DEMAND SIDE FLEXIBILITY THROUGH SMART HOMES

2017

DEMAND SIDE FLEXIE
THROUGH SMART H

2017

This study was carried out for ESMIG, Energy@Home and EEBu
by Joule Assets Europe and VaasaETT. The views expressed
document represent the findings of the study, and do n
represent the views of ESMIG, Energy@Home or EEB

Table of Contents

Table of Contents 3
List of Figures 4
Executive Summary 5
Section 1: Demand Side Flexibility and smart appliances in Europe 11
1.1 Introduction 11
1.2 Regulatory Context 12
General background 12
Timeliness of this study 15
1.3 The wider business context 16
Section 2: Study Definitions and Methodology 18
2.1 Definitions of key terms 18
2.2 User Stories 22
A. Smart meter rollout, dynamic pricing, control 22
B. Energy savings and demand response 23
C. Self-sufficiency: SME business development 24
2.3 Methodology 26
Source of pilot and consumer behaviour data 27
Quantification of Implicit Demand Response benefits 29
Section 3: Cost Benefit Analysis Results 36
3.1 Results: Demand Side Flexibility 36
Findings in detail 42
3.2 Automated Energy Efficiency 44
Findings in detail 45
3.3 Aggregated Costs and Benefits 47
Findings in detail 48
3.4 Results per household type 51
3.5 Energy and Capacity Savings 54
Capacity Building (MW) 54
Energy savings (MWh) 56
3.6 Relational sensitivity analysis 57
Section 4: Market Participants Benefits from smart appliances 60
4.1 Purposes of DSF from utility perspective 60
Retailers (and/or BRPs) 60
Transmission system operator 61
Distribution system operator 62
Aggregators for domestic consumers 62
5. Conclusions 64
ANNEX I: List of acronyms and key terms 65
About the Consultants 72
VaasaETT AB OY 72
Joule Assets Europe AB OY 72

List of Figures

Figure 1: Types of demand side flexibility included 19
Figure 2: The value of IDR & EDR per million households 37
Figure 3: The costs and benefits of EDR enabled through smart appliances 39
Figure 4: The costs and benefits of IDR enabled through smart appliances 40
Figure 5: IDR, EDR and societal benefits and related costs per million households 41
Figure 6: Costs and benefits enabled through automated energy efficiency using smart appliances 45
Figure 7: Full consumer benefits and costs per country 47
Figure 8: Full consumer benefits and costs per million households 48
Figure 9: Full benefits including societal benefits and related costs per country 50
Figure 10: Average annual household consumption per consumer group 51
Figure 11: Costs and benefits per million households per consumer group 52
Figure 12: Average load curtailment potential at TOP 500 hours in MW 55
Figure 13: GWh savings in energy efficiency per country 56
Figure 14: Relationship of uptake rates, total consumer benefits, benefits per household, payback time and costs 57
Figure 15: Relationship of household consumption, total consumer benefits, benefits per household, costs, and payback times 58
Figure 16: Relationship of electricity price benefits per household and payback time 59
Figure 17 Relationship of DR market opening, societal benefits and benefits per household 59

Executive Summary

This study quantifies the costs and benefits of demand side flexibility and energy savings through the ubiquitous rollout of smart appliances at a national level. The quantification is carried out within 4 EU Member States, France, Germany, Italy, the UK, and a reference country combining the most beneficial characteristics of each Member State. As a basis for the calculations, the study uses hourly market values and actual household consumption patterns. In order to model demand side flexibility, the averaged results of 140 residential pilots were used. What the study does not calculate or take into account is the benefits that would accrue to the network operators on the low and medium voltage systems. These calculations therefore in fact significantly underestimate the future potential benefits for the networks, given the introduction of electric vehicles, and the low voltage intermittent distributed generation.

Therefore, this study answers 2 important questions: If smart appliances were [illegible] the financial benefits for the participating consumers and society, against the actual cost of the smart appliance technologies? What amounts of flexible capacity (MWs) and energy savings (MWhs) could these appliances enable?

The findings were calculated assuming the full range of markets and programme types was open and available to consumers in accordance with the requirements of the Energy Efficiency Directive and the Network Codes.

The findings indicate that by creating demand side flexibility through smart appliances, these appliances have a significantly shorter payback time than almost all forms of generation. While a solar panel in Portugal today will require approximately 6.5 years to pay back, a coal or gas fired plant 25 to 30 years in Germany (at best) and a nuclear generator will simply not pay; the average time required to pay back smart appliances is between 1.2 and 3 years depending on the Member State, without including the value of societal or industry benefits. If surrounding benefits are included, payback time is under a year for the majority of consumers. This is less time than it takes to pay back an average energy efficient light bulb on a commercial site

Benefits accumulate over time while the purchasing decision is taken once. For example, if 30% of UK households made full use of smart appliances for creating flexible demand [illegible], the UK would have the potential to [illegible], the

consumer participation would create 1,198 MW of total flexible capacity with a payback time of 3 years. This is the equivalent of 2.3 500-MW power plants. Today these same plants are considered non-viable in the UK, due to the low market prices. Therefore, while a capacity resource from smart appliances could be paid back within 3 years at these same market prices, power plants are not viable even if investors will finance them for decades. Indeed, in response to this issue, the UK government has decided to subsidise generators through a capacity market.

Similarly, annual savings in Italy would be [illegible] billion [illegible] 10 years. The demand side flexibility created would be 1,227 MW of total capacity, with a payback time of 2.2 years for the technologies required. This is equivalent to 2.5 500-MW coal or gas fired plants.

In Germany [illegible] annually [illegible] Smart appliances could create 1,705 MW of flexible capacity, equivalent to 3.5, 500-MW power plants. All with an average payback time of 1.9 years, the building of comparable new generation capacity is considered impossible in Germany, due to the low electricity prices. Like the UK and France, the German government is therefore looking to subsidise generators through a new capacity market.

If the same percentage of French households had smart appliances, the total savings of [illegible] billion annually. Over 10 years the savings would be [illegible] billion. With a 30% uptake rate, 2,933 MW of total flexibility would be created with a payback time of an average of 1.2 years in France. This is the equivalent of almost 6 500-MW coal or gas fired plants or 3 nuclear power plants. Again, today EDF has requested subsidies in the form of a French capacity market, due to the impossibility of maintaining their nuclear fleet at today's prices. Yet smart appliances could be paid off in less than two years, with the exact same prices French generators find inadequate

Figure 1: Full benefits including societal benefits and related costs per country

Payback times	FRANCE	UK	ITALY	GERMANY	REFERENCE
Years:	0.8	1.2	1.0	0.9	0.6

Though smart home and appliance programmes would cost to rollout, sell and run, these calculations are still conservative, they include no avoided costs in network upgrades or indeed the cross-border benefits ‘ ˆ ‘ • ‡ … ‘ — • – ” › ï • ‡ ˆ ˆ ‹ … ‹ ‡ • … › Ž ‘ ™ ‡ ” ‹ • ‰ „ ƒ Ž the neighbouring country. Therefore, rolled across Europe, improving the intelligence of the European home is as good or better an investment than many other similar programmes.

However, though this study finds that the results of this cost benefit analysis are overwhelmingly positive, challenges remain and certain key lessons are described below:

1. Overcoming challenge of the purchase decision:

Uptake rates drive down costs by creating economies of scale and supporting the growth of service providers. There is also a direct correlation between the number of people actively using smart appliances and the development of societal savings and environmental benefits. Yet a positive cost benefit analysis at a national level, does not equal a compelling sales proposition for a single household. Moving consumers to a

purchase and implementation decision on the merits of energy related services alone will remain a challenge. The issue should therefore be addressed directly within the industry and at the regulatory level.

a. Smart technologies should be made ubiquitous and intelligence built into appliances. As there is a realistic and viable opportunity for the majority of European consumers to optimise their electricity (and gas) consumption at home, saving between 10% and 20% on their energy bills, it is highly logical to build intelligence into appliances and ensure interoperability from the start. Consumers should not be required to purchase such kits separately.

b. Multi-purpose service packages may be more compelling to buy than a purely energy centred offering. This does not have to be a barrier to roll out. Internet and communications companies bundle smart home applications with internet and phone services, security firms bundle warnings concerning faulty appliances and control capabilities with security services, health service companies (particularly for the elderly), bundle communication, control and warnings to the occupant and caregivers. Circumstantial evidence suggests that these offerings already compete today with those offered by utilities and will continue to do so.

2. Open competitive markets

Holistic regulatory support has been drafted by the European Commission and should be further refined and implemented at a national level. Today in Europe, the benefits quantified here are impossible to achieve, no matter the technologies in place, due to prohibitive regulatory barriers in the balancing markets and a general lack of dynamic pricing offers in the retail markets. This should change.

a. Participation regulation: While some markets are shut entirely to consumer load, other markets are open in theory but not in fact, for example they • *f* › î *f* Ž Ž ‘ ™ ï consumer load to act as a resource but require a consumer to inform the TSO weeks or even a month in advance, how much electricity they will be using each hour of each day. When these obvious barriers are removed, more subtle forms of bias often remain, such as only allowing consumers to participate during particular hours (unless they work with the national utility in which case these rules no longer apply), or paying consumers less MW for MW, than a generator providing the same quality service.

b. Healthy competition: Motivated service providers are key for market growth. However, independent retailers and aggregators may have difficulties entering a country due to biased market design which, for example, provides access to energy at higher costs and at shorter notice to them than to the established players, or makes gaining access to high quality meter data more complicated for a new entrant retailer than an established player or creates prohibitive barriers toward aggregators blocking them from offering consumers services at all.

The list of barriers is long. In short as governments and regulators want consumers to have access to services, they must continue to fight for consumer rights to access markets and encourage market competition between service providers including incumbent utilities, new entrant retailers and aggregators

3. Supported as a public service

The societal benefits created through demand side flexibility significantly outweigh the benefits to the households participating in the programmes. In other words, these consumers do even more good for society than they do for themselves. For example in France, consumers with smart appliances could earn B Z] million from DSF (not counting energy efficiency programs), while the societal benefits of the lowered clearing prices (through DSF) would be B 523 million annually. These benefits are spread across all consumers. In the UK, the difference is also dramatic, participating consumers earn B Y [ ] million while from DSF the societal benefits are B 334 million annually. In Italy, direct earnings for participating consumers are B 134 million while societal benefits are B 387 million, and in Germany participating consumers could earn B Z a ` • ‹ Ž Ž ‹ ‘ • † ‹ ” ‡ … – Ž › ™ Š societal benefits are B \ `.`

The calculations of societal benefit in this study are conservative, as the clearing cost reductions from energy efficiency, lowered distribution and transmission costs, the impact of programmes related to gas usage and cross boarder benefits have not been included. Therefore, the discrepancy in payments to participating consumers compared with societal benefits, would increase if a wider analysis was performed.

In this sense consumers, which participate in DSF programs are providing a public good. Smart appliances are key, enabling technology for this public good. This should be acknowledged through public support, for example by including smart appliances in white or green certificates programmes, encouraging participation in capacity markets and other forms of public acknowledgement

In conclusion: Smart meters and smart appliances are essential means for energy savings and for the further development of new energy services, dynamic prices and demandside flexibility programmes. DSF and home optimisation enabled through smart appliances are highly competitive when compared to either generation assets or indeed most energy efficiency measures.[1] In the ongoing deployment of the smart electricity metering infrastructure, not only the general roll-out is important but also the functionality of the meters themselves. A high frequency at which data can be updated and made available, as well as a standardized interface for the visualization of electricity consumptions, market conditions and price options, are fundamental to enable consumers to participate in the flexibility markets. The programmes they drive also provide significant benefits to society. That said, creating benefits in total is not the same as providing an immediate compelling salesoposition to individual consumers. Therefore, smart appliance capabilities should be built in to all appliances and communication interoperability should be insured. When this takes place, communications, health and security firms as well as retailers and aggregators will create viable bundled services with greater ease, ensuring significant uptake and usage. The European Commission and National Governments should enable this development through including smart appliances in public energy efficiency schemes and continuing to work toward open, competitive and consumer centric market structures

[1] As an investor, Joule Assets has a database of energy related investments and their return times. These comparisons are taken from this internal information.

Section 1: Demand Side Flexibility and smart appliances in Europe

1.1 Introduction

• ‡ ” ‰ › ‡ ˆ ˆ ‹ … ‹ ‡ • … › Š ƒ • „ ‡ ‡ • … ƒ Ž Ž ‡ † î th Š ‡ – b y Ž h e E ‰ r ” p e a n • ‘ ’ – ‹ ‘ • ï ƒ • Commission. It is quantifiably the cleanest and cheapest energy resource available to us today and therefore benefits from strong regulatory backing both at national and European levels.

At the same time, growth in renewable electricity generation brings with it an increasing need for demand side flexibility to lower the cost of solar and wind integration and avoid the need for unnecessary back up generation – generation used for only short periods of time. The ability to both increase and decrease demand is an important and price competitive resource in providing balancing services. TSOs benefit directly from increasing the liquidity of their balancing portfolios and lowering costs, when they enable demand side resources to participate (though they often also incur an upfront investment costs in IT improvements). Multiple successful trials and rollouts have been completed quantifying the potential of demand side flexibility (DSF) within the residential homes. Therefore, there is a recognized, robust and growing need for flexible demand side resources, at the same time as the costs of residential participation is being reduced.

Residential participation is strongly supported today by a complimentary set of regulations, which provide end-to-end support for deployment, though many of these new rules have yet to be implemented. However, within the last three years, European legislation has progressed from stating that energy efficiency and demand side flexibility are important in principle to creating a cohesive set of regulatory initiatives providing a comprehensive foundation for market growth. This is an achievement in its own right.

This study quantifies the costs and benefits of demand side flexibility and energy savings made possible through the ubiquitous rollout of smart appliances, at a national level. The quantification is carried out within 4 EU Member States, France, Germany, Italy, and the UK, and a reference country (best case) where beneficial characteristics of each Member State is combined. As a basis for the calculations, the study has used market values and actual household consumption levels for those same years. In order to model demand side flexibility, the averaged results of 140 residential pilots (involving over 950,000 households) were used.

Therefore, this study answers 2 important questions: If smart appliances were — „ ‹ “ — ‹ – ‘ — • – ‘ † ƒ › á ™ ‹ – Š – ‘, what would the financial benefits for ‡ • the participating consumers and society, against the actual cost of the smart appliance technologies? What amounts of flexible capacity (MWs) and energy savings (MWhs) could these appliances enable?

The findings were calculated assuming the full range of markets and programme types, were open and available to consumers in accordance with the requirements of the Energy Efficiency Directive and the Network Codes. These include Implicit Demand Response, in the forms of Real Time Pricing (RTP) and Critical Peak Pricing (CPP) and Explicit Demand Response within the balancing and ancillary services markets (wholesale markets were included within the implicit programme analysis). This free access to market is of course not the case today as household consumers have little access or market power or viable services available to them. Therefore, the findings highlight the value of implementing legislation at a national level as well as the smart infrastructure investments required for enabling the smart appliance technologies

The content of the study is organized as follows: Section 1 explains demand side flexibility in the smart home/smart appliance context, describing the types of services analysed; Section 2 describes the aims and the methodology of the study, Section 3 highlights the main findings, concerning costs and benefits of both implicit and explicit demand response, energy savings at a national and societal level. Lastly it provides the conclusions.

1.2 Regulatory Context

As stated above, for the first time, the European Commission has completed a set of regulatory and policy initiatives which lay the foundation for comprehensive growth. Below is a short overview of the main regulatory initiatives in place today and their main contents.

General background

In 2009, the European Council agreed to the long-term objective of reducing EU greenhouse gas emissions by at least 80-95% by 2050, compared to 1990 levels. In October 2014, the 2030 policy framework for climate and energy was adopted, in which the EU committed to reduce greenhouse gas emissions by 40% compared to 1990 levels by 2030, to achieve at least 27% renewable energy capacity but without country specific

targets and 27% energy savings compared to 2007.[2] In order to make this commitment a reality, the European Commission presented roadmaps for a competitive low carbon economy, resource efficiency, energy and transport.

Framework Strategy for the Energy Union, the European Commission (EC) sets the vision for the future and integrates a series of policy areas into one cohesive strategy. Š ‡ ï • ‘ • • — • ‹ … ƒ – ‹ ‘ • … ‘ • • ‹ † ‡ ” ‹ • ‰ î ” ƒ • ‡ ™ ‘ ” • – ” ƒ – ‡ ‰ › ˆ ‘ ” Union with a Forward ‘ ‘ • ‹ • ‰ Ž ‹ • ƒ – ‡ Š ƒ • ‰ ‡ ‘ Ž ‹ … › ï states that Z X Y] ` X ˆ ‹ • ƒ energy markets and power grids have to be capable of integrating renewable generation. It also states that energy markets should promote competition and enable a level playing field for a range of resources, including renewable and demand side resources. Within this context, smart appliances enable the more efficient use of on-site generation assets and allow the consumer to participate in these markets along with service providers through Demand Response. ò Š ‡ ‘ • • ‹ • • ‹ ‘ • ™ ‹ Ž Ž … ‘ • – ‹ • — ‡ – ‘ ’ — • Š ˆ ‘ ” • and to support the national roll-out of smart meters and to promote the further † ‡ ˜ ‡ Ž ‘ ’ • ‡ • – ‘ ˆ • • ƒ ” – ƒ ’ ’ Ž ‹ ƒ • … ‡ • ƒ • † • • ƒ ” – ‰ ” ‹ † • á • ‘ – Š ƒ – ˆ Ž ‡ š (...) "However, this will only work if market prices send the right signals."

The Energy Efficiency Directive (EED)[3] looks to establish a common framework of measures for the promotion of energy efficiency within the European Union. This was to secure – Š ‡ • ‹ ‘ • ï • target Z X Z X of a 20% for energy efficiency. Applicable measures included:

- If Member States roll out smart meters they should ensure that the metering systems provide final customers information on actual time of use, thereby supporting demand side flexibility programs.
- If final consumers request it, metering data on their electricity input and off-take should be made available to them or to a third party acting on their behalf.
- Member States should ensure that Demand Response is enabled both within the wholesale and balancing markets. This includes:

  Requiring network operators to treat DR providers in a non-discriminatory manner and

  - Ensuring technical modalities defining the demand side participation in balancing, reserve and other system markets are defined on the basis of

[2] Vito, Viegand & Maagøe, Armines and Bonn University (2016): Ecodesign Prepatory Study Smart Appliances (Lot 33). P. 10

[3] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

the technical requirements and capabilities of demand response (rather than generation assets only) - in cooperation with aggregators,
- Allowing aggregation and enabling aggregators to participate in these markets
- Ensuring that tariffs allow suppliers to improve consumer participation in

demand response, depending on national circumstances.

The Energy Efficiency Directive was therefore the first Directive to define consumer rights for participation within the energy markets. These principles have been built upon in the following Directives and Network Codes.

The Internal Market-legislation [4] further develops common rules for the internal electricity market, which include

- Market design shall encourage competition also between differing resources, including demand side resources.
- 80% of the consumers shall be equipped with intelligent metering systems by 2020 (where roll-out was assessed positively).
- Member States shall ensure that customers are entitled to receive all relevant consumption data, enabling them e.g. to improve efficiency and to participate in demand response programs [5].

Network Codes: One of the objectives of the ENTSO-E Network Code on Electricity Balancing is to facilitate participation of Demand Side Flexibility, including aggregation ^ƒ…‹Ž‹–‹•ƒ•†‡•‡”‰›•–‘”ƒ‰‡•—’’‘”–‹•‰–Š‡ƒ…Š‡ƒ˜‡•‹•
penetration of renewable generation. The Codes have been critical for the deployment of Demand Response as they take the principles outlined in the Energy Efficiency Directive and incorporate them into the full set of Codes used by TSOs across Europe for their cross-border balancing services. National TSOs use these as the basis for their own

[4] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC

[5] Also, related to metering, the Commission has issued on 9 March 2012 a recommendation on preparations for the roll-out of smart metering systems (2012/148/EU). It describes the minimum functional requirements for the smart metering system including: 1) Provide readings directly to the customer and any third party designated by the consumer by provision of standardised interfaces for ‡•‡”‰›•ƒ•†‡•‡”‰›•–‘Ž—–‹‹–‡•‘”•‹•–‡”ˆƒ…‡•2) Update the readings frequently enough (every 15 minutes) as a general rule. 3) Smart metering systems should include advanced tariff structures, time-of-use registers etc. to achieve energy efficiencies and reduce the peaks in energy †‡•ƒ††‡ƒ† (Vito 2016)

national codes as well. In their current form (at date of writing not all Codes are finalized) they include the requirements for grid connections, participation in balancing markets, communication and security provisions for demand facilities, and establish a common framework for connection agreements between the demand facility owner or the distribution system operator vis-à-vis the transmission system operators.

Energy Performance of Buildings Directive 2010/31/EU (EPBD) replaces Directive 2002/91/EC and defines a more ambitious framework to improve the energy efficiency of EU buildings in the light of the experience gained and progress made during the application. The Directive outlines the need for connectivity between buildings and the grid (smart, flexible buildings) in order to promote the efficiency of the system and the integration of intermittent renewables.

Appliances are the key for empowering residential and SME consumers to participate fully in the energy transition. The Ecodesign and Energy Labelling Directives are the core pieces in a comprehensive set of initiatives governing the energy markets and networks as a whole and provide guidance for the supply and demand side of smart and energy efficient appliances.

The Ecodesign Directive sets out standards for the energy efficiency of products. Ecodesign "contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply"[6]. The Ecodesign Directive • ‡ – • – Š ‡ ˆ ” ƒ • ‡ ™ ‘ ” • † ‡ ˆ ‹ • ‹ • ‰ – Š ‡ ò ” setting mandatory requirements to improve the environmental impact of products. The requirements are established in implementing measures (regulations) or, alternatively, voluntary agreements. The Energy Labelling Directive creates standards for labelling, helping consumers identify products with high environmental performance. It creates – Š ‡ ˆ ” ƒ • ‡ ™ ‘ ” • † ‡ ˆ ‹ • ‹ • ‰ – Š ‡ ò ” — Ž specific ˆ ” ‡ ‡ • ‡ ™ ‘ ” • ‡ ‡ ‰ ‡ ’ ” ‘ † — … – legislation on standardized information regarding the consumption of energy, water and other resources.

Timeliness of this study

Therefore, for the first time, there is now a set of Codes, Directives and Communications covering the full value chain, from energy market design to appliance labelling, which support the participation of demand side resources in the energy markets, through smart

[6] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, Article 1.

appliances and other technologies. This adds relevance to a study covering the potential costs and benefits of these capabilities. The study covers the full range of smart appliance enabled programs, including energy efficiency, Implicit Demand Response (IDR) in the form of Real-Time Pricing and Critical Peak Pricing, and Explicit Demand Response (EDR), i.e. balancing and ancillary services for TSOs.

1.3 The wider business context

This study provides a carefully quantified analysis of the costs and benefits of energy related services in the form of Demand Side Flexibility (DSF) through smart appliances. However, early anecdotal evidence suggests that demand side flexibility and improved energy controls are often not sold alone, rather they are sold within a large Smart Home package as part of a wider set of services. By necessity therefore, this study is incomplete as both the costs and benefits are centred on energy management and energy efficiency but in reality, these capabilities may well be sold to the consumer as part of a service package, a package which may include security services, health services, general home automation services, information and connectivity services, etc.

Indeed, today machines are able to communicate with each other, with their owners and also to receive and send messages to the outside world. This is all done in coordination with the movement of the sun, wind, or the stock market, or a patient's state of health, a security concern, the owners expected schedule and so on. The capabilities do not stop with energy management.

However, this focus on measuring energy savings is not without its problems, as it also plays into an industry culture which is used to thinking of itself as autonomous public utility providing the must-have service of electrification. However, if industry trends continue, this autonomy may be farther and farther from reality. On top of a natural increase in energy independence among home owners, utilities are competing in a crowded smart home industry: security firms, IT giants such as Google and Apple as well as health and human service providers are all already in the space and have a wealth of experience in customer service and business development.

Due to the important legislative effort behind the development of smart home and consumer access to energy related services as well as the significant potential benefits to energy management and savings can bring to society, it is non-the-less relevant to understand the potential value of the energy component of a smart home. That said, this study neither reflects the likely value chain within the market or the full value of the

product, nor the full range of products and services available. Rather it carefully quantifies the value of smart appliance enabled energy savings and energy management services as well as their benefits to the wider society.

Section 2: Study Definitions and Methodology

Section 2, provides a discussion of key terms and three descriptive User Stories meant to illustrate how and why consumers engage in smart appliance related programs. Finally the study's mathematical methodology and key assumptions are explained.

2.1 Definitions of key terms

Below are relevant definitions to the study. A full list of key terms can be found in Annex I. For the purpose of this cost benefit analysis, we use the definitions of smart appliance found in the European Commission preparatory study for ecodesign:[7]

Smart appliances: î Š ‹ • ‹ • † ‡ ˆ ‹ • ‡ † ƒ • ƒ • ƒ ' ' Ž ‹ ƒ • … ‡ – Š ƒ – • — ' ' ' " – • ‡ • (DSF):

- It 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);
- Š ‡ " ‡ • ' ' • • ‡ ‹ • ƒ … Š ƒ • ‰ ‡ ' ^ – Š ‡ ƒ ' ' Ž ‹ ƒ • … ‡ ï • The ž ‡ … – " ‹ … ‹ – … Š ƒ • ‰ ‡ • – ' – Š ‡ … ' • • — • ' – ‹ ' • ' ƒ – – ‡ " • ƒ " ‡ ™ Š ƒ – ™ ‡ … ƒ Ž Ž 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 in time by the consumer or a service provider

The flexibility potential of a group of appliances is defined by two parameters:

- î shifting potential = amount of energy that can be shifted, expressed in [MWh/h].
- Average maximal shifting period = average maximum number of hours [h] that appliance can be shifted (i.e., to consume later/earlier in time than initially planned)

Smart appliances may include all controllable devices within a home which consume electricity (or gas), such as heating, cooling, hot water boilers, ventilation systems, dishwashers, fridges, freezers, dryers etc.

Demand side flexibility programs included

[7] Vito (2016)

Smart home technologies enable a range of energy saving and energy management services. Today, demand side resources (including household consumers) are participating successfully in the full range of energy markets from the wholesale market, where prices are known the day before, to the frequency services, which require second by second controls.

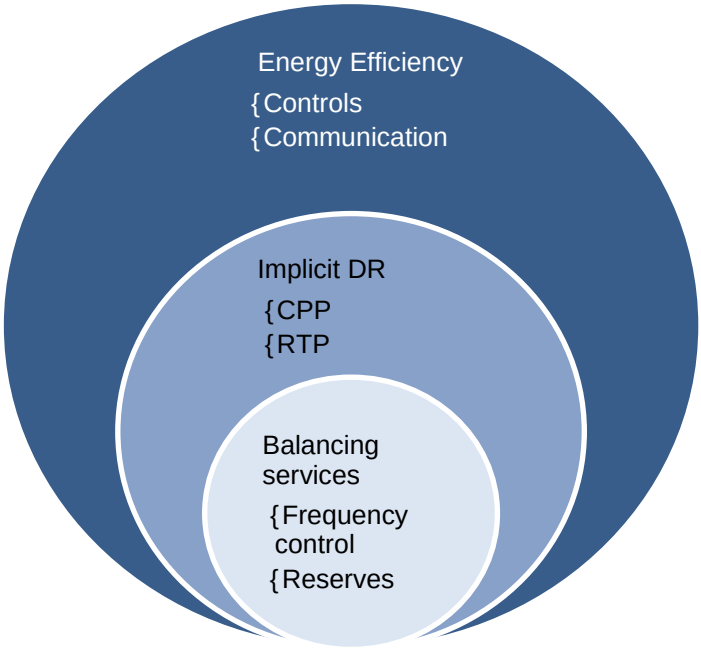

Figure 1: Types of demand side flexibility included

Below is a short description of the demand side flexibility programs covered. They include automated energy efficiency through improved controls, the Implicit Demand Response programs, Real Time Pricing (RTP) and Critical Peak Pricing (CPP), and services sold to the TSO to lower the cost of balancing. These explicit DR programs are those covered in the Network Codes: tertiary reserve, secondary reserve, primary reserve and for the UK, the triad program.

Automated Energy Efficiency (consumption optimization): With the support of smart appliances home automation, control and information are combined to lower the total consumption of the home or to optimise energy usage. The intelligence provided by the systems increases awareness but also enables sustainable choices. It is the difference between trying to remember to turn down the heat before going away for the weekend and having the central heating and hot water turned down every time the occupants are absent, e.g. every time they are at work. These same controls then warm the building again before they return. In cold climates, improved control and automation is critical it is highly unpleasant to return to a cold home after work. In this case, having the ability to