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# Smart home and appliances: State of the art

*Energy, Communications, Protocols, Standards*

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# Contents

## Abstract

This report aims to give an overview of the whole smart home ecosystems with a focus on the energy implications that incur from it. Throughout the report a focus is being given on how are the conditions for a successful roll-out of smart home technologies in Europe, what type of Information and Communication Technologies, Energy policies and Standards are in place regarding the Smart Home environment. The status of the European market is given a look into, regarding the smart readiness of EU Members States, Internet Access, Smart meter roll-out, Demand Response or the Smart Appliances market.

An outline of the Smart Appliances and Smart Home Technologies is given with also the types of networks, smart home wireless technologies and sensor types to be used in the Smart Home.

Finally the report addresses the potential energy savings to be achieved within the Smart Home environment.

# 1 Background and Introduction

The present report will focus on evaluating, the State of the Art in Smart Homes, Smart Appliances and connected devices and associated energy savings deriving from the use of such products, looking into its policy framework, market analysis and technical characteristics of the Smart Home ecosystem.

The methodology for the collection of information consisted in literature review existing on three main topics. Smart Homes and Smart Appliances features, interconnectivity and market evaluation; Smart Energy Feedback Systems, potential savings and market evaluation and Demand Response in the Residential Sector. The report aims to evaluate the state of the European Market to accommodate Smart Appliances and Smart Home technologies through the analysis on how the market is presently, how the regulatory framework is established and how the infrastructure is being outlined.

In terms of policy, the drive being made by the Energy Efficiency Directive, the Energy Performance of Buildings Directives on the information for consumers, and the roll-out of smart meters should present an added value on the dissemination of smart appliances and other smart home products in the European market. The same can be said of policies like the Digital Single Market framework policy that encourage the increase of smart connected devices within the household environment.

For a successful deployment and use of technologies like smart appliances and home energy management systems within the smart home there are several conditions that should be in place. The roll-out of smart meters, the existence of smart grids, an unobstructed market for Demand Response and the access of a fast internet access present itself as some of the most important. The European legislation has been taking solid steps to achieve this state. Weather through the Energy Efficiency Directive and the Directive for the common rules for the internal market in electricity and gas or the Digital Single Market Strategy are some of the most noteworthy policy diplomas that can help to achieve a status of “smartness” within the energy market and keep up with the technological changes being developed within the private sector. This will allow for a slow but steady change of paradigm where energy consumers pass from a passive to an active state within the energy system.

Consumer electronics have gained a big evolution in the last years, mainly pushed by the developments in personal computers from the 90’s and 2000’s. Firstly for work purposes with the advent of word and data processing tools, and then for entertainment and other uses like communication, with the globalization of internet services. One of the main reasons for such adoption was that the infrastructure for the implementation of such technologies was mainly dependent of the individual. In the case of smart appliances and the smart home, this is not necessarily the case. A smart home needs to interact with several agents in order to reach its full potential, such as energy or internet providers.

Buzzwords like Smart Homes, Smart Cities or Internet of Things have been populating lately the policy documents and society in general. More and more, with the advent of the smartphone and the massification of personal computers all over the world, being connected to the internet has passed from a work related need for almost a basic need in the developed world. Even if there have been solutions for smart homes, through home automation from the start of the 21st century, the consumers market has not embraced these solutions fully and only now, with the omnipresence of the smartphone, there are signs of a slow uptake of smart home technologies.

Smart appliances and Smart home devices like smart thermostats or smart plugs are for some years now becoming more and more present as an offer for consumers and some of the benefits that can be withdrawn in terms of energy savings are somehow noticeable, even if its full potential is still to be achieved.

In order for these technologies to achieve its potential is directly associated to a myriad of elements that cannot be overlooked. A smart energy grid with sufficient flexibility to house the needs of its consumers is needed and smart meters are necessary for this change but are not enough.

One of the main challenges in the smart home market is the amount of different communication standards and protocols that are being used for devices to communicate among themselves. Work is being done in order to make the devices “talking” with each other, through standardization bodies, policy makers and industry associations.

Another challenge for the proliferation of the smart connected devices within the households is a DYI mentality associated with the installation of these devices. A learning curve for users is needed and user-friendly interfaces with plug and play characteristics are critical for a smooth uptake of these devices.

With the rising costs of energy, the technological advances and the improvement of lifestyle of people and the fact that big consumer companies are entering the smart home ecosystem, may allow for an easier adoption, with smart home solutions coming as an added feature within the whole entertainment and personal use characteristics.

Smart home technologies set up new business opportunities for several sectors in the IT space with some of the potential benefits for the final users can be the improvement of convenience by the automation of mundane actions, the customization of living spaces adapted to ones’ needs, potential energy consumption and cost savings or an increase in security and safety of the home environment.

On the other hand, security is also one of the concerns when turning a household into a smart home. Other potential risks and hurdles to a full adoption of smart home technologies may be related with interoperability of the different devices, aftermarket support requirements or the increased price of these devices that may deter consumers of a faster adoption.

The conditions for the adoption of smart home technologies in a large scale are already available, in its most part, as can be assessed during the present report. But still there are some steps that are needed to be taken in order for this to become a reality. The agents working in the smart home ecosystem, from policy makers to telecommunication providers, city authorities to energy companies need to be working together in order for this technology to present itself as a valid, societal change and not be seen as a novelty or just a fad for the next gadget to eventually be forgotten.

# 2 Policy Context

There are two main policy fields that frame the subject studied in this report. Energy and Information and Communication Technologies (ICT). In this section an overview is given on the European policy in place for the regulation and promotion of smart appliances and smart connected homes, which somehow complement each other as for a strong smart energy and smart home market is laid on a policy framework that promotes a more efficient energy consumption with the aid of ICT where a two-way communication between the energy infrastructure and the final consumers is made in a seamless way.

The roll-out of a smart meter infrastructure, the development of Demand Response in electricity networks and products efficiency, along with the universal access of fast internet connections are the main policies that will allow for a connected energy system on behalf of the final consumers along with the connection with other connected devices.

Policy makers are looking into technology as a way for growth and connection between citizens. The policies now in place for helping to create framework platforms in order for the joint efforts of private developers and professional and standardization associations can be reflected into sound policies that can serve the consumers and the general public by the development of standards and pushing policy towards the adoption of a "smartization" mentality in the current and future societies.

## 2.1 Information and Communication Policies

### The Digital Single Market Strategy[1]

Following the launch, in 2010, of the Digital Agenda, part of the Europe 2020 strategy, the European Commission has launched, in 2015, its strategy on the Digital Single Market (SWD (2015) 100 final). Laid in three main pillars, the Digital Single Market aims for:

— A better access for consumers to digital goods and services across Europe;

— To create the right conditions and a level playing field for digital networks and innovative services to flourish;

— Maximizing the growth potential of the digital economy;

Although issues like cybersecurity and the development of the telecommunications market are intrinsically connected with the subject at study in this report on Smart Appliances and the Smart Home, the Single Digital Market strategy, namely the point on Digital Economy and Society with digital services tending to become mainstream instead of the exception. The widespread adoption of smartphones and tablets has pushed a remarkable semiconductor sector growth (5% between 2010 and 20132) due to consumer demand for smartphones going reaching to more than a billion devices in 20143. The main problems outlined in the Digital Single Market Strategy are the collection, processing and the protection of data.

The lack of Interoperability and absence of Standards are seen as a hurdle for the development of the Digital Single Market. ICT standardization is seen as essential for the interoperability within the Digital Single Market, allowing for the steering of the development of new technologies like 5G wireless communications, data-driven services, cloud services, Intelligent Transport Systems and the Internet of Things.

The digitization in basic sectors are seen as crucial in the strategy namely for e-Energy as it is seen as an important sector where it is acknowledged a radical change in the energy sector where "citizens, industries and commerce will engage in active

[1] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52015SC0100

[2] Bauer, Harald et al., The Internet of Things: Sizing up the opportunity, 2014

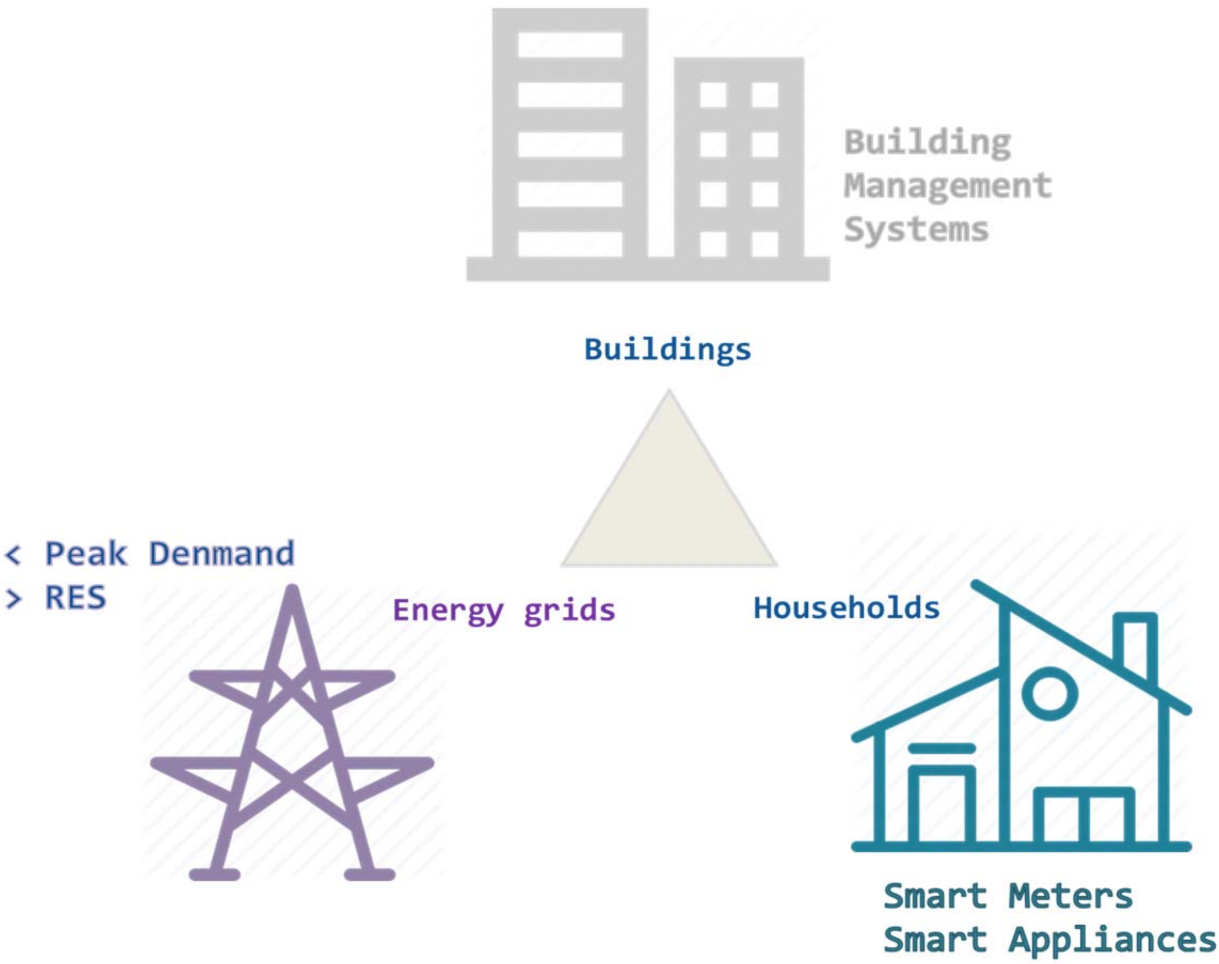
[3] Patel, Mark and Veira, Jan, Making connections: An industry perspective on the Internet of Things, 2014

management of their energy, first as consumers who adjust their consumption, but also as producers of electricity from residential, industrial or community-based renewable sources. Users and companies will be able to optimise their demand or supply of energy through different vectors and local storage, under a new energy market design as addressed in the Energy Union."

There are three interrelated areas where ICT is expected to have an impact on the efficiency of energy systems, according with the Digital Single Market strategy:

1. ICT in buildings - in the form of building management systems and sensor networks;
2. ICT in Energy Grids (Smart Grids) – In order to reduce peak demand and potentiate integration of renewable sources;
3. ICT in households – With the introduction of smart meters and smart appliances, making consumers aware of their energy consumption and potentiate behavioural change.

Figure 1 - ICT and Energy




The deployment of smart meters and other elements of smart grids are foreseen to generate massive amounts of data, allowing for new players in the sector such as aggregators for renewable energy sales and new energy services companies.

**Strategy on Connectivity for a European Gigabit Society**[4]

The European Commission's strategy on Connectivity for a European Gigabit Society (COM(2016)587), adopted in September 2016, sets a vision of Europe where availability and take-up of very high capacity networks enable the widespread use of products, services and applications in the Digital Single Market.

This vision is based on three main objectives for the year 2025:

— Gigabit connectivity for all main of socio-economic drivers,

— Uninterrupted 5G coverage for all urban areas and major terrestrial transport paths,

— Access to connectivity offering at least 100 Mbps for all European households.

## 2.2 Energy Policies

**Eco-design Directive**[5]

When talking about appliances, the Eco-design Directive is an obligatory mention. The Eco-design Directive (2009/125/EC) establishes a framework for the setting of Eco-design requirements for energy-related products by the definition of the mandatory elements required by products to comply, regarding the environmental impact of products. Eco-design requirements cover all the lifecycle stages of a product, from raw material extraction to the end of life of the product. From the first Eco-design Directive (2005/32/EC) several implementing regulations have been adopted introducing efficiency requirement for household appliances such as dishwashers, ovens, lamps, televisions, tumble driers or washing machines.

While most of the implementing regulations arising from the Eco-design Directive are specific to the products under them, there are also regulations that address issues transversally like standby modes.

More specifically on Smart Appliances, the European Commission is starting to have a look into regulations of this set of products, through an Eco-design Preparatory Study on Smart Appliances (Lot 33). This preparatory study represents a preliminary step towards possible efficiency, interoperability and energy labelling regulations and potentially be subject to an implementing measure.

**Energy Labelling Directive**[6]

Also relating to energy efficiency in products there is the Energy Labelling Directive (2010/30/EU), focused on the demand side, whereas the Eco-design Directive focuses on the supply side. Firstly introduced in 1992, the Energy Labelling Directive introduced the requirements of the information regarding the energy consumption and other environmental resources from household appliances.

In 2015, the European Commission proposed a review of the Energy Labelling Directive in order to further exploit the potential of the energy efficiency of households appliances by aiming to periodically rescale the existing labels and return to a A to G class instead of a more ambiguous scaling as is today (A+, A++, A+++).

**Energy Efficiency Directive**[7]

The Energy Efficiency Directive (EED) established in 2012 (2012/27/EU) establishes a set of binding measures in order to help the EU reach its 20% energy efficiency target by 2020. Under the EED, all EU countries are required to use energy more efficiently at all

[4] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52016DC0587
[5] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0125
[6] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0030
[7] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0027

stages of the energy chain from its production to its final consumption. In 2016 the European Commission proposed an update to the EED including a new 30% energy efficiency target for 2030, and measures to update the Directive to make sure the new target is met.

Specifically articles 9 on Metering outline that Member States when deploying smart meters in their territory provide information on actual time of use and that their information and the access to their smart meters may be accessed by third parties acting in the market.

On article 15 on Energy transformation, transmission and distribution outlines that Member States shall ensure the removal of tariff incentives that are detrimental to energy efficiency and that may obstruct Demand Response activities. Member States should also guarantee that demand side resources such as Demand Response should participate alongside supply in wholesale and retail markets and that demand response providers, including aggregators, are treated in a non-discriminatory manner, on the basis of their capabilities.

### Energy Performance of Buildings Directive[8][9]

The Energy Performance of Buildings Directive (EPBD) was adopted in May 2002 with a recast being made in 2010. The EPBD outlines that national authorities must set cost-effective minimum energy performance requirements and have these reviewed at least every 5 years. These requirements must cover heating, hot water, air-conditioning and large ventilation systems. New buildings must meet the minimum standards and contain high-efficiency alternative energy systems. Those owned and occupied by public authorities should achieve nearly zero-energy status by 31 December 2018 and other new buildings by 2 years later.

More concretely on smart buildings, the EPBD goes along with the directives for the internal market of electricity by stating that Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation.

Member states are also to encourage, where appropriate, the installation of active control systems such as automation, control and monitoring systems that aim to save energy.

In the new version of the EPBD, from 2018, a new concept was introduced that can be another push to the deployment of smart buildings. Article 8 of the new EPBD “Technical building systems, electromobility and smart readiness indicator” with the European Commission, having to adopt, by the end of 2019, a delegated act and establish an option common Union scheme for rating the smart readiness of buildings, with this rating being based on the an “assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance.” The idea of the smart readiness of buildings is for buildings to have an optimized energy use as function of local production, optimized local energy storage, automatic diagnosis and maintenance protection for vehicles and improved comfort for residents via automation.

### Directives concerning Common Rules for the internal market in Electricity and Gas[10][11]

The Directives 2009/72/EC and 2009/73/EC concerning the common rules for the internal market in electricity and gas outline the need for Member States to encourage the modernisation of distribution networks through the introduction of smart grids, smart

[8] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0031
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1529394717053&uri=CELEX:32018L0844
[10] http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32009L0072
[11] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0073

meters, and developing innovative pricing formulas.

In this set of diplomas, Member States were required, by 2012, to assess the long-term costs and benefits to the market and the individual consumers of the roll-out of smart metering systems. In the case of this assessment resulting positive, at least 80% of the consumers should be equipped with smart meters by 2020.

### Roll-out of smart metering systems[12]

The European Commission produced a recommendation for the preparations for the roll-out of smart metering strategies (2012/148/EU) which follows the directives concerning the common rules for the internal market in electricity and gas. In this recommendation, data protection and security considerations are outlined, along with the proposal for a methodology for the Cost-Benefit-Analysis that Member States should perform for the roll-out of smart meters.

The recommendation also outlines the common minimum functional requirements that smart meters should present.

For the costumer, the meters should provide readings directly to the costumer since direct consumer feedback is seen as essential to ensure energy savings on the demand side. There also the reference for standardized interfaces which should enable energy management solutions in real time like home automation and demand response schemes. In terms of reading updates, these should be of at least every 15 minutes.

On the metering operator side the meters should allow remote reading, provide two-way communication between the smart meter and external networks and allow frequent readings so that the information can be used for network planning.

Other requirements on the functionalities of smart meters are the provision of secure data communication, fraud prevention and detection and the provision for import/export and reactive metering to allow renewable and local micro-generation.

### Framework Strategy for the Energy Union[13]

In the European Commission's strategy for the Energy Union from 2015 (COM(2015) 80 final) a new deal for consumers is foreseen where energy consumers have understandable, readily-accessible information and user-friendly tools. The use of smart technologies will help consumers to reap the opportunities available on the energy market by taking control of their energy consumption (and possible self-production).

There is also the reference on the push for standardization and support to the roll-out of smart meters and the promotion of further development of smart appliances and smart grids. Synergies between the Energy Union and the Digital Single Market are foreseen.

With a goal to become the number one in renewables, the Energy Union will oversee that existing legislation and new market rules need to be fully implemented, enabling the roll-out of new technologies smart grids and demand response for an efficient energy transition.

On the chapter on an Energy Union for Research, Innovation and Competitiveness, one of the four priorities actions to be addressed is the facilitation of the participation of consumers in the energy transition through smart grids, smart home appliances, smart cities and home automation systems.

Demand Response is seen as a crucial technology on the Strategy for the Energy Union, by allowing the full participation of consumers in the market.

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[12] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32012H0148

[13] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=COM%3A2015%3A80%3AFIN

**Staff Working document on Demand Response[14]**

The 2013 Staff Working Document on Demand Response (SWD (2013) 442) explains the importance of demand side participation, demand response in particular. With the full transposition of the Energy Efficiency Directive and Electricity Directive, it allows for the right conditions being created for policy-makers, regulators, network operators and energy businesses to trigger more demand side participation in the energy market.

The document estimates that the volume of controllable load by smart appliances in the EU is of at least 60 GW, of which 40 GW would be economically viable. The shift of this load from peak times to other periods is expected to reduce peak-generation in the EU by 10%.

In terms of accelerating Demand Response in the residential sector, the promotion of household appliances that are able to modulate temporarily their energy use, smart metering systems and energy storage possibilities are seen as solutions for an effective adoption of Demand Response in the European market.

[14] http://ec.europa.eu/energy/en/content/incorporating-demand-side-flexibility-accompanying-swd2013-442

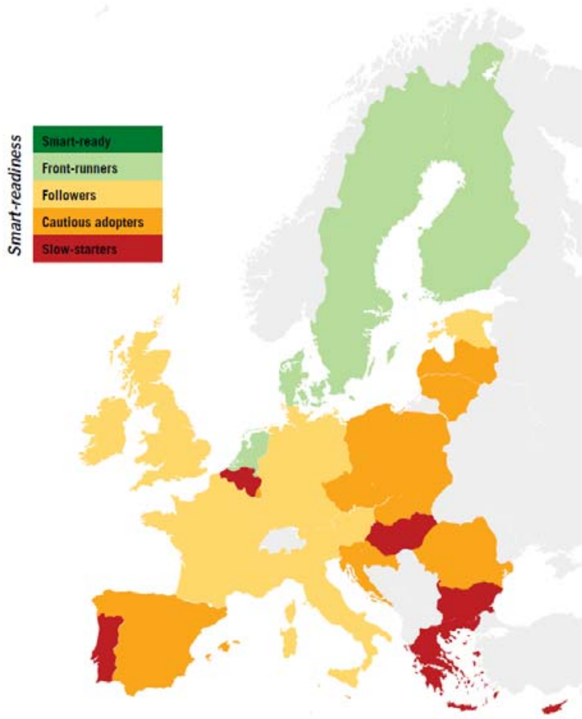
# 3 Status of the European Market

Smart Appliances and connected devices within the Smart Home are intrinsically linked with external conditions like the access to a fast internet, flexible energy providers with the given chance of Demand Response for final consumers and fast response from the grid through smart grids. This chapter aims to give an overview on the status of the European Market in terms of the current adoption of smart appliances and connected devices and its potential to further embrace these technologies by an universal access to fast internet, the roll-out of smart meters or the readiness of Member States to give access to Demand Response to final energy consumers.

## 3.1 Smart Readiness of EU Member States Buildings

BPIE has produced a report on whether Europe is ready for the Smart Buildings Revolution. In this report, an analysis is made weighing in on different aspects considered vital in order for buildings to be smart and a part of a global, dynamic and participatory energy system. Indicators like Building performance, Smart meter deployment, Dynamic market, broadband access, Demand Response availability or Renewable Energy access are analysed. The conclusions in this report are that although there are some Member States already on the right track for a smart buildings reality (Sweden, Finland, Denmark and Netherlands), there are still a long way to go in the remaining Member States in what concerns the development of a smartness environment in the building sector, both in terms of the private and public sector. [15]

Figure 2 - Smart readiness of EU Member States




Source: BPIE

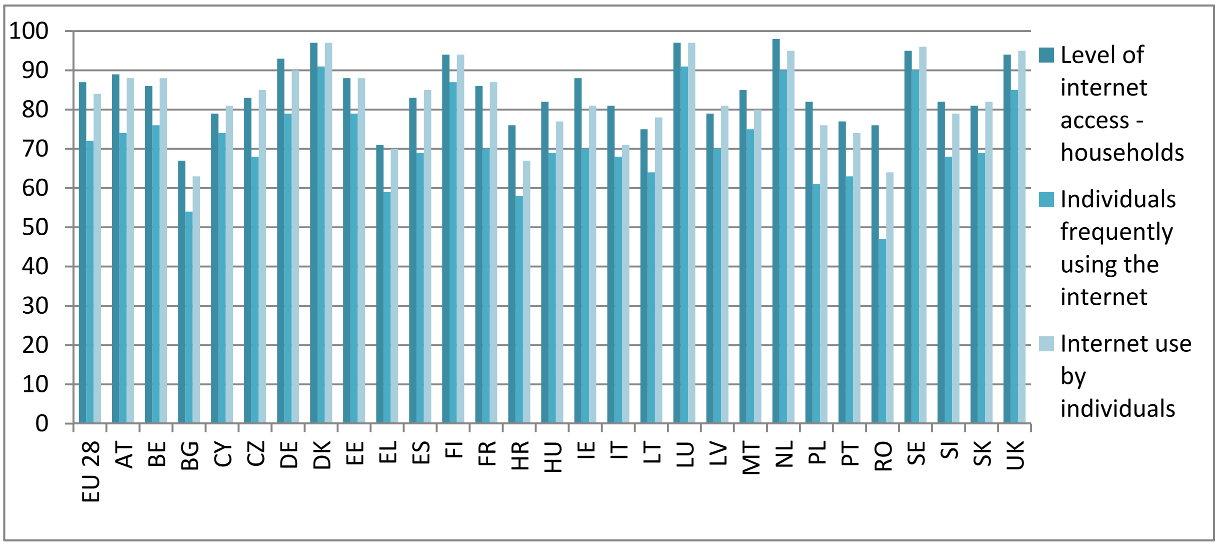
[15] http://bpie.eu/publication/is-europe-ready-for-the-smart-buildings-revolution/

### 3.2 Internet Access

In terms of internet access, according to Eurostat, in the year 2017, the great majority of households have internet access, with some Member States reaching up to almost 100% of access in their territories. As can be seen in Figure 3 - Level of internet access in Households, individuals and individuals frequently using the internet (2017) Member States like AT, BE, CZ, DE, DK, EE, ES, FI, FR, HU, IE, LU, MT, NL, PL, SE, SK and the UK have all a level of internet access within households of 80% or above. In terms of the overall EU28 population, 85% of all Europeans have internet access in their households.

In terms of Internet use by individuals the value is also quite high, with an overall 87% in the EU28 and AT, BE, CY, CZ, DE, DK, EE, ES, FI, FR, IE, LU, MT, NL, SE, SK and the UK with 80 % or more of internet use by individuals.

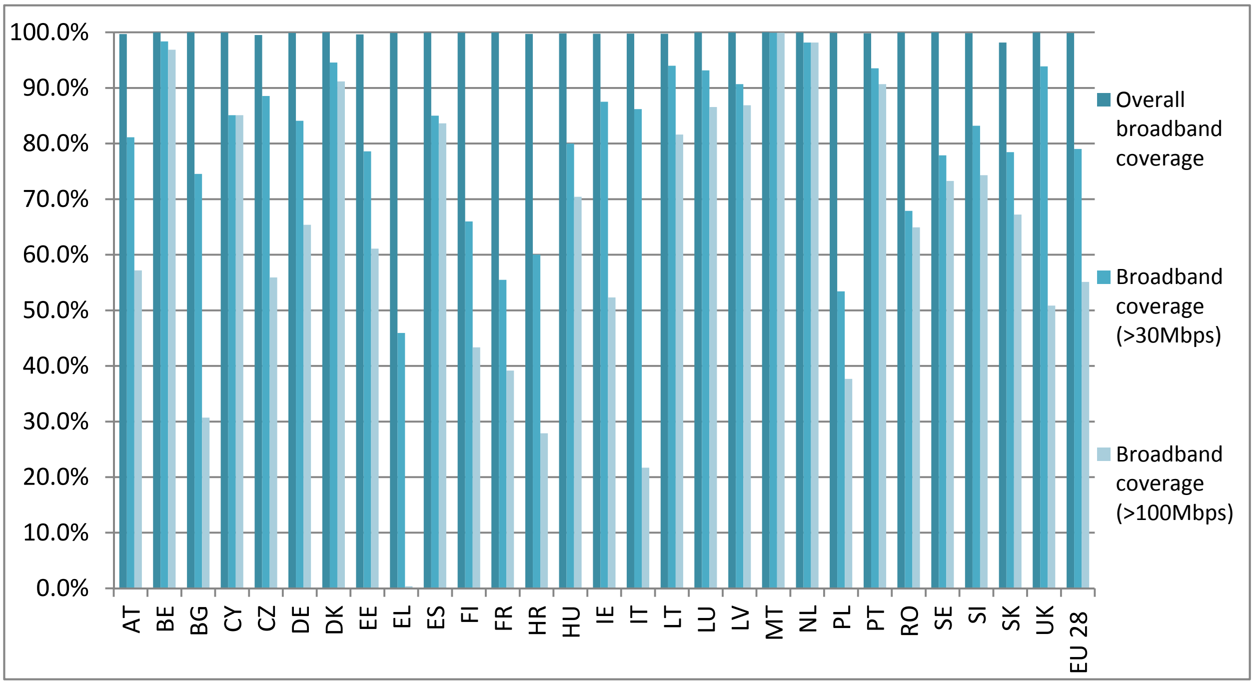
Figure 3 - Level of internet access in Households, individuals and individuals frequently using the internet (2017)




Source: Eurostat

In terms of the broadband coverage, all the EU28 had, in 2017 broadband coverage, with 99.7% of its territory covered with broadband, 81% over 30Mbps and 57% broadband coverage of over 100 Mbps. On a Member State level, AT,BE, CY, CZ, DE, DK, ES, HU, IE, IT, LT, LU, LV, MT, NL, PT, SI, and the UK have more that 80% of broadband coverage higher than 30Mbps and BE, CY, DK, ES, LT, LU, LV, MT, NL and PT having 80% or more of its territory covered by broadband speeds of 100 Mbps or higher.

Figure 4 - Broadband coverage in Europe (2017)




Source: European Commission[16]

## 3.3 Smart Meter Roll-out

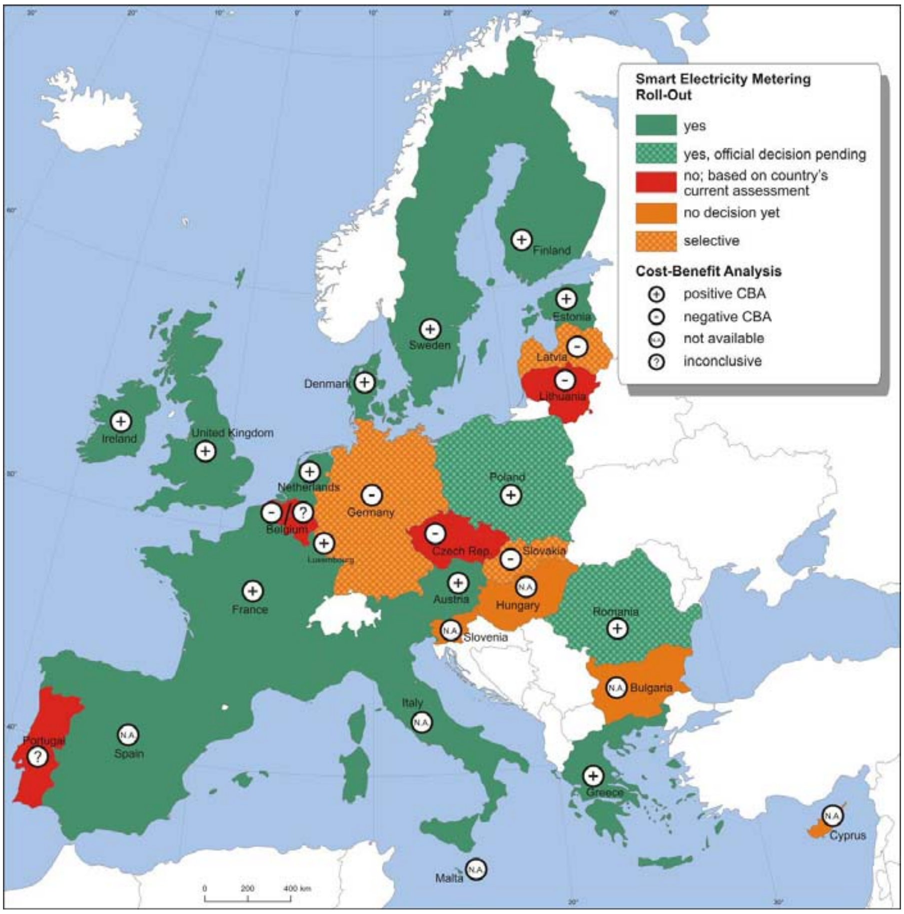
The installing of a smart meter is a starting point for an advanced control of the energy consumption profiles within the household. The fact that final consumers can benefit from almost real-time information on their consumption patterns and be able to act on it may give leverage on a change of the energy systems, both on the supply and demand sides.

By the Directives 2009/72/EC and 2009/73/EC concerning the common rules for the internal market in electricity and gas, Member States needed to perform, by 2012, a Cost-Benefit-Analysis for the roll-out of smart meters across its territory until 2020. The European Commission's Joint Research Centre (JRC), along with DG Energy has produced, in 2014, a report[17] on the benchmarking of smart meter deployment in the EU, with a focus on electricity. This report performs a benchmark of the Cost-Benefit-Analysis performed by Member States (27 at the time), in order to evaluate the feasibility of the global deployment of smart meters around Member States territory.

The conclusions of this benchmark are summarized in the following figure.

[16] https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2017
[17] http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

Figure 5 - Smart Electricity Metering Roll-Out (2014)




Source: European Commission

Figure 6 – State of play of the EU 27 on the roll-out of electricity Smart Meters

* 16 Member States (Austria, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Luxemburg, Malta, Netherlands, Poland, Romania, Spain, Sweden and the UK ) will proceed with large-scale roll-out of smart meters by 2020 or earlier, or have already done so. In two of them, namely in Poland and Romania, the Cost Benefit Analysis yielded positive results but official decisions on roll-out are still pending;
* In seven Member States (Belgium, the Czech Republic, Germany, Latvia, Lithuania, Portugal, and Slovakia), the Cost Benefit Analysis for large-scale roll-out by 2020 were negative or inconclusive, but in Germany, Latvia and Slovakia smart metering was found to be economically justified for particular groups of customers;
* For four Member States (Bulgaria, Cyprus, Hungary and Slovenia), the CBAs or roll-out plans were not available at the time of writing;
* Legislation for electricity smart meters is in place in the majority of Member States, providing for a legal framework for deployment and/or regulating specific matters such as timeline of the roll-out, or setting technical specifications for the meters, etc. Only five Member States (Belgium, Bulgaria, Hungary, Latvia and Lithuania), have no such legislation in place.

Source: European Commission

From this evaluation, it is only natural that the countries where smart meters are to be rolled out at a large scale, should also be the countries where smart appliances and households where energy management systems will be being adopted in a first stage. Although it is unlikely, there could still be individuals that choose to install their own smart meters and benefit from the added amounts of information to be received while also participating as an active participant of the efficiency of the networks, harvesting potential energy savings due to an increased control within the household.

## 3.4 Demand Response

As outlined in the Staff Working document on Demand Response (DR), Demand Response is an asset for both the retail and the wholesale market. The value of demand response for the wholesale and balancing markets, at various time scales (i.e. including the day-ahead, intraday and forward markets) is far from being tapped. Demand response is an integral part of a consumer-centric retail market vision in the energy sector. Its role is foreseen in the design of the EU internal energy market calling for consumer empowerment. In both wholesale and retail, demand response is centred on fair reward to consumers for demand flexibility and relies on available technical solutions.

Consumers today have the chance to participate in Demand Response programmes in multiple Member States in accordance with the requirements of the Energy Efficiency Directive, something that did not fully occur in the past.

The Joint Research Centre (JRC) on its report on “Demand Response status in EU Member States”[18] gives an overview on the state of Demand Response in the EU-28 and provides a review on the readiness of Member States in terms of the establishment of a legal framework and market readiness for the use of Demand Response in the energy market, thus having the ability to potentiate the deployment of smart homes as active partners in the energy infrastructure.

Some key elements for a successful development of Demand Response programmes outlined are: 1) the definition of independent aggregators that can ensure the consumer’s right to choose their energy service provider and allow full aggregation of consumer’s loads; 2) market design should enable the participation of Demand Response and other distributed resources like Virtual Power Plants and 3) Technical modalities enabling Demand Response should be defined by standardization and replication throughout whole Europe.

In the JRC report it is possible to realize a three-speed-Europe in terms of the status of Member States regulation concerning Demand Response.

First, there are the Member States that have yet to actively create a Demand Response policy. Member States like Portugal, Spain, Italy, Croatia, the Czech Republic, Bulgaria, Slovakia, Hungary, Cyprus, Greece, Poland or Malta had not yet adjusted their regulatory structures to enable demand side resources to participate in the markets, begun the process of defining the role of an independent aggregator and DR service provider, or adjusted critical technical modalities.

The second group of Member States more advanced on the enablement of Demand Response are Austria, Finland, Denmark, Germany, the Netherlands and Sweden by enabling Demand Response through the energy retailer. Rather than leaving to independent aggregators to offer demand response solutions for consumers in a more transparent way, the retailers in these Member States have their demand side solutions offers as a bundle with their electricity bill, leaving to consumers the choice to accept the entire package or refuse it entirely, making it hard for them to know what they are rejecting/accepting as they will hardly have a fully transparent offer.

[18] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/demand-response-status-eu-member-states

The third group of Member States enables both Demand Response and independent aggregation. This includes Belgium, France, Ireland and the UK. Belgium and France have both defined the roles and responsibilities around independent aggregation.

In the table below it is possible to get an overview of the status of Demand Response in the EU.

Table 1 - Overview of DR status within EU Member States (2016)

| | Ancillary services markets open to participants | Balancing markets open to participants | Wholesale open | Aggregators | Tech modalities adjusted | RESULT |
|---|---|---|---|---|---|---|
| **Austria** | Most markets open to ALL with limitations for aggregators | retailer only | retailer only | Retailer only | Yes with significant barriers remaining | Active participation of large industrial in balancing market. |
| **Belgium** | Most markets open to ALL | retailer only | retailer only | Yes (under development) | partial but innovative | Active participation of large industrial and some commercial in balancing market. Limited retailer activity wholesale market |
| **Bulgaria** | No DR at the moment | No | No | No | No | There is a major lag with liberalization and lack of competition |
| **Croatia** | No | Legally yes, in reality no | Legally yes, in reality no | No (no consideration) | No | The energy sector is concentrated with one single company, liberalization progress is slow. |
| **Cyprus** | No DR at the moment | No | No | No | No | Absence of competition in the energy sector |
| **Czech Republic** | No (though ripple control participates) | Legally yes, in reality no | Legally yes, in reality no | No | Significant technical barriers, CBA for SM is negative | Suboptimal solution of ripple control remains as a major obstacle |
| **Denmark** | ALL (with limitation for aggregators) | retailer only | retailer only | retailer only | Not yet sufficient to function | Little significant participation in any market by any group |

| | Ancillary services markets open to participants | Balancing markets open to participants | Wholesale open | Aggregators | Tech modalities adjusted | RESULT |
|---|---|---|---|---|---|---|
| **Estonia** | Unclear | Yes, but not used | Yes, but not used | No | Roll-out of SM by end of 2016 | No participation in any market by any group, although legally open |
| **Finland** | ALL (with limitation for aggregators) | retailer only | retailer only | retailer only | Yes - partially | Participation of large industrial and commercial and some residential in balancing market. Limited participation in wholesale through retailer. |
| **Sweden** | ALL (with limitation for aggregators) | retailer only | retailer only | retailer only | Not yet sufficient to function | Little significant participation in any market by any group |
| **France** | Most markets open to ALL | ALL | ALL | Yes | Yes with significant barriers remaining | (Limited) participation of all consumer groups in all markets |
| **Germany** | retailer only (severe limitations aggregators) | retailer only | retailer only | retailer only | Not yet sufficient to function | No significant participation in any market by any group |
| **Greece** | One program open to large consumers only | No | No | No (under review) | Yes for one open program | Participation of qualified large industrial in one balancing market program |
| **Hungary** | No (though ripple control participates) | Legally yes, in reality no (competition with ripple control) | yes (but very difficult to get license) | In theory possible, no examples | partial | One DR company on the wholesale, and 8 VPPs |
| **Ireland** | Two markets open to ALL | retailer only | retailer only | Yes | partial | Participation of large industrial and commercial in balancing market |
| **Italy** | No (under review) | In theory retailers are able | In theory retailers are able | No (under review) | No (under review) | No participation. (Single Existing program is not in full use and is not market based) |

| | Ancillary services markets open to participants | Balancing markets open to participants | Wholesale open | Aggregators | Tech modalities adjusted | RESULT |
|---|---|---|---|---|---|---|
| **Latvia** | Unclear | Unclear | Yes | Unclear | Not yet | Participation in the wholesale market |
| **7Lithuania** | Unclear | Unclear | Unclear | Unclear | Not yet | No significant participation in any market by any group<br>further support and encourage demand side resources such as Demand Response to participate alongside supply in wholesale and retail markets |
| **Luxembourg** | No | Legally yes, but no participants | Legally yes, but no participants | No | No | No DR used mainly due to technical/procedural reasons because of the interconnectedness with Germany |
| **Malta** | No | No | No | No | No | No regulatory framework for participation of DR |
| **Netherlands** | Most markets open to retailers only | retailer only | retailer only | retailer only | Yes | Participation of industrial and commercial in balancing and limited wholesale |
| **Poland** | Two programs open to large consumers only | In theory retailers are able | In theory retailers are able | no (Unrealistic also for retail) | not sufficient to function | Very limited participation in one balancing program by qualified large industrial consumers |
| **Portugal** | No | In theory retailers are able | In theory retailers are able | no (Unrealistic also for retail) | No | No participation |
| **Romania** | No | Legally retailers are eligible | Legally retailers are able | Not even mentioned | No | No DR participation |

| | Ancillary services markets open to participants | Balancing markets open to participants | Wholesale open | Aggregators | Tech modalities adjusted | RESULT |
|---|---|---|---|---|---|---|
| **Slovakia** | N/A | Legally ALL, but households | Legally ALL, but households | Legally ALL, but households | No, which is a main barrier | Very low DR participation, only large consumers |
| **Slovenia** | Yes, All | Yes | No | Limited | Partial | The business case is not evident, thus DR is limited. Aggregation has been restricted. |
| **Spain** | No (no competitive programs) | In theory retailers are able | In theory retailers are able | no (Unrealistic also for retail) | No | No participation (Single existing program is not in actual use and is not market based) |
| **UK** | Markets open to ALL | retailer only | retailer only | yes | partial - semi functional | (Limited) participation of all consumer groups in all markets |

Source: European Commission

Although there are some shy signs that Demand Response is taking off in several European Member States, there is still a long way for the whole Europe to be ready to offer sound Demand Response solutions for energy consumers, which ultimately will also impact in the development of the smart home environment in general and smart appliances and connected devices in particular.

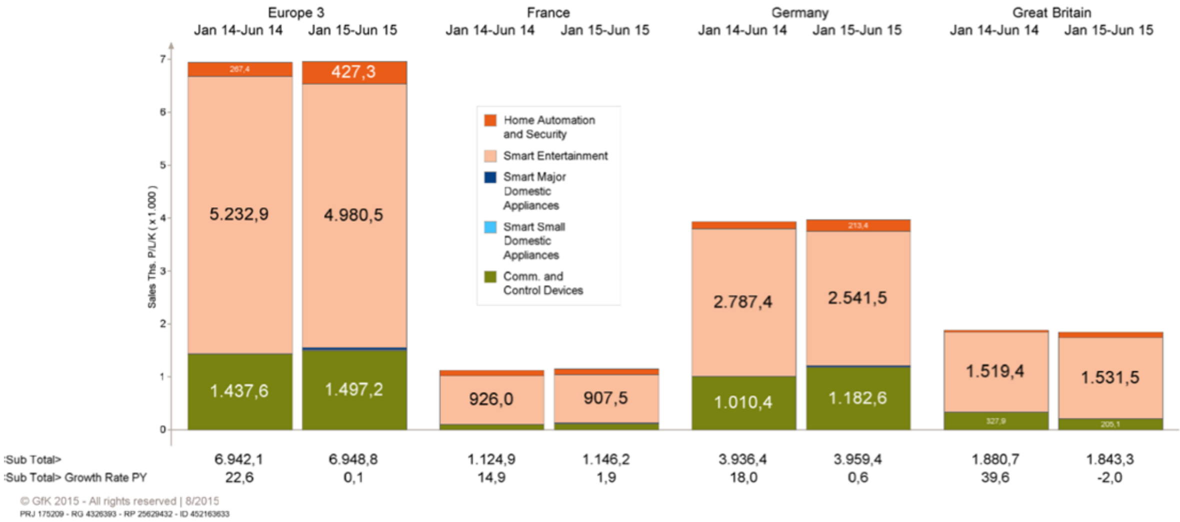
## 3.5 Smart Appliances and Connected devices market

In what concerns the market share of Smart Appliances and connected devices in the EU, there is still a gap in terms of information, mainly due to simply being still a relatively new market. Although there are some studies on the amount of smart appliances being sold, a more in-depth study to the whole connected devices market would be welcome.

At the EEDAL'15 conference, it was presented a paper on the market of smart homes and connected devices, with values on the dimension of the smart home market. This study had a focus on the French, German and UK markets and gives an insight on the numbers of smart connected devices sold in these countries.

The great amount of connected devices within Smart Homes identified relates to entertainment devices like Smart TVs, followed by Communication and Control Devices and Home Automation and Security. Smart Major and Small Domestic Appliances appear in much less quantities as seen in the figures below.

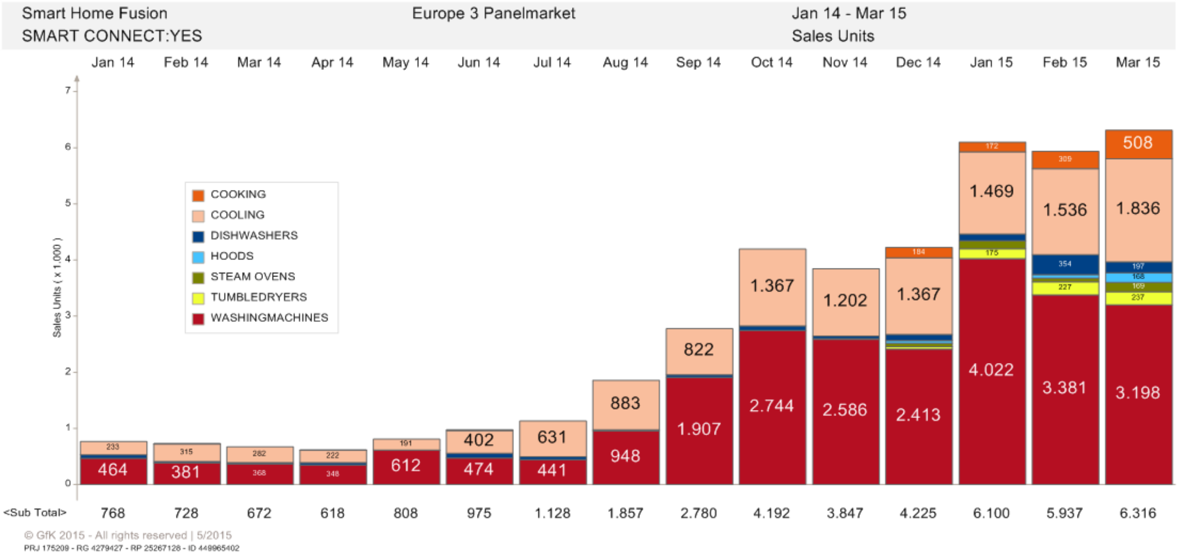
Figure 7 - Volume Sales of Smart Home categories in FR, DE, UK in 2014 and 2015




Source: GFK

More specifically in terms of Smart Appliances, these do not show sales numbers as other categories within the smart home environment like entertainment devices. From the GFK study, an increase of sales from January 2014 in comparison with January 2015 was observed – less than 800 units to 6100 units as can be observed in Figure 8.

Figure 8 - Volume sales of product groups from category Smart Major Domestic Appliances in FR, DE, UK (January 2014-March 2015)

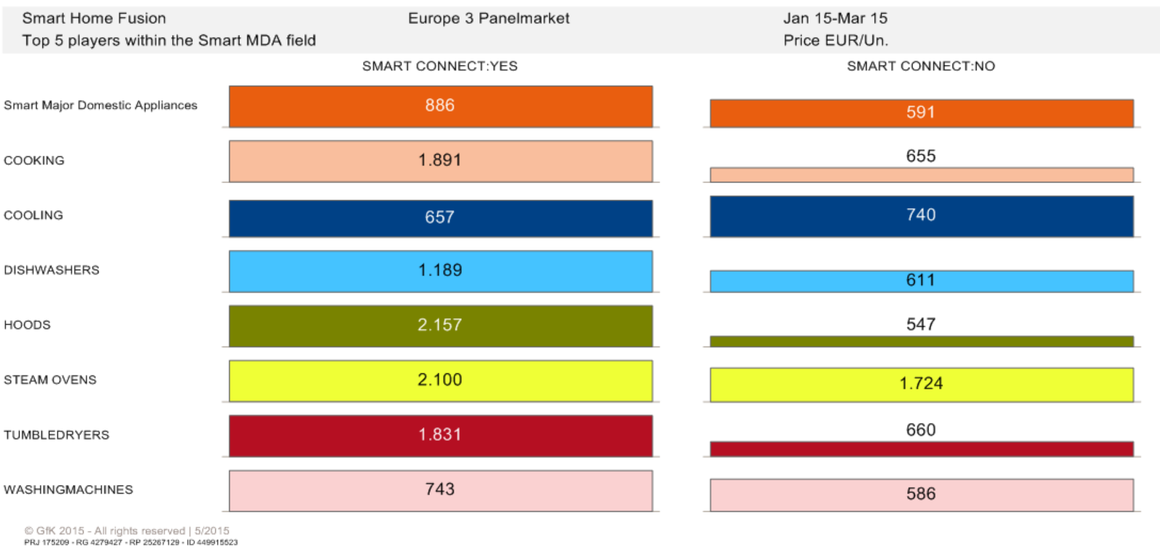



Source: GFK

Although not showing the sales volumes as other categories of the smart home market, Smart Appliances still have been having a growth in terms of sales, with Smart Washing Machines, with functions like start time washing programmes, being the category of Smart Major Domestic Appliances with the biggest sales, followed by refrigerators. Although there is a growth in sales for

One of the factors pointed to the slow adoption of smart appliances is the price, with the price points being very different from connected to non-connected appliances. The figure below gives an overview on the price differences found by the GFK study between connected and non-connected major appliances.

Figure 9 - Price comparison of smart and traditional appliances in FR, DE, UK (2015)



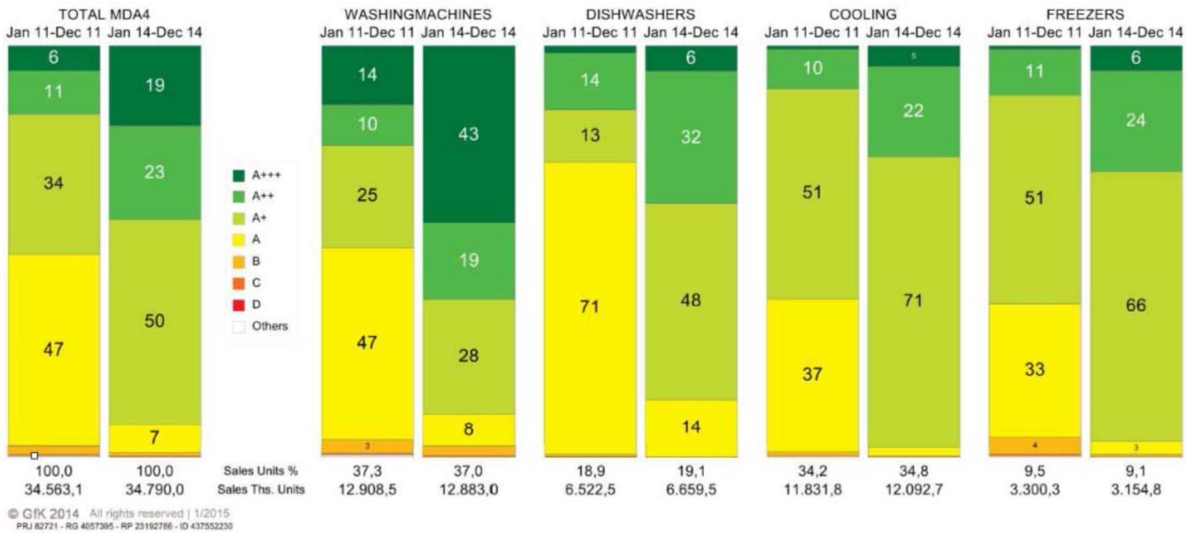

Source: GFK

With an analysis of the top five smart appliances manufacturers, the difference between the types of appliances is considerable. A difference of almost 300€ in the overall appliances, almost 600€ in dishwashers, 157€ in washing machines and more than 1000 € in tumble dryers, just to name a few of the most significant.

While traditionally, smart appliances were being sold through normal sales points, nowadays, a new type of market is appearing. Energy retailers are “giving” energy related appliances for consumers to engage as their clients. In the UK, for example, Energy retailers are providing smart thermostats to its client consumers as a way to customer loyalty.

One of the issues that can pose as a hurdle for the adoption of smart appliances within the European market could be the existing stock of appliances. With the success of energy efficiency policies in the major appliances sector (energy labelling and minimum energy performance standards). As described in the JRC report "Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2014"19, the success of the energy label for major domestic appliances is confirmed by the fact that the sales of models in top energy label classes have increased steadily in the recent years: the market share of A+ or higher class appliances jumped from 51% in 2011 to 92% in 2014 as shown in the Figure below.

Figure 10 - Market distribution by energy label classes and by products groups




Source: GfK Retail and Technology Panel

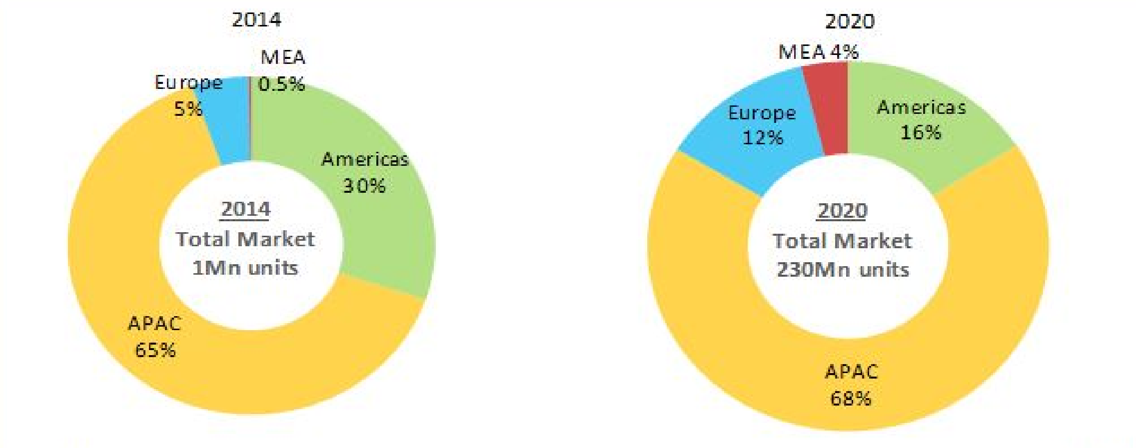
The fact that there are so many highly efficient appliances and the long lifetime of such appliances, may lead to a slow uptake of the smart appliance market. While for personal computers, for example, the lifetime of a personal computer is expected to not last more than maybe 5 years, due to the evolution of the technology and the constant demand of faster, lighter and more efficient computers, with appliances the consumers will expectedly tend to buy an appliance and use it further in time, since the main functionalities of such appliances have not been changed in years, with the occasional smart features that still represent a niche market in the appliance companies.

In the IHS Markit evaluation of the Home Appliance Market, a forecast on the smart appliance market estimates for a growth from less than 1 million units in 2014 to over

[19] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC101177/report%20energy%20trends%202000-2014_19.05.2016_final-pdf.pdf

223 million units worldwide as shown in the figure below. This forecast is considered conservative by IHS, with more space to grow.

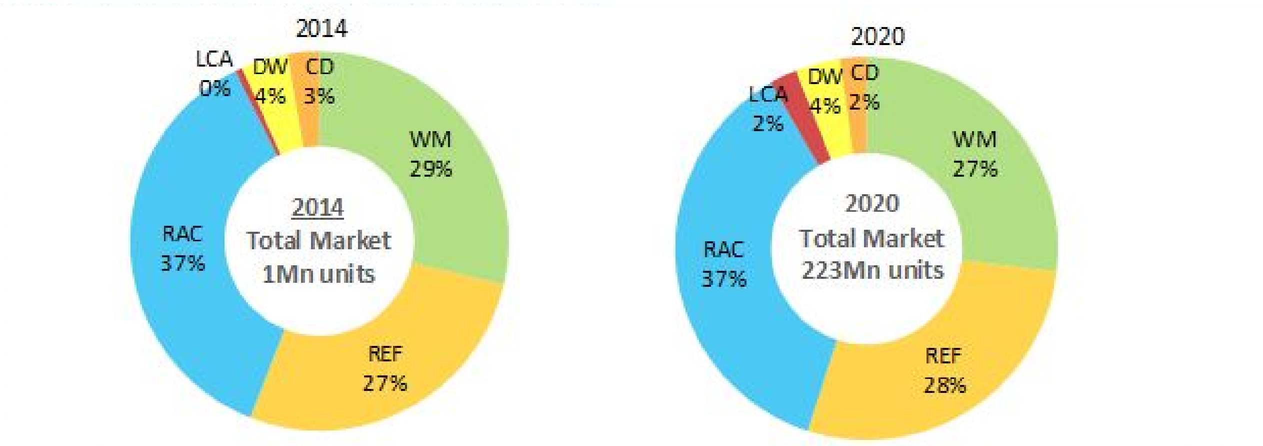
Figure 11 - World market for smart connected major home appliances in 2014 and 2020




Source: IHS

The penetration of these smart connected appliances is projected to grow from an estimated 0.2% in 2014 to 31.3% in 2020, with that of smart room air-conditioners reaching 52% and smart washing machines 42% in 2020. China is projected to be the leading market for smart connected major home appliances, followed by the United States. As demand for smart connected appliances develops in other countries, the share of Americas is projected to drop from an estimated 30% in 2014 to 16% in 2020.

Figure 12 - Worldwide market for smart connected major home appliances in 2014 and 2020



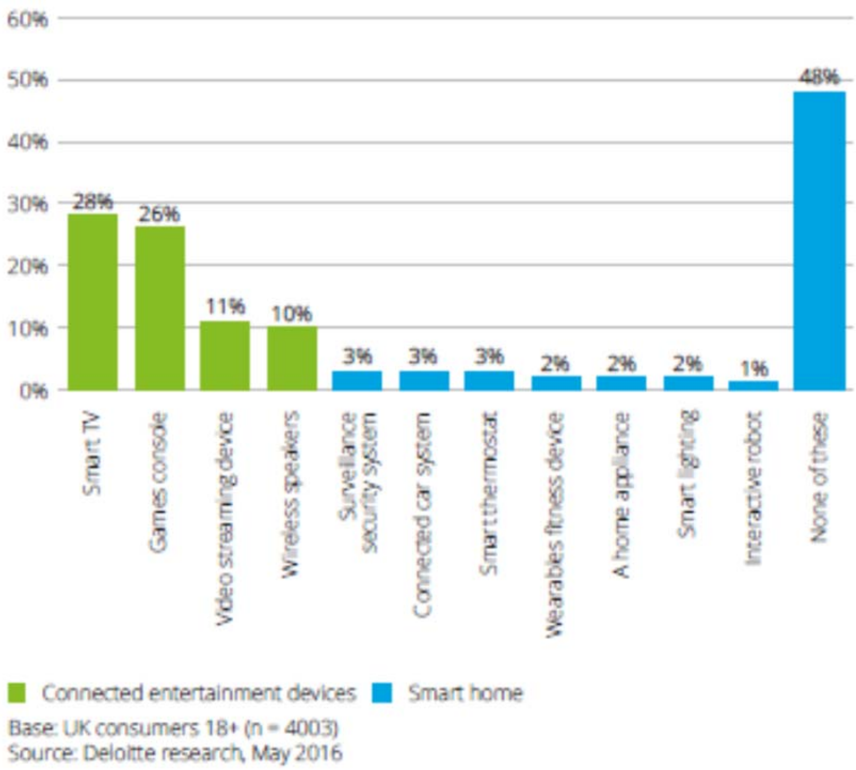

Source: IHS

Although the smart home market is still a relatively small one, according with the Deloitte consumer review of 2016 “Switch on to the connected home!” there are some signals of change that will reflect in an increase of the consumption of smart home devices, greatly due to a generational change. The report highlights that younger generations find more value in smart home devices, with UK consumers under 34 years old being more likely than older generations to purchase connected devices with the conviction that these would make their lives easier. In this study, 48% of the respondents said they think smart home devices are too expensive, while 26% refer to think that the technology needs to evolve further before they buy a smart device. Older consumers are more worried about the device's long replacement cycles than the price.

While in some categories such as entertainment, consumers are already purchasing connected devices, fewer people own devices in other areas of the smart home ecosystem, with only two or three percent of the consumers having purchased smart security systems, smart thermostats and lighting systems.

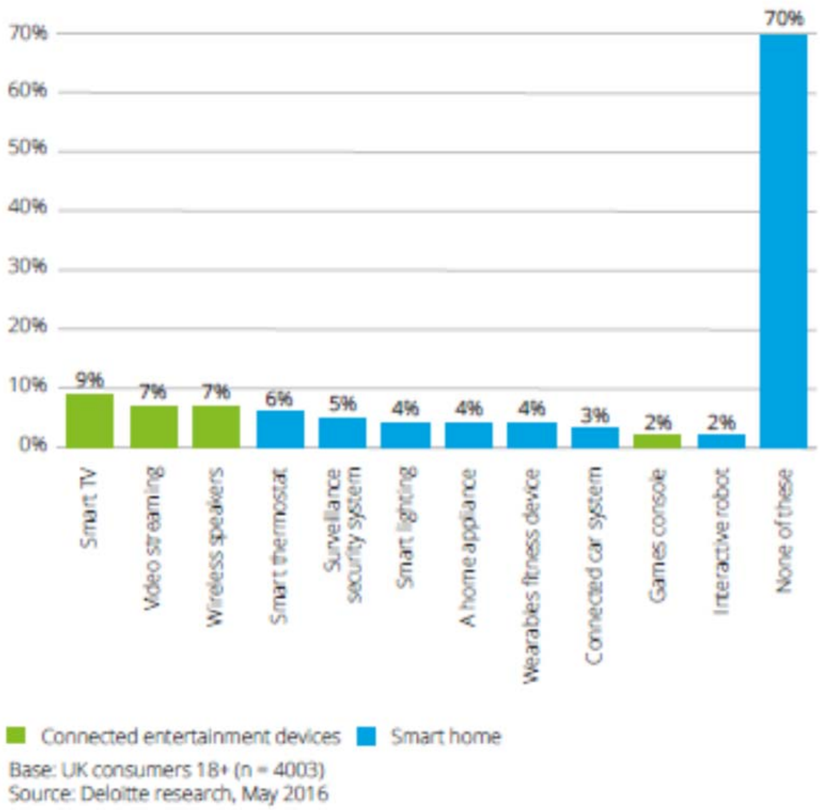
The majority of people within this study (70%) do not plan to buy any connected devices in the near future, and only plan to replace lighting and thermostats with connected devices once they need to.

Figure 13 - Consumer ownership of connected devices



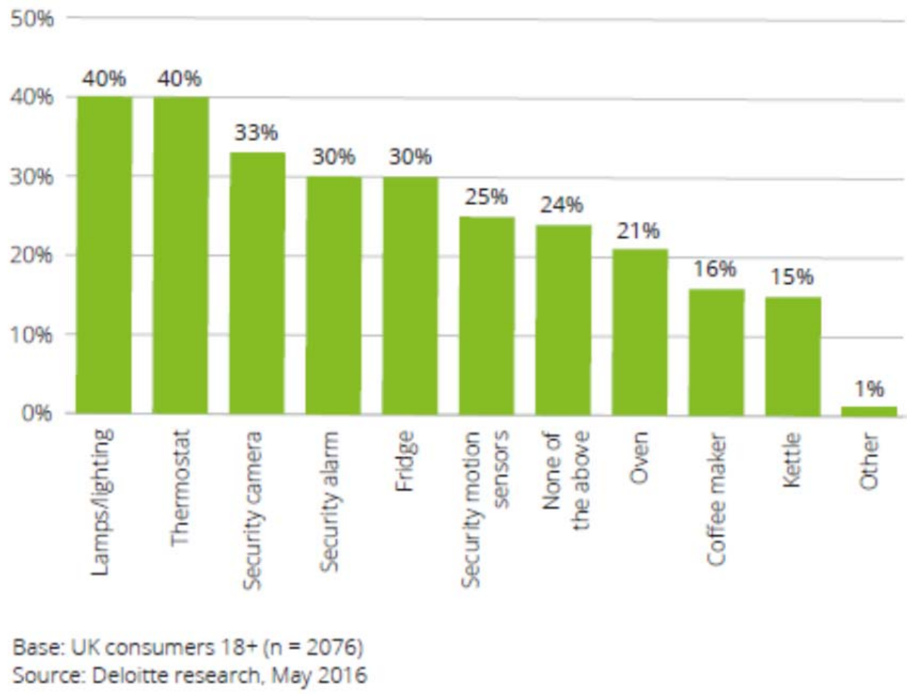

Source Deloitte (2016)

Figure 14 - Intent to purchase within 12 months




Source: Deloitte (2016)

Figure 15 - Appliances consumers are most likely to replace with a connected device




Source: Deloitte (2016)

Although encouraging, the forecasts of development of the smart home market are to be taken cautiously. It is natural that an evolution in the consumption patterns should occur. However, this market will need to be supported by a global ecosystem that can support its developments, by advances in telecommunication networks and energy systems and above all a common vision between all the agents present in this ecosystem.

## 3.6 Standardization work

In the 2017 European Commission's "Rolling Plan for ICT Standardization"[20] has identified five priorities on ICT standardization of the Digital Single Market – 5G cloud, cybersecurity, big data and Internet of Things. More specifically in terms of applications that will benefit from the development of these technologies, smart energy is seen as an important application to profit with these developments.

This section of the report gives an overview of the work being developed within the standardization bodies in the smart home and connected devices environment, with a focus in the European environment, following the Rolling Plan structure and information collected by the preparatory studies on Smart Appliances.

### CEN[21]

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries and is working in several of its working groups on the development of standards in the Internet of Things environment.

TC 225 is working on edgeware data capture, namely on bar codes, RFID, and RTLS. Working Group 6 (Internet of Things – Identification, Data Capture and Edge Technologes) focuses on the interface between edge data capture technologies and the IoT.

TC 294 is working with "Communication systems for meters and remote reading of meters" and focuses on the exchange of information to non-electricity meters and other supporting equipment.

### CENELEC

CENELEC is the European Committee for Electrotechnical Standardization and is responsible for standardization in the electrotechnical engineering field.

CENELEC is working in its CLC/TC59x Working group on the "Performance of household and similar electrical appliances" WG7 "Smart household appliances". This Working Group is performing standardisation work to enable domestic appliances to improve functionality through the use of network communication like smart grids, smart homes and home networks

### ETSI[22]

ETSI, the European Telecommunications Standards Institute, produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and Internet technologies.

On the Internet of Things, ETSI is tackling the issues relating to the connection of the smart objects into a communications network by developing standards for data security, data management, data transport and data processing, allowing to make sure that applications like smart metering reach its full potential.

[20] http://ec.europa.eu/DocsRoom/documents/21763
[21] https://www.cen.eu
[22] http://www.etsi.org/

Machine-to-Machine (M2M) communications are being looked into as a way to allow the interaction for smart devices, smart appliances, smart homes, smart buildings and smart cities. One of the objectives of ESTI is to provide an application-independent “horizontal” service platform capable to support a wide range of services. As a part of the oneM2M partnership project, ETSI is working among the other partners to create a common M2M service layer which can be embedded with different hardware and software in order to be connecting among themselves. On the work of oneM2M, the first release that came out of this group include specifications covering requirements, architecture, protocols, security and management, abstraction and semantics.

Also with the support of the Commission, ETSI has developed the SAREF[23] standard (Smart Appliances Reference ontology which is a shared model of consensus that facilitates the matching of existing assets (standards/protocols/datamodels/etc.) in the smart appliances domain. The SAREF ontology provides building blocks that allow separation and recombination of different parts of the ontology depending on specific needs

### IEC

The International Electrotechnical Commission (IEC) is working in its IEC/CLC/TC 13 “Electrical energy measurement and control” Working Group 14 (Electricity Metering data exchange) by developing the standards to be able to transfer consumption information that is registered in the electricity meter. Additional information related to DR that can be transferred.

IEC/TC 57 Working Group “Interfaces and protocol profiles relevant to systems connected to the electrical grid” is focusing on the functionalities and data definitions for Demand Response. Another working group comprising IEC/TC 57 WG21, CLC/TC 205 and CLC/TC 59X is collecting Use Cases and requirements for the Smart Grid and Smart Home. The use cases collected cover providing energy consumption information, controlling smart appliances, EV charging, power limitation, consumer offering flexibility, battery management, etc.

IEC/TC59 “Performance of household and similar electrical appliances“ Working Group 15 “Connection of household appliances to smart grids and appliances interaction” is establishing a set of common terms, concepts and criteria, to assist the TC 59 and its Subcommittees in addressing the technical aspects of interaction between household appliances and the smart grid.

IEC/TS 62950 ‘Household and similar electrical appliances - Specifying and testing smart capabilities of smart appliances - General aspects’ is developing the common architecture which applies to different use cases and appliance types, and the principles of measuring smart performance within the context of the common architecture.

### IEEE[24]

The Institute of Electrical and Electronics Engineers Standards Association (IEEE), on its side is in the process of developing a standard for a framework for the IoT (P2413).

### IETF[25]

The Internet Engineering Task Force (IETF) is working on developing standards regarding the interoperability between smart object networks and the definition of the necessary security and management protocol for building these networks.

Several working groups are in place. 6LO Working Group is applying IPv6 adaptation mechanisms to a wider range of radio technologies.

[23] https://sites.google.com/site/smartappliancesproject/ontologies/reference-ontology
[24] https://standards.ieee.org/
[25] https://www.ietf.org/

The Lightweight Implementation Guidance Working Group is focusing on smaller devices in order to build minimal IP-capable devices for the most constrained environments.

The ROLL working group is developing standards to support the routing of communications within low-power networks.

The Constrained Restful Environments (CoRE) Working Group is specifying protocols that allow applications running in resource-constrained environments to interoperate with each other and the rest of the internet.

### ISO[26]

The International Organization for Standardization (ISO) has a dedicated Working Group for the Internet of Things (ISO/IEC JTC1 WG10) that is developing ISO/IEC 30141 – the IoT reference architecture. This Working Group has ongoing work in the definition of Terms and Definitions for IoT vocabulary, IoT reference architecture, Support for interoperability of IoT systems in terms of framework, networking, syntactic and semantic operability, use-cases covered by IoT, Monitoring the ongoing regulatory, market, business and technology IoT requirements and IoT standards that build on the foundational standards in relevant Working sub-groups.

ISO/IEC 15067-3:2012 is working on the specification of an energy management model for programmes that manage the consumer demand for electricity using a method known as "DR". Three types of DR are specified in this standard: direct control, local control and distributed control.

### ITU[27]

The International Telecommunications Union (ITU) is an United Nations institution dedicated to the study and development of standards within the ICT environment and has a dedicated ITU-T Study Group 20 on "IoT and its applications, including smart cities and communities". The aim of this Study Group is to develop a set of IoT international standards. The work being developed include "Semantics-based requirements and framework for the IoT, "Requirements of the plug and play capability of the IoT"

On Energy management, ITU has developed within ITU-T Study Group 13 the Recommendation ITU-T Y.2070 "Requirements and architecture of the home energy management system and home network services".

### 3GPP[28]

The 3rd Generation Partnership Project (3GPP) has a group in charge of 2G, 3G and 4G standardization (GERAN group).

### OIC[29]

The Open Connectivity Foundation (OIC) is working on the definition of the connectivity of requirements for devices, by the definition of the specification and certification to deliver reliable interoperability.

### W3C[30]

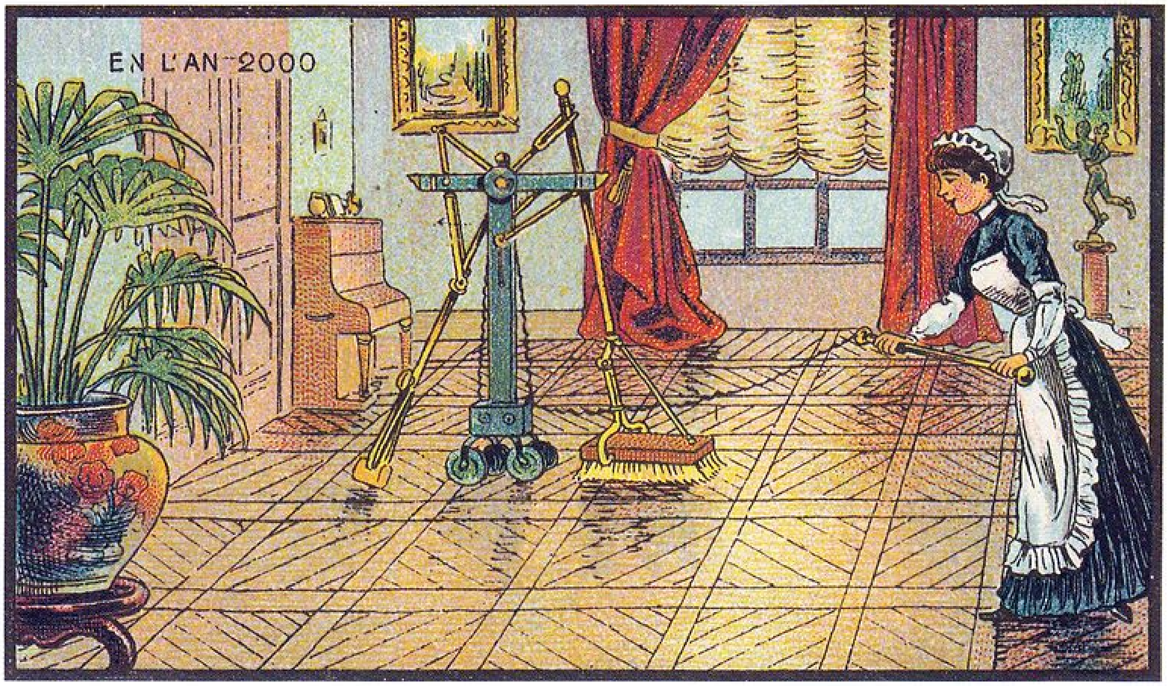
The Web of Things Interest Group is supporting the overcoming of fragmentation of the IoT by introducing a web-based abstraction layer capable of interconnecting the existing Internet of Things platforms and complementing available standards.

[26] https://www.iso.org/home.html
[27] http://www.itu.int
[28] http://www.3gpp.org/
[29] https://openconnectivity.org/
[30] https://www.w3.org/WoT/

# 4 Smart Homes and Appliances

From the beginning of the 20th century that a vision of a Smart Home has populated the imagination of the people. From flying electric cars, to automatic vacuum cleaners, popular culture has imagined ways in which people's life's' would become more easy and controlled via automatic devices with little human interaction.

Figure 16 - Painting of a smart home device from the beginning of the XX century




Electric Scrubbing

Although this vision is still yet to be fulfilled, there are already nowadays solutions that aim to transform the modern way of life more efficient by the action of automated or smart devices.

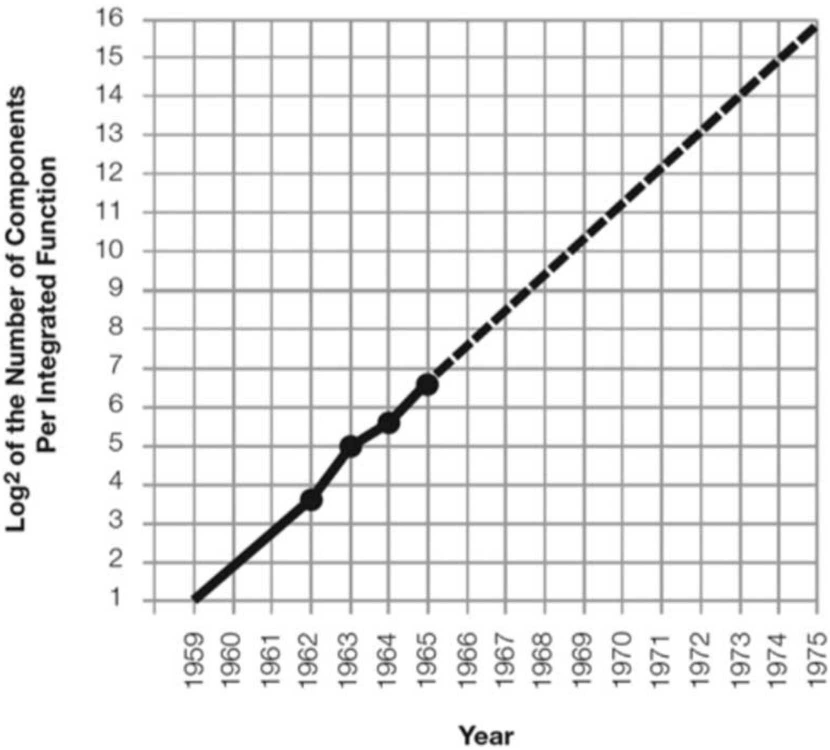
This chapter gives an overview of the smart home and connected devices ecosystem, with a special attention being given on smart appliances and Home Energy Management Systems.

The preparatory study for Smart Appliances promoted by the European Commission under the Ecodesign directive defines Smart Appliances as "an appliance that supports Demand Side Flexibility 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."

This definition does not necessarily meet eye to eye to the definition of "smart" that is commonly used, not only in smart appliances, but in other fields like smart devices, smart homes or smart cities. Usually, the term smart is used when a service or a product is somehow connected or connectable to other services or products through a network of some kind enabled by ICT services or goods. For the purpose of this report, smart or connected devices are devices with embedded ICT and that can be connected to other devices or systems via a cable or wirelessly.

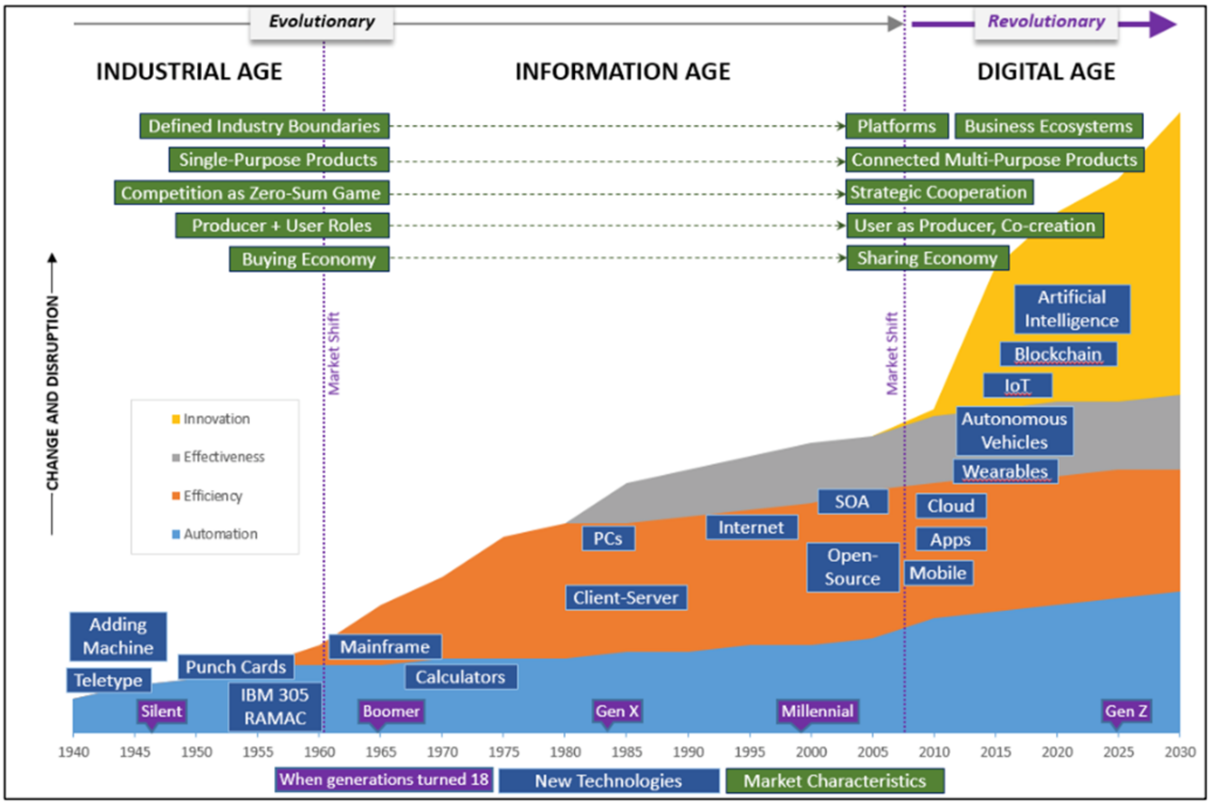
In 1965, Gordon Moore produced a paper that contained what would be commonly known as Moore's law. In this paper, Moore predicted the use of integrated circuits in "personal portable communications equipment", automated controls for automobiles, and home computers. But the what has led to Moore's law was the prediction of that the density of integrated circuits on a single chip would double every year for the next decade, which has become accurate, allowing for the personal computer industry to thrive. This has allowed for smaller, faster and cheaper computers that somehow have changed society from the last part of the 20$^{th}$ century onwards. Moore predicted that the innovation changes necessary to base this prediction would be thanks to the fulfilment of a three-way condition – design cleverness, increasing chip size and decreasing feature size.

Figure 17 - Moore's projection for doubling of the circuits' capacity every year (1965)




The realization of Moore's law, along with the advent of the internet, has made a change in the way people use computers firstly, and telephones secondly. The passing of the industrial age into the information age, with the micronization of the IT industry has allowed for a constant change of the use being given to computers and phones. In the last 70 years, computers have passed from research data processing machines to text processors, to powerful machines with limitless possibilities, from work to entertainment, from graphic design to gaming. The same occurred with phones. With the launch of the smartphone, telephones have passed from being instruments to make a phone call or being able to send text messages to nowadays being mini computers with high processing capabilities, with the ability to control every aspect of ones' life. The constant change in size and performance of these devices has originated a great turnover of devices, with users sometimes changing their computers and smartphones every couple of years.

Figure 18 - Majesco Disruption Model




The point is that the main functions for what these devices have been created are completely different than the use being given nowadays. The same does not occur with traditional appliances in the home environment. A fridge or a washing machine still have the main function as in the first day they were invented. To cool one's food and to wash one's clothes. Not being doted with "intelligent" circuits and with little change in its main functions, the turnover is much lower in traditional appliances, frequently only being replaced when there is no repair possible and after many years. Although the concept of smart appliance has been around for many years, not until recently and with the possibility of interconnection of appliances and personal handheld devices like tablets and smartphones, the smart appliances potentialities have been again in the order of the day.

## 4.1 Smart Appliances and the Smart Home Technologies

There are different types of Smart Appliances and Smart Home technologies. Each of these with different final use, type of connection and interaction.

In the report from 2015, Karlin, B. proposes distinct products aggregated into three groups, under a common nomenclature of Home Energy Management Systems (HEMS) that fit into the Smart Home/Connected Appliances ecosystem under study in this report:

In this chapter a brief product fiche is proposed outlining the main characteristics of the Smart Home Systems in terms of User Interfaces, Smart Hardware and software platforms.

### Energy Portal

Energy portals are informatics based application that delivers energy consumption information which was usually imperceptible to the consumer in a more user friendly way with information being explained in an easy to understand display of information.

This type of applications provides a more detailed and direct feedback than traditional bills and are usually provided as a service from energy utilities.

| Energy Portal | |
|---|---|
| **Main Functionality** | Energy data collection and transmission for the final consumer |
| **Specific Functionalities** | Receives energy consumption information from smart meters, smart appliances and other smart products within the household.<br>Allows more detailed and almost real-time energy consumption information than traditional bills<br>Allows users to act on the information given and remotely control appliances<br>Provides immediate feedback on actions, suggestions on potential savings and comparisons with similar consumers |
| **Interface** | Smartphones, Web based applications, computer software |
| **Communication** | Wi-Fi, LAN |
| **Interaction** | Bi-directional. Allows for interaction with other smart home products |
| **Noticeable market players** | Utilities' Energy Portals, Opower (Oracle), SmartThings |

### In-Home Displays

In-Home Displays are simple interfaces that provide immediate energy use feedback for the consumer also having the ability to send pricing signals. The type of information given is usually very simple and direct.

These devices are connected to the home energy network via a traditional normal meter and communicate with other peripheral devices through a home area network.

| In-Home Displays | |
|---|---|
| **Main Functionality** | Immediate energy data collection and real-time transmission for the final consumer. |
| **Specific Functionalities** | Receives energy consumption information from traditional meters, usually through the clamping of current transformers to the home electrical network.<br>Gives real-time energy consumption information<br>Programmable to send energy pricing signals |
| **Interface** | Device display, peripheral displays |
| **Communication** | Wireless communication |
| **Interaction** | Uni-directional from the device to the user |

### Load Monitors

Load Monitors give a simple piece of energy consumption information of an energy consumption device. These are connected between the power outlet and the actual device and give the energy consumption of the device.

The type of information given by Load Monitors is usually limited to the energy consumption and eventually a calculation of costs associated with this consumption, if these parameters are imputed by the user.

| Load Monitors | |
|---|---|
| Main Functionality | Immediate energy data collection of individual appliances |
| Specific Functionalities | Installed between energy plugs and the appliances<br>Receives real-time energy consumption information directly from individual appliances<br>More complex models also give simple price information |
| Interface | Device display |
| | Usually only visual information from the display |
| Interaction | Uni-directional from the device to the user |

**Smart Appliances**

Smart Appliances are defined in the Ecodesign Preparatory Study for Smart Appliances as appliances that are communication enabled. This communication platform can be used to offer multiple classes of functionalities like demand side flexibility.

On the energy aspect of smart appliances, these have the capability to receive, interpret and act on a signal received from an energy provider and adjust its operation according with the settings chosen by the energy consumer.

| Smart Appliances | |
|---|---|
| Main Functionality | Home appliances with the capability to communicate both with the user and other platforms and services |
| Specific Functionalities | Communication between the smart meter, providing information to the energy utility<br>Ability to change the appliance's consumption pattern<br>Possibility to adapt its consumption to energy produced on-site<br>Ability to support variable pricing based on day-ahead energy market |
| Interface | Device display, peripheral displays, web applications, energy portals |
| Communication | Wire and wireless communication |
| Interaction | bi-directional between the user and energy utilities |
| Noticeable market players | Major home appliances companies |

**Smart Thermostats**

Smart Thermostats ultimately have the same main functionality of traditional thermostats that is to control the temperature from a HVAC system. The added features of these devices in comparison with traditional ones are the added programming allowed, self-learning algorithms of the consumption patterns and intuitive interfaces with an easy user experience. Smart thermostats have

| Smart Thermostats | |
|---|---|
| Main Functionality | Temperature control with variable consumption parameters |
| Specific Functionalities | Self-learning of consumption patterns |

| | |
|---|---|
| | Geo-fencing activation/deactivation<br>Presence detection<br>Communication with user and possibility for remote control through other devices<br>Interaction with other smart home connected devices |
| **Interface** | Device display, peripheral displays, web applications |
| **Communication** | Wi-Fi |
| **Interaction** | bi-directional |
| **Energy relation** | Control of heating/cooling system. Possibility to control all HVAC system |
| **Noticeable market players** | Ecobee, Honeywell, Nest |

**Smart Lights**

Smart lights are lighting devices that incorporate normal lighting with embedded technology that allow for automatic control. These products are equipped with sensors and microprocessors that can detect environmental light or occupancy and act upon prompts defined by the user.

Smart lights allow users to adjust its lighting need by scheduling times and reduce over illumination, thus reducing the energy consumption associated with lighting.

Due to its smart features, smart lights can be remotely controlled and even support demand response programs in response to inputs from energy utilities.

| **Smart lights** | |
|---|---|
| **Main Functionality** | Lighting devices with connected features |
| **Specific Functionalities** | Lighting sensor<br>Dimming possibility<br>Presence detection<br>Demand response readiness<br>Lighting scheduling<br>Communication with user<br>Remotely controlled<br>Interaction with smart home hubs<br>Color changing |
| **Interface** | Web and smartphone applications |
| **Communication** | Wi-Fi |
| **Interaction** | bi-directional |
| **Energy relation** | Electricity consumption. Dimming and consumption reduction |
| **Noticeable market players** | Philips, GE, LIFX |

**Smart Plugs**

Smart plugs are devices that come between an energy plug and an energy consumption appliance. These devices have the characteristic to turn non-smart appliances into smart ones due to its incorporated intelligent features.

A Smart plug allows for appliances connected to it to be remotely controlled and provide feedback of the energy consumption of the appliance.

| Smart plugs | |
|---|---|
| **Main Functionality** | Control and feedback of energy consuming appliances |
| **Specific Functionalities** | Remote control of appliances<br>Turn non-smart appliances into "smart" ones<br>Communication with user<br>Interaction with smart home hubs |
| **Interface** | Web and smartphone applications |
| **Communication** | Wi-Fi |
| **Interaction** | bi-directional |
| **Energy relation** | Direct connection with white goods |
| **Noticeable market players** | Belkin, Wink |

**Smart Hubs**

Smart Hubs are devices that aggregate several smart connected devices within the smart home environment. The main objective of smart hubs is to integrate the functionalities of all these devices and communicate with all in a concerted way within a home network.

| Smart Hubs | |
|---|---|
| **Main Functionality** | Connection and integration of smart home connected devices |
| **Specific Functionalities** | Remote control of connected devices<br>Association of connected devices making them able to communicate among themselves<br>Internet access<br>Entertainment features |
| **Interface** | Hub display, Web and smartphone applications |
| **Communication** | Wi-Fi, bluetooth |
| **Interaction** | bi-directional |
| **Noticeable market players** | Samsung, Apple, Google, Amazon |

**Smart Water Heaters**

Smart Water heaters are retrofittable water heater controllers that turn an old gas or electric water heater into a smart one, giving the user the ability to heat water only if it is needed, via the control with a smart phone or smart hub. These smart water heaters have the ability to be coupled with other HVAC system controllers, making the whole system a smart one.

| Smart Water Heaters | |
|---|---|
| **Main Functionality** | Turn old water heaters with smart functionalities |
| **Specific Functionalities** | Remote control of water heater<br>Connection of water heater to other smart home appliances |

| | |
|---|---|
| **Interface** | Hub display, Web and smartphone applications |
| **Communication** | Wi-Fi |
| **Interaction** | Uni-directional |

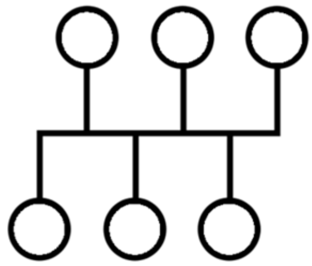
## 4.2 Types of Networks within the smart home environment

One of the main principles of a Smart Home is having its devices connected among themselves. This allows for a communication and integration of the different aspects of a household and the arrangement of the home networks has a direct influence in the efficiency of the smart home ecosystem.

There are several types of networks within the smart home environment. Each of them with its advantages and disadvantages.

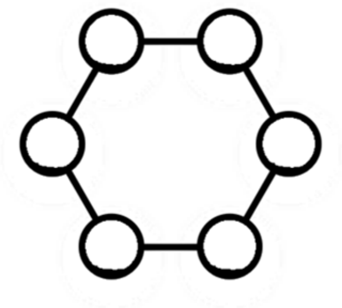
**Bus Networks** are networks in which the network nodes are directly connected through wire to a common link, called a bus. These are traditional networks existing in a household, where all the devices are connected through wires in a local area network (LAN). These are simple and reliable networks, where if a node ceases to operate, the rest of the network can still function and communicate with each other. The main limitations of bus networks are the cable losses that can occur or if the nodes are not located in a common line.

Figure 19 - Example of a Bus Network



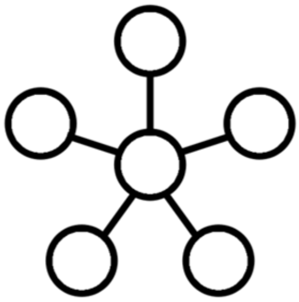
**Ring Networks** are local area networks in which the nodes are connected in a closed loop. While some nodes are directly connected, others are indirectly connected and data should pass through adjacent nodes to reach a destination node. If two or more breaks occur within a ring network, this may lead to a full disconnection of some nodes in the networks. Bandwidth is shared among all nodes of the network which could cause communication lag among all the nodes. Although this type of networks can be used in small networks, ring networks are not the most reliable.

Figure 20 - Example of a Ring Network



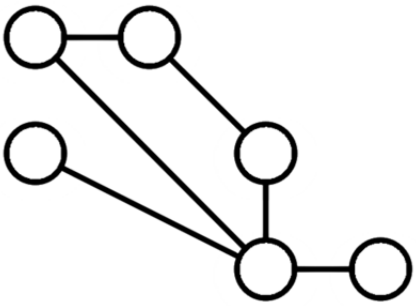
**Star Networks** are wired local area networks where a central computer functions as main control node to receive and transmit data. In this type of network, every of the computers within the network are connected to the main hub which them communicates with the others. This type of network has the advantage that if one or more nodes of the network fails, the remaining of the network is still able to operate and the disadvantage that if the main computer fails, it leads to the failure of the whole network.

Figure 21 - Example of a Star Network



**Mesh Networks** are expected to play an important role in the Internet of Things. Mesh networks are communication networks made up of radio nodes distributed in a mesh structures. Although possible to be wires, mesh networks get its most advantages in a wireless mode, where wireless mesh networks are transformed into a network of routers that work through the connection of radio devices, which can carry data without the need of wires. The nodes function both as a receiver and a transmitter, passing through the data to be transmitted. This type of network is particularly interesting in the way that each of the connected devices within the Smart Home can serve as a node, making the communication easier. These networks are especially interesting if redundancy is required.

Figure 22 - Example of a Mesh Network



## 4.3 Smart Home wireless technologies

Wireless technologies are commonly used within households as an easy and seamless solution for the transmission of data and working commands. In this section it is given an overview of these technologies existing within the smart home. Due to its lower cost of installation and equipment, wireless technologies are seen as crucial for the propagation of the smart home market, without the fuss of wired networks.

### Bluetooth

Bluetooth is a technology standard used for the exchange of data in short distances (+/- 10 m) with the use of short wave length radio waves. Due to its very low energy usage and fast data exchange is a very popular technology for its ease of use and secure connection characteristics

**GSM**

Global System Mobile or GSM is standard created to describe the protocol for digital cellular networks. Although being better known as a mobile wireless system, it also has applications within the Smart Home for the communication of devices. GSM has the advantage to have a range of several kilometres; it is a technology that is widely adopted, with a low cost and high compatibility.

**RFID**

Radio Frequency Identification (RFID) is a system using electromagnetic fields that aids Machines or computers to identify objects, record metadata or control individual targets through radio waves. RFID operates in both low (30 cm transmission distance), high (1.5 m transmission distance) or ultra-high (up to 15 m range frequencies and has the advantage to be a stable technology that is widely spread out in the market.

There are passive RFID tags that collect energy from a nearby RFID reader and active RFID tags that have a local power source incorporated and can operate away from the RFID reader.

**Wi-Fi**

Wi-Fi is commonly used technology, typically used in Home Area Networks, mobile phones or computers with a traditional star network structure. Due to being existent in the majority of electronic devices and its fast transmission speeds, Wi-Fi is a key communication technology in a smart home environment. Devices are able to connect to the internet via a WLAN network with a range reach from a couple of meters inside a room to hundreds of meters when the signal is unobstructed.

Wi-Fi works under the Standard IEEE 802.11 and under the Internet Protocol IPv6.

**WLAN**

Wireless Local Area Networks (WLAN) are wireless networks connected two or more devices using spread spectrum technology using a wireless distribution method. WLAN has a greater transmission distance than Wi-Fi, also wording under the IEEE 802.11 standard and protocol IPv6. WLAN is a more general type of wireless network while Wi-Fi is a type of WLAN.

**Z-Wave**

Z-Wave forms mesh networks and is commonly used for home automation. It is a proprietary standard intended to remotely control applications within the residential and business environments. Z-Wave has a simple command structure and a low interference from other networks. Z-Wave provides a reliable, low-latency transmission of small packets of data up to 100 kbps. Although with an outdoor range of 100 m, due to the fact that works in a mesh type of network

**ZigBee**

ZigBee, as Z-Wave, is another common communication protocol used for home automation, with the difference to work under the standard IEEE 802.15.4. It also works as a mesh network and low data rate for personal area networks. ZigBee devices usually have a low cost, and lower power consumption in comparison with other wireless network standards.

ZigBee works in a low-channel bandwidth and reaches an average of 10 to 30 meters. In comparison with Wi-Fi, ZigBee has a much lower transmission speed, reaching only up to 250 kbps in comparison to more than 10mps of Wi-Fi.

### 6LoWPAN

6LoWPAN (Pv6 over Low-Power Wireless Personal Area Networks) is a technology that allows IPv6 packets (the 6th and latest version of the Internet Protocol) to be carried within small link layer frames defined by the IEEE 802.15.4 standard, which is a technical standard defining the operation of low-rate personal area networks.

6LoWPAN has a transmission distance of up to 200m and has low energy usage.

## 4.4 Sensor types in the Smart Home

A major component of the smart home ecosystem are the sensors needed to operate and emit signals sensing human activity within a building.

One of the main functions of the Smart Home ecosystem and second most important sub-sector, after entertainment, is home security. With home security come several sensors, like contact sensors that detect the opening of a door or a window, video cameras that allow for home owners to survey the home and act upon.

Firstly, there are direct environmental sensors like binary sensors. Binary sensors detect the presence/absence of an object or a movement through a value of 1 or 0. Binary sensors within the smart home normally include motion detection, pressure or contact sensors. There are several types of motion detection sensors, like Passive Infrared, which detect body head and are very used for home security, Microwave sensors that send out microwave pulses to measure the reflection off moving objects, Dual Technology Motion Sensors that combine different sensor technologies, with both sensors needing to be triggered to set the alarm. Other sensors are Area Reflective Type sensors that emit infrared rays from an LED, Ultrasonic sensors that emit pulses of ultrasonic waves and Vibration sensors that detect vibration and can be triggered by an accelerometer or through a piezoelectric device.

Fire and Carbon Monoxide sensors are other types of sensors being used in the home environment within the security range and warn home occupants if levels of Carbon Monoxide are dangerous. Additionally to CO detectors there are also other environmental sensors that evaluate traditional meteorological parameters like temperature, pressure or humidity or environmental parameters like pollution indexes, air quality, dust or pollen.

Besides sensors per se there is a very important aspect that needs to be taken into consideration, that are the customizable prompts that a user can define based on the capabilities of the smart home system. For example, some Smart thermostats can detect when a user is at home or not and learn from the occupancy patterns of a building, whereas there are other smart thermostats that depend on geofencing, meaning that when connected with an app on your smartphone, the system is aware of you approaching your house from work and starts heating the house according to your settings, instead of having a pre-defined and less change oriented system. Ultimately it still depends on what type of use one gives to the information being fed, since fully automated systems are still a long way to being a reality, at least for the majority of the citizens.

# 5 Energy and Smart devices

The “green” potential of Information Technologies has been being pointed out as one of the advantages for the adoption of these new technologies by changing the way services are being substituted. The potential of energy savings within the smart homes is correlated with the feedback being provided to final energy consumers, in what regards the energy consumption within their homes.

Energy Feedback is a way to turn a resource that until recently was invisible to energy consumers, into a visible one, having ultimately the possibility of turning energy consumers from a passive to an active state. This change makes it possible to potentiate energy savings thanks to the actions stimulated from the collection and processing of energy consumption information and the consequent action from the consumer.

There are two types of feedback, direct and indirect, with sub-categories being defined under these two main categories. Regarding the subject of this report, Direct feedback and its impacts is being looked into. Direct Feedback can be divided into two sub-categories.

First there is Direct Feedback using In-Home Displays, where a device is installed in the home environment allowing the energy users to learn about the consumptions of different appliances by receiving immediate appliance-specific feedback. There are two ways to install the In-House energy displays, by clamping the device into the main electricity panel (for electric energy) or like lately, with the roll-out of smart meters, by connecting the In-Home Displays (IHD) via a direct connection to the smart meter, usually via a wireless system. These devices can give information on the energy use in terms of cost and can be also associated to a web environment providing extra information allowing for alarm setting and goal tracking. This type of feedback systems cannot, however, be operated in terms of demand response and dynamic pricing signals, since are one-way communication devices.

Secondly, there is the direct feedback with “connected devices” and automation, which is the most complete and engaging type of feedback before a fully automated system. To reach an accurate and effective feedback system, the user needs to have their home connected to a central device or web application, being able to control remotely at an appliance level the functionalities of the home, while having the ability even to receiving pricing signals and utility load control.

Overall the main differences between Indirect and Direct Feedback can be divided into three issues:

— Frequency: Indirect Feedback has a lower frequency (monthly bills at best in the case of standard billing)

— Medium: Direct feedback uses IoT devices for communication between the user and the utility, while indirect feedback is yet mainly through paper mailing.

— Communication: Indirect Feedback is one-way communication, while Direct Feedback can be two-way communication between the user and utility.

In the JRC report on Energy Feedback Systems[31], an overview of studies realized in the past years regarding energy feedback and its potential energy savings is given. More specifically regarding direct energy feedback, from 46 studies with direct energy feedback and In-House Display, where the users could actively see the energy consumption in real-time and act upon it, there were registered energy savings reaching up to more than 15% of energy savings, in some cases, as presented in Table 2 - Summary of relevant feedback studies.These values have, of course, to be taken in

[31] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/energy-feedback-systems-evaluation-meta-studies-energy-savings-through-feedback

carefully, since there may certainly be several external issues besides the installation of an In-Home Display that potentiate energy savings.

Table 2 - Summary of relevant feedback studies.

| Study | Consumption Type | Country | Media | Frequency | Sample size | Duration [months] | % Savings |
|---|---|---|---|---|---|---|---|
| **Allen & Janda (2006)** | Electricity | USA | IHD | Continuous | 60 | 2 | - |
| **Carroll et al. (2013), C** | Electricity and Heating | IE | IHD | Continuous | 636 | 12 | 2.0% |
| **DECC (2015)** | Electricity | UK | IHD | Continuous | 5145 | 12 | 2.3% |
| **DECC (2015)** | Heating | UK | IHD | Continuous | 5145 | 12 | 1.5% |
| **Dobson and Griffin (1992) in Darby (2006)** | Electricity and Heating | CA | IHD | Continuous | < 100 | 2 | 13.0% |
| **D'Oca et al. (2014)** | Electricity | IT | IHD | Continuous | 31 | 12 | 18.0% |
| **E.ON / AECOM 2011 d'** | Heating | UK | Mixed | Mixed | 1436 | 24 | 4.6% |
| **E.ON / AECOM 2011 d''** | Heating | UK | Mixed | Mixed | 1436 | 24 | 2.2% |
| **E.ON / AECOM 2011 d' (fuel poor)** | Electricity | UK | Mixed | Mixed | 2524 | 24 | 2.0% |
| **E.ON / AECOM 2011 d'' (high use)** | Electricity | UK | Mixed | Mixed | 2524 | 24 | 4.0% |
| **E.ON / AECOM 2011 d''' (not fuel poor)** | Heating | UK | Mixed | Mixed | 1436 | 24 | 4.9% |
| **E.ON / AECOM 2011 e** | Electricity and Heating | UK | Mixed | Mixed | 2524 | 24 | 3.0% |
| **EDF / AECOM 2011 b** | Electricity | UK | IHD | Continuous | 370 | 20 | 5.0% |
| **EDF / AECOM 2011 c** | Electricity | UK | IHD | Continuous | 200 | 20 | 7.0% |
| **Harrigan and Gregory(1994)** | Heating | USA | IHD | Continuous | 71 | 14 | 0.0% |
| **Houwelingen (1989) a** | Heating | NL | IHD | Daily | 50 | 12 | 8.0% |
| **Houwelingen (1989) c** | Heating | NL | IHD | Continuous | 50 | 12 | 1.0% |
| **Hutton et al. (1986) Study 1** | Electricity | USA-CA | IHD | Continuous | 371 | 5 | 4.1% |
| **Hutton et al. (1986) Study 2** | Electricity | USA-CA | IHD | Continuous | 377 | 5 | 5.0% |
| **Hutton et al. (1986) Study 3** | Electricity | USA-CA | IHD | Continuous | 336 | 5 | 6.8% |
| **Hydro One (2006)** | Electricity | CA | IHD | Continuous | 500 | 30 | 7.0% |
| **Hydro One (2006) b** | Electricity and Heating | CA | IHD | Continuous | 500 | 30 | 1.2% |
| **Hydro One (2006) c (electric hot water heating)** | Electricity and Heating | CA | IHD | Continuous | 500 | 30 | 16.7% |
| **Mansouri & Newborough (1999)** | Electricity | UK | IHD | Continuous | 31 | 2 | 20.0% |
| **Matsukawa (2004)** | Electricity | JP | IHD | Continuous | 319 | 5 | 1.8% |
| **McClelland & Cook (1979–1980)** | Electricity | USA | IHD | Continuous | 101 | 9 | 12.0% |
| **Mosler and Gutscher (2004) Fischer (2008)** | Electricity | CH | n/a | Daily | 48 | 1 | 6.0% |
| **Mountain (2007) Study 1** | Electricity | CA | IHD | Continuous | 118 | 15 | 18.1% |
| **Mountain (2007) Study 2** | Electricity | CA | IHD | Continuous | 110 | 15 | 2.7% |
| **Mountain Economic Consulting and Associates (2006)** | Electricity | CA | IHD | Continuous | 552 | 15 | 6.5% |
| **Nilsson et al. (2014) a** | Electricity | SE | IHD | Continuous | 20 | 1 | 0.0% |
| **Nilsson et al. (2014)** | Electricity | SE | IHD | Continuous | 13 | 1 | 0.0% |

| Study | Consumption Type | Country | Media | Frequency | Sample size | Duration [months] | % Savings |
|---|---|---|---|---|---|---|---|
| **b** | | | | | | | |
| **Pallak & Cummings (1976); Pallak et al. (1980)** | Electricity and Heating | USA | IHD | 1-4 times/week | 109 | 2 | 16.0% |
| **Parker et al. (2008)** | Electricity | USA | IHD | Continuous | 17 | 15 | 7.0% |
| **Robinson (2007)** | Electricity | USA | Mixed | 1-4 times/week | 141 | 5 | - |
| **Scottish Power/AECOM 2011** | Electricity | UK | Mixed | Mixed | 1603 | 10 | 0.0% |
| **Scottish Power/AECOM 2011** | Heating | UK | Mixed | Mixed | 1603 | 9 | 0.0% |
| **Seligman et al. (1978) Study 2** | Electricity | USA | Card | Continuous | < 50 | 0.5 | 13.0% |
| **Seligman et al. (1978) Study 3** | Electricity | USA | IHD | Continuous | < 50 | 0.5 | 15.7% |
| **Sexton et al. (1987); Sexton et al. (1989); Sexton & Sexton (1987)** | Electricity | USA | IHD | Continuous | 269 | 9 | - |
| **Sipe & Castor (2009) Study 1** | Electricity and Heating | USA | IHD | Continuous | 305 | 9 | - |
| **Sipe & Castor (2009) Study 2** | Electricity and Heating | USA | IHD | Continuous | 588 | 9 | - |
| **SSE/AECOM 2011 a** | Electricity | UK | IHD | Continuous | 2500 | 36 | 1.0% |
| **SSE/AECOM 2011 c** | Electricity | UK | IHD | Continuous | 524 | 24 | 2.0% |
| **SSE/AECOM 2011 c** | Heating | UK | IHD | Continuous | 204 | 24 | 3.0% |
| **Ueno et al. (2005); Ueno et al. (2006)** | Electricity and Heating | JP | PC or Web | Continuous | 19 | 9 | 12.0% |
| **van Elburg, H. (2008) b** | Electricity | IT | IHD | Continuous | 1000 | 12 | 10.0% |
| **van Elburg, H. (2008) c** | Electricity | NL | PC or Web | - | 60000 | 24 | 3.0% |
| **van Elburg, H. a** | Heating | LV | Bill | Monthly | 22 | 12 | 0.0% |
| **van Elburg, H. c** | Heating | NL | PC or Web | - | 60000 | 24 | 3.0% |
| **van Houwelingen & Van Raaij (1989)** | Heating | NL | Mixed | Mixed | 235 | 9 | 12.3% |
| **Wilhite & Ling (1995)** | Electricity | NO | Bill | Monthly | 1284 | 15 | 10.0% |
| **Wilhite et al. (1993)** | Electricity and Heating | NO | Bill | 2-6 months | 600 | 36 | 10.0% |
| **Wilhite et al. (1999)** | Electricity and Heating | NO | Mail | 2-6 months | 2000 | 24 | 4.0% |
| **Winett et al. (1979) a** | Electricity and Heating | USA | Mail | Daily | 12 | 1 | 13.0% |
| **Winett et al. (1979) b** | Electricity and Heating | USA | Mail | Daily | 16 | 1 | 7.0% |
| **Winett et al. (1982) Study 1** | Electricity | USA | Card | Daily | 49 | 2 | - |
| **Winett et al. (1982) Study 2** | Electricity | USA | Card | 1-4 times/week | 35 | 0.5 | - |

While energy feedback may have a key role in the user experience and how final energy consumers perceive energy consumption in their lives, energy savings cannot be assumed to occur by just the installation of devices and giving feedback to final energy consumers. The presentation of these values serves the purpose that the opportunity is there, but there are numerous factors that need to be in place for these savings to occur in the first place and most importantly, to continue throughout the years when the novelty of the "gadget" ceases to exist.

Nevertheless, with the increase of time being spent, interacting with computers and most notably smartphones, will allow for also an increase of the engagement of energy consumers for a large amount of time and in a more effective way. Further discussion is needed on what type of medium and what type of interaction can be chosen to increase such engagement, since there are too many variables to be taken into consideration. For instance, if you have an IHD needing an active prompting action as your only mean to get feedback versus a push notification from a smartphone that warns you during different energy consumption moments and may guide on how to proceed in order to potentiate energy savings.

Overall, In-House Displays are the smart home devices with the most studies on potential energy savings, but also other ways of energy interaction within the smart home indicate a way of saving energy. Normally the indication of energy savings from smart home applications are coming from the product developers themselves, with little hard evidence that the savings being declared can be reproduced accurately.

Companies working for utilities that develop software "applications as a service" which presented as Energy Portals, like Oracle Opower[32], claim energy efficiency savings in the order of 1.5 to 2.5% or smart thermostat companies[33] which claim energy savings after the installing of the thermostat of up to 10%. These results are to be taken cautiously though, since these are many times coming from the producers themselves and need to be followed upon.

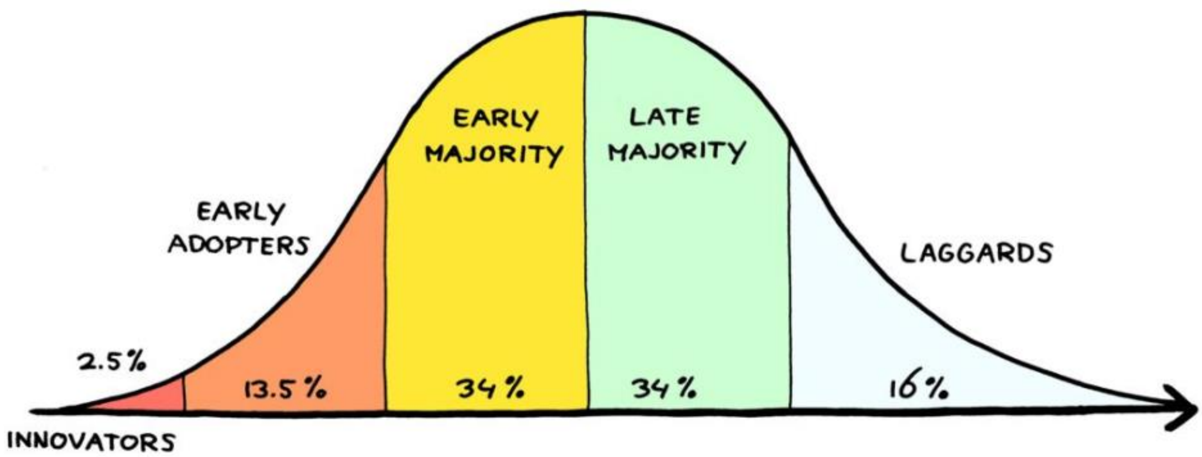
[32] http://www.oracle.com/us/industries/utilities/ou-opower-energy-efficiency-ds-3553419.pdf
[33] http://downloads.nest.com/press/documents/energy-savings-white-paper.pdf

# 6 Discussion

This chapter of the report intends to identify the perspective of market achievement of smart home and smart appliances technologies, the aspects that are hindering a global adoption of these technologies and the positive aspects that may help smart homes become mainstream earlier than later.

The introduction of a new technology can be theorized by the distribution of innovation curve below that was presented in 1962 by Everett Rogers. The concept behind this theory is that the adoption of a new idea, behaviour or product (as smart appliances) does not occur at the same time in a society, with some people being more prone to adopt these innovations than others. There are different types of adopter categories. Innovators that are the people who want to be the first to try the innovation, are willing to take risks and there is little to be done in the convincing of this type of adopters. Early adopters represent opinion leaders and are comfortable adopting new ideas without any convincing. The early majority people adopt new ideas before the average person as they see the advantages of the innovation before their own adopting and need some convincing. Late Majority are sceptical of change and will adopt an idea after it has been tested and validated by the majority. Finally, Laggards are usually very conservative and very hard to be convinced into adopting a new idea.

Figure 23 – Diffusion of Innovation Curve




With Smart Homes and Smart Appliances, it can be assumed that, at this point, the market is still of the innovators and early adopters, who are traditionally tech oriented people, with already some sensibility on the subject and are willing to take the risk of adopting a technology that will allow them to reap the announced advantages in terms of more autonomy in the house and contribute with potential energy savings.

An argument of why smart homes and smart appliance technologies is still not yet mainstream may be that, up to now, this category has been presenting solutions for problems not really needing a resolution. The great majority of people do not actually need a new thermostat, a wi-fi refrigerator or a smart lock to replace their existing fine-working devices, which in the most cases are not yet obsolete. Just old but working perfectly fine, reliable and easy to use. To change these existing objects for more expensive and potentially more complicated devices is not something that most people are willing to and are contented with their present situation.

Some exceptions to the initial sceptic reaction for the adoption of smart appliances has been the thermostat, with the introduction of smart features that have made these devices the most searched for and that before were usually more or less invisible within the home, maintaining the same pre-setting after the first use. The self-learning technology introduced with NEST thermostats, followed by other smart features introduced by other traditional thermostat manufacturers has made smart thermostats mainstream. The easy appealing design, beautiful user interface and user experience from the installation to the daily use has turned this before boring device into the most important item in the smart appliance ecosystem.

The straightforward setting with easy-to-use features of the smart thermostats, with the perceivable impact that lowering the temperature of your home or turning off the heating system when the house is empty has had, has not been accompanied by the remaining devices within the smart home. A great part of the smart gadgets and smart appliances require technical expertise to be installed and the benefits to be harvested with its installation are no much more than the improvement of convenience, leaving for Innovators the big part of the

A Do It Yourself (DIY) mentality is in fact something that is very much present in the whole experience of turning a home into a smart one. Although there are already some energy utilities offering smart home devices and accompanying its installation, it is still being left for the final users the onus to understand, install, conjugate and coordinate all the puzzle pieces within a smart home. Unless one is someone with a natural appetence for home work and tech oriented, the DYI aspect of the smartization of a home can become deterrent of a full transition into having a smart home. Home work is something that traditionally was always accompanied by experts and whenever an issue would arise, one would know who to call and get the problem fixed. Now, with little to none intermediaries between the moment of the purchase, the installation and the use phase, companies commercializing smart devices should be able to guarantee an accompaniment of their costumers, which is something that is not yet part of their business model at the moment.

Other matter often presented relates to safety and security of smart systems. With the information age, issues related with the collection of great amounts of data from the occupants of a home have become more sensible. Data like the occupancy of the building or financial information are have the potential to be stolen and be used against the homeowners. This is not much different than the safety matters regarding email accounts, internet passwords or computer hacking issues. Still, the fact that is one’s home is somewhat important and to be addressed.

The price of “smart things” is another aspect to be taken into consideration. Even if recognizing the virtues of a smart replacement for a traditional device, the fact is that smart devices are significantly more expensive than the devices being replaced. A normal light switch versus a connected light switch or a traditional light bulb versus a connected light bulb have completely disparate ranges of prices to perform a similar action, only by via a remote command. This may present itself hard for consumers to see the multiple benefits that can counter the multiple price increase.

The “complication” of smart devices may be another aspect that can be deterrent for the adoption of a certain technology. For example, the installation and use of a smart light switch is complicating the simple act of turning on and off the light, by installing it, configuring it and connecting it to the local network, in order for the user be able to turn on and off the light via a simple smartphone app wherever and whenever you are.

Finally, an important issue regarding the full adoption of smart home technologies into the daily life of citizens is the different array of smart home appliances, ecosystems and apps that one would expect to work together. Right now the Smart Home is a box of smart things with dissimilar smart devices that sometimes connect among themselves.

It has become more and more common for apps and smart home devices to communicate among them via a central hub and the term “works with X” became ever present in the product descriptions, so that the final users know that their devices can communicate among themselves. Still, a common language and interaction is something needed for the final user in order to have a seamless smart home experience.

Although all these barriers are to be taken into consideration, the adoption of smart devices within the home and the increasing integration of such devices in everyday life should be, in the big picture, unavoidable. Being via the novelty of a new gadget that connects to the home entertainment system, through demand flexibility characteristics imposed by energy companies or via the voice activated personal assistant that can serve as an egg timer and a central hub to control all the electronic devices and energy systems within a house. The immediacy of today's society where everything needs to be ready at the swipe of a touchscreen or a voice command should be able to push more and more for

Ultimately, it is generally expected from smart home devices, that these become a part of a home like traditional appliances with the same final objective of the latter. To make the life easier and save time and energy for the people who inhabit a home and be able to be seamlessly present in all aspects of someone's home life, from heating and cooling to entertainment.

Another positive aspect of automated devices may be that these may have the ability to impede users to return to their bad old habits. With automatization and self-learning devices, some choices related with energy consumption, can be left to the smart home system instead of the human controlling the device. It is not rare that a user, when faced with a new technology to have a big engagement with the new device and actually contribute to energy savings, to not long after return to the habits adopted before the novelty. The automation may contribute to minimize the cooling down from this user after a first phase of enthusiasm for the novelty.

An aspect that may contribute to the mass adoption of smart home technologies may come in fact from non-traditional appliance companies. As pointed out before, entertainment is still the main component of "smart things" within the house. Companies that traditionally operate in the entertainment and personal computing businesses (e.g. Apple Home, Amazon Echo, Google Home) are entering in full force in the smart home industry and may be the entryway for a steady adoption of smart home technologies in the everyday life of citizens.

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Xiaolin, J.; Quanyuan, F.; Taihua, F.; Quanshui, L. RFID technology and its applications in Internet of Things

## List of figures

## List of tables

KJ-NA-29750-EN-N

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