



Preparatory study on Smart Appliances

Task 2 Economic and market analysis

VITO: Dominic Ectors, Helena Gerard, Sarah Bogaert & Koen Vanthournout

Armines: Marcel Perret-Gentil & Philippe Rivière

Rheinische Friedrich-Wilhelms-Universität Bonn: Jasmin Geppert & Prof. Rainer Stamminger

Viegand Maagøe A/S: Jan Viegand

Wuppertal Institut: Thomas Götz

Project management: Sarah Bogaert

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VITO NV

Boeretang 200 - 2400 MOL - BELGIE
Tel. + 32 14 33 55 11 - Fax + 32 14 33 55 99
vito@vito.be - www.vito.be

BTW BE-0244.195.916 RPR (Turnhout)
Bank 375-1117354-90 ING
BE34 3751 1173 5490 - BBRUBEBB

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LIST OF ACRONYMS

AC	Air Conditioning
ADSL	Asymmetric Digital Subscriber Line
BAT	Best Available Technology
BRP	Balancing Responsible Parties
CBA	Cost-Benefit Analysis
CFL	compact fluorescent light
CHP	Combined Heat and Power
DHW	Domestic Hot Water
DOCSIS	Data Over Cable Service Interface Specification
DR	Demand response
DSO	Distribution System Operators
ETSI	European Telecommunications Standards Institute
EV	Electric vehicle
GLS	general lighting service 'incandescent'
GSM	Global System for Mobile Communications
GW	Gigawatt
HEG	Home Energy Gateway
HID	high intensity discharge lamp
HVAC	Heating, Ventilation and Air Conditioning
LED	light emitting diode
LFL	linear fluorescent lamp
LTE	3GPP Long Term Evolution (4G)
M2M	Machine to Machine
NRVU	Non-Residential Ventilation Units
PLC	power line communication
PV	Photovoltaic
RES	Renewable Energy Sources
RVU	Residential Ventilation Units
SAREF	Smart Appliances REference ontology
SOC	State Of Charge
TSO	Transmission System Operators
TWh	TeraWatt hour
UMTS	Universal Mobile Telecommunications System
UPS	Uninterruptible power supply
VDSL	Very-high-bitrate Digital Subscriber Line
VRF	variable refrigerant flow

TASK 2 ECONOMIC AND MARKET ANALYSIS

The objective of Task 2 consists of the assessment of the stock of smart appliances defined in Task 1 within the EU28.

An analysis has been made of current trends regarding the general Internet of Things market and more specifically the market for smart home and smart appliances. Although market reports give a good picture of general tendencies regarding the current and future supply of smart appliances, it was not possible to derive 'smart' shares of individual appliances for the various categories.

Smart appliances as defined in this study have not yet (fully) seized the market and no figures are available specifically for this subcategory of 'smart' appliances. Therefore, the current stock data for all appliances - including non-communication/communication enabled and non-DR/DR enabled appliances – is given as a starting point. Expert judgment estimations have been made per appliance type of the current share of DR enabled stock as well as predictions for 2020 and 2030.

In this Task report an overview is also given of the various types of economic instruments/remuneration mechanisms that could be used to pass the value of flexibility provided by smart appliances on to the end-user. These remuneration mechanisms can provide incentives in order to use more of the flexibility potential and will be combined with the modelling in Task 5.

2.1. MARKET TRENDS

This section describes a number of market trends regarding the general Internet of Things market and more specifically the market for smart home and smart appliances.

Important note: The market research reports use different terminology and categories to classify 'smart' appliances or devices¹, which makes it difficult to compare figures and trends. The reports mentioned in this section use the term 'smart' to indicate communication-enabled or 'connected' appliances or devices. Most of these 'smart' appliances or devices come with a smartphone or tablet app, which is indicated as 'app-enabled'. Only some of the 'smart' appliances or devices mentioned provide functionality to enable DR in 2015. Smart homes are sometimes classified as homes with at least one smart device/appliance, or as whole-home multi-function smart homes (based on a traditional home automation system or on an integrated solution of smart devices).

2.1.1. TRENDS IN THE FIELD OF SMART APPLIANCES / SMART HOME DEVICES

Several appliance manufacturers offer smart appliance lines in 2015. IFA (Internationale Funkausstellung) 2015 in Berlin, the global trade show for consumer electronics and home appliances, presented in September 2015 the latest products and innovations and is a unique opportunity to have an overview on the trends in consumer electronics. Smart homes and smart

¹ Devices are a broader term compared to appliances and can also include safety and security systems (internet-connected sensors, monitors, cameras and alarm systems) and energy equipment like smart thermostats.

appliances were very prevalent at this year's trade show². Examples of demonstrated available smart home appliances are e.g. the GE WiFi Connect, Hoover Wizard smart appliances range, Candy simply|Fi appliances, Haier's Intelius 2.0 lineup, Grundig's HomeWhiz appliances, Whirlpool's 6TH Sense Live range, Bauknecht (Whirlpool Group) appliances controlled with BLive app, Electrolux, LG, Miele's EditionConn@ct and Miele@Home appliances, and others. Samsung announced to bring all their devices within the IoT ecosystem by 2020. Most appliance manufacturers offer since this year a commercial product line of smart appliances, with a focus on dishwashers, washing machines, washer-dryers and refrigeration products. Other types of smart appliances commercially available in 2015 (or announced) are: the smart coffee machine, the smart robot vacuum cleaner, the smart toothbrush, the smart garden sprinkler, the smart hood, the smart hob or the smart oven.

Some smart appliances are designed in such a way that they can communicate information directly to the service operator for efficient and productive use of electricity. Some of these appliances have the ability to measure and control their energy usage. Promoting the added value of smart appliances towards customers is done by emphasizing the extra comfort (like remote control or status notifications via an app) and energy management functions. For instance Hoover's app monitors each product's energy consumption (energy management function) and can send updates and alerts, e.g. when the dishwasher needs more rinse aid or that the fridge's temperature is rising (comfort function).

The global consumer industry of smart appliances' overall turnover is forecasted to grow by 14% this year, from €783bn in 2014 to €891bn³ in 2015. The next subsections list several market research reports which give forecasts on the expected evolution of turnover of smart appliances and smart home devices.

2.1.1.1. SOURCE: IHS TECHNOLOGY

IHS Technology predicts the global market for smart connected household appliances to boom from around 1 million units sold in 2014 to 223 million units by 2020. The total addressable smart connected major home appliance (MHA) market is forecast to be 470 million units worldwide between 2015 and 2020. IHS calls this forecast "conservative" with an opportunity for the market to grow even more, depending on how rapidly appliance makers educate end-consumers and provide appropriate price-to-value balance.

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 followed by the United States. If the smart household category is widened out from kitchen goods, including fridges, washing machines, refrigerators and ovens to all connected household appliances, like coffee machines, robotic vacuums, rice cookers, microwave ovens, air purifiers, and electric toothbrushes, then the market could stretch to 700 million appliances by 2020⁴.

² <http://www.ifa-international.org/dailies>

³ Hans-Joachim Kamp, Chairman of the supervisory board of Consumer & Home Electronics GmbH (gfu), the organisers of IFA, <http://www.ifa-international.org/dailies>.

⁴ Dinesh Kithany, senior analyst for home appliances at IHS Technology, IFA 2015, <http://www.ifa-international.org/dailies>.

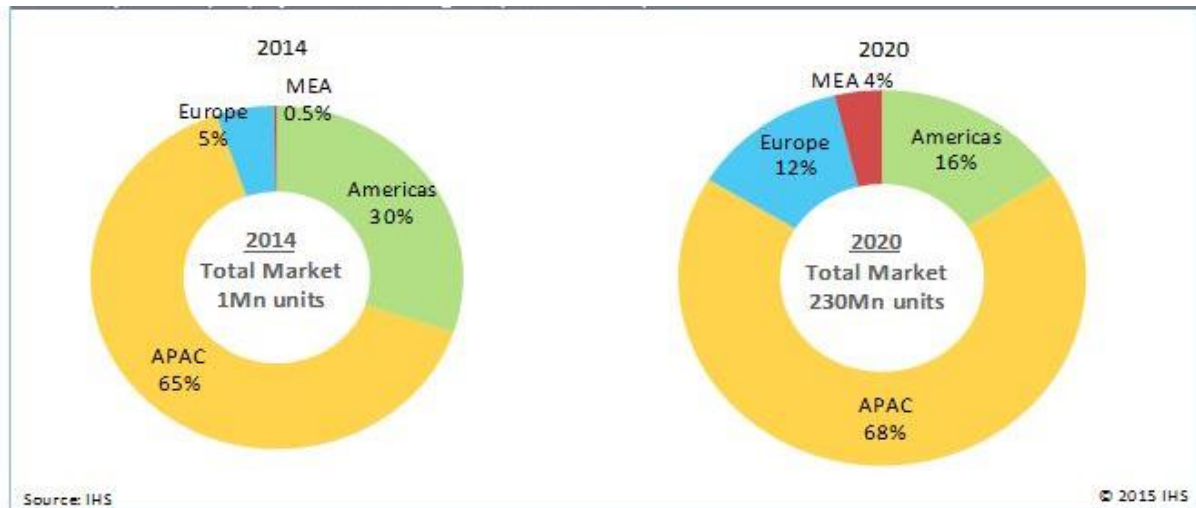


Figure 1 World market for smart connected major home appliances – Unit shipments (Mn) by share and region (2014 & 2020) - source IHS⁵

The appliance types covered in the IHS research include washing machines (WM), clothes dryers (CD), dishwashers (DW), refrigerators (REF), room air-conditioners (RAC), and large cooking appliances (LCA).

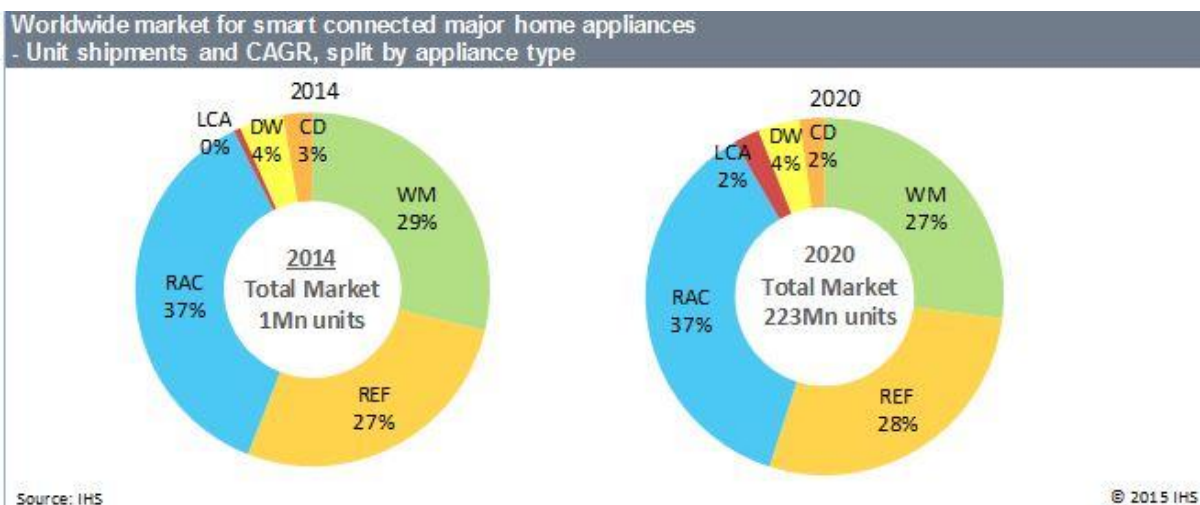


Figure 2 World market for smart connected major home appliances – Unit shipments and CAGR, split by appliance type - source IHS⁵

IHS cites the following reasons for this trend:

- Over the last decade consumers have evolved and quickly adopted new technology products thanks to the higher adoption of smartphones, familiarity with touch controls, the world of apps, and access to the internet.
- As smart appliances are expected to be more energy-efficient than their traditional counterparts, there is a push by governments and regulatory authorities to support and develop this trend⁶.

⁵ <https://technology.ihs.com/549694>

⁶ IHS cites this, but other sources do not agree (as demand shift capacity is often the main focus)

- Many appliance makers are shifting focus from the low-profit, low growth traditional 'non smart' segment toward the high-margin, revenue oriented smart appliance segment.

2.1.1.2. SOURCE: BI INTELLIGENCE (GLOBAL)⁷

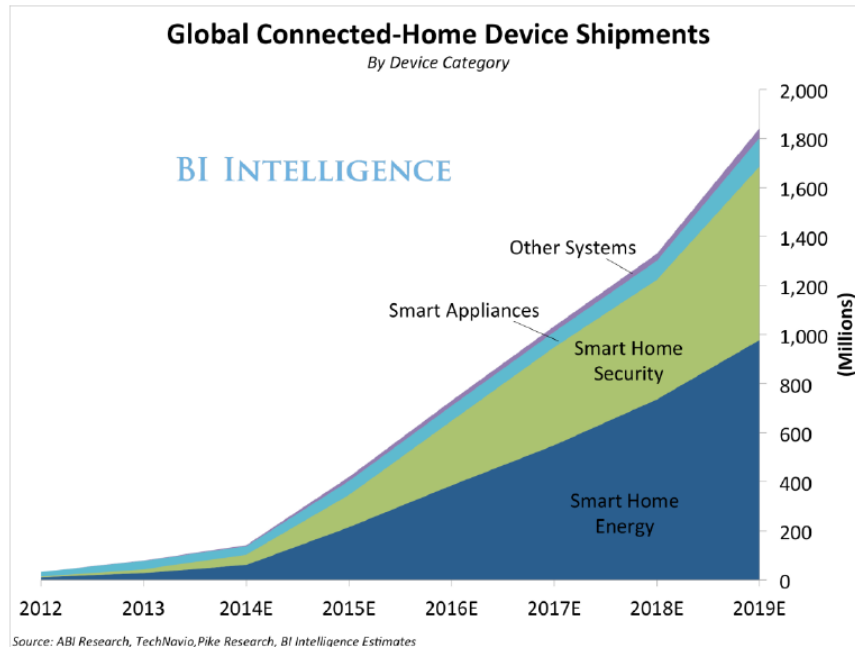


Figure 3: Global connected-home device shipments⁷

Connected home devices include all smart appliances (washers, dryers, refrigerators, etc.), safety and security systems (internet-connected sensors, monitors, cameras and alarm systems)⁸, and energy equipment like smart thermostats and smart lighting. Home-energy equipment and safety and security systems, including devices like connected thermostats and smoke detectors, are projected to become popular first, leading the way to broader consumer adoption. In 2019, connected-home device shipments will account for roughly 27% of the total global IoT market (23% in 2014). Connected-home device shipments will grow at a compound annual rate of 67% over the next five years according to BI Intelligence estimates. Smart home appliances will be the slowest-growing category, averaging 28% compound annual growth between 2014 and 2019 globally. This category includes products like smart refrigerators, smart washers and dryers and smart dishwashers.

As prices decline over the long run and consumers become more familiar with connected-home devices overall, the smart appliances' growth is expected to accelerate. One important factor that will make connected-home devices ubiquitous in the near term is the growth in the number of households worldwide with broadband internet connections. Between 2014 and 2019, the number of total global households equipped with a Wi-Fi connection will grow at a compound average rate of 15%. BI Intelligence estimates that in 2019, roughly 1.2 billion households globally will have Wi-Fi in

⁷ BI Intelligence (2014) THE CONNECTED-HOME REPORT: Forecasts And Growth Trends For The Leading 'Internet Of Things' Market
http://static1.squarespace.com/static/5129591ae4b0fd698ebf65c0/t/5467dface4b00178423ef007/1416093612167/bii_connectedhome_sept14.pdf

⁸ As this is a new product category for many households absolute energy consumption might actually rise

the home. On average, households within these 1.2 billion broadband-equipped homes will have 1.5 connected-home devices in 2019.

2.1.1.3. SOURCE: BI INTELLIGENCE US SMART HOME MARKET REPORT

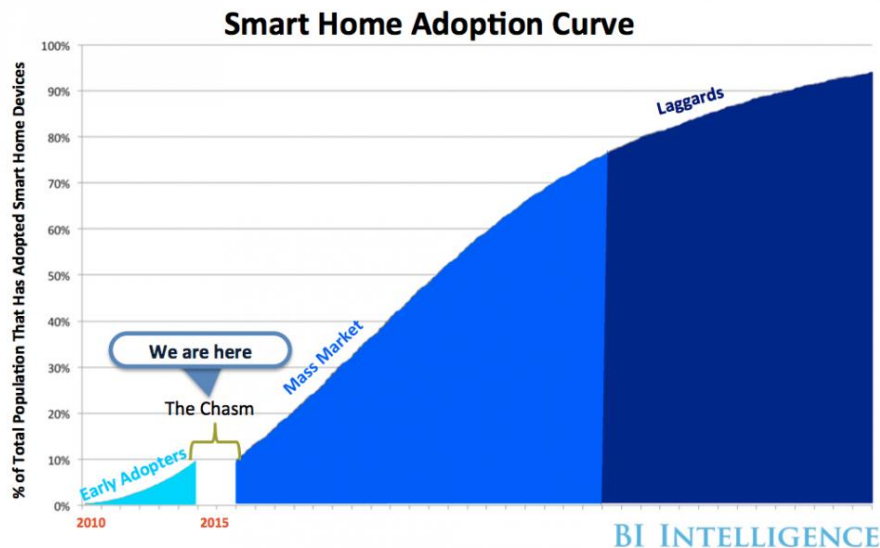


Figure 4: Smart Home Adoption Curve (source: BI Intelligence)

Key takeaways of a recent BI Intelligence report⁹ on the US smart home market are:

- Smart home devices¹⁰ are becoming more prevalent throughout the US. Multiple smart home devices within a single home form the basis of a smart home ecosystem.
- Currently, the US smart home market as a whole is in the "chasm" of the tech adoption curve (Figure 4). The chasm is the crucial stage between the early-adopter phase and the mass-market phase, in which manufacturers need to prove a need for their devices.
- **High prices, coupled with limited consumer demand and long device replacement cycles** are three of the four top barriers preventing the smart home market from moving from the early-adopter stage to the mass-market stage. For example, mass-market consumers will likely wait until their device is broken to replace it. Then they will compare a non-connected and connected product to see if the benefits make up for the price differential.
- **The largest barrier is technological fragmentation** within the connected home ecosystem. Currently, there are many networks, standards, and devices being used to connect the smart home, creating interoperability problems and making it confusing for the consumer to set up and control multiple devices. Until interoperability is solved, consumers will have difficulty choosing smart home devices and systems.
- **"Closed ecosystems" are the short-term solution to technological fragmentation.** Closed ecosystems are composed of devices that are compatible with each other and which can be controlled through a single point.

⁹ <http://uk.businessinsider.com/the-us-smart-home-market-report-adoption-forecasts-top-products-and-the-cost-and-fragmentation-problems-that-could-hinder-growth-2015-9?r=US&IR=T>

¹⁰ BI Intelligence uses a very broad definition for a smart home device. It defines a smart home device as any stand-alone object found in the home that is connected to the internet, can be either monitored or controlled from a remote location, and has a non-computing primary function.

2.1.1.4. SOURCE: RESEARCH AND MARKETS: GLOBAL FORECAST TO 2020¹¹

The smart appliances market is witnessing rapid growth. It is expected to reach USD 37.2 Billion by 2020, and grow at a CAGR of 15.4% between 2015 and 2020. In the smart appliances ecosystem, smart home (Washer, Dryer, Air Conditioner, Vacuum Cleaner) and smart kitchen appliances (Refrigerator, Dishwasher, Freezer) play a vital role. The market for smart home appliances was valued at USD 7.7 Billion in 2014 and it is expected to grow at a CAGR of 16.8% between 2015 and 2020. Smart washers and smart dryers accounted for a large market share, however the market for smart air conditioners is expected to grow at a high CAGR between 2015 and 2020.

2.1.1.5. SOURCE: DEUTSCHE TELEKOM & STRATEGY ANALYTICS¹²

Consumer spending on smart home products and services will hit €90.90 billion globally by 2018 and accelerate from there to €122.77 billion by 2020. Fewer than 25% of homes with broadband connections will have acquired any of these products and services by this time. Strategy Analytics claims that the home market in the EU could be worth over €15.46 billion annually by 2019, with 50 million Western European homes having installed IoT technology.

2.1.1.6. SOURCE: FROST & SULLIVAN: ANALYSIS OF THE EUROPEAN SMART THERMOSTATS MARKET¹³

This analysis from Frost & Sullivan finds that the EU market for smart thermostats earned revenues of \$152.5 million in 2014 and estimates this to rocket up to \$2,570.6 million in 2019 (more than 15 times the 2014 level). The United Kingdom, Germany and the Netherlands are projected to account for a lion's share of the market in Europe, while France will be the fastest growing. The report emphasizes that energy utility companies are critical value chain partners for the smart thermostat vendors. Capitalising on their highly convenient and reliable sales channel will facilitate access to the mass customer market in Europe.

2.1.1.7. SOURCE: BERG INSIGHT: SMART THERMOSTATS¹⁴

Compared to 2013, sales of smart thermostats in Europe in 2014 rose by 96% increase for a total of 0.7 million units. Berg Insight forecasts that the number of homes with smart thermostats in Europe and North America will grow at a compound annual growth rate of 64.2% during the next five years to reach 38.2 million units in 2019. North America will remain the largest market at the end of the forecast period, with 24.6 million homes having smart thermostats, whereas the installed base in Europe is expected to reach 13.6 million homes by 2019.

Consumers embrace smart thermostats primarily due to the potential for energy savings, increased comfort and convenience. For energy companies, they open up new possibilities to introduce consumer-friendly demand response and energy efficiency programmes. In 2014 and 2015 several

¹¹ http://www.researchandmarkets.com/research/zcsgb8/smart_appliances

¹² http://connectedhomeplatform.telekom.net/wp-content/uploads/Telekom_Market_Analysis_Report-How_to_create_Growth_from_the_Connected_Home.pdf

¹³ http://www.frost.com/sublib/display-report.do?id=MB01-01-00-00-&bdata=aHR0cDovL3d3Mi5mcm9zdC5jb20vbmV3cy9wcmVzcy1yZWxlYXNlcy9zbWFydC10aGVybW9zdGF0cy1tYXJrZXQtcmlja2V0LTl1LWJpbGxpb24tNS15ZWYycy1wcmVkaWN0cy1mcm9zdC1zdWxsaXZhibi9AfkBCYWNRQ_H5AMTQ0NjU2ODE1NDU5MA%3D%3D

¹⁴ <http://www.berginsight.com/ReportPDF/ProductSheet/bi-sh3-ps.pdf>

partnerships were announced in the EU between energy service providers and smart thermostat manufacturers¹⁵.

Berg believes that smart thermostats represent a particularly attractive opportunity in the smart home market, as they appeal to consumers, energy companies and HVAC (heating, ventilation and air conditioning) service providers alike.

2.1.2. TRENDS IN THE FIELD OF ENERGY MANAGEMENT SYSTEMS

The report “The scope for energy and CO2 savings in the EU through the use of building automation technology”¹⁶ projects the penetration of modern Building Automation Technology (BAT) and management systems to rise from 26% of all service sector floor area in 2014 to 40% by 2028 (BAU, without further policy intervention). In the residential sector, penetration of Home Energy management Systems (HEMS) is projected to rise from 2% of homes today to 40% by 2034 without additional intervention.

2.1.3. TRENDS IN THE FIELD OF SMART HOMES

Smart home solutions have been on the market for several years and yet, for a variety of reasons, have not yet found mass acceptance. Many of the solutions may have been simply too expensive, or have not yet reached full maturity. Over the last few years, industry has made considerable efforts to develop new, cheaper technologies and to keep on improving existing solutions, including numerous communications protocol. Thanks to all the hype surrounding the IoT in 2014 and 2015, the smart home has also achieved much greater visibility among the general public.

In 2015 the smart home has established itself as one of the leading markets in the IoT, as a variety of studies indicate, including those by Berg Insight¹⁷ and BITKOM.

According to Berg Insight, the European market for smart home systems is still in an early stage and 2–3 years behind North America in terms of penetration and market maturity. At the end of 2014, a total of 3.3 million smart home systems were in use in the EU28+2 countries, up from 1.75 million in the previous year. Around 0.34 million of these systems were multifunction i.e. whole-home systems whereas 2.93 million were point solutions of smart devices. This corresponds to around 2.7 million smart homes when overlaps are taken into account (some homes have more than one smart system), meaning that 1.2% of all households in this region were smart at the end of 2014.

Berg Insight expects that by 2017 there will be 17.4 million smart home systems installed in European homes, bringing in projected sales of 2.6 billion euros. The number of European households that

¹⁵ Some examples: The North American smart thermostat market is led by Nest, Honeywell and Ecobee. In Europe, the leading smart thermostat vendor is eQ-3, whose smartphone-controlled radiator thermostats have been installed in more than 300,000 homes. Other successful initiatives include the smart thermostat solutions offered by the energy companies British Gas in the UK and Eneco in the Netherlands. British Gas’ Hive solution had approximately 140,000 users at the end of 2014, whereas Eneco had signed up around 100,000 users for its Toon solution. (In the UK) Google-owned Nest is being offered to Npower’s customers, Berlin-based startup Tado has teamed up with SSE, Climote is working with Scottish Power, and French startup Netatmo recently partnered with EDF Energy.

¹⁶ The scope for energy and CO2 savings in the EU through the use of building automation technology, Second edition, 13 June 2014, Waide Strategic Efficiency Limited, http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/scope_for_energy_and_co2_savings_in_eu_through_ba_2nd_ed_2014-06-13.pdf

¹⁷ <http://www.berginsight.com/ReportPDF/ProductSheet/bi-sh1-ps.pdf>

have adopted smart home systems is forecasted to grow at a compound annual growth rate (CAGR) of 61% during the next five years, resulting in 29.7 million smart homes by 2019. Market revenues grew by 60% compared to 2013 to € 0.77 billion in 2014. The market is forecasted to grow at a CAGR of 58% between 2014 and 2019 to reach € 7.6 billion at the end of the forecast period.

A point solution will in most cases constitute the consumer's first smart home purchase. In fact, point solutions outsold whole-home systems in 2014 by a factor of six to one and generated 59% of the combined market revenues in North America and Europe. The most successful point solutions to date include smart thermostats, security systems, smart light bulbs, network cameras and multi-room audio systems.

According to the BITKOM Connected Home Working Group¹⁸ by 2020 there could be as many as 1.5 million smart home households in Germany.

According to Argus Insights, home automation was experiencing robust growth in 2014, however data show that as of May 2015 consumer demand for connected home devices experienced a 15% drop below the level of a year ago, a sign that consumer interest may be stagnating¹⁹.

In the past the home automation industry was the only player to provide smart home functionality; but in 2015 several market actors are lining up to take a share of the smart home market:

- Telecommunication providers already have a platform at the customers' home, via the broadband router and are very well positioned to enhance this platform towards a smart home platform (E.g. Qivicon product range offered by Deutsche Telecom; in the US Cable TV, Internet & Phone provider Comcast Corporation steps into the smart home market);
- Energy providers are providing smart thermostats and energy boxes to their customers to reinforce the customer-energy provider binding in a liberalized energy market. Some energy providers offer complete smart home solutions (E.g. RWE Smart Home products, Eneco's Toon thermostat, Eni's Anna thermostat);
- In the US, the home security industry is broadening their scope from alarm to smart home offerings. At the base, consumers value safety, but several consumer segments value energy management, especially when bundled with security and safety offerings (see Task 3);
- The traditional home automation industry, previously targeting the high-end market segment, are now offering slimmed down solutions for the middle-end market segment;
- The consumer industry, and especially some dominant and innovative actors like Google/Nest, Apple and Samsung are offering products or platforms for the smart home. These offerings may tie the customer to a particular ecosystem.

Regarding the path to the connected home, the Deutsche Telekom published the following conclusions in the 'How To Create Growth From The Connected Home' report¹²:

1. Connected devices will transform our homes over the next decade;
2. The market will be worth billions of euros;
3. The threat of disintermediation is very real with innovative players set to enter the home from adjacent markets;
4. Major players need to 'step up to the plate' in order to drive growth from IoT;
5. To engage consumers, focus on meeting their real needs;
6. The ultimate value for service providers, retailers and manufacturers will be in services;
7. The market is not homogeneous, it is distinct and regional and segment needs must be met;

¹⁸ <http://www.bitkom.org> ; <http://blog.bosch-si.com/categories/technology/2015/07/here-to-stay-the-smart-home-needs-standards/>

¹⁹ Source: Argus Insights (2015), <http://www.argusinsights.com/connected-home-release>

8. Create a win-win relationship with partners;
9. No one standard will meet the entire needs of the market, and hence an open architecture will be a prerequisite;
10. Platforms that support multiple use cases will be the only ones that succeed.

2.1.4. TRENDS/STATUS OF SMART METERS

The 2014 Commission Benchmarking Report²⁰ reflected on progress in the roll-out of smart metering across the EU and found a mixed picture (see Figure 5). Three Member States were advanced in their roll-out plans (Finland, Italy, Sweden), installing close to 45 million meters. Another thirteen Member States declared their intention to proceed with large-scale roll-out of smart meters by 2020, although they are at different stages of the process. In seven Member States, the cost-benefit analyses (CBA) proved negative or inconclusive (Belgium, Czech Republic, Germany, Latvia, Lithuania, Portugal, Slovakia). In Germany, Latvia and Slovakia, smart metering was found to be economically justified only for particular groups of customers. These countries now expect to roll out smart meters to around 23% of household consumers. Four Member States (Bulgaria, Cyprus, Hungary, Slovenia) did not produce CBAs or rollout plans at all. Although enthusiasm for smart electricity metering is not uniform across the EU, a majority of Member States still intend to proceed with large-scale deployment by 2020.

Based on the national CBAs, the estimated cost of installing smart electricity meters was identified to vary widely between different Member States, from €77 to €776 per customer. The Commission's benchmarking report expects that smart metering will lead to substantial cost savings in the longer run: the average consumer can reduce their energy costs by around 3%, while some types of consumers could reduce them by up to 10%. Evidence from Member States that have extensively deployed smart metering in the EU would suggest savings are likely to be more modest. Finland found the average savings to be only 1-2%, while Sweden gave a range of 1-3%. Other CBAs conducted by Member States predicted energy savings to be insignificant or as low as 1% per customer. Therefore some stakeholders argue that smart meters should only be installed for consumers with high energy usage, reducing the costs of deployment while keeping the average savings higher. The Commission argues that the extent of energy saving can depend heavily on the functionality of smart meters: those with broad functionality cost more in the short term but yield greater savings in the longer run. This is because they are able to provide a wider range of information to customers, which is more frequently updated and more easily accessible, thereby facilitating demand side response²¹.

According to the estimates in this report²⁰, the roll-out commitments amount to an investment of around €45 billion for the installation by 2020 of close to 200 million smart meters for electricity (representing approximately 72% of all European consumers) and 45 million meters (around 40% of consumers) for gas.

²⁰ Benchmarking smart metering deployment in the EU-27 with a focus on electricity, COM(2014) 356 final, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0356&from=EN>

²¹ [http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568318/EPRS_BRI\(2015\)568318_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568318/EPRS_BRI(2015)568318_EN.pdf)

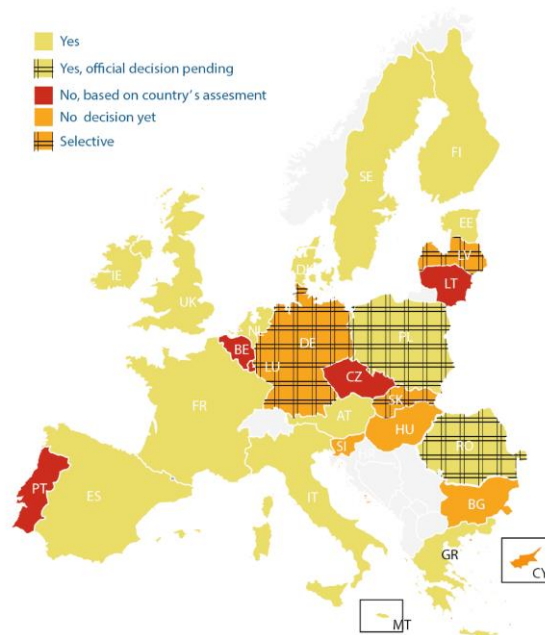


Figure 5: Deployment of smart electricity meters in EU Member States by 2020Error! Bookmark not defined.

2.1.5. TREND: TRADITIONAL ROLES WILL CHANGE

Upgrading appliances to smart appliances is more than just adding a communication hardware module and communication software to the appliance. Connectivity with the end-consumer could have a substantial impact on the business models of manufacturers. Several market research analysts indicate that traditional appliances manufacturers will have to approach the market more as technology providers instead of as manufacturing companies. The manufacturers need to engage not only with distributors, sales depots, retailers, and OEM players as they have done in past, but also with end-consumers. Manufacturers, distributors or retailers may take up the role of service provider and may provide a variety of services towards the consumer:

- Provide a maintenance service related the smart appliance or smart home systems. For instance a smart washing machine can proactively request maintenance ahead of failure;
- Provide an energy service. For instance smart home thermostat providers may offer the flexibility of the connected smart homes, with consent of the owner, to the energy market or utilities;
- Provide a sales channel to tertiary products; a smart fridge may order extra milk when run out of milk; a washing machine²² may order or send a message to your smartphone prompting you to order more when supplies of its detergent run low;
- The setup of these smart appliances may not be so easy for the average consumer. Setting up a single smart appliance may be not so difficult, but integrating several smart appliances to work together creating a smart system or smart home may be much harder. In this case the retailer for instance may take up the role of integrator or consultant of smart appliances/systems.

²² Miele's new Edition Conn@ct washing machine

Obviously these companies will try to convince consumers to buy in to connected machines from the same brand rather than shop across the category. The big advantage for those companies that succeed in making the right connected machines, is that upgrades can be simply plugged in to existing devices therefore keeping customers' loyal and potentially happy to stay with the brand long term. The new services, however, do not only provide new opportunities but also new obligations. For instance to convince the consumers these companies must assure the consumers that any data they share with their connected appliances will be handled securely.

2.1.6. EMERGING BUSINESS MODELS RELATED TO THE INTERNET OF THINGS

In its report "Monetizing the Internet of Things: Extracting Value from the Connectivity Opportunity"²³ Capgemini Consulting indicates that there are four distinct business models that are emerging (Figure 6):

1. "Hardware Premium" is the most basic form of business model. Organizations add connectivity options to an existing or new product and offer remote device management in the form of mobile apps. This basic level of connectivity and control enables organizations to charge a premium for their product.
2. The service model offers a recurring revenue stream and, more importantly, creates a relationship with the customer long after they have purchased a product.
3. Connected devices generate large volumes of sensor data. For many organizations, the ability to capture, package and sell this data offers a potential business model. Once this data has been aggregated and anonymized, organizations can choose to sell it raw, package insights from it or monetize it using advertising.
4. The IoT thrives in a connected ecosystem – the bigger the ecosystem, the greater is the value generated for all stakeholders. In an ecosystem, the focus is not on selling a product or a service, but on providing a shared platform to other players in the ecosystem – hardware manufacturers, software developers, service providers and related stakeholders. In such a model, the platform promoter ideally makes money from both, end customers as well as other platform users. Platform users pay the promoter for listing and the promoter also gets a share whenever a product is sold to the end customer on the platform.

²³ https://www.capgemini-consulting.com/resource-file-access/resource/pdf/iot_monetization_0.pdf

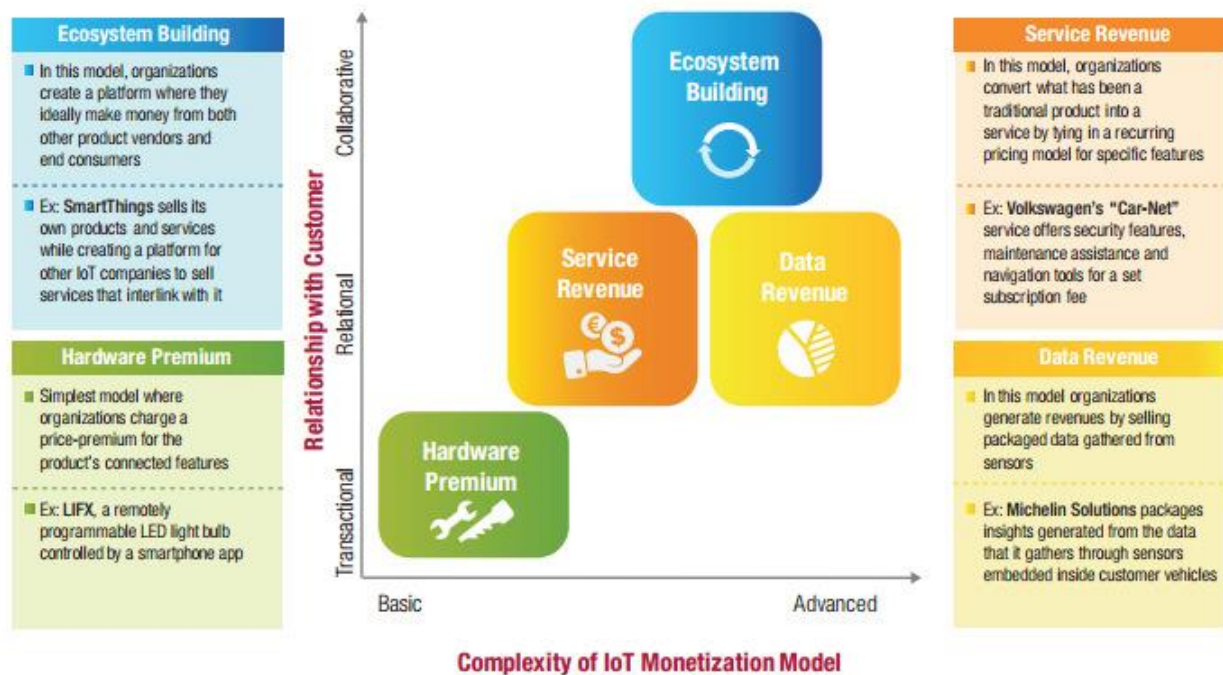


Figure 6 Business models related to IoT (source: Capgemini Consulting²³)

2.1.7. CONCLUSIONS

The terminology 'smart' used in market reports on the IoT and the smart home refers in most cases to 'connected' (communication-enabled) and 'app-enabled'²⁴. Only some of the 'smart' appliances or devices mentioned provide functionality to enable DR in 2015. It generally means that the device/system is connected to a digital communication network and provides the user with the ability to control the device/system by means of an app on a PC, smartphone or tablet. Although DR is not the focus of this market trend, this trend adds communication functionality to these devices which will facilitate the enabling of DR. Figures of DR ready smart appliances sales or stock are not publicly available.

Based upon trends and the forecasts by market research companies, one can conclude that digital communication functionality will be a common (commodity) function in most appliances sold from 2020 onwards. Manufacturers will most likely include digital communication functionality in all or special product series for all product categories in the scope of this study. However, this tendency does not imply that these appliances will be interoperable or will provide DR functionality.

In 2015 most of the smart appliances in this context (thus communication-enabled) are not part of a DR program. However, for two categories of these devices one can already see a path towards DR.

Smart thermostats:

Several European energy service providers are partnering with smart thermostat vendors and are offering smart thermostats to their customers. Some of these energy providers already offer along with the smart thermostat a DR program. Besides these offerings, customers are also buying off-the-

²⁴ Most of these 'smart' appliances or devices come with a smartphone or tablet app, which is indicated as 'app-enabled'.

shelf smart thermostats. Most of the smart thermostats are connected to a cloud and provide the necessary functionality to enable DR. With market research companies estimating an installed base of more than 10 million homes with smart thermostats in 2019, smart thermostats are likely to be the first smart appliances to offer significant DR capacity.

A second trend related to smart thermostats is that the thermostat is evolving into a residential energy management gateway or hub. In this role the smart thermostat is not only controlling the space heating and cooling, but it is also managing other energy using systems in the home like water heaters, pool pumps, smart plugs, EV chargers, etc.

Energy management systems:

Energy management systems do not only provide the ability to increase overall energy efficiency, but provide also the opportunity to offer DR capacity based upon the resources managed by the EMS.

According to the estimations made by the EC, 200 million smart meters for electricity will be installed in 2020, representing approximately 72% of all European consumers. The EC recommends that these intelligent metering systems should enable demand response and other energy services to evolve²⁰.

The trend towards ‘connected’ devices will have a significant impact on the business models, the roles, the sales channels and service channels in this market. Instead of a one-time contact (sales) with the customer, the manufacturer/vendor/service provider will in the IoT scenario have a permanent link with the customer for the entire lifetime of the product.

2.2. CURRENT STOCK OF APPLIANCES AND FIRST ESTIMATION OF SHARE OF SMART APPLIANCES

Smart appliances as defined in this study have not yet (fully) seized the market and no figures are available specifically for this subcategory of ‘smart’ appliances. Therefore, the current stock data for all appliances - including non-communication/communication enabled and non-DR/DR enabled appliances – is given as a starting point. Per appliance type, expert judgment estimations have been made per appliance type of the current share of DR enabled stock as well as predictions for 2020 and 2030.

2.2.1. PERIODICAL APPLIANCES

An overview of the installed units of **dishwashers** in 2010 and estimates for 2015, 2020, 2030 is given in Table 1. For 2020 and 2030, educated estimations were made of the share of smart appliances.

Table 1: Installed units of dishwashers in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Dishwashers			
Reference Year	2010	2015	2020	2030
Installed base	82,799,000	98,345,000	115,036,000	148,553,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances		0	575,180	29,710,600
Source		Conservative estimation of 0% of installed base	Estimation of 5% of installed base	Estimation of 20% of installed base
Reference countries		EU28	EU28	EU28

An overview of the installed units of **washing machines** in 2010 and estimates for 2015, 2020, 2030 is given in Table 2. In (GfK 2015²⁵) an estimation is made of the German market in terms of 50,000 smart washing machine sold in 2014/2015. Based on the total sales in Germany of 39,000,000 washing machines, this comes down to a penetration rate of 0,13%. If this share is multiplied by the total EU28 stock, a total sales amount is estimated of 252,335 smart washing machines in 2015. Note that this should rather be considered as a maximum amount considering the progress of the German market (see next section).

Table 2: Installed units of washing machines in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Washing machines			
Reference Year	2010	2015	2020	2030
Installed base	185,828,000	196,821,000	200,805,000	204,744,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	0	252,335	10,040,250	40,948,800
Source	Estimation of 0% of installed base	Extrapolation based on 0.13% Extrapolation based on 0.13% penetration of German market (GfK, 2015)	Estimation of 5% of installed base	Estimation of 20% of installed base
Reference countries	EU28	EU28	EU28	EU28

An overview of the installed units of **tumble dryers** in 2010 and estimates for 2015, 2020, 2030 is given in Table 3. For 2020 and 2030, educated estimations were made of the share of smart appliances.

Table 3: Installed units of tumble dryers in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Tumble dryers			
Reference Year	2010	2015	2020	2030
Installed base	62,723,000	68,018,000	71,801,000	77,778,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	0	0	3,590,050	31,111,200
Source	Estimation of 0% of installed base	Conservative estimation of 0% of installed base	Estimation of 5% of installed base	Estimation of 40% of installed base
Reference countries	EU28	EU28	EU28	EU28

²⁵ Presentation by Christiane Schoenwetter from GfK during the symposium "Die Vision der 2000-Watt-Gesellschaft" on 20th of October 2015 in Kupferzell/ Germany

Washer-dryers accounted for approximately 2.5% of total washing machines sales in Europe a few years ago (CLASP 2013 in TopTen, 2015²⁶). However, according to current market observations by Topten there are more and more manufacturers offering and promoting them. (Euromonitor International, 2014)²⁷ mentions a penetration rate of about 4% for washer-dryers in the EU²⁸. Applying this penetration rate to the 216,13 million households in EU-28 (most recent Eurostat figures available from 2014²⁹) results in a total number of 8,640,000 appliances. An overview of the estimated installed units is given in Table 4. For 2020 and 2030, educated estimations were made of the share of smart appliances.

Table 4: Installed units of washer-dryers in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Washer-dryers			
Reference Year	2010	2015	2020	2030
Installed base		8,640,000	10,800,000	17,300,000
Source		Estimated based on Euromonitor International, 2014		
Number of smart appliances		0	540,000	3,460,000
Source		Conservative estimation of 0% of installed base	Estimation of 5% of installed base	Estimation of 20% of installed base
Reference countries		EU28	EU28	EU28

2.2.2. CONTINUOUS APPLIANCES

An overview of the installed units of **household refrigerators and freezers** in 2010 and estimates for 2015, 2020, 2030 is given in Table 5. In (GfK 2015³⁰) an estimation is made of the German market in terms of 25,000 smart household refrigerators sold in 2014/2015. Based on the total sales in Germany of 40,000,000 refrigerators, this comes down to a penetration rate of 0,06%. If this share is multiplied by the total EU28 stock of 236,496,000 refrigerators (Kemna, 2014), a total sales amount can be estimated of 147,810 smart refrigerators in 2015. Note that this should rather be considered as a maximum amount considering the progress of the German market (see next section). For 2020 and 2030, educated estimations were made of the share of smart appliances.

²⁶ http://www.topten.eu/uploads/File/Topten_recommendations_Washing_machines.pdf

²⁷ Euromonitor International, 2014 quoted in http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/docs/Prepstudy_WASH_20150601_FINAL_v2.pdf

²⁸ It is not clear for the authors of Euromonitor International whether the 4% is expressed as a share of the total washing machine market or of the total number of households. For this study we took the more conservative 2nd assumption.

²⁹ [http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Private_households_by_household_composition,_2014_\(number_of_households_in_1_000_and_%25_of_household_types\).png](http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Private_households_by_household_composition,_2014_(number_of_households_in_1_000_and_%25_of_household_types).png)

³⁰ Presentation by Christiane Schoenwetter from GfK during the symposium "Die Vision der 2000-Watt-Gesellschaft" on 20th of October 2015 in Kupferzell/ Germany

Table 5: Installed units of household refrigerators and freezers in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Household refrigerators and freezers			
Reference Year	2010	2015	2020	2030
Installed base	297,800,000	303,200,000	308,000,000	317,600,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances		147,810	15,400,000	63,520,000
Source		Extrapolation based on 0.06% penetration of German market (Gfk, 2015)	Estimation of 5% of installed base	Estimation of 20% of installed base
Reference countries		EU28	EU28	EU28

An overview of the installed units of **commercial refrigerators and freezers** in 2010 and estimates for 2015, 2020, 2030 is given in Table 6.

Personal communication from Eurovent indicated that around 70% of remote display cabinets sold in France, Germany and Italy are connected to tele-monitoring systems, which is considered by the authors to be communication-enabled. The plug-in appliances are currently not subject to monitoring. Monitoring systems can be categorised into 2 families:

- A system dedicated only to the monitoring of the temperatures and pressures of the cabinets and cooling packs. This system covers 100% of the cabinets under tele-monitoring. They are used to indicate (not to forecast) the failures in the cooling system (cabinets and cooling packs). This system does not provide energy saving benefits.
- A system dedicated to the monitoring, fine-tuning (in terms of energy consumption) of the performance of cabinets and cooling packs, including the forecasting of possible failures. This system covers about 40% of the cabinets that are included in the system under the previous bullet.

Many manufacturers dealing with cooling systems have monitoring centres, these cover not just the cabinets but can also for example chillers. More information will be gathered to match the figures of Table 6 with the categorisation mentioned above.

Table 6: Installed units of commercial refrigerators and freezers in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Commercial refrigerators and freezers			
Reference Year	2010	2015	2020	2030
CF open vertical chilled multi deck	1,328,000	1,492,000	1,672,000	2,033,000
CF open horizontal frozen island	180,000	196,000	219,000	268,000
CF Plug in one door beverage cooler	6,378,000	6,833,000	7,240,000	8,040,000
CF Plug in horizontal ice cream	2,725,000	2,928,000	3,013,000	3,447,000

Appliance group	Commercial refrigerators and freezers			
Reference Year	2010	2015	2020	2030
freezer				
CF Spiral vending machine	1,157,000	1,382,000	1,674,000	2,341,000
Total installed base	11,768,000	12,831,000	13,907,000	16,129,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Reference countries	EU28	EU28	EU28	EU28

An overview of the installed units of **water heaters** in 2010 and estimates for 2015, 2020, 2030 is given in Table 7. The number for water heaters includes electric storage and instantaneous water heaters, gas-and oil fired storage and instantaneous water heaters as well as solar-assisted water heaters (note: instantaneous water heaters are part of ‘behavioural’ appliances).

According to estimates by JRC, the installed stock of **electric storage water heaters** in EU-27 in 2007 was 90 million units. Electric storage water heaters with a capacity of more than 30 litres represent 27 % of the installed base of primary water heaters. (Bertoldi and Anatasui, 2009³¹).

No data are available on the share of smart water heaters. There is a study from Sweden³² investigating the flexibility of water heaters, but it is not possible to extrapolate these data for EU-28.

Table 7: Installed units of water heaters in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Water heaters			
Reference Year	2010	2015	2020	2030
Installed base	157,293,000	161,740,000	165,192,000	172,268,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Reference countries	EU28	EU28	EU28	EU28

2.2.3. BEHAVIOURAL APPLIANCES

According to estimates by JRC, the installed stock of **instantaneous water heaters** in EU-27 in 2007 was 29 million units. Instantaneous water heaters (> 12 kW) represent a share of 6.6 % of the installed base of primary water heaters. In view of secondary installations, instantaneous water heaters have a share of 7 %. (Bertoldi and Anatasui, 2009³³)

An overview of the installed units of **electrical hobs** in 2010 and estimates for 2015, 2020, 2030 is given in Table 8. Electrical hobs only have an emergency flexibility potential.

³¹ Bertoldi, Atanasui (2009). Electricity Consumption and Efficiency Trends in European Union – Status Report 2009, European Commission DG Joint Research Centre

³² <http://publications.lib.chalmers.se/records/fulltext/195330/195330.pdf>

³³ Bertoldi, Atanasui (2009). Electricity Consumption and Efficiency Trends in European Union – Status Report 2009, European Commission DG Joint Research Centre

Table 8: Installed units of electrical hobs in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Electrical hobs			
Reference Year	2010	2015	2020	2030
Installed base	133,781,000	149,114,000	163,566,000	188,544,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential
Reference countries	EU28	EU28	EU28	EU28

An overview of the installed units of **electrical ovens** in 2010 and estimates for 2015, 2020, 2030 is given in Table 9. Electrical ovens only have an emergency flexibility potential.

Table 9: Installed units of electrical ovens in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Electrical ovens			
Reference Year	2010	2015	2020	2030
Installed base	191,823,000	199,332,000	209,502,000	232,059,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential
Reference countries	EU28	EU28	EU28	EU28

An overview of the installed units of **range hoods** in 2010 and estimates for 2015, 2020, 2030 is given in Table 10. Range hoods only have an emergency flexibility potential.

Table 10: Installed units of range hoods in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Range hoods			
Reference Year	2010	2015	2020	2030
Installed base	92,371,000	97,111,000	102,060,000	112,741,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential
Reference countries	EU28	EU28	EU28	EU28

An overview of the installed units of **vacuum cleaners** in 2010 and estimates for 2015, 2020, 2030 is given in Table 11. Vacuum cleaners only have an emergency flexibility potential.

Table 11: Installed units of vacuum cleaners in 2010 (reference) and 2015, 2020, 2030 (estimates)

Appliance group	Vacuum cleaners			
Reference Year	2010	2015	2020	2030
Installed base	364,226,000	388,857,000	419,407,000	545,178,000
Source	Kemna, 2014	Kemna, 2014	Kemna, 2014	Kemna, 2014
Number of smart appliances	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential	Only emergency flexibility potential
Reference countries	EU28	EU28	EU28	EU28

2.2.4. HVAC

2.2.4.1. HEATING

Joule heating

From the EuP DG ENER Lot 20 study (BIOIS, 2012), it is possible to extract the estimated stock of installed electric heating appliances in Europe and European consumption in 2010. Individual data for electric appliances are not available in the policy scenario analysis. Probably this population of electric heaters is no longer increasing anymore, due to the effect of the national building regulations.

Table 12: Electric heater units, power installed and consumption, Source: (BIOIS, 2012)

Electric heating type	EU-27 stock (in 1000 units)	TOTAL (GW) Installed capacity	Hours	Energy (TWh)
NO INERTIA, PORTABLE	61,400	63	324	20
NO INERTIA FIX	159,200	166	1,130	188
WITH INERTIA	13,800	37	1,324	49
TOTAL	234,400	266		257

Probably most inertia storage heaters are in the residential sector, while for units without inertia it is not clear. Indeed, according to (Bertoldi, 2009), the total residential and tertiary electric space heating consumption was close to 270 TWh in 2007. It probably means that both residential and tertiary electric radiators are included in the figures above.

Electric boilers

Electric boilers are simply water storage electric heating boilers similar to hot water electric storages for which the electric element is larger in order to be able to supply the heating needs of a dwelling. According to (VHK, 2007), the stock of units was around 1.1 million in 2004, with average size between 4 and 15 kW³⁴ or about 10 GW installed capacity / power (keeping a median 10 KW value per unit).

³⁴ <http://www.boilerguide.co.uk/articles/electric-boilers>

Electric heat pumps

(EHPA, 2014) gives an estimate of the market and stock for heat pumps in Europe. The total stock of heat pumps is estimated to 4.5 million units in 2010 and 6.7 million units in 2013. With an average of about 30 kW output (according to EHPA, 2014) and assuming a base temperature of - 7°C, this capacity reaches about 18 kW and the COP of approx. 2 (assuming most heat pumps are of the air source type), it leads to about 9 kW electric peak load per unit, resulting in 40 GW (at peak conditions i.e. for - 7 °C outside) for the total stock of heat pumps in 2010 and already about 60 GW in 2013. This is probably a conservative low-end figure because only a minor part of reversible air conditioners is taken into account as being really used as a heat pump. But at the same time, the share of non-residential units is not known.

Boiler circulators

There were about 103 million circulators installed in Europe in 2005 (VHK, 2007), serving all directly the boiler systems. Their energy consumption was estimated to be around 50 TWh/a (Stamminger, 2008). This total energy consumption is thought to decrease by at least a half by 2025, as the stock of boiler will have been replaced and newer boilers use circulators whose consumption can be 4 times less than for older boilers as consequence of the respective EU regulation. For most old circulators in the stock, the flow rate is constant during all the heating season, whereas in newer installations, circulators only work when there is a heat demand. With variable flow technology being the new standard, the power drawn by the circulator will more and more depend on the actual heat load as well as the outdoor temperature.

For an average heating season of 9 months, assuming a constant power drawn over 9 months (c.a. 6500 hours), the total power installed is close to 7.5 GW (equals to 50 TWh / 6500 h) for the residential sector.

Total installed base of electric heating (estimation from market research) in EU27

In 2010, the total installed base of electric heating systems is assumed to be close to 325 GW in Europe. A summary table for the whole group of electric heating systems is presented below. This figure probably contains a large part of the tertiary electric heating installations for joule heating and for electric heat pump.

Table 13: Electric heating units, installed power, summary table

	Million units	GW	GW Probable trend after 2014
Electric heating, without built-in inertia (2)	226.2	279	Decreasing
Joule fix residential + tertiary () 2010	159.2	166	Decreasing
Joule portable (residential + tertiary) 2010	61.4	63	Decreasing
Elec. Boiler (residential) 2005	1.1	10	Decreasing
Elec. Heat pump (residential + tertiary) 2010 (1)	4.5	40	Strong increase
Electric heating, with built-in inertia	13.8	37	Decreasing
Circulation pump	103	7.5	Strong decrease

(1) At -7°C full capacity

(2) Probably contains also part of tertiary building heating systems

Total installed base of electric heating (estimation from the grid)

Figure 7 is an interesting figure that is worth being compared with what is seen at the electricity grid level. RTE³⁵ is in charge of ensuring matching consumption and generation of electricity and releases information about the temperature sensitivity of electricity consumption in France every year.

Figure 7 shows the correlation between average daily outdoor temperature (weighted average temperature over 30 cities in France³⁶) and daily national energy consumption. The derivative of the heating slope is evaluated to be 2400 MW / °C (RTE, 2013). It means that below a certain threshold of around 15 °C, each decrease of 1 °C will increase the national electricity load by 2400 MW / °C. In 2012, the peak day in France occurred on February 8 with a daily average required power of about 93 GW. This is coherent with calculations based on the average daily temperature of about -4 °C, leading to an average load of 93.5 GW ($1150/24 + (15 - (-4)) * 2400 = 93.5$ GW)

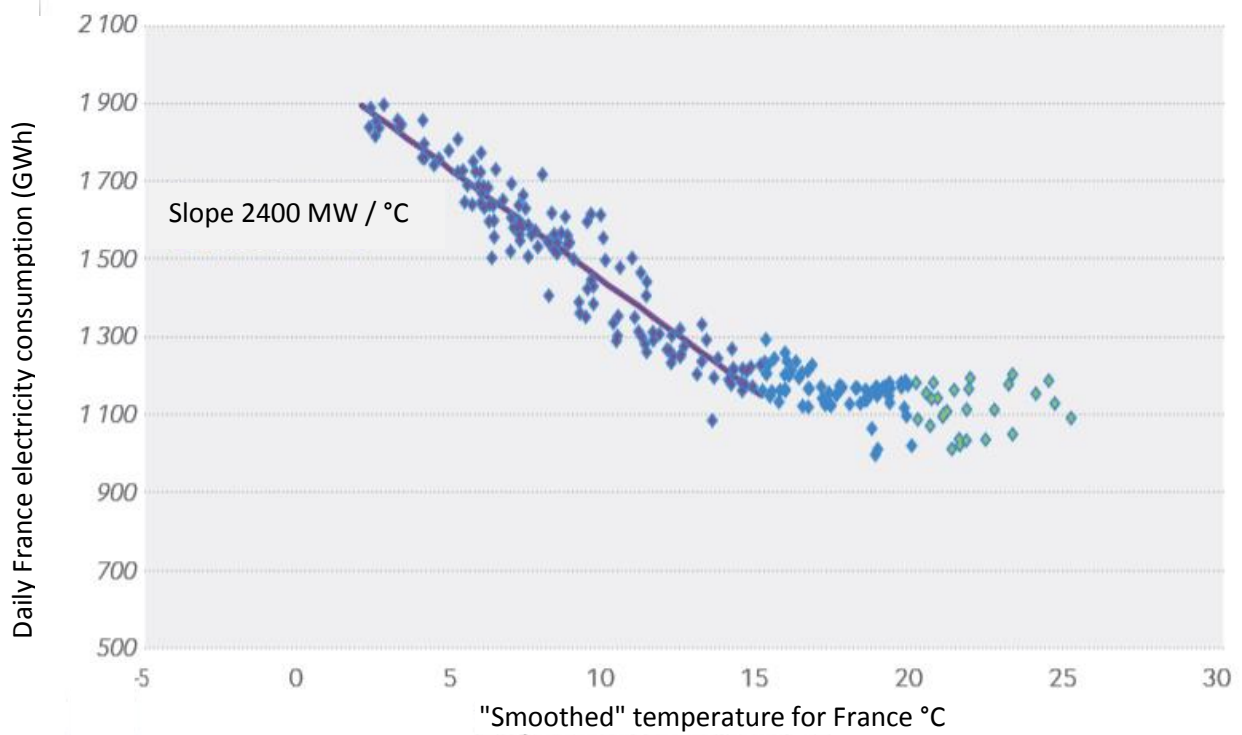


Figure 7: Temperature sensitivity of electricity consumption in France in 2013 - daily average electricity consumption VS smoother average France temperature and slope, from (RTE, 2013)

On Figure 8, the same slope is indicated for several EU countries and at EU level. It can be seen that France alone accounts for close to 50 % of the total temperature sensitivity of the EU electricity consumption as consequence of the widespread usage of electric heating systems.

³⁵ RTE (Réseau de transport d'électricité) - French electricity transmission system operator.

³⁶ Please note: To make this correlation, RTE filters the effect of nebulosity during the day, i.e. the load reduction due to solar radiation is not accounted for, although it has most likely only little impact during the coldest days of the year.

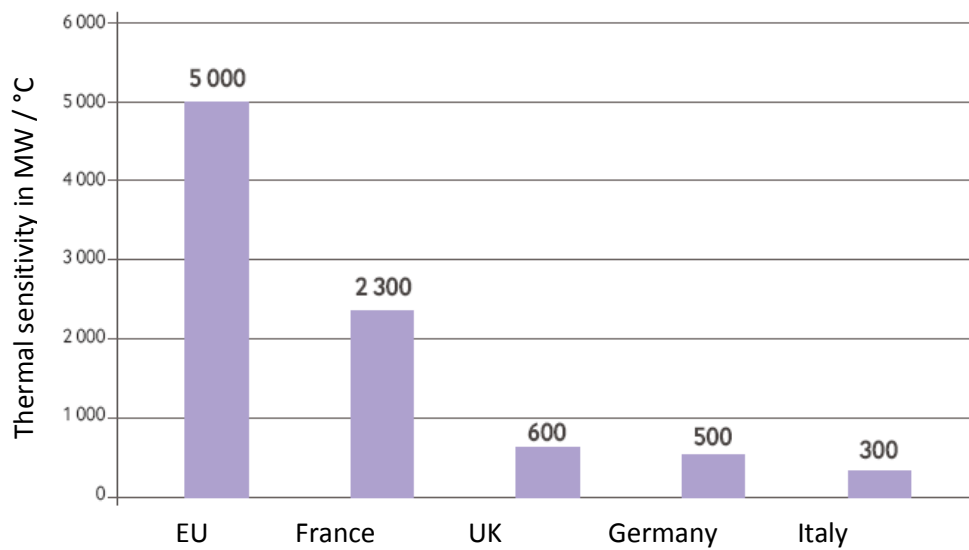


Figure 8: Temperature sensitivity of electricity consumption in France and other countries in Europe in 2012, from (RTE, 2012)

Assuming the same threshold temperatures apply for Europe and that EU average on February 8 was close to -4°C like in France, it gives a total electric heating contribution of around 5×19 or 95 GW. This is only to give an order of magnitude.

However, this estimation is noticeably much less than could be inferred from the market data, which indicated a total installed stock power close to 325 GW for electric heating. There may be many reasons for this important difference:

- Circulation pump consumption profile is probably not temperature sensitive nowadays (as most circulators are still with constant flow) so that the signal from the grid is underestimated by about 10 GW.
- Probably, some of the heaters are not in use (the case of many portable heaters probably, heating systems in secondary houses, secondary or backup systems).
- It is likely that many installations are oversized by 20 to 50 % because of local design habits.
- Others may be operated at peak conditions all year long (probably the case of some fan heaters in the industry) and thus their consumption is not sensible to the outdoor temperature.

Although this is a very rough estimation, it is most likely that the maximum electric demand in winter peak conditions for an typical meteorological year is close to 100 GW despite an apparently much larger installed base.

2.2.4.2. VENTILATION

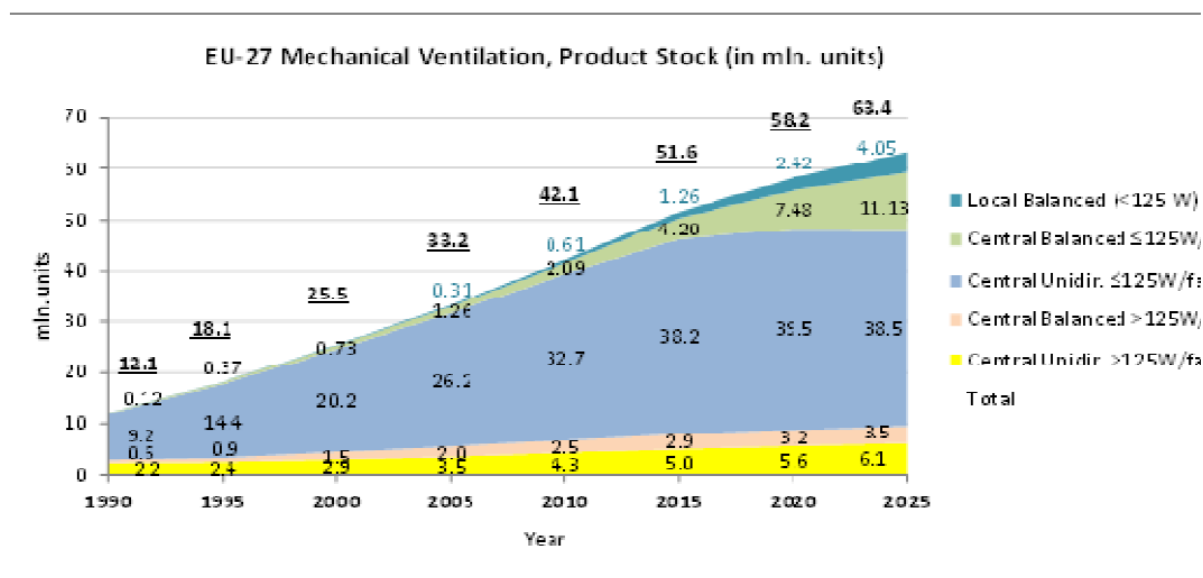


Figure 9: Stock of ventilation units in the EU 1990-2010 and projections 2010-2025 (BAU, source: preparatory studies), from (EU, 2014)

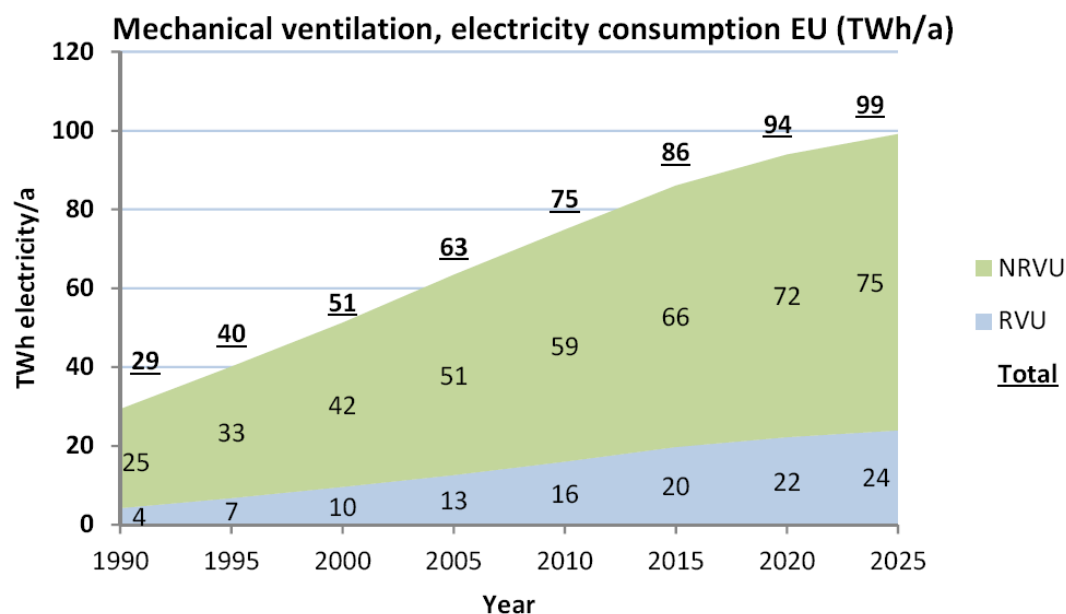
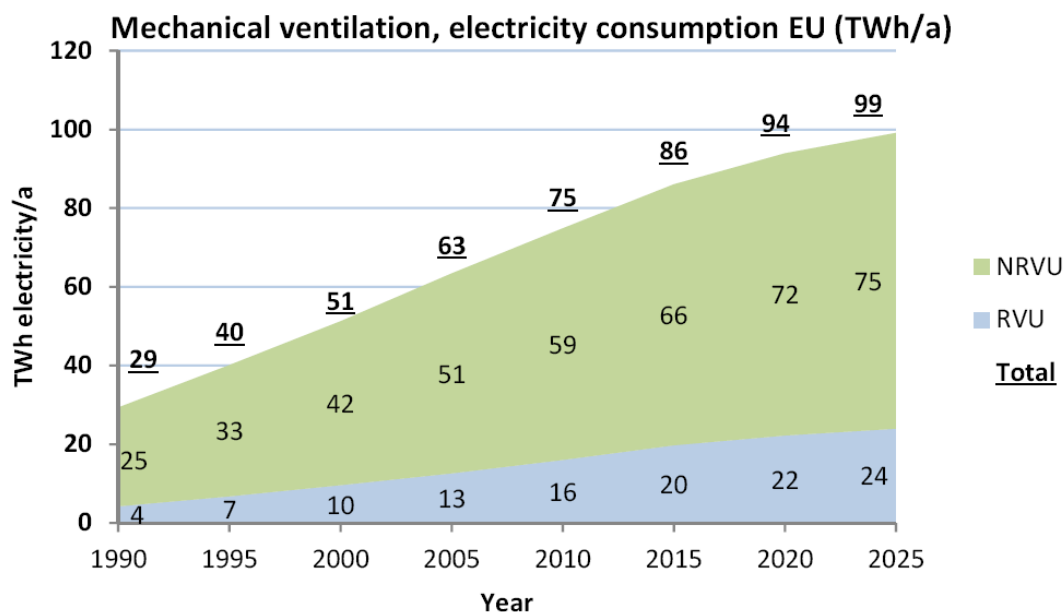


Figure 10: Mechanical ventilation, EU electricity consumption 1990-2010 and projections 2010-2025 (BaU) in TWh electricity per year (EU, 2014)

Please note that in comparison with figures in (Bertoldi, 2009), the presented electricity consumption is much lower (in 2007, 67.5 TWh/a on



versus 118 TWh/a in (Bertoldi, 2009)). But in total, the sum of air conditioning consumption estimated in preparatory studies³⁷ and of ventilation in (Eu, 2014) is quite close to (Bertoldi, 2009) estimates.

This consumption represents a near constant electric load of 1.8 GW for the residential sector. In the non-residential sector, ventilation is controlled at night and during weekends. The load is thus probably closer to 10 GW during the day (6.7 GW on average over 24 hours). These figures are expected to increase by 50 % between 2010 and 2025.

2.2.4.3. AIR CONDITIONING

Table 14: European stock of European air conditioning systems in GW of cooling capacity, source (Rivière, 2007) and (Rivière, 2012)

Peak power GW	1990	1995	2000	2005	2010	2015	2020	2025
Air conditioners < 12 kW (w/o portable)	8,8	21,2	37,9	61,8	85,7	89,3	99,6	108,1
Air conditioners > 12 kW	5,2	11,9	22,9	33,0	39,5	42,6	46,2	51,0
Chillers	31,1	40,0	49,2	61,2	72,8	81,9	90,1	97,3
Total	45,1	73,1	110,1	156,0	198,0	213,8	235,9	256,4

Energy consumption TWh	1990	1995	2000	2005	2010	2015	2020	2025
Air conditioners < 12 kW (w/o portable)	3,1	7,6	13,3	20,0	25,9	24,8	27,6	30,3
Air conditioners > 12 kW	2,2	5,3	10,2	15,6	19,7	20,8	21,9	23,8
Chillers	14,3	17,3	21,7	27,3	32,9	37,3	40,5	42,3
Total	19,7	30,2	45,2	62,8	78,5	82,9	89,9	96,3

³⁷ Air conditioning preparatory studies : Central air conditioning systems (Rivière, 2012) and room air conditioners (Rivière, 2009).

Portable air conditioners are not considered in this evaluation of the air conditioning potential for DR. Please note that post 2005 figures for lower than 12 kW units and 2010 figures for other figures for larger air conditioners and chillers are BAU scenarios.

(Bertoldi, 2009) shows lower estimates for tertiary air conditioning: in 2007, it is estimated to 21.6 TWh versus 42.5 TWh in (Rivière, 2012) but residential figures are matching. In addition, the sum of tertiary air conditioning and ventilation are relatively close in both (Bertoldi, 2009), and in (VHK, 2012) and (Rivière, 2012).

Please note that as opposed to the heating load, there is little information regarding the impact on the European grid, so it is difficult to make a reality check of these figures.

2.2.4.5. ESTIMATION OF SMART APPLIANCES' PENETRATION RATE

HVAC smart appliances penetration rate nowadays can be estimated as extremely low, according to the feedback of one HVAC manufacturer of this study.

Table 15 Sales of Air conditioners, by the Japanese Refrigeration and Air conditioning industry, 2014.

Region & Country		2009	2010	2011	2012		2013		2014	
		-	-	-	window	split	window	split	window	split
World wide		61,336	73,420	84,565	13,157	64,869	14,193	69,563	14,380	68,524
Japan		6,775	8,242	8,279		8,487		9,013		8,500
China		24,787	30,424	38,425	356	30,321	348	33,124	325	32,461
Asia		9,216	10,856	11,056	1,991	9,832	1,897	10,482	1,853	11,152
Middle east		3,297	3,474	3,639	1,635	2,046	2,480	2,187	2,480	2,223
Europe	sub total	4,441	5,741	7,037	116	6,153	104	5,944	92	4,951
	Russia	860	679	2,523	38	1,846	33	1,738	29	1,320
	Turkey	545	679	916	0	1,025	0	944		773
	Italy	906	983	977	6	866	6	909	5	726
	Spain	443	609	521	8	416	9	404	8	371
	France	268	316	305	4	265	5	274	4	271
	Ukraine	113	365	403	8	345	7	318	4	221
	Greece	353	260	225	0	266	0	219		178
	UK	61	70	76	1	72	1	72	1	76
	Germany	74	75	83	4	78	4	80	4	81
	Bulgaria	64	83	101	1	110	1	92	1	85
	Romania	82	76	87	1	99	1	95	1	79
	Portugal	83	118	97	0	60	0	59		58
	Poland	43	57	59	1	56	1	55	1	55
	Norway	47	70	69	0	63	0	59		54
	Sweden	64	61	62	0	52	0	50		54
	Netherlands	30	38	37	0	33	0	34		35
	Others	375	500	496	36	501	36	542	34	514
North America		6,270	6,550	6,726	7,082	463	7,372	522	7,647	590
Latin America		4,298	5,750	6,661	1,568	5,016	1,568	5,577	1,564	5,829
Africa		1,501	1,585	1,910	344	1,824	351	1,943	347	1,990
Oceania		781	798	832	65	727	73	771	72	828

It can be seen that the annual sales for air conditioning in Europe (excluding Russia and Turkey) correspond to approximately 3,2 million units. The sales of smart air conditioners (communication-enabled, future prospects for demand-response) for one manufacturer were about 23% of the total sales in 2014, out of which only 7% of the smart-enabled units (communicative, controllable via wireless technologies) were actually used in that way by the users. When extrapolating these figures, knowing that for EU28 in 2014 about 650.000 smart air conditioners were sold, with an estimated share of around 45.500 are incorporated in a smart interface (e.g. mobile app, energy manager). This represents about 1,5% of the sales' share of air conditioners in EU28 for 2014.

To build an air conditioner stock, the market would need sales for the lifecycle period of the appliance (in HVAC 15 years approximately). Assuming that communication-enabled air conditioners appeared with the wide use of the Smartphones in 2010 (5 years ago), the stock of smart air conditioners represents only a third of the estimated percentage, being 0.5% of the installed base by 2014. This result can be used as well for heat pumps, due to the fact that controlled variables and the machine's technology is actually the same.

Regarding electrical radiators, boilers, circulator pumps the installed base of smart heating technology is negligible due to the following factors: low-cost of the technology and the already installed base. For electric radiators, the simplicity of the system and the low-cost of the installation (300€ aprox.) does not encourage manufacturers to develop high-technology to this kind of

communication/demand-response. Similarly for boilers and circulator pumps, where only new technology would have a communicating-enabled system. Therefore, a first approximation is 0.1% for the current installed basis for 2014.

Regarding built-in inertia radiators, the stock of smart heating is 0%, following the hypothesis that almost all of these radiators are only charged during the night and release heat freely during the day (except those regulated by a fan), hence not requiring any control.

For ventilation, the assumed stock is 0% as well, given that almost all of the installed units need hardware intervention to enable demand-response (no electronically measured variables or actuators, but an electrical intervention is needed). For the residential sector, ventilation is not controlled in most of the cases in Europe.

The following Table resumes the estimated % share of smart appliances (communication-enabled, prospect for demand-response) in the total installed base of HVAC by 2014.

Table 16: Estimated share of installed base that is communication-enabled

HVAC Technology	% Stock			
	2010	2015	2020	2030
Air conditioning	0%	0,50%	5%	20%
Electric Radiators	0%	0,10%	0,10%	0,10%
Heat Pumps	0%	0,50%	5%	20%
Electric Boilers	0%	0,10%	5,00%	10%
Circulator Pumps	0%	0,10%	5,00%	10%
Electric Radiators (inertia)	0%	0,00%	0%	0%
Ventilation	0%	0,00%	n/a	n/a

Table 15 values were estimated following these assumptions: for air conditioners and heat pumps, the growth was assumed important given that both technologies have growing stock trends. For boilers and circulator pumps, growth is smaller because both technologies have a decreasing trend from 2015 (but assumed that new technologies will be communication-enabled). For electric radiators it was remained constant following the line of little interest on investing, and the decreasing trend. There is not available information for ventilation, but it is assumed to not be really significant, due to the fact that energy consumption of ventilation units is around ten times smaller than it is for cooling and heating.

2.2.5. BATTERY OPERATED RECHARGEABLE APPLIANCES

The installed base of battery operated rechargeable appliances is very high. For smartphones only the expected sales figures (IDC, Gartner and JPMorgan) worldwide have gone from 300 million in 2010 to more than 650 million in 2012 and is expected to grow above 1 billion in 2016. The estimated total installed base for smartphones only will exceed 2 billion. The situation is similar for tablets worldwide, with sales growing from 200 million in 2013 to an expected 350 million in 2016 (Gartner, 2012). Estimates of laptop sales vary between 200 and 180 million.

For Europe (EU28), the sales of all mobile phones (smartphones and regular mobile phones) range from 227 million in 2009 to 213 million in 2013. Sales of personal navigation devices (PNDs) in Europe

peaked at 17 million units in 2008 and fell to less than 10 million units by 2012. Digital camera figures remained around 30 million till 2012. It is expected that this figure will decrease in the subsequent years in favour of smartphones with advanced integrated cameras.

Figures for other appliances are harder to find, but it is estimated that all together they represent annual sales of more than 50 million units in the EU³⁸.

2.2.6. RESIDENTIAL ENERGY STORAGE SYSTEMS

In 2015, approximately 25,000 batteries are expected to be operational in Germany³⁹. The German market can currently be considered as the only mature market of home battery storage applications (in combination with PV-installations). In Germany, a large amount of solar panels in combination with a subsidy scheme for residential energy storage (up to 30% of initial investment is subsidized), makes a home battery system attractive. Estimates predict that by 2018, the German market will have stabilized with on average 100,000 units per year. As a result, by 2020, a total of 500,000 units are estimated to be installed by 2020 in Germany⁴⁰.

Recent information provided by Panasonic in the press shows the intention of battery suppliers to target other European markets as well, including France and the UK⁴¹. However from the available information today, based on current policies, subsidy schemes and costs, no mature market can be expected by 2020 in EU28 apart from Germany.

Few information exists on the potential of residential energy storage systems for 2020 and 2030. Estimates by Roland Berger, Avicenne and BCG indicate that the global market for residential energy storage systems could grow up to 3 to 10 GWh in 2020 and 6 to 15 GWh in 2025⁴². This large range of estimated future potentials makes it clear that experts find it very difficult to make clear projections for the period between 2020-2030. An important reason for this is that the success of residential energy storage systems in 2030 is highly dependent, on the one hand, on the national subsidy schemes for both renewable energy (feed-in tariffs) and home battery systems and on the other hand on the evolution of the purchasing cost of home battery systems.

In the framework of this study the assumption has been made that in 2015 and 2020 the EU28 market will have a size that is comparable with the size of the German market which may be considered as a conservative estimation. For 2030, the penetration level of residential energy storage systems is highly depending on evolutions in technology and policy decisions therefore no clear assumption can be put forward. In task 7, a sensitivity analysis will be presented analysing several scenario's with respect to the penetration rate of residential energy storage systems by 2030.

Regarding uninterruptible power supply (UPS), the total installed base for 2011 was calculated as 7.5 million UPS units⁴³ in EU27, represented by the following size categories:

- Below 1.5 kVA products: 53% of the total installed base
- 1.5 to 5 kVA products: 41% of the total installed base
- Above 5 kVA products: 6% of the total installed base

³⁸ Framework Service contract ENTR/2008/006/Lot 1, Study on the Impact of the MoU on Harmonisation of Chargers for Mobile Telephones and to Assess Possible Future Options

³⁹ http://www.insightenergy.org/ckeditor_assets/attachments/48/pr1.pdf

⁴⁰ http://www.insightenergy.org/ckeditor_assets/attachments/48/pr1.pdf

⁴¹ <http://www.greentechmedia.com/articles/read/Panasonic-Enters-Europes-Burgeoning-Home-Battery-Market>

⁴² http://www.insightenergy.org/ckeditor_assets/attachments/48/pr1.pdf

⁴³ ErP Lot 27 – Uninterruptible Power Supplies, Preparatory Study - Final Report

The above figures include mainly UPS systems used in data centres and larger organisations (companies, hospitals, etc.), which are however out of the scope of this study. In Western Europe, in 2013 the annual data centre load requirement was an estimated 79 TWh. So only a very small fraction of these systems is located in residential and small business setups. No exact figures were found for these specific products.

2.2.7. LIGHTING

Please find below an overview of the estimated stock year 2013 based on the Ecodesign Preparatory Study on Light Sources (ENER Lot 8/9/19 (VITO, 2015):

- LFL: Linear fluorescent lamp: 2209 million units
- CFL: Compact fluorescent light: 4406 million units
- Tungsten: 2569 million units
- GLS: General lighting service ('incandescent'): 561 million units
- HID: High intensity discharge lamp: 84 million units
- LED: Light emitting diode: 144 million units

Separately, the estimated number of street lighting luminaires in EU-25 is about 60 million (2004 figures) (VITO, 2007).

2.3. ECONOMIC INSTRUMENTS - REMUNERATION MECHANISMS

The pre-conditions for an uptake of smart appliances and implementation of smart grids are:

- that the EU Member States have provided access to demand side resources according to the Energy Efficiency Directive art. 15, item 8. The requirement is that the TSOs and DSOs treat DR providers including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities. This is however subject to technical constraints inherent in managing networks.
- that the smart appliances need to be in the homes, offices etc. and the end-users must also have accepted that the BRPs, aggregators etc. control their energy usage in the DR perspective, which again requires sufficient incentives and remuneration for the end-users.

In order to boost the market for demand response, the EC emphasizes the importance of market-based and dynamic and transparent incentives that reward participation through dynamic prices without unnecessary constraints⁴⁴.

First, it should be used to transfer (part of) the value of the flexibility of smart appliances to end-consumers. Second, it is a key to incentivize end-consumers to shift their consumption and offer the flexibility of smart appliances when the value for society is high. This is the case when the system is under stress and prices (day-ahead prices and/or imbalance prices) are high. A proper remuneration system will also increase the level of self-consumption of households that have a combination of local production (e.g. solar panels), storage (e.g. batteries) and flexible consumption (e.g. smart appliances) at their disposal. To note that financial incentives through a dynamic pricing scheme on

⁴⁴ https://ec.europa.eu/energy/sites/ener/files/documents/com_2013_public_intervention_swd07_en.pdf

itself are not sufficient to establishing a structural change in consumer behaviour⁴⁵. Task 3 of this report will discuss more in detail the drivers for consumer behaviour, besides financial incentives.

In this section, an overview is given of the most important remuneration mechanisms existing today. A proper implementation of these dynamic tariffs requires smart meters that enable the communication between the meter of the end-consumer and the utility.

2.3.1. USE CASES

As will be further explained in Task 3, smart appliances can be used for different use cases. Two distinct use cases can be defined, based on two important time blocks in the market: day-ahead versus real-time.

1) Day-ahead use case

In day-ahead, the schedule of electricity production and consumption is determined. In order to match supply and demand, balance responsible parties have several possibilities. First, they can adapt their production volume by optimizing own generation units or by participating to the various European Power Exchanges that enable them to trade volumes in the short term (day-ahead). The prices on the power exchange are determined on an hourly basis and are published in a transparent way. The prices on the day-ahead market reflect the marginal cost of the last unit that is needed to produce these volumes.

DR could directly participate in the day-ahead market platform. The Balancing Responsible Parties (BRPs) have also the possibility to modify the load in order to match supply and demand. Load reduction or load shifting can avoid costs of additional production during hours with high prices. In this case, the flexibility of demand response is directly integrated in the portfolio of the BRP. Independent how demand response by the use of smart appliances is offered in day-ahead, it will support the matching of supply and demand at a lower cost. In case of high estimated production of RES during certain hours, load could be shifted or increased during these hours. In case of high estimated load, a decrease or shift in load will have a downward effect on prices.

2) Imbalance use case

In real-time, deviations are observed between supply and demand. Different reasons can explain these deviations. Changing weather conditions are the primary source of these deviations. The realised production of renewable energy sources (wind and solar) is highly dependent on the weather. The demand or load is also affected by weather conditions such as temperature and cloud cover. In addition, non-weather related causes such as sudden outages of generation units or human errors e.g. in load forecasts can also explain why there is an imbalance between supply and demand in real-time.

The TSO is responsible for the stability of the grid and security of supply at the lowest cost in real-time or in near real-time. It will monitor in real-time the deviations of the grid and activate the necessary ancillary services in order to balance the system. Ancillary services can be provided by

⁴⁵ Boork M, Thomtén M, Brolin M, Uytterlinde M, Straver K, Kraan C, Kleine-Hegermann K, Laes E, Valkering P, Maggiore S. Key success factors and barriers to end-user engagement in smart grid projects. Paper presented at the 2014 BEHAVE conference, London. Available from: <http://behaveconference.com/wp-content/uploads/2014/08/F_Magdalena_Boork_Technical_Research_Institute_of_Sweden.pdf>

both, generation and load management, dependent on the type of ancillary service product. Dependent on the country, ancillary services are contracted by the TSO via yearly, monthly or weekly tenders. Today, the three categories of ancillary services are FRC⁴⁶, FRRa⁴⁷ and FRRm⁴⁸. The relevant ancillary services for demand response today are FCR and FRRm. FRC is used by the TSO to ensure that the grid frequency stays within a certain range within the interconnected high-voltage European system. FRRm is used by the TSO to cope with major imbalance and congestion issues.

The cost of the activation of ancillary services (FRRa and FRRm) is reflected in the imbalance price published afterwards. As each BRP is responsible for the balance of its own portfolio, their individual imbalances will be invoiced based on the imbalance prices.

Similar to the day-ahead use case, demand response can be part of the imbalance use case in different ways. First, demand response can participate directly in the market of ancillary reserves (FCR and FRRm). An example of demand response participating to the market of FRRm is the product R3DP in Belgium (see later). The response time for FRRm is on average 15 minutes, which is sufficient for demand response to participate. In general, it is more difficult for demand response to participate in the market of FCR due to the fast response time that is required (15 seconds). However, applications based on batteries could participate to this market.

Alternatively, demand response can be used by the BRPs in order to optimize the balancing of their portfolio which results in a decrease of their imbalance costs.

Note: besides the two main use cases as discussed above, demand response could serve other objectives as well, such as DSO grid congestion cases, reactive power voltage support in the transmission grid,.... However, these use cases are less mature (e.g. DSOs are today not incentivized to contract flexibility as costs for flexibility are not remunerated) and the value of flexibility from smart appliances cannot be estimated based on today's situation.

2.3.2. OVERVIEW OF REMUNERATION MECHANISMS⁴⁹

The dynamics of different remuneration mechanisms are defined by the number of time blocks per day, the price update frequency, the price difference between blocks and the presence of special events (with limited duration and occurrence) that trigger higher or lower prices. Responses to price signals by end-users can be manual or fully automated.

Most tariff structures can be classified in following categories:

1. Time-Of-Use Pricing (TOU)

⁴⁶ FRC = frequency containment reserves or currently called primary reserves. FCR are continually activated and have a fast response time (15 sec).

⁴⁷ FRRa = automated frequency restoration reserves or currently called secondary reserve. FRRa is activated on automated basis.

⁴⁸ FRRm = manual frequency restoration reserves of currently called tertiary reserves.

⁴⁹ Additional information on tariff schemes can be found in: <http://www.aemc.gov.au/getattachment/04f6b84c-d839-4cc5-9f4b-35f9e321c3c5/The-Brattle-Group-%E2%82%AC%E2%80%9CManaging-the-costs-and-benefi.aspx> and on the project website of the S3C ("Smart Consumer, Smart Customer, Smart Citizen") project www.s3c-project.eu. The S3C project analyses new options deriving from smart grid technologies for the activation and long-term engagement of end users.

Time-Of-Use Pricing divides the day into a predefined set of time-blocks (typically blocks of 3 to 6 hours). The price for each block is constant and predetermined. The aim is to shift the average consumption pattern in such a way that it follows closer the estimated production profile of RES and reduces peak demand. This static pricing mechanism does not take into account the dynamic real-time system conditions. The price the end-consumers receive for the energy that is shifted will reflect the average system cost over a certain period of time.

2. Real Time Pricing (RTP)

Dynamic Real-Time Pricing is based on real-time hourly or quarter-hourly prices or on day-ahead hourly prices. Real Time Pricing is reflecting the actual state of the system and the related system costs. Real-time Pricing provides a dynamic temporal resolution in passing through real-time prices to consumers. However, as it requires a continuous monitoring of prices, an adequate and automated control system is required.

3. Critical consumption pricing (critical peak pricing CPP” and critical peak rebate)

In case of high anticipated load and resulting prices or high production of RES, a critical event is defined during a specified time period by the utility. During this time period, the energy price is raised or decreased significantly. As a result, critical peak pricing is used to reduce the critical peak load (in case of grid overload) or to increase the load (in case of excess power from RES). Critical peak rebate is a similar concept where end-consumers receive a rebate in case they consume less than expected (in case of grid overload) or in case they consume more than expected (in case of excess power from RES). These remuneration mechanisms are only used for a limited number of major events during the year.

4. Variable Peak Pricing (VPP)

This pricing mechanism is a hybrid form of TOU Pricing/CPP Pricing and RTP Pricing. The time blocks are predetermined, such as within the TOU pricing mechanism/or for a CPP event. However, the price for each block is not predetermined and is based on real-time market conditions.

5. Capacity remuneration

The pricing schemes explained before will remunerate the flexibility by pricing the energy shifted (€/MWh). It is also possible to remunerate the owner of a smart appliance upfront based on the available capacity (€/MW). This capacity remuneration can be fixed on an annual base, or even on shorter time periods such as a monthly base. Historically, capacity remuneration mechanisms were used in the context of the remuneration of ancillary services for balancing purposes. This capacity remuneration can be combined with energy remuneration in case of activation of the flexibility.

6. A combination of several tariff schemes

As explained, smart appliances can be used for different use cases. Therefore, dependent on the category of smart appliances, several of the remuneration mechanisms can be combined. A common combination is a TOU-tariff together with a CPP mechanism for special events.

7. Other incentives (e.g. reduction purchase price)

Besides remuneration for the offered flexibility, additional incentives to stimulate the investment in smart appliances could be considered. For example a reduction in the purchasing price of eligible

appliances could lower the barrier for end-consumers to buy smarter appliances and to use actually the flexibility inherent in the appliance.

2.3.3. EXAMPLES OF GOOD PRACTICES

The Smart Energy Demand Coalition (SEDC) has assessed the DR activities for EU Member States, Norway and Switzerland and reported the results in a report published in April 2014⁵⁰. SEDC is an industry group dedicated to the development of demand side program development. SEDC has assessed the access for DR providers. In addition, there may exist DR activities in not-open power markets performed by the national energy regulatory operators though these typically would be targeted larger energy consumers such as manufacturing industry.

The report has mapped the progress of the Member States in meeting the requirements of Article 15, item 8 and reviewed the regulatory structures of 13 Member States, Norway and Switzerland.

The report summarizes the progress of the EU Member States as:

- Commercially active: Great Britain, Ireland, France, Belgium, Finland;
- Partial opening: The Netherlands, Austria, Sweden;
- Preliminary development: Germany, Poland, Denmark, Slovenia;
- Closed: Spain, Italy;
- No thorough regulatory review, but on first review, DR development not visible in the remainder of the Member States.

The conclusion is that only five Member States have reached a level with access for commercial DR providers.

There has however been development from 2013 to 2014 and it is expected to continue developing. Examples of dynamic tariff schemes that are tested or applied for the residential segment are listed below. The first dynamic pricing mechanisms are mainly developed within countries that experience a need for demand response. For example countries with a high share of renewable energy (Nordic countries, Germany, Belgium, Italy) or an important share in electric heating, resulting in high peak demand during winter (e.g. France, Nordic countries), have taken the first steps towards introducing dynamic pricing in the market.

- Sweden: In Sweden, the roll-out of smart meters has been completed. Since 2012, energy providers started to offer retail consumers electricity contracts based on day-ahead hourly prices⁵¹. Until now, only a small part of customers have adopted real-time-price contracts. This is an example of real-time pricing. In general, there is an evolution to energy contracts based on hourly prices. An important condition is that hourly metering for these consumers is available. A study on the impact of these dynamic pricing schemes in Sweden highlights the fact that not only RTP-tariffs are needed, they have to be accompanied by appropriate home automation technologies on the one hand and the necessary feedback strategies in order for consumers to understand and modify their daily consumption pattern⁵².

⁵⁰ "Mapping DR in Europe Today. Tracking Compliance with Article 15.8 of the Energy Efficiency Directive". Smart Energy Demand Coalition. April 2014.

⁵¹ http://energia.fi/sites/default/files/dokumentit/ajankohtaista/Tapahtumat/2013/ST-pooli/esitys_soderbom.pdf

⁵² <http://www.researchgate.net/publication/254864389>

- France: EDF offers the Option Tempo product to consumers. Days are categorized according to three colours: blue, white and red reflecting the state of the system. On a daily base, the colour of the day is defined and communicated and prices vary accordingly. This is an example of critical pricing where the utility determines a special event during a limited number of days⁵³.
- The Netherlands: Eneco organizes the smart charging of Tesla electric vehicles based on energy market prices⁵⁴.
- Belgium: Pilot project Linear⁵⁵ tested in a field test a TOU pricing mechanism. There were 6 fixed time blocks defined upfront. Prices were defined on a daily base, based on Belpex day-ahead market prices and the predicted generation of wind and solar. The average daily price spread was around 0,08€/kWh.
- Belgium: the Transmission System Operator in Belgium has designed a new product for tertiary reserve 'R3Dynamic Profile'. This product targets sheddable load and production at distribution grid level. The remuneration is based on a capacity fee⁵⁶. The average capacity fee for R3DP is estimated around 3,38 €/MW/h.
- Germany: the AlpEnergy project (Allgaeu trial site)⁵⁷ tested two types of TOU tariffs. The first tariff was a more static tariff type with 2 time blocks with a yearly price update. The second tariff was a more dynamic tariff with 5 time blocks with an update of the price every 36 hours. The price spread was in both TOU tariffs equal to 0,05€/kWh. Results showed an average load shift of 2% for the more static tariff and an average load shift of only 1% for the more dynamic tariff, indicating that in case of manual response, tariffs should not be too complex.
- Germany: the German smart grid project eTelligence⁵⁸ developed a combination of a TOU tariff with two price levels (price spread of 0,26€/kWh), and in addition so-called bonus (0€/kWh) and malus events (1,2€/kWh) that were based on the availability of RES (announced day-ahead). Electricity savings up to 20% in case of malus events and additional electricity consumption up to 30% during bonus events were observed.
- Germany: The E-DeMa trial project offered end-users the choice to switch their remuneration mechanism on a monthly basis. Most end-users opted eventually for a relatively static and simple TOU tariff, again emphasizing that tariff structures that are too complex hinder the adoption of dynamic pricing⁵⁹. The average price spread was between 0,10 and 0,20€/kWh.

⁵³ <https://particulier.edf.fr/fr/accueil/facture-et-contrat/contrat/consulter-les-jours-ejp-et-tempo/option-tempo.html>

⁵⁴ <http://cleantechnica.com/2015/03/18/eneco-smartcharging-app-dutch-tesla-drivers-charge-price-low/>

⁵⁵ <http://www.linear-smartgrid.be/en>

⁵⁶ http://www.elia.be/~media/files/Elia/Products-and-services/ProductSheets/S-Ondersteuning-net/S_Grid%20support_En.pdf

⁵⁷ http://www.alpenergy.net/images/stories/AlpEnergy_Final_Guideline.pdf

⁵⁸ Agsten M. *et al.* eTelligence Abschlussbericht. Neue Energien brauchen neues Denken. Oldenburg: EWE AG; 2012.

⁵⁹ Becher S *et al.* Verbundprojekt E-Energy: E-DeMa, Entwicklung und Demonstration dezentral vernetzter Energiesysteme hin zum E-Energy Marktplatz der Zukunft. Essen: RWE AG; 2013.

- Germany: The MoMa project⁶⁰ tested a RTP tariff with daily price updates (price spread of 0,075€/kWh). Results showed that on average a price increase of 100% gave a decrease in demand of around 10%.
- Norway: Nord-Trøndelag Elektrisitetsverk (NTE), announced in March 2014 that it would partner with Swedish ICT company Maingate to run a pilot project investigating customers' response on real-time electricity prices.⁶¹
- Italy: A simple TOU tariff is introduced to all households in Italy, consisting of two time blocks per day (peak and off peak), with quarterly price updates. The maximum price spread was equal to 0,02€/kWh. The results showed a shift of 1% of total energy consumption from peak to off-peak hours with respect to the period prior to the introduction of the TOU tariff⁶². Results have shown that consumers barely changed their consumption pattern. Main reason was the fact that the price spread was not sufficient to stimulate consumers to shift their consumption⁶³.
- UK: The CLNR project (Customer Led Network Revolution) in the UK uses a three-rate TOU tariff which is updated once a year. The average price spread between the highest and the lowest price was around 0,20€/kWh. Preliminary field trial results showed that the average half-hourly load reduced by 14% during the peak period (between 4pm-8pm)⁶⁴.
- US: In the state Illinois, the two main state-utilities (ComEd and Ameren Illinois) have introduced RTP-programmes as from 2007, but in the course of 2014, only 1% of their customer base had adopted the new tariff⁶⁵. Several reasons have been mentioned why these programs are not yet embraced by a large audience. Elements highlighted in order to increase the number of participants are: increasing awareness and understanding of dynamic pricing by using simple communication, easy enrolment in the program and proof towards customers that participation is not complex⁶⁶.
- US: Austin Energy and CPS Energy offer consumers a free thermostat or a thermostat rebate in exchange for the control on the air-conditioning. This could be considered as an example of an alternative remuneration mechanism to incentivize consumers to offer the flexibility of their smart appliances⁶⁷.
- Australia: Consumers are offered a rebate on the cost of an air conditioner, compliant with a demand response platform and activated at installation. The load of the air conditioner is then modulated by a third party⁶⁸.

⁶⁰ Kießling A. Modellstadt Mannheim Abschlussbericht. Beitrag von moma zur Transformation des Energiesystems für Nachhaltigkeit, Beteiligung, Regionalität und Verbundenheit. Mannheim: MVV AG; 2013.

⁶¹ <http://www.m2mnow.biz/2014/03/27/19247-maingate-nte-together-towards-tomorrows-energy-market/>

⁶² Maggiore S, Gallanti M, Grattieri W, Benini M. Impact of the enforcement of a Time-of-Use tariff to Residential customers in Italy. Paper presented at the CIRED 22nd International Conference on Electricity Distribution, June 2013

⁶³ <http://www.slideshare.net/drsea/07-maggiore-simoneieadsmgrazoctober2014>

⁶⁴ British Gas. Initial Time of Use tariff trial analysis. Report CLNR-L015, London: British Gas; 2013.

⁶⁵ <http://www.power-technology.com/features/featuredynamic-energy-pricing-will-the-public-buy-in-4294096/>

⁶⁶ <http://aceee.org/files/proceedings/2010/data/papers/1967.pdf>

⁶⁷ <https://nest.com/energy-partners/austin-energy/>

⁶⁸ https://www.energex.com.au/__data/assets/pdf_file/0006/126375/PeakSmart-Air-Con-Terms-and-Conditions.pdf

- UK: Retailer Tempus Energy offers electricity consumers a flat rate tariff, significantly below normal market prices. In exchange, Tempus Energy is allowed to install a smart meter and demand response equipment at the user's residence and to manage the user's flexibility. Tempus Energy uses this flexibility to obtain lower prices at the day ahead energy market and to reduce balancing costs. The reduced flat tariff can thus be seen as a very simple and easy to understand demand response capacity fee⁶⁹.

2.3.4. IMPORTANT FACTORS TO TAKE INTO ACCOUNT TO ESTABLISH A SUCCESSFUL DR REMUNERATION MECHANISM

The analyses of different smart grid pilot project within the context of the S3C project⁷⁰ highlighted some key elements that determine the success of a Demand Response remuneration mechanism⁷¹.

- The information from the remuneration mechanism has to be clear and understandable
- The price updates and special events has to be announced timely
- The financial incentives need to be high enough
- Additional incentives (besides financial) support behavioural change (such as providing the end-user with a feeling of achievement)
- Manual control can support end-user acceptance as it is the first step in the learning process
- Automated control can prevent response fatigue, especially in case of more complex remuneration mechanisms

For both use cases described earlier, the state of the system needs to be taken into account in the pricing system. This makes a remuneration mechanism only based on Time-of-Use Pricing less appropriate. However, TOU pricing could be combined with other more real-time pricing mechanisms.

In the case of the day-ahead use case, TOU pricing would allow to change the average daily pattern of consumption in order to match it better with the available generation. In addition, CPP pricing could incentivize an additional load shifting in case the system is under stress due to extreme events (power plant outage, extreme weather conditions,...).

TOU pricing is in theory not appropriate for the imbalance use case, as no predictable patterns should be present in the imbalance market. In order to allow smart appliances to value their flexibility for this use case, real-time pricing is needed. This can be only real-time-pricing, or a combination with for example a capacity fee.

Independently of the remuneration mechanism, the price incentive should be large enough, not too complex and reflecting the underlying cost of the energy system. These elements will make it easier for the end-user to understand the pricing mechanism and as a result, respond in the most optimal way. In addition, it is important to analyse in depth the typical smart appliance-related practices in order to determine the optimal remuneration mechanism.

⁶⁹ tempusenergy.com

⁷⁰ S3C consortium. Report on state-of-the-art and theoretical framework for end user behaviour and market roles. S3C project Deliverable 1.1. Available from: < www.s3c-project.eu >

⁷¹ Additional information can be found in: Kim J-H, Shcherbakova A. Common failures of demand response. Energy 2011; 36: 873-880. and Faruqui A, Hledik R, Sergici S. Piloting the Smart Grid. The Electricity Journal 2009; 22: 55-69.

A smart remuneration mechanism will enable consumers to better match their production profile of the solar panels on their pattern of own consumption. This will lower the costs for the producer which should reflect in lower costs for the consumer as well.

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