specific and meaningful guidance to policy makers when developing demand flexibility roadmaps.

- **Group 1:** Demand response is in preliminary development and is non-automated. The demand response capacity is low and rarely used (*i.e.*, emergency services) and is typically limited to the commercial/industrial sector. Aggregated demand response is not allowed in any markets.
- **Group 2:** Demand response is utilised today but in limited capacities. Some markets and services are open to aggregated demand response, but barriers exist that limit capacity. Automated demand response and residential demand response are emerging but not widely used today.
- **Group 3:** Demand response is well established, and demand flexibility is emerging. Most/all markets are open to demand response and aggregators and new ancillary services are emerging. Demand flexibility pilot programmes have been established (ADR and DER aggregation) but are not widespread yet.

6.2.1 Phase 1: Planning and Preparation

6.2.1.1 Characterise the Scope and Current State of Demand Flexibility

The first step in developing a demand flexibility roadmap is to establish the starting point. First, the organisation must establish the scope and timeframe for the roadmap to achieve the goals and vision (5-year, 10-year, 20-year, *etc.*). Countries/regions in Group 1 would likely have a longer roadmap time frame than countries/regions in Group 3.

Next, the organisation must characterise the current state of demand response and demand flexibility including: electricity markets, utility programmes, policies, grid system needs, and demand flexibility technologies. Chapter 3 of this report may serve as a starting point for these 23 identified countries.

This step should address these questions:

1. *What is the status of demand response participation in electricity markets? Which markets and grid services are open to demand response participation? Can independent aggregators participate in markets?*

The potential for demand flexibility depends on the availability of structured markets for revenue and demand aggregators to provide meaningful grid services (large capacity). Countries/region with more established and advanced demand response have a variety of markets and services open to demand response and aggregators.

2. *How is demand response currently provided? What types of demand response/flexibility programmes exist today and what customers can participate? Is it automated? How is demand response used today (peak reduction, emergency events, ancillary services, *etc.*)?*

The types of demand response programmes currently offered, and customer participation rates are an important indicator of progress toward established demand

flexibility. Key progress toward demand flexibility includes: establishing residential demand response programmes, established ADR and/or DER aggregation programmes, and utilizing demand response for fast-response and real-time services.

3. *What are the current and projected grid system needs? What are the current and projected generation resources? How can demand flexibility be used to meet grid system needs?*

The generation resources strongly influence the grid system needs and the potential services that demand flexibility could provide. In regions with high solar penetration, demand flexibility could provide balancing services and load shifting to consume more energy during periods of high solar generation. In heavily populated regions, demand flexibility could provide peak reduction and/or congestions services to avoid the use of costly peaker plants.

4. *What is the current state of demand flexibility technologies? What is the penetration of smart meters and smart home technologies? Which technologies have the greatest flexibility potential in the country/region?*

The demand flexibility technology infrastructure outlines the potential in the region. Regions with high penetration of smart meters and smart home technologies are ripe for establishing widespread demand flexibility. Countries/regions will also need to determine the key flexible technologies to focus on in their region. Highest potential technologies in the region correspond with the highest overall residential electricity use and peak period electricity use. Considerations for this include: air conditioning penetration rates, use of natural gas vs. electric water heaters/heating systems, peak seasons (summer vs. winter peaking), EV adoption, and rooftop solar PV adoption rates. For instance, Hawaii's DER aggregation pilot Jumpstart Maui focused on rooftop solar PV, batteries, and EVs, while utilities in Finland have established demand flexibility programmes utilizing space heating and water heater controls.

An effective characterisation of the current state of demand flexibility also requires collecting baseline data for relevant demand flexibility metrics such as:

- Percentage of households with smart meters and connected technologies/DERs by location;
- Current demand response and demand flexibility capacity and participation;
- Number of utility ADR and DER aggregation programmes and number of participants;
- Residential electricity use data broken down by end use and time; and
- Generation supply mix differences by region and time.

Where data is lacking, an important first step is to develop more robust data collection methodologies.²⁷⁷

²⁷⁷ IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

6.2.1.2 Develop and Convene Working Groups of Stakeholders

Implementing the demand flexibility roadmap depends on the input and expert judgement of a wide array of stakeholders in demand flexibility. Stakeholders are defined as ‘relevant individuals who have an interest in seeing the roadmap developed and implemented.’²⁷⁸ Though more stakeholder involvement may increase the overall roadmapping time, the increased knowledge, support, resources, and commitments is essential to roadmap implementation. A roadmap without committed partners implementing the goals and initiatives will not succeed.

Regardless of the development status of demand response and demand flexibility (Group 1, Group 2, or Group 3), potential demand flexibility stakeholders should include leaders covering electricity market regulators, flexible technology development, demand response programme administration, policy development, and researchers. Essentially, stakeholders should cover all parties necessary to achieving the roadmap goals and vision. Example stakeholders are shown in Table 6-1 below. The more diverse the stakeholder group is, the more robust the roadmap will be, helping to eliminate gaps in the plan.²⁷⁹

Table 6-1. Key Stakeholder Organisations

Topic	Organisations
Market	<ul style="list-style-type: none"> • Transmission organisations/system operators • Energy regulators
Technology	<ul style="list-style-type: none"> • Controls and connected device manufacturers • Smart grid/smart meter developers • DER (batteries, rooftop solar PV, etc.) developers • DERMS, DR, and controls software developers • Industry associations
Programme Administration	<ul style="list-style-type: none"> • Utilities/energy companies • Demand aggregators
Policy	<ul style="list-style-type: none"> • Energy governmental organisations (national/regional) • Technology standards bodies (communication, cybersecurity, etc.)
Research	<ul style="list-style-type: none"> • Energy laboratories and academia • DR related NGOs and advocacy groups • Energy consultants

Key points to consider when developing and convening stakeholder working groups are:

1. What level of involvement should each stakeholder have? Are they serving an advisory role, or will they be responsible for initiatives and action items? What level of commitment should they provide?
2. What is the ideal number of stakeholders involved for each key step: visioning, roadmap development, monitoring, and revising? Increasing the number of stakeholders involved can substantially increase the development time and detail of the roadmap. Vision workshops typically consist of 10 to 40 people while expert workshop groups could be as many as 200 people.²⁸⁰

²⁷⁸ *Ibid.*

²⁷⁹ *Ibid.*

²⁸⁰ IEA. ‘Energy Technology Roadmaps: A Guide to Development and Implementation.’ 2014.

3. How will the roadmap be communicated and disseminated to all necessary stakeholders and partners? How will stakeholders be held responsible for initiatives and action items?

A common stakeholder strategy is to establish groups with varying degrees of involvement and responsibility. IEA suggests creating: a small steering group with main authority on goals, scope and boundaries; a core team undertaking the majority of the work on the roadmap; an expert group of representatives who can attend workshops, provide input, and review the roadmap; and a group of interested stakeholders who are informed during the process but not actively involved.²⁸¹ This stakeholder strategy is shown below in Figure 6-2.

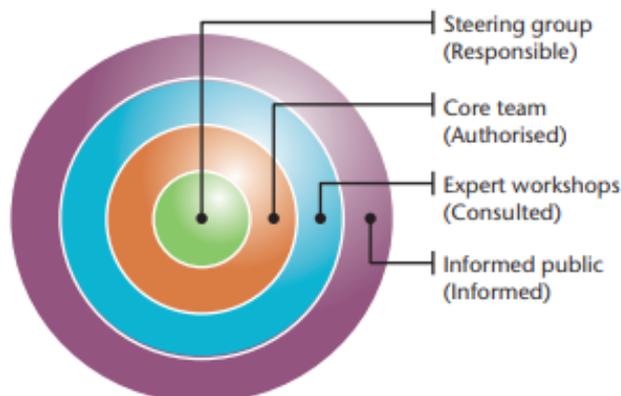


Figure 6-2. Stakeholder Involvement Strategy

Source: IEA (2014)²⁸²

Once stakeholder working groups are developed, periodic workshop meetings are used throughout the roadmapping process to develop the demand flexibility vision, identify challenges and barriers, establish goals and metrics, and identify and execute initiatives and action items.

6.2.2 Phase 2: Visioning

6.2.2.1 Establish Long-Term Demand Flexibility Vision

The vision of the roadmap is the long-term ideal future scenario that is intended to be the ultimate outcome of the roadmap. The process of developing a vision (with the input of the stakeholder working group) will involve an in-depth modelling and analysis of future scenarios. The vision process should utilise the characterisation and baseline data collection completed in phase 1 as the starting point. Then, modelling and scenario analysis can be used to project potential future changes in energy demand and population growth, generation resource mixes, grid conditions and constraints, projected technology adoption (smart metering and flexibility technologies), and any planned policies and/or programmes. It should also consider constraints and uncertainties including funding, resources, and regulatory limitations. Researchers and governmental leaders are key to the vision development and modelling process.

The vision should be focused on widespread adoption of demand flexibility in the residential sector and should not differ substantially between countries/regions in Group 1, 2, or 3. For

²⁸¹ *Ibid.*

²⁸² IEA. 'Energy Technology Roadmaps: A Guide to Development and Implementation.' 2014.

most countries, the vision will be built on a two-way power system run primarily on renewable energy sources (both utility scale and distributed). The execution of this vision will vary by region and factors such as the types of renewable energy sources available (solar, wind, hydro, etc.), availability of storage technologies, grid constraints, and energy demand patterns in the region. Realizing this vision cost-effectively will require the use of demand flexibility in most cases.

In an ideal future scenario, VRE will be widespread and demand flexibility will be standard in buildings. Government organisations and regulators will implement top-down policies requiring renewable energy generation and demand management. Utilities, energy companies, regulators, and programme administrators will collaborate to offer cost-effective ADR and DER aggregation programmes to customers. Open electricity markets will allow demand aggregators to provide a variety of grid services to support grid reliability and VRE integration. Residential customers will be incentivised to install a variety of grid-interactive technologies, controls, and DERs including smart thermostats, home energy management systems, smart water heaters, battery storage, distributed solar PV, and/or EV chargers.

The key elements needed for this demand flexibility vision include:

- 1. Open Electricity Markets.** DER aggregation programmes are dependent on the existence of electricity markets for revenue. Ideally, a variety of electricity markets should be open to demand response participation and independent aggregators, including: balancing markets, ancillary services, wholesale markets, capacity markets, and/or congestion management. In addition to open markets, key barriers to entry for demand aggregators should be removed such as minimum capacity requirements and bilateral contracts.
- 2. Smart Metering Infrastructure.** Smart metering infrastructure should be widespread (80-100% penetration). Smart meters can enable demand flexibility by facilitating grid-to-device communication in homes and capturing granular data on energy loads to provide measurement and verification services.
- 3. Balancing and Ancillary Grid Services.** With increased penetration of VRE comes the need for new grid services aimed at providing real-time balancing and reliability services to the grid such as frequency regulation, voltage support, load following reserves, and replacement reserves. These markets should be open and favourable to demand response and independent aggregators including product requirements and financial incentives.
- 4. ADR and DER Aggregation Programmes.** Utilities and programme administrators must work to establish and scale ADR and DER aggregation programmes. These programmes should be designed to provide substantial financial incentives to participants while minimizing/eliminating the impacts to customer comfort and convenience.
- 5. Widespread Smart Home Technologies.** Smart home technologies and DERs should become the norm in homes. Decreasing initial costs and/or providing financial incentives for grid-interactive smart home technologies is the first step in increasing adoption. In addition, cybersecurity and communication standards should be established and widely adopted.
- 6. Distributed Energy Resource Management System Platforms.** DERMS platforms are needed to enable utilities to communicate with aggregated DERs and control them or request the service from an independent aggregator. In the future, a standardised

DERMs platform will help enable and ease the implementation of large-scale DER aggregation programmes.

There is no one-size-fits-all vision for demand flexibility. Each of these elements listed above will vary in terms of relative value and necessity to each country/region. This vision represents an ideal and comprehensive scenario which is currently not a reality in any country or region. There are a variety of solutions that can be implemented to achieve the end goal of cost-effective high renewable energy penetration. When developing a tailored demand flexibility vision for a country/region, these elements should serve as a starting point.

6.2.3 Phase 3: Roadmap Development

6.2.3.1 Identify Challenges, Barriers, and Infrastructure Needs

After developing the vision, the roadmap development process begins with identifying the key challenges, barriers, and infrastructure needs that are hindering the development of demand flexibility. The diverse stakeholder group will be instrumental in identifying comprehensive challenges related to the flexibility market and programme implementation, technology adoption and integration, and policy and regulatory development. The challenges identified in Chapter 5, shown in Table 6-2 below, should serve as a starting point.

Table 6-2. Summary of Key Challenges

Topic	Challenges
Market	<ul style="list-style-type: none"> • Markets and services not open to demand response and aggregators • Barriers and lack of incentives for demand flexibility participation
Programme Implementation	<ul style="list-style-type: none"> • Low customer awareness and participation in flexibility programmes • Acquiring new customers and retaining existing customers
Technology	<ul style="list-style-type: none"> • Integrating and aggregating DERs through DERMS • Ensuring connected devices are interoperable and cybersecure • Increased complexity and difficulties in installation, configuration, operation, and maintenance • High capital costs of flexibility technologies and DERs
Policy	<ul style="list-style-type: none"> • Slow process for implementing regulations • Developing and adopting common standards and frameworks (<i>i.e.</i>, communication protocols, roles for demand aggregators)

In addition, region-specific challenges must also be identified. Questions to help identify these for countries/regions in Group 1, Group 2, and Group 3 are presented below.

Group 1. *Why has demand response been slow to develop? Why is the current form of non-ADR in use? Are the current uses of demand response providing meaningful value? What is the potential for demand response to provide additional services?*

Challenges for Group 1 are focused on establishing the markets, policies, and technology infrastructure necessary for demand flexibility. Key stakeholders for identifying challenges include policymakers, transition organisations/system operators, energy regulators, and

researchers. A common challenge in Group 1 countries/regions is the perceived lack of value of demand response. Implementing demand response/flexibility in new areas may require analysis to prove that the initial technology investments (controls, software, etc.) will provide meaningful value to the power system. Modelling and data analysis studies and smaller ADR pilots could potentially demonstrate the potential of demand flexibility to regulators to jumpstart ADR development and market reform.

Group 2. *Why are only certain markets open to demand response/aggregators? If markets are open, why is capacity limited? Do product requirements need to be changed? Are additional financial incentives needed? What is the current adoption of demand flexibility technologies and smart metering infrastructure?*

The key challenges for Group 2 are focused on removing market and regulatory barriers to enable the development of demand flexibility pilot programmes and expanding adoption of demand flexibility technologies. Key stakeholders for Group 2 include policymakers, regulators, utilities, and demand aggregators. Addressing these challenges will likely require top-down policy mandates and regulations.

Group 3. *What has worked in the pilot programmes so far and what challenges did they face? Are there additional technology and infrastructure needs (software, smart meters, etc.)? What processes in implementing the pilot programmes were the most time-consuming, expensive, and resource intensive? Were programme participants satisfied, and did they remain in the programmes? Was the flexibility programme successful in providing the requested grid services?*

Challenges for Group 3 are focused on programme implementation and scaling. Utilities, demand aggregators, and partner technology developers with experience in ADR and DER aggregation programmes are key stakeholders. These pilot ADR and DER aggregation programmes help to identify region-specific implementation challenges. Challenges identified here must be resolved before pilots can be scaled into larger flexibility programmes. Participant surveys may be needed to identify programme implementation barriers. Common challenges identified in existing flexibility pilots include: software compatibility with DERMS, customer acquisition and retention, communication gaps with DERs, variance in the performance of DERs to provide services, and delays in the deployment of DERs.²⁸³

6.2.3.2 Establish Goals and Metrics

Next, the goals and metrics should be established to address the key challenges and barriers identified in the previous step. While the long-term vision has already been established, incremental short-term and mid-term goals are also needed. Similar to identifying the challenges and barriers, establishing goals should rely on stakeholder input and consensus through workshops.

Figure 6-3 provides guidance for establishing goals for countries and regions in Groups 1, 2, and 3 for the near-term (about 1-2 years) and mid-term (about 3-5 years). As shown in this diagram, all roadmaps will ultimately achieve the long-term vision of widespread demand flexibility through this process. As progress is made, the goals for Group 1 flow into Group 2, and then the goals for Group 2 flow into Group 3. The goals for Group 1 should focus on establishing potential for demand flexibility through proving the value of demand response, opening markets, developing technology infrastructure, and developing ADR pilot programmes. The goals for Group 2 should focus on removing regulatory and market

²⁸³ Cook et. al, 'Expanding PV Value: Lessons Learned from Utility-led DER Aggregation in the US.'

barriers and establishing DER aggregation capabilities through market and technology development. The goals for Group 3 should focus on expanding and improving existing demand flexibility pilot programmes and developing pilots in new regions.

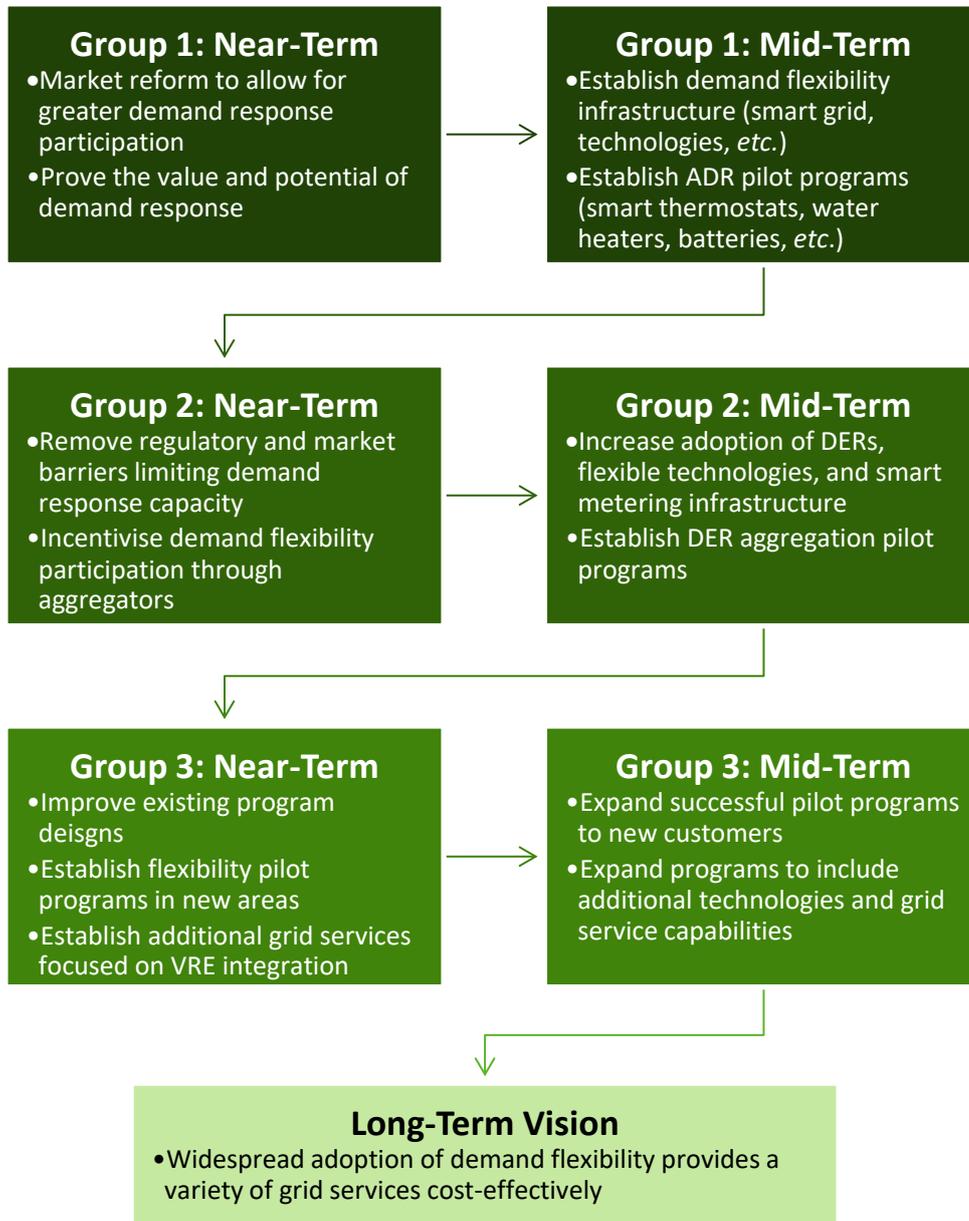


Figure 6-3. Demand Flexibility Goal Development Guidance

Goals are defined as: ‘a clear and concise set of targets that, if achieved, will result in the desired outcome.’²⁸⁴ Goals providing the most guidance and value should be specific, measurable, attainable, relevant, and time-based. Measurable goals require the establishment of metrics as well as methods for data collection. Potential metrics for measuring progress toward demand flexibility include: number/percentage of enrolled participants in flexibility programmes, penetration of DERs and smart meters, total demand flexibility capacity participating in markets, and number or percentage of utilities offering ADR and DER aggregation programmes. A complete goal would include a timeframe,

²⁸⁴ IEA. ‘Energy Technology Roadmaps: A Guide to Development and Implementation.’ 2014.

metric, and specifics such as, ‘by 2025, 30% of all residential utility customers are enrolled in an ADR and/or DER aggregation programme’ or ‘by 2030, increase demand flexibility participating capacity 50% relative to 2020 levels.’ Developing these short-term and mid-term goals may require additional modelling and data analysis, similar to the development of the long-term vision.

6.2.3.3 Identify Initiatives and Action Items

Initiatives and action items must be developed to correspond to each established short-term and mid-term goal. Responsible stakeholders must then be assigned to each initiative and action item. Then, these initiatives need to be prioritised according to the established timeframes for each goal. Further, many initiatives may be dependent on the completion of another to proceed. The roadmap should include a summary of each initiative, stakeholders involved and responsible, and a timeline for completion. Creating and executing initiatives generally requires collaboration amongst multiple stakeholder groups to define the objective, complete activities, collect data, and report on findings.

Chapter 5 includes potential recommendations for addressing general challenges which can serve as a starting point for developing initiatives and action items. These market, programme implementation, technology, and policy recommendations along with potential stakeholder organisations are summarised in Table 6-3.

Table 6-3. Initiative and Action Items Recommendations

Topic	Recommendations	Key Stakeholders
Market	<ul style="list-style-type: none"> • Pass regulations to open new electricity markets to DR and aggregators • Develop balancing and ancillary services for renewable integration • Remove unnecessary requirements limiting demand flexibility participation 	<ul style="list-style-type: none"> • Regulators, system operators, transmission organisations, and demand aggregators
Programme Implementation	<ul style="list-style-type: none"> • Evaluate and test different incentive/rebate structures to ensure customers see the value and benefits of programme participation • Evaluate pilot programmes and customer satisfaction during programmes to improve future programme designs • Invest in marketing and customer support mechanisms for demand flexibility programmes • Focus programmes on technologies with low occupant impact (batteries, water heaters, <i>etc.</i>) 	<ul style="list-style-type: none"> • Utilities, energy companies, and partner organisations
Technology	<ul style="list-style-type: none"> • Develop DERMS to cost-effectively integrate DERs with different communication protocols • Implement common communication protocols and standards to increase reliability of communication between DERs • Provide consumers and installers with tools, documentation, and customer service support to help ease technology installation, configuration, operation, and maintenance • Provide rebates in programmes to reduce capital costs of DER equipment to customers • Invest in manufacturing R&D to reduce technology equipment costs (controls, software, DERs, <i>etc.</i>) 	<ul style="list-style-type: none"> • DERMS software developers • Controls and connected device manufacturers and DER developers • Technology standards bodies • Technology laboratories and researchers

Policy	<ul style="list-style-type: none"> • Increase collaboration between regulators and utilities to expedite the programme development process • Include demand flexibility mandates in resource planning • Adopt standards for common communication around DERs and DERMS platform • Create a standardised framework for roles and responsibilities of demand aggregators 	<ul style="list-style-type: none"> • Regulators, policy-makers, governmental organisations, and standards bodies
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6.2.4 Phase 4: Monitoring and Revision

6.2.4.1 Measure Progress Towards Goals

As mentioned previously, the roadmapping process is not over when the initial roadmap is complete. It is a living and evolving process that should continue past the publication until the long-term vision is achieved. First, it is important to measure and track the progress made toward the goals periodically. Depending on the type of goal and metric, this could involve additional data collection and analysis to determine trends. For example, to track the goal ‘by 2030, increase demand flexibility participating capacity 50% relative to 2020 levels’ will require baseline 2020 data and annual data collection to determine if the goal is on track. The key stakeholders assigned to each initiative should be responsible for collecting and reporting data on a regular basis.

6.2.4.2 Reassess and Revise Roadmap

Based on the progress made toward the goals, reassessing and revising roadmap goals will likely be necessary. Roadmap adjustment workshops can be used to gain stakeholder input and consensus for the changes being made.²⁸⁵ These meetings should determine if changes should be made to priorities, timeline, and/or goals based on what initiatives have been successful/unsuccessful thus far. Meetings such as these ensure stakeholders are engaged and held accountable for their commitments.

Countries and regions in Group 1 and Group 2 will need to go through periodic roadmap revisions to reach widespread adoption of demand flexibility. For example, once Group 1 has established the necessary technology infrastructure, opened markets, and developed demand response programmes, they should create goals focused on increasing adoption of DERs and establishing DER aggregation pilot programmes. Similarly, once Group 2 countries have established DER aggregation pilot and evaluations, they should develop goals focused on scaling these programmes to new customers and more regions.

²⁸⁵ IEA. ‘Energy Technology Roadmaps: A Guide to Development and Implementation.’ 2014.