Preparatory study on Smart Appliances (Lot 33)

Task 1 Scope

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AC	Air Conditioning
ADSL	Asymmetric Digital Subscriber Line
AMI	Advanced Metering Infrastructure
BAT	Best Available Technology
BRP	Balancing Responsible Parties
CEM	Customer Energy Manager
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
EC	European Commission
ECHR	European Convention for the Protection of Human Rights and Fundamental Freedoms
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
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
TEU	Treaty on European Union
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 1: SCOPE

1.1. CONTEXT

1.1.1. POLICY CONTEXT

Since the 1990s the EU has been pursuing climate change mitigation targets. Following the international commitment to the legally binding greenhouse gas reduction under the Kyoto Protocol, the 2020 policy package consists of a set of binding legislation to ensure that the EU meets its climate and energy targets for the year 2020. The package sets three key targets: 20% reduction in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables (as well as a 10% target for renewable fuels) and 20% improvement in energy efficiency. The targets were set by EU leaders in 2007 and enacted in legislation in 2009[1]. They are also headline targets of the Europe 2020 strategy for smart, sustainable and inclusive growth.

In 2009, the European Council agreed the long-term objective of reducing EU greenhouse gas emissions by at least 80-95% by 2050, compared to 1990 levels[2]. To outline the path towards such a low carbon future, the EC presented roadmaps for a competitive low-carbon economy[3], resource efficiency, energy and transport. In October 2014, the 2030 policy framework for climate and energy[4] was adopted in which the EU committed to **reduce greenhouse gas emissions with 40% compared to 1990 levels by 2030 and at least 27% renewable energy without country specific targets and 27% energy saving compared to 2007**[5].

→ Specific policy context - Energy efficiency of products

Ecodesign "contributes to sustainable development by **increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply**"[6].

The **Ecodesign Directive** sets the framework defining the “rules” for setting mandatory requirements to improve the environmental impact of products. The requirements are established in implementing measures (regulations) or, alternatively, voluntary agreements. While most of the implementing measures are product-specific, there are also measures that address horizontally modes or functions (standby, networked standby).

[1] http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm
[2] Council of the European Union. 1 December 2009, http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/110889.pdf
[3] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Roadmap for moving to a competitive low carbon economy in 2050, Brussels, 8 March 2011, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0112
[4] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A policy framework for climate and energy in the period from 2020 to 2030, Brussels, 22 January 2014, COM(2014) 15 final http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2014%3A15%3AFIN
[5] On the basis of the Energy Efficiency Directive, the European Council has endorsed an indicative energy savings target of 27% by 2030 (this target was not included in the Communication COM(2014) 15). This target will be reviewed in 2020 having in mind a 30% target.
[6] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, Article 1.

An energy-related product is defined within the framework of the amended Energy-Related Product Directive[7] as *"any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently"*.

The **Energy Labelling Directive**[8] helps consumers identify products with high environmental performance. It gives the framework defining the "rules" for setting product-specific requirements/ legislation on standard information regarding the consumption of energy and other environmental resources.

While the Ecodesign Directive addresses the supply side, the Energy Labelling Directive addresses the demand side - it is the combined effect of both measures which ensures a dynamic improvement of the market.

In the Ecodesign Commission's work plan for 2012-2014, smart appliances/meters had been identified as one of the priority product groups to be assessed in the frame of preparatory studies and to potentially be subject to an implementing measure (Lot 33).[9].

→ **The wider policy context**

For smart appliances that do not only focus on energy efficiency, but also bring about benefits for the integration of renewable energies and thus for the efficiency and sustainability of the energy system as a whole, there is a broad range of policies that are relevant for their design and deployment:

With its **Framework Strategy for the Energy Union**, the European Commission (EC) sets the vision for the future and integrates a series of policy areas into one cohesive strategy. The EC's Communication considering 'A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy' (COM(2015) 80 final)[10] states that energy markets and grids have to be fit for renewables to integrate renewable production progressively and efficiently into a market that promotes competitive renewables and drives innovation. Smart technologies will help consumers and energy service companies working for them to reap the opportunities available on the energy market by taking control of their energy consumption and possible self-production. Existing legislation and new market rules need to be fully implemented, enabling the roll-out of new technologies, smart grids and Demand Response.

The Staff Working document (SWD) on Demand Response[11] back in 2013 already called for actions aimed at the development of demand response in the EU to form an integral part of its energy

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

[8] Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products

[9] Commission staff working document. Establishment of the working plan 2012-2014 under the Ecodesign Directive. SWD(2012) 434 final. 7/12/2012

[10] Energy Union Package - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank, 'A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy', Brussels, 25 February 2015, COM(2015) 80 final http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF

[11] Commission Staff Working Document "Incorporating demand side flexibility, in particular demand response, in electricity markets" [SWD(2013) 442] accompanying the document COMMUNICATION FROM THE COMMISSION Delivering the internal electricity market

policy and of its forthcoming actions on the retail aspects of the internal energy market. *"Actions by other policymakers, regulators and energy companies are equally needed to trigger more demand response participation in the short term. Together, they should ensure that both price-based and incentive-based demand response programmes are available to different types and sizes of consumers while demand side participation in the market should be given a fair treatment and clear, practical set of technical rules. They should also ensure that demand response is able to play the role it deserves in contributing to system efficiency and reliability."*

The Commission will prepare an ambitious redesign of the electricity market, followed by legislation in 2016. It will push back on the renationalisation of energy policy through for example capacity mechanisms and propose new incentives for smart grids and rewards for flexibility[12]. *"The Commission will continue to push for standardisation and to support the national roll-out of smart meters and to promote the further development of smart appliances and smart grids, so that flexible energy use is rewarded." (…) "However, this will only work if market prices send the right signals."*

In July 2015 the European Commission proposed a 'Summer Package'[13] as a step towards implementing its Energy Union strategy. The package proposes a 'new deal' for energy consumers, a redesign of the electricity market and a revision of the energy label for more clarity (see Commission Report on Review of the energy labelling Directive[14]). In the Communication from the Commission considering 'Delivering a New Deal for Energy Consumers' (COM(2015) 339 final)[15] the following three key points have been identified as core: consumer empowerment, smart homes and networks and finally data management and protection. One of the steps to achieve this, is to make sure that smart home appliances and components are fully interoperable and easy to use and that smart metering systems fit for purpose with the recommended functionalities, in order to maximise their benefit to consumers.

Reviews of existing legislation (the Energy Efficiency Directive, the Energy Performance of Buildings Directive, and the Renewable Energy Directive) are planned to identify where action is required at EU level in order to deliver this new deal.

The **Energy Efficiency Directive** (EED)[16] establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20% headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date and includes the following elements to be highlighted:

- When Member States roll out smart meters they should ensure that the metering systems provide to final customers information on actual time of use and ensure the data security and privacy of final customers and that, if final consumers request it, metering data on their electricity input and off-take is made available to them or to a third party acting on their behalf.

and making the most of public intervention, https://ec.europa.eu/energy/sites/ener/files/documents/com_2013_public_intervention_swd07_en.pdf

[12] Energy Post, 'Highlights from the Energy Union package – and responses', February 26, 2015, http://www.energypost.eu/highlights-energy-union-package-responses

[13] https://ec.europa.eu/energy/en/news/new-electricity-market-consumers

[14] http://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v5.pdf

[15] COM(2015) 339 final, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committeee and the Committee of the Regions, 'Delivering a New Deal for Energy Consumers', Brussels, 15 July 2015, https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8.pdf

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

- Member States shall ensure the removal of those incentives in network tariffs that are detrimental to energy efficiency and that might hamper DR.
- Member States shall ensure that national energy regulatory authorities encourage demand side resources, such as DR, to participate alongside supply in wholesale and retail markets.
- Member States shall ensure that network operators treat DR providers in a non-discriminatory manner and that technical modalities for the participation in balancing, reserve and other system markets are defined on the basis of the technical requirements and capabilities of DR; they should be defined in close cooperation with DR services providers and shall include the participation of aggregators.
- Member States shall ensure that tariffs allow suppliers to improve consumer participation in DR, depending on national circumstances.

The **Internal Market-legislation**[17] on common rules for the internal electricity market holds the following elements relevant in the context of this study:

- Member States (or the regulatory authority) shall strongly recommend that electricity undertakings optimise the use of electricity for example by introducing intelligent metering systems or smart grids.
- Member States shall ensure that customers are entitled to receive all relevant consumption data.
- 80% of the consumers shall be equipped with intelligent metering systems by 2020 (where roll-out assessed positively).

Also related to metering, the Commission has issued on 9 March 2012 a recommendation on preparations for the **roll-out of smart metering systems** (2012/148/EU). It describes the minimum functional requirements for the smart metering system including:

- Provide readings directly to the customer and any third party designated by the consumer by provision of standardised interfaces for energy management solutions in 'real time' for DR services etc.
- Update the readings frequently enough (every 15 minutes) as a general rule.
- Smart metering systems should include advanced tariff structures, time-of-use registers etc. to achieve energy efficiencies and reduce the peaks in energy demand.

The **Network Code on Demand Connection** (adoption of Commission Regulation planned for 2015) is foreseen to lay down the requirements for grid connections of demand facilities and distribution systems and to establish a common framework for connection agreements between the demand facility owner or the distribution system operator vis-à-vis the transmission system operators. Inter alia it will set out procedures and overall technical requirements for the equipment intended to provide DR services. It will address active power control, reactive power control, transmission constraint management, system frequency control and very fast active control. It will not apply for DR services other than those delivered to the transmission system operators.
One of the objectives of the ENTSO-E Network Code on Electricity Balancing (Version 3.0, 6 August 2014) is to facilitate participation of Demand Side Response including aggregation facilities and energy storage supporting the achievement of the EU's targets for penetration of renewable generation.

An evaluation is ongoing of the **Energy Performance of Buildings Directive** 2010/31/EU (EPBD) replacing Directive 2002/91/EC setting a more ambitious framework to improve the energy efficiency of EU buildings in the light of the experience gained and progress made during its

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

application. Some of the elements investigated in the public consultation (due by the end of 2016[18]) and relevant in the context of this study is whether DR is being stimulated at the individual building level and if so, how this is done. The consultation also aims to have a better understanding of the impact of the EPBD framework on the self-consumption of electricity in buildings.[19]

The **Renewable Energy Sources (RES) Directive** 2009/28/EC requires Member States, in their building regulations and codes, to use minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation. These provisions are complementary to the Near Zero-Energy Building (NZEB) requirements in the EPBD, which recommend that the nearly-zero or very low amount of energy needed should be covered to a very significant extent by energy from renewable sources.

1.1.2. TECHNICAL AND ECONOMIC CONTEXT

→ The energy transition

The European electricity system is quickly evolving. Although there a large national differences, there is a tendency of decreasing classical centralised power plants with controllable production power and increasing intermittent electricity production from Renewable Energy Sources (RES), combined with growing electrification of heating and transport. As the share of controllable production lowers, maintaining the balance between production and consumption becomes more difficult, leading to both energy shortages and energy excesses. Additionally, the grid capacities have not been designed to include the increased local electricity consumption and production, which leads to more grid congestion.

Demand response (DR) is one of the concepts to overcome this and to achieve a better balancing of energy supply and energy demand while accommodating more renewable energy and increasing the energy efficiency of the energy conversion, transmission and distribution, thereby avoiding electricity grid congestion. DR refers to intentional modifications to consumption patterns of electricity of end-use customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption[20]. Or, according to the Smart Grid Coordination Group:

Demand response (DR)[21]: '*A concept describing an incentivizing of customers by costs, ecological information or others in order to initiate a change in their consumption or feed-in pattern ("bottom-up approach" = Customer decides)*'.

Demand Side Management (DSM)[22]: '*Measures taken by market roles (e.g. utilities, aggregator/flexibility operator) controlling electricity demand as measure for operating the grid ("Top-down approach")*'.

Technically, this can take many forms: peak demand reduction reserves, frequency containment reserves, frequency restoration reserves, emergency reserves, day-ahead or intra-day BRP

[18] https://ec.europa.eu/energy/en/consultations/public-consultation-evaluation-energy-performance-buildings-directive
[19] https://ec.europa.eu/eusurvey/runner/EnergyPerformanceBuildingsDirectiveConsultation1
[20] Albadi, M. H.; E. F. El-Saadany (2007). "DR in Electricity Markets: An Overview". IEEE
[21] Overview of the main concepts of flexibility management, CEN-CENELEC-ETSI Smart Grid Coordination Group, version 3.0, 11/2014.
[22] Overview of the main concepts of flexibility management, CEN-CENELEC-ETSI Smart Grid Coordination Group, version 3.0, 11/2014.

(Balancing Responsible Party) portfolio balancing, etc. Demand response can be implemented at industrial, commercial and residential level.

→ **The role of smart appliances in the energy transition**

Smart appliances are probably the main option to achieve flexibility of the energy demand in the residential and commercial sector. The energy consumption load patterns of smart appliances can be remotely shifted or otherwise altered with acceptable user impact.

In providing flexibility, smart appliances potentially have a positive impact on the environmental performance of the energy system:

- by helping accommodating renewable energy and limiting the required installed capacity of (peak) fossil fuel generation,
- by increasing the energy efficiency over the whole system (energy conversion, transmission and distribution),

Thus they can help save primary energy and CO2. Moreover, they can contribute to security of supply.

To achieve larger uptake of smart appliances, consumer agreement and/or consumer enabling of the electricity consumption altering functionality is needed, which requires that incentives – typically financial through tariffs or a capacity payment – should be offered to the consumers.

DR and DSM are well-developing in the industrial sector, where the large energy consumption of a single installation justifies a customised approach and technical solutions. Industrial and possibly commercial consumers are generally more aware of demand response-functionalities and solutions, not at least because they have better access to time-differentiated pricing and other reward schemes. On the other hand, residential DR and DSM are only developing slowly. The cause is what can be described as a “Chicken and Egg Problem”:

- On the one hand, limited/no residential DR products are developed, as there is insufficient capacity available due to a low installed base of appliances enabling demand side flexibility. Without consumers equipped to participate in DR, there is less (or no) incentive to offer time-differentiated supply contracts.
- On the other hand, development of appliances with demand side flexibility features is low, as there are insufficient DR products that can offer sufficient return for the user stimulating him/her to invest in this extra functionality. Without price signals, capacity fees and/or other rewards, there is no incentive for consumers to buy smart appliances and to participate in DR.

Nevertheless, there are many developments that support the introduction of DR and uptake of smart appliances:

- Rollout of smart meters with electricity consumption measured in intervals of typically 15-60 minutes and in some cases with a possibility of reporting live power data;
- Rollout of internet connections to a large proportion of end-users all over EU;
- An introduction of networked appliances, which can be controlled over the internet or other networks through smart phones, tablets, computers etc. and which can go into a networked standby and be woken up via a network trigger signal. There is beginning interest from consumers to acquire these appliances.

1.2. OBJECTIVE OF THE PREPARATORY STUDY ON SMART APPLIANCES (LOT 33) AND OF TASK 1

The objective of this Ecodesign Preparatory Study on Smart Appliances (Lot 33) is to analyse the technical, economic, market and societal aspects with a view to a broad introduction of smart appliances and to develop adequate policy approaches.

The study will follow the MEErP (Methodology for Energy related products), although it should be acknowledged that this methodology has been designed for mainly specific and rather homogenous product groups.

The lot 33 "Smart appliances" differs from this in two important aspects:

- Smart appliances can be very different products that just have one functionality in common. The approach of the study (not necessarily the policy measures) will thus be horizontal. This means that the definitions, analyses and policy measures related to this study should be generally applicable to all existing and future appliances, which are "smart" in the sense of the study. Consequently, even though we base much of the study on analyses of selected appliances, it is important that the terminology and concepts for smart appliances can be applied to all other relevant appliances, also those not in scope of this study.
- Secondly, positive environmental impacts are mainly generated at the level of the overall energy system, not at the product itself. Hence, the MEErP approach and the calculation tools will fit well for some aspects, less for others.

The aim of Task 1 is to clearly delineate and define the scope of the Preparatory Study. It consists of 4 parts:

- Section 1.3 defines what is meant by ‘smart’ appliances in the context of this Lot 33 study.
- In section 1.4, information regarding today’s status of the Demand Response (DR) readiness of the various appliances is investigated;
- In section 4.5, information regarding today’s status of the interoperability of the various appliances is given;
- Last, the conclusions from the previous parts are summarised and formalised which determine the scope of this Preparatory Study on Smart Appliances.

1.3. SMART APPLIANCES WITHIN LOT 33

Only energy related products within the scope of the Ecodesign and Energy Labelling Framework Directives are in the scope of this study, as these Directives form the legal background for the study and policy measures potentially to be implemented after the study. As such, means of transport for persons or goods including electric vehicles (EVs) are not in scope of the Ecodesign Framework Directive and consequently are not in scope of the present study. The focus of this study is on ‘**end devices**’, meaning the appliances that are being controlled and that alter their electricity consumption, as opposed to those devices that control other appliances or end devices. There will be no specification of who or what should activate the DR functionality. All control architectures should be supported.

Building automated control systems on the other hand are one of the product groups that might be included in the Ecodesign Working plan 2015-2017 and which would then probably be addressed by a separate preparatory study[23]. However, certain aspects in the on-going process (like

[23] The adoption of the Ecodesign Working Plan was originally foreseen for December 2015.

interoperability, measurement standard for demand responsiveness) could prove to be relevant for BACs as well.

The following categories and types of appliance will be subject to further study:

- Household appliances:
  - Periodical appliances: Dishwashers, washing machines, tumble dryers and washer dryers;
  - Energy storing appliances: Refrigerators, freezers, commercial refrigeration products and storage water heaters;
  - Behavioural appliances: Electrical hobs, ovens, hoods, vacuum cleaners and instantaneous water heaters;
- Heating, ventilation and air conditioning (HVAC):
  - Electric heating: Electric radiators, electric boilers, electric and hybrid heat pumps and boiler circulators;
  - Ventilation: Local and central extraction fans and local and central heat recovery ventilation units and central extractors and air handling units;
  - Air conditioning: Residential, non-residential air conditioners;
- Battery operated rechargeable appliances: Multimedia devices, power tools etc.;
- Residential energy storage systems: Backup systems like UPS (uninterruptible power supply systems) and home battery storage systems;
- Lighting systems: Lighting in residential and commercial indoor areas and street lighting.

1.3.1. Definition

Smart appliances - in its broadest sense, and not only limited to smart grid functionality – are mostly understood as appliances that are communication enabled. This communication platform can be used to offer multiple classes of functionality (see Figure 1):

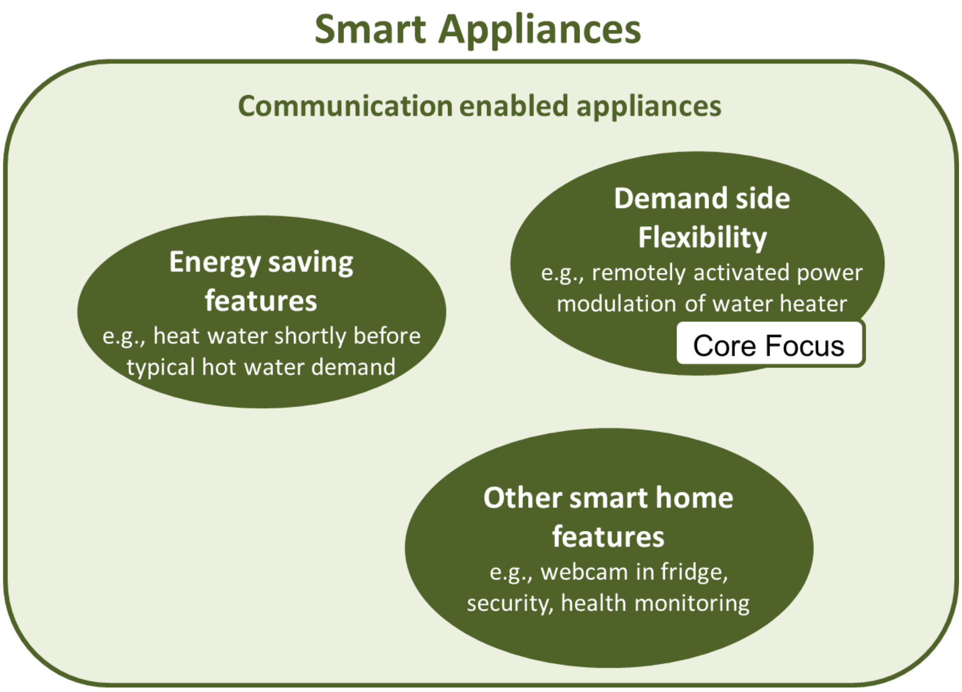

Figure 1 The functionality classes associated with smart appliances, with the focus functionality class of this study highlighted, i.e., demand side flexibility.

As a result of reflections and discussions with stakeholders and under the perception that the study needed to be refocused to produce tangible results for a potential regulatory process, the present study will focus on appliances with demand response-enabling functionalities.

It will not address functionalities that make appliances "energy-aware", i.e. functionalities that enable an appliance to measure, calculate and visualise energy consumption and potential energy efficiency losses over time. This is despite the fact that energy awareness as such might trigger substantial energy savings, mainly through changing consumer behaviour, as existing programmes and projects suggest[24].

Likewise, appliances that provide other features that help save energy (e.g. through better maintenance and direct communication with the retailer/installer or through intelligent sensors) will not be addressed here. Instead, energy awareness and other features with potentially positive impact on energy consumption could be tackled in other horizontal or product-specific lots.

Hence, for the purpose of this preparatory study, a smart appliance is an appliance that **supports Demand Side Flexibility**:

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

Whereby:

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

Note that manual start time delay is not considered smart control because it is not automated. The action of the user would be smart, but the smartness is not part of the appliance.

Automatic actions to safeguard the technical safety of the appliance are not considered smart control. Examples of this are a washing machine that is switched off because of a tripped fuse or the activation of its overvoltage protection.

Behavioural and electricity consumption data from appliances that cannot adapt their electricity consumption may still be relevant information for the DR/DSM control systems. However, the focus of the study is on those appliances that can offer a large flexibility potential with limited or no comfort impact.

[24] See for example http://www.ict-nobel.eu. A further, rough estimation of the saving potential through energy awareness will be provided in the Task 7 report although energy awareness is not subject to any policy options to be assessed under this study.

In order to enable the modelling of economic and environmental impacts, a definition of flexibility potential is required. The **flexibility potential** of a group of appliances is defined by two parameters:

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

1.3.2. USE CASE EXAMPLES

We present a set of use cases examples, serving the purpose of an overall understanding of the scope and of the functionalities that appliances may support and to illustrate the connection between the supply side system and the demand side i.e. the appliances.

The use cases are intended to be representative rather than exhaustive. Variations of the examples given may emerge, both regarding variety and complexity of control objectives, as regarding variety or number of appliances. However the aim is to illustrate the typical modes of operation from the point of view of the smart appliance.

→ **Use case example 1: Load shifting of heat pump supplied houses**

The use case is based on the assumption that an agreement exists between the consumer and an aggregator or similar intermediate organisation.

Suppose that a peak load is foreseen the next day at 18h, which would have required starting up power generating units at higher costs and/or higher environmental impacts. Instead, the BRP sends a signal to the aggregator requesting a reduction of 50 MW during 1 hour from 18h onwards. The aggregator sends signals to the heat pumps and/or the Home Energy Gateways in 50,000 houses requesting these are not switched on during the mentioned period, resulting in an average 1 kW load per house reduced.

The local heat pump or Home Energy Gateway secures that there is sufficient heat stored in the building components and the warm water tank to limit the impact on the user. The heat pump owner may be remunerated for his/her flexibility, e.g. by means of a yearly capacity fee.

→ **Use case example 2: Self-consumption of on-site produced RES energy**

Several possibilities for in-house power generation are available on the market. These comprise mostly PV systems, but also smaller wind turbines and gas fired micro-CHP (small combined heat and power systems). Often, such prosumers receive no remuneration for the energy injected in the grid, or a remuneration lower than the electricity purchase price. The prosumer has thus an incentive to use its own production locally as much as possible.

In this case, the prosumer has a Home Energy Controller, which may take the form of a separate energy gateway device, or which may be integrated, e.g., in the PV inverter controller. This controller measures the local RES production, the local (non-controllable) consumption and dispatches smart appliances to minimise the injection of RES energy in the grid.
For instance, if the user owns a PV installation and a battery system, then the controller will charge the battery when the PV production exceedes the non-controllable consumption of the household,

which will typically occur at noon, and will order the discharge of the battery when consumption exceeds the PV production.

→ **Use Case Example 3: Variable pricing support by a washing machine**

In this use case, the user has an electricity contract based on variable prices, e.g., prices based on the day ahead energy market,
Those prices are directly downloaded to the washing machine, which has a communication interface that supports the used pricing scheme and which is equipped with dynamic pricing scheduling logic.

When the user configures the machine, he/she sets a deadline when the laundry should be finished the latest, and the washing machine then automatically starts the washing programme such, that the total energy price for the programme is cheapest, while the laundry is still finished in time. The washing machine may also give indications via its user interface to the user on when the cheapest and/or highest prices occur, such that the user can take this into account during configuration.

→ **Use Case example 4: Appliance-based System Frequency Control of freezers**

Suppose that an emergency situation occurs in the power system, resulting in a reduction in voltage and frequency at the consumers' level in a local area. Suppose that 1,000 households with system frequency control freezers switch off, resulting in a total load reduction of 100 kW, sufficient to stabilise the grid.

The freezers dispose of built-in control, securing a maximum of half a degree raise of temperature during maximum 1 hour. The household owners could be remunerated for the flexibility.
This type of DR is based on internal measurements and control: The appliance is equipped with power measurements (e.g., frequency and voltage) and it switches or modulates its electricity consumption in function of those measurements. This type of control requires no communication to or from the appliance.

→ **Use case example 5: distribution grid congestion management by buffered water heaters**

Suppose a very high installed base of photovoltaic panels within a single low voltage distribution grid segment, in which the injection of energy would cause frequent overvoltages if no countermeasures are taken. In this use case example, the distribution system operation (DSO) has chosen to use DR. The DSO has an agreement with the local owners of buffered water heaters, e.g., in the form of an annual capacity fee. At noon, when the local solar production is high, the water heaters are automatically switched on. The increased consumption drops the voltage levels, the amount of injected energy is reduced, and overvoltages are avoided. The heat generated is stored in the thermal buffers and remains there until the heater owner requires it. The DSO has avoided grid reinforcements and the associated investment cost.

→ **Use case example 5: Frequency restoration reserves based on commercial refrigeration**

Suppose a supermarket chain with a large number of cooling assets distributed across its sites. These refrigerators and freezers are all connected to a central energy management system, allowing the supermarket chain to offer ancillary services to the Transmission System Operator

(TSO), more specifically emergency frequency restoration reserves. In case of a production shortage, the TSO sends a signal to the energy management system of the supermarket chain, which automatically powers down all operational compressors of refrigerators and/or freezers with a temperature below a maximum allowed temperature. In case of a production surplus, the TSO can remotely switch on the compressors of all refrigerators and/or freezers with a temperature above the lowest allowed temperature. The supermarket chain receives a capacity reservation fee based on the guaranteed minimum power it can switch on/off, supplemented with an activation fee every time the TSO calls on the reserve.

→ Use case example 6: Peak shaving combined with energy efficiency by appliances controlled by a building automation and control system

Suppose a building automation control system that centrally monitors and controls all smart appliances within a large building, e.g., heating, HVAC, ventilation, etc. The owner of the building has a contract with an aggregator to supply emergency peak shaving reserves. Besides a fixed capacity fee per year, the owner of the building receives an activation fee, each time a peak shaving signal is sent to the building automation system. The number of peak shaving signals per day is contractually limited to, e.g., one single signal per day. When such a signal is received, the building automation system decreases the total electricity consumption of the building below the contractually agreed levels for a predefined fixed period of time, e.g., 3 hours. Outside of the peak shaving periods, the building automation system controls the smart appliances as to optimise the energy efficiency of the building as a whole.

1.3.3. SYSTEM FREQUENCY CONTROL

In certain cases smart appliances locally measure a grid parameter and autonomously respond to this, with system frequency control by thermal appliances as the best known example. The operating principles of the latter are:

- the appliance temperature set points remain user controlled,
- the appliance measures the frequency in a given interval and with a certain accuracy,
- the appliance operates normally within a defined deadband around the nominal frequency (50.00 Hz),
- if the frequency drops below the deadband, the hysteresis offset point is lowered for heating systems and raised for cooling systems; the inverse is executed when the frequency raises above the deadband.

If this control is realised without changes to the temperature setpoint and if the hysteresis range settings are not exceeded nor altered, then there is no noticeable impact on consumer comfort.

This type of DR differentiates itself, as – from a purely technical standpoint - no communication is required from the smart appliance to the outside world. The grid frequency reflects the electricity system balance and ‘communicates’ what proper actions to take for the smart appliance. Note that the same principle can be used for other grid parameters, e.g., line voltage, three-phase voltage or current imbalance, etc. With exception of the system frequency, these are typically grid parameters that reflect the state of the local distribution grid.

System frequency control based on smart appliances with local measurements has a number of advantages and disadvantages. The strongest advantage is that extra communication links are redundant. Costs are avoided, no privacy issues emerge and uptake is not hindered for people who lack affinity with networked technology. On the other hand, the appliance must be equipped with extra measurements. They also cannot participate to other DR schemes, unless extra communications are established, which forfeits a lot of the advantages.

A distinct difficulty due to the lack of a communication channel, is that the DR contribution of the appliance cannot be easily measured, nor verified. As such, simple and transparent compensation mechanisms are hard to establish[25]. Nevertheless, because of the many advantages of frequency control based on local measurements, system frequency control remains a viable DR option.

System frequency control is also one of the DR mechanisms that is addressed in the Network Code on Demand Connection (adoption foreseen in 2015). A mandatory deployment of frequency control-enabled temperature-controlled appliances, as initially proposed by ENTSO-e, is no longer envisaged.

The Demand Connection Code[26] establishes, *inter alia*, technical rules for equipment that is contracted to provide DR reserves. As technical specifications (deadband width, nominal frequency/voltage/…, etc.) depend for the moment on the specific needs of the local TSO, these need to be programmed in the appliance. Harmonisation across Europe of the minimum ranges within which the technical specifications are being defined would reduce costs for the manufacturers and hence the end user. Further harmonisation of the technical requirements would be necessary in the longer run. The findings of this study and the Ecodesign Smart Appliances process might be able to support this process.

1.4. DEMAND RESPONSE READINESS STATUS

An important point of attention of this preparatory study, is the functionality required for smart appliances to support and offer demand side flexibility and the resulting flexibility potential per appliance type, which varies per appliance type. This section discusses these aspects and classifies the appliance types in scope of the preparatory study based on flexibility potential and the associated impact on the user's comfort. We further discuss the possible control architectures and the impact of those on this study. Also the impact on the study of the energy market organisation and of the possible DR business cases is discussed.

There are today a limited number of appliances with built-in smartness and it is necessary to redesign the appliances in minor or larger degree, depending on the level of smartness to build in and the type of appliances.

The redesigns should include:

- A communication module to communicate with the system, e.g., using wireless, wired and/or power line communication (PLC) technology.
- A control module for switching on, off, load modulation etc. of the relevant components of the appliance.

[25] Probably the most practical remuneration scheme for system frequency control is a simple capacity fee in the form of single time bonus when the appliance is purchased, or a fixed annual reduction to the energy bill. Biggest drawback of such schemes is that the fee has no relation to the effective capacity made available to the frequency reserves.

[26] See the site of ENTSO-e for more information: www.entsoe.eu

- Components separating the ones applicable for the load shifting from the ones not applicable. E.g. in the case of a fridge, the light should be always on when the door is open, even though the compressor has received a pause signal. Also the internal control unit needs to adapted to handle this separation.
- Additional logic to safeguard the comfort should be added.

The redesigns will have a different nature depending on the type of appliance. For some appliances a redesign of the compete design platform is needed, while other appliances only need smaller redesigns.

Demand Response Readiness gap
The main gap is that similar appliances of different manufacturers should provide the same demand side flexibility functionality, or a subset of a commonly agreed upon set of functionalities, such that the demand control system does not need to differentiate between appliances of different brands. This also maximises the guarantee for the end-consumers that the available DR systems support the appliance of choice.

Appliance gaps are taken into account by TC 59.

1.4.1. FLEXIBILITY POTENTIAL OF APPLIANCES

Each main category of appliances within the scope of this study, as listed in Section 1.3, is described in detail in Annex 1 of this report regarding:

- Installed base
- Electricity consumption
- Identification and description of the energy shifting and/or power modulating possibilities - the nature of it, size, in which periods (working days, weekends, seasons etc.).
- Estimation of the flexibility potential per appliance
- Estimation of total flexibility potential for the category based on an estimate of the total amount of appliances in EU and the potential per appliance
- Identification and description of any comfort and user impact
- Identification and description of any gaps and/or pre-conditions for the flexibility potential (technical maturity, redesign needed, availability, other)

Note that in the following Task reports, more details will be integrated on these characteristics.

In relation to comfort and user impact, it is important to emphasize that this will have an important impact on the flexibility potential. It is however not possible to look at it in an isolated way because it also depends on the economic benefit and/or other benefits related to accepting that the appliances will be DR enabled. We have therefore tried to estimate a balance between possible comfort losses and user benefits when estimating the potential.

We consider as a pre-condition that the smart appliances are being designed for the demand side flexibility functionality and that there would be no negative impact on the lifetime and repair costs. The technical analyses are described in Task 4 report.

No negative impacts on privacy protection is also a pre-condition. This is further detailed in Task 3.

It is necessary to look into the single appliances, because eventually a possible regulation would cover individual appliances.

Below, we summarise the results of the detailed analyses and references as described in Annex 1 and conclude with a ranking of the appliance types, according to flexibility potential and user comfort impact.

→ **Periodical household appliances: Dishwashers, washing machines, tumble dryers and washer dryers**

Periodical appliances are appliances that periodically execute a user initiated cycle. There is no interaction with the user while running and often the user does not require the programme to be finished as soon as possible.

There are three different possibilities to shift energy or modulate power:

1. Start time delay controlled by the user: This is a common function in dishwashers and washing machines, 30-40 % of the appliances have the functions. This function is not considered "smart" in the sense of the study.
2. Remote activation: the user selected programme is remotely activated before the user deadline is reached.
3. Altered electricity consumption pattern: while the appliance is activated, the consumption patterns changed through pausing the operation, changing the temperatures, etc.

The complexity of technical adjustments and redesign needed increases from the first to the third level.

Appliances in this category offer a high energy shifting capacity and a limited power modulation capacity. Pilot studies in the framework of the Linear project indicate that around 30% of the configurations of washing machines and tumble dryers can be with remote activation. For dishwashers this is 56%. Depending on the study, the average length of the time window for remote activation varies from 3 to 8h.

Flexibility is typically situated in the afternoon and especially in the evening. The evening flexibility peak is most pronounced for the dishwashers. There is more flexibility in the weekends than in during weekdays. For dishwashers and washing machines, there are almost no seasonal effects. However, tumble dryers are predominately used in winter season.

In the framework of the Smart-A project, it was estimated that about 20 % of dishwashers, 10 % of washing machines and 30 % of tumble dryers may be operated in altered consumption pattern mode.

Consumer's acceptance for remote activation is expected to be rather high, especially so for dishwashers and washing machines. However, there can be concerns regarding an external steering of appliances as well as regarding safety (especially in periods of absence) and noise (during the night). Altered consumption mode operation may have an impact on the quality of the appliance's operation (e.g. changes in cleaning performance or colour fading due to pausing and prolonging the operation) and on its energy consumption. If a process, for example, is interrupted during a critical heating phase, the process temperature will decrease due to heat losses and additional energy is needed after the pause to compensate for this lost heat.

The total energy consumption of dishwashers, washing machines, washer dryers and tumble dryers is relatively small in comparison to other household appliances (e.g. refrigerators or water heaters), as the operation time and number of operation cycles is limited. However, the higher power during operation, the larger delay windows (higher flexibility) and the high market penetration in Europe, especially in the case of washing machines and dishwashers, results in a significant DR potential.

By taking into account all households in Europe, an energy shifting potential of washing machines of about 5 GWh was calculated. For tumble dryers, it is between 3 and 10 GWh and for dishwashers, it amounts to 8 GWh.

→ **Energy storing household appliances: Refrigerators, freezers and storage water heaters**

Energy storing appliances are appliances that provide a capacity to store energy in a form ready to be delivered to the user without any further transformation. These appliances require no interaction with the user after initial set up, although user actions can impact the appliance's operation.

There are two different possibilities to shift energy or modulate power:
1. Remote activation: the cooling or heating is remotely activated or delayed.
2. Altered electricity consumption pattern: changes in the operational parameters of the appliance (motor speed, temperature settings, etc.) allow modification of the consumption pattern.

The complexity of technical adjustments and redesign needed is higher for the second option.

For appliances in this category, flexibility depends on the thermal storage capacity. In first instance, it may be considered as evenly distributed throughout the day and throughout the week. For refrigerators and freezers, seasonal effects are only weak. Water heater loads are highly seasonal with highest potential occurring in winter. This can be explained by the fact that both, differences in water temperature and hot water consumption are higher in winter season.
Appliances in this category offer a high flexibility in energy shifting operation. Consumer's acceptance is assumed to be rather high if food safety and quality is not compromised and if there is no loss of comfort. Short-term interruptions of heating or heating processes or power modulation (e.g. changes in temperature setting or reduction in motor speed) can be realised for all appliances in this category. In this way, power demand curve can be changed instead of merely shifted.

Assuming a potential for short term interruptions of 5 Wh per household in Europe, an energy shifting potential of 1.56 GWh for refrigerators and freezers in 2025 was calculated.

→ **Behavioural household appliances: Electrical hobs, ovens, hoods vacuum cleaners and instantaneous water heaters**

Behavioural appliances are appliances where the operation is linked to its functionality and whose operation require the active involvement of consumers[27].

[27] Robot vacuum cleaners can be regarded as an exception to this. However, as the flexibility of robot vacuum cleaners is in the charging of the battery, the assessment is part of the analysis of chargers.

There are three different possibilities to shift energy or modulate power:

1. Manual intervention by the user. This option is not considered "smart" in the sense of the study
2. Altered electricity consumption pattern: pause between heating cycles, interrupt the heating phase, etc.

The complexity of technical adjustments and redesign needed increases from the first to the third level.

An estimate on the shifting potential is hard to state, since not much research has been done on this in view of appliances in this category.

Concerning hobs and ovens, it has to be examined whether short term interruptions of heating phases or prolongation of the interval between two heating phases by seconds or minutes compromise the cooking process and consequently the performance**.** However, the consumer’s acceptance is supposed to be low.

In view of range hoods and vacuum cleaners, a reduction of power will result in a lower air change rate or a loss of suction power, respectively, leading to a lower effectiveness and a highly variable background noise.

For instantaneous water heaters, the aforementioned scenarios are improbable. Short term interruptions in power supply would cause losses in comfort, which will not be accepted by consumers.

→ **Heating (electric and hybrid) (permanent appliances): Radiators, boilers, heat pumps and circulators**

This category comprises direct effect electric radiators (with or without built-in heat storage capability), electric and hybrid (gas or fuel + electric) heat pumps and boiler circulators.

There are three different types of flexibility involved for heating :

- Inertia of the building (this includes all types of electric heating without storage and boiler circulation pump),
- Inertia built in the heating system (electric storage radiators and electric boilers)
- Energy source shift (gas or fuel) for hybrid electric heat pumps during peak hours; this potential is extremely high - the electricity consumption can be lowered at any time, but the market for hybrid heat pumps is just at its beginning (still negligible in 2014).
- Power to heat aims to absorb power supply peaks, which can be achieved for example by electrical heaters inside storage tanks of hydraulic heating systems. Switching to electrical heating has no restrictions for the user.

All electric heating appliances include some sort of controls, mainly thermostatic. Newer installations of electric heaters and heat pumps have more advanced control systems though typically not enabled for exchanging signals with third parties.. Recently, smart thermostats have been proposed to customers of energy suppliers, allowing to control electric radiators and boilers, but only in the mode ON/OFF. HVAC manufacturers typically offer central controllers with more sophisticated controls for their own units (integration of other variables as variable speed of the compressor drive), which may communicate with a building controller or a network for some of them.

The smart control might (or not) be integrated directly into the unit, the ensemble "control+unit" is considered the smart appliance as a whole, thus encompassing 1 or 2 energy related products. Therefore, smart thermostats are considered as smart energy related products.

Potential is estimated at:

- Peak power: Up to about 95 GW (2010)
- Energy consumption: About 280 TWh/year
- Potential energy to be shifted: About 30 TWh/year and about 100 GWh/day in the coldest winter months

The flexibility potential is divided at about 50/50 between built-in system inertia (storage radiators, electric boilers) and building thermal mass (inertia). This means about 40 % (40 GWh/day) can be used to store renewable heat in excess during coldest winter days (wind or solar photovoltaic electricity which can be used to heat electric storage, instead of using grid electricity). Regarding the use of building thermal mass, several smart grid and DR experiments are on-going in France. They will help characterise the user acceptance regarding the comfort variations due to heating power modulation and the need for two way communication in order to satisfy comfort and then ensure the durability of any DR programme based upon electric heating.

Comfort is the limiting factor as temperature will drop in the house when the heating system is stopped. Strategies can be adapted (heat pre-charging of the building structure, ventilation can be stopped) but this requires two way communication. Another limiting factor is the speed of air temperature variation in the house, if it is too drastic, occupants' comfort might be jeopardised. This may be mitigated by modulating the orders (not full stop but only 50% of the capacity supplied over a longer period).

→ **Ventilation (permanent appliances): extraction fans, heat recovery ventilation units and air handling units**

This category comprises local and central extraction fans and local and central heat recovery ventilation units in the residential sector and central extractors and air handling units in the tertiary sector.

In the residential sector, ventilation is mainly constituted of one or several local exhaust fans (mainly in wet rooms) or of a central extractor. Balanced ventilation units with heat recovery are growing in numbers, but still represent a very limited share of market and stock.

All these systems operate continuously and may be controlled by the end-user. Some central extraction units are equipped with two speeds with manual control - either by wired control or radio frequency control. Best available technologies (here with the meaning of Ecodesign Best Available Technologies, see DG ENER lot 10[28] & ENTR lot 6[29] studies for these products) include demand controlled ventilation based on CO_2 or other presence sensors, balanced heat recovery ventilation and motors having the capacity to adapt the motor frequency to adjust the flow but they have very low sales share.

In the non-residential sector, ventilation works on the same principle with larger and more sophisticated units.

[28] http://www.eceee.org/ecodesign/products/airco_ventilation
[29] http://www.eceee.org/ecodesign/products/standby

Air handling units encompass more air treatment functions, which require more sensors for control. Local sensor can communicate with the products through radiofrequency and it is now common to see manufacturers proposing web interface for their products, for maintenance and energy consumption and performance measurement. The share of end-user buying these options is not known.

As a conclusion, some degree of smartness already penetrated the non-residential sector, but probably a small part only, while the residential sector is probably fully without smartness.

The power consumption can be shifted directly, i.e. by stopping or modulating the fan electric power. For ventilations systems which also transport heating and/or cooling this will have an impact on the heating and cooling consumption. In this section, only ventilation shifting potential is included.

The limit for the stopping or reducing the ventilation is the CO_2 concentration, but there still could be a shifting potential if associated with-periods with higher than necessary ventilation levels. However, with air volume change per hour of 0.8, this probably leads to potentials of a few minutes only.

Maturity and potential probably exclude residential ventilation, because unitary power per unit is very low.

Flexibility potential :

- The peak power of non-residential ventilation is relatively low, about 10 GW.
- 59 TWh in 2010 for non-residential ventilation. Energy consumption of non-residential ventilation is relatively important because units operate all year long during working hours.
- Units may probably shift about 10 GWh/day during working hours in the week.

The main risk regards health because of increased CO_2 concentration levels.

→ Air conditioning (permanent appliances): Residential and non-residential air conditioners

This category comprises all cooling systems for comfort cooling:

- Residential air conditioners, mainly split and multi-split systems, but also portable air conditioners
- Non-residential air conditioning systems, i.e. chillers, large split, multi-split and VRF (variable refrigerant flow) systems, rooftop air conditioners and cooling systems of air handling units

Air conditioning units are equipped with sophisticated controllers and except small split units using a remote control, a central controller is generally installed with the unit. To get smarter, air conditioners may require slight adaptation however, they can be equipped with DR capability by adding a network adaptor as an interface to a listed protocol or a centralised controller. Australia has for instance adopted a standard (AS 4755, 2008) for air conditioners to be equipped with specific DR signals (stopped, working at 50% or 75% of their demand) in order to ease the interaction with a standardised DR enabling device which can be operated by external agents.

As for heating, electric cooling shifting potential mainly relies on the building capacity to maintain indoor air temperature within acceptable limits when the cooling power is reduced or cut. All new equipment sold from 2012 onwards are equipped with multi-stage compression circuit or variable speed drive to control the cooling capacity output.

It is believed some electric cooling appliances are equipped with the communication and control functionality to support DR, due to the fact that they are already capable of exchanging signals with a domestic control server or remote activation via wifi for example. Although smart thermostats are offered in Europe mainly for heating, they could also provide communication and control functionality for cooling appliances.
Potential reduction in user comfort is the main limiting factor of the shifting potential in the residential sector. For tertiary purposes, many restrictions according to the industry might be limiting factors (e.g. temperature controls in pharmaceutical laboratories).

Another important issue regarding flexibility potential for air conditioners are restrictions related to ensure secured spaces during heat waves in Europe. In France for example, after the heat wave of 2003 where more than 15000 elder died, dictated that at least one conditioned space must exist in a retirement home. Specific restrictions regarding electricity supply also exist. In addition to local regulations, flexibility potential will be modulated by the acceptance of DR mechanism by the end-users.

Flexibility potential:

- Peak power: Up to about 160 GW (2010)
- Energy consumption: About 80 TWh in 2010
- Potential energy to be shifted: About 65 GWh/d in the summer and about 8 TWh/a in total

→ **Battery operated rechargeable appliances**

This category comprises charging of battery equipped (low power) appliances. These include all kind of multimedia devices (phones, tablets, video cameras etc.), power tools and other household appliances with rechargeable batteries (clocks, electric shaving, toothbrushes, etc.) on a low power level.

Currently little of these appliances are ready for smart charging. However, a distinction needs to be made between the devices with a rather large processing power capability (most multimedia appliances) and network communication support and those without. Smart charging functionality could be added as a software application without the need to further adaptations. The latter need extra (physical) adaptations, which in the light of the ‘low’ selling prices of these appliances, could be relative expensive. An alternative could be the usage of general purpose smart power adapters, but then the control logic is part of the adapter and not the end device.

There is a certain potential, however its capacity will depend on controlling large numbers. Peak powers and average consumption is rather low for these appliances. Numbers are very high (millions).

Limited research has been done on the potential of smart charging in the low power appliances, but similar techniques already were investigated for electric vehicles, which could also be applied for this.

The comfort impact may be small, if the shifting periods are limited and take place during a no-use period such as during the night.

→ **Residential energy storage systems**

This category comprises larger battery storage systems:

- Backup systems like uninterruptible power supply systems (UPS)
- Battery energy storage systems, which are mainly meant for load levelling and peak power shaving. E.g. minimising the PV power injection into the grid.

UPS systems already have a high technical maturity and already were subject of an ecodesign preparatory study. The battery energy storage systems for residential use are rather new. For load shifting a redesign might be needed.

Both described battery storage systems are from a technical point of view similar to each other but differ in their usage. The backup systems, by the nature of their usage, do not allow a large amount of flexibility.

The battery energy storage systems are meant exactly to provide flexibility for different usages, but at the moment their installed base is limited, so also the total capacity. However, when in future these systems will find their way to the market, they could represent a larger potential.
These units could be controlled through a control logic that optimises along a given strategy ("kWh, €, $CO2$…).
Because transport is not part of the ecodesign and energy labelling framework directives, battery charging systems for electric vehicles cannot be included in implementing measures. However it should be noted that the expansion of electric transport will entail a modification of the load curve, especially in the night period.

→ **Lighting (behavioural appliances)**

This category comprises lighting in residential and commercial indoor areas and street lighting using the following lighting technologies: LFL (linear fluorescent lamp), CFL (compact fluorescent light), Tungsten, GLS (general lighting service 'incandescent'), HID (high intensity discharge lamp) and LED (light emitting diode).

There are the following possibilities to shift or modulate capacities:

- For advanced LED light bulbs: There are already LED light bulbs on the market, which can be controlled by a smart phone over Wi-Fi – in some cases combined with a special hub for the bulbs. This can be further developed into a system controlled by signals from the power supply system. For LED systems there will be no technical problems in dimming and switching off the light.
- For CFLs: It is also possible to build in DR enabling, but in a less extent dimming compared to LEDs.
- Generally, for all light bulbs (LED, CFL, Tungsten, GLS) it is technical possible to mount an extra DR module for switching on and off the bulbs.
- For luminaries and lighting systems in commercial areas (mainly LFL): There are already advanced systems on the market, which can be controlled by local conditions in the lighted area through presence sensors and solar radiation sensors combined with the time of day. This can be further developed into a system controlled by signals from the power supply system.
- Street lighting: Street lighting are already highly controlled from outside and it is possible to combine this with a DR module.

Many light technologies can be dimmed (tungsten, halogen, fluorescent, LED etc.) resulting in reduction in power load and energy consumption.
Lighting including street lighting is naturally mostly switched on in periods with no solar radiation apart from indoor areas with no or few windows such as basements, commercial centres etc. meaning that the energy consumption is higher in evenings and during nights, though also depending on time of year and geographical location within EU. For offices and some other commercial area, the energy consumption is reduced during weekends.

The energy consumption is higher during these periods, which would be a basis for the flexibility potential.

There are not many technological gaps, because the technology exists. There may be technological gaps regarding some lighting technologies, which are not suitable for dimming and/or often switching on/or, else the gaps are few and technology are already used for lighting systems on the market.

Due to already effective energy labelling and ecodesign measures, there is a high focus on energy efficient lighting, both regarding efficient lighting devices and regarding efficient control (presence sensors, automatic dimming according to actual needs, etc.). When lighting is an energy service, which needs to be produced simultaneous as the needs occur, all lighting load shifting will have serious user impacts, which may include safety issues.

Therefore, even though the technical potential is large, the flexibility is low, especially for homes and commercial areas, and the real potential will mainly exist for short periods of emergency load shifting.

There is very little data on shifting potential for lighting. Based on available data and assumptions on stock, lumen, efficiencies, comfort impact etc. we have estimated a total shifting potential at about 28 GW corresponding to about 4 GWh/day. Of this street lighting is estimated at about 5 GW corresponding to about 2,5 GWh/day.

→ **Conclusion**

We have divided the appliances into 3 categories of potentials:

- High flexibility potential with few comfort and/or performance impacts: Dishwashers, washing machines, washer dryers, buffered water heaters, radiators, boilers, heat pumps, circulators, residential and non-residential air conditioners and battery storage systems;

- Smaller flexibility potential and/or larger comfort/health impacts: Tumble dryers, refrigerators, freezers, extraction fans, heat recovery ventilation and air handlings units and chargers (low power);

- Only emergency flexibility potential: Electrical hobs, ovens, hoods, vacuum cleaners and lighting.

Further product development including the products' control system may move more products to the high flexibility potential category. E.g. refrigerators and freezers may have more cooling capacity built in and may store more cool before the planned shifting period in order that the temperature variation would be minor.

1.4.1. CONTROL ARCHITECTURES (IMPACT ON SMART APPLIANCE FUNCTIONALITY)

From the point of view of the smart appliance, 3 approaches exist to establish control of the smart appliances, within the comfort limits set by and agreed upon with the user and in function of the DR objective. Note that a smart appliance may be equipped with the functionality to be interoperable to multiple of these approaches.

<u>External control and external objectives</u>
The smart appliance is connected to an external control system via a generic flexibility interface. This interface allows the control system to read the flexibility status of the appliance, and allows the control system to switch or modulate the electricity consumption or production of the smart appliance. Comfort protection based settings by the smart appliance of those control signals may be possible. Use case 1 (load shifting of heat pump supplied houses) illustrates this scheme.

In this case, the information layer data model (see Figure 5: Data transfers between the appliance and the power system) contains flexibility status information and control actions. It must be extended when smart appliances offer new types of flexible behaviour. This implies updates of the control systems, but not of the installed smart appliances. Different or new uses of flexibility in the energy markets require no data model updates nor smart appliances firmware updates.

As the smart appliance's interface is flexibility based, and not DR control objective based, the appliance can be used for any current or future DR scheme, provided the timing requirements of the control objective can be met by the DR communication and control infrastructure.

The control system can be either a home controller, or a cloud based systems.

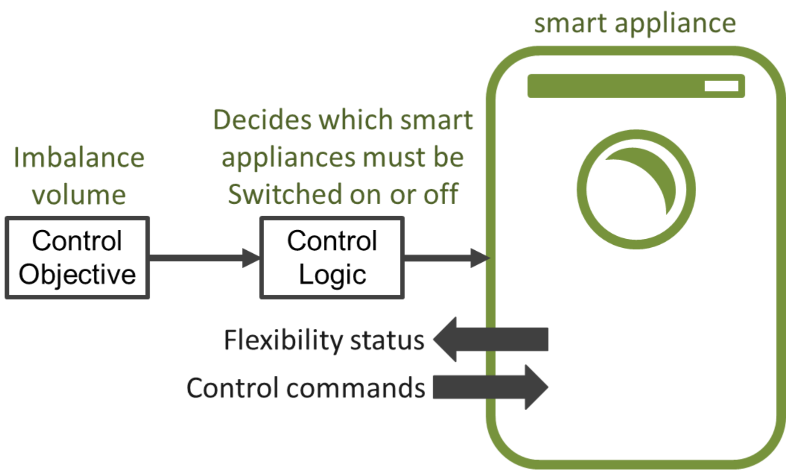

Figure 2 Example: the flexibility of smart appliances is used to maintain the intraday balance between electricity production and consumption, using an external control and external objectives setup.

<u>Internal control and external objectives</u>
The smart appliance is connected to an external control system via a DR objective based interface, e.g., a variable energy price interface. The DR objectives are sent to the smart appliance, and the smart appliance independently adapts its energy profile in function of the sent objectives and the user's configurations and settings. Optionally, the smart appliance may report its actions back to

the originator of the control objectives. Use case 2 (variable pricing support by a washing machine) illustrates this scheme.

In this case, the information layer data model contains DR control objective specific data. This implies that the smart appliance must support DR control objective specific functionality and that each smart appliance must support the control objectives it is potentially used for (variable pricing, frequency restoration reserves, emergency reserves, grid congestion reserves, …). New uses of flexibility in the energy markets require data model updates and firmware updates of all smart appliances that participate to this new scheme. These updates include the required optimisation and control logic. When smart appliances offer new types of flexible behaviour, then only those appliances are impacted, but not the data model.

Control objectives can be sent to the smart appliances both using the home energy gateway model or using the cloud model.

As the control decisions reside with the smart appliances, this architecture is mainly suited for open loop control DR, such as dynamic pricing. If the DR response scheme requires closed loop control, e.g., if an exact increase or decrease of the consumption is required, for instance, for intraday BRP portfolio management purposes, then this can only be achieved by iterative control algorithms (if the smart appliances report their actions), or by statistically modelling the response of the smart appliances.

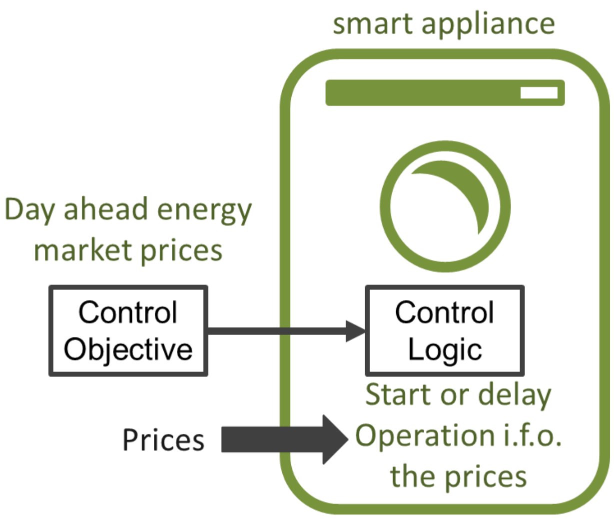

Figure 3 Example: smart appliances respond to day ahead energy market prices, making use of internal control and external objectives setup.

<u>Internal control and internal objectives</u>

The smart appliance requires no communication links, but rather optimises its energy consumption profile based on locally measured parameters only. Use case 3 (appliance-based system frequency control of freezers) illustrates this scheme.

The number of DR control objectives that can be realised using this scheme is limited, as there must be a correlation with, typically, the voltage and/or frequency as measured by the smart appliance.

New or future control objectives require firmware updates of the smart appliance, and possibly a hardware update, should the supported measurements not suffice.

As the control loop includes no external communications, very fast response is possible. Only open loop control is possible.

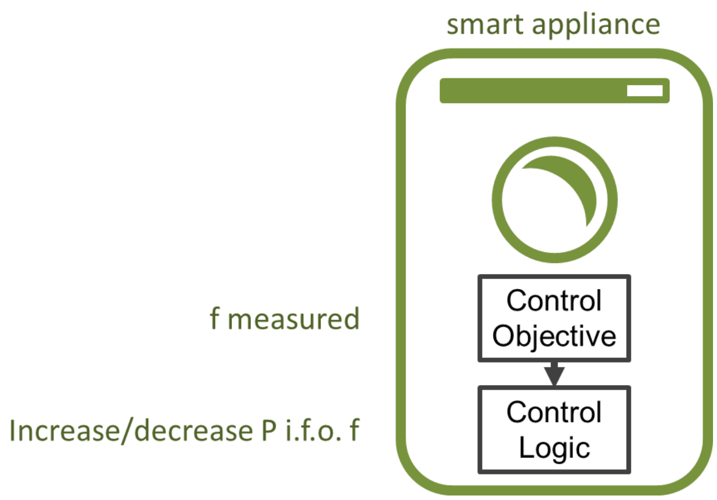

Figure 4 Example: smart appliances realise automated frequency restoration based on local frequency measurements, in an internal control and internal objectives setup.

<u>Conclusions</u>

Both the appliances and the data model (see Section 1.5) must accommodate for the control architecture(s) selected, as each model requires different logic in the appliances and different data communicated. Furthermore, if the control is internalised, as for two of the models, then the use of the flexibility may be limited. Most standardisation efforts today partly support a mixture of the three models. E.g., SEP2 supports both variable prices sent to directly to the smart appliances and direct control.

If the external control and external objectives model is to be supported, additional work is required to define broadly applicable generic flexibility interfaces for the smart appliances.

If the internal control and external objectives model is to be supported, additional work is required to define what control a smart appliance should at least support and how the objectives for each control case are formatted.

If the internal control and internal objectives model is to be supported, additional work is required to define what control a smart appliance should at least support.

1.4.2. Residential DR and the EU energy markets

The organisation of the energy markets has a strong impact on DR/DSM. More specifically, it has an influence on what DR business cases are possible, what the return of those business cases is, and how this return can be distributed over the various actors involved (the end consumer being one of these actors), and on the possible end consumer remuneration mechanisms.

However, there are significant variations in the setup of the energy markets of the member states. E.g.,:

- the ownership of the smart meter is not harmonised;
- the TSO ancillary service products and access to those services for DR sources is not harmonised;
- the support of variable tariffs and/or the tariff structures vary;
- the role, obligations and rights of DR aggregators is not harmonised;
- the rights and methods of DSO’s to interact with DR for the purpose of safeguarding distribution grids from this extra source of variability is not harmonised;
- the mechanisms to alter perimeter of BRPs with the effects of residential DR (settlement) vary or are not yet established.

The focus of this study is on smart appliances and their capability and potential to support an as wide as possible range of DR business cases and energy markets. **This study is not about market design, i.e. what market structure or business cases are to be preferred.** As such, above topics are not in scope of this preparatory study.

1.5. Interoperability Status

1.5.1. Principles

For the purpose of this report interoperability is understood as the link between the individual appliance and the supply side (BRP, aggregator, energy efficiency service provider, grid operator, etc.) via a home energy manager or internet/cloud systems and in some cases also the AMI (Advanced Metering Infrastructure), making it possible to achieve a better balancing of energy generation and energy consumption within the grid and/or to avoid grid congestion.

In the context of the smart home and smart appliances cross-platform, interoperability is an essential requirement to guarantee flexibility and security of possible investment for the customer. An end-customer, who is faced with the choice in case of a smart home set-up, is initially motivated by its intended application goals, such as increasing the living comfort or the saving of energy. When comparing the available technical solutions, the extensibility and upgradability of the system, the compatibility with other systems (of different manufactures and brands), the long-term availability of spare parts and operation security are important criteria, which influence this decision.

Interoperability amongst smart appliances – including those of various manufacturers – must be ensured. The smart appliance should be interoperable and communicate with/to other elements in the home such as the central energy manager, information display and smart phone.

In addition, it will be in the interest of the consumers that the operation of the system is manageable even without expert knowledge, ideally in the sense of a "plug and play"-solution, and this via an intuitively usable, integrated user interface. These system objectives require that the subsystems involved are syntactically and semantically interoperable, so the data is correctly exchanged, information and commands understood and correctly interpreted. The interchangeability of the subsystems requires the use of a technology neutral and standardised language, which is implemented through the relevant communication protocols.

In this section we assess the interoperability issues and gaps while in the next chapter we consider ways of reducing the gaps. We focus on the first link, i.e. from - and inside - the appliance itself to the first component of the DR control infrastructure.

Figure 5 details the data transfers between the appliance, the communication architecture (home energy gateway or cloud service provider), the energy service provider and possibly the aggregator. The 2 upper parts of the illustration show the 2 basic communication models, the Home Energy Gateway model and the Cloud model, respectively. The bottom part of the illustration explains the 3 layers.

The information layer contains the same information content from the aggregator to the appliance. The communication layer contains the specific protocols transmitting the information. Each protocol has its own encoding of the information content. The component layer contains the hardware component varying for each part of the communication system.

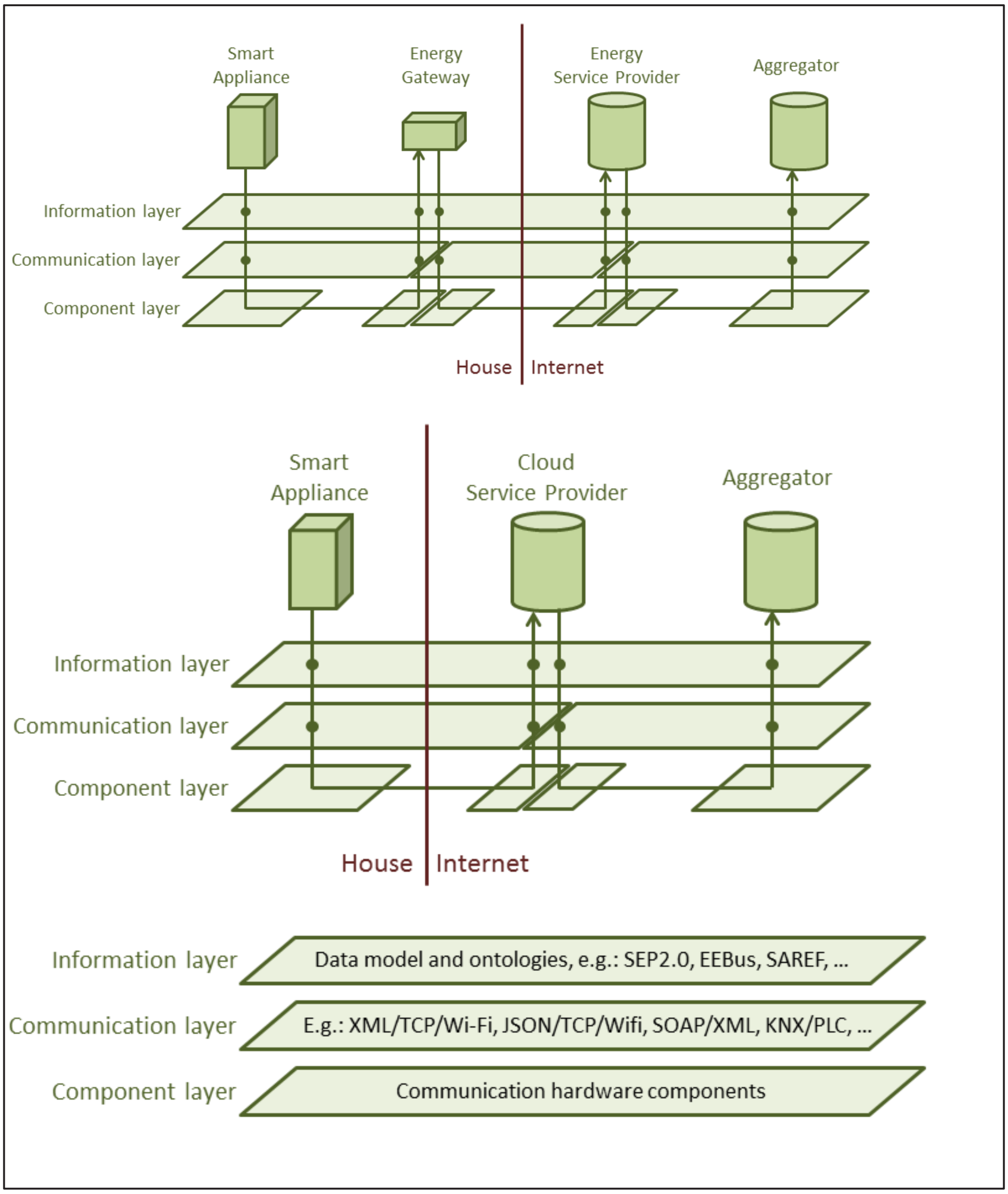

Figure 5: Data transfers between the appliance and the power system

Examples of information content include:

- unique identification of the appliance, which again is related to the consumer;
- control signals from the aggregator to the appliance. E.g., stop now, stop within xx [time period], do not start, reduce load to xx percent, stop if [condition], use own storage etc.;
- information signals from the aggregator to the appliance. E.g., price information;
- control/status related signals from the appliance to the aggregator. E.g., consumption information, state of the product, time to finish a cycle, expected response to DR requests or price signals, etc.;
- information signals from the appliance to the aggregator. E.g., data related to information required to reduce energy consumption or increase appliance energy efficiency, and intended to other purpose, e.g. safety / comfort / maintenance functionalities.

1.5.2. COMMUNICATION ARCHITECTURES

For the purpose of the study, an architecture is defined as the control and communication connection from the communication enabled appliance with demand side flexibility to a hub in the smart grid such as a central building management system, Home Energy Gateway, an aggregator or BRP / DSO (Distribution System Operators) / TSO (Transmission System Operators). The communication submitted could be price signals that the appliances react on and control signals for direct control of the appliances.

In this section we are not assessing the appliance-based system frequency control because it is based on internal measurements and control and does not need have a more extended communication architecture.

There are a large number of initiatives investigating smart grid architectures. Most of the architecture activities have a broader scope than the scope for this study, i.e., demand side flexibility. From the point of view of the appliance, there are two ways for appliances to interact with the energy system:

- The central energy manager model: The application communicates locally to a central energy manager (the Home Energy Gateway, or Building Control Unit[30]). In this case, the interoperability gap is situated at the level of the communication interface between appliance and central energy manager. Note that the smart meter could also take up this role, provided it supports sufficiently timely and reliable backend communications, which is often not yet the case for the current installed base. Also, adapted regulation would be required in many member states.

- The cloud model: The appliance connects directly to an appliance manager in the cloud, often through the internet via a wireless modem or similar. This appliance manager then communicates in turn with the energy service provider. If the appliance manager is the manufacturer, then the interoperability problem is located on the level of the interface made available at the manufacturer’s backend to allow the energy service provider to control the appliance.

[30] A special example of this are Building Automation and Control Systems (BACS), which already today are used in larger/non-residential buildings to control and optimize the energy consumption of the building. Contrary to typical residential appliances, the communication and control functionality required for DR is already largely available. BACS can support DR through its control of the HVAC, heating, etc. systems in the building, while at the same time optimize the energy efficiency of the building as a whole.

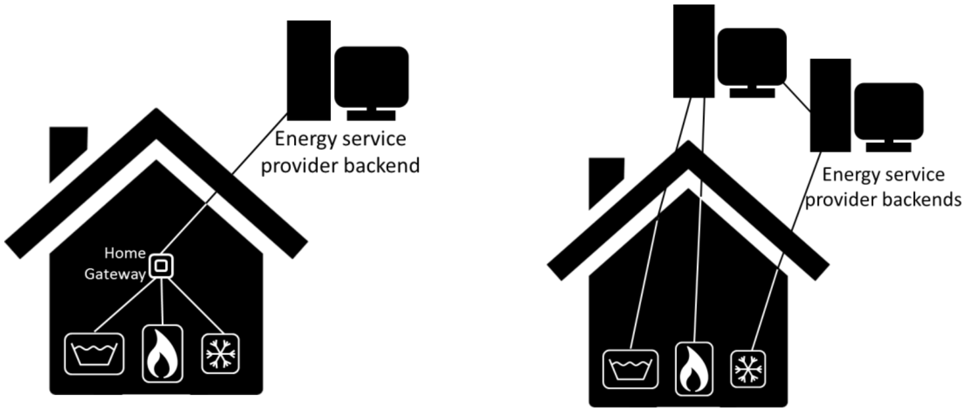

Figure 6: The two communication architectures: left the central energy manager model, right the cloud model.

Both models each have their pros and cons. The gateway model requires the installation of extra hardware. However, the cloud model requires that each smart appliance (and measurement component) guarantees all on-board functionality to establish a stable and secure extra-house communication link (authentication, encryption, handling dynamic IP addresses, handling firewalls, etc.). The gateway model implies interoperable interfaces on the devices, whereas the cloud model shifts this interoperability problem up to the level of the communication between the servers.

An important reason why the cloud model emerged, is that appliance manufacturers are no longer dependent on a gateway provider to integrate their device and that it allows them to provide device specific functionality.

This preparatory study focusses on the smart appliance and its demand side flexibility. What control architecture is more or less suited is out of scope of the study and is best left to the market to decide. However, from the point of view of the smart appliance, the principle is honoured that a as wide as possible range of control architectures should be supported. This includes, but is not limited to:

- **both the cloud model or central energy model;**
- **the option that the central manager could be a BACS that controls the smart appliances, both for DR and energy efficiency;**
- **the option that the central manager could be the smart meter.**

We describe in the following a selection of the most relevant architecture activities.

<u>Common ontology for M2M</u>

The European Commission/DG Connect is collaborating with ETSI (European Telecommunications Standards Institute) on developing an ETSI M2M (Machine to Machine) architecture. A dedicated Technical Committee will develop standards for “Machine to Machine” Communications, ETSI M2M. The group will provide an end-to-end view of Machine to Machine standardisation. More information on this initiative can be found in section 1.5.3.

Besides this initiative, DG Connect has also launched a study carried out by TNO (the Netherlands) "Available semantics assets for the interoperability of smart appliances. Mapping into a common ontology as a M2M application layer semantics". The study aims to provide the material needed to define the semantic tools and unified data models for specific devices to be used in the ETSI M2M architecture. The tools and data models can subsequently be applied by the industry to produce ETSI M2M compliant devices, or interoperability boxes to make existing, non-ETSI-M2M devices interoperable with an ETSI M2M system, while ensuring the fulfilment of user's expectations in terms of performances. The tasks consist of taking stock of existing semantic assets and use case assets, performing a translation exercise of each model or use case to a common ontology language (called SAREF, Smart Appliances REFerence) and subsequently a mapping between these models and finally to propose a common ontology and document it into ETSI SmartM2M/oneM2M architecture. As a common ontology language, SAREF can be adapted for multiple standards and protocols to facilitate interoperability.

The architecture defines various classes being e.g. building objects (door, window), devices (door switch, energy meter, sensor etc.), function (level control function, start stop function etc.), time (day of week) etc.

The ontology specifies recurring core concepts in the smart appliances domain as given by the assets, the main relationships between these concepts, and axioms to constrain the usage of these concepts and relationships. SAREF is based on the fundamental principles of reuse and alignment of concepts and relationships that are defined in existing assets, modularity to allow separation and recombination of different parts of the ontology depending on specific needs, extensibility to allow further growth of the ontology, and maintainability to facilitate the process of identifying and correcting defects, accommodate new requirements, and cope with changes in (parts of) the SAREF ontology. The project has found that there is a good correlation between the ETSI M2M Architecture and SAREF's function-related device categories.

This ontology work is broader than the scope of this study being appliances comprised by the ecodesign and energy labelling regulation, while the ontology also includes sensors, actuators etc.

The final report of the study can be found at https://sites.google.com/site/smartappliancesproject/deliverables.

A first version of Smart Appliances Reference ontology can be accessed here: http://ontology.tno.nl/saref/.

Common language for smart home

AGORA, Energy@Home and EEBus has recently agreed (published November 2014) to establish a common language for the European Smart Home. The organisations have developed a list of key functionalities based on agreed use-case scenarios serving as a common base. They have agreed in the context of cooperation to provide extensible functionality in order to adapt the system to future technical developments. These key functions were initially focused on energy management, and to add more specific functionalities of smart homes.

According to the initiatives interoperability will be ensured through an open and standard communication protocol that is technology neutral.

Their goal is to reach a simple plug and play solution, which enables consumers across Europe to connect their devices.

Communication architecture gaps

A main interoperability gap is lack of one data model and communication architecture standard applicable in all Member States for the appliances in scope of this study. The standards should be able to work on top of the various possible hardware carriers, and should carry commonly defined status and command data, such that all possible use cases are supported, e.g. variable tariffs, balancing reserves, grid support, etc.

Many initiatives have been launched within this area with the purpose to define one common data model and reference communication architecture.

1.5.1. COMMUNICATION CARRIERS

The communication carriers from the end-user (home, office etc.) are mainly the internet. The connection can be through broadband (ADSL (Asymmetric Digital Subscriber Line), VDSL (Very-high-bitrate Digital Subscriber Line), DOCSIS (Data Over Cable Service Interface Specification]etc.), GSM (Global System for Mobile Communications), UMTS (Universal Mobile Telecommunications System), LTE (3GPP Long Term Evolution (4G)) etc.

The level of internet access in households in EU28 in 2014 is in average 81%[31]. The range is from 57 % (Bulgaria) to 96 % (Luxembourg and the Netherlands). There are thus Member States where lack of internet access might be a barrier towards full use of the DR enabled appliances.

Within the end-users' premises, the communication carriers are more diversified. The communication between smart appliance and Energy or Internet gateway (in the case of the cloud model), include wired Ethernet, WiFi, Bluetooth, Zigbee, Z-Wave etc. Which carrier is reliable or not depends on the layout of the home, the building style, the location of the smart appliances and energy/internet gateway and the energy consumption. There are already a broad range of products using the above mentioned communication carriers.

Wide adaptation of smart appliances requires that the user (or installer) should be able to use the most/a reliable carrier, based on the criteria mentioned before. Moreover, the communication carriers should support the communication signals transferred.

However, lack of internet access should not be a main gap and further development to support the communication signals should neither be a gap once the common communication architectures have been developed.

1.5.2. SMART METERS

Smart meters are being rolled out in many EU Member States, however, in different speeds and with different functionalities. Smart meters are assumed to continue to be important for the main metering and payment of the energy delivered, and can support the transmission of DR relevant information like for instance consumption/generation limits between the demand and supply side. However, they are not always equipped with the full set of necessary functionalities to play the role of central energy manager, i.e., as live two-ways connection between the supply side and the demand side.

[31] Eurostat figures on "Level of internet access – households"

Smart meters are included in the study specifically and only with respect to their energy consumption as part of the overall communication infrastructure.

1.5.3. STANDARDS (EU, MEMBER STATE AND THIRD COUNTRY LEVEL)

This section presents standards related to smart appliances. The scope of standardisation in the field of smart appliances is strongly related to information exchange for DR and for connecting demand-side consumer equipment and/or systems into the smart grid.

→ **Introduction**

In the context of the smart home and smart appliances cross-platform interoperability is an essential requirement to guarantee flexibility and security of investment for the customer. An end-customer, who is faced with the choice in case of a smart home set up, is initially motivated by its intended application goals, such as increasing the living comfort or the saving of energy. When comparing the available technical solutions, the extensibility of the system, the compatibility with other systems (of different manufactures and brands), the long-term availability of spare parts and operation security are important criteria, which influence this decision. In addition, it will be in the interest of the consumers that the operation of the system is manageable even without expert knowledge, ideally in the sense of a "plug and play"-solution, and this via an intuitively usable, integrated user interface. These system objectives require that the subsystems involved are syntactically and semantically interoperable, so the data is correctly exchanged, information and commands understood and correctly interpreted. The interchangeability of the subsystems requires the use of a technology neutral and standardised language.

In this context standardisation (CEN-CENELEC-ETSI) is proposing an architecture (Figure 7) where a Customer (Energy) Management function[32] processes and acts upon (DR related) information from the smart grid, smart meter information and information from one or more smart appliances. To handle different communication languages and different information models, all specific information models are translated into a common and neutral information model accessible via an neutral interface.

[32] Note that this CEMS function doesn't necessary need to be located at the customers' premises. It could be part of a backend or cloud system (as many commercial products are heading this way). However, keeping requirements upon data privacy in mind, locating this function at the customers' premises could be a recommendation made in the context of privacy by design. It can also be located in the smart appliance when it is managing just one appliance.

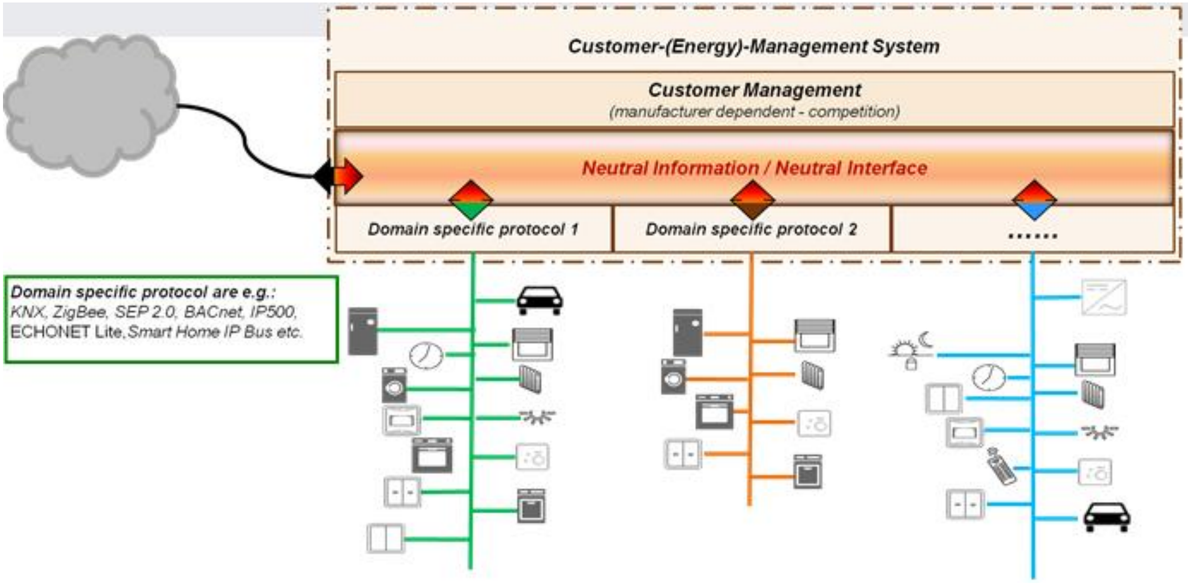

Figure 7: Neutral interface concept[33]

This means that for each domain-specific protocol a translator function (to the neutral information model) has to be implemented. To limit the number of domain specific protocol translators in the gateway manufacturers of smart appliances could integrate this translation step into the smart device (Figure 8).

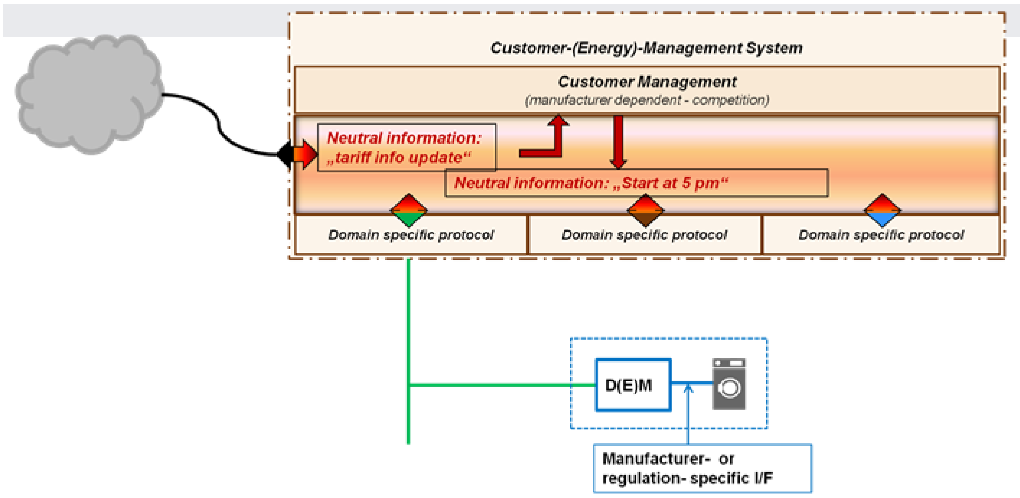

Figure 8: Device with Energy Management function[33]

In this approach all interface signals, functions and mappings are specified in open standards and thus available for all. On the basis of these standards manufacturers can realise their own standards-compliant software platforms.

[33] Josef Baumeister, IEC & CLC Smart Home Standardization – status September 2014

→ Status of Standardisation (EU)

In this section the current most relevant standardisation activities related to smart appliances are described, focusing on activities at EU level (and interaction with international level). Using the flexibility functional architecture as a starting point the standardisation activities related, the CEM - smart meter interface and the Smart Grid - CEM - smart appliance interface are briefly explained.

→ Flexibility functional architecture

On 1 March 2011 the European Commission issued Mandate 490 - Standardisation Mandate[34] to European Standardisation Organisations (ESOs) to support European Smart Grid deployment. To accomplish this task, CEN-CENELEC-ETSI established the Smart Grid Coordination Group (SG-CG), now succeeded by the Smart Energy Grid Coordination Group (SEG-CG) to coordinate standardisation activities in Smart Energy (e.g. electricity, heat, gas) Grid(s). SEG-CG includes interactions between energy systems and interaction with end-users.

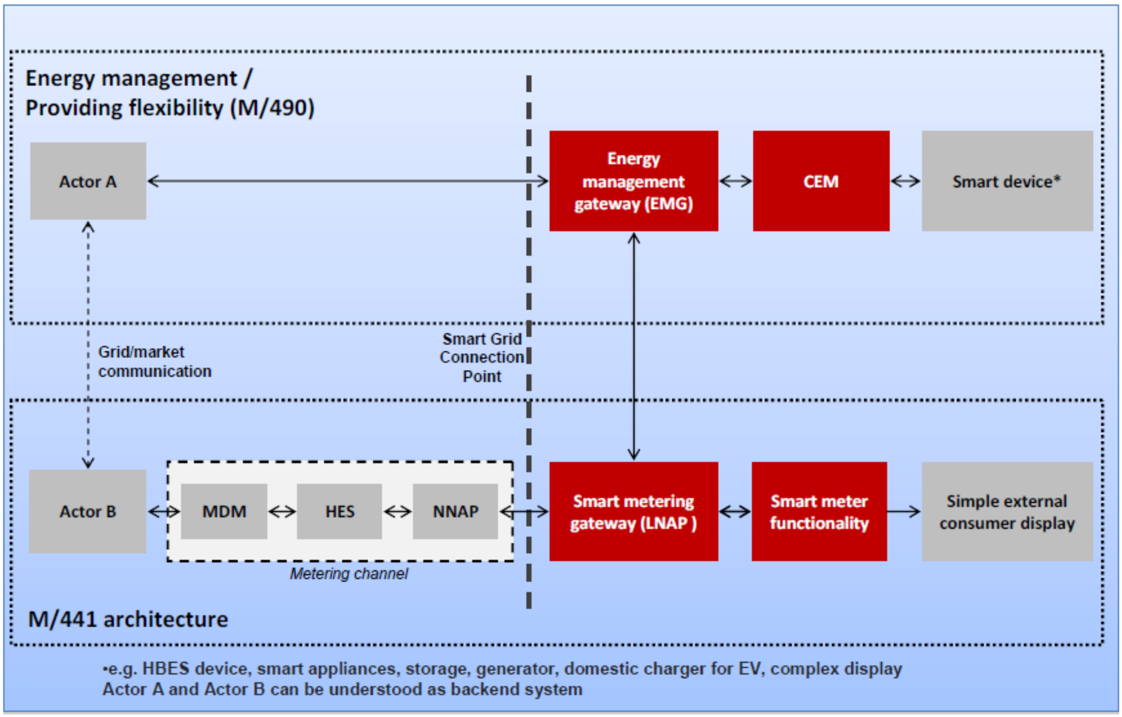

Figure 9: Flexibility functional architecture[35]

The flexibility functional architecture model in Figure 9 has been developed by the SG-CG. In this architecture the Customer Energy Manager (CEM) provides the flexibility of connected smart devices, through the energy management gateway, while the smart meter and the simple external consumer display provide a number of functionalities that are described more detailed in work of the Smart Meters Coordination Group (SM-CG). The energy management gateway communicates with the metering channel and the smart metering through the Smart Metering Gateway. The gateways in this architecture split different networks (Wide Area Network, Neighbourhood Area Network and Local Area Network) and may be integrated with other functional entities. The actors

[34] http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2011_03_01_mandate_m490_en.pdf
[35] ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Methodology_FlexibilityManagement.pdf

in this architecture are functional / logical entities, which means that some of them may be part of the same physical device.

Note that the communication path between the smart metering gateway and energy management gateway is optional (as are all communication pathways in this architecture). In the aforementioned case, the information exchange between the metering channel and energy management channel will take place between Actor A and Actor B. The external actors A and B, identified in this functional architecture represent (a bundle of) roles that communicate through the Smart Grid Connection Point. Examples of these roles are a meter data collector, meter operator, aggregator/flexibility operator, supplier etc.

→ **Smart meter interface**

The following Figure gives an overview of the standardisation activities related to the smart meter interface, mapped onto the flexibility functional architecture.

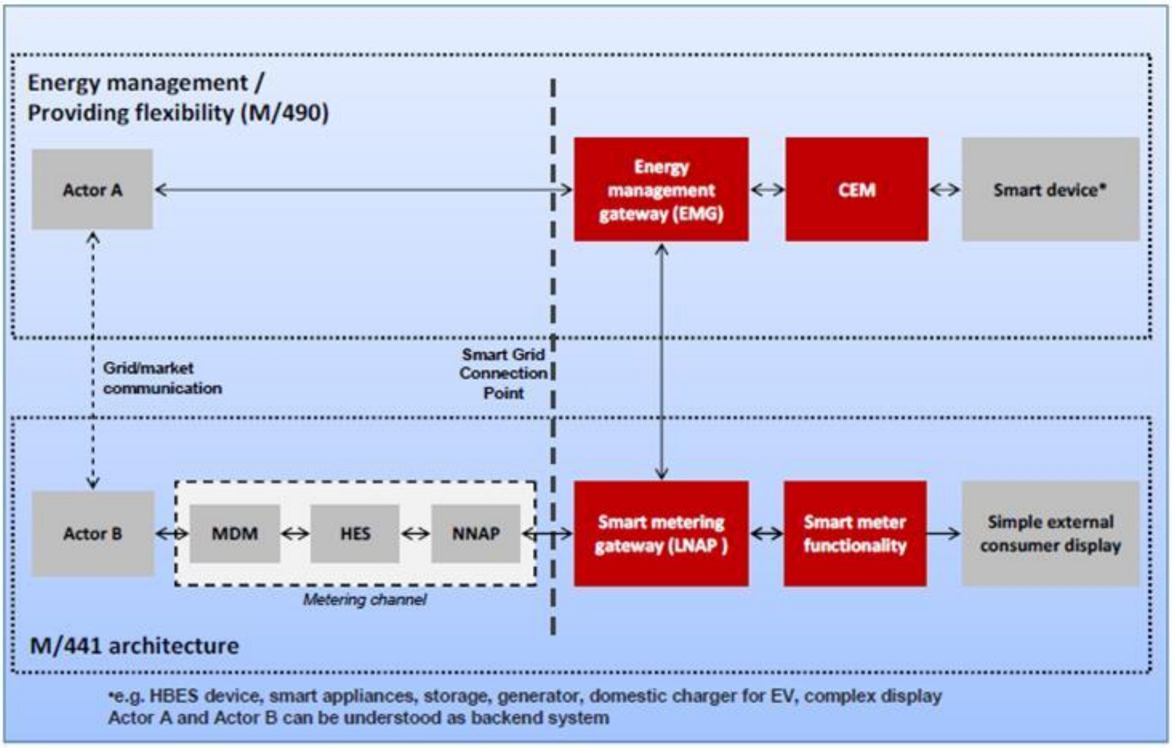

Figure 10: Standardisation activities mapped onto flexibility functional architecture[36]

The interfaces in this architecture **(**Figure 10) relevant for the interaction between the metering end device and end consumer devices are:

- interface H1 for a local connection to a simple external consumer display.
- Interfaces H2 and H3 for interaction with home automation end devices (including more advanced displays). These interfaces support the provision of energy efficiency and demand-side management services.

[36] ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/Reference_Architecture_final.pdf

Within the SG-CG, a dedicated Task Force looked at the 'possible need for further standardisation work order to include in the AMI an open interface to provide energy management services beyond the utilities, focusing on consumers' needs'. In this context, the Task Force performed a technical analysis which focused on the following aspects:

- interfaces 'H2' and 'H3' and the blocks 'EMG', 'CEM', 'LNAP', and 'Smart meter functionality'
- consider functionalities (a) and (b) of the Recommendation 2012/148/EU, and investigate how these are involved in the flexibility architecture.

These aspects are currently covered by the activities of IEC/TC 13 'Electrical energy measurement and control', CEN/TC294 'Communication systems for meters and remote reading of meters', CLC/TC 205 'Home and Building Electronic Systems (HBES)' and IEC/TC 57 'Power systems management and associated information exchange'.
According to the Task Force, there is no need for additional standardisation initiatives (e.g. further standardisation mandate) in order to include in the AMI an open interface to provide energy management services beyond the utilities, focusing on consumers' needs (further development is happening in the work of IEC/TC 57 WG 21).

a. IEC/CLC/TC 13 "Electrical energy measurement and control" WG14 (Electricity Metering data exchange)
Working Group 14 of IEC/TC 13 has developed the standards for the exchange of information through the AMI from the Head End System (HES) to the meter: IEC 62056 series. In the first place, these standards are able to transfer consumption information that is registered in the electricity meter. Additional information related to DR that can be transferred concerns for example tariff information, power limitation, connect/disconnect and prepayment settings. Standards developed by IEC/TC 13 are voted in parallel at European level (CLC/TC 13). Working Group 14 has recently developed a new international standard for the (uni-directional) provision of metering data from a meter to an external device, such as an In Home Display: IEC 62056-7-5. This relates to the H1/H2 interface. The status of this standard is currently CDV (Committee Draft for Vote), which implies it should normally be available in 2015.

b. CEN/TC 294 "Communication systems for meters and remote reading of meters"
The work performed in this TC is similar to the work in IEC/CLC/TC 13, but is focussed on the exchange of information to non-electricity (Gas/Water/Heat and beyond) meters and other supporting equipment: EN 13757 series. Standards related to consumption and DR related information transfer are available or under finalisation.

c. CLC/TC 205 Home and Building Electronic Systems WG 18 (Smart Grids) and WG 16 (Display)
CLC/TC 205 current work is centred on two aspects for home & building electronic systems: firstly home displays and the H1 interface in the smart meter reference architecture (prEN 50491-11) and secondly the interface and framework for customers (prEN 50491-12), which concerns the H2/H3 interface. The work of TC 205 envisages the need for sufficiently frequent information updates for the customer depending on the demand . It also anticipates advanced tariff structures, time-of-use registers and remote tariff control, with automatic transfer of information about advanced tariff options to final customers via the interfaces H2/H3. The standards developed by TC205 concerns the definition of data models that can be used on top of the communication profiles identified by IEC/TC 13 and CEN/TC 294. IEC TC13 requested that the data models proposed by CLC/TC 205 are linked to the existing data models of the IEC 62056 series.

The status of the work is as follows:

- prEN 50491-11 is the responsibility of TC 205 WG16. This work item has been completed and the standard EN 50491-11:2015 is published in June 2015.
- prEN 50491-12 is the responsibility of TC 205 WG 18. It is focused on data modelling and is expected to be available mid-2015, beginning of 2016.

→ Smart grid – smart appliance interface

The following Figure provides a situational overview of some relevant standardisation documents related to Smart Appliances and Smart Home interoperability[37]:

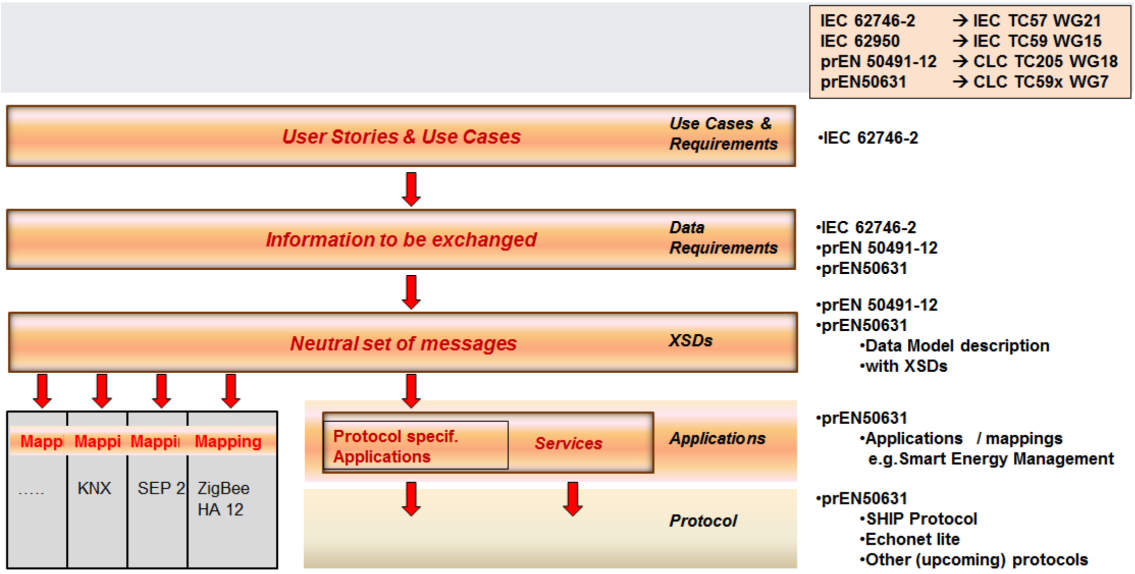

Figure 11: Selection of relevant documents related to Smart Appliances & Smart Home interoperability

a. IEC/TC 57 WG21 "Interfaces and protocol profiles relevant to systems connected to the electrical grid"

IEC/TC 57 addresses the market aspect as well as the grid operation. WG21 of IEC/TC 57 is focusing on the functionalities (Use Cases) and data definitions for DR in its Technical Report IEC TR 62746. These functionalities and data definitions are used by CLC/TC 205 to have a reference for the data and transactions to be supported.

A joint working group of IEC/TC 57 WG21, CLC/TC 205 and CLC/TC 59X has been collecting Use Cases and requirements for Smart Grid/Smart Home. The Use Cases cover for example: providing energy consumption information, controlling smart appliances, EV charging, power limitation, consumer offering flexibility, manage DER, battery management, etc. These Use Cases and requirements are listed in IEC TR 62746-2. The architecture document IEC 62746-3 is currently distributed as Committee Draft to the national committees.

In order to solve the interoperability issue, TC 57 and PC 118 'smart grid user interface' have agreed to continue the development of IEC 62746 towards a CIM-compatible DR standard, by first defining an openADR <-> CIM adaptor, followed by a purely CIM-based version of OpenADR. WG21

[37] Communication from Josef Baumeister, IEC & CLC Smart Home Standardization

is managing the connections with WG16 (energy market information exchange), WG 15 (Cyber Security) and WG17 (DER) of IEC/TC 57. In parallel with the work on functionalities, new work will commence to consider the technologies that should be supported to transfer the data.

b. IEC/TC59 "Performance of household and similar electrical appliances" WG15 "Connection of household appliances to smart grids and appliances interaction"

IEC/TC 59 WG15 is establishing a set of common terms, concepts and criteria, to assist the TC 59 and its Subcommittees in addressing the technical aspects of interaction between household appliances and the smart grid.

IEC/TS 62950 'Household and similar electrical appliances - Specifying and testing smart capabilities of smart appliances - General aspects' (work version) is intended to develop the common architecture which applies widely to different use cases and appliance types, and the principles of measuring smart performance within the context of the common architecture. The use cases considered initially (see previous paragraph) are based on the energy/electricity aspects pf performance, but future revision of this Technical Specification may not be limited to these aspects.

c. CLC/TC59x "Performance of household and similar electrical appliances" WG7 "Smart household appliances"

CLC/TC59x WG7 performs standardisation work to enable domestic appliances to improve functionality through the use of network communication. Examples of network communication include smart grid, smart home and home network. The working group is working on prEN 50631 "Home network and smart grid connectivity ", a first readable draft version is expected soon.

d. ETSI M2M

The European Telecommunications Standards Institute (ETSI) has created a dedicated Technical Committee with the mission to develop standards for "Machine to Machine" Communications, ETSI M2M[38]. The group will provide an end-to-end view of Machine to Machine standardisation. Besides standards at the architecture level, ETSI also works on test specifications to demonstrate end-to-end interoperability.

In ETSI, smart appliances standards are being handled by the **SmartM2M technical committee** and by the **oneM2M** partnership project. In 2013, much of the work of ETSI's M2M committee, including the development of the core M2M specifications, was transferred to the new oneM2M Partnership Project. The committee's new focus is now services and applications, especially aspects of the Internet-of-Things and smart cities, and it has adopted a new name, the Smart Machine-to-Machine Communications Technical Committee (TC SmartM2M), to reflect this new work. TC SmartM2M will also support relevant European policy and regulatory requirements, and handle the conversion of oneM2M specifications into European Standards.

In 2013 collaboration was initiated with the EC specifically related to the interface between service and application layers. ETSI began work on smart appliances – products such as white goods, heating, ventilation and air conditioning (HVAC) systems, storage systems and micro renewables, which are able to communicate with facility management systems, energy management systems, so-called 'Energy Boxes' and other systems using a common language and semantic. In November 2013, TC SmartM2M began to plan its activities for 2014 to support the creation of a standard for smart appliance communication. The plan was expected to include a common data model (see also next chapter on the common ontology for M2M) and identification of a communication

[38] http://www.etsi.org/technologies-clusters/technologies/m2m

architecture and the related protocols. A clear roadmap and milestones were introduced by TC SmartM2M and the first ETSI specifications are planned to be published during 2015.

The planned specifications regarding smart appliances are:

- **TS 103 264** "SmartM2M Smart Appliances Common Ontology and SmartM2M/oneM2M mapping";
- **TS 103 267** "SmartM2M Smart Appliances Application of ETSI M2M Communication Framework";
- **TS 103 268** "Conformance testing".

TS 103 264 has two major objectives:

- To provide a standardised framework for the common ontology derived from the EC Study Group on Smart Appliances[39];
- To map the common ontology onto the elementary ETSI M2M and possibly oneM2M standardised resources and services.

TS 103 267 defines a framework for Smart Appliances communication based on ETSI M2M and (potentially) oneM2M specifications. It will also provide the proper configuration support and adjustments as required by the interested stakeholders.
This TS includes:

- a general description of the ETSI M2M/oneM2M framework;
- the specification of the interworking framework for Smart Appliances with normative reference to ETSI M2M and oneM2M specifications;
- the specification of all the required configurations and settings to assure a full interworking with plug and play support for Smart Appliances.

In this context the study "Available semantics assets for the interoperability of smart appliances. Mapping into a common ontology as a M2M application layer semantics"[39] aims to provide the material needed to define the semantic tools and unified data models for specific devices to be used in the ETSI M2M architecture. The tools and data models can subsequently be applied by the industry to produce ETSI M2M compliant devices, or interoperability boxes to make existing, non-ETSI-M2M devices interwork with an ETSI M2M system. Ideally, the achieved interoperability would comply with the highest levels as defined by e.g. CENELEC[40], but it all depends on the dimension of the protocol interfaces, and how well the implemented data models translate into the unified ones.

e. ISO/IEC JTC 1/SC 25/WG 1 - HES

JTC stands for the Joint Technical Committee of International Standardisation Organisation and International Electro-Technical Commission. The Home Electronic System (HES)[41] is a family of international standards for home systems under development by experts from Asia, Europe, and North America. The experts are organised into a formal Working Group1 that writes the standards and submits them for approval by the member nations.
A primary goal of HES is to specify hardware and software that enable a manufacturer to offer one version of a product for connection to a variety of home automation networks. To accomplish this, the Working Group has published an architecture that specifies the following components for HES:

[39] http://www.etsi.org/images/files/Events/2014/201405_DGconnect_SmartM2MAppliances/Extended_Summary_Smart_Appliances_EU_study_2013-0077.pdf;
http://sites.google.com/site/smartappliancesproject
[40] CENELEC CWA50560:2010 IFRS (Interoperability Framework Requirement Specification)
[41] http://hes-standards.org/

- Universal Interface: An interface module to be incorporated into an appliance for communicating over a variety of home automation networks.
- HomeGate: A residential gateway to link home control networks with external service provider networks.
- Application Interoperability methods and models

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

→ **Standards USA**

NIST / ANSI

The National Institute of Standards and Technology (NIST) has been given "primary responsibility[42] to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability[43] of smart grid devices and systems." In response to the urgent need to establish interoperability standards and protocols for the smart grid, NIST developed a three-phase plan:

1) To accelerate the identification and consensus on smart grid standards
2) To establish a robust Smart Grid Interoperability Panel (SGIP) that sustains the development of the many additional standards that will be needed
3) To create a conformity testing and certification infrastructure

As information technologies expand on the electric grid (and to other cyberphysical systems, such as those dealing with natural gas and water), cybersecurity becomes a critical priority. NIST plays a central role in working with industry to develop appropriate guidance for protecting these systems from cyber attacks.

The progress made up till 2014 is documented in the "NIST Framework and Roadmap for Smart Grid Interoperability Standards", release 1[44] (2010), release 2[45] (2012) and release 3[46] (draft, 2014).

In 2009 the Smart Grid Interoperability Panel (SGIP) was established for the further development of consensus-based smart grid interoperability standards. In 2013, the SGIP transitioned to an industry-led incorporated non-profit organisation, sometimes referred to as SGIP 2.0.
As of October 2013, SGIP 2.0 had over 200 members, and 56 standards accepted into the SGIP Catalog of Standards (CoS).

Similar to the work on the new item IEC 62746 "System interfaces and communication protocol profiles relevant for systems connected to the smart grid" by the working group IEC TC 57 WG21 SGIP started up a priority action plan (PAP) investigating three industrial initiatives: OpenADR 2.0, ZigBee Smart Energy Profile 2.0 and OASIS Energy Interoperation (EI 1.0).

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[42] "The Energy Independence and Security Act of 2007" (Public Law 110-140, or EISA)
[43] "Interoperability" refers to the capability of two or more networks, systems, devices, applications, or components to exchange and readily use information—securely, effectively, and with little or no inconvenience to the user.
[44] http://www.nist.gov/public_affairs/releases/upload/smartgrid_interoperability_final.pdf
[45] http://www.nist.gov/smartgrid/upload/NIST_Framework_Release_2-0_corr.pdf
[46] http://www.nist.gov/smartgrid/upload/Draft-NIST-SG-Framework-3.pdf

ASHRAE/NEMA SPC201P Facility Smart Grid Information Model (FSGIM)[47]

In US the National Electrical Manufacturers Association (NEMA) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have joined forces to develop an industry standard called Facility Smart Grid Information Model (FSGIM), an abstract, object-oriented information model for energy management purposes, providing a generic view on controllable devices.

ASHRAE is accredited by the American National Standards Institute (ANSI) and follows ANSI's requirements for due process and standards development. The standard, being developed by ASHRAE Standard Project Committee 201P (SPC 201P) is also part of the work programme of ISO/TC 205.

The purpose of this standard is to define a model to enable appliances and control systems in homes, buildings, and industrial facilities to manage electrical loads and generation sources in response to communication with a “smart” electrical grid and to communicate information about those electrical loads to utilities and other electrical service providers. It has been particularly drafted for DR purposes, and can be mapped to different Home Automation protocols. Object models from various standards have been reused (CIM, Energy Interop, IEC 61850, etc.). The FSGIM, being a North American initiative, may be less relevant for Europe, but indirectly it may have an impact. The ASHRAE BACnet standard for instance, a building automation standard commonly used in Europe and connection point for DR, is an example of a target protocol standard that will make use of FSGIM.

→ **Standards Australia**

Australian/New Zealand national standard AS/NZS 4755 “DR capabilities and supporting technologies for electrical products” is a standard for communicating DR commands to residential appliances (airco, water heaters, pool pumps, EV, etc.). Communications end at DR Enabling Device (DRED) external to the appliance. The standard allows communication of basic commands such as turn on, shut off, reduce load, increase load. This standard is currently supported by several Air Conditioning manufacturers. Messages can be communicated across any network, including AMI.

The parts of AS/NZS 4755 published since 2007 cover the physical and electrical connections between the DRED and the following electrical products:

- AS/NZS 4755.1 : Part 1 - Framework for DR capabilities and requirements for DR enabling devices (DREDs)
- AS/NZS 4755.3.1 : Part 3.1 - Interaction of DR enabling devices and electrical products—Operational instructions and connections for airconditioners. This standard describes how manufacturers of air conditioners below 30 kW must adapt their units to enable their controls from the DRED (Communications end at DR Enabling Device). Units must be equipped with standardised connections enabling the activation of different operating modes described in the figure below: compressor off, 50 % of rated power input and 75 % of rated power input.
- AS/NZS 475 5.3.2: Part 3.2 - Interaction of DR enabling devices and electrical products - Operational instructions and connections for devices controlling swimming pool pump-units
- AS/NZS 4755.3.3: Part 3.3 - Interaction of DR enabling devices and electrical products - Operational instructions and connections for electric storage and electric-boosted storage water heaters

[47] https://osr.ashrae.org/Public%20Review%20Draft%20Standards%20Lib/ASHRAE%20201%20APR%20Draft.pdf

- AS/NZS 4755.3.4: Part 3.4 - Interaction of DR enabling devices and electrical products - Operational instructions and connections for grid connected charge/discharge controllers for electric vehicles
- AS/NZS 4755.3.4: Part 3.5 - Interaction of DR enabling devices and electrical products - Operational instructions and connections for grid-connected Electrical Energy Storage Systems

Standards for the DRED (AS/NZS 4755.1), for electric vehicle supply equipment intended for home use (4755.3.4) and stationary storage batteries (4755.3.5) are currently in preparation.

Australian governments[48] (Commonwealth, state and territory) are considering making compliance with the standard mandatory for all air conditioners, water heaters, pool pump controllers and electric vehicle supply equipment (EVSE) designed for residential use, from a date to be determined (probably January 2016). All of these appliances will therefore have to be sold with a built-in standardised interface, which will allow them to connect to a communications system and participate in DR schemes. The economic case for this policy initiative was published in early 2013 and the proposal is still being considered within the Government. Although it would be mandatory for all products sold to have an AS/NZS 4755 interface, it would not be compulsory for consumers to have it activated. It would be up to the electricity utilities to offer consumers DR contracts that are sufficiently attractive.

→ **Standards Japan**

Regarding smart grid standardisation, Japan is involved in following technical committees and workgroups:

- At International Level (IEC):
  - TC57 WG16, WG21
  - TC59 WG15
  - TC65 WG17
  - PC118

- Via the joint working group (JWG) in:
  - TC57 WG21,
  - CLC TC205 WG18
  - CLC TC59X WG7

- At regional level
  - The Japan Smart Community Alliance (JSCA)[49]
  - OpenADR

In case of DR there are some differences in the viewpoints of Japan and Europe:
- In Japan the focus is on “Grid Request power reduction” scenario whereas SG-CG definition (in SG-CG/M490/L Flexibility Management) of DR seems to be a “Customer Decide” scenario.
- The Japanese User Stories/Use Cases mainly focus on “Plan Based” scenario whereas SG-CG definition of DR seems to be “Near Real time Based” scenario.

[48] Australian government policy on demand responsive (‘smart’) appliances
[49] https://www.smart-japan.org/english/index.html

- The SG-CG scenarios (Customer Decide & near Real Time based) are intended for future advanced grids whereas Japanese User Stories/Use Cases (Grid Request & Plan based) are based upon conventional grids.

The recommendation made by Japan is that both viewpoints should be covered by the International Standards.

The **Japan Smart Community Alliance** (JSCA) (Figure 12) was established in April 2010 with the aim of resolving and overcoming the obstacles of individual organisations through collaboration of the public and private sectors. JSCA has a wide range of members from various private enterprises and organisations, including public service corporations, universities and local municipalities. In the context of smart home/smart appliances the JSCA Smart House and Building workgroup undertakes activities toward further dissemination of smart houses and smart buildings.

Figure 12: JSCA organisational structure

The ECHONET Consortium[50], formed in 1997 in Japan, promotes the development of software and hardware for home networks that can be used for remote control or monitoring of home appliances. The aim in doing so has been to reduce CO_2 emissions while responding to the increasing sophistication of home security and home healthcare.
The Consortium developed 2 sets of specifications as well as the basic technology for these ECHONET specifications. The original ECHONET specification focused on power line and radio frequency communication to provide a low-cost data transmission implementation without requiring additional wiring. The specification is published as ISO/IEC 14543-4-1 and ISO/IEC 14543-4-2. The consortium continued to developed the home network technologies on home appliances and home facility equipment, and published the “ECHONET Lite Specification” as an open standard interface on HEMS in 2011. Compared to ECHONET, is ECHONET Lite easier to use and able to work on top of other standard protocols. Echonet Lite is an upper layer (application layer) protocol to control home appliances. All smart meters in Japan for instance support ECHONET Lite over IP over the local meter interface. The ECHONET Lite Specification was approved as an international standard (ISO/IEC 14543-4-3), in 2013.

[50] http://www.echonet.gr.jp/english/index.htm

→ Standards China

China established a national SC (TC46/SC15) for smart household appliances and involved leading manufacturers in development.
Two standards on Smart Household Appliances have been published so far:

- GB/T 28219-2011 General rules of intelligentisation technology for intelligent household appliances
- QB/T 2836-2006 General requirements for networked home appliances

Ten national smart household appliances standards are in development and targeting for approval in 2015. Of these 10 national standards 7 are in NP stage:

- Smart household appliance service platform requirement
- Automatic identification and interoperation
- Making the smart household appliance intelligent: test method and evaluation criteria
- special requirement of smart air conditioner
- special requirement of smart refrigerator
- special requirement of smart washing machine
- special requirement of smart wine cabinet

The white paper “Smart Household Appliances White Paper” has been published in June 2014.
China is following a somehow different approach looking more on ‘intelligence’ than on DR.

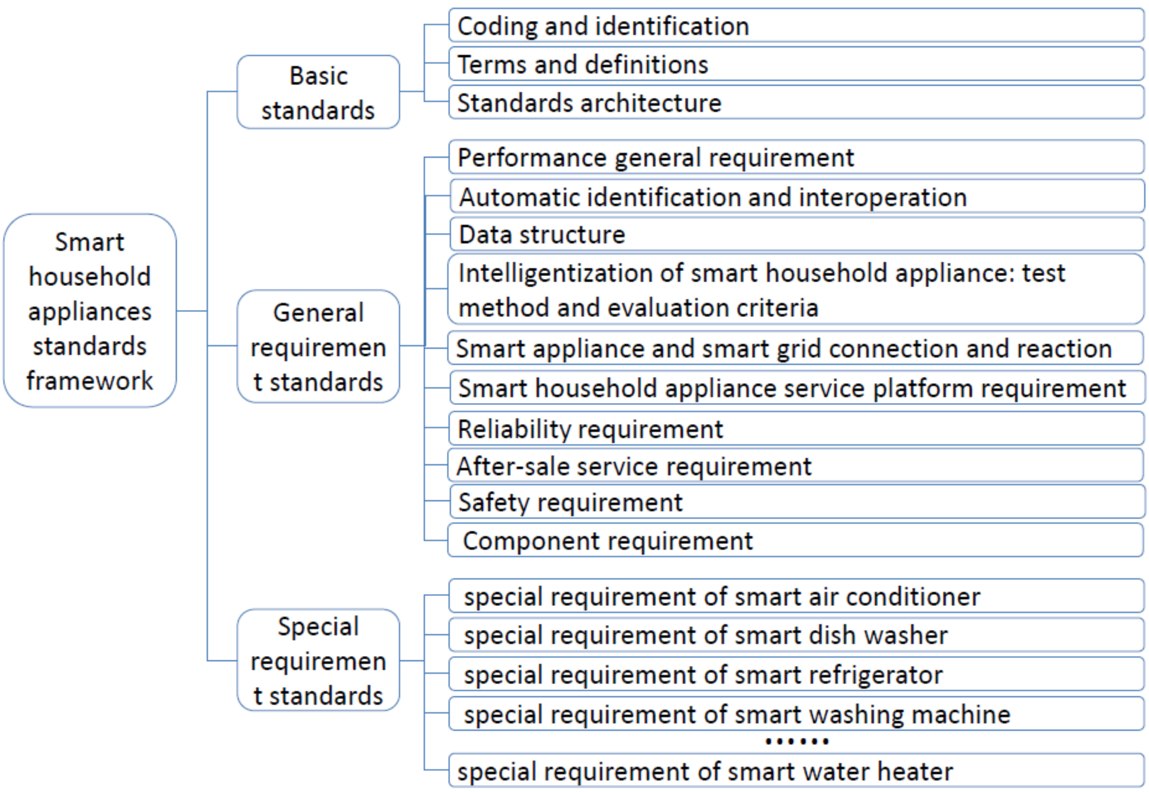

Figure 13: Standards Framework of China TC46/SC15

→ **Research & industry initiatives**

Considering the large number of initiatives by industry and research that can be noticed in the field of smart appliances, Internet Of Things (IoT), and DR this section will provide a condensed summary of this trend. A more elaborated version can be found in Annex 2.

The Internet of Things (IoT) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure. Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications. Smart appliances can be regarded as a subset of these machines, and in the context of this study the focus for these appliances will be on energy management and energy efficiency.

Dozens of consortiums, commercial alliances, and standards groups have been formed in the past few years to address the question of interoperability amongst these devices and systems.

As the AllSeen Alliance outlines, creating common standards for “interoperable products that can discover, connect, and interact directly with other nearby devices, systems, and services regardless of transport layer, device type, platform, operating system, or brand.” will have a tremendous impact on the growth, acceptance and functionality of the IoT. To accomplish this the global technology industry would have to agree on a universal set of technical standards. The important question here is whose standards, as this will give the initiator a head start and significant advantage.

Along the “interoperability” specifications these alliances produce, they generally offer a (open source) software reference framework, and sometimes also a certification process. The goal of these software frameworks is to provide solutions for service discovery, interoperability, security and device management, and to facilitate the work of developers. By doing so, these developers can concentrate on the creation of innovative services without having to be hindered by the complexity of interoperability and security.

In contrast to most alliances, some players try to enter the market by using their market dominance to enforce their ecosystems. In some cases these ecosystems are rather closed, and interested parties have to comply with rules set by the ecosystems’ owner.

Another trend to be noticed is the large amount of start-ups and innovation that is going in the IoT sector. A lot of IoT products like smart bulbs, smart locks, modules to make an appliance smart and so on are being developed. While most of them make use of standard communication technologies and protocols, the information layer used on top of these technologies is often unique and proprietary. In this aspect the lack of interoperability standards is hindering innovation.

To tackle interoperability at the lowest layer of the communication stack some players provide a multitude of communication technologies in their devices, while others provide an interface to different communication modules. Often an additional hub or gateway offered by the manufacturer of the IoT devices is needed to communicate with these devices.

A new trend (in research projects), we see at this level, is to make this layer more software defined. Instead of communication technology solutions being wired into the hardware the functionality is provided by firmware. This way the communication technology (MAC layer, modulation and so) can be remotely reconfigured or even upgraded to the newest technologies and standards. This is certainly important in the case of appliances with a medium to long lifetime like HVAC or even some whitegood appliances.

→ **Conclusions**

Several standards mentioned in this section are still “work in progress”. Initiatives (see annex) like EEBus, energy@home and Agora are evaluating these concepts and contributing to standardisation. Expected is that several of these standards will be released in the 2015/2016. The focus of this standardisation effort is currently on the energy domain, but in the near future this (energy) information model may be merged with other domain information models like Ambient Assisted Living or eHealth models.

This standardisation effort does not only address interoperability but also aspects like ICT security and safety. For instance, the requirements identified in current electrical end-product safety standards for household appliances are intended to address the anticipated risks associated with the product’s design or use. However, smart functions may cause potential new safety issues, which may make the smart appliance not comply with the safety requirements of the IEC 60335 series standards, managed by IEC TC61. To judge whether an appliance (both normal appliance and smart appliance) is safe or not, the IEC 60335 series shall be applied. For networked devices or appliances, EN50491 series apply.

At the same time several initiatives from the industry are going ahead. Some actors rely on their market dominance to ‘convince’ the smart appliance industry to be compliant with their ecosystem, while others like AllSeen and OIC tackle the issue in the IoT context by providing software frameworks addressing connectivity, device/service discovery, security and ease of use for developers.

In general, there is strong progress and convergence on the establishment of a common data model for demand side flexibility. This study will follow this progress closely and will support and encourage the initiatives were required or useful.

1.6. Scope summary

Only energy related products within the scope of the **Ecodesign and Energy Labelling Framework Directives** are in the scope of this study, as these Directives form the legal background for the study and policy measures potentially to be implemented after the study.

This study is not analyzing all communication-enabled appliances. For the purpose of this preparatory study, **a smart appliance is an appliance that supports Demand Side Flexibility**:

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

Whereby:

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

The following clarifications can be added to this definition:

- Manual start time delay is not considered smart control because it is not automated.
- Automatic actions to safeguard the technical safety of the appliance are not considered smart control.

The focus of this study is on '**end devices**', meaning the appliances that are being controlled and that alter their electricity consumption, as opposed to those devices that control other appliances or end devices. There will be no specification of who or what should activate the DR functionality. All control architectures should be supported.

Smart meters are included in the study specifically and only with respect to their energy consumption as part of the overall communication infrastructure.

The focus of this study is on the smart appliances and the potential flexibility generated, independent of how this flexibility is used in a specific energy market structure. A range of DR business cases and energy markets should be supported that is as wide as possible. This study is not about market design, i.e. what market structure or business cases are to be preferred.

The focus of this study is on the '**end-user**', i.e., residential consumers, because the challenges linked to smart appliances are most relevant for their use by residential consumers:

- residential consumers are not yet aware of demand response functionalities because this is a new market;
- residential consumers need more guidance for the use of digital technologies;
- the "Chicken and Egg Problem", as described in 1.1.2;
- households are more in need of an "any to-any " neutral solution across very different appliances in a household while interoperability problems can be more easily solved within a system approach and with a focus on certain appliances.

However, also commercial and industrial products can potentially benefit from the development of interoperability solutions and measurement standards. Provided that data are available, the following **commercial cases** are included in the scope of the study:

- Commercial refrigeration appliances;
- HVAC in the tertiary sector.

The **appliances in scope** of the study are sorted into 3 categories according to the flexibility potential (based on details in Annex 1):

- High flexibility potential with few comfort and/or performance impacts: dishwashers, washing machines, washer dryers, buffered water heaters, radiators, boilers, heat pumps, circulators, residential and non-residential air conditioners and battery storage systems;
- Smaller flexibility potential and/or larger comfort/health impacts: tumble dryers, refrigerators, freezers, extraction fans, heat recovery ventilation and air handlings units and chargers (low power);
- Only emergency flexibility potential: electrical hobs, ovens, hoods, vacuum cleaners and lighting.

Generally, it can be put that the higher the potential, the more the appliance will be studied in detail in the next Task reports.

An essential part of the study is the connection between the demand side and the supply side, more specifically, the data exchange with the smart appliance and the functions supported by the smart appliance, that implement changes in the electricity consumption. Due to this, the study includes topics regarding interoperability and demand response readiness. Similar appliances of different manufacturers should provide the same demand side flexibility functionality, or a subset of a commonly agreed upon set of functionalities, and should support interoperable communications, such that the demand control system does not need to differentiate between appliances of different brands. This will also maximise the guarantee for the end-consumers that the available DR systems support the appliance of choice.

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ANNEX 1 ANALYSIS PER APPLIANCE CATEGORY

HOUSEHOLD APPLIANCES

ELECTRICITY CONSUMPTION, MOST IMPORTANT PRODUCTS

Household appliances category contains the main appliances destined for private use: dishwashers, washing machines, tumble dryers, washer-dryers, refrigerators, freezers, water heaters, hobs, ovens, range hoods and vacuum cleaners.
In the following table, energy consumption data of the appliances in this category is shown to provide a first overview in view of DR potentials.

Table 1 : Total and household appliances electricity consumption in Europe (Bertoldi, 2012; Kemna, 2014)

	2010	2010
	TWh	**% total**
Electricity consumption EU27	2836	100%
Residential	842,5	ca. 30%
Dishwashers	25.3	0.9 %
Washing and drying	60.7	2.1 %
Refrigerators	82.0	2.9 %
Freezers	40.0	1.4 %
Water heaters	73.0	2.6 %
Hobs	40.1	1.4 %
Ovens	23.0	0.8 %
Range hoods	12.3	0.4 %
Vacuum cleaners	25.3	0.9 %

According to their main characteristics, all appliances mentioned above were divided into three categories: periodical appliances, permanent appliances and behavioural appliances.

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PERIODICAL APPLIANCES

DESCRIPTION

Periodical appliances are appliances that periodically execute a user initiated cycle, such as dishwashers, washing machines, tumble dryers (electric vented, electric condenser) and washer-dryers destined for private use. There is no interaction with the user while running and often the user does not require the programme to be finished as soon as possible.

INSTALLED BASE (EU27)

Dishwashers: in 2010, there were 82.799.000 appliances in stock. According to estimations, the number increases up to 98,345,000 in 2015, 115,036,000 in 2020, 131,797,000 in 2025 and 148,553,000 in 2030. (Kemna, 2014)
Washing machines: in 2010, there were 185,828,000 appliances in stock. According to estimations, the number increases up to 196,821,000 in 2015, 200,805,000 in 2020, 202,648,000 in 2025 and 204,744,000 in 2030. (Kemna, 2014)
Tumble dryers: in 2010, there were 62,723,000 appliances in stock. According to estimations, the number increases up to 68,018,000 in 2015, 71,801,000 in 2020, 75,767,000 in 2025 and 77,778,000 in 2030. (Kemna, 2014)
Washer-dryers: in 2012, sales of washer-dryers in the EU were above 700,000 units (about 4 % of the washing machine market) and the market is expected to grow. However, there is no information on installed base. (Kemna, 2014)

SHIFTING OR CAPACITY MODULATING POTENTIAL

SHIFTING OR CAPACITY MODULATING POSSIBILITY

There are three options to change the electricity consumption profile of periodical appliances:

1. For dishwashers, washing machines and washer-dryer, **start-time delay** or pre-select functions are already available on the market. This is the option for the user to manually shift the operation of the selected programme to a later moment in time. The power demand curve on activation of the appliance remains the same. Overall, 39 % of dishwashers and 32 % of washing machines are equipped with this option, but differently in various countries. The option allows anticipating or postponing power demand at any time. An average delay of 3 hours can be expected, the estimated maximum is about 19 hours for dishwashers and 9 hours for washing machines and tumble dryers. (Stamminger, 2008) Due to its manual nature, the start-time delay function is outside the scope of this study.
2. Second option is **remote activation**. The user configures a deadline in function of when the selected programmemust be finished at the latest. Based on DR control signals or power grid measurements and respecting the time window set by the user, the appliance is automatically activated at the optimal time. The power demand curve on activation of the appliance remains the same. Figures on the average length of the delay window vary from 3 hours (Stamminger, 2008) up to 8.5 h, 7.3 h and 8.1 h for dishwashers, washing machines and tumble dryers, respectively (Linear, 2014). One can assume that both user motivation and user remuneration has a large impact on the average delay window length. Pilots demonstrate a large user-

dependent spread on the length of the window, ranging from 1 h up to 9 h for dishwashers and washing machines (Stamminger, 2008) or 24 h (Linear, 2015). Although user questionnaires indicated that the user acceptance with regard to delaying tumble dryers may be low, and higher for washer-dryers (Stamminger, 2008), pilots showed that the share of 'smart' configurations for washing machines (29 %) and tumble dryers (31 %) is about equal. User acceptance for dishwashers is the highest: 56 % of smart configurations (Linear, 2014). Most smart configurations take place during the evening, most explicitly so for dishwashers. Hence most flexibility in terms of shiftable energy is during the night. There is a higher chance of day-time smart configurations in the weekends.

3. Third and most advanced option is to not only shift the execution of the program, but to also **alter the electricity consumption pattern** during programmeexecution, e.g., pause in between the different phases, interrupt the heating phase, use lower temperatures, etc. It is estimated that about 20 % of dishwashers, 10 % of washing machines and 30 % of tumble dryers may be operated in this mode. (Stamminger, 2008)

For appliances in this category, flexibility is typically situated in the afternoon and especially in the evening. The evening flexibility peak is most pronounced for the dishwashers. There is more flexibility in the weekends than in during weekdays.
For dishwashers and washing machines, there are almost no seasonal effects. However, tumble dryers are predominately used in winter season.

Shifting or capacity modulating potential per appliance

Data on energy shifting or power modulating potential per appliance are scarce. The following data are derived from a Swedish study on DSM-potential in Swedish households. In this study, the energy shifting potential of dishwasher in Sweden is expected to be between 0.6 - 1.7 GWh/day depending on the day of the week. For washing machines and tumble dryers, expectations are between 0 - 1.9 GWh/day and 0 - 1.3 GWh/day, respectively, depending on the day of the week and the season. By absolute numbers, the peak reduction in view of dishwashing and laundry is between 150 MW to 300 MW and remains the same all over the year. Expressed as a percentage, the peak load in Sweden could be reduced by 1.1 – 2.3 %. (Puranik, 2014)
Within the scope of the Smart A project, scenarios were simulated for various regions representative for different parts of Europe to estimate potential for load shifting. In all simulation scenarios, the average energy shifting potential of a washing machine in an average European household in 2015 amounts to about 24 Wh/ day per household. The potential of tumble dryers range from 40 to 125 Wh/ day per household depending on penetration rates and consumer's acceptance in the respective regions. For dishwashers, an energy shifting potential of 62 Wh/ day was estimated per household. For scenarios where the smart appliance react to locally measured grid parameters, such as the frequency, a 10 % shift (anticipating or postponing) of operation at any time is estimated. (Stamminger, 2008)
Within the Linear project, the flexibility offered by dishwashers, tumble dryers and washing machines was extrapolated to calculate the Belgian potential (4.6 million households). This indicated that around 00:00 in the weekend a maximum increase of 2 GW during 30 minutes can be realised in Belgium. During the week this maximum drops to 1.4 GW. In the forenoon and early evening during the week, the maximum increase drops to 800 MW. Flexibility showed asymmetric properties: more surplus power can be realised at a certain moment by activating waiting appliances than power can be reduced by shifting appliances away from where they would normally have run. The 4 hour evening peak can be reduced by 200 MW. (Linear, 2014)
Reducing or increasing the demand at a certain time creates rebound. The total energy consumption remains the same, even if it is shifted. Energy consumed extra or less at a certain point in time must

be compensated for at another time. In the case of short term interruptions, heat may be lost during the pause resulting in an additional energy consumption. (Stamminger, 2008; Linear, 2014)

TOTAL SHIFTING POTENTIAL OF APPLIANCE CATEGORY

For 2025, the following load shifting potentials can be calculated based on data from Smart A project (Stamminger, 2008): By assuming 202,648,000 washing machines in stock in 2025 and an average shifting potential of washing machines in an average European household of 24 Wh, the energy shifting potential of all washing machines in Europe is about 4.86 GWh. For tumble dryers, it is between 3.03 and 9.47 GWh and for dishwashers, it amounts to 8.17 GWh.

COMFORT AND USER IMPACT

Start-time delay: in the case of dishwashers and washing machines, there is almost no comfort or user impact. Users maintain the control whether or not to react to the incoming signal. In view of tumble dryers, the consumer's acceptance is expected to be low because it is likely that the drying process cannot start immediately after washing and wet clothes remain inside the machine. This was confirmed in the Linear pilot, where extra persuasion was required for the smart use of tumble dryers. This problem doesn't persist in case of washer dryers, if drying capacity fits washing capacity. (Stamminger, 2008; Linear, 2014)

Remote activation: The impact is the same as for start-time delay, except for concerns about safety (especially in periods of absence) and noise (during the night)**.** (Stamminger, 2008; Linear, 2014)

Altered consumption pattern: With regard to washing machines, stops of the machine and prolongation of washing and rinsing time can occur. Also damages of laundry, e.g. fading of colours, are possible. In the case of dishwashers and tumble dryers, short-term interruptions are hard to notice, almost no comfort or user impacts are expected. However, the tumble dryer should continue tumbling during interruptions exceeding 5 minutes to avoid textile damages. For all three appliances, interruptions during heating phases or phases at high temperatures may increase total energy consumption. (Stamminger, 2008)

GAPS AND/OR PRE-CONDITIONS FOR THE POTENTIAL TO BE REALISED

Start-time delay function is already available on the market and in almost 40 % of appliances in stock. By using this option, additional energy is needed in start-time delay mode (>0-1 W). The same additional energy consumption (> 0-1 W), occurs for other delayed start methods.

All gaps and interoperability issues as listed in the main text are valid: the smart appliance needs to be equipped with extra communication, measurement and/or control functionality, which depends on the communication and control architectures, the selected communication carrier, the communication standards, etc.

As operation may occur in periods of absence or during the night, safety of appliances should be increased (e.g. by measures slowing down or stopping fire spread inside the appliance, overheat protection, Aqua stop) and noise level decreased to address concerns of consumers.
Additional costs for consumers should be low to guarantee amortization within a reasonable period of time.

Functionalities supporting energy efficiency

As all three appliances in this category have options to operate at higher temperatures, they could be connected to hot water supply or use the heat produced by CHP, solar plants or district heating. Power consumption for appliance-internal electric-resistance heating can be reduced by 50 % (hot water supply) up to (in principle) 100 % (all other cases). (Stamminger, 2008)
A further possibility is to transfer heat from one process to another (e.g. by using tanks or phase change material), which results in a 50 % reduction in heating power. (Stamminger, 2008)
Information on the energy consumption of the appliances may help the user in selecting the most energy efficient program.

Conclusion

With regard to dishwashers, washing machines washer dryers and tumble dryers, three different levels of energy shifting or power modulating possibilities could be identified. The complexity of technical adjustments increases from the first to the third level. Appliances in this category offer a high flexibility in energy shifting operation.

Consumer's acceptance of shifted operation is high despite some concerns about safety during absence periods and noise during the night. In view of tumble dryers, the consumer's acceptance of shifted operation is expected to be lower because it is likely that the drying process cannot start immediately after washing and wet clothes remain inside the machine. Short-term interruptions (e.g. interruption or delay in heating phase) can be realised for all three appliances in this category. In this way, power demand curve of a single appliance can be changed, instead of merely shifted.

The total energy consumption of dishwashers, washing machines, washer dryers and tumble dryers is relatively small in comparison to other household appliances (e.g. refrigerators or water heaters), as the operation time and number of operation cycles is limited. However, the higher power during operation, the larger delay windows (higher flexibility) and the high market penetration in Europe, especially in the case of washing machines and dishwashers, results in a significant DR potential.

By taking into account all households in Europe, an energy shifting potential of washing machines of about 4.86 GWh was calculated. For tumble dryers, it is between 3.03 and 9.47 GWh and for dishwashers, it amounts to 8.17 GWh.

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ENERGY STORING APPLIANCES

DESCRIPTION

Energy storing appliances are appliances destined for private use that provide a capacity to store energy in a form ready to be delivered to the user without any further transformation , such as refrigerators, freezers and water heaters (storage). These appliances require no interaction with the user after initial set up, although user actions can impact the appliance's operation.

INSTALLED BASE (EU27)

Refrigerators and freezers: in 2010, there were 297,800,000 appliances in stock. According to estimations, the number increases up to 303,200,000 in 2015, 308,000,000 in 2020, 312,800,000 in 2025 and 317,600,000 in 2030. (Kemna, 2014)
Water heaters[51]: in 2010, there were 157,293,000 appliances in stock. According to estimations, the number increases up to 161,740,000 in 2015, 165,192,000 in 2020, 168,688,000 in 2025 and 172,268,000 in 2030. (Kemna, 2014)

SHIFTING OR CAPACITY MODULATING POTENTIAL

SHIFTING OR CAPACITY MODULATING POSSIBILITY

There are two options to change the electricity consumption profile of energy storing appliances:

1. For refrigerators, freezers and water heaters, **remote activation** is a possible option to harmonise the available power on the grid with demand. Based on DR control signals or power grid measurements, start of the compressor or the water heater may be delayed. Storage water heaters may also be called to anticipate their operations for storing energy in anticipation of future use in the coming hours In terms of cooling appliances, temperature inside the compartment must determine time of delay for food safety reasons. The power demand curve on activation of water heaters remains the same. In view of refrigerators and freezers, operation time may be prolonged. It is estimated that this strategy allows shifting 5 % of individual operations of refrigerators and freezers and 75 % of operations of water heaters by seconds or minutes. (Stamminger, 2008)
2. Second and most advanced option is to **alter electricity consumption pattern** during operation time, for cooling appliances e.g. interruption of cooling process, changes in temperature setting, prolongation of cooling process by reducing motor speed, enlargement of temperature hysteresis, for water heaters e.g. interruption of heating phase, reducing the desired water temperature. It is estimated that this strategy allows shifting 5 % of all individual operations of refrigerators and freezers as well as 75 % of all operations of water heaters by seconds or minutes. (Stamminger, 2008)

[51] The numbers for water heaters include: electric storage and instantaneous water heaters, gas-and oil fired storage and instantaneous water heaters as well as solar-assisted water heaters.

For appliances in this category, flexibility depends on the thermal storage capacity. In first instance, it may be considered as evenly distributed throughout the day and throughout the week. For refrigerators and freezers, seasonal effects are only weak. Water heater loads are highly seasonal with highest potential occurring in winter. This can be explained by the fact that both, differences in water temperature and hot water consumption are higher in winter season. (Stamminger, 2008, Puranik, 2014)

SHIFTING OR CAPACITY MODULATING POTENTIAL PER APPLIANCE

Data on shifting or capacity modulating potential per appliance are scarce. The following data are derived from a Swedish study on DSM-potential in Swedish households. In this study, the energy shifting potential of water heaters in Sweden is expected to be between 8 - 9 GWh/day in winter, 3.3 - 5 GWh/day in spring, 2.5 - 5 GWh/day in summer and 3 - 5 GWh/day in autumn. The maximum peak load reduction observed in winter, spring, summer and autumn is 0.95 GW, 0.872 GW, 0.69 GW and 0.9 GW, respectively. (Puranik, 2014)

Within the scope of the Smart A project, scenarios were simulated for various regions representative for different parts of Europe to estimate potential for energy shifting. In all simulation scenarios, the potential for short term interruptions of refrigerators amounts to about 8 Wh/ day per household in UK, but might be lower in all other parts of Europe. (Stamminger, 2008)

Reducing or increasing the demand at a certain time creates rebound. The total energy consumption remains the same, even if it is shifted. Energy consumed extra or less at a certain point in time must be compensated for at another time. (Stamminger, 2008; Linear, 2014)

TOTAL SHIFTING POTENTIAL OF APPLIANCE CATEGORY

Assuming a potential for short-term interruptions of 5 Wh per household in Europe, a shifting potential of 1.56 GWh for refrigerators and freezers in 2025 can be calculated.

COMFORT AND USER IMPACT

Refrigerators and freezers: With regard to refrigerators and freezers, smart operation may in principle not affect food safety and quality negatively. For this reason, temperature inside the cooling compartments has to be kept constant within narrow specific ranges to prevent microbial growth. Whereas it is possible to store energy by cooling to lower than normal storage temperatures in the case of freezers, this possibility is limited in the case of refrigerators because of the risk of freezing sensitive food and loosing food quality. If no influence on food quality occurs, high consumer acceptance can be assumed in view of remote activation and altered consumption pattern. (Stamminger, 2008)

Storage of energy by cooling down freezers to lower than normal storage temperatures results in surplus energy consumption due to a larger temperature difference and associated a lower coefficient of performance.

Water heater: Shifts in operation of water heaters may cause shortages or even interruptions of hot water supply, especially in the case of water heaters with small storage capacities. Because of that, shifts in operation are improbable for these types of appliances. In terms of devices with large storage capacities, shifts in operation are possible without comfort or user impact. An alteration of consumption pattern, e.g. reduction of the desired water temperature (at present about 60 °C) might be critical from a hygienic point of view as the growth of microorganisms such as *Legionella* can only be reliably prevented at higher water temperatures of about 60 °C. If there is no loss of comfort, consumers would accept remote activation and altered consumption pattern. (Stamminger, 2008)

Gaps and/or pre-conditions for the potential to be realised

All gaps and interoperability issues as listed in the main text are valid: the smart appliance needs to be equipped with extra communication, measurement and/or control functionality, which depends on the communication and control architectures, the selected communication carrier, the communication standards, etc.

Additional costs for consumers should be low to guarantee amortization within a reasonable period of time.

Functionalities supporting energy efficiency

In case of refrigerators and freezers, phase change material could be used to balance interruptions in power supply over a longer period of time. A further possibility is to implement absorber technology, which is driven by heat produced by solar collectors or CHP. (Stamminger, 2008)
Water heaters could be connected to CHP, solar plants or district heating. Electricity is only needed for basic functions of the device and the pump. (Stamminger, 2008)

Conclusion

With regard to refrigerators, freezers and storage water heaters, two different levels of shifting or power modulating possibilities could be identified. The technical adjustments are more complex for the second level. Appliances in this category offer a high flexibility in energy shifting operation. Consumer's acceptance is assumed to be rather high if food safety and quality is not compromised and if there is no loss of comfort. Short-term interruptions of heating or heating processes or power modulation (e.g. changes in temperature setting or reduction in motor speed) can be realised for all appliances in this category. In this way, power demand curve can be changed instead of merely shifted.

Assuming a potential for short term interruptions of 5 Wh per household in Europe, an energy shifting potential of 1.56 GWh for refrigerators and freezers in 2025 was calculated.

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BEHAVIOURAL APPLIANCES

Description

Behavioural appliances are appliances where the operation is linked to its functionality and whose operation require the active involvement of consumers, e.g. electrical hobs, ovens, hoods, vacuum cleaners[52] and instantaneous water heaters destined for private use.

Installed base

Electric hobs: in 2010, there were 133,781,000 appliances in stock. According to estimations, the number increases up to 149,114,000 in 2015, 163,566,000 in 2020, 176,468,000 in 2025 and 188,544,000 in 2030. (Kemna, 2014)
Electric ovens: in 2010, there were 191,823,000 appliances in stock. According to estimations, the number increases up to 199,332,000 in 2015, 209,502,000 in 2020, 220,505,000 in 2025 and 232,059,000 in 2030. (Kemna, 2014)
Range hoods: in 2010, there were 92,371,000 appliances in stock. According to estimations, the number increases up to 97,111,000 in 2015, 102,060,000 in 2020, 107,267,000 in 2025 and 112,741,000 in 2030. (Kemna, 2014)
Vacuum cleaners: in 2010, there were 364,226,000 appliances in stock. According to estimations, the number increases up to 388,857,000 in 2015, 419,407,000 in 2020, 487,849,000 in 2025 and 545,178,000 in 2030. (Kemna, 2014)
Instantaneous water heaters: no separate numbers are available for instantaneous water heaters (see water heaters)

Shifting or capacity modulating potential

Shifting or capacity modulating possibility

There are two options to change the electricity consumption profile of behavioural appliances:

1. The first possibility is that consumer receives information on availability of power e.g. via smartphone and the consumer shifts operation of hobs, ovens range hoods and vacuum cleaners to any time of the day, when a huge amount of energy is available. Due to the fact that eating times are more or less fixed times during the day, shifts of not more than 30 minutes seem to be realistic for cooking appliances (hobs, ovens and range hoods). In view of vacuum cleaners, longer shifts up to 2-3 hours are assumed to be feasible. For instantaneous water heaters, this scenario is improbable. (Stamminger, 2009) Due to its manual nature, this option is out of scope of the study.
   DR
2. Third and most advanced option is to not only shift the execution of the process, but also to alter the electricity consumption pattern during the process, for hobs and ovens e.g., prolongation of

[52] Robot vacuum cleaners can be regarded as an exception to this. However, as the flexibility of robot vacuum cleaners is in the charging of the battery, the assessment is part of the analysis of chargers.

intervals between two heating phases or interruption of heating phase, for vacuum cleaners and range hoods e.g. reducing power. For instantaneous water heaters, this scenario is improbable. From an energy point of view, interruptions are not applicable in the first few minutes after the heating phase in terms of hobs and ovens. Referring to range hoods and vacuum cleaners, interruptions are improbable as their power demand remains constant during operation and interruptions in power supply would could cut them off. The pattern of the power demand curve of a single appliance can be changed in different ways, e.g. shift in operation time or reduction of power. It is estimated that about 5 % of consumers would accept this option. (Stamminger, 2009)

Shifting or capacity modulating potential per appliance

If looking at the annual energy consumption of these appliances in 2010, the potential seems to be significant:

- Hobs: 300 kWh/a
- Ovens: 120 kWh/a
- Range hoods: 133 kWh/a
- Vacuum cleaners: 69 kWh/a
- Instantaneous water heaters:

However, according to literature and own estimations, the acceptance by residential end-users may be limited to about 5 % for interruptions by seconds and minutes. So acceptance appears to be the limiting key factor. (Kemna, 2014; Stamminger, 2009)

Total shifting potential of appliance category

An estimate on the shifting potential is hard to state, since not much research has been done on this in view of appliances in this category.

Comfort and user impact

Concerning hobs and ovens, it has to be examined whether short term interruptions of heating phases or prolongation of the interval between two heating phases by seconds or minutes compromise the cooking process and consequently the performance**.** However, the consumer's acceptance is supposed to be low.

In view of range hoods and vacuum cleaners, a reduction of power will result in a lower air change rate or a loss of suction power, respectively, leading to a lower effectiveness and a highly variable background noise.

In view of instantaneous water heaters, short term interruptions in power supply would cause losses in comfort, which will not be accepted by consumers.

Gaps and/or pre-conditions for the potential to be realised

All gaps and interoperability issues as listed in the main text are valid: the smart appliance needs to be equipped with extra communication, measurement and/or control functionality, which depends on the communication and control architectures, the selected communication carrier, the communication standards, etc.

The most important factor is the willingness of end-consumers to apply the smart functionalities. Business cases should be available to ensure that savings balance the additional costs and to provide sufficient incentives for end consumers to participate in this.

Functionalities supporting energy efficiency

With respect to hobs, efficiency differs significantly between different types. During operation, the induction hobs are the most efficient ones ahead of ceramic hobs. Sealed plate hobs are the least efficient ones.

Conclusion

Due to a lack of consumer acceptance, the potential is assumed to be low.

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HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

HVAC ELECTRICITY CONSUMPTION, MOST IMPORTANT PRODUCTS

HVAC category contains 4 main functions and related residential / commercial appliances: heating, cooling, ventilation and humidity control.
Smart heating, ventilation and dehumidification equipment can contribute to shift / reduce electricity load in the winter period, while cooling and dehumidification appliances may contribute in the summer.
For this first overlook of the DR potentials, it is important to have in mind orders of magnitude of total electric consumption corresponding to the different appliances.

Table 2: Total and HVAC electricity consumption in Europe from (Bertoldi, 2009) and (Bertoldi, 2012)

	2007	2007	2010	2010
	TWh	% total	TWh	% total
Electricity consumption EU27	2797	100%	2836	100%
Residential	800	29%	842,5	30%
Electric heating / boilers (2)	150	5%	152	5%
Ventilation (2)	22	1%	22	1%
Air conditioning (2)	17	1%	17	1%
		0%		
Tertiary	760	27%	834	29%
Electric heating and water heating	150	5%	160	6%
Ventilation	96	3%	104	4%
Air conditioning	21,6	1%	24	1%
Pumps	45	2%	49	2%
Residential + Tertiary				
Electric heating/boilers (1)	270	10%	280	10%
Ventilation	118	4%	126	4%
Air conditioning	38,6	1%	41	1%

(1) Tertiary electric water heating supposed to account for 20 % of tertiary space and water heating (French case) is not accounted[53]

(2) Residential split not available in 2010 - shares of 2007 are supposed to remain constant in 2010

Regarding humidity control in the residential sector, (Rivière, 2007) gives an idea of the consumption of dehumidifiers (consumption of products sold in 2006 : 0.03 TWh / year). It is also stated that humidifiers may consume as much energy as dehumidifiers although there is no figure. The humidity function probably consumes less than 1 TWh of electricity and respective appliances are mainly

[53] In (Bertoldi, 2009), the electricity consumption of electric heating and water heating is not disagregated. Based on French statistics, 20 % of the total figure (150 TWh in 2009) is attributed to water heating to make an estimate of tertiary electric heating.

portable products. So their potential for DR is considered as very limited and consequently these products are not further analysed in this study.
In contrast, the focus of the following analysis is lead on electric heating (including, direct joule heating, electric and heat pump boilers as well as circulation pumps), electric air conditioning and ventilation.

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HVAC/ELECTRIC HEATING

DESCRIPTION

Electric heating covers direct joule effect electric radiators (with or without built-in heat storage capability), electric and hybrid (gas or fuel + electric) heat pumps. Electricity consumption in Europe (EU27) is assumed to be around 150 TWh for the residential sector and 130 TWh for tertiary sector in 2010.
(BIOIS, 2012) describes the different types of electric radiators installed in Europe. Following (Stamminger, 2008), electric heating appliance categories are separated depending on the thermal inertia they can activate, which then will condition the load shifting potential.
No inertia: Portable - convector panel, radiators, Fan heaters, Radiant panel heaters, Ceramic heaters, Visibly glowing radiant heaters; Fix - Convector panel heaters, Radiators, Fan heaters, Radiant panel heaters, Visibly glowing radiant heaters, Towel heaters for bathrooms (with or without fans)
With inertia: Underfloor heating (thin film, cable), Storage heaters (static - heat release is ensured by natural convection and radiative heat transfer), Storage heaters (dynamic - heat release is ensured by a thermostat controlled fan). Storage heaters are typically charged during off-peak conditions (Stamminger, 2008) so that they have a shifting potential of several hours (typically half a day). These are more easily controlled than underfloor heating for which control of the ground temperature to ensure occupant comfort is an issue. The inertia of underfloor heating systems is in fact dependent upon the specific building soil installation and not of the heating product per se.
Regarding electric heat pumps, these are air based (air is the indoor heating vector as for reversible split air conditioners) or water based. Water based heat pumps are further broken down depending on the heating source (air, water, geothermal energy). Some of the water-based heat pumps may have built-in system inertias, through water storage (to ease water temperature control) and for underfloor heating (part of the building mass can be activated via the heating system - as for underfloor electric heating). In practice, the water inertia is generally low when the heat pump is used at full capacity (typically 3 to 10 minutes) so that their main load shifting potential is the one of the building. Thus the only specific category with higher shifting potential is the floor heating category. However, heat pump floor applications are not dominant (because of higher costs and the fact that they can only be installed in new or largely retrofitted buildings). Consequently, all heat pumps are added in the "no inertia" electric heating category hereafter.
It is interesting to notice that hybrid heat pumps (products that combine a gas or liquid fuel boiler and an electric heat pump) can shift from electricity to gas when required and may shift almost completely their energy consumption to gas if it is required. However, the market for such hybrid products is still very small as these products are just entering the market.
We thus distinguish three main types of electric heating appliances to differentiate potential analysis: electric heating (joule effect or heat pump), electric with inertia (underfloor heating with static and dynamic storages) and boiler circulators.

INSTALLED BASE

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 3: 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 kW[54] or about 10 GW installed capacity / power (keeping a median 10 KW value per unit).

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

[54] http://www.boilerguide.co.uk/articles/electric-boilers

In 2010, the total installed base of electric heating systems is 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 4: 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)
This is an interesting figure that is worth being compared with what is seen at the electricity grid level. RTE[55] 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 4 below shows the correlation between average daily outdoor temperature (weighted average temperature over 30 cities in France[56]) 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) (See below).

[55] RTE (Réseau de transport d'électricité) - French electricity transmission system operator.
[56] 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.

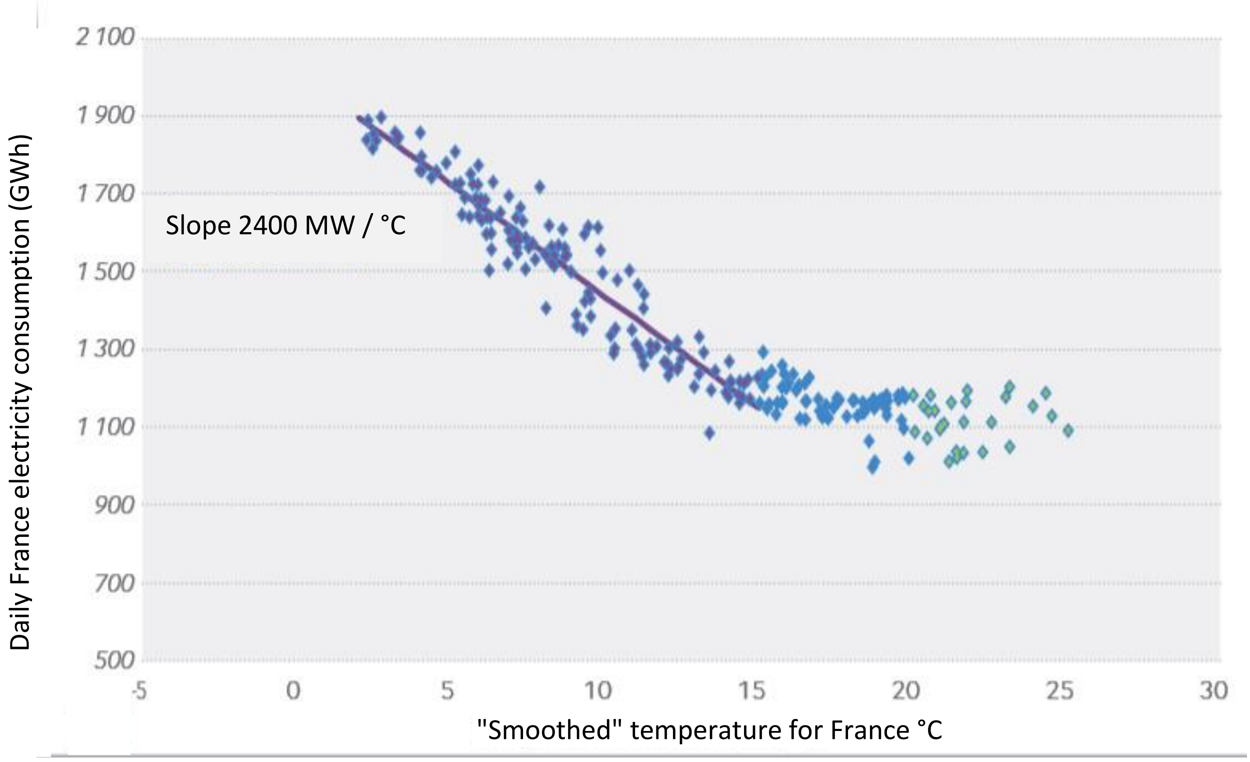

Figure 14: Temperature sensitivity of electricity consumption in France in 2013 - daily average electricity consumption VS smoother average France temperature and slope, from (RTE, 2013)

On the Figure below, 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.

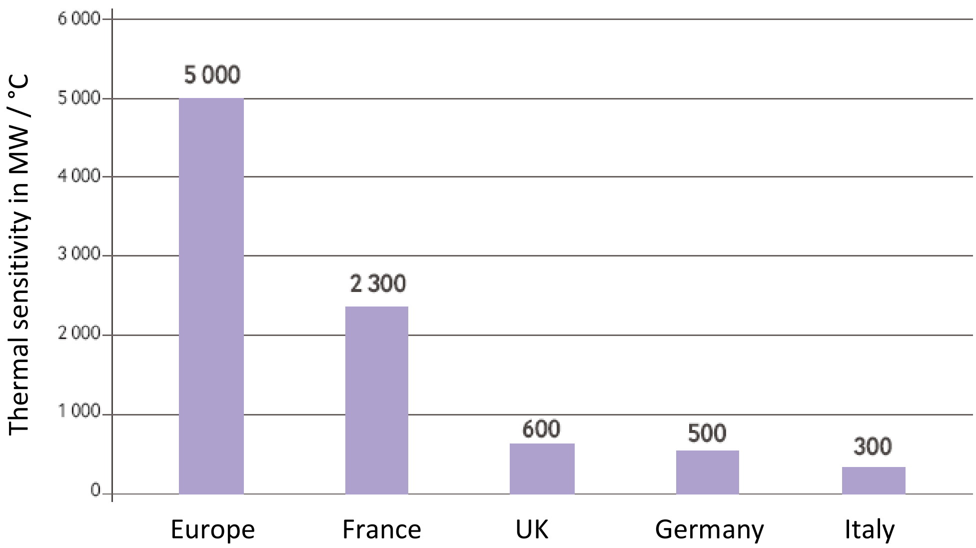

Figure 15: Temperature sensitivity of electricity consumption in France and other countries in Europe in 2012, from (RTE, 2012)

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 magnitudes.
But 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.

SHIFTING OR CAPACITY MODULATING POTENTIAL

All electric heating appliances (except boiler circulators) include thermostatic control.
Portable electric appliances have generally no planned connection to a central controller and are operated manually (switch on-off, temperature setting and fan speed for fan heaters).
Newer installations of fixed joule heating now have multiple standard control modes (4 or 6 modes) enabling a central controller to send standardised orders to reduce consumption over a period of time chosen by the end-user (Typically: Comfort - heating at locally adjusted set point, Eco - locally set point temperature minus 1 or 2 °C, night or absence setback, anti-freezing set point, stop). The physical link between the radiator and the controller is called in France "pilot wire" and has become a national industry standard for some years. However, concerning the total stock, this control approach is only applied to a small portion of the installed systems.
Generally, current electric heating controllers cannot exchange information with the grid. Only for very specific DR programs, such connections are made (for instance, the firm Voltalis in France installs a box in the fuse box on the electric heating cable to enable consumption measurement and control of the electric heating). In France, this type of DR programmerepresented less than 100 MW in February 2013 (RTE, 2013).

More recently, smart heating thermostat have been offered to customers by energy providers. Smart thermostats are two way (internet) communication devices, which monitor a combination of several variables in the houses (like air temperature possibly by zone, occupation possibly by zone, user comfort habits and satisfaction), and can also include GPS position tracking of the dwelling's tenants, price tables or signals, and weather previsions, in order to help customers to reduce their heating bills by improving the control of the heating system. These systems are only beginning to spread and in Europe, most solutions are reserved for traditional boiler systems (dominant type in Europe). Nevertheless, solutions do exist for electric heating which could be a support to realise DR potential.[57]
Heat pumps generally require more sophisticated controllers than electric radiators, which in turn enable to include more functions. Recently web based applications enabling the distant monitoring

[57] http://www.theguardian.com/environment/2015/jan/27/smart-thermostats-reviewed-which-can-save-you-most

and parameterization of heat pumps have reached the market. This option is presently used by the end-user itself. The German Smart Home Ready label[58] has gained popularity for heat pumps, since its introduction in 2013, and could help to standardise communication orders.
Note that smart thermostats are also proposed for heat pumps.

Regarding heat storage, as they are conceived to benefit from night tariffs, these are most probably linked to the grid operator at the fuse box level so that their charging may be operated distantly.
There are three different types of flexibility involved for heating:

a) Inertia of the building (this includes all types of electric heating without storage and boiler circulation pump),
b) Inertia built in the heating system (electric storage radiators and electric boilers)
c) Energy source shift during peak times for hybrid gas or fuel electric heat pumps. This potential is extremely high as the electricity consumption can be shifted at any time, but the market for such hybrid heat pumps is just at its beginning (still negligible in 2014).

Shifting or capacity modulating possibility

This varies depending on the type of inertia involved:
a) Shifting potential is limited by the comfort of the occupants. (Da Silva, 2011) suggests that the heating load can be typically shifted by 1 hour per day for old buildings and by up to 2 hours for new buildings (figures are for France and new buildings are the ones built after 2005, equalling about 15 % of the French building stock) in order to remain in the EN 15251 (CEN, 2007) standard comfort zone. But even in those new buildings, during the coldest days of the year, it is likely that occupants feel uncomfortable because of the too high variation of the indoor air temperature (more than 2 K / h). The situation can be improved if heat pre-charging of the building is allowed, which is less energy efficient but enables to gain acceptance from the end-user point of view. The potential could amount to about two hours, but this requires two-way communication with the indoor thermostat, which is commonly not available today.
b1) Basically, the heating storage is built to enable the electricity to be consumed mainly during the night, while heating is supplied night and day. For a typical day (in Germany), the heating energy which can be shifted from day to night represents close to half of the daily energy consumed by one unit (Stamminger,2008).
b2) For heating electric boilers, they can be flow boilers[59] (instantaneous) or storage boilers[60] with inertia ranging from 1 hour to 4 hour of shifting potential under peak conditions and up 4 hours and 12 hours at 30 % load. 20 L / kW or about 1 hour inertia in peak conditions are assumed.
c) All the energy consumed by the unit can be almost completely supplied by gas or fuel (but in that case, it would not make sense for the end user to have bought a hybrid heat pump).

Shifting or capacity modulating potential per appliance

This varies depending on the type of inertia involved:
a) 1 hour with simple stop of the heating radiators or about 4 % (1/24), 2 hours (with two way communication enabling pre-charging of the building and other optimised strategies) or about 8 % (2 /24) - 8 % are kept to establish the total potential
b1) About 50 % the consumption of the storage unit
b2) As a) plus 20 L / kW water inertia
c) 100 %

[58] Described in more details in Annex 2 on page 119.
[59] See for instance http://www.heatraesadia.com/docs/Amptec_-_Issue_9.pdf
[60] See for instance http://www.thermaflowheating.co.uk/our-brochure/

TOTAL SHIFTING POTENTIAL OF APPLIANCE CATEGORY

The total shifting potential is summarised in the Table 6 below. Electric radiators and storage installed capacities, and heat pump average performance curves have been adjusted so that the total electricity consumption is in line with Bertoldi (2009 and 2012) and RTE peak power observations.
It is important to notice that residential and tertiary units are certainly included in the estimate below.

End use sectors (residential and tertiary) might have different flexibility limitations other than occupants' comfort. While for residential units, the main constraint is acceptance from the end-user to allow a third party control the HVAC system of his/her dwelling, for tertiary buildings there might be other type of constraints. These limitations regarding mainly temperature regulations, might be related to security reasons in tertiary buildings like hospitals, laboratories, agro-industrial sites.

Table 5: Electric heating function in Europe, Estimation of energy consumption for Europe in 2010, of total shifting potential and of peak power

	Monthly avg. Temp.	Circulation pumps	Storage	Elec fix radiators	Elec boiler	Elec HP	Total energy	Power (wo pump)	Total shift potential	Storage share	Elec fix radiators share	Elec boiler share	Elec HP share
		cons	cons	cons	cons	cons	cons	Power	cons				
MONTH	**°C**	**TWh**	**TWh**	**TWh**	**TWh**	**TWh**	**TWh**	**GW**	**TWh**	**%**	**%**	**%**	**%**
JAN	2,2	5,5	4,2	27,9	3,7	7,3	48,7	59,0	5,6	38%	40%	11%	11%
FEB	3,1	5,5	3,9	26,0	3,5	6,6	45,6	54,8	5,2	38%	40%	12%	10%
MAR	5,2	5,5	3,2	21,4	2,9	5,1	38,0	44,5	4,3	38%	40%	13%	9%
APR	8,7	5,5	2,1	13,7	1,8	2,9	26,0	28,0	2,9	36%	38%	17%	8%
MAY	13,8	5,5	0,4	2,6	0,3	0,5	9,3	5,2	0,8	24%	26%	45%	5%
SEP	14,4	5,5	0,2	1,3	0,2	0,2	7,4	2,6	0,6	17%	18%	61%	3%
OCT	10,5	5,5	1,5	9,8	1,3	2,0	20,0	19,9	2,1	35%	37%	21%	8%
NOV	6,2	5,5	2,9	19,3	2,6	4,5	34,7	40,0	3,9	37%	39%	14%	9%
DEC	2,8	5,5	4,0	26,6	3,6	6,8	46,4	56,0	5,3	38%	40%	12%	10%
Peak conditions	-4	5,5	6,3	41,4	5,5	13,8	72,5	**91,6**	8,3				
ANNUAL ENERGY (TWh)		49,2	23	148,5	4,4	36,1	**276,2**		**30,7**	37%	39%	15%	9%
Installed base correction factor for radiators and storage units:						0,45							
Correction made in coherence with Bertoldi 2009 and 2012 reports and RTE observations													
Inertia of electric boiler in L / kW :			20										

In case the electric boilers do not supply water inertia, their share is reduced to standard building inertia and the total potential to shift energy is close to 27 TWh.

Comfort and user impact

Comfort is the limiting factor, as temperature will drop in the house when the heating system is stopped. Strategies can be adapted (heat pre-charging of the building structure, ventilation can be stopped) but this requires two-way communication. Another limiting factor is the speed of air temperature change in the house. More than 2 K / h is outside the comfort range of the EN 15251 standard. This may be mitigated by modulating the system control orders (e.g. not full stop, but only 50 % of the capacity supplied over a longer period).

Gaps and/or pre-conditions for the potential to be realised

Several smart grid and DR experiments are on-going in France. They will help to characterise the user acceptance regarding the comfort degradation due to heating power modulation and the need for two way communication in order to satisfy comfort as well as to ensure the durability of any DR programme based upon electric heating.

Functionalities supporting energy efficiency

For electric heat pumps, more and more complex CPUs are integrated in the products in order to achieve the control of the units (in the tertiary sector, large VRF[61] units may control up to 50 indoor units in addition to the one of the heating generator). For maintenance purpose, interfaces are generally available for more than 10 years for more advanced brands, in order to ensure optimal and energy efficient operation.
It is believed that for most other electric heating units, there are no supporting energy efficiency features.

Conclusion

Flexibility potential:

- **Peak power: up to about 95 GW (2010)**
- **Energy consumption: about 280 TWh/a**
- **Potential energy to be shifted: about 30 TWh/a, about 100 GWh/day in the coldest winter months**

The flexibility potential is divided at about 50/50 between built-in system inertia (storage radiators, electric boilers) and building thermal mass inertia. Regarding the use of building thermal mass, several smart grid and DR experiments are on-going in France. They will help to characterise the user acceptance regarding the comfort degradation due to heating power modulation and the need for two way communication in order to satisfy comfort as well as to ensure the durability of any DR program based upon electric heating.

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[61] VRF - Variable refrigerant flow system. Split system with several indoor units connected on a refrigerant loop with individualized controls per room.

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HVAC/VENTILATION

DESCRIPTION

Ventilation includes energy using products whose main function is to renew the air of occupied buildings.

Ventilation products are:

- In the residential sector, local and central extraction fans and local and central heat recovery ventilation units (noticed below as RVU for "Residential Ventilation Units")
- In the tertiary sector, central extractors and air handling units (noticed below as NRVU for "Non-Residential Ventilation Units")

INSTALLED BASE

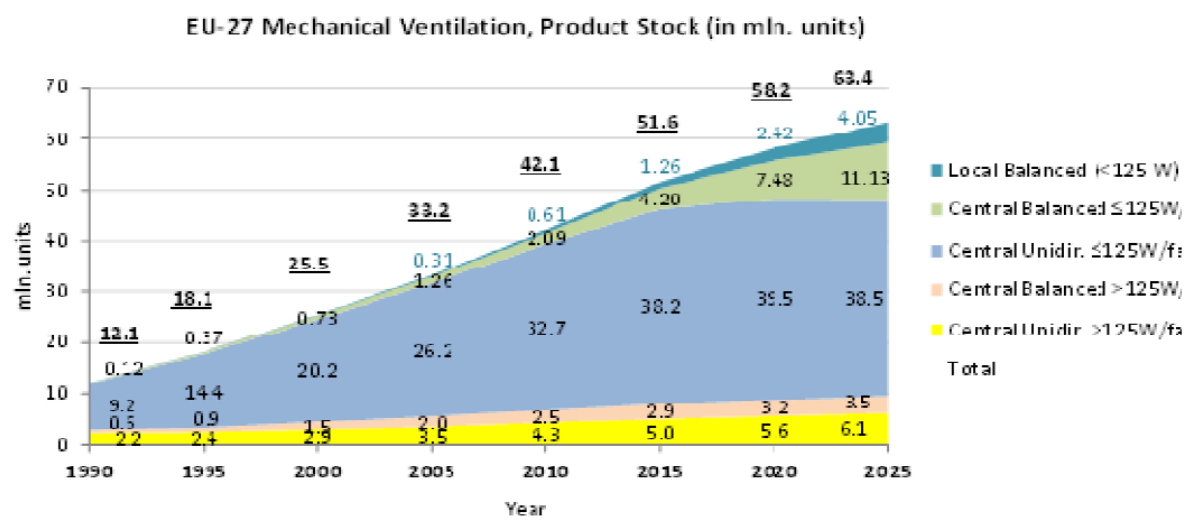


Figure 16: Stock of ventilation units in the EU 1990-2010 and projections 2010-2025 (BAU, source: preparatory studies), from (EU, 2014)

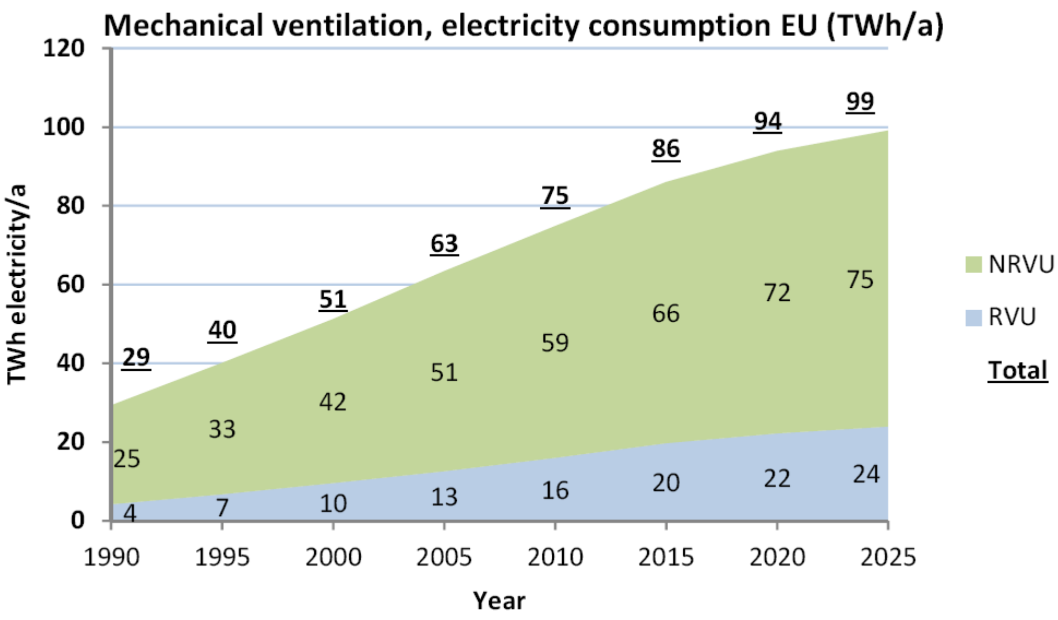
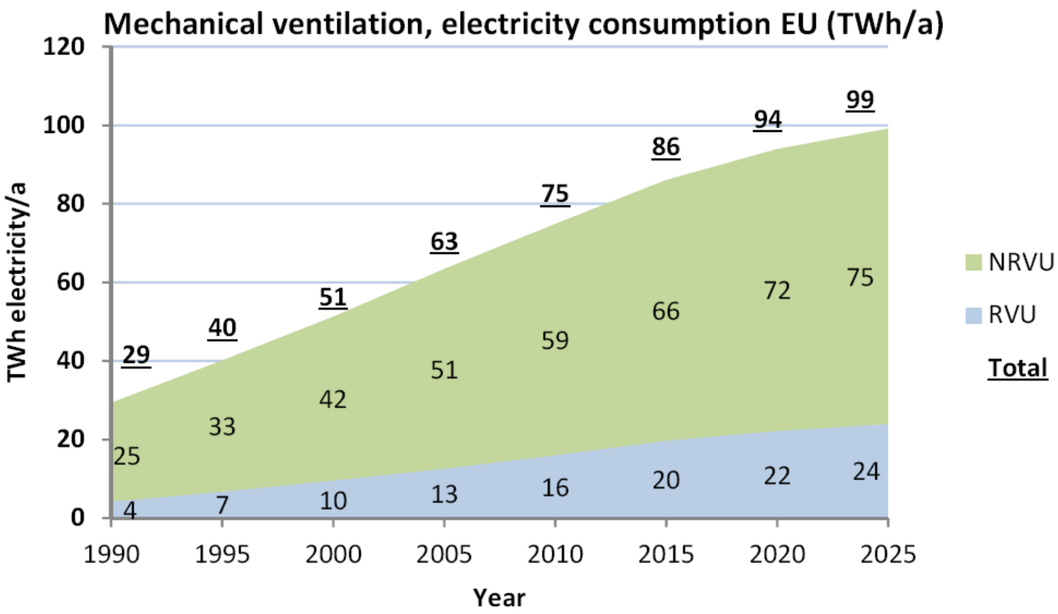


Figure 17: Mechanical ventilation, EU electricity consumption 1990-2010 and projections 2010-2025 (BaU) in TWh electricity per year (EU, 2014)

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 studies[62] 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.

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

SHIFTING OR CAPACITY MODULATING POTENTIAL

Presently, in the residential sector, ventilation is mainly constituted of one or few local exhaust fans (in wet rooms) or of a central extractor. Balanced (with heat recovery) ventilation units are growing but still represent a very limited share of market and stock.
All these systems operate continuously and may be controlled by the end-user. Some central extraction units are equipped with two speeds (case in France) with manual control (which can be either adjusted by wired or radio frequency control). Best available technologies (BAT) include demand controlled ventilation (based on CO_2 or other presence sensors), balanced heat recovery ventilation, as well as EC (electronically commutated) motors (having the ability to adapt the motor frequency to adjust the flow), which still represent very low market shares.
In the non-residential sector, ventilation works on the same principle with larger and more sophisticated units.
Air handling units allow more air treatment functions, which require also more sensors for control. Local sensors can communicate with the products through radiofrequency and it is now common to see manufacturers offering web interfaces for their products, for maintenance as well as energy consumption and performance measurement. The share of end-users buying these options is not known.
As a conclusion, some degree of smartness already penetrated the non-residential sector, but probably a small part only, while the residential sector is probably fully "non smart" technology.

SHIFTING OR CAPACITY MODULATING POSSIBILITY

Electric energy can be shifted directly, i.e. by stopping or modulating the fan electric power.
But when the ventilation system is specifically installed in a building that is heated or cooled by an electric generator, reducing the air renewal flow rate will also reduce the total heating / cooling load. Please note that the thermal energy saved by reducing the ventilation is much higher than the electricity consumption of the fan itself (typical rate: 4 or 5 to 1). In low energy dwellings, the share of the heating load due to air renewal may well reach 50 % but in general for a standard building in the stock, it is supposed to lie between 20 and 40 %). Please also note that some authors, e.g. (Da Silva, 2011), have proposed to increase the comfort during heating DR programmes by stopping completely the ventilation, i.e. coupling heating and ventilation in order to propose optimised DR strategies for buildings using electric heating. Note that this also applies for cooling. In this document, this contribution is included in the parts dedicated to heating / cooling and thus, only the electric consumption shifting potential from ventilation is considered.
For RVU, the electric power of the fan is generally constant (single speed unit). Central extractors have developed towards two speed models due to the national building codes (typically, the fans operate at 40 % except during 1 or 2 hours a day when operating at 100 % to remove humidity from showers or cooking). Control is mainly manual but can be automated when associated with a humidity control (popular in France). Balanced ventilation are operated all year long at constant flow.
For NRVUs, air handling units have more control options:

a) Clock control (on/off flow)
b) Air flow adjustment using dampers (creating more or less pressure drop and thus changing the total flow rate) (note: this type of control does not cut power consumption, but only adjust flow rate by flow resistance)
c) Multi-speed or variable speed control

SHIFTING OR CAPACITY MODULATING POTENTIAL PER APPLIANCE

For residential ventilation, the DR potential is probably too diffuse and challenging to be really economical (30 W or less per fan for central extraction unit). It is probably only interesting because of its indirect effect on thermal loads.

For non-residential ventilation, these products are included in DR programmes in the USA (LBNL, 2013). For systems with variable speed control or with several speeds / air handling units, there is a potential to reduce flow rates for DR programmes. The ventilation system is designed for peak conditions but without advanced demand control installed, the ventilation is mostly programmed by clock with fan power reduction at night (and possibly during lunch time), when the building is empty. The shifting potential then depends on the occupancy of the building. (LBNL, 2013) classifies commercial ventilation as suitable for "energy" DR programmes, i.e. around 50 % of the electric load can be shifted in time for more than 1 hour up to two times per day (or in total the full power more than 1 hour per day). But in the following report (NREL, 2013), the same authors eventually limit commercial ventilation to shorter-term grid services with a maximum of one-hour shift. Thus 1 hour is assumed, based on the US literature.
However, this potential is thought to be not sustainable, at least as building operations become more and more efficient. Indeed, the minimal ventilation consumption corresponds to a building operated with variable speed fan motors and demand controlled ventilation with CO_2 concentration sensors. The EN15251 standard specifies the maximum allowed CO_2 concentration in the air, which in turn defines the minimum ventilation flow rate. Hence, for an optimal building from the point of view of ventilation, it should be operated close to that minimum level with no possibility to go below.
With the limit being a maximum CO_2 concentration, there still could be a shifting potential if associated with a pre-period with higher than necessary ventilation levels. However, this probably leads to potentials of a few minutes only.

Total shifting potential of appliance category

About 10 GWh/day today but probably decreasing drastically with the increasingly intelligent and more energy efficient ventilation systems.

Comfort and user impact

The standard EN 15251 regarding comfort criteria in buildings defines required air renewal flow rates to reach acceptable levels of concentration for indoor pollutants. Assuming a perfect demand controlled ventilation system, limiting the air flow renewal exactly to the quantities to maintain the required levels of indoor pollutants with variable speed adjustment of the fan, there would be no place for DR programmes.

Gaps and/or pre-conditions for the potential to be realised

Installation of sensors and variable speed control for the fans, in order to comply with comfort criteria and to make sure for the building manager that comfort rules are respected despite lower air renewal flow rates.

Functionalities supporting energy efficiency

Distant maintenance and parameterization, energy and efficiency metering.

Conclusion

Maturity and low potential probably exclude residential ventilation, because power per unit is very low.
Flexibility potential:

- The peak power of non-residential ventilation is relatively low, about 10 GW.

- With 59 TWh in 2010 energy consumption of non-residential ventilation is relatively important because units operate all year long during working hours.
- Units may probably shift about 10 GWh/day during working hours in the week.

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HVAC/AIR CONDITIONING

Description

All cooling systems for comfort cooling:

- Residential air conditioners, mainly split and multi-split systems, but also portable air conditioners
- Non-residential air conditioning systems, i.e. chillers, large split, multi-split and VRF[63] systems, rooftop air conditioners and cooling systems of air handling units

Installed base

Table 6: 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**

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 that is difficult to make a reality check of these figures.

[63] VRF - Variable refrigerant flow system. Split system air conditioner with several indoor units connected on a refrigerant loop with individualized controls per room.

Shifting or capacity modulating potential

Air conditioning units are typically equipped with sophisticated controllers. For most units, except small split units using a remote control, a central controller is generally installed with the unit. Controls of air conditioning units may be proprietary of the brand of the unit or bought to a specialised OEM. The same is true for the central controller. It is then thought that protocols of information and parameterisation data exchange are standardised and can be used to give indirect operation order to the unit (by shifting set point or thermostat). To get smarter, air conditioners may require slight adaptation however. Australia has for instance adopted a standard (AS 4755, 2008) for air conditioners to be equipped with specific DR signals (Defined modes: Stopped, working at 50 % or 75 % of their demand) in order to ease the interaction with a standardised DR enabling device which can be operated by external agents (typically agregators). The price of such a modification for air conditioners is estimated to 10 $(AUD).

However, the units sold in Europe do not have this functionality so far and are not directly “smart” even if the Australian example shows that it does not require a large adaptation.

Although smart thermostats are offered in Europe mainly for heating, they could also provide internet communication and control functionality for cooling appliances, thus helping to make a larger share of the installed based of air conditioners smart.

Shifting or capacity modulating possibility

As for heating, electric cooling shifting potential mainly relies on the building thermal capacity to maintain indoor air temperature within acceptable limits when the cooling power is reduced or cut. As for heating, alternative strategies such as pre-charging of the building mass is feasible in case of two-way communication. All new equipment sold from 2012 onwards are equipped with multi-stage compression circuit or variable speed drive to control the cooling capacity output.

(Reddy et al., 1991) proposed a simplified formula to evaluate the time an air conditioning system could be stopped in a building without leading to temperature variations of more than 2 °C. His results show that for most buildings, air conditioning can be stopped for at least one hour a day. Recent evaluation of DR capability in the USA (NREL, 2013) have evaluated that between 20 and 70 % of the load can be shifted of at least one hour twice a day in the residential sector and between 40 and 50% in the commercial sector. Thus, 2 hours a day are assumed to make a first estimate of the potentials.

Shifting or capacity modulating potential per appliance

(Stamminger, 2008) states that for residential air conditioners, the acceptance by residential end-users may be limited to about 10 % of dwellings and for air conditioning stopped from 15 to 60 minutes per day. So acceptance appears to be a limiting factor. More sophisticated options than curtailment, like pre-charging of the building could probably improve this low acceptation level.

Total shifting potential of appliance category

The total potential is thus assumed to be in a magnitude of 160 GW over one hour over the cooling season during week days (but also week-ends for residential units). In practice however, this could only be reached if all the appliances would operate at about 35 °C, which is most probably not the standard case in Europe, meaning that 130 GW (for about 30 °C average temperature) is probably a maximum. On average over the summer, the required daily peak load would be most likely only the half or about 65 GW. The main load occurs during the day, at noon in the commercial sector and in the afternoon for residential air conditioners.

Shifting potential in terms of energy can then be estimated to: 4 (months) * 65 GW * 30.5 (day/month) * 1 h = 7.9 TWh/a or 65 GWh per day on average during the summer period (June to September). Please note that as for heating, this figure will vary with outdoor temperature and the potential will be only available during daytime.

Comfort and user impact

The rationale is the same as for heating. Comfort is the main limiting factor of the shifting or curtailment potential.

Gaps and/or pre-conditions for the potential to be realised

The full potential requires comfort acceptance. And this could be achieved by two-way communication used to minimise the impact of DR on the user comfort. The level of acceptability for residential cooling DR programmes has been estimated to only 10 % in Germany (Stamminger, 2008) and between 10 and 40 % in the USA (LBNL, 2013).

Functionalities supporting energy efficiency

The same trends as for heat pumps can be observed : more and more complex CPUs integrated in the products in order to achieve the control of the units ; in addition, for maintenance purpose, interfaces are generally available for more than 10 years for more advanced brands, in order to ensure optimal operation and thus energy efficient operations.

Conclusion

It is believed that about 15 % of all electric cooling appliances are equipped grid communication and control.

Flexibility potential :

- Peak power : up to about 200 GW (2010) but probably not more than 160 GW even in case of extreme events.
- Energy consumption : about 80 TWh in 2010
- Potential energy to be shifted : about 65 GWh/d in the summer and about 8 TWh/a in total

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LIGHTING

Description

This category comprises lighting in residential and commercial indoor areas and public street lighting.

Installed base (EU 27)

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).

Total calculated energy consumption year 2013 calculated on the basis of (Kemna, 2014):

- LFL: Linear fluorescent lamps: 126 TWh/year
- CFL: Compact fluorescent light: 33 TWh/year
- Tungsten: 57 TWh/year
- GLS: General lighting service ('incandescent'): 13 TWh/year
- HID: High intensity discharge lamp: 48 TWh/year
- LED: Light emitting diode: 1 TWh/year
- Total: 279 TWh/year

Total energy consumption (2020) of street lighting is 35 TWh/year (VITO, 2007).

Shifting or capacity modulating potential

Shifting or capacity modulating possibility

There are the following possibilities to shift or modulate capacities:
For advanced LED light bulbs: There are already LED light bulbs on the market, which can be controlled by a smart phone over Wi-Fi – in some cases combined with a special hub for the bulbs. This can be further developed into a DR enabled system controlled by signals from the power supply system. For LED systems there will be no technical problems in dimming and switching off the light.
For CFLs: It is also possible to build in DR enabling, but in a less extent dimming compared to LEDs.

Generally, for all light bulbs (LED, CFL, Tungsten, GLS) it is technical possible to mount an extra DR module for switching on and off the bulbs.
For luminaires and lighting systems in commercial areas (mainly LFL): There are already advanced systems on the market, which can be controlled by local conditions in the lighted area through presence sensors and solar radiation sensors combined with the time of day. This can be further developed into a system controlled by signals from the power supply system.
Street lighting: Street lighting systems are already highly controlled from outside and it is possible to combine this with a DR module.
Many light technologies can be dimmed (tungsten, halogen, fluorescent, LED etc.) resulting in reduction in power load and energy consumption. Lighting including street lighting is naturally mostly switched on in periods with no solar radiation apart from indoor areas with no or few windows such as basements, commercial centres etc. meaning that the energy consumption is higher in evenings and during nights, though also depending on time of year and geographical location within EU. For offices and some other commercial area, the energy consumption is reduced during weekends. The energy consumption is higher during these periods, which would be a basis for the flexibility potential.

SHIFTING OR CAPACITY MODULATING POTENTIAL PER APPLIANCE

Data on shifting or capacity modulating potential per appliance in a smart grid perspective are scarce. Instead, we have assessed the potential from available data on stock, lumen output, operating hours, and efficiency (Kemna, 2014) combined with more details on street lighting (VITO, 2007).
Based on average data on lumen/unit and lumen/watt, the average wattage for each unit is:

- LFL: Linear fluorescent lamps: 29 watt
- CFL: Compact fluorescent light: 11 watt
- Tungsten: 50 watt
- GLS: General lighting service ('incandescent'): 51 watt
- HID: High intensity discharge lamp: 144 watt
- LED: Light emitting diode: 5 watt
- Tungsten stock: 36 watt

The technical potential for load shifting for each light bulb is of the same size assuming switching off. Modulating i.e. dimming potential is much less but naturally depends on the dimming level.

TOTAL SHIFTING POTENTIAL OF APPLIANCE CATEGORY

Based on data on the total amount of lumen for EU27 and the lighting efficiency (Kemna, 2014), we have calculated the total power draw for each type of lighting technology assuming full simultaneous power draw:

- LFL: Linear fluorescent lamps: 56 GW
- CFL: Compact fluorescent light: 36 GW
- Tungsten: 49 GW
- GLS: General lighting service ('incandescent'): 8 GW
- HID: High intensity discharge lamp: 7 GW
- LED: Light emitting diode: 29 GW
- Total: 185 GW

This figure needs to be reduced with a simultaneity factor i.e. taking into account that all lighting devices are not switched on all the time. As a rough estimate, we assume a 30 % simultaneity factor

and a 50 % comfort factor i.e. only 50 % would be possible to switch off without losing unacceptable comfort losses. The total shifting potential is therefore about 28 GW.
Of this total shifting potential, street lighting is estimated at about 5 GW (based on VITO, 2007) and residential and commercial indoor lighting is 23 GW.

If assumed maximum 5 minutes and 30 minutes of acceptable off time per day for residential and commercial indoor lighting and street lighting, respectively, then the switching potential would be about 4 GWh/day.

Comfort and user impact

Assuming that the use of the lighting is already well controlled, either manually or automatic, the negative comfort impact of dimming or switching off will be large; especially in the homes and commercial areas, which may include safety issues. Only very short periods of time would be accepted; we assume 5 minutes per day.

For street lighting the comfort impact may be more limited, at least for shorter periods of time. On average, we assume half an hour per day.

Gaps and/or pre-conditions for the potential to be realised

There are not many technological gaps, because the technology exists.
There may be technological gaps regarding some lighting technologies, which are not suitable for dimming and/or often switching on/or, else the gaps are few and technology are already used for lighting systems on the market.
The control systems may result in standby power consumption.
The main gap is the user impact regarding comfort loss.

Functionalities supporting energy efficiency

For lighting in homes and commercial areas, information feedback on the level of consumption; when the consumption takes places in relation to the needs and efficiency and possibilities of impacting the consumption by behaviour changes and change of bulbs and lighting systems may provide substantial energy savings.
Street lighting is typically highly controlled and professional procured, and only few savings would be possible to achieve with more information feedback.

Conclusion

Due to energy labelling and ecodesign measures, there is a high focus on energy efficient lighting, both regarding efficient lighting devices and regarding efficient control (presence sensors, automatic dimming according to actual needs, etc.). When lighting is an energy service, which needs to be produced simultaneous as the needs occur, all lighting load shifting would have serious user impacts.
Therefore, even though the technical potential is large, the flexibility is low, especially for homes and commercial areas, and the real potential will mainly exist for short periods of emergency load shifting.

References

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BATTERY OPERATED RECHARGEABLE APPLIANCES

DESCRIPTION

This factsheet covers (low power) appliances equipped with battery charging function. These include all kind of multimedia devices (phones, tablets, video cameras, etc.), power tools and other household appliances with rechargeable batteries (clocks, electric shaving, toothbrushes, etc.) on a low power level.
Not included are high power chargers for electric vehicles or in home battery storage, Uninterruptible power supplies (UPS) or industrial appliances.

INSTALLED BASE

The installed base of these appliances is very high.
For smartphones only, the sales figures (IDC[64] and Gartner[65]) worldwide have gone from 300 million in 2010 to more than 650 million in 2012 and grew above 1 billion in 2014. 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 260 million in 2016 (Gartner, January 2015)[66]. 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 EU[67].

SHIFTING OR CAPACITY MODULATING POTENTIAL

SHIFTING OR CAPACITY MODULATING POSSIBILITY

Currently, only a minority of these appliances are ready for smart charging. However a distinction needs to be made between the devices with a rather large processing power capability (most multimedia appliances) and network facilities as well as those without these features. Smart charging functionality could be added as a software application without the need to further adaptations. In the light of the comparatively 'low' selling prices of these appliances, the need for further (physical) adaptations would be also a significant financial barrier.

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[65] Gartner Press Release : Gartner Says Smartphone Sales Surpassed One Billion Units in 2014, March 2015, http://www.gartner.com/newsroom/id/2996817

[66] Gartner, Press Release : Gartner Says Tablet Sales Continue to Be Slow in 2015, January 2015, http://www.gartner.com/newsroom/id/2954317

[67] 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

Shifting or capacity modulating potential per appliance

When looking at the total energy consumption of these appliances:

- Smartphone: 3 to 5 kWh/year
- Tablet: 12kWh/year
- Rechargeable Power Tool: 38 kWh/year

it can be concluded that a flexibility capacity would come from the large number of appliances, rather than the individual power consumption.
Since the multimedia appliances have a high annual usage and therefore will be charging often, there will be a significant potential that can be shifted. This is less the case for other appliances like e.g. rechargeable power tools, since their usage is less predictable.
Also peak powers in the charging of these appliances are rather low, often < 50 W.

Total shifting potential of appliance category

The overall shifting potential of this group of appliances is hard to evaluate, since not much research has been done on this topic. It can be assumed that the largest potential is situated overnight when many of these appliances are connected to the chargers, but as stated, no real figures were found to support this. Also no figures were found on the relationship between average charging times of the appliances and concrete time periods for the connection with the charger.

Comfort and user impact

For evaluating the comfort and user impact, 2 basic scenarios have to be considered. One that keeps the appliance on a minimum “State Of Charge” (SOC) and a second where the appliance should be fully charged at a certain point in time.
In the first scenario, the process could be implemented so that it is executed without user interaction. We could think of laptops that reside a lot in docking stations. This however implies that the appliance cannot be predicted or guaranteed to be fully charged at a certain point of time, limiting flexibility, ‘mobility’ and therefore the comfort level.
The second scenario requires the user to set the ‘be fully charged time’. This could be either done each time the appliance charges, according to defined schedules, or following other similar solutions. The comfort level is higher, but user interaction (change of habits) is required.

Gaps and/or pre-conditions for the potential to be realised

As stated before some appliances could exploit the smart charging facilities just by means of a software adaptation. But for others functional hardware extensions are needed to be able to execute smart charging, i.e. not charging completely to the maximum as soon as connected.
A second important factor is the willingness of end-consumers to apply the smart charging functionality, in order to address e.g. the question: “What is the benefit for users to provide this flexibility?” Business cases should be available to provide sufficient incentives for end consumers to participate in this.

Functionalities supporting energy efficiency

For some battery types (e.g. NiMh) the efficiency is higher between certain SOC levels. The smart charging implementation could include this information. Note that this is not the case for Lithium-ion batteries which represent a large number in the installed base of the here described appliances.

Conclusion

There is a certain potential, however its capacity will depend on controlling large numbers of products. Peak powers and average consumption is rather low for these appliances, whereas numbers are very high (millions).

Limited research has been done on the potential of smart charging in the low power appliances sector, but similar techniques already were investigated for electric vehicles, which could also be applied for this.

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RESIDENTIAL ENERGY STORAGE SYSTEMS

DESCRIPTION

This category represents larger battery storage systems. They fall into the 2 main categories (1) ”backup systems” like Uninterruptible Power Supply systems (UPS) as well as (2) “Battery Energy Storage Systems”, which are mainly designed for load levelling and peak power compensation.

INSTALLED BASE

UPS:

The total installed base for 2011 was calculated as 7.5 million UPS units[68] 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

Important note: 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.

Battery Energy Storage Systems:

Figures of the rated power of US battery grid storage projects in 2013 indicated a total of 304 MW (Grid Energy Storage U.S. Department of Energy), but these are all big installations outside the scope of this study. No figures were found on residential systems, but considering the limited amount of vendors and product availability, figures will be very low at the moment.

SHIFTING OR CAPACITY MODULATING POSSIBILITY

The primary purpose of a UPS is to bridge an unexpected power gap and/or to provide the amount of power needed to safely power down the connected load. Apart from that it can also be used to maintain voltage and frequency within rated steady state and transient bands or to compensate distortions or interruptions to the supplied power within specified limits. Although these systems represent a relevant potential capacity, due to their original purpose, the SOC of these systems has usually to be kept at a fixed ‘high’ level, which strongly limits the shifting possibility.

The main purpose of Battery Energy Storage Systems is to store excess energy produced when demand is low and then make it available when demand is high (E.g. store energy from solar panels during the day and use this during evening hours). Another intended usage is peak power compensation. In this case stored energy is delivered from the Battery Energy Storage Systems to avoid power peaks on the distribution grid.

Other intended usages are power smoothing to prevent sudden surges or drops in power supply, to operate remote and isolated installations (temporary or permanent) not connected to the distribution grid, as well as regulation of grid frequency within pre-set limits. Note that respective legislation rules apply on operating in “off-grid mode” as well as converting to grid connection.

[68] ErP Lot 27 – Uninterruptible Power Supplies, Preparatory Study - Final Report

SHIFTING OR CAPACITY MODULATING POTENTIAL PER APPLIANCE

UPS systems for residential and small business range from 100 kVA up to 5,000 kVA and are usually designed to provide short term bridging periods, e.g. for several minutes to few hours.
On residential and small business level the capacity of Battery Energy Storage Systems usually ranges between 1 and 10 kWh. It should be noted that not many commercially available systems exist at the time of this study, but several manufacturers are already in the process of developing and commercialising such products.

The systems exist as standalone setup (e.g. Samsung) or in combination with energy production systems like PV panel invertors (e.g. Tesla, NEDAP). Some vendors provide systems where the control of production, storage and consumption is fully integrated (e.g. SMA), …

TOTAL SHIFTING POTENTIAL OF APPLIANCE CATEGORY

The potential of both systems is very limited at this moment. For the UPS systems, this is due to its original purpose and the small installed base on residential and small business level.
Battery Energy Storage Systems are still in an early phase of commercialisation, so the installed base is currently very small. From its nature it has a large potential once installed in larger numbers.

COMFORT AND USER IMPACT

Both systems can operate automatically and thus require limited user interaction. The comfort is twofold: improving power quality and providing power assurance (for limited periods).

GAPS AND/OR PRE-CONDITIONS FOR THE POTENTIAL TO BE REALISED

UPS systems already have a high technical maturity and already were subject of an Eco-Design study[i].
The Battery Energy Storage Systems for residential use are rather new, but share technology with UPS systems. However they will operate frequently in different SOC levels and will have therefore different requirements to the batteries used. Additionally the control logic could be more complex, certainly in combined systems as described above.

FUNCTIONALITIES SUPPORTING ENERGY EFFICIENCY

Local storage can aid in the reduction of grid losses.

CONCLUSION

Both described battery storage systems are from a technical point of view similar to each other but differ in their intended usage. The backup systems, by the nature of their usage, do not allow a large amount of flexibility.

The Battery Energy Storage Systems are meant exactly to provide flexibility for different usages, but at the moment their installed base is limited and consequently also the total capacity. However when in future these systems will find broadly their way to the market, they could represent a larger potential.

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Grid Energy Storage U.S. Department of Energy

ANNEX 2: SELECTION OF INITIATIVES RELATING TO DR, SMART HOME AND SMART APPLIANCES

→ Framework Document for the physical characterization of grid-connected buildings

The U.S. Department of Energy (DOE) is working on a Framework Document[69] for the physical characterization of grid-connected buildings end-use equipment and appliances.
The US DOE plans to convene industry and other stakeholders for a harmonised development of protocols while avoiding undue burden on industry, and to measure the responses that connected equipment can provide. The main goals of developing this framework are the following:

- Promote innovation among the industry players.
- Help to establish a scalable market for connected equipment through developing data and information to inform consumers/building owners, manufacturers, and electric and gas utilities.
- Protect consumer value through quality of service and other benefits provided by the equipment as well as to minimise life-cycle operation cost.
- Protect manufacturers by avoiding damage to equipment, violation of warranty, and consumer dissatisfaction.
- Inform utilities and service providers of the end-user, societal, grid, and energy market services that the connected equipment can deliver, as well as create an opportunity for new services and value streams for the different stakeholders in the future.

Status
At an initial public meeting held on April 30th, 2014 in Golden, CO, (79 FR 19322) there was general support from attendees for DOE's vision for characterization of connected equipment and their role as convener of industry stakeholders to develop the characterization protocols in an open and transparent process. A second public meeting was held on July 11th, 2014 in Washington, D.C. (79 FR 32542), at which structure and content for this draft framework document was presented and the attendees were given the opportunity to provide input and discuss the details of the characterization framework. The framework covers the scope, terminology, and definitions of connected equipment, the details of the characterization protocol framework, and the process for developing the characterization protocols. On August 14th 2014 DOE announced the Framework Document and performed a request for comment. Comments were accepted till September 29, 2014.

The **primary objective** of this framework is to describe the characterization protocol structure and performance metrics that stakeholders may use to evaluate the services that connected equipment can deliver. This framework applies to connected buildings' end-use appliances and equipment within residential, commercial, and industrial buildings. The document also described a process for collaborating with industry stakeholders to develop characterization protocols and performance metrics for connected equipment in the future. However, communications and interoperability barriers such as cybersecurity, privacy, message syntax, or signal transmission are not within the scope of this framework document. In addition, DOE is generally aware of several activities ongoing within the industry related to connected appliances and equipment, such as the activities in AHAM, AHRI, ASHRAE, EPA and many other professional societies and trade associations. DOE acknowledges

[69] http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-NOA-0016-0022

the changing landscape of the industry and is performing due diligence to understand ongoing complementary activities underway by stakeholders.

→ Home Gateway Initiative (HGI)

The HGI[70], founded in 2004 by major broadband service providers and joined by leading vendors of digital home equipment, focusses on the way that services are delivered in the digital home. Starting from use-cases and service needs, the HGI publishes requirements and test plans for home gateways, infrastructure devices, and the home network. HGI's strategic focus is helping applications, home gateway middleware and home network-based devices to connect seamlessly. The HGI has members from across the globe, representing the entire spectrum of players in the broadband home area.

HGI is currently looking at smart home architecture and device abstraction aspects. Every device automation solution and HAN technology makes use of assumed/defined models (known properties) for the connected devices. Instead of creating a „superset" of those HAN models, HGI is investigating if a modular extensible modelling template (Smart home Device Template, SDT) can be defined to describe almost every device type (Figure 18).

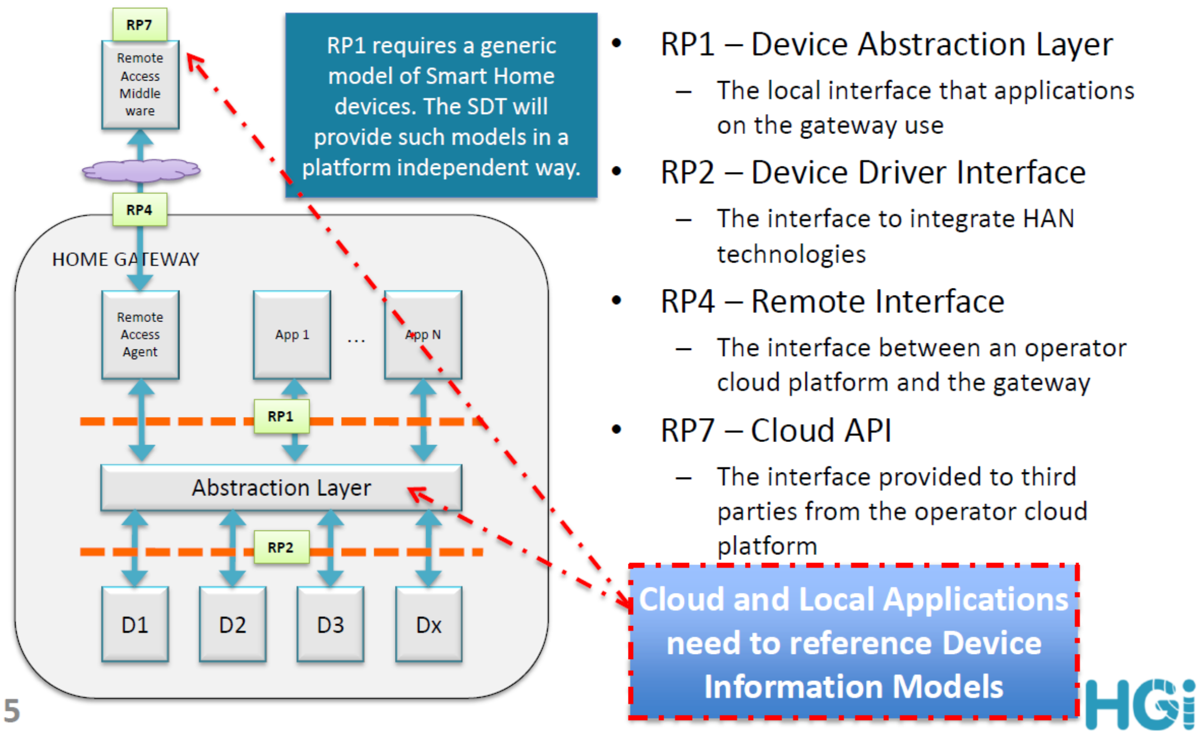

Figure 18: HGIs' Smart Home architecture reference points[71]

[70] http://www.homegatewayinitiative.org/
[71] Open source project at HGI for Smart Home device abstraction templates (SDT), https://www.eclipsecon.org/europe2014/sites/default/files/slides/HGI-SmartDeviceTemplates-Project.pdf

→ OASIS

The Organization for the Advancement of Structured Information Standards (OASIS) is a not-for-profit consortium, that aims at the development, convergence and adoption of open standards for the global information society[72].

Currently, the OASIS Smart Grid Suite of Standards consists of three standards:

- **Energy Interoperation 1.0:** published in December 2011. Energy Interoperation specifies an information model and messages to enable standard communication of DR events, real-time price, market participation bids and offers (tenders) as well as load and generation predictions. Energy Interoperation serves primarily at the interface to deliver DR and DER communications from a grid-side service provider (e.g. a distribution utility, or an aggregator) to a customer facility/home. The specification and schema are all freely available from OASIS[72]
- **EnergyMarket Information Exchange (eMIX)** provides a standardised methodology to describe energy products that might be traded in a competitive marketplace and includes an information model for energy and market information.
- **WS-Calendar** provides a common information model and vocabulary for calendaring and scheduling.

Standards related to IoT/M2M:

- OASIS Advanced Message Queuing Protocol (AMQP) : defines a ubiquitous, secure, reliable and open internet protocol for handling business messaging.
- OASIS Message Queuing Telemetry Transport (MQTT) : provides a reliable lightweight publish/subscribe messaging transport protocol suitable for communication in M2M/IoT contexts where a small code footprint is required and/or network bandwidth is at a premium.
- OASIS Open Building Information Exchange (oBIX) : enables mechanical and electrical control systems in buildings to communicate with enterprise applications

→ Open Interconnect Consortium (OIC)

The Open Interconnect Consortium[73] has being founded by leading technology companies with the goal of defining the connectivity requirements and ensuring interoperability of the billions of devices that will make up the emerging Internet of Things (IoT).
The Open Interconnect Consortium (OIC) will seek to define a common communication framework based on industry standard technologies to wirelessly connect and intelligently manage the flow of information among devices, regardless of form factor, operating system or service provider. OIC also intends to deliver open source implementations for a variety of IoT market opportunities and vertical segments from smart home solutions to automotive and more. At the end of 2014 OIC released the first version of its open source IOTivity[74] resource framework.

The intention of OIC is to create standard specifications for interoperability across connected devices. It will encapsulate various wired and wireless standards and utilise additional standards to create a cross device/cross technology framework for secure device discovery and connectivity. OIC is agnostic to any wireless or wired technology and will work across technologies including Wi-Fi, Bluetooth, Bluetooth LE, Wi-Fi Direct, Zigbee, Zwave, Ant+. It is OIC's intention to create a specification and an open source project that will allow interoperability for all types of devices and operating systems. A OIC certification process is planned but not yet defined.

[72] http://www.oasis-open.org
[73] http://openinterconnect.org/
[74] https://www.iotivity.org/

Leading members (diamond and platinum members) are Intel, Cisco, Mediatek, Samsung, ADT, Atmel, Dell, Eyeball networks, HP.

→ HomeKit - Apple

HomeKit[75] is Apple's attempt to enter the home automation market. It is in fact a home automation framework for developers and uses a common network protocol that devices can employ. The user needs only one app to control all the devices. Thanks to the market dominance of Apple's ecosystem many manufacturers are integrating HomeKit support into their products. Apple's ecosystem is however a closed system. A MFi (Made For iPhone) license is necessary to use particular technology like HAP (HomeKit Accesory Protocol).

→ ThreadGroup

The ThreadGroup[76] is a not-for-profit organization responsible for the market education around the Thread networking protocol and certification of Thread products. Thread is an IP-based wireless networking protocol that addresses the need for a new and better way to connect products in the home. With Thread, product developers and consumers can easily and securely connect more than 250 devices into a low-power, wireless mesh network.
Thread is an IPv6 networking protocol built on open standards, designed for low-power 802.15.4 mesh networks. Existing popular application protocols and IoT platforms can run over Thread networks.
The charter of the Thread Group is to guide the adoption of the Thread protocol. Thread Group founding members consist of industry-leading companies including Yale Security, Silicon Labs, Samsung Electronics, Nest Labs, Freescale® Semiconductor, Big Ass Fans and ARM.

→ Allseen (AllJoyn)

The AllSeen Alliance[77], formed in December 2013, is a nonprofit consortium dedicated to driving the widespread adoption of products, systems and services that support the Internet of Everything with an open, universal development framework. The Alliance hosts and advances an industry-supported open software connectivity and services framework based on the AllJoyn open source project with contributions from Premier and Community Members as well as from the open source community. This open, universal, secure and programmable software connectivity and services framework enables companies and individuals to create interoperable products that can discover, connect and interact directly with other nearby devices, systems and services regardless of transport layer, device type, platform, operating system (OS) or brand.

Initially developed by Qualcomm Innovation Center (QuIC), Inc (Qualcomm's open source subsidiary), AllJoyn is transport-, OS-, platform- and brand-agnostic, enabling the emergence of a broad ecosystem of hardware manufacturers, application developers and enterprises that can create products and services that easily communicate and interact.

[75] https://developer.apple.com/homekit/
[76] http://www.threadgroup.org/
[77] https://allseenalliance.org/

The AllSeen Alliance will not develop standards in the traditional sense. The Alliance seeks to advance and promote a de facto standard through reuse of a common codebase developed in an open source project.

The AllSeen Alliance has nine working groups. One of the working groups, the Smart Home Working Group, develops an AllJoyn smart home service framework focusing on the centralised management aspects for proximal home appliances based on AllJoyn, including both smart home client API and smart home server API. The device implements AllJoyn smart home server API acting as the central control and management point for home appliances operating in the home network that implement AllJoyn smart home client API. The smart home server in the smart home system provides a number of connected-home services for home appliances like centralised security, group control, data collection and logging and so on.

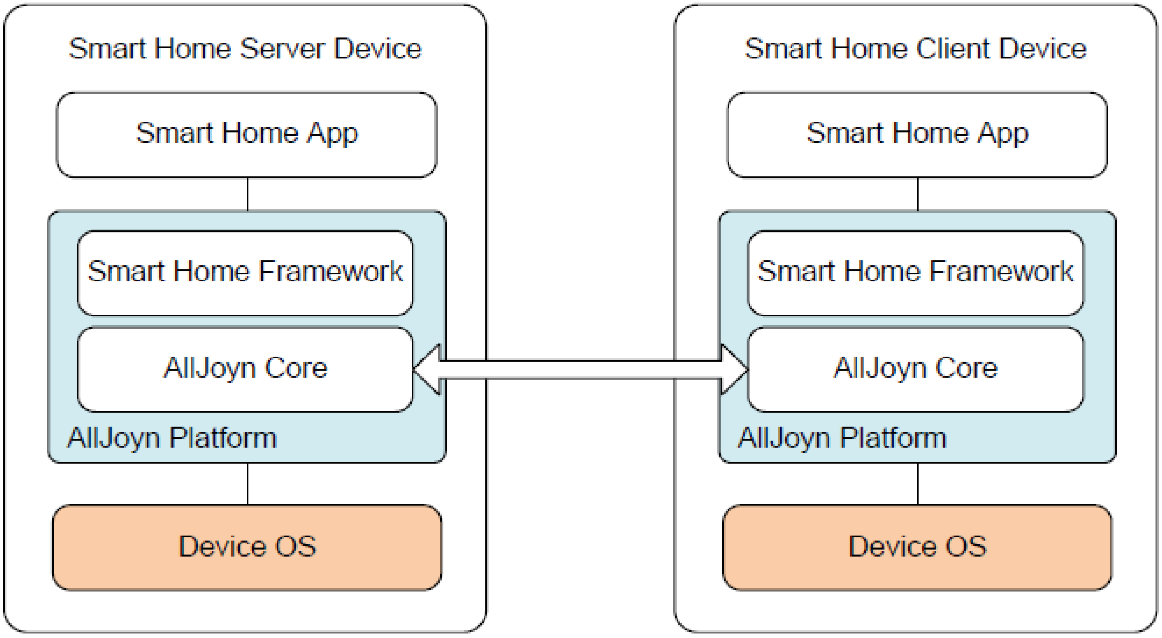

Figure 19: Smart Home service framework architecture within the AllJoyn framework[78]

The Alliance's members are leading consumer electronics makers, industrial solutions providers, service providers, software companies and chipset manufacturers. Premier Members are Electrolux, Hayer, LG Electronics, Microsoft, Panasonic, Qualcomm, Sharp, Silicon Image, Sony, Technicolor and TP-Link.

→ **EEBus - EEBus e.V.**

EEBus[79] is a data model and framework for a Energy Mamagement System (EMS) gateway at home. Many German and some international companies active in home automation and energy management manufacturers like ABB, Schneider Electric, SMA and others are member of the EEBus Initiative e.V. alliance. EEBus cooperates with the KNX association, ZigBee Alliance, Energy@Home alliance and Agora.

[78] Introduction of Smart Home Service framework, Allseen Alliance
[79] http://www.eebus.org/eebus-initiative-ev/

EEBus participates in CLC TC 205 WG 1 regarding the development of standard prEN 50491-12 “Smart Grid interface and framework for Customer Energy Management” and IEC TC 57 WG 21 regarding the development of a Standard IEC 62746 “Systems Interface between Customer Energy Management System and the Power Management System”.

→ **AGORA**

AGORA[80] was born when several large French companies and SMEs (with an opening to international partners) joined forces to design and distribute components, products and terminals that would communicate with services to provide better «smart home» living. The idea was to jointly review all ways to enable domestic technologies to communicate, interact and cooperate. The Parties’ shared goal was to provide residents of «smart homes» with more responsive, more economical and more efficient services by building a bridge linking everything together. This «bridge», in terms of a new household system language, could improve the management of energy, communications, comfort, entertainment, security, home care services and e-health, while protecting personal data. What’s more, it would create new opportunities and open up new ideas, for example through interaction with social networks.

→ **Energy@Home alliance**

Energy@home[81] is a nonprofit association that, for the benefit of the environment, aims at developing and promoting technologies and services for energy efficiency in the home, based upon device-to-device communication. Energy@home envisages a holistic approach where the house is an ecosystem of connected and interacting appliances and sub-systems that coordinate themselves in order to optimise energy consumption, increase energy efficiency and create new services for end customers.
The association's goal is to promote the development and spreading of products and services based on interoperability and collaboration of the different appliances within the household and with the energy infrastructure.

→ **OneM2M**

oneM2M[82] is a global standards initiative for Machine to Machine Communications and the Internet of Things. Seven of the world's leading ICT standards bodies, five global ICT fora and 200+ companies from all industrial sectors are involved.
The purpose and goal of oneM2M is to develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide.

→ **ClimateTalk Alliance**

The ClimateTalk Alliance[83] is an organization of companies who are committed to developing a common communication infrastructure for HVAC and Smart Grid devices, enabling the

[80] http://www.reseau-domiciliaire.fr/home
[81] http://www.energy-home.it/SitePages/Home.aspx
[82] www.onem2m.org
[83] http://www.climatetalkalliance.org

interoperability of diverse systems. The ClimateTalk Common Information Model defines a set of messages and commands that diverse applications can use to communicate with each other. These messages and commands form the presentation and application layers as defined by the OSI model. Below the application layer, ClimateTalk messages can be carried over any type of physical medium.

→ ZigBee Alliance

The ZigBee Alliance[84] developed a set of network and application standards, whereby the network standards provide mesh capability on top of IEEE 802.15.4 wireless networks. Most of the ZigBee application standards are targeted at specific applications (application profiles), but in the context of IoT there is a trend to reunite the different application profiles into one standard, as it is the case with SEP 2.0 and ZigBee 3.0.

ZigBee IP is an open standard for an IPv6-based full wireless mesh networking solution, which provides seamless Internet connections to control low-power, low-cost devices. ZigBee IP was designed to support ZigBee 2030.5 (formerly known as ZigBee Smart Energy 2). It has been updated to include 920IP, which provides specific support for ECHONET Lite and the requirements of Japanese Home Energy Management systems. 920IP was developed in response to Japan's Ministry of Internal Affairs and Communications (MIC) designation of 920 MHz for use in HEMS and Ministry of Economy, Trade, and Industry (METI) endorsement of ECHONET Lite as a smart home standard.

Smart energy Profile 2.0

Smart energy Profile 2.0 (SEP 2.0) has been developed by the ZigBee Alliance in cooperation with WIFI and HomePlug Alliance. It offers a global standard for IP-based control systems, both wired and wireless, for energy management in Home Area Networks (HANs). To ensure interoperability of products, the members of the Consortium for SEP 2 Interoperability (CSEP) are working together to develop common testing documents and processes for certifying SEP 2 interoperability. SEP 2.0 is selected by the United States National Institute of Standards and Technology (NIST) as a standard profile for smart energy management in home devices. IEEE adopted the application standard (formerly known as ZigBee Smart Energy 2) in 2013 as IEEE 2030.5-2013

ZigBee 2030.5 is the ZigBee IP-based implementation of IEEE 2030.5-2013, using ZigBee IP on top of IEEE 802.15.4.

ZigBee 3.0 is the unification of the Alliance's wireless (application) standards into a single standard. It is currently under development and is expected to be ratified by the Alliance members in Q4 2015. ZigBee 3.0 is mainly a wireless protocol stack standard, integrating the former application profiles (ZigBee Building Automation, ZigBee HomeAutomation, ZigBee Light Link, ZigBee Smart energy, etc.) on top of ZigBee Pro.

The ZigBee alliance announced in April 2015 that its' application layer will also run on top of the Thread protocol.

ZigBee Alliance[85]

The ZigBee Alliance consists of a group of companies that maintain and publish the ZigBee standards. The Alliance has three levels of membership: Promoter, Participant and Adopter. The Promotors are: Comcast, Freescale, Itron, Kroger, Landys&Gear, NXP, Philips, Legrand, Schneider Electric, Silicon Laboratories and Texas Instruments.

[84] http://zigbee.org/
[85] http://zigbee.org/zigbeealliance/our-members/

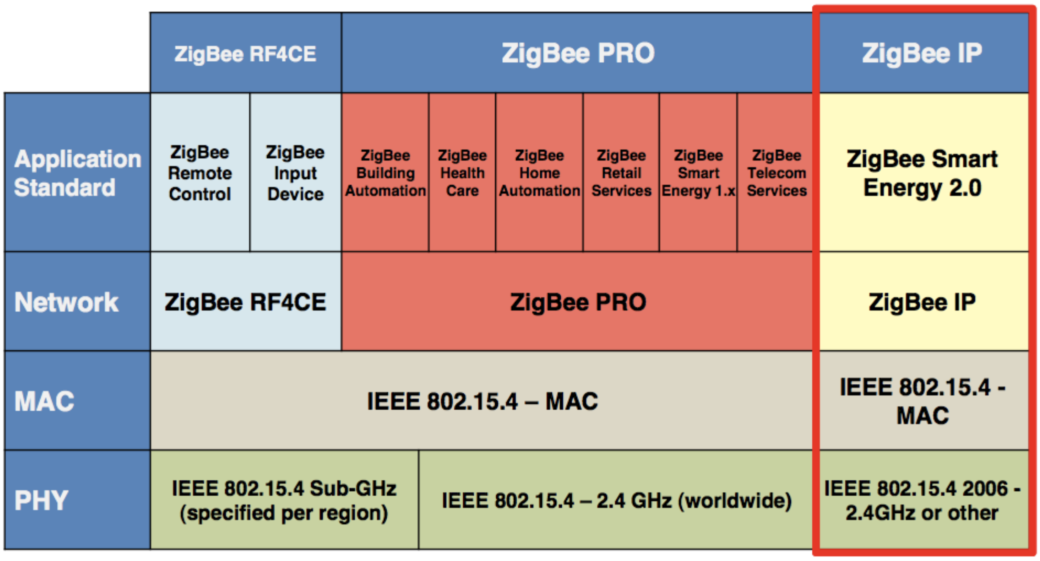

Figure 20: ZigBee protocol stacks[86]

→ **OpenADR Alliance**

The OpenADR Alliance[87] fosters the development, adoption, and compliance of the Open Automated DR (OpenADR) standard through collaboration, education, training, testing, and certification. The OpenADR Alliance is open to all interested stakeholders interested in accelerating the adoption of the OpenADR standard for price- and reliability-based DR.

OpenADR 2.0 is a profile on Energy Interoperation serving DR and DER communications as well as price distribution for both wholesale and retail markets. The OpenADR 2.0 Profile Specifications are developed and maintained by the OpenADR Alliance and available to the public. There are currently two profiles (a and b; c is in progress) to serve less and more capable devices, and diversity in DR and price-responsive programmes. A testing and certification programme has been set up. OpenADR was developed by Lawrence Berkeley National Laboratory to address a low-cost and reliable automation infrastructure to support DR and price communication, allowing electric service providers to communicate DR event signals to customers with automated response capabilities. OpenADR 2.0 is based upon a subset of Energy Interoperable 1.0 (EI 1.0)[88].

The OpenADR 2.0b Profile Specification is approved by the IEC as the Publicly Available Specification (PAS) "IEC/PAS 62746-10-1:2014: Systems interface between customer energy management system and the power management system - Part 10-1: Open Automated DR (OpenADR 2.0b Profile Specification)".

[86] http://greentechadvocates.com/2013/04/04/zigbee-ip-smart-grid-meet-the-internet-of-things/
[87] http://www.openadr.org/
[88] OASIS Energy Interoperation version 1, http://docs.oasis-open.org/energyinterop/ei/v1.0/os/energyinterop-v1.0-os.html

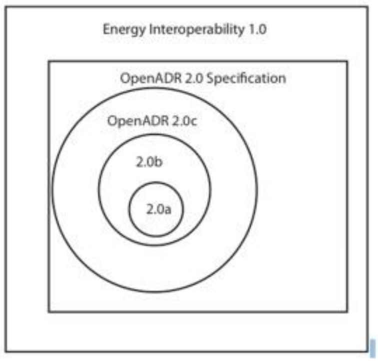

Figure 21: OpenADR profiles

The key difference between the OpenADR and SEP 2.0 is that, while SEP 2.0 is meant to contain all the instructions to command individual devices to take power-saving actions, OpenADR is more of a communications standard to get messages from utilities to their customers.
Originally the scope of OpenADR covered the interface between the utility / energy service provider (ESP) and the customer (energy management gateway), but direct communication with end-devices at the customer premises is included. The scope of SEP 2.0 pertains to the Home Area Network (HAN), but future versions may address communications with other field devices upstream from the home or utility customer premises. (see).

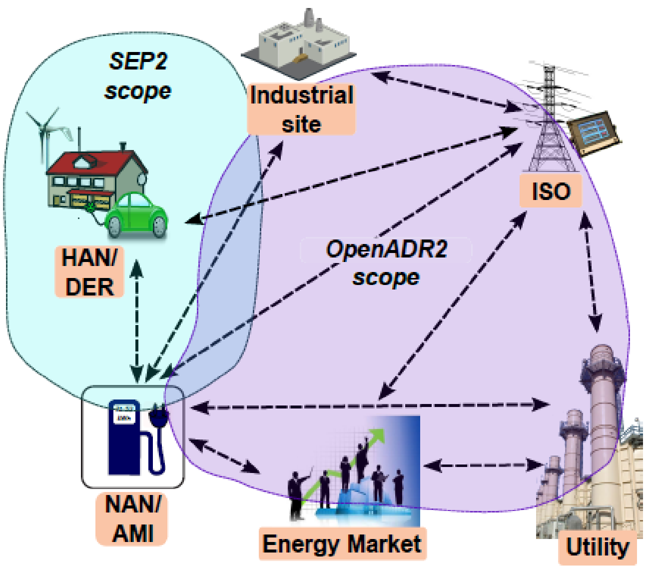

Figure 22: SEP 2.0 versus OpenADR 2.0 scope[89]

[89] [31] R. Kyusakov, J. Eliasson, J. van Deventer and J. Delsing, R. Cragie, "Emerging Energy Management Standards and Technologies - Challenges and Application Prospects.", in Emerging Technologies & Factory Automation (ETFA), 2012 IEEE 17th Conference on, pages 1-8, sept. 2012

→ StarGrid project

The STARGRID[90] project has been initiated by the European Commission in 2012 to provide a clear overview of the current activities, to lay down requirements and evaluation criteria for Smart Grid standards, and to work out recommendations on the future strategy of the Commission regarding Smart Grid standardization. Besides classical Smart Grid topics like interoperability and security, the particular focus of the project is placed on industry requirements. The focus is on three Smart Grid areas: DER integration and Grid Control**,** DR, and Smart Metering.

Two reports (date December 2014) have been prepared by the STARGRID consortium in WP2 ("State of the Art: existing standards and smart grids industry initiatives") to get a comprehensive view of the standardization activities and industry initiatives currently in progress regarding smart grids:

- D2.1 – Smart grid standardization documentation map
- D2.2 – Smart grid industry initiatives documentation map

→ IoT-A

IoT-A[91] was a European FP7 project (September 2010 till November 2013) that addressed the Internet-of-Things Architecture, and created an architectural reference model (ARM)[92] together with the definition of an initial set of key building blocks (terminology[93]). Partners were Alcatel Lucent, CEA, CFR, CSE, FhG IML, Hitachi, IBM, NEC, NXP, SAP, Siemens, Sapienza University of Rome, University of St. Gallen, University of Surrey, University of Würzburg, VDI/VDE-IT and VTT.

→ IPSO alliance

The IPSO Alliance[94] is a global forum that serves as a resource center and thought leader for industries seeking to establish the Internet Protocol as the basis for IoT and M2M applications. The objective of the Alliance is not to define technologies, but to document the use of IP-based technologies defined at the standard organizations such as IETF with focus on support by the Alliance of various use cases. IPSO Alliance promotes the use of smart objects enabling a wide range of applications in areas such as home automation, building automation, factory monitoring, smart cities, structural health management systems, smart grid and energy management, as well as transportation. The Alliance complements the work of entities such as the Internet Engineering Task Force (IETF), the Institute of Electrical and Electronics Engineers (IEEE), the European Telecommunications Standards Institute (ETSI) and the ISA. IPSO Alliance membership is open to any organization supporting an IP-based approach to connecting smart objects.

For instance the IPSO Application Framework document defines a RESTful design for use in IP smart object systems such as Home Automation, Building Automation and other M2M applications. This framework is designed to be complementary to existing Web profiles including SEP2 and oBIX. It provides a 'power' function set to represent power measurement and control related resources, such as power meters, relays and loads. The 'load control' function set is used for demand-response load control and other load control in automation application (not limited to power).

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[90] http://stargrid.eu/
[91] http://www.iot-a.eu
[92] http://download.springer.com/static/pdf/62/bok%253A978-3-642-40403-0.pdf?auth66=1418119352_9e4b9d61f36457488e65265f98fa0c3b&ext=.pdf
[93] http://www.iot-a.eu/public/terminology
[94] www.ipso-alliance.org

→ Open Mobile Alliance (OMA)

OMA was formed in June 2002 by the world's leading mobile operators, device and network suppliers, information technology companies and content and service providers. OMA delivers open specifications for creating interoperable services that work across all geographical boundaries, on any bearer telecommunication services. OMA's specifications support the billions of new and existing fixed and mobile terminals across a variety of mobile networks, including traditional cellular operator networks and emerging networks supporting machine-to-machine device communication.

The motivation of LightweightM2M is to develop a fast deployable client-server specification to provide machine to machine service. LightweightM2M is a device management protocol, but it should be designed to be able to extend to meet the requirements of applications. LightweightM2M is not restricted to device management, it should be able transfer service / application data.

→ Association of Home Appliance Manufacturers (AHAM)

As the trade association that represents the (American) home appliance industry, the Association of Home Appliance Manufacturers (AHAM) is committed to providing innovative and sustainable products that improve the lives of consumers. AHAM represents manufacturers of major, portable and floor care home appliances, and suppliers to the industry. AHAM's membership includes over 150 companies throughout the world.

Because home appliances are an integral part of the Smart Grid, AHAM has drafted a White Paper[95] to communicate the home appliance industry's principles and requirements for the development and implementation of a successful Smart Grid.
A follow-up report of this white paper is a study titled "Assessment of Communication Standards for Smart Appliances"[96] and is a technical evaluation of communication protocols for smart appliances.

This report concluded that:

- For the Application layer, SEP 2.0 and OpenADR scored the highest.
- Across the media and network layers evaluated, Wi-Fi, ZigBee, and HomePlug Green PHY, scored the highest.
- Although there could be other viable architectures, the assessment reflects a clear preference by the home appliance industry that the best communications architecture at this time features a hub or gateway that can communicate using common protocols and serve as the adapter or bridge to other devices on the Home Area Network (HAN).

→ Deutsche Kommission Elektrotechnik and Elektronik Informationstechnik im DIN und VDE (DKE) & Verband Der Elektrotechnik (VDE)

The German Association for Electrical, Electronic & Information Technologies (VDE) with its 36,000 members (including 1,300 companies, 8,000 students, and 6,000 young professionals) is one of the largest technical and scientific associations in Europe. It combines science, standardization work as well as testing and certification under one roof.

[95] AHAM Smart Grid White Paper, http://www.aham.org/ht/a/GetDocumentAction/i/44191
[96] AHAM study, Assessment of Communication Standards for Smart Appliances, http://www.aham.org/ht/a/GetDocumentAction/i/50696

The “Die Deutsche Normungs-Roadmap Smart Home + Building”[97] report describes the German standardization roadmap for smart homes and smart buildings focusing on the energy management, security, entertainment, eHealth/Ambient Assisted Living/Wellness and smart home infrastructure and automation domains.

The report ”Smart Home, IT-Sicherheit und Interoperabilitat als Schrittmacher fur den Markt”[98] looks at IT security and interoperability in the Smart Home. One of the conclusions of this report is the proposal of a voluntary Smart Home Ready label that guarantees not only the interoperability of the different smart home products, but also the compliance of the overall integrated system to general requirements like information security and data privacy. To support such a label a reliable certification approach is necessary. This is the subject of the German, funded project “Zertifizierungsprogramm Smart Home + Building” or the Smart Home Certification Program. In this context the VDE Institute provides the Smart Home test platform for evaluating, testing, and certification of all smart home technologies of the various industries (multimedia, domestic appliances, building automation, heating etc.) currently on the market.
Test procedures for testing interoperability and IT security of systems, components and devices for all areas of smart home applications are developed based on defined test guidelines.
Key aspects of services for smart home applications:

- Testing interoperability and conformity based on use cases in order to be able to connect devices in different systems;
- Testing information security to protect privacy, availability, and integrity of all information in the entire system;
- Providing test methods for protecting against unauthorised intrusion and undesired control capability in the house;
- Testing the functional overall system security of the networked smart home systems on the system level.

→ **White Paper KNX Demand Side Management**

The “White Paper KNX Demand Side Management” document[99] describes the application of demand side management by means of the building automation bus protocol KNX (EN50090). Figure 23 shows an overview of the Demand Side Management beyond the SGCP. Beside DR based upon tariffs also direct load control is considered in load management according EN 50090.

[97] DKE-VDE, “Die Deutsche Normungs-Roadmap Smart Home + Building”, November 2013, http://www.dke.de/de/std/Informationssicherheit/Documents/Deutsche%20Normungs-Roadmap%20Smart%20Home%20+%20Building.pdf
[98] DKE-VDE, ”Smart Home, IT-Sicherheit und Interoperabilitat als Schrittmacher fur den Markt”, November 2014, http://partner.vde.com/smarthome/news/statusbericht/documents/broschuere%20statusbericht%20smart%20home_a4_60%20seiten.pdf
[99] KNX Association, “White Paper KNX Demand Side Management”, Version 2, November 2013

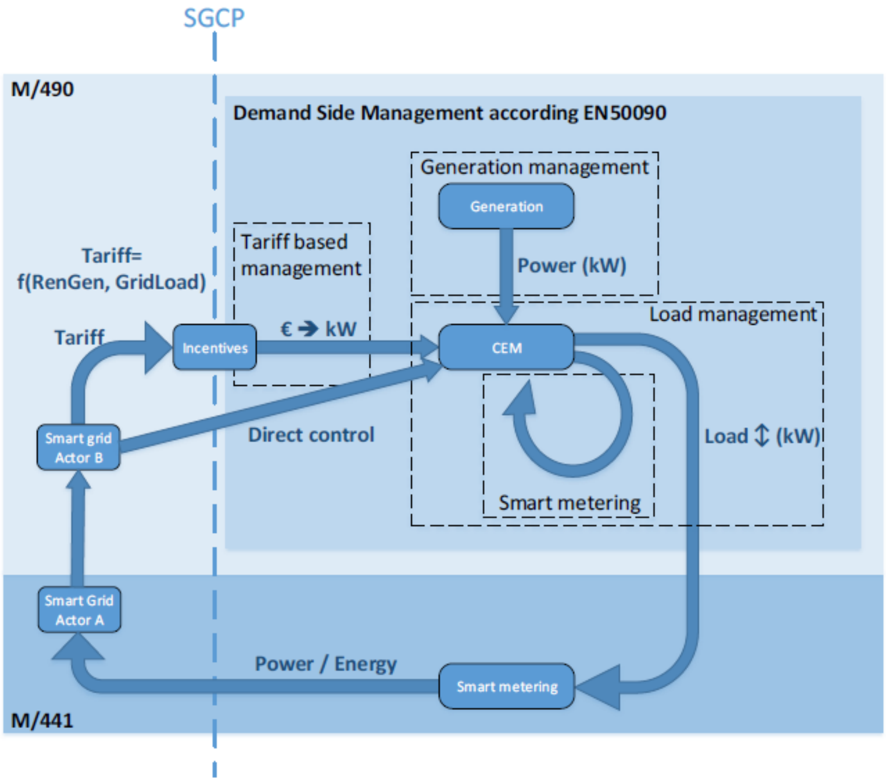

Figure 23: Demand Side Management according the EN50090 in the DR use case[100]

For example to provide the tariff information to KNX new datapoint types (DPTS) in accordance to the EN50090 series can be used. In the paper two DSM approaches can be distinguished:

- Decentralised load management: the CEM recommends new load behaviour. Whether the load behaviour is taken over or not is decided by KNX application managers (for instance a HVAC manager, or a lighting manager) depending on local parameters and boundary conditions.
- Centralised load management: the CEM has direct access to the actuator of the load and can increase, decrease the load or simply switch it on or off.

In case of decentralised load management KNX provides a mechanism called 'Mode Based Load Management' for operating different CEM actors in combination with KNX actors. Different CEMs request a KNX application manager to change its mode in order to increase or decrease the load. Only the CEM with the highest priority level p will affect the KNX application manager. This CEM requests a mode level m with a certain priority level from the KNX application manager. The KNX application manager will only follow this request, if the requested priority level is higher than the currently active priority. The KNX application manager determines the MDT internally based on received parameters from the connected KNX application controllers. In this way it is possible to consider local boundary conditions.

[100] http://www.knx.org/media/docs/Flyers/KNX-Demand-Side-Management-White-Paper/KNX-Demand-Side-Management-White-Paper.pdf

→ ABB, Bosch, Cisco cooperate on smart-home platform

ABB, Robert Bosch and Cisco are forming a joint venture to develop and operate a smart-home software platform. The three companies expect the Germany-based joint venture to start operations in early 2015. The new company will build a platform that will make communication between smart-home appliances and other devices easier. The aim of the joint venture is to develop and operate an open software platform that will enable this simple exchange of data between different manufacturers' devices. The planned platform will also allow the provision of services related to household devices. These could include energy management, security technology and entertainment.

→ Usef – Universal Smart Energy Framework

USEF[101] is a partnership between energy suppliers, network operators, electrical equipment manufacturers, consultancy and ICT companies in the Netherlands. To accelerate the development of commercially viable offerings based on the framework, USEF develops specifications and guidelines that enable you to develop smart energy products, services and solutions in an unambiguous way.

→ IERC - European Research Cluster on the Internet of Things

The IERC[102] - IoT European Research Cluster - European Research Cluster on the Internet of Things is bringing together EU-funded projects with the aim of defining a common vision on the IoT technology and development research challenges at the European level in the view of global development. The rationale for IoT is to address the large potential for IoT-based capabilities in Europe - coordinate/encourage the convergence of ongoing work on the most important issues - to build a broadly based consensus on the ways to realise IoT in Europe.

[101] http://www.usef.info/Home.aspx
[102] http://www.internet-of-things-research.eu/about_ierc.htm

ANNEX 3: KEY STANDARDS RELATING TO DR, SMART HOME AND SMART APPLIANCES

Table 7: Key standards relating to DR, Smart Home and Smart Appliances

TC	TC Reference + title	Availability
IEC, CLC/TC 13	EN 62056-3-1:2014 'Electricity metering data exchange - The DLMS/COSEM suite - Part 3-1: Use of local area networks on twisted pair with carrier signalling'	Available
IEC, CLC/TC 13	EN 62056-5-3:2014 'Electricity metering data exchange - The DLMS/COSEM suite - Part 5-3: DLMS/COSEM application layer'	Available
IEC, CLC/TC 13	EN 62056-6-1:2013 'Electricity metering data exchange - The DLMS/COSEM suite - Part 6-1: Object Identification System (OBIS)'	Available
IEC, CLC/TC 13	EN 62056-6-2:2013 'Electricity metering data exchange - The DLMS/COSEM suite - Part 6-2: COSEM interface classes'	Available
IEC, CLC/TC 13	EN 62056-7-6:2013 'Electricity metering data exchange - The DLMS/COSEM suite - Part 7-6: The 3-layer, connection-oriented HDLC based communication profile	Available
IEC, CLC/TC 13	EN 62056-8-3:2013 'Electricity metering data exchange - The DLMS/COSEM suite - Part 8-3: Communication profile for PLC S-FSK neighbourhood networks'	Available
IEC, CLC/TC 13	EN 62056-9-7:2013 'Electricity metering data exchange - The DLMS/COSEM suite - Part 9-7: Communication profile for TCP-UDP/IP networks	Available
IEC, CLC/TC 13	FprEN 62056-1-0 'Electricity metering data exchange - The DLMS/COSEM suite - Part 1-0: Smart metering standardization framework'	Available
IEC, CLC/TC 13	FprEN 62056-4-7 'Electricity metering data exchange - The DLMS/COSEM suite - Part 4-7: DLMS/COSEM transport layer for IP networks'	Nov. 2015
IEC, CLC/TC 13	EN 62056-5-3:2013/FprA1 ''Electricity metering data exchange – The DLMS/COSEM suite - Part 5-3: DLMS/COSEM application layer'	Nov. 2015
IEC, CLC/TC 13	EN 62056-6-1:2013/FprA1 'Electricity metering data exchange – The DLMS/COSEM suite - Part 6-1: Object Identification System (OBIS)'	Nov. 2015
IEC, CLC/TC 13	EN 62056-6-2:2013/FprA1 'Electricity metering data exchange – The DLMS/COSEM suite - Part 6-2: COSEM interface classes'	Nov. 2015
IEC/TC 13	IEC 62056-7-5 'Electricity metering data exchange – The DLMS/COSEM suite – Part 7-5: Local data transmission profiles for Local Networks (LN)'	Mar. 2016
CEN/TC 294	EN 13757-3 :2013 'Communication systems for and remote	Available

	reading of meters - Part 3: Dedicated application layer’	
CEN/TC 294	EN 13757-4 :2013 ‘Communication systems for meters and remote reading of meters - Part 4: Wireless meter readout (Radio meter reading for operation in SRD bands)	Available
CEN/TC 294	prEN 13757-5 ‘Communication systems for meters and remote reading of meters - Part 5: Wireless relaying	Sept.2015
CEN/TC 294	FprEN 13757-1’ Communication systems for and remote reading of meters - Part 1: Data exchange	Sept. 2014
CEN/TC 294	EN 13757-3:2013/prA1 ‘Communication systems for meters and remote reading of meters - Part 3: Dedicated Application Layer’	New Work
CEN/TC 294	prEN 13757-6 ‘Communication systems for meters and remote reading of meters - Part 6: Local Bus	New Work
CLC/TC 205	prEN 50491-11’ General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) – Part 11: Smart Metering - Application Specifications - Simple External Consumer Display’	Sept. 2015
CLC/TC 205	prEN 50491-12 ‘General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) – Part 12: Smart grid - Application specification - Interface and framework for customer’	2016
IEC/TC 57	IEC 62746 ‘System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid’	2014/2015
IEC/TC 57	IEC 62746-2 TR Ed.1: Systems interface between customer energy management system and the power management system - Part 2: Use cases and requirements	New work
IEC/TC57	IEC 62746-3 ‘Systems interface between customer energy management system and the power management system - Part 3: Architecture’	New Work
IEC/TC 57	IEC/PAS 62746-10-1:2014: Systems interface between customer energy management system and the power management system - Part 10-1: Open Automated DR (OpenADR 2.0b Profile Specification)	2014
SC25/WG1	ISO/IEC 15045-1:2004 Information technology – Home electronic system – Gateway – Part 1: Introduction	2004
SC25/WG1	ISO/IEC 18012-1:2004 Information technology – Home electronic system – Guidelines for product interoperability – Part 1: Introduction	2004
SC25/WG1	ISO/IEC 15045-2:2012 Information technology – Home electronic system – Gateway – Part 2: Modularity and Protocol	2012
SC25/WG1	ISO/IEC 18012-2:2012 Information technology – Home electronic system – Guidelines for product interoperability – Part 2: Taxonomy and Lexicon	2012
SC25/WG1	ISO/IEC 15067-3:2012 Information technology – Home Electronic System (HES) application model – Part 3: Model for an energy management system for HES	2012

ISO/TC 205	Building Automation and Control Systems (EN ISO 16484) (BACS) mainly covers the tertiary sector. EN ISO 16484 Part 5: Data communication – Protocol, prepared by the ASHRAE[103] (this part is identical to the BACnet standard ANSI/ASHRAE 135-2004 standard), defines the communication protocols of Building Automation and Control Systems, including ventilation, air conditioning and heating products.	2010
IEEE	**IEEE 2030.5-2013 - IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard**[104] The defined application protocol is an IEEE adoption of the Smart Energy Profile 2.0 protocol and is an IEC 61968 common information model (IEC 61968) profile, mapping directly where possible, and using subsets and extensions where needed, and follows an IETF RESTful[105] architecture.	
ANS/CEA; ISO/IEC	**Modular Communication Interface: ANSI/CEA 2045** The specification details the mechanical, electrical, and logical characteristics of a socket interface that allows communication devices to be separated from end devices. It provide a means by which residential products may be able to work with any load management system through user installable plug-in communication modules. This specification identifies the physical and data link characteristics of the interface, along with certain network and application layer elements as needed to assure interoperability over a broad range of device capabilities. In addition, it defines a mechanism through which application layer messages (defined in other standards) may be passed across the interface. It also specifies a basic DR interface. This standard provides a solution to the heterogeneous communication environment in a building through a modular communications interface (MCI) enabling any product to connect to a variety of demand-response systems. The concept is: encourage manufacturers to build an MCI into their products that can accept a simple communications module. Consumers and programme managers are then free to select whatever communication solution works best for their particular environment. This ANS/CEA standard is being submitted to ISO/IEC and is currently a working draft standard ISO/IEC 10192-3 “Modular communications interface for energy management”.	ISO/IEC working draft standard

[103] ASHRAE : American Society of Heating Refrigeration and Air-Conditioning Engineers
[104] http://standards.ieee.org/findstds/standard/2030.5-2013.html
[105] "RESTful" refers to the Representational State Transfer (REST) architecture