Electronic Devices & Networks Annex
EDNA

Policy Guidance for Smart, Energy-Saving Consumer Devices

MAY 2020

Technology Collaboration Programme
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Energy Efficient End-use Equipment
International Energy Agency

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.

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Electronic Devices & Networks Annex
EDNA

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**

Guidehouse

Policy Guidance for Smart, Energy-Saving Consumer Devices

Prepared for:

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

4E Electronic Devices & Networks Annex EDNA

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Table of Contents

List of Figures

List of Tables

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Acronyms and Abbreviations

AC	Air Conditioner
ACEEE	American Council for an Energy Efficient Economy
ADR	Automated Demand Response
AHAM	Association of Home Appliance Manufacturers
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AMCA	Air Movement and Control Association
ASHRAE	American Society of Heating and Air-Conditioning Engineers
BACS	Building Automation and Control Systems
BYOD	Bring Your Own Device
CEC	California Energy Commission
CFA	Consumer Federation of America
COAG	Council of Australian Governments
CoC	Code of Conduct
CTA	Consumer Technology Association
DER	Distributed Energy Resource
DIGIT	Developing Innovation and Growing the Internet of Things
DOE	Department of Energy
DR	Demand Response
EDNA	Electronic Devices and Networks Annex
ED	Ecodesign Directive
EED	Energy Efficiency Directive
ELR	Energy Labelling Regulation
EPA	Environmental Protection Agency
EPBD	Energy Performance in Buildings Directive
EPRI	Electric Power Research Institute

EU	European Union
EV	Electric Vehicles
GW	Gigawatt
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
ISO	International Standards Organization
ITU	International Telecommunication Union
LAN	Local Area Network
LED	Light-emitting Diodes
LPWAN	Low Power Wide Area Network
MEPS	Minimum Energy Performance Standards
NEMA	National Electrical Manufacturers Association
NGO	Non-governmental Organisation
NIST	National Institute of Standards and Technology
NRDC	Natural Resources Defense Council
OpenADR	Open Automated Demand Response
PAN	Personal Area Network
PC	Personal Computer
PV	Photovoltaic
RAC	Room Air Conditioner
SGIP	Smart Grid Interoperability Panel
SHEMS	ENERGY STAR Smart Home Energy Management System

SRI	Smart Readiness Indicator
TCP	Technology Collaboration Programme
TV	Television
TWh	Terawatt-hour
UK	United Kingdom
US	United States
USB	Universal Serial Bus
WAN	Wide Area Network
WUR	Wake-Up Radio

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.

Connected device	A device with network capability.
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 jeopardised
Demand response	A change in electric power demand in response to grid systems needs and/or market conditions.
Intelligent Efficiency	Operation of the device such that it responds to the changing conditions of the external environment, in order to maximise energy savings.
Interoperability	The ability of different types of devices, and/or devices from different manufacturers, to communicate and function with each other.
Load Shedding	Reducing electricity demand for a short time period in response to a peak or emergency event.[1]
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 variable renewable energy generation periods.[1]
Local Area Network (LAN)	A local area network (LAN) is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building.
Mesh network	A network made up of devices, or nodes, that communicate with each other to act as a single network, as opposed to connecting to a central network source.
Peak Demand	The highest electric power demand over a specified time period (typically daily).
Personal Area Network (PAN)	A personal area network (PAN) is a computer network for interconnecting devices centred on an individual person's workspace.
Plug-and-play	The ability for a device to function as intended when first used or connected, and without additional user configuration.
Semantic interoperability	The interoperability of commands on a central platform which communicates between different types of devices.

[1] 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

Status reporting	Provision to the consumer, in a timely and useful and manner, of sophisticated operational information related to the device.
Two-way communication	Usually refers to bilateral communication between a utility, or energy service provider, and a device, or consumer.
Wide area network (WAN)	A telecommunications network that extends over a large geographical area.

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, 'Policy Guidance for Smart, Energy-Saving Consumer Devices', is the first in a series of three reports written by Guidehouse for EDNA. This report provides considerations for policy makers to encourage 'smart' consumer devices which save energy and provide demand flexibility. It includes key findings for the prioritisation of consumer devices and policy recommendations. The report 'Roadmap for Consumer Devices to Participate in Demand Flexibility'[2], provides a roadmap that lays out specific steps needed to achieve widespread demand flexibility of consumer devices in the residential sector. Lastly, the report 'Energy Applications within IoT and Digitalisation Strategies',[3] provides guidance for developing IoT and digitalisation strategies for purpose of enhancing energy efficiency.

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 policies to encourage smart, energy-saving consumer devices which can also provide demand flexibility. The policy recommendations will target specific devices that would benefit most from incorporation of 'smartness' to achieve energy savings, effectively participate in demand flexibility activities, and increase consumer awareness of energy consumption. This report is presented in nine chapters:

- **Chapter 1 (Introduction)** provides background information on the scope of the report, the objective, and a general overview of the approach taken to write the report.

- **Chapter 2 (Smart, Energy-Saving Consumer Devices)** presents an analysis of existing definitions for smart and a proposed definition to use for the scope of the report and policy recommendations. This chapter also includes a market and technology assessment of smart devices.

- **Chapter 3 (Challenges and Recommendations for the Adoption of Smart, Energy-Saving Devices)** summarises overall market, technology, and economic challenges related to the adoption of smart devices.

- **Chapter 4 (Prioritisation of Devices to Target)** provides a list of devices to target with policy recommendations based on certain criteria.

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[2] 4E Electronic Devices & Networks Annex, EDNA, Publications, 'Roadmap for Consumer Devices to Participate in Demand Flexibility', https://edna.iea-4e.org/library

[3] 4E Electronic Devices & Networks Annex, EDNA, Publications, 'Energy Applications within IoT and Digitalisation Strategies', https://edna.iea-4e.org/library

- **Chapter 5 (Communications Protocols)** provides a summary of the types of communications used among smart devices and smart home energy management systems (SHEMS). This chapter also discusses the state of technology of communication protocols and presents challenges associated with the technology.

- **Chapter 6 (Smart Devices Network Standby Energy Use)** includes a brief discussion on the potential negative impacts smartness can have on standby energy use and presents certain solutions to minimise standby energy use.

- **Chapter 7 (Residential Demand Flexibility Programs)** draws largely from Report 2 to discuss the type of residential demand flexibility programs and how smart devices can participate in these programs.

- **Chapter 8 (Existing Policies and Programs to Encourage the Use of Smart, Energy-Saving Devices)** examines existing policies and voluntary programs related to smart devices.

- **Chapter 9 (Considerations for Policy Makers)** presents potential technical considerations to craft policy options and discusses various available policy types to encourage the use of smart devices.

1. Introduction

1.1 Smart, Energy-Saving Consumer Devices

The consumer appliances market is undergoing a major evolution with the advent of smart home products. Intelligent and connected technologies are rapidly entering the marketplace to improve the lives of homeowners and occupants. Products such as smart thermostats and connected lighting are becoming prominent, and major household appliances, such as refrigerators, water heaters, clothes washers, and dishwashers now include a growing number of connected models as well. A smart home could revolutionise the way we live and interact in our ecosystems. While demand flexibility and intelligent efficiency initiatives may not be prevalent today, they are likely to be in the future. Moreover, some devices on the market, particularly large appliances, water heaters, or HVAC equipment, have life cycles of up to 20 years.[4] Thus it is imperative for devices, especially those with long life cycles, to adopt smart, energy-saving features and for these types of devices to be widely available on the market such that consumers can start purchasing and implementing these devices in their homes earlier, rather than waiting for up to 20 years to purchase an appliance with smart, energy-saving functionalities.

Connecting household devices to the internet has major implications for energy use. First, there is an energy cost associated with connecting devices to the network. This is a challenge that needs to be managed and it must be ensured that network connectivity power consumption does not become excessive as more devices are designed with network functionality. Second, connected devices have the ability to participate in demand flexibility, which is the ability of a device to respond to the variable electricity generation patterns of renewable energy sources and adjust its own energy use accordingly. Demand flexibility allows devices to shed, shift, or modulate electricity loads in response to grid needs and/or market conditions and provides benefits beyond energy savings. Lastly, connected devices can participate in intelligent efficiency, which is the ability of a device to learn systems and user preferences and take actions independently to save energy.

However, several barriers must be addressed, particularly regarding the creation of a standardised approach to operating such devices and how they interact. Many definitions, standards, and protocols exist for smart consumer devices and privacy, security, and interoperability issues may inhibit market acceptance. Inappropriate use of these devices may also counter the ultimate goal of energy savings if smart devices use more energy to be ‘smart’ than the energy saved from intelligent efficiency and demand flexibility. Given the early stages of the smart consumer devices market, governments and international organisations are well-positioned to develop policies to help shape and incentivise this market, particularly focusing on energy savings and the issues of harmonisation, interoperability, security, and adoption of smart consumer devices.

This report’s objective is to examine existing government policies regarding smart consumer devices and provide recommendations for appropriate policies that can be implemented by policy makers and government agencies to encourage the development and adoption of such devices.

[4] ATD Home Inspection, ‘Average Life Span of Homes, Appliances, and Mechanicals’, https://www.atdhomeinspection.com/advice/average-product-life/

1.2 Report Scope and Approach

This report characterises smart devices, discusses the challenges with adoption of these devices and potential recommendations for overcoming these barriers, identifies existing government programs and policies that encourage their adoption, and provides considerations for EDNA members (or any other country/region, globally) to facilitate such adoption and use of smart consumer devices and automated home energy management systems.

First, this report defines the devices that are, or could be developed as, smart and that could be the subject of regulatory policy. It then provides the barriers that hinder adoption of smart, energy-saving devices and recommends solutions to mitigate these challenges.

The criteria for prioritizing consumer devices are discussed along with a list of devices to prioritise for potential energy savings. Finally, this report assesses existing government policies for smart, energy-saving consumer devices and provides an implementation plan that outlines the steps to ensure the selected smart consumer devices can achieve energy savings.

In addition to a robust review of existing policies and development of policy guidance to encourage the adoption of smart, energy-saving devices, this report examines other aspects related to these devices such as their existing participation in demand flexibility programs, their network standby energy use, and their communication architecture. These aspects are examined in the context of achieving the following goals: increased energy efficiency, open communication protocols, interoperability, and low network standby energy use.

2. Smart, Energy-Saving Consumer Devices

Connected devices are a relatively nascent area of technology. With recent technological advances in telecommunications hardware, manufacturers are implementing communication capabilities into various types of devices, thereby making them 'connected'. In the past few years, the consumer devices market has witnessed the emergence of products such as connected home appliances (heating, ventilation, and air conditioning equipment (HVAC), water heaters, refrigerators, *etc*.), smart thermostats, connected lighting, energy management systems, and electronics with network and/or communication capabilities. Even though all connected devices have the ability to connect to a network, the functionality a network connection provides can vary between types of devices. For example, some connected devices can remotely provide operational and energy consumption information to consumers, participate in demand flexibility, enable remote management, intelligently predict a user's behaviour, or automatically perform actions, among a wider variety of features. Such devices are referred to as 'smart, energy-saving devices' (or simply, 'smart devices') in this report because they can use network connectivity functionality to reduce and/or monitor energy consumption. Because these devices are relatively new to the market and are gradually being adopted by consumers, it is important to clearly define a 'smart, energy-saving device' for the purpose of this report and its policy guidance presented in Chapter 9. This report focuses on connected devices that provide increased functionality related to (intelligent) energy efficiency and energy management, *i.e.,* smart, energy-saving devices. As such, connected devices that do not offer increased energy efficiency or improved energy management are not considered in this report.

2.1 Existing Definitions of Smart, Energy-Saving Devices

To define the focus of this report, it is necessary to establish a definition of smart, energy-saving devices, which would also serve to outline the capabilities of such a device. The following subsections analyse existing definitions of smart devices used in government energy programs, policies, or strategies. Each subsection provides the definition and analyses its pros and cons as related to promoting (intelligent) energy efficiency or improved energy management.

In general, the analysis focuses on how each definition addresses key performance characteristics of interest such as (intelligent) energy efficiency, status reporting, or improved energy management. Additionally, the analysis also examines how each definition promotes interoperability (*e.g.,* through open communication protocols, or standards), and the ease of implementation of the definition in the context of device adoption (*i.e.*, whether it presents too much burden on manufacturers, or its scope is too narrowly defined).

2.1.1 Joint Stakeholder Petition to ENERGY STAR

In January of 2011, industry stakeholders filed a petition to the United States (US) Environmental Protection Agency's (EPA's) ENERGY STAR® Program, recommending standards, test procedures, and incentives for smart appliances.[5] The joint stakeholders include the Association of Home Appliance Manufacturers (AHAM), American Council for an Energy Efficient Economy (ACEEE), Natural Resources Defense Council (NRDC),

[5] Petition to ENERGY STAR from Joint Stakeholders (2011) https://www.energystar.gov/sites/default/files/specs/private/Petition_to_ENERGY_STAR_from_Joint_Stakeholders.pdf

Consumer Federation of America (CFA), and many others. In the petition, stakeholders defined a smart appliance as follows:

'The term 'smart appliance' means a product that uses electricity for its main power source which has the capability to receive, interpret and act on a signal received from a utility, third party energy service provider or home energy management device, and automatically adjust its operation depending on both the signal's contents and settings from the consumer. The product will be sold with this capability, which can be built-in or added through an external device that easily connects to the appliance. The costs of such devices shall be included in the product purchase price.[6]

These signals must include (but are not limited to) appliance delay load, time-based pricing and notifications for load-shedding to meet spinning reserve requirements. Any appliance operation settings or modes shall be easy for an average, non-technical consumer to activate or implement. Additionally, a smart appliance or added device may or may not have the capability to provide alerts and information to consumers via either visual or audible means. The appliance may not be shipped with pre-set time duration limits that are less than those listed in the petition for each appliance, but may allow consumer-set time duration limits on smart operating modes, and will also allow consumers to override any specific mode (*e.g.,* override a delay to allow immediate operation, limit delays to no more than a certain number of hours, or maintain a set room temperature).'

Furthermore, as per the petitioners, a smart appliance must have the following attributes:

'The term "delay load capability" refers to the capability of an appliance to respond to a signal that demands a response intended to meet peak load deferral requirements, but which also could be used to respond to a sudden maintenance issue at another time of day.

The term "spinning reserve capability" means the capability of an appliance to respond to a signal that demands a response intended to temporarily reduce load by a short-term, specified amount, usually 10 minutes.'

Additionally, the petitioners defined product-specific criteria for various appliances such as refrigerators/freezers, washers, dryers, room air conditioners (RACs) – also known as window ACs, and dishwashers.

Advantages

The following are advantages of this definition:

- Specifies that the product must be sold with demand flexibility capability
- Specifies that the capability can be either external or internally built into the appliance
- Includes specific demand response capabilities that a product must have, such as delay load capability and spinning reserve capability, yet provides manufacturers flexibility in implementation

[6] If additional requirements are needed to activate the product's 'smart' capabilities as purchased, then prominent labels and instructions must be displayed at the point of purchase and in product literature on what specifically consumers or utilities need to do to achieve these capabilities (*e.g.,* 'This product requires snapping in the compatible network module and utility installation of a smart meter or other device for use of capabilities that earned the ENERGY STAR label').

Disadvantages

The following items are disadvantages of this definition:

- Does not include any mention as to what type of communications protocols it should use
- May be too narrow in scope and thus limits other potential smart capabilities
- Includes status reporting as an optional requirement: 'a smart appliance or added device may or may not have the capability to provide alerts and information to consumers via either visual or audible means.'

While ENERGY STAR did not formally adopt this definition, it utilised various aspects in their product-specific specifications for smart devices. Section 2.1.2 discusses ENERGY STAR's approach for characterizing smart appliances, referred to as 'Connected Functionality'.

2.1.2 ENERGY STAR

The ENERGY STAR program is a voluntary program that promotes energy efficiency using standardised test methods and qualification criteria that identify consumer devices with superior energy efficiency.[7] Products that meet the criteria set by EPA, as certified to the program by the manufacturer, earn an ENERGY STAR label that the manufacturer can display on the consumer product itself as well as in marketing materials. Due to the increasing prevalence of smart devices on the market, ENERGY STAR has also developed test methods to promote 'connected' functionality for various types of devices. Connected functionality is described generally as follows:

'ENERGY STAR certified products with connected functionality are designed to encourage interoperability and offer the following features: low energy use, energy use reporting, and consumer ownership of all data. Some products, such as appliances and smart thermostats also offer the features listed below.

- Alerts for energy wasting conditions, for instance a refrigerator door left open.
- Ability to communicate with [a] local utility through a demand response program (with [the consumer's] permission) enabling [the user] to support a smarter, cleaner electricity system.
- Ability to allow utility control (with [the consumer's] permission) of certain functions (*e.g.,* shifting refrigerator defrost time to the middle of the night when energy demand is low).
- Ultimate control over the product by the consumer, including ability to override utility requests.'[8]

Each product type that is certified as having connected functionality must meet certain criteria as specified in its respective specification. These criteria include requirements for hardware capabilities, communication protocols, energy consumption and operational status

[7] ENERGY STAR, 'Overview', https://www.energystar.gov/about

[8] ENERGY STAR, 'ENERGY STAR + Connected Functionality', https://www.energystar.gov/products/smart_home_tips/about_products_connected_functionality_0

reporting, demand response, and remote management. The specific requirements can vary on a product basis.

Table 2-1 summarises all ENERGY STAR products for which EPA offers connected functionality certification and the respective requirements for each product category. As shown in the first column of Table 2-1, all devices certified with Connected Functionality must ship with the necessary hardware and software.

Table 2-1. Summary of ENERGY STAR Devices with Optional Connected Functionality Requirements

	Comm. Hardware/ Software	Energy Consumption Reporting	Operational Status Reporting	DR	DR Override by Consumer	Remote Management	Open Access	Open Comm. Protocol
Smart Thermostats	✓	✓	✓	✓	✓		✓	✓
Dishwashers	✓	✓	✓	✓	✓	✓	✓	✓
Room ACs	✓	✓	✓	✓	✓	✓	✓	✓
Refrigerators / Freezers	✓	✓	✓	✓	✓	✓	✓	✓
Clothes Washers	✓	✓	✓	✓	✓	✓	✓	✓
Clothes Dryers	✓	✓	✓	✓	✓	✓	✓	✓
Lighting	✓	✓	✓			✓	✓	✓
Pool Pumps	✓	✓	✓	✓	✓	✓	✓	✓
Electric Vehicle Supply Equipment	✓			✓	✓		✓	✓
Ceiling Fans	✓	✓	✓			✓	✓	✓

Advantages

The advantages of ENERGY STAR's approach to defining connected functionality in its test specifications are:

- Test specification for each product is comprehensive and contains specific requirements
- Requires products to use one of the specified communications protocols, such as Smart Grid Interoperability Panel, National Institute of Standards and Technology (NIST) Smart Grid Framework, or from another trusted organisation such as, *e.g.*, the International Electrotechnical Commission (IEC), the International Standards Organization (ISO), the Institute of Electrical and Electronics Engineers (IEEE), the International Telecommunication Union (ITU), or the Internet Engineering Task Force (IETF).
- Requires that the communication hardware be built into the appliance or provided at the time of sale
- Requires products to display some sort of energy consumption reading

Disadvantages

The main disadvantage to this the definition is that the product requirements are not consistent across all products; specifically, some products are not required to participate in demand response activities.

2.1.3 European Union Ecodesign Preparatory Study on Smart Appliances

The European Union (EU) 'Ecodesign Preparatory Study on Smart Appliances' analyses the technical, economic, market, and societal aspects of smart appliances to develop policy approaches to encourage the uptake of smart appliances. [9] In this report, a smart appliance is defined as:

'an appliance that supports Demand Side Flexibility:

- is an appliance that is able to automatically respond to external stimuli[,] *e.g.,* price information, direct control signals, and/or local measurements (mainly voltage and frequency);
- The response is a change of the appliance's electricity consumption pattern. These changes to the consumption pattern [are] the 'flexibility' of the smart appliance;

Whereby:

- The specific technical smart capabilities do not need to be activated when the product is placed on the market; the activation can be done at a later point of time by the consumer or a service provider;
- A distinction might be made later in the process between appliances able to communicate and process external signals and (non-communicating) appliances automatically reacting to local power quality measurements.'

For this study, the term 'appliances' includes devices such as household products (*e.g.,* refrigerators, dishwashers, *etc.*), commercial products, non-residential ACs, and batteries.

Advantages

The advantage of this definition is that it exclusively and intentionally focuses on smart appliances that can participate in demand side flexibility. Moreover, the definition elaborates on what flexibility means, *i.e.*, a change in electricity consumption in response to price information, direct control signals, and/or local measurements automatically. This level of detail would set clear guidelines for manufacturers to ensure that their devices provide some sort of energy management feature.

[9] European Commission, 'Ecodesign Preparatory Study on Smart Appliances', 2017 https://eco-smartappliances.eu/sites/ecosmartappliances/files/downloads/Ecodesign%20Preparatory%20Study%20on%20Smart%20Appliances%20_Tasks%201%20to%206.pdf

Disadvantages

The disadvantages of this definition are as follows:

- Does not specify that it must use open communications protocols.
- Does not specify that the hardware capabilities should be built-in; *i.e.*, gives manufacturers the choice to include it as an external product.
- Does not specify any sort of status reporting features.
- Limits the application of the definition to appliances. Other devices such as battery storage products would not be encompassed in this definition.

2.1.4 United Kingdom Consultation on Proposals Regarding Smart Appliances

The United Kingdom (UK) 'Consultation on Proposals Regarding Smart Appliances' sets out proposals to mandate standards for smart appliances. These standards would impose certain design requirements for smart appliances to encourage demand side response and achieve energy savings. As such, a smart appliance is defined as follows.

' energy-related products can be smart appliances, for the purpose of this policy, when they are:

- Communications-enabled; and
- Able to respond automatically to price and/or other signals by modulating their electricity consumption. These changes to consumption patterns are what we call the "flexibility" of the smart appliance.'[10]

Advantages

Similar to the EU Ecodesign definition of a smart appliance, this report's definition explicitly states that a smart appliance must participate in demand flexibility. Unlike the EU Ecodesign definition, the scope of this definition is not limited to only appliances, rather it is intended for 'energy-related products' which could also encompass battery storage devices, a key component of effective demand flexibility.

Disadvantages

The following are disadvantages of adopting this definition:

- No status reporting requirement.
- Although it requires that the appliance be 'communications-enabled' it makes no indication as to what type of communication it should use.

[10] UK Department for Business, Energy & Industrial Strategy, 'Consultation on Proposals Regarding Smart Appliances', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/690805/Consultation_on_Proposals_regarding_Smart_Appliances-.pdf

- Requires smart devices to participate in demand flexibility. This definition would exclude devices with other types of smart features such as providing energy consumption or operational status information, or remote management, but not demand flexibility.

2.2 Summary of Existing Definitions

Each of the definitions presented in the preceding sections required that a smart appliance must be able to participate in demand flexibility. However, many of these definitions did not include additional requirements such as status reporting, or open communication protocols. The presence of these features can enhance utility for consumers and encourage interoperability among devices and platforms. Table 2-2 summarises the key provisions addressed by each definition.

Table 2-2. Summary of Smart Definitions

	Joint Stakeholder Petition to ENERGY STAR	ENERGY STAR	EU Ecodesign Preparatory Study on Smart Appliances	UK Consultation on Proposals Regarding Smart Appliances
Demand Flexibility / Response	✓	✓	✓	✓
Status reporting		✓		
Open Communications Protocols		✓		

2.3 Proposed Definition for Smart, Energy-Saving Devices

The definition presented in this section defines the general scope of the policy guidance presented in Chapter 9 of this report regarding the capabilities of a smart, energy-saving device. Like the definitions presented in Section 2.1, EDNA's proposed definition of a smart, energy-saving device includes a requirement for network communication. However, in contrast to the previously examined definitions in Section 2.1, EDNA's proposed definition considers devices to be smart if they have demand flexibility capabilities, operational status reporting capabilities, and/or are able to operate more efficiently (aka intelligent efficiency).

As defined by EDNA, a smart, energy-saving device is:

'A smart, energy-saving device is a product that has the capability to receive inputs, including through an external network, process these inputs and independently take action, including providing information, for the purpose of one or more of the following:

- Status reporting
- Demand flexibility

- Efficient operation.

Policy makers may choose to incorporate any or all of these three functions into their policy, and this will depend on policy goals and the scope of the products covered by the policy. For example, water heaters might be required to participate in demand flexibility, while refrigerators or freezers might not. Explanatory notes relating to definition of smart:

1. “Device” means an energy-using product which is sold or provided to the user inclusive of all components required for the capability outlined above (although as noted in #4 below, some processing may be undertaken external to the device).
2. “Capability” means capability which is included in the device (although as noted in #4 below, some processing may be undertaken external to the device).
3. “Inputs” means external inputs, including via an external communications network.
4. “Process” means data processing undertaken by an internal computer processor or microprocessor. However, some processing may be undertaken externally, noting that this may have implications for energy usage.
5. “Independently” means independent from the user.
6. “Take action” means responding based on the results of the processing.
7. “Status reporting” means provision to the consumer, in a timely and useful and manner, of sophisticated operational information related to the device, for example:
    - Alerts for conditions such as faults and excessive energy consumption.
    - Reminders to service or replace filters/refrigerants, *etc*.
    - Measured or estimated power/energy usage (with possible inclusion of energy/demand savings).
8. “Demand flexibility” means 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 jeopardised.
9. “Efficient operation” means operation of the device such that it responds to the changing conditions of the external environment, in order to maximise energy savings. This is also known as “intelligent efficiency”.
10. Note that other non-smart products may fulfil a similar role to smart devices, for example a water heater with a relay and basic communications module (but without processing capabilities).
11. In the future, additional (energy-related) functions may become available and the definition should evolve to suit these.’

This definition addresses three key aspects of smartness: (a) status reporting, which is information about the device’s own performance; (b) demand flexibility, which is the ability of a device to respond to variable electricity generation patterns from renewable energy sources; and (c) efficient operation, which is the ability of the device to optimise systems and learn user preferences to act independently to save energy (also known as intelligent efficiency).

The flexibility of the definition allows for a wide variety of devices to be classified as smart. For example, an intelligent sensor may be able to provide status reporting information but may not be able to participate in demand flexibility, yet it can lead to energy savings by responding to stimuli or lack thereof. The goal of the definition is to provide flexible guidelines to encourage widespread adoption of a variety of smart, energy-saving devices.

2.4 Devices Available on the Market

The term 'smart' when used in reference with a consumer device usually refers to a 'connected' device or one that is communication-enabled. Recently, the market has seen an advent of all types of smart devices that are communication-enabled, giving consumers an unprecedented level of control in their homes. Figure 2-1 illustrates various types of smart devices that could be installed in a home.

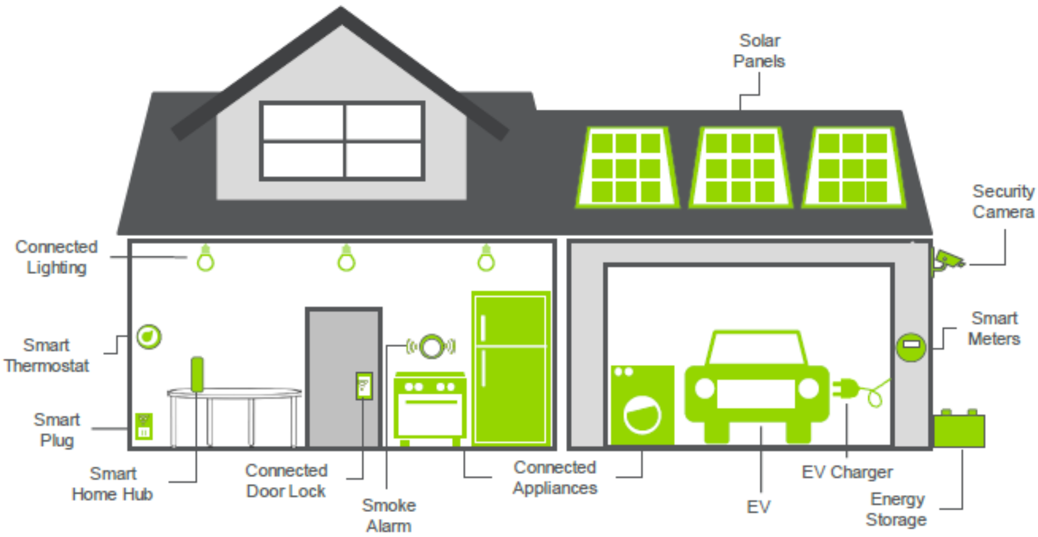

Figure 2-1. Connected Devices in the Smart Home

Source: Navigant Research

Table 2-3 lists various types of residential devices with smart, or connected, functionality. While there are many types of devices that are branded as 'smart', only some of these smart-branded devices in the market provide functionality as related to the features included in the smart, energy-saving device definition presented in Section 2.3. This report will not focus on other types of smart, or connected, devices which are not encapsulated in EDNA's definition of a smart device as defined in Section 2.3 of this report.

Table 2-3. Types of Smart/Connected Devices

Product Group	Devices
Smart Thermostats	Smart Thermostats
Connected Lighting	Lightbulbs, lamps/luminaries, controls
Home Security	Video doorbells, wireless cameras, door locks, garage door controls, smoke and carbon monoxide detectors, leak detectors and water sensors, sirens and alarms, motion sensors, home security control panel
Smart Appliances	Clothes washers and dryers, dishwashers, cooktops, ovens, ranges, refrigerators and freezers,
HVAC	Room ACs, and portable ACs
Water Heaters	Tankless and storage heat pump water heaters, tankless and storage gas water heaters
Smart Electronics	Televisions, smart plugs, voice-activated speakers
Other	Connected car, electric vehicle charging equipment, solar panels, battery storage

2.5 Adoption of Existing Devices

Globally, smart electronics make up approximately half of the shipments of smart devices. Connected lighting products make up approximately 20% of shipments, and smart appliances and thermostats each make up 12% of smart device shipments.[11] Figure 2-2 summarises the distribution of global smart device shipments in 2019 across various product groups, as defined in Section 2.4.

[11] Navigant Research: Leuschner, P and Strother, N. 'Market Data: Smart Home Hubs, Navigant Research', 3Q 2019 https://www.navigantresearch.com/reports/market-data-smart-home-hubs

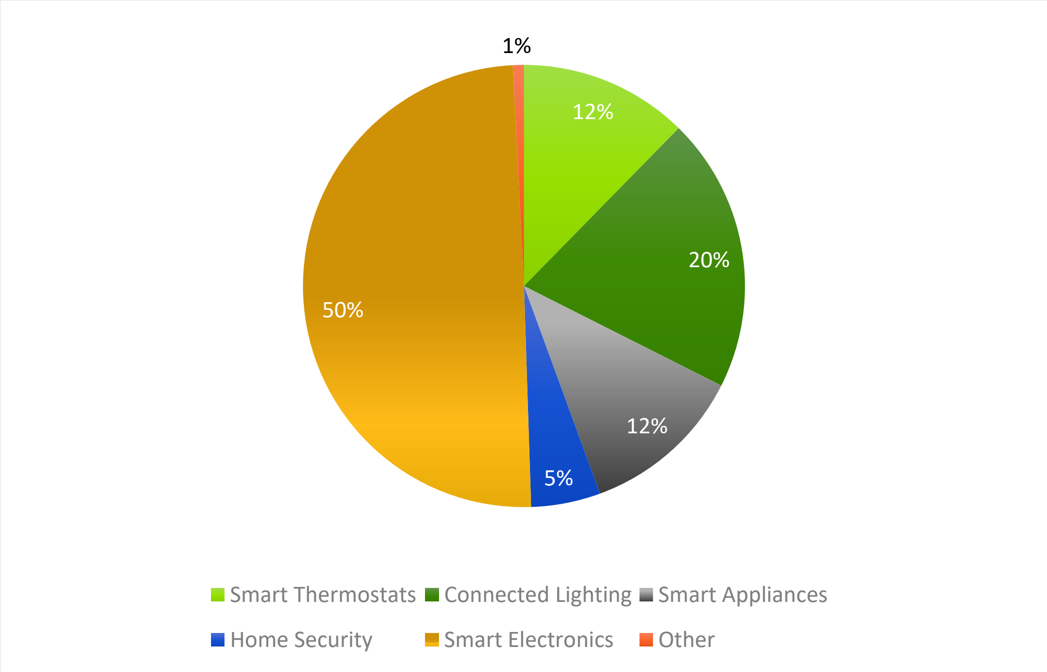

Figure 2-2. Global Smart Device Shipment Distributions in 2019

Source: Navigant Research[12]

In 2019, North America contributed to approximately 64% of smart home device shipments, followed by Europe at 27%, and Asia Pacific at 9%.[12] While the prevalence of smart devices is increasing, not all of these devices are capable of participating in intelligent efficiency or demand flexibility; many smart devices are designed and manufactured to provide consumer comfort and other functions associated with connectivity that don't necessarily improve energy efficiency performance. Smart devices, *i.e.*, devices that can take independent action for (intelligent) energy efficiency purposes, participate in demand flexibility programs, and/or provide operational status information have only penetrated the market to a minor degree. There are limited data available on the installed base, or annual shipments of these types of devices, but this is an area where significant growth is expected in the coming years. Although the market is still in its infancy, it is estimated that global revenue from smart appliances will increase from $4.9 billion in 2017 to more than $68.1 billion in 2027 at a compound annual growth rate of 29.9%.[13] It is expected that at least some of these smart appliances will feature functions related to intelligent efficiency and/or demand flexibility along with providing consumers convenience and access associated with network connectivity.

[12] Navigant Research: Leuschner, P and Strother, N. 'The Smart Home Overview, Smart Home Device Shipments by Region, World Markets: 2019-2028', Section 5.3.1.1, 2Q 2019, https://www.navigantresearch.com/reports/the-smart-home-overview

[13] Navigant Research: Strother, N and Leuschner, P. 'Smart Appliances Expand Smart Home IoT Opportunity for Energy Customers, 2018', 1Q 2018, https://www.navigantresearch.com/reports/smart-appliances-expand-smart-home-iot-opportunity-for-energy-customers

3. Challenges and Recommendations for the Adoption of Smart, Energy-Saving Devices

Even though smart technology is advancing rapidly, smart, energy-saving consumer devices are not yet ubiquitous. While most types of smart-branded devices would be considered connected devices, *i.e.,* devices which utilize network connectivity, not all of these devices inherently reduce overall energy consumption. Therefore, while manufacturers are marketing devices with connected functionality and consumers are cautiously exploring this functionality, it is important to ensure that energy savings are realised alongside consumer convenience and comfort from the same device. It would be counterproductive if the tremendous opportunity for energy savings via network connectivity of smart devices is not realised and instead, overall energy consumption increases due to the additional demands on smart devices for maintaining a network connection (see Chapter 6 for detailed discussion on standby power energy use of connected devices). Hence, it is imperative to encourage adoption of smart devices that reduce energy consumption or encourage energy savings through participation in intelligent efficiency, demand flexibility, and status reporting.

To encourage the adoption of smart, energy-saving devices, manufacturers, policy makers, and standards organisations will need to overcome the challenges and barriers that currently exist. These barriers can be broadly categorised as market challenges, technology challenges, and economic challenges. The following sections discuss the barriers to adoption of smart, energy-saving devices and provide recommendations to overcome these barriers.

3.1 Market Challenges and Recommendations

Market challenges primarily exist in terms of customer acceptance of smart, energy-saving devices and participation in intelligent efficiency and demand flexibility. A summary of some of these challenges and recommendations is provided in the following sections.

3.1.1 Challenges

Like many new technologies introduced to the market, the adoption of connected devices has been slow in the beginning with innovators and early adopters being the primary users of such devices. Consumers have several concerns regarding the availability of network functionality in traditionally non-connected devices (*i.e.,* devices that are operated exclusively by consumers and cannot take actions independently). The primary concern among consumers regards privacy and security issues surrounding network connected devices. Consumers are concerned about devices being hacked when connected to the network, leaving the devices vulnerable and potentially unable to operate as intended. Further, a vulnerable connected device could potentially provide backdoor access or compromise other systems on the same network.

Another major privacy concern with connected devices is that device manufacturers and/or operators could become privy to consumer usage patterns, behaviour, as well as other data, which many consumers consider to be an invasion of their privacy.

Another concern that consumers may have regarding connected devices is the lack of knowledge regarding the presumed benefits that these devices could offer. In particular, intelligent efficiency and demand flexibility are both still in their nascent stages. Therefore, it is difficult to quantify and visualise the potential benefits that could be achieved in these areas via network connectivity and smart capabilities.

Consumer acceptance of connected devices is especially important for devices with a 'pay with your data' type of pricing model. This pricing model allows manufacturers, or other third-party services, to lower the cost of connected devices in exchange for user data which could be used for the improvement of services, or targeted advertisements. Furthermore, these data could be further sold or otherwise disseminated to other third parties that consumers may not be aware of. If users are not comfortable with sharing their personal data, then the cost of connected devices could increase which in turn would hinder the adoption of connected devices.

3.1.2 Recommendations

Policy makers and manufacturers need to address the privacy and security concerns of connected devices. Federal and/or regional governments can tackle this challenge by developing policies that specify certain minimum criteria that connected devices must meet in order to provide consumers' confidence regarding the privacy and security of these devices. These policies must be clearly stated and communicated.

An important aspect of privacy and security is the handling of personal and private consumer data. Policy makers, manufacturers, and other stakeholders (such as network connectivity providers and connected functionality service providers) need to come together to prioritise these concerns and address them satisfactorily. It would be beneficial to provide more control to consumers regarding how their data is stored, accessed, and utilised. An effective way to address this barrier would be to develop and implement privacy and security standards (such as the European Telecommunication Standards Institute cybersecurity standard for consumer IoT devices[14]). These standards and best practices can be established through standards organisations with input from various stakeholders including manufacturers and industry leaders. The standards could be global or regional depending on the issue being addressed. At the same time, many standards have already been developed to address some of these challenges. Policy makers can implement these standards to mitigate some of the concerns associated with privacy and security.

Once relevant stakeholders have developed methods to protect and secure data as well as the devices, the next step is to communicate these effectively to consumers to alleviate their concerns. This step is especially important for devices with a 'pay with your data' pricing scheme, which could require users to share their data with manufacturers and other third parties. While privacy and security policies are often lengthy and legally complex, effort must be made to communicate these to end users in an easy-to-understand manner. Graphic representations and use-case scenarios describing the implications of privacy policies are often effective ways of communicating the policies to consumers. Another approach would be to use a labelling program; devices that meet certain minimum policy requirements surrounding privacy and security, can obtain a label that is universally recognised, similar to an ENERGY STAR label that consumers identify with energy efficiency. Given the rapidly evolving nature of privacy and security, policy makers should also commit to regular, frequent reviews and appropriate revision of standards. This would be one way to instil confidence in consumers about their government's commitment to user privacy and security of personal information.

[14] 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

Marketing, promotion and labelling programs could be effective to address the lack of knowledge about the benefits of smart devices. Such programs have already been implemented in some jurisdictions such as the German Smart Grid Ready Label[15] and Australian Energy Rating Label for residential ACs.[16]

3.2 Technology Challenges and Recommendations

Similar to the challenges faced by consumers in accepting a new technology option, manufacturers also face technological challenges when introducing a new technology or technological concept. The complexity and risks associated with a new technology are the primary technological challenges for introducing smart, energy-saving devices, as discussed in more detail below.

3.2.1 Challenges

Residential consumer products are undergoing disruptive innovation with the addition of network connectivity, wireless control, learning, and data analytics capabilities in smart devices. Connected light bulbs and luminaires, for example, are equipped with the ability to wirelessly connect with an end user's phone and be controlled digitally via a mobile or PC application. This is dramatically different from controlling a light bulb via a switch because such a light bulb is physically connected to the switch via electrical wiring. Connected light bulbs on the other hand, include circuitry to hold the network communication protocol, which is a complex process because manufacturers must determine the optimal design of the device (in this case, a light bulb) such that it continues to provide its primary function while also accommodating additional electronics to enable network connectivity. In designing and manufacturing connected devices, manufacturers are dealing with new and inherently complex products, and they must ensure that the operation and performance of such a device is comparable to the existing non-connected devices for consumer acceptance. While technological innovation is not a challenge specific to wireless connectivity, this challenge poses an obstacle for manufacturers to easily include smart features in their devices. Manufacturers must innovate the designs of their products to include smart features with minimal impact to performance.

Another technological barrier that hinders the adoption of smart, energy-saving devices is the lack of interoperability across platforms. This is applicable to both interoperability amongst different connected devices as well as interoperability between devices in the consumer's home and various demand flexibility management platforms. If consumers have connected devices that are from several different brands and each brand has its own communication platform, it becomes increasingly difficult and cumbersome for consumers to learn and maintain communication across different platforms. It also limits consumers' ability to participate in different types of demand flexibility programs, if each program has its own communication platform which is not interoperable with other platforms.

The issue of interoperability is not only an issue of communication between different types of platforms, but also an issue of the interpretation of commands on a central platform which communicates between different types of devices, known as semantic interoperability. For example, if a user sends a command via a central device manager to switch off certain devices, it is possible that the 'off' command may translate to different types of requests to

[15] For more information on the requirements for the label, visit https://www.ecodan.de/en/knowledge/sg-ready/

[16] For more information on the Australian Energy Rating label, visit https://www.energyrating.gov.au/products/air-conditioners

different types of devices. Whereas the 'off' command could mean shutting off cooling for a smart AC, it could also mean activating a standby mode on a smart TV.

3.2.2 Recommendations

As connected devices become ubiquitous, some of the technological challenges (complexity, operational challenges) discussed in Section 3.2.1 may either resolve themselves or become easier to address. To aid in resolving these issues, manufacturers could design and market demo devices which could provide consumers with the opportunity to use a device prior to purchasing it. This would be similar to taking a car for a test drive before consumers make a purchasing decision.

Manufacturers would also find greater success in the adoption of connected devices if they could better communicate the benefits and features of these devices through marketing efforts. It is also important to acknowledge issues and concerns of previous generation models and the efforts taken to mitigate these concerns in newer generations of the devices.

Interoperability challenges can be addressed by promoting and utilizing open protocols. While some manufacturers may prefer closed or proprietary platforms, this approach would generally be a hinderance to consumers. One potential approach to address this would be to have smart hubs that can communicate across different platforms with connected devices, and operate as a central, single hub for consumer communication with all devices as well as with the grid. Additionally, open communication protocols can be beneficial to manufacturers as well because it allows them to provide their services through multiple platforms and application stores without significant development costs.

Lastly, to alleviate the issues caused by semantic interoperability, communication protocol standards can define a single core information model which every device must comply with.[17] This core information model defines commands which a user can request. Individual manufacturers must design the actions of a device according to each type of command.

3.3 Economic Challenges and Recommendations

The economic burden of connected devices is a barrier for both consumers and manufacturers. The following sections discuss some of the challenges as well as recommendations to overcome these barriers.

3.3.1 Challenges

From a consumer perspective, another major concern of connected devices is the high cost for procuring these devices. All else being equal, a consumer product with connected functionality is typically more expensive than a comparable consumer product without connected functionality. In addition, connected functionality in devices is often packaged with other premium features that further increase the cost (sensors, touchscreens, cameras, *etc*.)

If consumers do not purchase connected devices, it would also impact manufacturers economically. Manufacturers are less likely to design and manufacture connected devices if

[17] Jacoby, M., Antonić, A., Kreiner, K., Łapacz, R., and Pielroz, J. 'Semantic Interoperability as Key to IoT Platform Federation', April 2017, https://www.researchgate.net/publication/315862252_Semantic_Interoperability_as_Key_to_IoT_Platform_Federation

there is not sufficient consumer demand for them, particularly in industries such as appliances where cost margins are already low. Another economic barrier for manufacturers is the lack of commercial incentives (for example via rebates) to design, manufacture, and market these products.

3.3.2 Recommendations

The high cost for procuring connected devices can be mitigated via consumer subsidies and/or rebate programs. However, this approach may not necessarily lower the cost of smart, energy-saving devices since the cost would be shifted from the manufacturers to the managers of the rebate program (*e.g.*, utilities, government, or other stakeholders.) To lower the total cost of these devices, before rebates or incentives, economic principles dictate that the quantity of devices in the market must increase. This increase in quantity could be achieved through mandatory design requirements for smart, energy-saving devices, or other policy measures, as outlined in Chapter 9 of this report. Moreover, stimulating competition in the market will also decrease prices. Effective promotion and communication of the benefits of connected devices, particularly in terms of money saved from energy savings (lower utility bills), could be another way to manage the high cost of connected devices.

Manufacturers can also provide commercial incentives to design, manufacture, and market connected devices. This can be done through several avenues such as recognition of ‘most-efficient’ devices, rebate programs, and regulations that encourage and facilitate new business models. Unlike traditional consumer devices that are sold as a product to consumers, smart, energy-saving devices can be viewed as an on-going service provided to consumers either by their utility provider or manufacturers themselves. This business model could open new avenues for how these devices are sold and managed in the field.

4. Prioritisation of Devices to Target

Not all devices would benefit to the same extent from smart, energy-saving capabilities. This section presents various types of devices in the market that should be targeted by the available policy types presented in Chapter 9 of this report.

4.1 Criteria for Selecting Devices to Target

In order to assess the devices that would provide the most benefits as smart, energy-saving devices, the following criteria and evaluative measures were used:

- Flexibility potential (high/medium/low): The flexibility potential of a device depends on the amount of energy that can be shifted, shed, and/or modulated during a demand response event, and the typical response duration. Devices that can provide a high flexibility potential will be able to achieve the most cost savings for a consumer.

- Comfort impact (high/medium/low): the comfort impact criterion is evaluated qualitatively according to how the introduction of smart capabilities affects a consumer's regular use of a device type. For example, if lighting products were able to participate in demand flexibility programs by dimming the lights in a consumer's home then it could pose a significant impact on the comfort of a consumer depending on the degree to which the lights are dimmed. A high comfort impact rating represents the greatest inconvenience to consumers and a low rating represents the least inconvenience.

While these criteria provide an indication of demand flexibility potential only, additional devices can benefit from the functions of status reporting and (intelligent) energy efficiency. A final list of devices to target with the criteria is presented in Section 4.2.

4.2 Proposed Devices to Target

Table 4-1 summarises the demand flexibility potential and comfort impacts of the 11 technologies analysed in this section. As shown here, the highest potential technologies include ACs, water heaters, smart thermostats, and batteries. The following sections provide additional justification for these ratings. Note that end-uses not covered in Table 4-1, *e.g.,* electronics, cooking, and miscellaneous loads, are assumed to have no demand flexibility potential.

Table 4-1. Summary of Smart Device Prioritisation

Sources: Flexibility potential adapted from US Department of Energy (2019)[18]

Product	DF Potential			Comfort Impact	Overall DF Potential
	Shed	Shift	Modulate		
Air Conditioners (ACs)	Low	High	Low	Medium-High*	**High**
Water Heaters	Low	High	Medium	Low	**High**
Thermostats	Medium	High	Low	Medium	**High**
Battery Storage (incl. vehicles)	None	High	High	None	**High**
Electric Vehicle Chargers	None	Medium	Medium	Low	**Medium**
Lighting	Medium	None	None	High	**Medium**
Refrigerators / Freezers	None	Medium	None	Low	**Low**
Dishwashers & Clothes Washers	None	Medium	None	Low	**Low**
Clothes Dryers	Low	Medium	Medium	Medium	**Low**

* Comfort impact is dependent on the heating/cooling strategies and the available thermal storage capacity in the building envelope (walls, windows, and roof).

4.2.1 Air Conditioners

ACs are generally available in two configurations: (a) self-contained ACs are typically in their own casing and are designed to be mounted in a window or through a wall; (b) central ACs circulate cool air from an AC unit outside of the home through a system of supply and return ducts. Smart ACs on the market can provide additional features such as remote management through mobile applications, voice control, cooling schedules, and detailed

[18] US Department of Energy Grid-Interactive Buildings Technical Report Series (2019), https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings (US DOE, 'GEB')

energy consumption information. The demand flexibility potential of ACs varies by climate and the penetration of AC in the region. Naturally, the flexibility potential of ACs in warmer climate zones is much higher. In these regions, ACs are well suited to help control peak demand because residential space cooling is typically the biggest contributor to summer demand peaks. Accordingly, AC switches are commonly used in demand flexibility programs. ACs can provide flexibility primarily through load shifting to reduce peak period energy consumption.

Australia has adopted a mandatory energy labelling requirement for ACs to display whether product models can participate in demand response.[19] A product can certify according to three different types of demand response modes according to the percent of power that can be reduced based on utility signals. Furthermore, in the US and Canada, the ENERGY STAR specification for ACs includes optional requirements for connected functionality. The requirements also include mandatory demand response capabilities as well as communication protocol requirements, operational status reporting, and energy consumption reporting among other requirements.

The main limiting factor for smart ACs is the impact on occupant comfort. However, with strategic cooling schedules (pre-cooling strategies) and insulated building envelopes (walls, roof, and windows), the impact on user comfort could be curbed. Additionally, remote management and status reporting for ACs could offer enhanced usability for consumers.

4.2.2 Water Heaters

Water heaters are usually available in two different configurations: tankless and storage. Tankless water heaters provide heated water as demanded by a user; when hot water is requested, the water heater turns on and provides hot water. Storage water heaters heat water through either a heat pump or electrical resistance and store it for use at a later time. Due to the on-demand nature of a tankless water heater, there is limited opportunity for participating in demand flexibility. These types of water heaters must be able to operate whenever a user requests hot water. Storage water heaters function as an energy-storage device, meaning the energy intensive action of heating water could be performed at any time of day and the user would be able to request heated water at any time. This report focuses on storage water heaters since they offer a higher flexibility potential.

Several utilities have utilised water heaters in residential demand flexibility pilot programs. 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 noticeably impacting the hot water supply to consumers. Connected water heaters can be used for load shifting by pre-heating water during off-peak periods to enable no power draw during peak events.[20] They could also potentially shed load during emergency events.

[19] Australian Energy Rating Label for Air Conditioners, http://energyrating.gov.au/products/space-heating-and-cooling

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

Currently, the ENERGY STAR specification with requirements for connected water heaters is in development. However, several utilities in the US, Europe, and Australia have launched demand flexibility programs specifically for water heaters.[21]

4.2.3 Smart Thermostats for HVAC Systems

Thermostats control central heating and AC units in homes. This device is often one of the first smart devices that consumers adopt because it offers energy savings and convenience at a relatively low cost. A smart thermostat can gather and transmit temperature data to consumers and set heating and cooling schedules based on a consumer's preference.

For central HVAC systems, the flexibility potential also depends largely on the building thermal inertia. Since occupant comfort is the limiting factor, the potential energy use that can be shifted depends on user preference and the building thermal inertia. However, many smart thermostats have data analytics and learning capabilities to optimise occupant comfort, efficiency, and demand flexibility needs.

Smart thermostats are by far the most common technology used in residential ADR programs. Smart thermostat programs are typically used for load shifting either to reduce peak or for emergency demand response events. In these programs, utilities offer rebates and other financial incentives for consumers to install a smart thermostat in their home and participate in demand response events. Additionally, the ENERGY STAR specification for smart thermostats encourages energy efficiency through energy consumption reporting and requires that each certified model have the ability to participate in demand response.

4.2.4 Battery Storage

Smart home battery storage can serve as a valuable asset to the grid, particularly in regions with high variable renewable energy generation. Batteries can provide demand flexibility without impacting occupant comfort. Several utility demand flexibility programs to date have utilised home batteries. In bring your own device (BYOD) programs, 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). Recharging of batteries could be aligned with off-peak hours (low cost electricity) or it could be aligned with periods of high variable renewable energy generation. Battery storage can be an even more valuable asset to the grid when coupled with onsite distributed generation (*i.e.*, solar photovoltaics (PV)) as batteries can recharge without utilizing grid electricity.

Currently, adoption of smart home batteries is low, but it is expected to grow. 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.[22]

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[21] EDNA, 'Roadmap for Consumer Devices to Participate in Demand Flexibility'

[22] Navigant Research: Rodriguez, R. and Eller, A. 'Residential Energy Storage.' 2019, https://guidehouseinsights.com/reports/residential-energy-storage

4.2.5 Electric Vehicle Chargers

Connected electric vehicle (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, range limits, lack of charging infrastructure, and consumer preferences, among others.

Several utility programs to date have utilised EV chargers to shift energy consumption, though public EV chargers are more common than residential chargers. In addition, the flexibility potential for EV chargers is innately limited to periods when the EVs are plugged in, which may not align with the needs of the grid. Further, in the US and Canada, the ENERGY STAR specification for EV supply equipment includes optional requirements for connected functionality, including demand response capabilities and open communication protocols.

4.2.6 Lighting

Lighting products encompasses light bulbs and light fixtures for the purposes of this discussion. After smart thermostats, connected lighting products are the most prevalent smart devices in the residential sector. Connected lighting allows users to control lighting products remotely, create on/off schedules, and adjust lighting based on sensor data.

Currently, grid-responsive lighting is non-existent in the residential sector, but potential exists. Connected lighting adoption in the residential sector is expected to grow rapidly over the next decade.[23] Connected lighting can participate in demand flexibility through dimming (typically around 10-20%) to provide load shedding, which may impact consumer comfort depending on the dimming amount. However, additional smart features can help achieve energy savings through the use of sensors, controllers, and automation. For example, smart bulbs can be automatically switched off with schedules determined by users through an application. The ENERGY STAR specification for connected lighting products requires such devices to report energy consumption and operational status information but does not include demand response capabilities.[24]

4.2.7 Refrigerators / Freezers

Because refrigerators have thermal storage capacity, they can offer flexibility in energy shifting operation depending on the thermal storage capacity. However, since refrigerators are appliances that run continuously, they require more careful planning to ensure that customer utility, particularly as it pertains to food quality and safety, is maintained. The device would need to carefully and intelligently set precooling strategies or adjust setpoints to ensure that the contents within the refrigerator are not compromised. In addition, delayed icemaking/defrost cycles could be used to shift loads for demand flexibility. However, residential refrigerators/freezers are not often used today in demand flexibility programs.

[23] Navigant Research: Leuschner, P. and Strother, N. 'The Smart Home Overview.'
[24] See ENERGY STAR specifications for light fixtures and ceiling fans at https://www.energystar.gov/products/lighting_fans

A smart refrigerator could also provide valuable operational maintenance information; for instance, it could include a sensor that detects leaks which can alert a user of a potential problem ahead of a destructive and potentially dangerous situation. In addition to many convenient features, such as expiration date alarms, smart recipes, and automatic food ordering, smart refrigerators can also offer various status reporting, operational maintenance, and demand flexibility options. The ENERGY STAR specifications for residential refrigerators/freezers includes Connected Functionality requirements for energy consumption reporting, operational status reporting, demand response capabilities, remote management, open access, and open communication protocols.

4.2.8 Dishwashers and Clothes Washers

Dishwashers and clothes washers operate on similar finite cycles, including washing, rinsing, and spinning/drying portions of the cycle. The primary flexibility benefit of these technologies is through load shifting by defining an end time or delaying the start time of the wash cycle. However, the overall potential of these technologies is limited as they are intermittently used and relatively smaller loads. In addition, consumers may find the delayed start/end times disruptive to their schedules. Accordingly, clothes washers and dishwashers are not often used in demand flexibility programs. However, ENERGY STAR specifications for both technologies do include optional include Connected Functionality criteria for energy consumption reporting, operational status reporting, demand response capabilities, remote management, open access, and open communication protocols.[25]

4.2.9 Clothes Dryers

Similar to dishwashers and clothes washers, clothes dryers are machines that run on finite cycles which are manually operated by the user. They can provide load shifting flexibility through delayed start controls. Clothes dryers can also be designed to run at lower power by modulating or staging the heating with the use of controls.[26] These clothes dryers provide additional efficiency and flexibility capability through modulating to potentially provide fast response ancillary services.

However, the energy use of residential clothes dryers is intermittent as consumers typically use clothes dryers for only a few hours each week. Consequently, this limits overall demand flexibility potential. In addition, delayed start for demand flexibility could be disruptive to consumers who would likely disapprove of delaying clothes drying. Clothes dryers are not often used for demand flexibility, but ENERGY STAR specifications include Connected Functionality criteria for energy consumption reporting, operational status reporting, demand response capabilities, remote management, open access, and open communication protocols.[27]

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[25] Note: The Connected Functionality test procedures to validate demand response capabilities are not yet finalized for dishwashers and clothes washers.

[26] US DOE, 'GEB: HVAC'

[27] Note: The Connected Functionality test procedures to validate demand response capabilities are not yet finalized for clothes dryers.

5. Communications Protocols

Connected devices rely on various protocols to communicate with the grid, other devices, and consumers. Connected devices are typically composed of a hardware layer (which transmits the signals), a network layer (through which devices communicate with each other), and an application layer (through which end users deliver commands).[28] In order to maximise the reliability, security, and interoperability of smart devices, these protocols must be open, flexible, secure, and limited in number. This section discusses various types of communication protocols used today, briefly considers the state of infrastructure of communication protocols, and defines the barriers to adoption for a standard communication protocol. This section also discusses the network and application layer protocols commonly found in smart devices today.

5.1 Network Layer

Communication protocols can be proprietary or open. Although there are many types of communication protocols for smart devices, the most commonly used are Wi-Fi, Bluetooth, Zigbee, and Z-Wave.

- **Wi-Fi** is a networking protocol based on the IEEE 802.11 family of standards commonly used for wireless local area networking (LAN). This technology is widely available in homes and can support high transfer speeds, wide range, and a large number of connected devices. Devices which use Wi-Fi typically have relatively high-power consumption compared to devices using Bluetooth or cellular networks.[29] However, a relatively nascent technology called Wake-Up Radio (WUR) offers a solution to significantly reduce the power consumption of devices using Wi-Fi. WUR utilises a low power radio which is attached to the main radio in charge of receiving Wi-Fi signals. Thus, the main, most consumptive, radio can remain asleep until it receives a signal from the low-power radio, significantly reducing a device's overall energy use.[30]

- **Low Power Wide Area Network (LPWAN)** is a wireless wide area network (WAN) designed to allow for long-range, low bit rate data transmission between devices. LPWAN is especially suited for applications that require devices to send small amounts of data periodically over long ranges and devices that use batteries that need to last years on a single charge. Moreover, LPWAN protocols are lightweight and reduce the complexity of hardware design, thus lowering the cost of a device with LPWAN capability.

- **Bluetooth** offers short range point-to-point and mesh networking, offering personal area networks (PAN). Mesh networks allow devices to link together instead of connecting to a central point. The more devices on a mesh network, the greater the

[28] Sethi, P, and Sarangi, S. 'Internet of Things: Architectures, Protocols, and Applications', https://new.hindawi.com/journals/jece/2017/9324035/

[29] Thomas, D, Wilkie, E, and Irvine, J. 'Comparison of Power Consumption of WiFi Inbuilt Internet of Things Device with Bluetooth Low Energy', November 10, 2016, https://pdfs.semanticscholar.org/622a/90a90108e947b15c3d0f065274d770ea27ad.pdf?_ga=2.71218896.1930417554.1577981997-1553924280.1577981997

[30] Bello, H., Xiaoping, Z., Nordin, R., Xin, J. 'Advances and Opportunities in Passive Wake-Up Radios with Wireless Energy Harvesting for the Internet of Things Applications', July 12, 2019, https://www.mdpi.com/1424-8220/19/14/3078

range of the network. Bluetooth is commonly used in wireless audio streaming applications but is becoming increasingly common in smart home applications such as lighting, appliances, and hubs.

- **Zigbee** is an open wireless mesh networking standard used for applications that require low bit rate data transfer, long battery life, and secure networking. The protocol is based on the IEEE 802.15.4 standard and is intended to be simpler and less expensive than other networking technologies. In the UK, Zigbee is used for smart metering.[31] The Zigbee Alliance is an organisation comprised of various companies that creates the wireless specifications and encourages interoperability across a wide range of devices.

- **Z-Wave** is an open wireless mesh networking protocol which uses low-energy radio waves to communicate between devices. Z-Wave is designed to achieve reliable communication and operation with devices from various manufacturers in the Z-Wave alliance. In April 2018, Silicon Labs, one of the leading developers of the Zigbee protocol, acquired Z-Wave.[32] This acquisition could increase interoperability between the two protocols.

- **Thread** is an open wireless mesh networking technology that is based on the same IEEE 802.15.4 standard as Zigbee. Thread is intended to offer more security and reliability at low power modes.

5.2 State of Infrastructure of Network Communications Protocols to Aid in Adoption of Smart, Energy-Saving Devices

In order to facilitate the adoption of smart, energy-saving devices, consumers should not be burdened with additional hardware requirements, or complex installation and maintenance. Additionally, a communication protocol should be able to operate seamlessly with other devices, a utility, or smart home energy management systems.

Zigbee, Z-Wave, and Bluetooth are examples of protocols which do not require additional software such as a web server or hardware such as a PC.[33] In contrast, Wi-Fi requires a router to transmit the signal to devices. However, one key advantage to Wi-Fi is its bandwidth. Wi-Fi is designed to have higher end signal processing for higher bit rate data transmission. Moreover, protocols with mesh architectures, such as Zigbee, Z-Wave, Bluetooth, and Thread, can increase their ranges by increasing nodes in a network. The more nodes present in a network, the greater the range throughout the home.

For demand flexibility, two-way communication and automated control technologies are required between devices and utilities. Two-way communication capabilities allow a utility/program to send signals based on real-time grid prices. In the residential sector, two-way communication can be enabled between individual devices and the utility. From the perspective of a smart device, this can be achieved in two ways: via a central energy manager gateway/hub, or via an individual appliance manager system in the cloud. Either of

[31] Nhede, N. 'Zigbee's smart energy certification chosen for UK smart meter rollout'; May 2, 2018; https://www.smart-energy.com/industry-sectors/data_analytics/zigbee-alliance-uk-certification/

[32] Silicon Labs, Sigma Designs, Inc. 'Silicon Labs Completes Acquisition of Sigma Designs' Z-Wave Business', April 18, 2018; https://news.silabs.com/2018-04-18-Silicon-Labs-Completes-Acquisition-of-Sigma-Designs-Z-Wave-Business

[33] AHAM, 'Assessment of Communication Standards for Smart Appliances', October 2010, https://www.smartgrid.gov/files/Assessment_Communication_Standards_for_Smart_Appliances_Home_201002.pdf

these approaches would require the signal to be translated from the utility to the device, and vice versa. Figure 5-1 shows a connected RAC, a window mounted AC system. The AC communicates with the grid via a protocol translation. The three blocks represent the translation of signals via either a gateway/hub or the cloud. The translated protocol then communicates with a utility or energy provider to activate demand flexibility actions.

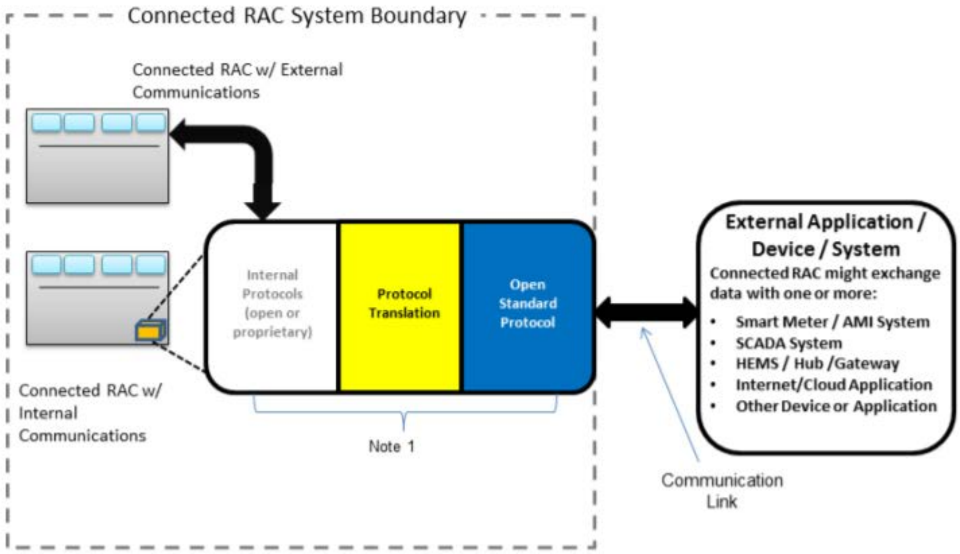

Figure 5-1. Connected RAC system

Note 1: Communication device(s), link(s) and/or processing that enables open standards-based communication between the Connected RAC System and Energy Management Device/Application(s). These elements could be within the appliance, and/or an external communication module, a hub/gateway, or in the Internet/cloud.

Source: ENERGY STAR Program Requirements Specification for Room Air Conditioners Version 4.1

Figure 5-2 illustrates the two types of models. The illustration on the left shows the gateway/hub model in which a variety of smart devices connect to the gateway which communicates with the energy service provider. The illustration on the right shows the cloud model in which each device is connected to the energy service provider, or to its device manager system in the cloud which connects to the energy service provider.

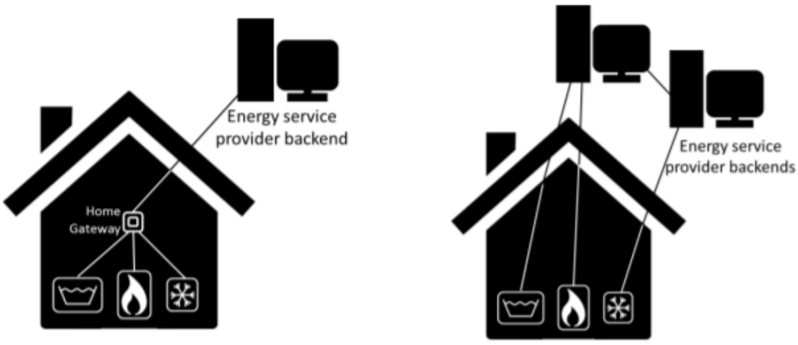

Figure 5-2. Two types of communication architectures: gateway/hub model on the left, cloud model on the right

Source: Ecodesign Preparatory Study on Smart Appliances

5.3 Application Layer

The application layer provides a user interface and allows a user to directly control a smart device through a smartphone application, website, or energy hub. The application layer is crucial for interoperability efforts and usability of smart devices. If smart devices only work with proprietary applications, then users may be forced into a ‘vendor lock-in’ in which a user is dependent on a vendor for products and services, unable to use another vendor without incurring substantial costs, or increasing the complexity of a system.[34] Vendor lock-in could pose a barrier to the adoption of smart, energy-saving devices if manufacturers only use proprietary applications for their smart devices.

Platforms and programs currently exist that are open, secure, and allow two-way communication. One example is the open automated demand response (OpenADR) model.[35] Mobile and PC applications that allow users to connect to various network connected devices across many different brands also exist. An example is the Yonomi One application.[36] With this application, users can create and execute routines such as turning on the AC when a user arrives home from work or shutting off all lights at night. These actions have the potential both to save energy and increase the energy use of devices. If users are offered the ability to activate devices with increasing ease, then it could result in higher energy consumption. However, these opportunities can also achieve energy savings as users are able to also operate their devices more efficiently by turning them off when not in use. The implications for energy use may depend heavily on user preferences and the amount of interaction they have with the application.

[34] Opara-Martins, J., Sahandi, R., and Tian, F. ‘Critical analysis of vendor lock-in and its impact on cloud computing migration: a business perspective.’ 2016

[35] OpenADR Alliance, https://www.openadr.org/

[36] Yonomi One, https://cdn2.hubspot.net/hubfs/3836060/yonomi-one-overview.pdf?__hssc=206628044.4.1579226129051&__hstc=206628044.1a8c10f69bd7922845f9828b208f6593.1579226129051.1579226129051.1579226129051.1&__hsfp=645916085&hsCtaTracking=02be4c79-a8dc-4e9c-bdfe-4db82544a73a%7Cfde430e8-1988-44e5-a612-00d010787cc5

Another application available for smart devices is Samsung's SmartThings app.[37] The SmartThings app is not only compatible with Samsung devices, but also devices that include the 'works with SmartThings' label. These devices include appliances, lighting products, outlets, cameras, electronics, and HVAC equipment. Like the Yonomi application, users are able to create routines to activate devices based on their preferences or schedules. Moreover, SmartThings offers an energy-specific service that allows users to monitor their energy consumption, control appliances remotely, and save on energy bills.[38] This service relies on demand flexibility to shift energy usage and thus lower energy costs. Currently, this service is only offered to customers in the UK who use Bulb Energy[39] as their energy service provider.

Other companies such as Amazon, Apple, and Google have developed similar applications and platforms. Usually, the packaging of a smart device indicates which platforms a device is compatible with. However, since most consumer electronic companies do not manufacture major appliances such as refrigerators, dishwashers, clothes washers, or clothes dryers, manufacturers of these devices could limit their use with proprietary applications.

In order to maximise interoperability among devices and improve the user experience, policy options could require the open access of data such that any platform could connect with a smart, energy-saving device. Currently, the ENERGY STAR Connected Functionality criteria require that devices utilise open standards for energy consumption reporting, operational status reporting, and demand response activities.[40] The ENERGY STAR SHEMS specification requires that smart home systems 'provide a remote consumer interface (*e.g.*, application, website, display) that allows end users to control all the devices connected to the SHEMS package from outside the dwelling.'[41] Similar to the ENERGY STAR specifications, policy recommendations related to the application layer should encourage the open access of data rather than mandating one type of application to be used. These measures would ensure interoperability across platforms and devices while maintaining competitiveness in the smart home platform market. Additionally, smart home platform developers can further encourage smart energy use by providing services similar to Samsung SmartThings' Energy offering, which helps users reduce their energy consumption through energy monitoring and easily activated demand flexibility activities.

5.4 Barriers to Adoption

Numerous factors exist that contribute to the complexity of communication hardware and software that is necessary to facilitate the installation and operation of smart, energy-saving devices in a home. The gateway/hub model would require additional hardware which could add cost burden to the consumer and increase the complexity of installation of smart, energy-saving devices. However, the cloud model requires that each device include the

[37] Samsung SmartThings App, https://www.samsung.com/global/galaxy/apps/smartthings/

[38] Samsung SmartThings Energy, https://www.samsung.com/uk/smartenergy/

[39] Bulb, https://bulb.co.uk/

[40] See, for example, ENERGY STAR Program Requirements for Room Air Conditioners, https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%204.1%20Room%20Air%20Conditioners%20Specification.pdf

[41] ENERGY STAR Program Requirements Product Specification for Smart Home Energy Management Systems, https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20SHEMS%20Version%201.0%20Program%20Requirements.pdf

necessary components to communicate with an energy service provider. This approach could increase manufacturer cost and design complexity.

Another factor that contributes to the complexity of the smart environment is the numerous amounts of communication protocols in the market, and the lack of a clear standard. Such a diversity of proprietary, and open, communication protocols would limit the interoperability of smart devices and would potentially require additional hardware. In its assessment on the communication standards for smart appliances, AHAM concluded that a central gateway/hub in a home that is compatible with various types of communication protocols would limit the overall complexity of a smart device environment.[42] This type of architecture provides simplicity for the consumer and offers more flexibility for future development needs. Many larger and more expensive appliances have average lifespans greater than 10 years.[43] This longevity requires communication systems to adapt and function across many years of technological development in the protocols.

On an individual product level, there are various physical constraints which could impact the performance of a smart, energy-saving device. Devices can be located in homes in manners that interfere with signal transmission. For example, it is common for washers and dryers to be located in a basement, where a signal may not have enough range to reach the device. For mesh networks, this issue could be alleviated with the addition of devices on the network which could increase the overall range of the network with proper placement. For Wi-Fi networks, Wi-Fi repeaters/extenders can boost the range of networks by amplifying the signal from a router. Another factor that is important to consider is the energy consumption of the network capabilities of a smart device. Communications protocols such as Zigbee, Z-Wave, and Bluetooth offer low power consumption. However, signals such as Wi-Fi could significantly impact the standby energy consumption of a device.[29] The issue of the standby power energy consumption of a smart device is discussed in more depth in Section 6 of this report.

[42] AHAM, 'Assessment of Communication Standards for Smart Appliances: The Home Appliance Industry's Technical Evaluation of Communication Protocols', October 2010, https://www.smartgrid.gov/files/Assessment_Communication_Standards_for_Smart_Appliances_Home_201002.pdf

[43] Appliance Magazine, 'The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2014', October 2014

6. Smart Devices Network Standby Energy Use

Network connectivity comes at an energy cost. Network standby refers to a function that allows a network connected device to maintain network connection and await a network 'trigger' or message to be awoken as needed.[44] IEA estimates that electricity demand from information and communication technology is growing at a much faster rate than overall demand, and around 40% of this electricity is used by network-enabled devices in offices and homes around the world.[45] By 2030, it is estimated that 300 Terawatt-hour (TWh) per annum could be wasted by network standby energy globally, which is equivalent to the current electricity consumption of the UK.[46]

Three factors determine the functionality delivered and power required by the network standby function: 1) the number and type of network interfaces, 2) the status (or level of functionality) of the network interfaces and 3) network traffic management strategies.[47] The network interface of a device maintains a product's connection to the network and communicates with other devices through network protocols and wired or wireless connections. For network interfaces, the primary factors that impact the power draw are the data transfer rate for wired or wireless devices, frequency, and range for wireless devices.[48] Figure 6-1 illustrates the relationships between energy consumption, data rate, and range of various types of network interfaces.

[44] Mercier, C., Dayem, K., May-Ostendorp, P., Wagner, J. 'Network Standby Power Basics: Factors Impacting Network Standby Power in Edge Devices', April 27, 2018, https://edna.iea-4e.org/tasks/task5

[45] IEA, 'More Data, Less Energy', July 2, 2014; https://webstore.iea.org/more-data-less-energy

[46] IEA, 'The Wasted Energy of Connected Devices', https://www.iea-4e.org/document/444/policy-brief-the-wasted-energy-of-connected-devices

[47] Mercier, et al. 'Network Standby Power Basics: Factors Impacting Network Standby Power in Edge Devices'

[48] *Ibid.*

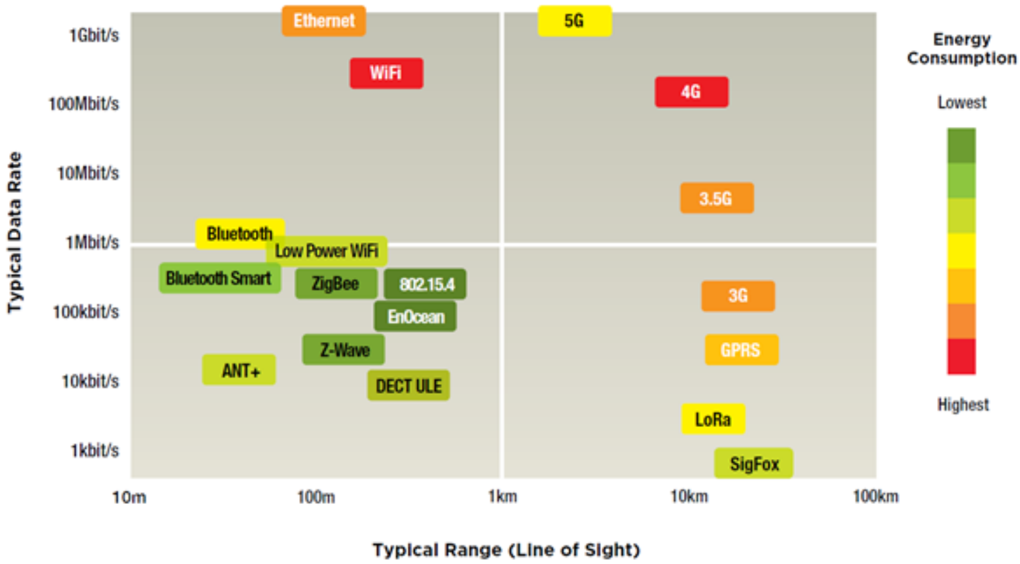

Figure 6-1. Energy Consumption of Network Protocols Based on Data Rate and Range

Source: IEA[49]

The functionality of a network interface also affects the power draw of a network connected device. Devices with lower functionality network interfaces may only require the network connection to receive simple commands such as to wake up or perform an action. Devices with higher functionality network interfaces may need to understand more complex forms of data and process more data. In general, more processing requires more power.[50] Figure 6-2 illustrates three different types of conditions with increasing complexity and energy use.

[49] IEA, 'The Wasted Energy of Connected Devices'

[50] Mercier, et al. 'Network Standby Power Basics: Factors Impacting Network Standby Power in Edge Devices'

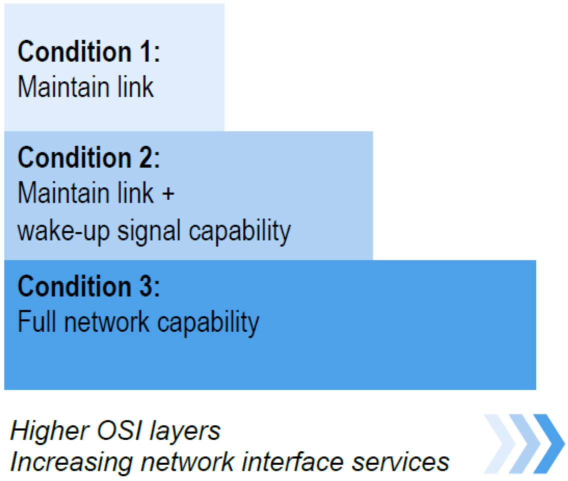

Figure 6-2. Network Functionality Conditions

Source: EDNA[51]

Finally, how a product manages incoming network traffic also has an impact on network standby energy use. Effective traffic management strategies optimise how a product manages network traffic. Some products may require a high degree of participation in a network, whereas others would only require occasional communication. Without effective network management strategies, such devices would be continually waking up and sleeping, rather than waiting for an appropriate wake signal. Traffic management strategies use a minimal amount of processing in a device and reduce the frequency with which other components need to be activated to respond to network communications.[52] Figure 6-3 illustrates three examples of network traffic management strategies and their effect on a device's network standby power. Example 1 shows a device with no traffic management and continuous waking. Examples 2 and 3 illustrate traffic management strategies that reduce the amount of wake events, and as a result, reduce the effective network standby power of a device.

[51] *Ibid.*

[52] *Ibid.*

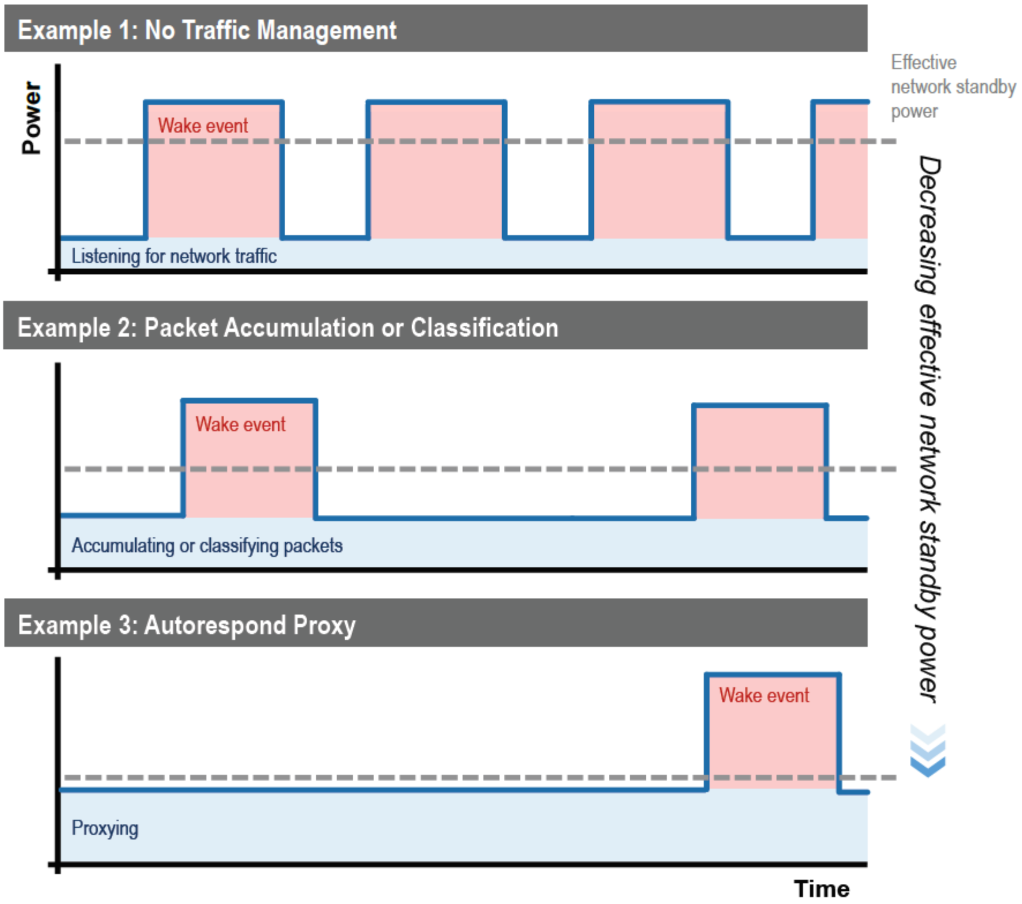

Figure 6-3. Illustration of Relative Power Impacts of Traffic Management Strategies

Source: EDNA[53]

These three aspects of network standby energy use are dictated to some degree by a device's intended functions, its network environment, and consumer preferences. Network standby energy use can be mitigated through the selection of appropriate network interfaces, and implementation of policies. Examples of mandatory and voluntary policies include the EU Ecodesign regulation for network standby[54], Korea's E-standby label[55], the US ENERGY STAR program[56], and voluntary industry agreements in the EU[57] and USA[58] for set-top boxes.

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[53] *Ibid.*

[54] European Commission, 'Off mode, standby and networked standby', https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/mode-standby-and-networked-standby_en

[55] Korea Energy Agency, 'e-Standby Power', https://www.energy.or.kr/renew_eng/energy/appliances/program.aspx

[56] See, for example, Televisions Key Product Criteria, https://www.energystar.gov/products/electronics/televisions/key_product_criteria

[57] 'Voluntary Industry Agreement to improve the Energy Consumption of Complex Set Top Boxes within the EU', April 2, 2018, http://cstb.eu/wp-content/uploads/2018/08/EU-VA-V6.pdf

[58] 'Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Set-top Boxes', January 22, 2020, https://www.energy-efficiency.us/library/pdf/Set-top-Box-Voluntary-Agreement-2018-2.pdf

7. Residential Demand Flexibility Programs

Residential demand flexibility was historically used during emergency or peak events, but new opportunities are emerging. Today, demand flexibility is evolving to become part of the broader distributed energy resource (DER) landscape, which provides flexibility to the grid. The growth of demand flexibility is driven by the increased adoption and innovations in smart devices, energy management software, and smart grid technologies. These new technologies allow demand flexibility to be used for load shedding/shifting for peak reduction or renewable integration.[59]

Smart, energy-saving devices include advanced communication and control capabilities to automatically and dynamically change energy use in response to changing electricity prices and grid system needs (*i.e.,* demand flexibility). This section of the report summarises residential demand flexibility programs and the rate of adoption of smart, energy-saving devices. For a more in-depth discussion of demand flexibility, see report titled 'Roadmap for Consumer Devices to Participate in Demand Flexibility.'[60] The discussion presented in this section is largely drawn from that report.

7.1 Types of Residential Demand Flexibility Programs

Residential demand flexibility programs generally consist of ADR and DER aggregation projects. ADR programs 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 plants programs have consisted of smaller utility programs and pilots.

ADR is currently more established and prevalent than DER aggregation. In the residential sector, these programs consist typically of technologies such as smart thermostats, connected water heaters, batteries, and/or smart appliances. A common program design is the BYOD model which allows customers to purchase and enrol their smart device in the utility's demand flexibility programs in exchange for payments.

Demand aggregators are also often used in the residential space to aggregate smaller loads to be able to provide more impactful load shifting to the grid. DER aggregation programs are more nascent than ADR programs as they generally require more complex grid-interactivity and integration. These projects often include batteries, EVs, and rooftop solar PV in addition to smart devices.

Additional examples of residential demand flexibility program designs are provided in Table 7-1. Many of these programs require demand aggregators to allow residential customers to participate.

[59] Navigant Research: Mehrhoff, J. and Feldman, B. 'Market Data: Residential Demand Response'
[60] EDNA, 'Roadmap for Consumer Devices to Participate in Demand Flexibility'

Table 7-1. Example Demand Flexibility Programs

Demand Flexibility Program	Description	Purpose
Smart Thermostat Program/Direct Load Control	• 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.	• Peak reduction • Emergency reserves
Fast DR Dispatch/Ancillary Services Program	• 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.	• Grid reliability • Power quality[61]
EV DR Program	• The cost of charging EVs is modified to cause consumers to shift consumption patterns.	• Peak reduction
DER DR Program	• Customers with distributed generation and storage can store excess energy when electricity prices are low to utilise when electricity prices are high.	• Distributed generation integration • Load following reserves

7.2 Rate of Adoption of Smart, Energy-Saving Devices

The adoption of devices with demand flexibility is poised to grow rapidly. The most common devices that participate in residential demand flexibility programs are smart thermostats and water heaters. The ENERGY STAR specification for smart thermostats requires that each certified model have the ability to participate in demand response. Recent estimates suggest that smart thermostat penetration will increase globally from 1% in 2018 to 8% of all installed thermostats in 2027.[62] According to a 2017 survey by the Smart Electric Power Alliance, about 2 percent of electric water heaters are participating in utility demand flexibility programs.[63]

The growth in all smart home technologies with demand flexibility capabilities 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. Smart thermostats and SHEMS 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 7-1.[64] 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 devices could actively be participating in demand flexibility, providing 185 GW of capacity.[65]

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[61] Including frequency regulation and voltage control
[62] Navigant Research: Leuschner, P and Talon, C., 'Market Data: Advanced Thermostats', 4Q 2018, https://www.navigantresearch.com/reports/market-data-advanced-thermostats
[63] Chew, B., Feldman, B., Esch, N., and Lynch, M. '2017 Utility Demand Response Market Snapshot', October 2017, https://sepapower.org/resource/2017-utility-demand-response-market-snapshot/?utm_source=Internal&utm_medium=DRSnapshotPress+Release&utm_campaign=2017DRSnapshot
[64] Navigant Research: Leuschner, P. and Strother, N. 'The Smart Home Overview.'
[65] IEA, 'Digitalisation & Energy' 2017. https://www.iea.org/reports/digitalisation-and-energy

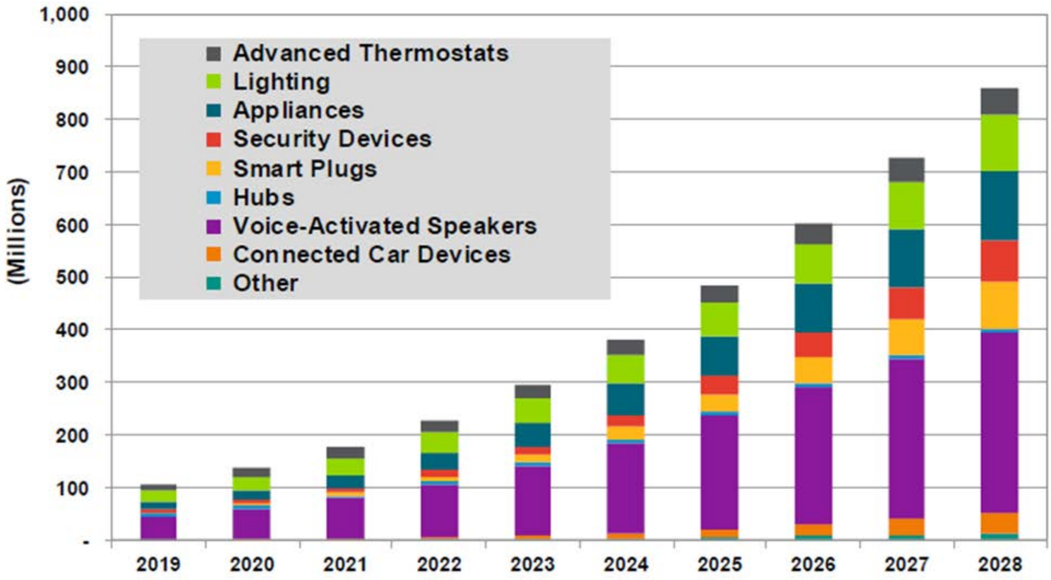

Figure 7-1. Annual Smart Home Devices Global Shipments

Source: Navigant Research[66]

[66] Navigant Research: Leuschner, P. and Strother, N. 'The Smart Home Overview.'

8. Existing Policies and Programs to Encourage the Use of Smart, Energy-Saving Devices

As the Internet of Things (IoT) continues to develop, government and industry have been analysing the opportunities that smart devices present and have been developing policies and programs to harness these opportunities. Many of the existing policies and programs focus on a specific device rather than broader policies that would be applicable to any type of device. However, these policies and programs provide valuable information about approaches that are successful and could be used for other smart, energy-saving devices as well as for broader implementation programs.

This section summarises and analyses existing reports, policies, and programs that are dedicated towards smart, energy-saving devices. The approaches outlined in these policies and programs are used as a starting point for the recommendations included in Chapter 9 of this report.

8.1 Reports

The European Commission has released two reports related to smart appliances and building automation and control systems (BACS).

8.1.1 Ecodesign Preparatory study on Smart Appliances

The 'Ecodesign Preparatory Study on Smart Appliances (Lot 33)' report[67] analyses the technical, economic, market, and societal aspects that are relevant for broad market introduction of smart appliances and to develop policy approaches to support such uptake. The report addresses several aspects of smart appliance market adoption, such as scope; market, user, and technical analyses; and policy proposals along with example scenarios. The study was conducted over the course of 4 years, with the first draft task published in June of 2015, and the final task published in October of 2018.

As discussed in Section 2.1.3, this report defines a smart appliance as an appliance that supports demand side flexibility. The study examined various appliances and sorted them into three categories based on their flexibility potential: (1) high flexibility with little impact on comfort and/or performance, (2) smaller flexibility potential and/or larger comfort/health impacts, and (3) emergency flexibility potential only. In its overall analysis, the report focuses on appliances with higher flexibility potential and does not include significant analysis on appliances with lower flexibility potentials. Most importantly, the report presents a robust market analysis of the appliance market, examines demand flexibility use cases, and characterises the challenges, both technical and societal, related to demand flexibility with each appliance. The report also examines several policy approaches for encouraging the use of smart, energy-saving devices, such as mandatory energy performance requirements, mandatory energy labelling requirements, voluntary programs, and industry self-regulation measures. The recommendations presented in Chapter 9 draw from some of the policy approaches presented in this report.

[67] European Commission, 'Ecodesign Preparatory Study on Smart Appliances'

8.1.2 Ecodesign Preparatory Study for Building Automation and Control Systems

The 'Ecodesign Preparatory Study for Building Automation and Control Systems (BACS) Implementing the Ecodesign Working Plan 2016 -2019'[68] aims to develop the scope for a full Ecodesign preparatory study for BACS. While building automation primarily exists for commercial building use, some of the same systems can also be implemented for residential building use. BACS are defined in European and international standards as 'comprising all products and engineering services for automatic controls (including interlocks), monitoring, optimisation, for operation, human intervention and management to achieve energy-efficient, economical and safe operation of building services.'[69] This definition encompasses smart devices in a similar context as this report.

This report presents the following existing policy tools that can support the uptake of BACS: Energy Performance in Buildings Directive (EPBD), Energy Efficiency Directive (EED), Ecodesign Directive (ED), and Energy Labelling Regulation (ELR). Each of these policies can set requirements for technologies, ensure that information is reported and accurate, limit self-consumption of BACS, ensure interoperability and longevity of products, all of which could be useful for crafting policy guidance specific to smart devices.

The report also considers how the combination of policy options can be structured to work together to support a common goal and identifies the specific requirements that would be implemented by certain policies, such as energy labelling regulations. Moreover, the report presents barriers to implementing these measures. Additionally, this report also discusses the importance of standardised information, limiting standby consumption, periodic maintenance, and the limitations of certain technologies.

While the findings in this report are directly applicable only to the EU, specifically its regulatory structure, they are useful approaches to consider as general policy guidance.

8.1.3 EU Smart Readiness Indicator for Buildings

In the EPBD, one focal point is to improve the realisation of smart technologies in the building sector. The EU Smart Readiness Indicator (SRI) is a voluntary program to rate the smart readiness of buildings. SRI aims to make the value of building smart readiness more tangible for building owners, tenants, and smart service providers. Figure 8-1 illustrates a potential logo for the SRI, where each letter grade corresponds to a building's smart readiness rating. The SRI functions across different policy segments such as energy, buildings, and ICT.

[68] European Commission, 'Ecodesign Preparatory Study for Building Automation and Control Systems (BACS) implementing the Ecodesign Working Plan 2016 -2019', https://ecodesignbacs.eu/sites/ecodesignbacs.eu/files/attachments/BACS_scopeReport.pdf

[69] *Ibid.*

Figure 8-1. Potential EU SRI Logo

Source: Summary of State of Affairs in 2nd Technical Support Study on the Smart Readiness Indicator for Buildings[70]

According to the SRI, the smartness of a building is defined as 'the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems or the external environment (including energy grids) and to demands from building occupants.'[71] Therefore, the SRI for buildings provides information on the technological 'readiness' of buildings to interact with their occupants and energy grids, and on their capabilities for more efficient operation and enhanced performance through the use of ICT technologies. In this technical study, the authors emphasised the distinction between 'smart ready' versus 'smart now' capabilities. The term 'smart ready' implies that the building itself is smart, but its potential to realise the benefits from smart services may be constrained by limiting factors in the capability of the services it connects to at its boundary (*e.g.,* smart meters). The SRI is intended to rate the potential smartness of a building, in contrast to its actual operational smart capability.

The proposed SRI rating methodology assesses the smart ready services present in a building, which are defined by catalogues of smart ready services. Each catalogue lists the relevant services, devices, technologies, and their expected impacts towards building users and the grid. Specifically, the catalogue evaluates smart ready services based on three key functionalities:

1) The ability to maintain energy efficiency performance and operation of the building through the integration of various energy sources (*e.g.*, renewable sources.)

2) The ability to adapt its operation mode in response to the needs of the occupant, paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions, and ability to report on energy use.

[70] European Commission, 'Summary of State of Affairs in 2nd Technical Support Study on the Smart Readiness Indicator for Buildings', February 7, 2020, https://smartreadinessindicator.eu/sites/smartreadinessindicator.eu/files/sri_summary_3rd_interim_report.pdf
[71] *Ibid.*

3) The flexibility of a building's overall electricity demand, including its ability to enable participation in active and passive as well as implicit and explicit demand-response, in relation to the grid, for example through flexibility and load shifting capacities.[72]

The SRI aims to influence the adoption of smart services through a 'market pull' by raising awareness among stakeholders and through a 'market push' by encouraging smart service providers to market their offerings to building owners in order to improve their building capabilities and attract tenants.

On February 21, 2020 the third interim report on the technical study of the SRI was published. The technical support study will end its activities in June 2020, after which stakeholders will consult with EU policy makers to assess the technical feasibility and the effective implementation of an SRI scheme.

8.2 Policies

The following policies are designed to increase the uptake of smart devices mainly through labelling provisions. Currently, no regulations requiring smart capabilities exist in any jurisdiction.

8.2.1 Australia/New Zealand Energy Rating Label for Air Conditioners

In Australia, space heating and cooling account for an average of 40% of a household's energy use, and 33% in New Zealand.[73] Single-phase non-ducted ACs for household use are regulated for energy labelling in Australia and New Zealand. These products are required to display the following information on their energy rating label[74]: efficiency performance, input power, capacity output, variable compressor capability, and demand response capability. Figure 8-2 shows an example of an energy rating label for ACs.

[72] *Ibid.*

[73] Australian Energy Rating Label for Air Conditioners, http://energyrating.gov.au/products/space-heating-and-cooling

[74] *Ibid.*

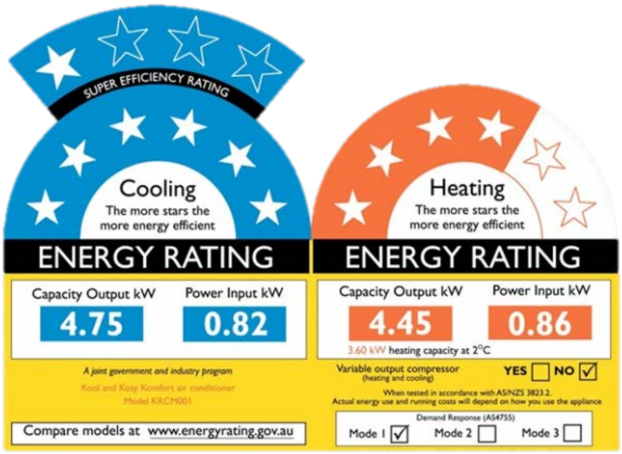

Figure 8-2. Australia / New Zealand Energy Rating Label for Air Conditioners

If a model has demand response capability, manufacturers are required to specify their capabilities according to three modes, as shown in Figure 8-3.

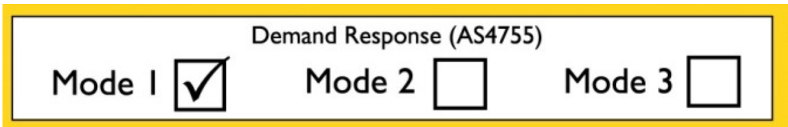

Figure 8-3. Australian Energy Rating Label Demand Response Modes

Each mode is defined and corresponds to the extent that demand response can affect the functionality of an AC, as follows:

- Mode 1 means the appliance is capable of being turned off and back on.
- Mode 2 means the appliance is capable of being turned down by 50%.
- Mode 3 means the appliance is capable of being turned down by 25%

While the label requires models to display whether or not they have demand response capabilities, there aren't any mandatory requirements for including these capabilities. Moreover, in 2019, the Council of Australian Governments (COAG) agreed to draft regulatory impact statements on ACs, pool pumps, and certain electrical appliances to be demand response enabled.[75] This consultation proposes to mandate demand response modes for all new models on the market.

8.2.2 South Korean Labelling Regulation for Air Conditioners

The South Korean labelling regulations for ACs requires that, in order to be labelled with the highest energy grade, products must include 'smart' functions.[76] Smart functions are defined

[75] COAG Energy Council, 'Meeting Communique', December 19, 2018, http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/21st%20COAG%20Energy%20Council%20Communique.pdf

[76] Nordman, B, and Meier, A. 'Energy Aware Devices - Study of Policy Opportunities', October 2016, https://cda.iea-4e.org/document/58/energy-aware-devices-study-of-policy-opportunities

as the ability for users to view energy consumption through a mobile or PC application, and the ability for the user to control the AC through an application. While this regulation does not include any provisions related to demand flexibility, it aims to encourage status reporting which is also an important aspect of smart devices.

8.2.3 California Bill SB-49 Energy: Appliance Standards and State Water Project Assessment

In October 2019, California signed into law a bill designed to provide recommendations on the improvement of grid reliability by advancing the development of smart appliances.[77] The law requires the California Energy Commission (CEC) to adopt standards for demand flexibility technologies. The regulations may include labelling provisions to promote the use of smart appliances. Additionally, the law requires that the communication protocols conform to cybersecurity protocols such as NIST's reliability and cybersecurity protocols, or the North American Electric Reliability Corporation's Critical Infrastructure Protection standards.

8.3 Programs

The following programs are voluntary programs established either by government agencies or utilities to encourage the use of smart, energy-saving devices.

8.3.1 ENERGY STAR Connected Functionality Criteria for Appliances

EPA's ENERGY STAR Program has established several product specifications with Connected Functionality criteria. These specifications include requirements for energy consumption reporting, operational status reporting, and demand flexibility capabilities, among other requirements. The program is available for dishwashers, ACs, refrigerators, clothes washers and dryers, and other products. Table 2-1, shown in Section 2.1.2, summarises the requirements for each product specification.

As discussed in Section 2.5, the prevalence of models certified with Connected Functionality is limited in the US market; only a small percentage of appliance models are certified according to the Connected Functionality criteria. However, as smart devices become more prevalent and demand flexibility programs more robust, voluntary programs such as ENERGY STAR can help promote the use and participation of these devices.

In the US, the ENERGY STAR program has demonstrated impressive success. According to its website, more than 700 utilities, state and local governments, and non-profits leverage ENERGY STAR in their efficiency programs, reaching roughly 95% of households in all 50 states. Nationwide, utilities invested $7.9 billion in energy efficiency programs in 2017.[78] In terms of recognition, more than 90% of US households recognise the ENERGY STAR label, and about three-fourths of US households report the ENERGY STAR label as influential in their purchasing decisions.[79] ENERGY STAR has become synonymous with good quality

[77] California Legislative Information, Senate Bill No. 49, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49
[78] ENERGY STAR by the Numbers, https://www.energystar.gov/about/origins_mission/energy_star_numbers
[79] *Ibid.*

products, benefiting both manufacturers who choose to participate in the program, and consumers who want to purchase high quality, energy efficient products.

8.3.2 Smart Home Energy Management System

The ENERGY STAR SHEMS Program[80] establishes requirements for energy-saving smart features designed to achieve cost savings as well as improve user convenience. This specification requires smart home service providers to include several features in their smart home package such as providing reliable occupancy detection to power down equipment when no one is home, limiting standby power of connected devices, and providing feedback to users about the energy impact of their settings. SHEMS includes several smart devices such as smart plugs, smart power strips, connected thermostats, and ENERGY STAR-certified connected lighting products. The SHEMS package also requires services such as field data reporting and grid services. As an extension of the trusted ENERGY STAR brand, this service allows for users to implement smart devices in their homes with the assurance that the system will achieve energy savings in a safe and reliable manner. The ENERGY STAR SHEMS Program has potential to encourage the adoption of smart devices and realise energy savings through intelligent efficiency and demand flexibility.

8.3.3 German Smart Grid Ready Label

The Smart Grid Ready Label[81] in Germany is awarded to AC heat pumps or water heat pumps which can communicate with the grid. Heat pumps that receive this label are capable of shutting down in the event of power shortages due to variable renewable energy production. Alternately, these heat pumps can also store excess energy when more electricity is generated than is consumed. In order to receive the label, a device must be able to operate in 4 modes based on grid signals including standby mode, thermal energy storage, space heating, and variants of storing and heating.

8.3.4 Utility and Energy Service Provider Programs

Utilities are beginning to offer devices at a reduced, if not zero, cost if a customer chooses to participate in a demand response program. BYOD programs refer to utility and non-utility programs that allow customers to purchase their own pre-approved, grid-responsive devices from a vendor of their choosing. Customers can integrate the technology into demand response or energy efficiency programs managed through the utility, an energy supplier, or a third-party systems integrator.[82] BYOD programs also utilise incentives such as technology-specific rebates or annual enrolment incentives to encourage consumers to participate in the program.

Initially, BYOD programs were more commonplace for thermostats. Customers could purchase their own pre-approved thermostats and enrol in a utility's demand response or energy efficiency program. However, some utilities and program managers are exploring

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[80] Smart Home Energy Management Systems, https://www.energystar.gov/products/spec/smart_home_energy_management_systems_pd

[81] SG Ready Heat Pumps, https://www.waermepumpe.de/normen-technik/sg-ready/

[82] Navigant Research: Feldman, B., Strother, N., Mehrhoff, J., Taylor, R. 'Bring Your Own Device DSM Programs for Utilities and Retail Energy Suppliers', 4Q 2018, https://www.navigantresearch.com/reports/bring-your-own-device-dsm-programs-for-utilities-and-retail-energy-suppliers

opportunities beyond thermostats, and offer BYOD programs for the following additional devices:

- Water heaters,
- Energy storage devices,
- Electric vehicles and electric vehicle supply equipment,
- Solar arrays and smart inverters, and;
- Smart appliances.

As BYOD programs grow, they can expand beyond utilities. Customers in deregulated energy choice markets can choose to participate in a BYOD program from their energy provider. In this case, the energy provider assumes the role of a utility, sending grid signals to a device to activate demand response capabilities.[83]

[83] Navigant Research: Feldman, B., Strother, N., Mehrhoff, J., Taylor, R. 'Bring Your Own Device DSM Programs for Utilities and Retail Energy Suppliers', Section 2.2.5: 'Non-Utility Programs'

9. Considerations for Policy Makers

This chapter outlines a set of issues that policy makers should consider when developing policies designed to stimulate or mandate 'energy smartness' within devices. These cover two aspects: the technical considerations that policies should address, and the types of policies that are available.

9.1 Technical Considerations

This section addresses the technical considerations that policies should address, drawing on various sections of this report.

9.1.1 Smart Functionalities

It is recommended that any policy include a definition of smart, and this will also serve to outline the smart functions that are being stimulated or mandated. The definition developed for this report in Section 2.3 can serve as the basis:

A smart, energy-saving device is a product that has the capability to receive inputs, including through an external network, process these inputs and independently take action, including providing information, for the purpose of one or more of the following:

- Status reporting
- Demand flexibility
- Efficient operation

Policy makers may choose to incorporate any or all of these three functions into their policy, and this will depend on policy goals and the scope of the products covered by the policy. For example, water heaters might be required to participate in demand flexibility, while refrigerators or freezers might not.

Explanatory notes relating to definition of smart:

1. "Device" means an energy-using product which is sold or provided to the user inclusive of all components required for the capability outlined above (although as noted in #4 below, some processing may be undertaken external to the device).
2. "Capability" means capability which is included in the device (although as noted in #4 below, some processing may be undertaken external to the device).
3. "Inputs" means external inputs, including via an external communications network.
4. "Process" means data processing undertaken by an internal computer processor or microprocessor. However, some processing may be undertaken externally, noting that this may have implications for overall energy usage.
5. "Independently" means independent from the user.
6. "Take action" means responding based on the results of the processing.

7. “Status reporting” means provision to the consumer, in a timely and useful and manner, of operational information related to the device, for example:

    - Alerts for conditions such as faults and excessive energy consumption.
    - Reminders to service or replace filters/refrigerants, *etc*.
    - Measured or estimated power/energy usage (with possible inclusion of energy/demand savings).

8. “Demand flexibility” means 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 jeopardised.
9. “Efficient operation” means operation of the device such that it responds to the changing conditions of the external environment, in order to maximise energy savings. This is also known as “intelligent efficiency”.
10. Note that other non-smart products may fulfil a similar role to smart devices, for example a water heater with a relay and basic communications module (but without processing capabilities).
11. In the future, additional (energy-related) functions may become available and the definition should evolve to suit these.

9.1.2 Product Scope

In principle many products can benefit from the functions of status reporting and (intelligent) energy efficiency. Regarding demand flexibility, Table 9-1 provides an indication of potential, for various device types as presented in Section 4.2 of this report. Note that end-uses not covered in Table 9-1, *e.g.,* electronics, cooking and miscellaneous loads, are assumed to have no demand flexibility potential.

Table 9-1. Device potential with regard to demand flexibility

Sources: Flexibility potential adapted from US Department of Energy (2019)[84]

Product	DF Potential			Comfort Impact	Overall DF Potential
	Shed	Shift	Modulate		
Air Conditioners (ACs)	Low	High	Low	Medium-High*	**High**
Water Heaters	Low	High	Medium	Low	**High**
Thermostats	Medium	High	Low	Medium	**High**
Battery Storage (incl. vehicles)	None	High	High	None	**High**
Electric Vehicle Chargers	None	Medium	Medium	Low	**Medium**
Lighting	Medium	None	None	High	**Medium**
Refrigerators/ Freezers	None	Medium	None	Low	**Low**
Dishwashers & Clothes Washers	None	Medium	None	Low	**Low**
Clothes Dryers	Low	Medium	Medium	Medium	**Low**

* Comfort impact is dependent on the heating/cooling strategies and the available thermal storage capacity in the building envelope (walls, windows, and roof)

9.1.3 Communications Protocols

Policy makers should consider requiring the use of open protocols for both the network and application layers of smart, energy-saving devices. Network layer protocols are used by the product to transmit and receive information (*e.g.,* Wi-Fi, Zigbee, Bluetooth, *etc.*). These should be open protocols which are widely used in the market, and which minimise the need for the consumer to purchase new hardware such as routers and hubs.

The application layer protocols used by a device will determine which other products and platforms the device can communicate with. These protocols are generally developed by device manufacturers or proprietors of smart home platforms. Careful consideration should be given by policy makers regarding ‘vendor lock-in’ effects that can occur from the use of proprietary application layer protocols.

[84] US DOE, ‘GEB’

In the past, standards/protocols have been developed by industry associations and standards bodies which were aimed at facilitating openness and including smart functions within popular application layer protocols.

9.1.4 Usability

Policy makers may also choose to incorporate useability requirements (or suggestions) into their policies, such that smart, energy-saving devices will readily 'plug-and-play', be straightforward to operate, and have the ability for the user to over-ride various inputs or the actions undertaken as a result of those inputs.

9.1.5 Data Privacy and Security

Policy makers should consider data privacy and security requirements for products. This is a complex area and is discussed in more detail in Section 3.1.

9.1.6 Network Standby Energy Use

Policy makers should place requirements on the power consumption of products when in network standby mode. Related to this, where devices undertake both internal and external processing, policy makers may wish to consider the total energy used for both (noting that operation of processing functions may mean that the device is not in a network standby mode).

9.2 Available Policy Types

In general, the goal of policies is to increase the adoption/market take-up of 'appropriate' smart, energy-saving devices, *i.e.*, products that fulfil certain requirements regarding smartness (as outlined in this report). Two approaches exist: mandate those requirements; or stimulate them. Note that these two approaches do not necessarily equate to 'mandatory' and 'voluntary' measures, *e.g.,* an energy label with information on smartness can be mandatory but does require that the products shall be smart.

If the approach is stimulating market uptake, then attention should be paid to the attractiveness to manufacturers and consumers (in addition to ensuring appropriate product smartness as outlined in this report). In the case of a mandatory approach, only the smartness requirements need to be set.

A number of available policy types are summarised below, although this is not intended to be an exhaustive list. Even though the adoption of smart, energy-saving devices is still at a nascent stage, these policy approaches could effectively leverage existing programs, collaboration among stakeholders, and other mandatory requirements.

9.2.1 Mandatory Requirements

The first policy approach to consider is mandatory device requirements. In this approach, policy makers prescribe mandatory requirements that manufacturers must comply with in order to sell their products. Such requirements could be included in minimum energy performance standards (MEPS) that many countries around the globe have already implemented for various products. Some of these measures also prescribe maximum network standby energy consumption limits.

Regarding device smartness, mandatory design requirements could prescribe certain smart functions that would have to be implemented in a product, *e.g.,* demand flexibility capabilities, energy consumption reporting, or (intelligent) energy efficiency. An interim step is also to include this kind of functionality as an option within a product standard.

Another option is to mandate that only connected devices (*i.e.*, those sold with networking capabilities) are required to incorporate smartness (as defined in this report) rather than all devices. For example, only network-connected dishwashers must meet the definition of smart, rather than all dishwashers.

Additionally, measures should also include (a reference to) test procedures and guidelines to verify the capability of smart, energy-saving devices. For example, the ENERGY STAR Connected Functionality criteria for certain products includes a test method for validating demand response capabilities of a product.[85] These test procedures would ensure that products are incorporating smart functions as defined by the measures and could also present an opportunity to increase interoperability among smart products if a certain communication protocol is required.

9.2.2 Mandatory Labelling Requirements

Another type of mandatory policy approach is labelling. This policy could go hand in hand with mandatory design requirements, but it could also be implemented on its own. An example exists in Australia, which requires all ACs to include on their energy label whether they have the capability to participate in demand response programs (see Section 8.2.1 for more detail).[86]

This type of policy approach encourages the use of smart, energy-saving devices by highlighting the differences in offerings among products on the market. For these devices, the rating label could include the following types of information:

- Network connectivity
- Demand flexibility capabilities
- Status reporting capabilities
- (Intelligent) energy efficiency capabilities
- Compatibility/interoperability.

Depending on their performance features, different products could be required to display different types of information.

Similar to mandatory design requirements, this policy approach would require a prescribed test procedure for each labelling requirement. Moreover, this policy approach could also

[85] See the ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Test%20Method%20for%20Room%20Air%20Conditioners%20to%20Validate%20Demand%20Response.pdf
[86] Australian Energy Rating Label for Air Conditioners, http://energyrating.gov.au/products/space-heating-and-cooling

require manufacturers to provide information via marketing materials. This would allow for consumers to easily identify devices that offer smart capabilities.

9.2.3 Voluntary Measures

The next policy approach is to establish voluntary measures. The primary example of this is a voluntary label. There are (at least) two options: include smart, energy-saving device requirements in an existing label specification (*e.g.,* Australia for ACs) or develop a separate label for smartness. Currently, certain ENERGY STAR specifications use the former of these approaches. They include optional Connected Functionality criteria requirements for devices to include smart features such as network connectivity, demand response capabilities, energy consumption reporting, operational status reporting, and specific communication protocols.

9.2.4 Incentive Programs

Another approach to encourage the adoption of smart, energy-saving devices is through incentive programs. In some countries, utilities offer financial incentives to consumers to participate in programs that encourage energy savings or demand flexibility. Additionally, in some countries, Federal or state governments, quasi-government organisations, or non-governmental organisations (NGO) offer incentives for participation in energy efficiency measures via tax credits, rebates, and/or subsidies.[87] To encourage the adoption of smart, energy-saving devices, such incentive programs could be developed that would encourage consumers to purchase such devices for their homes. As with mandatory and voluntary policies, product eligibility criteria and compliance regimes should be integral to these programs.

9.2.5 Industry Self-Regulation

A final type of policy approach is industry self-regulation, *i.e.,* industry develops requirements for a certain product group and monitors and enforces these requirements themselves. Typically, self-regulation measures are a form of voluntary agreement designed for specific products or specific features, *e.g.,* device smartness. In most cases, industry is represented by their industry organisation(s), *e.g.,* AHAM for household appliances in the US or Digital Europe for consumer electronics in the EU.

In the EU self-regulation initiatives are an alternative to ecodesign measures, provided a number of conditions are met amongst others that the signatories should at least cover 80% of the market. In practice this means that establishing a self-regulatory initiative becomes more difficult as more manufacturers are involved. Currently three self-regulatory initiatives under ecodesign exist: game consoles, complex set-top boxes, and imaging equipment. In the US manufacturers and energy efficiency advocates can negotiate a voluntary agreement on energy efficiency requirements for a product, which then can be endorsed by DOE; examples are voluntary agreements on set-top boxes and small network equipment.

Industry self-regulation on device smartness could include the same type of requirements as mandatory requirements or labelling/information requirements discussed in previous sections 9.2.2 and 9.2.3, respectively. The main challenge is likely to be achieving sufficient

[87] Super-efficient Equipment and Appliance Deployment ('SEAD'), 'A Global Review of Incentive Programs to Accelerate Energy-Efficient Appliances and Equipment', August 2013, https://ies.lbl.gov/sites/all/files/lbnl-6367e.pdf

market coverage. This is easier if the voluntary agreement is restricted to a certain product group, *e.g.,* residential air conditioners, compared to a voluntary agreement that covers smartness horizontally across multiple product groups.