Preparatory study on Smart Appliances (Lot 33)

Task 7 – Policy and Scenario analysis

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LIST OF ACRONYMS

LLCC	Least Life Cycle Cost
BAT	Best Available Technology
BAU	Business As Usual
CEM	Customer Energy Manager
DR	demand-response
DSF	Demand Side Flexibility
EPBD	Energy Performance of Buildings Directive
GPP	Green Public Procurement
HEM	Home Energy Manager
IoT	Internet of Things
KPI	Key Performance Indicator
MEErP	Methodology for Energy related products
NEEAP	National Energy Efficiency Action Plan
RES	Renewable Energy Sources
VRES	Variable renewable energy resources

INTRODUCTION

The general objective of this Task 7 report is the identification of policy approaches and key elements for potential Ecodesign/Energy Labelling implementing measures that support the introduction, acceptance and uptake of smart appliances in the context of this preparatory study.

The report is organized in 2 main parts: "Part I: Focus" and "Part II: Technical requirements". Part I starts with the identification of the broad categories of policy approaches that have potential to be chosen to stimulate uptake of energy smart appliances: mandatory versus non-mandatory, horizontal versus vertical, standardization, etc. and concludes with a general policy approach. Due to the broad appliance scope, today, not all appliances in scope are subject to Ecodesign minimum requirements and/or Energy labelling directives. Part I summarizes the conclusions of Task 5 and 6 which are used as starting point for the appliance categorization. All appliances are split-up in groups with similar technical properties. In the scenario and impact analysis, the use cases were focused on the system level benefits which do not directly relate to specific requirements at the level of the appliance. Part I discusses the relationships between the system level use cases and use cases as they are experienced from a customer/appliance point of view. This will result in a number of interface architectures which will be discussed. Attention will be paid as well to the level of interoperability which should be defined in the policy recommendations.

After the categorization and refinement of the focus in Part I, the technical requirements for energy smart appliances will be defined in Part II. In some cases several requirement options are discussed and a recommend option will be selected. Some requirements are worked out per appliance group.

PART I: Focus

7.1. Overview of policy approaches

There are several product policy instruments available, which could be used to support the desired development of energy smart appliances. The basic types of policy instruments as presented below will be analysed in the following sections for the specific case of energy smart appliances.

The first overall decision to be made is whether there is a need for EU intervention. In any case, a no EU action scenario needs to be defined, because this will be the BAU scenario against which the other policy scenarios will be assessed.

EU product legislation in the area of environmental performance is mainly based on the following individual or combined options:

- Ecodesign requirements (under the Ecodesign Directive (2009/125/EC)): This means mandatory minimum requirements would be introduced for a set of parameters, the manufacturers would bear the responsibility for their products to be compliant when placed on the market and the Member States would verify compliance via market surveillance activities. This acts as a "push" instrument for products to achieve better performance because all appliances will have a minimum level of energy efficiency performance regulated by the implementing measure.
- Energy labelling (under the Energy Labelling Regulation (2017/1369/EU)[1]): This implies mandatory labelling of the product for a set of parameters. Manufacturers are responsible for labelling their products and it is also enforced by Member State market surveillance. This acts as a "pull" instrument because the consumers will choose the products they want to purchase which can pull the market towards higher energy performance
- Self-regulation as an alternative to Ecodesign requirements: The Ecodesign Directive (2009/125/EC) recognizes self-regulation by industry as an alternative to binding legislation. Self-regulation, which can be based on voluntary agreements, is a valid alternative as long as it delivers the policy objectives set out in the legislation faster and in a less costly manner than mandatory requirements. The directive gives specific requirements for self-regulative measures.
- Voluntary labelling: This implies manufacturers can choose whether to label their products. In the case of ENERGY STAR[2] and Ecolabel[3], the specifications are established through regulations, ensuring that the labelled product belongs to the upper segment of the market in terms of energy consumption and other environmental aspects. Member States are responsible for market surveillance.

The ecodesign policy option can be implemented as a horizontal measure i.e. broadly over a range of products, or as a vertical measure i.e. only for a particular product group, where the latter can be valid for several types of products but with different requirements for each product type.

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[1] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU

[2] Regulation (EC) No 106/2008 of the European Parliament and of the Council of 15 January 2008 on a Community energy-efficiency labelling programme for office equipment (recast version)

[3] Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel

Complementarily, Ecodesign and Energy Labelling Regulations usually are accompanied by harmonized European standards for the measurement method. Harmonised standards are developed by the ESOs (European Standardisation Organisations), always upon a standardisation request from the European Commission. The harmonised standards may be developed after the effective dates of the regulations and transitional methods of measurement and calculation may be published in advance of the harmonised standards.

This section lists and describes the various policy instruments applicable in more detail. Section 7.1.4 lists and describes the proposed policy options for an implementing measure.

The Regulation, setting a framework for Energy Labelling[4], indicates that the Commission is empowered to adopt delegated acts relating to specific product groups which shall specify, where appropriate: "the inclusion of a reference in the label allowing customers to identify products that are energy smart, that is to say, capable of automatically changing and optimising their consumption patterns in response to external stimuli (such as signals from or via a central home energy managing system, price signals, direct control signals, local measurement) or capable of delivering other services which increase energy efficiency and the up-take of renewable energy, with the aim to improve the environmental impact of energy use over the whole energy system".

In line with this Regulation, appliances which are capable of adapting their energy consumption pattern as a response to external stimuli (e.g. price signal, control signal) will be called "energy smart appliances" in the remainder of this document. This replaces the name DSF enabled appliances which was used in Tasks 1 to 6 of this study.

7.1.1. NO EU ACTION

The no EU action option implies that no further legislative actions at European level on energy smart appliances will be implemented. This is also known as the Business-as-Usual (BAU) scenario, which means that existing EU regulations will continue to be in place. Member States and industry will potentially take further measures to increase the uptake of smart appliances. The BAU scenario also serves as a reference for assessments of impacts for proposed policy options.

The assumptions on the developments of the smart appliances in the BAU scenario are detailed in Task 6:

- The market of the appliances in scope of the study will continue to increase in terms of sales and stock cfr. the tendencies identified in Task 2;
- The inclusion of networked and smart functionalities of the appliances in a broad understanding (i.e. not specifically for energy smart) will continue to grow;
- At a low degree, some appliances will provide energy smart functions – probably mainly manually adaptable by the user i.e. the users will be able to switch on and off and/or set a scheduling either in relation to time or to flexible tariff signals;
- Energy utilities will mainly use flexible tariffs as a means for obtaining demand side flexibility;
- For the appliances with larger flexibility potential (cfr. Task 3), individual and non-harmonised schemes are expected to be set-up for the larger Member State markets at a low scale;

[4] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU

- There will be no harmonised labelling of DSR-functionalities, neither a harmonised test method for these functionalities;
- Appliances will not be interoperable across technical solutions and connectivity platforms.

7.1.2. Non-Mandatory Options

Non-mandatory policy approach could mean voluntary labelling schemes or voluntary agreement proposed by the industry for energy smart appliances.

7.1.2.1 Voluntary labelling

Voluntary labelling could be established in such a way that manufacturers may label their products if compliant with requirements of the label and after application or registration at an EU central body or at national bodies.

It would then be up to the manufacturers to decide if they want to have their product labelled, but if they choose so, they need to comply with the technical requirements. Usually manufacturers apply for the label, such as Ecolabel, for their product, and once confirmed that the product is compliant with the voluntary labelling requirement, then the product will receive permission to be labelled, this ensures no product is labelled without being compliant.

There has been neither formal proposal from the industry to the Commission, nor serious discussion of the possibility of voluntary labelling. This is mostly likely because this area covers broadly many types of manufacturers and industry associations and it would be quite difficult to agree and coordinate between them, contrary to the existing Voluntary Agreements which are for the same type of industry.

7.1.2.2 Self-regulation

The idea behind self-regulation provided in the Ecodesign Directive is that *"Priority should be given to alternative courses of action such as self-regulation by the industry where such action is likely to deliver the policy objectives faster or in a less costly manner than mandatory requirements. Legislative measures may be needed where market forces fail to evolve in the right direction or at an acceptable speed."*[5] It was anticipated in the Directive that self-regulation can be established easier, faster and cheaper and be more adaptive regarding the technological and market development compared to regulation.

If a self-regulation should be an alternative to an implementing policy measure, the self-regulation should comply with a number of criteria such as openness of participation, added value, representativeness, quantified and staged objectives, involvement of civil society, monitoring and reporting, cost-effectiveness of administering a self-regulatory initiative, sustainability and incentive compatibility.[6]

[5] 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 (recast).
[6] Details are provided in Annex VIII of the Ecodesign Directive.

Self-regulation is as such a voluntary and non-mandatory option, but the manufacturers who have agreed to follow the voluntary agreement under the self-regulation, will be obliged to do it, else they risk to be removed from the agreement. If there is a too low coverage of the industry sector, the self-regulation is not complying with the objectives and the European Commission may not continue to see it as a valid alternative to regulation.

Typically, self-regulation in the form of a voluntary agreement is used for smaller and well-defined product groups such as imaging equipment and complex set-top boxes. For a broader product area, such as smart appliances, it would be more challenging to establish self-regulation. Just the requirement of representativeness would be difficult to manage for a horizontal regulation covering many types of products.

Therefore, self-regulation is not an obvious option in the context of Lot 33, due to the very broad product scope involving many industry sectors and many actors, contrary to the existing Voluntary Agreements. It would especially be difficult for sectors with fragmented manufacturing structure, where the risk would be not to have sufficient manufacturer participation and there might be competitive advantages for free-riders and non-participants.

It is furthermore not an option that the European Commission would launch a self-regulation initiative, but rather up to industry actors to take such initiative. Until now, the industry has not proposed any self-regulation measure.

For these reasons, this option has not been further analysed.

7.1.3. MANDATORY OPTIONS

A mandatory approach initiated by the European Commission would typically be implemented via an Ecodesign and/or Energy Labelling implementing regulative measure. This means that products in scope of the implementing measure would need to comply with the minimum requirements set out in an Ecodesign and/or an Energy Labelling Regulation to be placed on the EU market and are subject to Member States' market surveillance.

Three types potential requirements should be differentiated up-front:

a) Ecodesign minimum requirements on (so far non-energy smart) appliances
b) Ecodesign information requirements on energy smart appliances
c) Energy Labelling requirements on energy smart appliances

See the following sub-sections for assessing the appropriateness in setting these types of requirements.

When setting a mandatory option, most often, there is a need to develop harmonized European standards to verify compliance with regulation, though the standards may not need to be in place before the requirements take effect. This may concern measurement of consumption levels, verification of power management requirements, material content, functionality, test product configuration, test setup, etc. A possible basis for the standards to be developed include international standards, industry standards and industry practices. Often there will be transitional test methods to be used until a harmonized standard is developed.

The European Commission may issue a standardisation request to the ESOs with the aims of the standard(s) to be developed, timeframe etc.

Specifically in the context of Lot 33, a harmonised standard could serve to describe a procedure that verifies energy smart functionalities and/or, interoperability. It could also be an option to develop an interoperability standard.

For mandatory options, Member States are responsible for the market surveillance. Typically, market surveillance is taking place by checking the technical documentation of the product to assure that the product is compliant based on this documentation. A further market surveillance can take place by selecting products for laboratory tests, where the product is tested with respect to its specific requirements.

7.1.3.1 Ecodesign policy option

Ecodesign requirements typically include minimum energy performance standards e.g. minimum energy efficiency levels, power management requirements and other types of requirements which will have an impact on use of energy and other resources. Requirements in implemented measures can be established for particular product types in vertical regulations or for groups of products as horizontal measures. All products in scope need to comply with the requirements within a given timeline.

The basic idea is to remove the worst-performing products from the market, where non-compliant products are not allowed to be marketed and sold in EU. Typically, information requirements are also included, which make the manufacturer responsible for publishing on a website and in the user manual a set of information items and data which helps the consumer in selecting and using products with respect to their energy consumption.

a) Ecodesign requirements on (so far non-energy smart) appliances
A potential Ecodesign Regulation could be adopted for all appliances in scope to implement energy smart functionalities, it is probably the most ambitious policy approach. It has several implications.

As a point of reference, Ecodesign and Energy Labelling are traditionally based on the least life cycle costs of a product or product group. Buying an Ecodesign-conform product or a product with a high energy efficiency class on the label will have a proven positive energy cost impact for the users of the products. This is not the case for energy smart appliances, because the enabling of the energy smart functionality does not necessarily lead to operating cost savings for the appliance, as these are dependent on the financial remuneration provided through the tariff structures or though contractual arrangements with energy service providers, such as aggregators and network operators. Thus, the main part of the benefits will only occur for the users, when they enter such contractual arrangements.

On the other hand, an Ecodesign requirement, which would require an appliance to provide energy smart-functionalities would typically have an immediate increase in the purchasing cost. However, the mandatory ecodesign requirement would create a very large market with substantially reduced costs of the energy smart functionality and interoperability for the individual appliance resulting a very low or zero increase in purchase price.

At the same time, it can be expected that many of the appliances covered would never be used for demand side management, which means that the additional manufacturing and purchasing costs may never be off-set for the consumer and in macro-economic terms.

Some stakeholders indicated that mandatory ecodesign requirements are needed in order to guarantee the wide penetration of energy smart products in EU and to ensure a higher economic value for the whole energy system. Furthermore, for the types of appliances (e.g. household appliances) with a relatively low impact, penetration should be high in order to obtain substantial flexibility.

The comments submitted from a broad range of industry stakeholders and Member States generally do not support mandatory ecodesign policy option at this moment with the following arguments:

- Consumers would not have the choice between energy smart capable and non-energy smart capable appliances;
- The market is technically not yet fully ready which could result in a higher cost increase if all products over a short period of time would need to be converted to smart appliances (this also depends on the tiers chosen). Technical implementation is expected to be too costly compared with the currently expected amount of users interested in energy smart appliances and the related economic benefit for the society;
- Consumers would risk higher appliances prices without any compensation and the financial benefits are still uncertain (depending on the business cases and the degree to which these are picked up);
- Low end products would not have the sufficient functionality and computing power to sustain the energy smart functionalities and would therefore have a relatively higher cost increase too add this than high end products.

Only in a future situation where the appliances marketed are smart and additional functionality for being energy smart only implies minor or zero costs, this may be economic feasible to implement.

Ecodesign minimum requirement option is therefore not assessed further.

b) Ecodesign information requirements on energy smart appliances

Ecodesign Regulation is not only an instrument to set minimum requirements, but also to set information requirements on the product itself, publically accessible websites and technical documentation that could be useful for consumers. Energy smart appliances, already covered by Ecodesign Regulations, can utilise the existing policy infrastructure and a single implementing measure can be used to amend all relevant Ecodesign Regulations with information requirements for an energy smart icon/label for energy smart appliances. More ambitious ecodesign requirement could be set besides the labelling of Energy smart appliance, e.g., to include technical requirements for supporting energy efficiency at the user level, such as measuring and logging the total power consumption.

Smart

Figure 1 Example of smart appliance logo for ecodesign information or icon on energy labels

Presentation, location and design of the logo can take inspiration from the draft working document on amended ecodesign regulation on displays where it is required that: “electronic displays shall be labelled with the "Mercury inside" logo. A "Mercury free" logo may be used if no mercury is used in the backlighting system or other component. The logo shall be visible without the removal of a cover, durable, legible and indelible. The logo shall be in the form of the following graphic”. However, the same icon/label would be used for ecodesign and energy labels if both options are chosen for the product group.

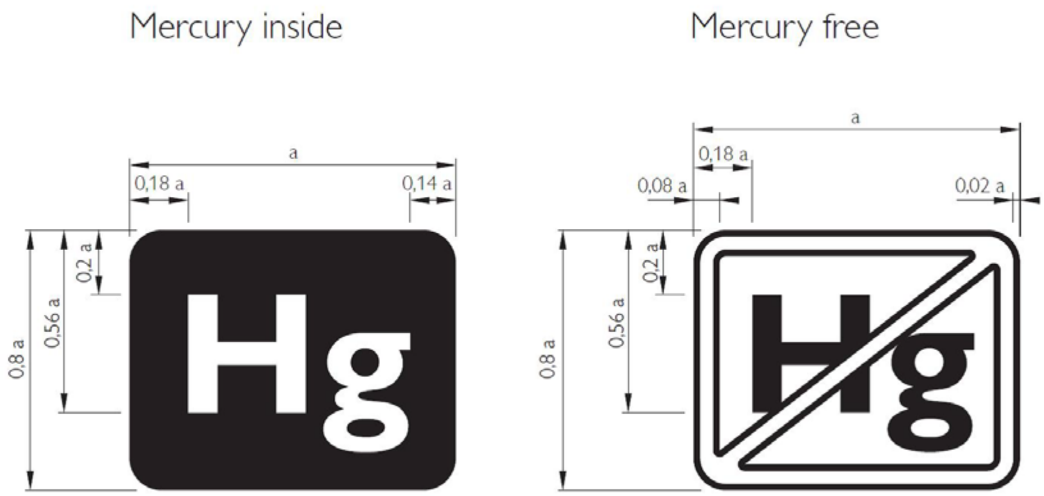

Figure 2 Example of "Mercury inside" logo and "Mercury free" logo proposed for the ecodesign working document for electronic displays

This option could be used for products under existing ecodesign measures, which are not under energy labelling measure and it is therefore considered as a recommended policy instrument for smart appliances.

7.1.3.2 Energy labelling policy option

Complementarily to Ecodesign which acts as a “push” force for the market to increase efficiency via removing the worst performing market, Energy Labelling acts as a “pull” force for the general market performance. However, Energy Labelling requirements are just as mandatory as ecodesign, if the product is to be placed on the EU market.

c) Energy labelling requirements on energy smart appliances
A potential Energy Labelling option would be to define energy smart appliances and to establish labelling requirements for this category of appliances.

Labelling of smart appliances can be implemented under the Energy Labelling regulation,[7] which would enable the end-user to recognize energy smart capabilities of the appliance. Use of this policy option would require that either existing energy label regulations (delegated act) for each of the product types in scope should be introduced or revised to require inclusion of the above mentioned information.

Specific mandatory Energy Labelling could be: A smart appliance that is currently covered by an existing Energy Labelling Regulation, needs to comply with specific criteria for energy smart functionality to be allowed to use the “energy smart - icon” on the label.

Thereby, only appliances meeting these criteria would be allowed on the market with the Energy Label for energy smart appliances. However, non-smart appliances would not be banned from the

[7] Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU

market. Consumer choice would not be restricted and end-users would have the choice between energy smart and non-energy smart appliances.

Labelling also ensures that the specifications and definitions used by manufacturers for energy smart functionality and interoperability are harmonized. The Energy Labelling Regulation could also require manufacturers to provide additional information on the label such as the energy consumption when the product is in an energy smart mode, or network protocol. Another option would be to include the information in the product fiche, which is targeted the consumers. Hence, labelling creates a level playing field which allows the end-user to make a better informed choice.

The Energy Labelling is therefore considered as a recommended policy instrument for smart appliances.

Additional to an energy smart - icon on the energy label, it should be investigated how other names for similar energy smart functionality can be protected (e.g. 'smart appliance', 'DR ready', 'DSF capable', etc.). Allowing the use of these terms only for appliances that comply with the requirements, guarantees a level playing field, transparency, protection for consumers, and avoids free-riding by non-compliant manufacturers using those terms.

7.1.3.3 Vertical versus Horizontal Options

The measures could be implemented via a horizontal regulation covering all relevant product groups, where the requirements are generic because they should apply to different product groups. Alternatively or additionally, various vertical product-specific regulations could be implemented, respectively, relevant elements could be included in existing vertical regulations with the requirements being adapted to the specific functionalities of each product group.

The advantages of the horizontal regulation are that it is easier to develop and adopt, because it is concentrated in only one regulation. It is also easier for the consumers to understand, because the same requirements apply to all product groups in scope. However, some functionality may be lost due to the need to harmonize across product groups.

Industry stakeholders generally tend to support vertical regulations with the argument that the regulation needs to be adapted to the individual product groups. Specifically in the context of Lot 33, reference is made by industry stakeholders to the possibilities and requirements of energy smart functionality which differs between products; covering everything in a single horizontal approach risks to lead to a very complicated approach. It was recommended that horizontal policy approaches should only be applied at a relatively generic requirement level, such that industry keeps the necessary freedom to adapt different innovative solutions to specific product needs. To cover everything in a single horizontal approach will make it unduly complicated for some products and may create a situation where opportunities for other products are missed.

Product groups, selected to be part of energy smart policy measures, with existing relevant ecodesign and/or energy labelling regulations may need to be investigated regarding confusing or even contradicting provisions that may emerge. A concrete example is the ecodesign requirements under Lot 2 for water heaters which specify minimum functionality for smart control. 'Smart control' is defined in regulation No 814/2013 of 2 August 2013 as: "a device that automatically adapts the water heating process to individual usage conditions with the aim of reducing energy consumption". It needs to be investigated if the existing regulation may need to be amended in order to avoid confusion of the end consumer as to the implications of the term 'smart' or whether other instruments such as e.g. a unique label can be a sufficient solution.

Vertical options for smart appliances do not have to be administratively cumbersome, as one implementing measure can amend a number of energy labelling regulations within the scope at the same time, with amendment text in each annex. Inspiration can be taken from precedent of Commission Delegated Regulation (EU) No 518/2014 with regard to labelling of energy-related products on the internet [8] and Commission Regulation (EU) 2016/2282 amending various regulations with regard to the use of tolerances in verification procedures[9].

7.1.4. Proposed policy option

Based on the assessment of the policy options and in line with Regulation (EU) 2017/1369, the inclusion of a reference under the form of an icon in the Energy Label combined with a label information requirement under the ecodesign regulation is the best policy instrument as it does not limit consumer choices, while providing uniform information to enable better comparison of products, as well as ensuring compatibility of energy smart appliances. This allows consumers to purchase without need of in-depth technical understanding.

Therefore, one Energy Labelling implementing measure for energy smart appliances is proposed for the products currently covered by an Energy Labelling Regulation.

For other energy smart products, which currently are not covered by Energy Labelling already, cannot be included unless an in-depth study of each product group is performed for proposing a new Energy Labelling Regulation.

For these products not under Energy labelling regulation but under the Ecodesign regulation, it is proposed to use the information requirement possibility in the ecodesign framework directive.

A brief summary of the recommendations is:

1. For all appliances in scope and covered by existing Energy Labelling Regulation, an energy smart icon should be added on the energy label if the product complies with the criteria for energy smart functionality and possible additional technical requirements for supporting energy efficiency at the user level. Additional information such as the energy consumption in an energy smart mode, or network protocols supported could be added to the label or the product fiche.

2. For all appliances in scope and not covered by an existing Energy Labelling Regulation, but covered by an existing Ecodesign Regulation, the product should have an energy smart icon attached if the product complies with the criteria of energy smart functionality and possible additional technical requirements for supporting energy efficiency at the user level.

3. Appliances in scope and not under neither Energy Labelling nor Ecodesign regulation and within scope (see Table 8) are home batteries and electric vehicle chargers. For inclusion of

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0518&from=EN

[9] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2282&from=EN

these products, preparatory studies should be performed for possible inclusion under the Energy Labelling or Ecodesign regulations.

Furthermore, it is recommended that the requirements are verified by and independent third party.

7.2. SCENARIO ANALYSIS

According to MEErP and based on the results of the policy analysis, a (package of) policy instrument(s) should be selected and in a next step the impacts of this policy scenario should be assessed on the energy system, the end-user and on industry in comparison with the impacts of the BAU scenario that was assessed in the Task 6 report.

In the previous chapter, various policy options have been described which can support the uptake of energy smart appliances, thereby indicating the potential impacts they may have. At this stage however, it is not feasible to bring the impact of single or the combination of policy measures in relation to a specific increase in share of appliances that will be used in a smart way (as defined in this Lot 33). Such an increased uptake depends on numerous factors, as explained in the introduction, such as the development of the general market design including the development of business cases and the access to demand service providers. It is due to this complexity that any prediction of the uptake of energy smart appliances comes with large uncertainty.

Because of these uncertainties the authors of this report have opted not to quantify estimates of uptake of energy smart appliances as a result of specific (combinations of) policy options. By contrast it was decided to build a theoretical scenario of a maximum uptake of 100% for each of the years: in case all appliances would be used in the 'smart' way as defined in the context of this Lot 33, how would the environmental and economic impacts then change compared to the BAU results of Task 6?

It is recognized that a 100% uptake scenario will in reality probably only be achieved in case of a strict mandatory policy approach, which is not the identified recommended policy package. On the other hand tendencies elaborated in Task 2 and 3 and indicated further in this report show that end-consumers are expected to take up energy smart appliances, even if it comes at a higher purchasing cost. It will then depend of the specific business case if they will step on board of programme to use their appliance in the smart way as defined in the context of this Lot 33.

A '100% smart scenario' will show a theoretical and maximum value in case all appliances would be used in a smart way. The recommended policy package thus will have impacts on the energy system that range between the BAU scenario and this 100% smart scenario and these scenarios need to be considered as a lower and upper bound of what is expected to happen in reality.

In Task 6, the impact of flexibility from energy smart appliances has been investigated for the BAU scenario.

Table 1 repeats the overview of the share of energy smart appliances in the EU28 area and summarizes the impact on the Key Performance Indicators (KPIs) for the total energy system in case the flexibility from the energy smart appliances would be used.

Table 1 Percentage of energy smart appliances per benchmark year in the EU-28 area in the BAU scenario (as defined in Task 5).

Year		2014	2020	2030
Group	**energy smart appliance**	**%**	**%**	**%**
Periodical appliances	Dishwashers	0	2	8
	Washing machines	0	1	4
	Tumble dryers, no heat pump	0	2	16
	Tumble dryers, heat pump based	0	2	16
Energy storing appliances	Refrigerators and freezers (residential)	0	5	20
	Electric storage water heaters (continuously heating storage)	0	5	20
	Electric storage water heaters (night storage)	0	5	20
	Tertiary cooling - compressor[10]	0	10	50
	Tertiary cooling - defrost	0	10	50
Residential cooling and heating (heat pump based)	HVAC cooling, no storage	5	18	54
	HVAC cooling, with thermal storage	5	18	54
	HVAC heating, no storage	5	18	54
	HVAC heating, with thermal storage	5	18	54
Tertiary cooling and heating (heat pump based)	HVAC cooling, no storage	5	18	54
	HVAC cooling, with thermal storage	5	18	54
	HVAC heating, no storage	5	18	54
	HVAC heating, with thermal storage	5	18	54
Joule based tertiary and residential cooling and heating	Electric radiators, no inertia	0	3	21
	Electric radiators, with inertia	0	3	21
	Boilers	0	3	21
Residential energy storage systems	Electric vehicles	0	50	75

In the supplementary report, the economic and environmental benefits for the total energy system were quantified by means of four KPIs:

1. KPI1: Economic value in terms of total energy system costs. This KPI quantifies the avoided costs related to the more efficient use of the energy system following the introduction of the flexibility from energy smart appliances.
2. KPI2: Total amount of CO_2 emissions over the considered period. This KPI quantifies part of the environmental benefits of decreased utilization of the less efficient and more CO_2 emitting peaking power plants in the system.

[10] For tertiary cooling processes (compressor and defrost), instead of number of appliances, total nominal square meters, obtained as explained in Task 3 report, are given.

3. KPI3: Energy efficiency of the utilized generation mix over the considered period. This KPI more specifically indicates the increased share of Renewable Energy Sources (RES) integrated in the generation mix, and decrease in utilization of low efficient, often peaking, generating units. Energy efficiency of the utilized generation mix as defined here is related to the primary energy savings in the electricity production. It is not related to e.g. decrease in total consumption due to more efficient energy utilization.
4. Primary energy savings [TWh].

7.2.1. Business as usual scenario (Task 6) and 100% scenario

In Table 2, differences in KPIs as a consequence of utilizing flexibility from energy smart appliances for the day-ahead use case and each of the benchmark years, for BAU and 100% scenario are shown.

Table 2 Differences in KPIs as a consequence of utilizing flexibility from energy smart appliances for the day-ahead use case and each of the benchmark years, for BAU and 100% scenario

Day ahead use case	KPI1 (total system costs) [M€]		KPI2 (CO2 emissions) [Mt]		KPI3 (efficiency of the utilized generation mix) [%]		KPI4 (primary energy consumption) [TWh]	
Scenario	BAU	100%	BAU	100%	BAU	100%	BAU	100%
2014	61.961	60.997	748	740	57,8	58,3	3.580	3.546
2020	69.838	68.831	732	725	62,4	63,1	3.086	3.055
2030	94.181	80.231	640	582	64,1	66,3	3.085	2.628

The results of the BAU scenario clearly indicate the positive effect of flexibility in the day-ahead use case. In 2030, compared to 2014, there are significant savings in total system costs, CO_2 emissions and the use of primary energy resources. The results show that, with an increasing share of renewable energy sources (RES) on the one hand and an increasing share of energy smart appliances on the other hand, total benefits increase.

7.2.2. Theoretical 100% smart scenario

In Table 2, the results for the four KPIs are given for the day-ahead use case, based on the assumption that 100% of the appliances in each of the considered benchmark years are used in a smart way. Table 3 presents the share of flexible demand over the years for the 100% smart scenario.

The results show a similar pattern compared to the results of the BAU scenario in task 6. An increase in total costs for electricity production, i.e. KPI1, is observed over the years. All costs are given in $€_{2014}$ value, with the most interesting outlier for year 2030 in which the costs are significantly higher compared to the other two benchmark years. The main reason for this increase is the assumed increase of the CO_2 emission price and fuel prices[11] (see also 7.3.3). KPI2 shows a decrease in CO_2 emissions due to i.e. the higher share of capacity of variable renewable energy resources (VRES) installed in the system. KPI3 also shows an improvement in the efficiency of the utilized generation mix, whereas the total primary energy consumption decreases over the coming years for both BAU

[11] The assumptions for fuel prices and CO_2 are explained in task 5.

and 100% scenario. This is also due to the increase of installed capacity of VRES and the switch from electricity production by coal-fired power plants to gas-fired power plants (latter having a higher efficiency).

Table 3 Share of flexible demand over the benchmark years for the 100% scenario

Day ahead use case	Share of flexible demand for energy in the total demand for energy[%]		Share of peak flexible demand in the total demand [%]		Peak flexible power in the EU-28 area [GW]	
scenario	BAU	100%	BAU	100%	BAU	100%
2014	0,2%	19%	0,9%	40%	2,8	183
2020	1,2%	18%	3,2%	39%	9,8	179
2030	4,6%	17%	10,7%	36%	43,4	180

In the 100% scenario, the share of flexible demand for energy in the total demand for energy is relatively constant over the years, which means that the representation of the considered household appliances remains constant over the years. Similarly, the peak power, and the share of peak flexible demand in the total demand remain constant. Compared to the BAU-scenario, the increase in both the share of flexible demand and the share of peak flexible demand (compared to total demand) is significant.

7.3. IMPACT ANALYSIS

7.3.1. ENVIRONMENTAL IMPACTS

7.3.1.1 At the level of the energy system

The impact of an increase in the share of appliances that are used in a smart way can be estimated by comparing the KPIs for the 100% smart scenario with the BAU scenario (Task 6). Table 4 summarizes the results for the different KPIs.

ΔKPI2 (CO_2 emissions) and ΔKPI3 (improvements in energy efficiency of the utilized generation mix expressed as percentual primary energy savings) both compile the environmental impact. For these two KPIs, the difference between the 100% smart scenario and the BAU scenario is considerable.

Table 4 Differences in KPIs as a consequence of utilization of flexibility from smart appliances for the day-ahead use case and each of the benchmark years for the 100% scenario

Day ahead use case	ΔKPI1 (savings in total system costs) [M€]		ΔKPI2 (savings in CO_2 emissions) [kt]		ΔKPI3 (primary energy savings) [%]		ΔKPI4 (primary energy savings) [TWh]	
Scenario	**BAU**	**100%**	**BAU**	**100%**	**BAU**	**100%**	**BAU**	**100%**
2014	23	987	182	8.412	0,0	0,5	1	35
2020	1.451	2.458	13.667	20.481	0,1	0,9	60	91
2030	482	14.433	32.136	89.513	0,3	2,5	4	461

It is clear that an increase in the appliances used in a smart way generates important absolute primary energy savings by comparing the values of ΔKPI4 over the years and scenarios. The values presented in Table 4 for the 100% scenario provide an upper bound of total savings at the level of the energy system (without taking into account potential additional energy consumption directly attributed to smart capabilities).

7.3.1.2 At the level of the end-user

As explained in Task 6 and recapitulated in the following paragraphs, the use of the smart energy appliances flexibility may result in operating points that deviate from the most energy efficient operation point, e.g., by cooling deeper or heating higher. However, it should be stressed that the assumptions underlying the estimates of the value of flexibility in this study were chosen in such a way that this surplus consumption is considered to be negligible, for more details see chapters in Task 3 on user behaviour. Therefore it should be clear that more flexibility would potentially be available if less efficient operating points are permitted. In this case, the end-user should be compensated for this surplus energy consumption with an acceptable margin that still lies within the surplus added value of providing the extra flexibility. From a system perspective, this can be interesting provided that such a case allows for increased share of RES, leading to reduced CO_2 emissions despite the surplus energy consumption.

If the appliance is equipped with extra energy smart specific electronics, then the operation of these may cause a small to negligible surplus electricity consumption, as discussed in Task 4. On the other hand, the functionality required for demand side flexibility support also offers opportunities for improved energy efficiency, as energy smart appliances allow a detailed view of the energy consumption of those appliances, provided such insights are shared with the end user. A number of studies [Darby 2006; Fischer 2008; Ehrhardt-Martinez 2010; Faruqui 2010; Stromback 2011; Lewis 2014; Van Elburg 2014] have assessed the effectiveness of energy use feedback (broadly defined, taking into account multiple feedback channels ranging from awareness campaigns to dedicated in-home displays showing energy consumption in real time), mostly in terms of achieving energy savings. These studies show consistently that there is considerable case-to-case variation of reported energy savings, typically in the range of 0 - 20%[1], with usual savings between some 5 and 12% [Fischer 2008]. Variation may be explained by a variety of factors other than the feedback design, including the climate conditions, the length of pilot, the number of participants and the level of education provided [see Stromback 2011 for an overview]. Studies specifically addressing smart meters have demonstrated that providing detailed electricity consumption information to end consumers, in the combination with advice on how to reduce energy consumption result in significant electricity consumption savings of up to 8% per household[12].

Secondly, the measurement and control functionality, required for energy smart functionality, can also be used to analyse and optimize the operation of the energy smart appliance from an energy efficiency point of view[13]. Energy smart appliances also allow a more user-friendly operation (e.g. through use of apps as opposed to manuals) which leads the end-user to the optimal operational setting under the given circumstances. Even though quantitative evidence is not yet available, the operational mode which is advised by the smart setting is expected to be more energy efficient compared to the setting the end-user would choose manually. The degree of increased energy efficiency will depend on various factors such as the specific energy smart appliance (e.g. more potential for a dishwasher compared to a washing machine), risk aversion from the end-user (e.g. washing at higher temperature which may be more optimal), potential rebound effects (e.g. end-user is more confident to use the appliances), etc.

[1] Reported ranges: 0-15% [Darby 2006], 1-20% [Fischer 2008], 4-12% [Ehrhardt-Martinez 2010], 3-13% [Faruqui 2010], 2-12% [Stromback 2011], 3-7% [Van Elburg 2014].

[12] Eandis, Infrax, "*POC II Smart Metering, energie-efficiëntie, resultaat verbruik*"

[13] See, e.g., the 'smart control' functionality as defined in the Ecodesign requirements for water heaters and hot water storage tanks, set via regulation No 814/2013 of 2 August 2013: 'smart control' means a device that automatically adapts the water heating process to individual usage conditions with the aim of reducing energy consumption.

7.3.2. Socio-economic impacts

7.3.2.1 At the level of the energy system

The socio-economic impact is estimated by means of the difference in ΔKPI1 as presented in Table 5.The higher the share of appliances used in a smart way, the larger the total savings (avoided costs) for the energy system. In the model, these savings are transferred to the end-user by means of an impact on the average marginal electricity prices. Compared to the situation without energy smart appliances (cfr Task 5), there is a potential decrease in marginal electricity prices of almost 18%. Also, the difference between the 100% scenario and the BAU-scenario is obvious. However, the decrease is less compared to the delta between the BAU-scenario with and without energy smart appliances. This indicates that a level of saturation can be observed as the hours with the highest need for flexibility (and as a result, providing the highest cost reduction) will be served first.

Table 5 Average marginal electricity prices [€/MWh] for the day-ahead use case, base, BAU, and 100% scenario: differences due to utilization of flexibility from energy smart appliances

	100% scenario	BAU scenario	Base case
2014	44,81 €/MWh	44,92 €/MWh	44,93 €/MWh
2020	56,64 €/MWh	56,75 €/MWh	58,02 €/MWh
2030	61,79 €/MWh	73,67 €/MWh	73,74 €/MWh

In addition, the share of load shedding decreased significantly in the 100% smart scenario, indicating that the higher the 'social cost' allocated to load shedding, the more value can be obtained by the use of flexibility.
Table 6 gives an overview of the value due to flexibility of energy smart appliances per enabled energy smart appliance per year (given in [€/year/appliance]) in the 100% scenario and in the BAU scenario (see also supplementary report report). The results are discussed in the next section.

Table 6 Value of benefits due to flexibility of energy smart appliances per enabled energy smart appliance per year (given in [€/year/appliance]) in the 100% scenario and in the BAU scenario

		2014		2020		2030	
Group	**Energy smart capable appliance**	**BAU**	**100%**	**BAU**	**100%**	**BAU**	**100%**
Periodical appliances	Dishwashers	0	1,3	5,2	1,3	3,6	1,0
	Washing machines	0	0,7	2,9	0,7	2,0	0,5
	Tumble dryers, no heat pump	0	1,4	5,6	1,4	3,7	0,9
	Tumble dryers, heat pump based	0	1,2	4,5	1,1	3,0	0,8
Energy storing appliances	Refrigerators and freezers (residential)	0	0,2	0,6	0,2	0,4	0,1
	Electric storage water heaters (continuously heating storage)	0	0,9	2,4	0,9	2,4	0,7
	Electric storage water heaters (night storage)	0	1,4	15,2	1,4	8,4	1,0
	Tertiary cooling - compressor[14] and defrost	0	0,6	0,2	0,6	0,8	0,5
Residential cooling and heating (heat pump based)	HVAC cooling, no storage	1,7	0,2	1,4	0,3	0,8	0,3
	HVAC cooling, with thermal storage	14,6	1,5	11,3	1,8	5,4	2,0
	HVAC heating, no storage	22,1	2,8	14,2	2,2	8,3	1,3
	HVAC heating, with thermal storage	156,7	16,4	106,3	13,6	45,9	5,6
Tertiary cooling and heating (heat pump based)	HVAC cooling, no storage	12,3	1,9	11,6	1,4	5,9	0,9
	HVAC cooling, with thermal storage	198,4	19,4	149,0	11,6	47,8	7,4
	HVAC heating, no storage	3,2	0,5	2,5	0,4	1,5	0,3
	HVAC heating, with thermal storage	29,0	3,3	20,2	2,3	9,7	1,2
Joule based tertiary and residential cooling and heating	Electric radiators, no inertia	0	0,2	1,4	0,2	0,8	0,1
	Electric radiators, with inertia	0	0,4	2,2	0,4	1,3	0,2
	Boilers	0	1,8	10,9	1,8	6,6	1,0
Residential energy storage systems	Home batteries	0	14,8	35,5	14,5	26,2	6,6
	Residential electric vehicles	0	8,9	34,7	6,8	17,1	3,9

7.3.2.2 At the level of the end-user

» **Financial impact**

Resulting from this scenario analysis and as indicated in Table 6, the added value of the demand side flexibility per end-consumer appliance, when committed in the day ahead electricity markets, is estimated to be up to 106€/year in 2020 and up to 46€/year in 2030 with ranges varying strongly between appliances. Also for residential storage, the value decreases significantly between the two scenarios. When committed in the imbalance markets, the added value is in the same order of magnitude, although for some appliances is might be higher (e.g. refrigeration). Note that for the valorisation of this added value, investment and operational costs should be covered by both the end consumer and other actors such as the aggregator or ESCO.

Compared to the results presented in Task 6 for the BAU-scenario, the following observations could be made:

- **The total value per appliance decreases for the majority of appliances** due to the fact that there are many more appliances used in a smart way. This means that, although the total absolute value for the system increases, the value per individual appliance decreases. This can be regarded as a **saturation effect**.
- **For a number of appliances the value per appliance is increasing, which indicates that even in a 100% scenario the saturation level is not yet attained** for these appliances (electric storage water heaters (night storage), tertiary cooling – compressor/defrost and HVAC cooling no storage/with thermal storage). To note that this also means that other sources of flexibility (e.g. industrial demand response) could also capture this value by offering flexibility with the same characteristic as these groups.
- **The change in value per appliance is different for each appliance group** and is dependent on the characteristics of the flexibility, i.e. when is it available. It is for example possible that a certain type of flexibility is less needed or valued in the system. Parameters such as the seasonality of the flexibility, day-night pattern, shifting potential etc., will play a role here. This also indicates that policy makers should carefully assess which group of smart appliances to specifically support, in case any choice has to be made between appliances.

As explained in the Task 6 report and in the supplementary report, demand side flexibility can also be used for other applications, such as grid congestion management or other ancillary reserves, the value of which could be higher than these figures. The added value for these cases is country, region or even district dependent. E.g., in districts in which all houses are equipped with photovoltaic panels and heat pumps, the value of demand side flexibility for grid congestion management can be larger than the value for day ahead or imbalance markets, depending on the local situation.

The financial cost elements have been discussed in Task 4 and Task 6, they mainly consist of the initial investment costs on the one hand and the recurrent operational costs on the other hand which can be specifically attributed to the energy smart functionality of the appliance (mainly operating cost of the communication infrastructure and the costs related to increases in energy consumption). As explained in Task 6, the operational cost that can be attributed to the smart appliances is therefore case dependent, but is assumed to be very low or negligible compared to the investment costs.

As explained in Task 4 and 6, following analysis of publicly available information and contacts with industry it is very difficult to derive generalised estimations of the additional investment costs that can only be attributed to the energy smart feature specifically subject to this Lot 33 Preparatory Study. Additional costs of the necessary adaptations specifically attributed to the energy smart feature will mainly depend on the amount of products in the series of appliances produced. Assuming larger product series in a context of a future smart grid market, cost levels at manufacturer's level including testing and documentation are generally estimated as follows:

- A networked appliance only needing software modifications, testing, documentation etc.: 5-10€
- A non-networked appliance also needing a network connectivity module etc.: 10-20€

The assumed additional costs are to be interpreted as the absolute upper bound. For instance, according to the recently conducted Impact Assessment Study On Downstream Flexibility, Price Flexibility, Demand Response & Smart Metering (: https://ec.europa.eu/energy/sites/ener/files/documents/demand_response_ia_study_final_report_12-08-2016.pdf), the additional costs in range between 1,70 € and 3,30 € for each of the appliances shall be expected. According to another pilot study demonstrated by CECED, for some products there might be no additional costs, as they already satisfy the interoperability requirements to act in an energy smart way. Nevertheless, some adaptations in line with the herein presented requirements may be required, and hence zero additional costs are considered to be unrealistic. A third source, building upon the findings of the Xylon study[15], reports the expected costs (assuming economies of scale) to be around 4,40 € per appliance. The costs reported in these three sources deal only with the technological additional costs, whereas there might be some other costs (such adaptation of technical documentation) which additionally have to be accounted for. Therefore, the costs as reported above (5-10€ for a networked appliance and 10-20€ for a non-networked appliance) will be taken as a reference, and shall be interpreted as the upper bound.

These additional manufacturing costs make abstraction of R&D costs and are exclusive of mark ups for distribution and retail level. As an outlier, industry indicated that adding DR to thermodynamic appliances (heat pumps and air conditioning) would raise the retail price approximately with 100€-200€ including software adaptation and development, installation costs, intervention etc. According to the authors of this Task report, these costs are assessed to include research & development costs and costs associated with the first appliances being produced in small series in a short term perspective. It is clear that the closer to the 100% uptake scenario, the lower the additional unit costs per appliance are expected to be due to economies of scale that will occur for manufacturers and other operators in the value chain.

It can be concluded that the extra functionality of smart appliances implies a surplus cost. The distribution and size of this surplus cost depends strongly on the choice for a mandatory or non-mandatory approach. In case of a mandatory approach, the extra cost per appliance is the lowest due to the scale advantage. However, mandatory measures also imply that the costs are socialized and distributed across all appliance owners, including those owners that do not use and receive added value from the demand response flexibility. The latter is avoided with a non-mandatory approach. However, in this case the surplus cost of a smart appliance will be higher due to the loss of the scale advantage. There is then also the risk that smart appliance ownership for less fortunate people is hindered, and that they share less in the added value of demand response.

The distribution of costs and benefits will depend strongly on the energy market organisation. If consumers in a certain region or country have no or less access to DR programs, then they can also

[15] A. Ikpehai et al. - Experimental Study of 6LoPLC for Home Energy Management Systems, available online at https://www.google.be/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjJ8o6r6tvVAhXBblAKHQT6AKUQFggtMAA&url=http%3A%2F%2Fwww.mdpi.com%2F1996-1073%2F9%2F12%2F1046&usg=AFQjCNGIQSiy2XCi1s0q9k8-4s3hgigmUA

share less in the added value. A consumer right for access to variable tariffs or other DR mechanisms can alleviate this, as are actions to organize the energy market so that DR is supported or other governmental support schemes for demand response.

» **Consumers' willingness and capability to engage in the use of smart appliances**

Consumer acceptance and willingness to engage in the use of smart appliances play a crucial role for their success, as demand side flexibility may have a decisive influence on the daily routines of consumers and may require behavioural changes.

A number of studies have revealed that consumers, in principle, are interested in smart appliances and have a positive attitude towards them. A recent global survey by Gfk[16] with 7000 participants in seven markets (Brazil, China, Germany, Japan, South Korea, the UK and the US) has shown that 77 % of consumers find the smart home idea appealing, very appealing or extremely appealing.

However, there is also a variety of barriers and objections from the consumer's point of view, which present manufacturers, utilities, service providers, policy makers and other stakeholders with some challenges. These include on the one hand product/ service-related concerns as for example:

- lacking interoperability,
- too complicated handling,
- error-proneness/ durability of appliances,
- lacking updateability and reparability of the devices,
- expected loss of control,
- expected loss of comfort,
- safety aspects (e.g. unattended operation of appliances)
- reduction of performance for some appliances (e.g. refrigerators, washing machines)

and on the other hand economic and regulatory concerns, for instance:

- rollout of smart meters,
- product prices and hidden costs,
- mistrust in providers,
- data privacy and data protection.

For some of the aforementioned objections, potential solutions are already available. The rollout of smart meters, for example, is ongoing and it is expected that almost 72% of European consumers will have a smart meter by 2020 (JRC, 2016[17]). In view of safety aspects, attention is often drawn to the fact that absolute safety can never be guaranteed. While creating tariff models, it is important to consider that for some appliances, unattended operation may increase the risk of fatale fires and to inform consumers adequately about this risk (Mook et al., 2016[18]). The impact on comfort is treated further in this section.

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[16] Dale (2016): Realizing the future of the smart home with early adopters. Available from: https://blog.gfk.com/2016/04/realizing-the-future-of-the-smart-home-with-early-adopters/. Last access: 27 of August, 2016.

[17] JRC (2016): Smart Metering deployment in the European Union. Available from: http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union. Last access: 31 of August, 2016

[18] Mook, Norrie-Moe, Rudi (2016): Status of NVE's work on network tariffs in the electricity distribution system. Rapport nr. 62-2016. Available from: http://publikasjoner.nve.no/rapport/2016/rapport2016_62.pdf. Last access: 1. of September, 2016.

After removing the barriers, smart appliances will most probably not turn automatically into a fast-selling item. Information and transparency are seen as key factors by many experts (Deloitte, 2013[19]; Lamprecht, 2013[20]; Picot et al., 2008[21]). For consumers, smart appliances and related features are completely new; they are lacking knowledge and experience and should be informed adequately. According to a survey by Forsa (2010[22]) with about 1000 participants in Germany, the vast majority (more than 80%) of consumers do not feel well informed or not informed at all about technical possibilities in a smart home.

Consumers are also not aware of all the benefits and possibilities smart appliances may provide. These are not restricted to demand side flexibility, but also include other potential applications. Comfort and security applications, emergency systems, e-health as well as multimedia and entertainment applications may be named as some examples. The aforementioned applications, in parts, are less complex and have already reached a certain market maturity. As a consequence, these applications are often seen as entry-level applications, which have the potential to open up significant market potential, whereas energy related applications like demand side flexibility may follow in a second step (Strese et al., 2010[23]). Also additional features like monitoring features or "all power off"-switches, remote control functions via smart phone or tablet as well as remote diagnostics and maintenance for mechanics may arouse consumer's interest in smart appliances and drive towards a mass market adoption.

According to experts, also the group of early adopters plays a vital role for reaching higher market penetration of smart appliances and can predict their future to some extent. Early adopters are those consumers adopting products or services at a very early stage; they tend to be well informed and are highly influential for other potential adopters (e.g. by sharing their experiences in social media or product reviews). The global survey by Gfk[16] mentioned above specifically studied the group of early adopters (17% of all participants) by comparing their attitude towards smart home with the one of other consumers. The study revealed that early adopters are more positively disposed towards smart homes in comparison to other consumers. The vast majority of early adopters stated to see an added value and expected smart home to have a strong impact on their future life. White goods like smart

[19] Deloitte & Touche GmbH Wirtschaftsprüfungsgesellschaft, eds. (2013): Licht ins Dunkel. Erfolgsfaktoren für das Smart Home. Studienreihe „Intelligente Netze". Report 11/2013. Available from: http://www.connected-living.org/content/4-information/4-downloads/4-studien/21-licht-ins-dunkel-erfolgsfaktoren-fuer-das-smart-home/licht-ins-dunkel-erfolgsfaktoren-fuer-das-smart-home.pdf. Last access: 19 of August, 2016.

[20] Lamprecht (2013): Smart Home – der Weg in den Massenmarkt. Energiewirtscaftliche Tagesfragen 63 (2013) vol. 8, p. 89. Available from: www.utec-deutschland.de/file_download/39/. Last access: 27 of August, 2016.

[21] Picot, Neuburger, Grove, Janello, Konrad, Kranz, Taing (2008): Studienreihe zur Heimvernetzung. Treiber und Barrieren der Heimvernetzung. BITKOM (Bundesverband Informationswirtschaft, Telekommunikation und neue Medien e.V.) (eds.): Ergebnisse der Arbeitsgruppe 8 „Service- und verbraucherfreundliche IT" zum dritten nationalen IT-Gipfel 2008. Volume 3. Available from: https://www.bitkom.org/Publikationen/2008/Leitfaden/BITKOM-Studie-Treiber-und-Barrieren-der-Heimvernetzung/Studie-Treiber-Barrieren-der-Heimvernetzung.pdf. Last access: 31. of August, 2016.

[22] Forsa (2010): Vorstellung der Konsumenten-Studie "Heimvernetzung". Präsentation: Michael Schidlack, BITKOM, München: Waggener Edstrom Worldwide.

[23] Strese, Seidel, Knape, Botthof (2010): Smart Home in Deutschland. Untersuchung im Rahmen der wissenschaftlichen Begleitung zum Programm Next Generation Media (NGM) des Bundesministeriums für Wirtschaft und Technologie. Institut für Innovation und Technik (iit). Available from: https://www.vdivde-it.de/publikationen/studien/smart-home-in-deutschland-untersuchung-im-rahmen-der-wissenschaftlichen-begleitung-zum-programm-next-generation-media-ngm-des-bundesministeriums-fuer-wirtschaft-und-technologie. Last access: Last access: 27 of August, 2016.

refrigerators and washing machines are among the most attractive products, whereas remote control or remote maintenance functions are most important for them. However, the author of the study emphasised that the results may indicate a future trend, but have to be interpreted with some caution as early adopters are better informed about and more familiar with smart home applications than other consumers. This may be the reason of their interest and again highlights the importance of information and transparency to enable mass uptake of smart appliances.

With regard to the costs, studies (Mert et al., 2008[24]; Weiler, 2014[25], Geppert and Stamminger, 2015[26]) have shown that they are not a critical barrier for the entrance to mass market. Consumers are in general willing to accept higher initial prices for smart appliances, if they clearly recognise an added value. This does not necessarily mean monetary savings, but also higher comfort or additional functions can offer an added value for consumers and consequently increase their willingness to pay. This trend can also be observed in other markets, e.g. mobile phones and TVs, where consumers accept significantly higher prices for smart devices offering additional features (smart phones or smart TVs). More than the initial price, consumers fear hidden costs (e.g. costs for installation, operation or repairs, Mert et al., 2008[24]). Bundled offers or all-inclusive-services may be a viable option and introduce more transparency for consumers (Deloitte, 2013[19]).

» **Privacy protection, privacy enhancement and data handling requirements**

From the consumer's perspective, privacy as well as security aspects are among the major concerns expressed (see Task 3 for more details). Unless it is ensured that data protection and privacy of individuals are respected, consumers will most probably not accept energy smart applications. On the other hand, implementing any measures enhancing security or privacy causes additional costs and inconvenience for consumers as well as for other parties involved. However, these costs and inconveniences are negligible in comparison to the damages on individual appliances or the whole system (attacks, complete blackouts), which may be inflicted. Therefore it is essential to inform consumers in an adequate way to raise awareness for security issues and to implement support systems for consumers. Consumers should be able to make a well-informed decision about whether or not they want to use any smart appliances and which inconvenience they are willing to accept in order to improve security and privacy.

An in-depth analysis of security aspects is given in Annex of the Task 3 report. This analysis describes potential threats to Smart Appliances and ideal and basic approaches to mitigate the former, by using the principles of defense-in-depth, security by design and security by default. As the concept of Smart Appliances includes the processing of potentially sensitive user data, also privacy concerns are a major subject of this analysis, particularly in respect with the European Data Protection Regulation. The according recommendations therefore suggest anonymization and pseudonymization techniques (such as k-anonymity and its enhancements) and giving as less information away from end customers as possible (according to the need-to-now principle). They further suggest using a neutral party to enforcing this principle or using aggregation to enhance privacy. Further, user data could be marked in order to allow prosecuting data protection violations. The insights gained should serve as a basis

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[24] Mert et al. (2008): Consumer acceptance of smart appliances. D 5.5 of WP 5 report from Smart-A project. Available online: http://www.smart-a.org/WP5_5_Consumer_acceptance_18_12_08.pdf

[25] Weiler (2014): Marktchancen vernetzter Haushaltsgeräte angesichts der Entwicklung des Internets der Dinge - Eine Verbraucherstudie zur Beurteilung der Kundenakzeptanz und Zahlungsbereitschaft im Segment vernetzte Haushaltsgeräte. Available online: https://hdms.bsz-bw.de/files/2552/Bachelorarbeit_Anja_Weiler.pdf.

[26] Geppert and Stamminger (2015): Online study on consumer acceptance and perceptions of smart appliance. Not published yet.

for further research in Smart Appliance Security. Particular needs are reference architectures and norms, elaboration of privacy models, certification models and, after adoption of this technology on a broader basis, practical security surveys

Despite the costs and the inconvenience they might cause, the following minimum requirements could be identified in view of security and privacy measures:

Access control and authentication are basic measures enhancing security. Authentication by password can be seen as the simplest form, whereas the enforcement to change or not have a default password, high password strength and regular changes of the password[27] are considered necessary. With an increasing number of smart appliances available in the household, this may cause considerable inconvenience for consumers. Potential solutions include one-time passwords generated by special devices, two-factor authentication or secure single sign—on systems.

As another minimum requirement, data at rest and for communication should be **encrypted** using encryption methods that meet state of the art standards.

From the consumer's perspective, the **"security by design and by default"** principles are highly recommended. "Security by design" means that potential attacks and abuses are already considered and secure technologies are embedded at an early stage of product design. The "security by default" principle guarantees that the default settings are the most secure ones.

"**Privacy by design and by default**" should be ensured for both, the smart appliance as well as the connection/communication channel between the smart appliance and other connected devices. Product design should be in compliance with the data protection legislation. Privacy by Design means that privacy is embedded into design and architecture of the whole system. It should ensure data reduction and data economy as readings should take place only in intervals necessary for the respective system and service. The same applies for the transmission of readings. In general, processing and transmitting of data should be reduced to a minimum following the "need-to know principle". Data should remain on the consumer's side to the highest possible extent.

If data transfer outside the consumer's premise is necessary, data **pseudonymisation** is inevitable in order to hamper the possibility to link consumption data and identity information.

Data may not be transferred or disclosed to any third party without knowledge and **consent** of the consumer. At the same time, consumers should be granted the right to access their own data.

Another important issue is the "**right to be forgotten**" and, linked to this, the "**right of rectification or erasure**", which are already covered by the new European General Data Protection Regulation.

It has to be mentioned that none of the security measures are impregnable. Therefore, it is recommended to combine different measures ("defence-in depth-principle") to mitigate the risk of any particular attack.

[27] Although not generally recommended by all experts.

7.3.2.3 At the level of industry

As stated in the Task 6 report (Section 6.4.3) it has not been possible to make an analysis of the impacts of on industry regarding required investment levels and the derived impacts on the sector's profitability, competitiveness and employment due to the limited available data on additional cost.

The assumption is that the digital communication functionality will be a common functionality in most product categories covered by the scope of this study – apart from some low end appliances.

The general assumption on average additional costs at manufacturer's level including testing and documentation for larger product series in a context of a future smart grid market of the necessary adaptations specifically attributed to the energy smart feature (assessed in Task 4 report) is:

- A networked appliance only needing software modifications, testing, documentation etc.: 5-10€
- A non-networked appliance also needing a network connectivity module etc.: 10-20€

As discussed above, these numbers shall be regarded as the upper bound on the additional costs.

These additional manufacturing costs make abstraction of R&D costs and are exclusive of mark ups for distribution and retail level.

It is assumed that these costs can be covered by a price increase at the consumer side, because the products will have extra functionality (namely the energy smart functionality), which will give the consumer the opportunity to receive a remuneration.

7.3.3. SENSITIVITY ANALYSIS OF MAIN PARAMETERS

The results presented for the day-ahead use case and imbalance case are dependent on the chosen parameters. The results of this Task 7 report already indicated that an increase in the share of appliances used in a smart way could increase or decrease the value of these appliances, depending on the characteristics or flexibility profile delivered by the smart appliance.

The robustness of the parameters that are used to model the electricity system is of crucial importance. These parameters were extensively discussed in Task 5 and Task 6. In July 2016, the EU Reference Scenario 2016 was published. In order to check the robustness of our results, the assumptions used in Task 5, 6 and 7 were compared with the assumptions used by PRIMES 2016. Important parameters for the model are the growth in energy demand, the installed capacity of conventional generation, the installed capacity of variable renewable energy resources (VRES), the fuel prices (gas, coal, oil and biomass) and the prices for CO_2.

The yearly growth in demand in PRIMES 2016 between 2015 and 2030 is on average 0,3% while in the model an assumption of 0,5% is made (based on PRIMES 2013). The impact of this difference on the value of smart appliances is difficult to estimate. If the decrease in growth mainly consists of a decrease in peak load, a negative impact can be expected on the value for smart appliances, as the need for flexibility will decrease. However in case the decrease in growth is mainly a decrease in e.g. baseload demand (i.e. linked to industrial processes), there will be no impact on the value of smart appliances. Independent of the origin of the decrease in growth of energy demand, benefits for the end consumer are still expected coming from lower energy prices or the possibility to create value with flexibility.

The installed capacity of conventional generation has changed between PRIMES 2013 and PRIMES 2016. The results presented in this and in the supplementary report are obtained under the PRIMES

2016 scenario assumptions. The results presented in Task 5 and Task 6 are obtained under the PRIMES 2013 scenario assumptions.

The price of CO_2 has an important impact on the energy system in 2030. In Task 5 and Task 6, assumptions for CO_2 were based on current market prices for 2020 (9,07 €/ton) and a Thomson Reuters estimate for 2030 (48€/ton). As discussed, there is a general consensus that until 2020, the price of CO_2 will stay relatively stable and as from 2020, a sharp increase can be expected. The PRIMES 2016 scenarios take a value of 15€/ton for 2020, which is higher compared to our value. For 2030, a value of 33,5€/ton is reported in PRIMES 2016. For 2040, PRIMES 2016 estimates CO_2 prices at 50€/ton and for 2050 even at 88€/ton. It is clear from all sources that the price of CO_2 will impact the value of the entire energy system, which is logical as it is a sign of the change towards a renewable CO_2-neutral energy mix. Also the fuel prices are assumed to be the same as in PRIMES 2016 scenario, whereas in task 5 and 6, they were compiled from different sources as cited in the corresponding reports.

7.4. APPLIANCES IN FOCUS AND APPLIANCE CATEGORIES

In section 7.1 and 0, a BAU and 100% smart appliance scenario have been evaluated. It is concluded that consistent system cost savings and primary energy resource reduction can be achieved when more smart appliances are in the market. Further it is estimated that an average value of up to 54€/year in 2020 and up to 96€/year in 2030 can be generated for the customer investing in a smart appliance. During the analysis in Task 5 and 6, the impact for large product groups has been evaluated. In this section, a mapping back to concrete appliances will be done and justified which appliances are in/out of scope for policy recommendations.

Table 7 shows a summary of all appliances and evaluations that were done during this preparatory study, and contains the following columns:

- **Group, Subgroup and Appliance**: These columns show the original groups, subgroups and appliances as they were listed in the scope of Task 1.
- **Split-up/naming in Task 6**: In task 6 some appliances (groups) were further split-up and adapted naming was used. This column maps the Task 6 naming back on the original appliances.
- **Task 1 Ranking**: Ranking as it was done at the end of Task 1 into appliances with high potential, smaller potential and emergency potential for demand side flexibility. The high potential and some of the smaller potential appliances (depending on availability of data) were further investigated in Task 5 and 6.
- **Task 6 "Significant impact?":** Mainly based on the value the flexibility could generate for the customer, some appliances are not further considered for policy recommendations.
- **Task 7 "Flexibility in the appliance"**: In some cases, it is not obvious to determine whether the energy smart functionality and the controller are physically located in the appliance itself or not. E.g., for heat pumps for residential heating: how long the heat pump can be switched off depends on the properties of the building and not on the properties of the heat pump itself. Further, the heat pump can have an external thermostat which is purchased separately. In that case, the heat pump cannot decide autonomously on the flexibility status. This column is added because it has consequences on which properties can be qualified by the appliance manufacturer.
- **Task 7 "Energy labelling coverage":** This column indicates whether the appliance is currently covered by an Energy labelling regulation.
- **Task 7 "Ecodesign coverage":** This column indicates whether the appliance is currently covered by Ecodesign requirements regulation.
- **Proposed action:** This column indicates the current status of the kind of action which will be proposed as a policy recommendation.

7.4.1. TECHNICAL APPLIANCE CATEGORIES

In this section, the appliances are categorized based on technical properties. Appliances with similar properties, which can be treated as a group in the detailed technical requirements, will be grouped together.

<u>Category I: Periodical appliances</u>

Dishwasher, **washing machine** and **tumble dryer** (with or without heat pump) were ranked as high potential appliances and it is shown in Task 6 that their flexibility can generate value for the consumer. Washer dryer combinations were not further investigated due to the very limited market share. For the same reason they will not be considered for policy recommendations. The 3 selected appliances are covered by Ecodesign requirements, as well as by energy labelling. The appliances show similar properties and will be treated as a single group when the requirements are further detailed. All periodical appliances are covered by an existing Energy Label and the requirements, defined later in this document should be interpreted as requirements to put an energy smart icon on the Energy Label.

<u>Category II: Thermal appliances</u>

A very large group of appliances with high potential are related to heating or cooling, and have similar properties. Typically they aim at controlling a temperature to a certain target value and the flexibility is in the fact that a small temperature deviation from the target value is acceptable in combination with the present thermal inertia of the system.

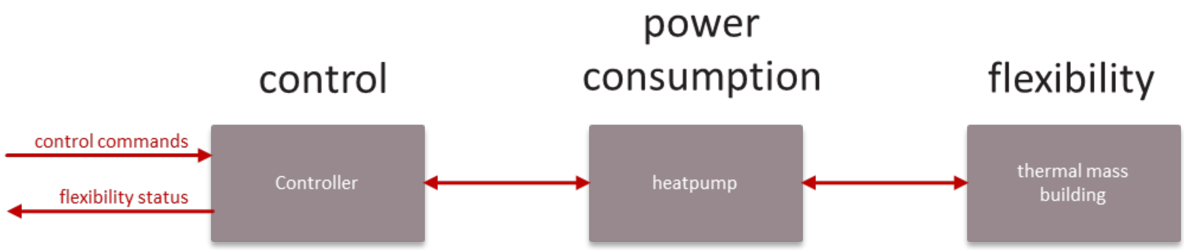


Figure 3: Core properties of a “smart appliance”

Whereas, it is pretty straightforward to see that periodical appliances intrinsically contain the flexibility, have a built-in controller and consumes the electricity itself, this is not the case for typical HVAC appliances. shows a typical example for the HVAC sector, where the controller, heat pump, and the flexibility of the thermal mass of the building are situated in different system components. Typically,

(1) the flexibility is in the thermal inertia of the building mass → flexibility
(2) a heat pump consumes the electricity → power consumption
(3) the control of the whole system is done by an external controller or building automation system → control.

The fact that these 3 core properties for “smartness” are spread over different components makes a “clean” definition of a thermal energy smart appliance challenging, and complicates the definition of the requirements for HVAC equipment.

<u>Category IIa: Thermal appliances with internal controller and internal flexibility</u>

This category considers the thermal appliances where the controller (which implements the flexibility interface), the flexibility (the thermal inertia of the system), and the power consumption are bundled together in the appliance. **Refrigerator**, **freezer**, **commercial refrigeration**, **continuous storage water heaters** fit in this category.

Electric radiators with inertia, residential heat pumps with thermal storage, non-residential heat pumps with thermal storage, residential air conditioners with thermal storage and **non-residential air conditioners with thermal storage** also fit under this category under the condition that the controller is included as well, which is not always the case because in many configurations an external controller (or thermostat) is (or can be) used. Due to the inertia and/or the thermal storage, at least a part of the flexibility is present in the appliance itself although the thermal mass of the building can add to it.

Refrigerators, freezers, commercial refrigeration appliances, continuous storage water heaters, residential heat pumps with thermal storage and residential air conditioners with thermal storage are covered by an existing Energy Label and the requirements, defined later in this document should be interpreted as requirements which should be met in order to have an energy smart icon on the Energy Label.

Electric radiators with inertia, non-residential heat pumps with thermal storage and non-residential air conditioners with thermal storage do not have an existing Energy label but are covered by existing Ecodesign regulation. The requirements, defined later in this document should be interpreted as the requirements which should be met in order to have an energy smart icon on the appliance and/or packaging and/or documentation.

Category IIb: Thermal appliances with internal controller and external flexibility:
The strict definition of appliances in category IIa results in the fact that a large share[28] of the appliances in HVAC sector would not be in the scope for the smart appliance study. Keeping in mind the large potential of HVAC (mainly heat pumps and air conditioning), thermal appliances without internal flexibility will be considered further as well. Although most of the requirements will be similar as for appliances in category IIa, the main difference will be in the testability and minimum requirements on the amount of flexibility.

Electric radiators without inertia, residential heat pumps without thermal storage, non-residential heat pumps without thermal storage, residential air conditioners without thermal storage and non-residential air conditioners without thermal storage fit in this category under the condition that the controller is included.

Residential heat pumps without thermal storage and residential air conditioners without thermal storage are covered by an existing Energy Label and the requirements, defined later in this document should be interpreted as requirements which should be met in order to have an energy smart icon on the Energy Label.

Electric radiators without inertia, non-residential heat pumps without thermal storage, non-residential air conditioners without thermal storage do not have an existing Energy label but are covered by existing Ecodesign regulation. The requirements, defined later in this document should be interpreted as the requirements which should be met in order to have an energy smart icon on the appliance and/or packaging and/or documentation.

Since this study focusses on a single functional unit with all components delivered together, it is not possible to consider smart appliances which do not contain a controller implementing a flexibility interface. In the HVAC sector, however, the approach is quite often component-based instead of product-based: this means that several components (e.g. heat pump, controller, different room units, …) are combined according to the needs of the customer to create a working system. Although the overall system can be "smart", it is not possible to define requirements on an individual components basis. In general, the approach in Ecodesign is focussed on "products" and has limitations in handling (component based) systems.

[28] According to the current market share, it is estimated that approximately 95% of the HVAC appliances do not fit under the defined category IIa.

Category III: Energy storage systems:
At the time of writing this document, there were several factors that impacted the extent to which the vertical policy recommendations for the residential energy storage systems can be developed.

First, the residential energy storage systems market is a fast growing and developing market. As described in task 2 of the study, even in Germany, where the share of the residential energy storage systems is the highest, and subsidies and legislation are most advanced, it is still not possible to talk about a mature market. Little information exists on the potential technical and economic development and possibilities of residential energy storage systems market.
Second, at this point in time, there is no Energy labelling coverage or Ecodesign coverage for this group of appliances. The importance of such coverage for the development of smart energy requirement was discussed previously in this report, and holds for the residential energy storage systems as well.
Last, the residential energy storage systems are component based systems (typically battery pack, battery management system and inverter), where the flexibility source, the controller and the power consumption are not by definition located in the same product. The fact that these core elements for defining energy smartness of an appliance are spread over different components makes the definition of the requirements for residential energy storage systems challenging.

A key difference between residential storage systems and the other appliances in scope, is that the energy flexibility is the core purpose of the storage. This is opposed to all the other appliances in scope, for which provision of flexibility is additional, secondary functionality. Therefore, a set of minimum requirements for the residential energy storage systems should be further investigated.

At this point in time, the residential energy storage systems market have not yet reached the mature stage, as they are still experiencing fast growth and a high level of innovation. Moreover, partly due to the market immaturity, at this point there are no instruments in place to develop a policy set with requirements for definition of energy smart residential energy storage systems. Although it is highly advisable to develop such measures, they will not be the main focus of this study.

Once addressed, the development of requirements for an energy smart label or a set of minimum requirements for residential energy storage systems can rely on the requirements already previously developed within lot 33. More specifically, all horizontal requirements as presented in the subsequent chapters of this report can be adopted. The vertical requirements will need to be defined specifically for the residential storage systems, but it is expected that it will be possible to take inspiration from the requirements for HVAC appliances with storage.

Category IV: Electric vehicle charging systems:
Although, EV charging shows similarities with home battery systems, it was considered to handle them in a separate category for the following reasons:

- The battery is not part of the charging system
- The main goal of a battery in an electric vehicle is securing mobility for the EV owner, which heavily constraints the use of the battery for demand side flexibility.

At the time of writing this document and similarly as for the residential energy storage systems, there are several factors that impact the extent to which the vertical policy recommendations for the EV charging systems can be developed.

First, the EV charging systems market is a fast growing and developing market. As described in the accompanying report of the follow-up study, it is still uncertain how and in which direction the

market will develop, which makes it insufficiently mature market to define the policy recommendations.
Second, at this point in time, there is no Energy labelling coverage or Ecodesign coverage for this group of appliances.
Last, the EV charging systems are component based systems (typically, the battery and the battery management system in the car, and the external charging station, where a single car is not always charged by the same charging station), where the flexibility source, the controller and the power consumption are not situated in a single product. The fact that these core elements for defining energy smartness of an appliance are spread over different components makes the definition of the requirements challenging, as it is not always clear whether a certain product (part of the system) or the whole system shall comply with the specified requirements.

At this point in time, the EV charging systems markets have not yet reached the mature stage, as they are still experiencing fast growth and a high level of innovation. Moreover, partly due to the market immaturity, at this point there are no instruments in place to develop a policy set with requirements for definition of energy smart residential energy storage systems. Although it is highly advisable to develop such measures, they will not be the main focus of this study.

When addressed, the development of requirements for an energy smart label for EV charging systems can rely on the requirements already previously developed within lot 33. More specifically, all horizontal requirements can be adopted. The vertical requirements will need to be defined specifically for residential storage systems, but most likely will be able to take inspiration from the requirements for HVAC appliances with storage.

Table 7 Overview of appliances and evaluations during the preparatory study.

Group	Subgroup	Appliance	Splitup/naming in Task 6	Task 1 Ranking: High potential	Task 1 Ranking: Smaller potential	Task 1 Ranking: Emergency potential	Task 6: Significant impact?	Task7: Flexibility in the appliance?	Task7: Energy labelling coverage	Task7: Ecodesign coverage	Proposed action
household appliances	periodical appliances	dishwasher		•			yes	yes	•	•	Icon dishwasher energy label
		washing machine		•			yes	yes	•	•	Icon washing machine energy label
		tumble dryer	No heat pump		•		yes	yes	•	•	Icon tumble dryer energy label
			Heat pump				yes	yes	•	•	
		washer dryer		•			n.a.				
	energy storing appliances	refrigerators			•		yes	yes	•	•	Icon refrigerator/freezer energy label
		freezers			•						
		commercial refrigeration products	Tertiary cooling - compressor		•		yes	yes	•	•	Icon professional refrigeration energy label
			Tertiary cooling - defrost		•		yes	yes			
		storage water heaters	Continuous	•			yes	yes	•	•	Icon storage water heater energy label
			Night storage	•			no				
	behavioural appliances	electrical hobs				•					
		ovens				•					
		hoods				•					
		vacuum cleaners				•					
		instantaneous water heaters				•					
HVAC	electric heating	electric radiators	without inertia	•			yes	no		•	TBD
			with inertia				yes	yes		•	TBD
		electric boilers		•			yes	no	•	•	Icon on the electric boiler energy label
		residential electric heat pumps	HVAC heating, no storage	•			yes	no	•	•	TBD
			HVAC heating,with thermal storage				yes	no	•	•	Icon on the heat pump energy label
		non-residential heat pumps	HVAC heating, no storage				yes	no		•	TBD
			HVAC heating,with thermal storage				yes	no		•	TBD
		hybrid heat pumps		•			n.a.	no	•	?	TBD
		boiler circulators				•					
	ventilation	residential ventilation				•					
		non-residential ventilaton			•		n.a.	no			
	air conditioning	residential air conditioners	HVAC cooling, no storage	•			yes	no	•	•	TBD
			HVAC cooling, with thermal storage				yes	no	•	•	Icon on the air conditioning energy label
		non-residential air conditioners	HVAC cooling, no storage	•			yes	no		•	TBD
			HVAC cooling, with thermal storage				yes	no		•	TBD
battery operated rechargeable appliances		multimedia devices			•		n.a.	yes	?		low priority
		power tools			•		n.a.	yes	?		low priority
residential energy storage systems		Backup systems (UPS)				•					
		home battery storage systems		•			yes	yes			TBD
lighting systems		Residential lighting				•					
		Commerical indoor lighting				•					
		Street lighting				•					

7.4.2. Appliances under the EU's Energy Labelling Directive

Table 8 gives a more detailed overview of the existing Ecodesign and Energy labelling coverage for the appliances in scope for policy recommendations. Although not subject of the original Preparatory Study, it was also advised that electric vehicles chargers should be subject of further investigation, as they have a large demand side flexibility potential with low consumer impact, and as the installed base is expected to grow rapidly. The large potential was also confirmed in the supplementary report to the follow-up study, and the EVs are added to the scope of the study.

Most appliances are covered by Ecodesign requirements, except home battery systems and electric vehicle charging stations. Not all products are covered by an Energy Label.

Table 8 Overview of the Ecodesign and Energy labelling coverage for the appliances in scope for policy recommendations.

Group	Energy smart appliance	Energy Labelling coverage	Ecodesign coverage
Periodical appliances	Dishwashers	Household dishwashers are covered by Regulation No 1059/2010	Household dishwashers are covered by Regulation No 1016/2010
	Washing machines	Household washing machines are covered by Regulation No 1061/2010	Household washing machines are covered by Regulation No 1015/2010
	Tumble dryers, with or without heat pump	Household tumble dryers are covered by Regulation No 392/2012	Household tumble dryers are covered by Regulation No 932/2012
Energy storing appliances	Electric storage water heaters (continuously heating storage)	Electric water heaters with rated heat output ≤ 70 kW and hot water storage tank ≤ 500 litres with back-up immersion heater are covered by Regulation No 812/2013	Electric water heaters with rated heat output ≤ 400 kW and hot water storage tank ≤ 2000 litres with back-up immersion heater are covered by Regulation No 814/2013
Residential cooling and heating (heat pump based)	HVAC cooling, with thermal storage	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 626/2011	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 206/2012
	HVAC heating, no storage	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 626/2011 Heat pump space heaters with a rated heat output ≤	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 206/2012 Heat pump space

		70 kW are covered by Regulation No 811/2013	heaters with a rated heat output ≤ 40 kW are covered by Regulation No 813/2013
	HVAC heating, with thermal storage	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 626/2011 Heat pump space heaters with a rated heat output ≤ 70 kW are covered by Regulation No 811/2013	Air conditioner with rated capacity of ≤ 12 kW are covered by Regulation No 206/2012 Heat pump space heaters with a rated heat output ≤ 40 kW are covered by Regulation No 813/2013
	Household refrigerating appliances	Electric mains-operated household refrigerating appliances with a storage volume between 10 and 1 500 litres are covered by Regulation No 1060/2010	Electric mains-operated household refrigerating appliances with a storage volume up to 1 500 litres are covered by Regulation No 643/2009
Tertiary cooling and heating (heat pump based)	HVAC cooling, no storage	Not covered by Energy Labelling	Cooling products with a rated cooling capacity ≤ 2 MW are covered by Regulation No 2016/2281
	HVAC cooling, with thermal storage		
	HVAC heating, no storage		Air heating products with a rated heating capacity ≤ 1 MW are covered by Regulation No 2016/2281
	HVAC heating, with thermal storage		
	Professional refrigeration	Professional refrigerated storage cabinets are covered by Regulation No 2015/1094	professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers are covered by Regulation No 2015/1095
Joule based tertiary and residential cooling and heating	Electric radiators, no inertia	Not covered by Energy Labelling	Electric local space heaters ≤ 50 kW for domestic, ≤ 120 kW for commercial are covered by

			Regulation No 2015/1188
	Electric radiators, with inertia	Not covered by Energy Labelling	Electric local space heaters ≤ 50 kW for domestic, ≤ 120 kW for commercial are covered by Regulation No 2015/1188
	Boilers	Electric boiler space heaters and boiler combination heaters are covered by Regulation No 811/2013 Electric water heaters with rated heat output ≤ 70 kW are covered by Regulation No 812/2013	Electric boiler space heaters and boiler combination heaters are covered by Regulation No 813/2013 Electric water heaters with rated heat output ≤ 70 kW are covered by Regulation No 814/2013
Residential energy storage systems	Home batteries	Not covered by Energy Labelling	Not covered by Ecodesign
	Electric vehicle chargers	Not covered by Energy Labelling	Not covered by Ecodesign

7.5. INTERFACE SCOPE

This section starts from a number of very practical use cases, defined from a customer/appliance point of view. For each use case, high level interface requirements will be determined resulting in 3 types of control architectures: a control architecture with a ***direct flexibility interface***, a control architecture with an ***indirect flexibility interface*** and a control architecture based on an ***internal measurement interface***. Next, the relationships between these control architectures will be discussed and the importance of the “direct flexibility interface” as a building block for the other control architectures will be discussed.

7.5.1. USE CASES FROM A CUSTOMER/APPLIANCE POINT OF VIEW

In Task 3, a number of demand side flexibility use cases are described from a system perspective. In Task 5 and 6, these use cases are used to calculate the impact of smart appliances at system level and the monetary consequences in terms of Life Cycle Costs for the customer. Task 5 and 6 have focussed on the day-ahead use case and the imbalance use case. In practice, however, these system level use cases have only a limited relevance for the appliance configuration at the customers premises. In this section, a number of use cases are described which approach the context of smart appliances from an appliance and local customer configuration point of view. These use cases will be used later in order to define requirements at the level of the appliance which will lead to policy recommendations.

7.5.1.1 Explicit demand response use case

Description

In this use case the smart appliance communicates its flexibility status (availability, flexibility, …) to an external party (grid operator, supplier, flexibility provider, …). The smart appliance allows the external party to switch ON/OFF or modulate the electricity consumption/production within certain (comfort) limits.

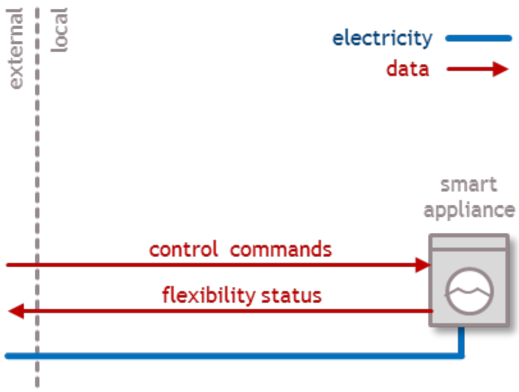


Figure 4: Explicit demand response use case

Example

A washing machine is programmed at 22:00h in the evening to be ready the latest at 7:00h in the morning. The selected washing program will take 3h so the washing machine should start the latest at 4:00h. The appliance communicates the duration of the program (3:00h) and the latest hour the program should be completed (7:00h), it communicates as well that it will start at 4:00h if it does not get any external control command. The external party has the possibility to send a control command between 22:00h and 4:00h in order to start the appliance earlier than its default behaviour.

Mapping on system level use cases

The "explicit demand response use case" is a well-accepted concept in today's industrial demand response programs , mainly used for imbalance control via frequency containment (FRRa, FRRm) and replacement reserves (RR). The same concept can be used for flexibility in smart appliances. The external party can be a grid operator or an aggregator. Also electricity suppliers/BRP's are interested in flexible electricity consumption/production and might be interested to use and explicit demand response scheme to improve the balance in their portfolio. Further, the concept is suited for local grid support schemes for voltage control, load shifting or peak shaving. In that case the external party will be the local distribution grid operator.

Remuneration scheme(s)

The remuneration scheme is quite often a combination of an "availability fee" and an "activation fee" in a contractual agreement between the customer and the third party.

Top level interface requirements at appliance level

The appliance needs a bi-directional communication interface which is able to send "flexibility status information" and receive "control commands" to/from the external partner. Since the external partner can influence the behaviour directly by means of control commands, this interface type will be called a ***direct flexibility interface*** in the remainder of this document. In this configuration, it is important that the external party can verify whether the appliance acted upon contractual agreement. This imposes additional "settlement" and/or "verification" requirements.

Practical examples

Example 1: Belgium (Flemish region)

[phase: pilot, application: residential flexibility]

The Pilot project Linear tested the potential of residential automated demand response. The customer received a "smart start" capacity fee (1 Euro/40 h of start delay configured) for the flexibility provided from their smart appliances (EVs and periodical appliances, except hot water buffers). For some of the smart appliances the controller was embedded in the appliance (I.e. Miele washing machine, tumble dryer, dish washer) and for some others the controller was provided externally (I.e. Siemens washing machine and dish washer). This pilot project implemented a bidirectional communication to control the smart appliance that started with the setting of comfort boundaries. In practice, participants interacted with their smart appliances only to set their comfort boundaries (e.g. specifying the time at which the washing machine should finish its cycle). Comfort boundaries were sent to the home gateway (interface with the outer world) and then transferred to the Linear Pilot Backend (complex ensemble of multiple servers situated outside the household) where all required operations for the pilot were processed. Based on the amount of hours of delay configured by the user, the backend calculated the actions (e.g. load shifting) to be taken by each smart appliance in the test.

References:

Linear - Intelligent Networks: Demand response for families (Final report), 2014.

Example 2: Australia (South East Queensland)

[phase: commercial, application: residential flexibility + tertiary flexibility]

The energy company Energex offers a program "PeakSmart air-conditioning" to cap the energy consumption of air-conditioners. The program is used to reduce peak demand for short periods on a few days of the year without affecting the performance of the appliance. Subscribers to this program only interact with the smart appliance to set their comfort boundaries (set and forget approach). The energy company uses the power lines to send a signal to the signal receiver (provided by the retailer or installer) connected directly to the appliance. This device then talks to the appliance to engage its built-in energy efficiency program to cap the unit's energy use (similar to economy mode operation). Signals are only sent when the system reaches peak demand. To modulate (cap) the energy consumption of the appliance, the air-conditioning must be able to interact with the signal receiver. Currently, many models have this capability out-of-the-box (factory), while other models need additional components. Subscribers to the program receive a reward according to the cooling capacity of the unit (from AU$100 for a capacity lower than 4kW up to AU$400 for a capacity of 10kW or more).

References:

Energex, n.d. PeakSmart - The facts [WWW Document]. URL
https://www.energex.com.au/home/control-your-energy/positive-payback-program/positive-payback-for-households/air-conditioning-rewards/peaksmart-the-facts (accessed 5.16.17).

Example 3: Germany

[phase: commercial, application: industrial flexibility]

The energy company EWE offers the "Intelligent Load Manager" product to applications with thermal flexibility potential such as cold storage houses, large green houses, supermarket chains, flour mills, bucket elevator pumps, waterworks, as well as customers in the paper and cement industry. This product enables customers to reduce their energy cost by shifting load to times with high availability of renewable energy. The intelligent load manager fulfils the same tasks as the virtual power plant (VPP) in the eTelligence trial. The VPP manages both generation (e.g. wind farms, photovoltaics and biogas systems) and consumption systems (refrigerated warehouses) online via a common control room. The VPP coordinates the operations of decentralized systems by sending optimized schedules to the operators of the cold storages based on when they could obtain particularly cheap amounts of electricity on the EPEX spot market. Then, the VPP buys the inexpensive electricity for the cold storage operators which then, followed the schedule indication to make best use of the situation. This process was in most cases automated and thus, requiring minimal interaction with the flexibility owner. Today, the utility optimizes their applications' schedules with the goal to pay the least expensive price for their consumption.

References:

www.ewe.com

eTelligence – Including commercial customers with an IEC 61850 based energy management system [WWW Document], n.d. URL http://www.gridinnovation-on-line.eu/Articles/Library/ETelligence--Including-Commercial-Customers-With-An-IEC-61850-Based-Energy-Management-System.kl (accessed 5.16.17).

Example 4: United States (Austin)

[phase: commercial, application: residential flexibility]

The Austin energy company offers a voluntary energy cycling program. Subscribers to this program allow the utility to adjust thermostat settings (between 2-4 degrees) during "rush-hour" events. These events are limited to one per day. To adjust the settings of the Internet-connected thermostat the utility sends a message with the scheduled Rush Hour. In the case of the Nest thermostat, the smart appliance will look at the usual temperature schedule (historical data) and tune the heating or cooling up or down a few degrees. Historical data provides indications of how quickly the house heats and cools, what temperatures the user likes, the outside temperature, and even the weather forecast. The thermostat makes adjustments to the temperature based on the presence of the user (larger if not at home and smaller otherwise). Although the whole process is automated, the owner of flexibility has always the possibility to manually change the temperature of the thermostat during a rush-hour event. Subscribers for the Rush Hour Rewards program receive a one-time payment of US$85 for each Energy-approved Internet-connected thermostat.

References:

Nest Thermostat, Nest Protect and Nest Cam support [WWW Document], n.d. . Nest. URL https://www.nest.com/support/article/ (accessed 5.16.17).

Austin Energy, 2017. Power Partner Thermostats [WWW Document]. URL http://savings.austinenergy.com/wps/portal/rebates/residential/offerings/cooling-and-heating/pp-thermostat/!ut/p/a1/jZHBbsMgDIafZQeOBItJSbRb1MPaqFWndFUpl4m0BCIlgIB02p5-dNtxWcvFwvpt_59NOGGEG3HplYi9NWK4_nn-BrSkywXQ1TPUBVR1s9_mr7u62NIkOM4LmpzeWT_zKrhVX98xgPrNYqMIdyJq3JvOEnayduiNwsKcsZaJ1ijCnMNRSz_aEEUkB8L_692sixuCK_yPYJ4u2VeDbb83faxM-1gmn1520kufTT6ldYzuCQGCkO5iVMjEFJJdaaRXH9nJjgjeXUDgrI9iQOBlK6JMCdHaKf4G3CXGycvzX2N04iVsrj1x4559rpfQv4yHMlQPX1FnLAA!/dl5/d5/L2dBISEvZ0FBIS9nQSEh/ (accessed 5.16.17).

Example 5: United States (California)

[phase: commercial, application: residential flexibility]

The electric Motor Werk (eMW) company offers EV charging stations (EVSE), smart grid EV charging networks, and charging systems for high-voltage and DC fast charging. In 2016, the company sold 0.9 MW capacity on a Demand Response Auction Mechanism (DRAM) to utilities in California. According to the company, their products are able to modulate load 100% in 3 seconds. This allows them to participate in the real time five minute energy market and the frequency markets (which require a 4 seconds response). eMW communicates with the management systems of utilities to know when energy is needed. Via the JuiceNet product, the company centrally decides how to charge the electric vehicle in a way that maximizes the use of renewable energy and minimizes the contribution to grid congestion, and all of this in a fully automated manner (taking into account user's comfort boundaries). However, EV owners are always able to overwrite the program. Participants to this program receive incentives (based on payments from utilities and grid operators).

References:

Electric Motor Werks, 2017. JuiceNet [WWW Document]. URL https://emotorwerks.com/products/juicenet (accessed 5.17.17).
Herman K. Trabish, 2016. What to expect from California utilities' new aggregated demand response offerings [WWW Document]. Utility Dive. URL http://www.utilitydive.com/news/what-to-expect-from-california-utilities-new-aggregated-demand-response-of/412614/ (accessed 5.17.17)

7.5.1.2 Implicit demand response use case

Description
In this use case the smart appliance receives variable electricity price information from an external party (grid operator or supplier). Within the comfort boundaries, the smart appliance decides itself to reduce/increase electricity consumption or production in order to minimize the electricity consumption cost or to maximize the electricity production fee.

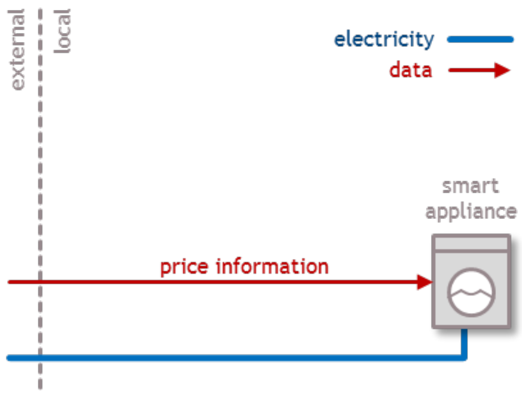


Figure 5: Implicit demand response use case

Example
The same washing machine is still programmed at 22:00h in the evening to be ready the latest at 7:00h in the morning with the same 3h program. The appliance received or requested the variable electricity price rates. The appliance decides autonomously to start the washing program at 1:45h in the morning because the energy intensive warming up of the machine will take place in the cheapest time slot between 2:00h and 3:00h.

Mapping on system level use cases
The “implicit demand response use case” is suitable for customers with variable electricity price contract, including variable prices which are derived from the day-ahead market prices. In that sense this concept maps directly on the day-ahead use case at system level. Depending on how the variable price signal is set by the external party, the implicit demand response concept can also support peak-shaving and load shifting grid support use cases.

Remuneration scheme(s)
The remuneration is intrinsically present in the variable price concept. The more flexibility the customer can give to its smart appliances, the more options the appliance has to select the cheapest moment in time and reduce its electricity cost.

Top level interface requirements at appliance level
The appliance needs a uni-directional communication interface which is able to receive “price information” from the external partner. Since the external partner cannot influence the behaviour of the appliance directly by means of control commands and the price signal only has an indirect effect

on the appliance behaviour, this interface type will be called an ***indirect flexibility interface*** in the remainder of this document.

Practical examples

Example 1: Belgium (Flemish region)

[phase: pilot, application: residential flexibility]

The Pilot project Linear tested indirect control of appliances. Testing subjects with no smart appliances received price signals (dynamic tariff remuneration scheme). This remuneration scheme served as a bonus or cost reduction as it did not replace the original energy contracts of the participants. Testing subjects were presented with prices for the current and next day via the linear portal and were requested to react manually. That is, the test used unidirectional communication to present tariff to the end-user. For the test, 6 fixed time periods were defined upfront (time of use pricing mechanism). Electricity prices were determined daily, based on prices from Belpex day-ahead wholesale market and the predicted generation of wind and solar. The average daily price spread was around 0,08€/kWh. Remuneration for testing subjects was based on energy shifts relative to their reference consumption.

References:

Dupont, B., Vingerhoets, P., Tant, P., Vanthournout, K., Cardinaels, W., De Rybel, T., Peeters, E., Belmans, R., 2012. LINEAR breakthrough project: Large-scale implementation of smart grid technologies in distribution grids, in: Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition On. IEEE, pp. 1–8.

Linear - Intelligent Networks: Demand response for families (Final report), 2014.

Example 2: Germany (Cuxhaven Region - Lower Saxony)

[phase: pilot, application: residential flexibility]

The smart grid project eTelligence used dynamic pricing and real-time feedback to motivate consumers to provide flexibility. Within the project two types of time of use (ToU) tariff (an event-tariff and a quantity-tariff) were developed. Each tariff had two price levels. For the event-tariff additional bonus (0€/kWh) and malus events (1,2€/kWh) could be offered based on the availability of RES (announced day-ahead). Via a unilateral communication, consumers had to respond manually on the observed prices. Electricity savings up to 20% in case of malus events and additional electricity consumption up to 30% during bonus events were observed. Results suggest that a quantity-tariff may bring savings to households (up to 13% during the trial) based on the feedback of electricity consumption in real time, while the time-variable Event-Tariff may achieve load transfers that efficiently use renewable energy. During the test load transfers of up to 30% were achieved.

References:

Tanja Schmedes, 2012. eTelligence - Energy meets Intelligence.

eTelligence Project | The Renewable Energy Stocktake [WWW Document], n.d. URL https://renewablestocktake.com.au/directory/project-636 (accessed 5.16.17).

eTelligence [WWW Document], n.d. URL http://www.gridinnovation-on-line.eu/Articles/Library/ETelligence.kl (accessed 5.16.17).

Example 3: Netherlands

[phase: commercial, application: residential flexibility]

The Jedlix company (subsidiary of the energy company Eneco) offers a smart charging app (iOS and android) for any electric or plug-in hybrid car. The apps takes into account the comfort boundaries of the car owner (I.e. time at which the car must be fully charged) to control the charging of the EV based on the balance between consumption and supply of renewable energy. That is, the app determines the charging pattern with the lowest rate during the charging period by keeping track of energy prices (via direct communication with the energy exchange) and controlling the charge speed of the battery. Charging of the car can be done in public charge points (previous registry of charging cards) or at home (currently only for Tesla). On the road, the app directs the EV owner to a suitable charging point to ensure the best charging times. At home, the charging pattern is directly sent to the EV (Tesla only).

References:
Jedlix, Start smart charging your EV today!, [WWW Document], n.d. URL https://jedlix.com/start-smart-charging/ (accessed 5.16.17).

7.5.1.3 Local optimal energy consumption use case

Description

In this use case, the smart appliance tries to make optimal use of locally produced energy (e.g. from PV panels, micro-CHP). A local controller has access to local measurements (e.g. net consumption, PV production eventually via a smart meter) and can decide at which moment in time it is beneficial to reduce/increase electricity consumption. The smart appliance communicates its flexibility status (availability, flexibility, …) to the controller which can decide to switch ON/OFF or modulate the electricity consumption of the appliance. The use case includes the term “local” because there is no interaction/communication with an external party.

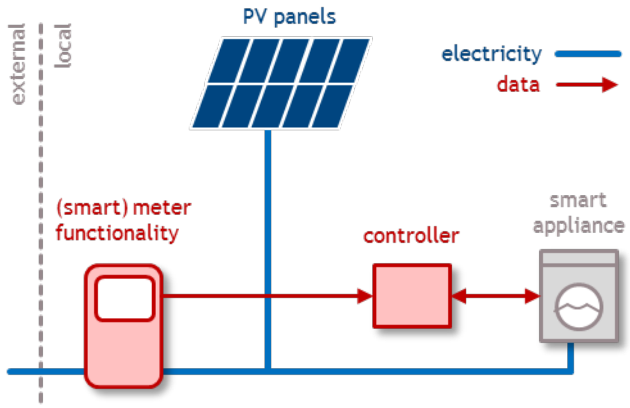


Figure 6: Local optimal energy consumption use case

Example

The same washing machine is still programmed at 7:00h in the morning to be ready the latest at 18:00h in the afternoon with the same 3h program. The appliance communicates it can start its program from 7:00h till 15:00h the latest, it communicates as well that it will start at 15:00h if it does not get any external control command. The controller decides to send a START command at 14:00h because the local PV production results in a net injection into the grid.

Mapping on system level use cases

The “local optimal energy consumption use case” does not directly map on the traditional system level use cases. Indirectly, however, this use case has a positive impact on the grid and reduces injection peaks, voltage problems and frequency problems.

Remuneration scheme(s)

The remuneration might be present in the difference between consumption and injection prices. In countries where the injection price is lower than the consumption price, it is financially beneficial to avoid injection and consume as much as possible of the own local production.

Top level interface requirements at appliance level

In this use case, the appliance communicates with a (local) controller which is also responsible for collecting information on the electricity consumption and/or production. From an appliance point of view, the interface is equal to the interface used in the “explicit demand response use case”. The only difference is that the appliance sends “flexibility status information” and receives “control commands” to/from a local controller instead of an external party. Although there are differences from privacy and security point of view, from a functional point of view, this is the same ***direct flexibility interface***. Due to the fact that no contractual agreement is in place between the appliance and an external party, there is less need for “settlement” and/or “verification” requirements.

Practical examples

Example 1: Germany (Cuxhaven Region - Lower Saxony)

[phase: commercial, application: residential flexibility]

The energy company EWE offers the EQOO smart storage system. This system stores solar power from PV panels when it is not instantly consumed. The system is able to satisfy a large part of the household electricity demand (around 70% for an average household in this region of Germany) with locally generated renewable electricity. The remainder is provided by the utility from renewable sources. The system is fully automated but the household owner can take control of the system (remotely via Web portal or App) at any time. The user can set his preferences on how much electricity should be saved or fed to the grid and also the time to do so. In practice, the system stores energy not immediately consumed for up to one day before excess energy is fed into the grid.

References:

https://www.ewe.com/en/ewe-group/energy-innovations/household/intelligent-energy-from-the-roof

https://www.eqoo.de/

Example 2: United States

[phase: commercial, application: residential flexibility]

Tesla offers two products: the Solar roof and the Powerwall home battery. The combination of these two products allows the user to get a continuous supply of electricity (even during grid outages). The user can monitor and manage both products with an app. The user may decide when and who much electricity is delivered to the home (e.g. to charge EVs) and to the grid (in case of excess energy).

References:

https://www.tesla.com/powerwall

https://www.tesla.com/solarroof

7.5.1.4 *Standalone demand response use case*

Description

In this use case, the smart appliance has built-in functionality to measure a grid parameter, typically voltage and/or frequency. When the specified grid parameter exceeds a certain value, the smart appliance adapts its electricity consumption/production in a way which is beneficial for the grid. Typically, the appliance reduces its electricity consumption or increases its electricity production when the frequency and/or voltage are low, the appliance increases its electricity consumption or decreases its electricity production when the frequency and/or voltage is too high. The use case includes the term “standalone” because there is no interaction/communication with any controller or external party.

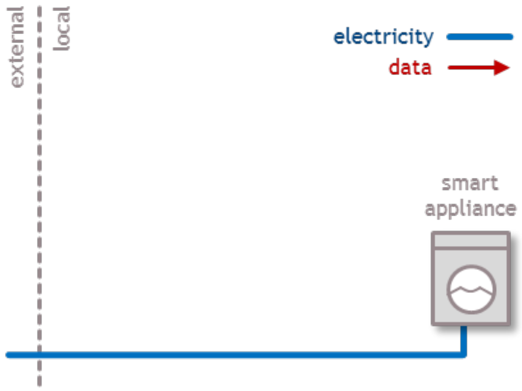


Figure 7: Standalone demand response use case

Example

The same washing machine is still programmed at 7:00h in the morning to be ready the latest at 18:00h in the afternoon with the same 3h program. During the warming-up cycle of the washing program, the grid frequency drops below a certain threshold value. The washing machine switches of the heating and motor and waits till the grid frequency recovers in order to proceed its program.

Mapping on system level use cases

The “standalone demand use case” maps directly on the voltage control grid support use case and the frequency containment use case, which is a specific part of the imbalance use case at system level.

Remuneration scheme(s)

The remuneration scheme is typically based on a contractual agreement between the customer and a third party, typically the grid operator or an aggregator. For some types of appliances and in some countries, this built-in demand response mechanism is obligatory and included in the grid code, without remuneration.

Top level interface requirements at appliance level

The appliance measures a grid parameter itself and does not need a communication interface with an external controller or party. Since the appliance changes its behaviour based on an internally measured grid parameter, this type of interface will be called an ***internal measurement interface*** in the remainder of this document.

Practical examples

Example 1: Belgium (Flemish region)

[phase: pilot, application: residential flexibility]

The Pilot project Linear tested local voltage control using available flexibility of residential smart appliances with the objective to mitigate over- and under-voltages on the low voltage distribution grid. The control mechanism/system was based on "local drop control". The mechanism used local measurements (measured at the household connection to the low-voltage distribution grid, e.g. smart meter) and communication (only between smart appliances within the household) to bring voltage closer to an acceptable range. In lab and field tests the mechanism controlled flexibility from electric vehicles (EV), washing machines (WM) and hot water boilers (HWB). Participants of this test received a capacity fee for the flexibility provided (1euro/40h). Flexibility response was automatic and based on a merit order that took into account the state of the smart appliances and the measured voltage. The interaction between flexibility owners and the smart appliance was limited to the provision of comfort settings (e.g. end-time for washing machine).

References:

D'hulst, R., Vanthournout, K., Hoornaert, F., 2014. LV distribution network voltage control mechanism: Experimental tests and validation, in: IECON 2014 - 40th Annual Conference of the IEEE Industrial Electronics Society. Presented at the IECON 2014 - 40th Annual Conference of the IEEE Industrial Electronics Society, pp. 3504–3509. doi:10.1109/IECON.2014.7049019

Example 2: United States (Pacific Northwest)

[phase: pilot, application: residential flexibility]

The Grid Friendly Appliance Project tested an autonomous, grid-responsive controller called the Grid Friendly appliance (GFA) controller. This device is a small electronic controller board that autonomously detects under-frequency events and requests that load be shed by the appliance that it serves. The GFA controller was configured to observe the nominally 60-Hz ac voltage signal to recognize instances when the measured grid frequency fell below a 59.95-Hz threshold and to promptly alert the controlled appliance about the impending under-frequency event. Participants of the study were offered a new Sears Kenmore HE dryer, manufactured by Whirlpool Corporation, as their principal participation incentive. There were also retrofitted residential water heaters. The appliances were modified to shed major portions of their electrical loads when they received signals from their GFA controllers. The signal was passed on to the appliance within about ¼ second after a sudden drop in frequency and the load shedding lasted from several seconds to 10 minutes. The GFA controller was placed between the loads and their electric service and performs its duties autonomously. The only communication that it requires is the ac voltage signal that is available at any appliance's wall-plug. GFA controller could also receive and react to other demand-response requests. When surveyed at the conclusion of the project, residential participants confirmed that they had not been inconvenienced by the autonomous under-frequency control of their appliances, and most would purchase an appliance configured with such a grid-responsive control.

References:

DJ Hammerstrom, 2007. Part II. Grid Friendly™ Appliance. Pacific Northwest National Laboratory.

7.5.2. Interoperability between different business cases or use cases

Demand side management at residential level is in its first steps of development and it is important to ensure that a smart appliance is flexible enough to be used in different business cases or use case configurations. In 7.5, use cases were described from a customer/appliance point of view and 3 types of interface architectures were defined/observed in order to support a multitude of customer and system level use cases. By doing so, the business case interoperability concern has been translated into interface architecture requirements. Consequently, the **scope of the policy recommendations** will be on interface requirements and **not on specific business case / use case interoperability**.

7.5.3. Overview of system level use cases mapping on customer/appliance level use cases

In the previous sections it was indicated how the use cases, as seen from a customer/appliance point of view map on the system level use cases which were used earlier in this study. Figure 8 summarizes this mapping under the form of a matrix. All system level use cases can be implemented by the defined customer/appliance level use cases. Some customer/appliance level use cases do not directly map on a specific system level use case, but they will have an indirect positive impact to the electricity system.

		imbalance					grid support		
	day-ahead	portfolio management	FCR (frequency control)	FRRa	FRRm	RR	voltage control	peak-shaving	load shifting
Explicit demand response	•	•	•	•	•	•	•	•	•
Implicit demand response	•	•						o	o
Local optimal energy consumption			o				o	o	
Standalone demand response			•				•		

• direct mapping

o indirect impact

Figure 8: Mapping of system level use cases on customer/appliance level use cases

7.5.4. Relationships between smart appliance interface architectures

In section 7.5.1 it was explained that the common customer use cases require 3 types of interface architectures: a ***direct flexibility interface***, an ***indirect flexibility interface*** and an ***internal measurement interface***. In this section the relationships between these interface architectures are discussed.

7.5.4.1 Smart appliance interfaces overview

Direct flexibility interface

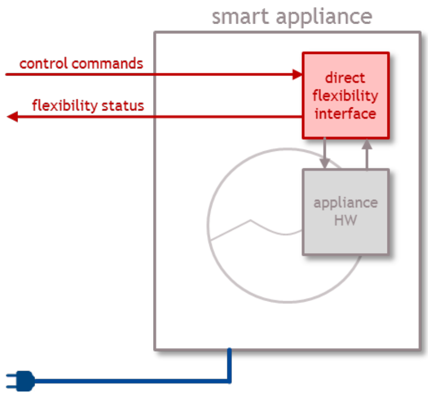


Figure 9: Direct flexibility interface

Figure 9 gives a schematical overview of the direct flexibility interface. It consists of a bi-directional communication interface which can send flexibility status information and receive control commands. Since the behaviour can be changed directly by means of control commands, this interface type is called a direct flexibility interface.

Indirect flexibility interface

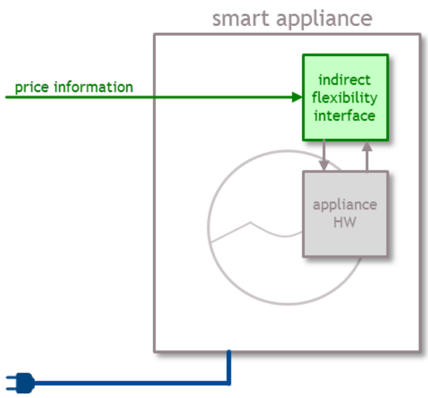


Figure 10: Indirect flexibility interface

Figure 10 gives a schematical overview of the indirect flexibility interface. It consists of a uni-directional communication interface receives price information. Based on the flexibility settings and status of the appliance, the appliance selects the cheapest timeframe to schedule its activities. Since an external party cannot influence the behaviour of the appliance directly by means of control commands and the price signal only has an indirect effect on the appliance behaviour, this interface type is called an indirect flexibility interface. It is important to mention, however, that this interface requires more advanced decision logic compared to a direct flexibility interface which in principle only follows external instructions.

Internal measurement interface

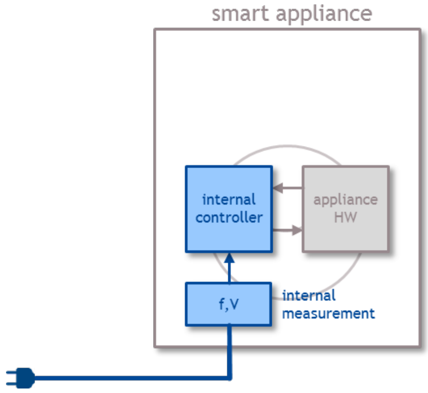


Figure 11: Internal measurement interface

Figure 11 gives a schematical overview of the internal measurement interface. The appliance itself measures a grid parameter (typically voltage and/or frequency) and when it exceeds a certain value, the smart appliance adapts its electricity consumption/production in a way which is beneficial for the grid. Since the appliance changes its behaviour based on an internally measured grid parameter and needs no further communication to the outside world, this type of interface is called an internal measurement interface.

7.5.4.2 The direct flexibility interface with external controllers

An appliance, which only has a direct flexibility interface can also be used for use cases which require an indirect flexibility interface or an internal measurement interface by means of an external controller.

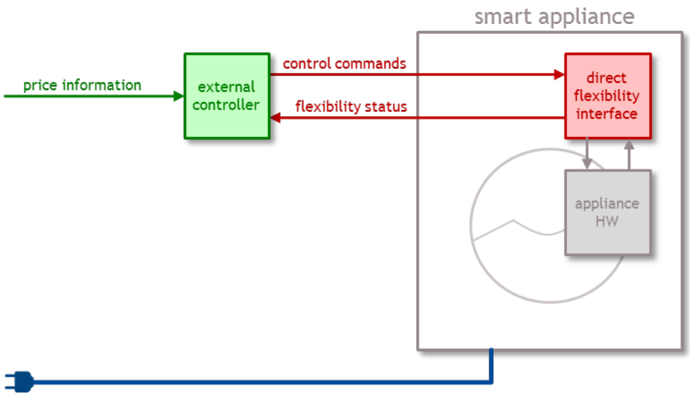


Figure 12:Implementation of an indirect flexibility interface as a cascade of an external controller and a direct flexibility interface.

Figure 12 shows an appliance with an direct flexibility interface which is connected to an external controller. The external controller receives the price information and requests the flexibility information from the appliance. Based on this information, it makes an optimal schedule and sends control commands at the appropriate moments to the appliance.

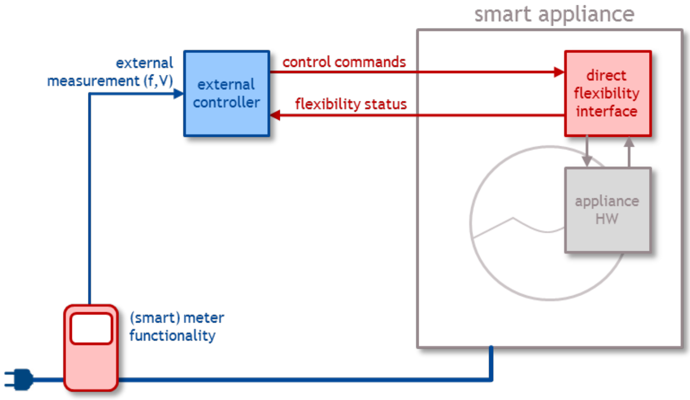


Figure 13:Implementation of an internal measurement interface as a cascade of an external measurement device, an external controller and a direct flexibility interface.

In a similar way, an internal measurement interface can be implemented, as shown in Figure 13. An external measurement device (e.g. smart meter) measures the grid parameter and sends this to an external controller which knows the flexibility status of the connected appliance via the direct flexibility interface. In case a grid parameter exceeds a certain value, the external controller sends a request to smart appliance to change its energy consumption in a beneficial way for the grid.

7.5.4.3 Access to a direct flexibility interface by bypassing internal controllers

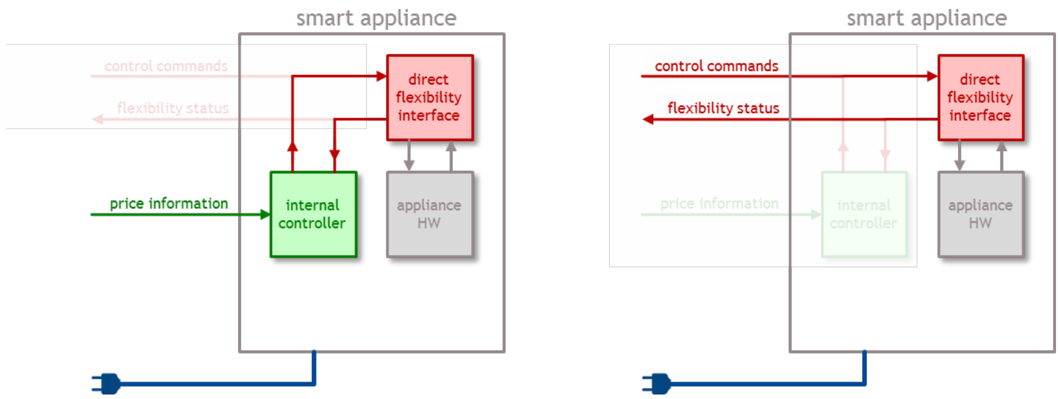


Figure 14:Implementation of an indirect flexibility interface as a cascade of an internal controller and a direct flexibility interface.

The cascading principle can be used to create smart appliances with multiple interfaces. Figure 14 shows an appliance with an indirect flexibility interface which internally is configured as a series connection of a controller and a direct flexibility interface. In the left figure, the indirect flexibility interface is used while in the right figure, the internal controller is bypassed to access the direct flexibility interface.

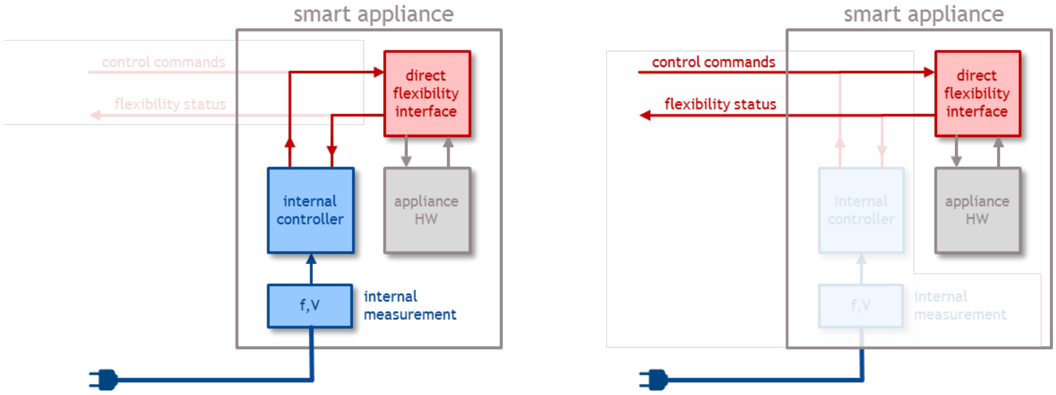


Figure 15:Implementation of an internal measurement interface as a cascade of an internal measurement device, an internal controller and a direct flexibility interface.

In a similar way, Figure 15 shows an appliance with an internal measurement interface which can be converted into an appliance with a direct flexibility interface. In the left figure, the appliance uses its internal measurement interface while in the right figure, the internal controller is bypassed to access the direct flexibility interface.

7.5.5. INTERFACE SCOPE FOR THE POLICY RECOMMENDATION

In this section, the 3 different types of flexibility interfaces have been discussed. It is shown how the direct flexibility interface can be used as a building block to implement the other types of interfaces. Further, it is shown that appliances can be setup internally as a series connection of an internal controller and a direct flexibility interface at the lowest level. By making the direct flexibility interface accessible (or bypassing the internal controller), very generic smart appliances can be created which support a multitude of customer use cases and indirectly a multitude of system level use cases.

Demand response for residential customers is still under development and it is very unclear what direction will be the most interesting for the grid and financially for the customer. For that reason, it is important that smart appliances should have an interface which is versatile enough to support multiple business cases. This section shows that the direct flexibility interface is an important building block towards versatility. **The direct flexibility interface is therefore considered an appropriate topic for policy requirements**.

Appliances with an internal measurement interface are typically linked to grid support mechanisms for frequency and/or voltage control. These grid support mechanism are typically implemented by local and/or country regulation and result in mandatory rules for certain types of appliances in that area. Due to its very specific nature, the different interaction with the consumer and mandatory character, standalone demand response use cases with **internal measurement interface are not further assessed**.

7.6. INTEROPERABILITY SCOPE

As stated from Task 1 onwards, interoperability is a corner stone for the successful introduction of energy smart appliances. Making energy smart appliances interoperable ensures that is possible to use and interchange any energy smart appliance of any brand/vendor in any DR program and any DR control infrastructure in all of EU and EEA. This prevents user vendor lock-ins, both to the vendor or manufacturer of the appliances, and to the energy retailers, and encourages competition and innovation. Interoperability is the property that ensures that consumers can choose any/other brands and ensures a level playing field for the industry. Achieving interoperability of energy smart appliances is also a clear policy objective defined in line with the communication 'Delivering a New Deal for Energy Consumers'[29] which stresses the importance of giving consumers a wide choice of actions.

It is important to mention that the interoperability discussion goes far beyond the scope of this study. Although it is important that appliances will be interoperable with future Home Energy Manager systems (HEM's), Customer Energy Manager systems (CEM's), Building Automation Control Systems (BACS), these management systems are not part of this study. By defining a set of interoperability requirements at appliance level only, it attempts to break the "chicken and egg" discussion.

7.6.1. THE INTEROPERABILITY IN THE HOME ISSUE

As a starting point, the flexibility functional architecture, as it is proposed in flexibility management overview document of the Smart Grid Coordination Group (SG-CG)[30], will be used. The report provides an overview and background to the main concepts related to flexibility management. It also provides first suggestions for functional architectures that are required to detail the generic use cases. It also aims to further develop standardization recommendations as well as recommendations to organizational / regulatory issues.

[29] European Commission: 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Delivering a New Deal for Energy Consumers*', Brussels, 15/7/2015, COM(2015) 339 final, https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8.pdf.

[30] Overview of the main concepts of flexibility management, Version 3.0, CEN-CENELEC-ETSI Smart Grid Coordination Group ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Methodology_FlexibilityManagement.pdf

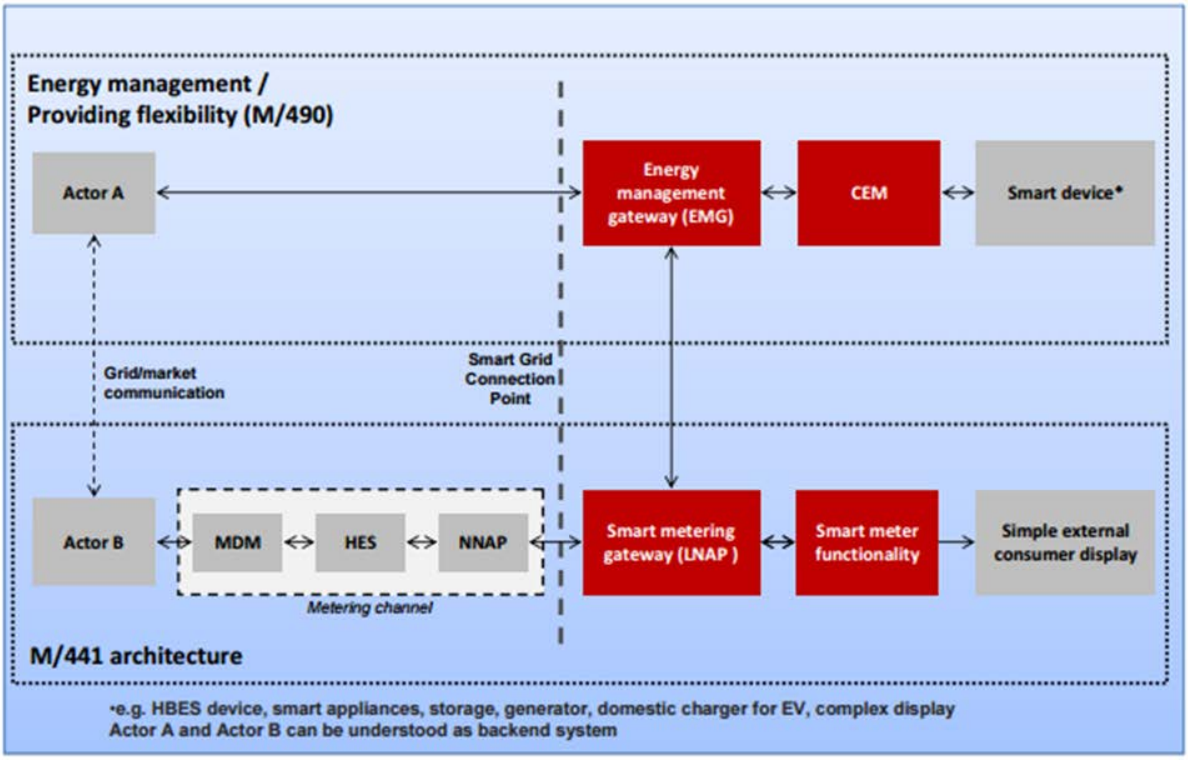


Figure 16: Flexibility functional architecture as proposed by the CEN-CENELEC-ETSI Smart Grid Coordination Group

According to the report, most Demand Response (DR)/Demand Side Management (DSM) use cases can be mapped on a common functional architecture, which is shown 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 the different networks (WAN, LAN).

The reference architecture has been determined from a top-level (use case) point of view but makes abstraction of the complex in home interoperability issue which has to be solved. Figure 17 gives an example of multiple smart appliances from different manufacturers all with their proper communication and protocol choices (e.g. WiFi, ZigBee, wired IP, KNX, PLC, …) which have to be able to communicate in an interoperable way with a CEM. At first sight, guaranteeing interoperability could be requested from a CEM which could support a variety of communication technologies and protocols.

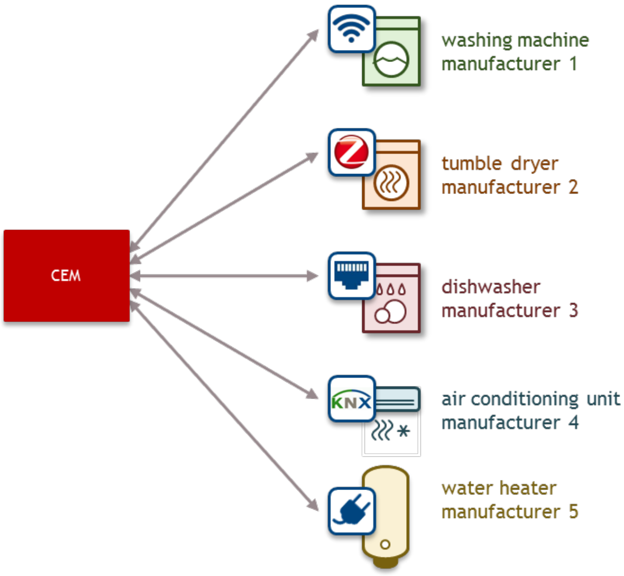


Figure 17: Example of the complexity of the in home interoperability.

7.6.2. Current market evolutions

An important trend today, is to increase the customers comfort and control by means of remote control and remote access via smart phone apps. In most cases this means that the manufacturer makes sure that the appliance and the smart phone connect to a proprietary cloud platform which links them together, as shown
Figure 18. In order to make this work, there are 3 fundamental steps which are found in many solutions:

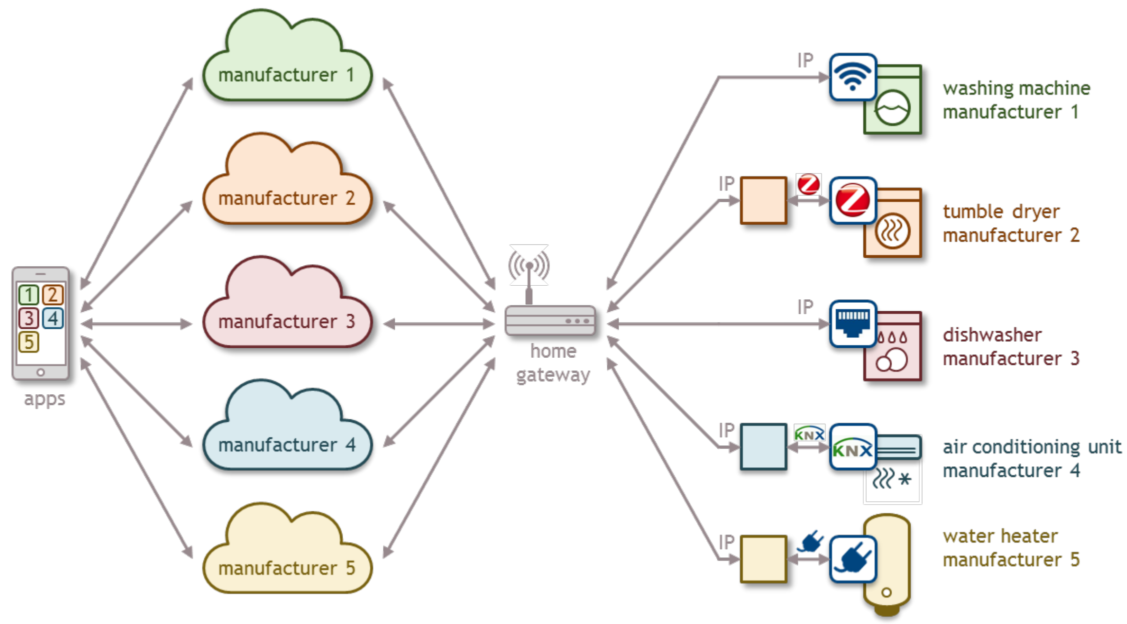
- The existing home gateway (internet connection) is used as an intermediate communication element between the appliance and the cloud platform
- At some point (in the appliance, in a manufacturer proprietary conversion box, manufacturer gateway, …) a conversion to Internet Protocol (IP) is needed to create the communication via the home gateway to the cloud platform
- In most solutions, the linking of the remote control (smart phone) and the appliance happens with the intermediation of proprietary (manufacturer) or a common cloud platform

7.6.3. Interoperability scope for the policy recommendations

Although connectivity with appliances for comfort and remote control reasons is beyond the scope of this study, the trend clearly shows that different in house communication technologies do not restrict streamlining all communication via the IP protocol. This reasoning will be used to **focus in the policy recommendations on a common data model** and not on a common or a list of common communication protocol.

If smart energy capable appliances share a common data model, then this enforces – regardless of the protocol used – the capacity for appliances to understand each other. A common data model does not hinder further competition and innovation in software and hardware. Note that a data model can encompass more than demand side flexibility alone, and that it is relevant for all IoT functionality. Requirements on a specific communication protocol may hamper innovation and slow down the introduction of new, better, and/or cheaper communication technologies.

Figure 18:Internet Protocol (IP) and cloud platforms as de facto intermediate "standards" in the communication link between appliances and the smart phone.



7.6.4. Role of Smart meter and customer/home energy managers in interoperability

Smart meters and customer/home energy managers (CEM/HEM) are mentioned in many residential smart grid architectures and undoubtedly will play an important role in the roll-out, growth and integration of energy smart appliances in services and support of the electricity system. Interoperability between the interfaces of energy smart appliances, smart meters and CEMs/HEMs is crucial.

Smart meters:
The rollout of smart meters is ongoing and it is expected that almost 72% of European consumers will have a smart meter by 2020 (JRC, 2016[31]). The smart meter can fulfil 2 important roles in its interaction with smart appliances:

- Variable price information interface: In the implicit demand response use, appliances need to receive price information. In many studies, the smart meter is seen as a possible interface to receive this information and forward this to connected smart appliances. A survey by the Expert Group 1 on Standards and Interoperability of the European Smart Grids Task Force issued a survey[32] revealed, however, that 5 out of 17 EU Member States are not planning to implement support for advanced tariff schemes, which means that the appliances should be able to receive price information via an alternative way.

[31] JRC (2016): Smart Metering deployment in the European Union. Available from: http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union. Last access: 31 of August, 2016

[32] Report on a survey regarding Interoperability, Standards and Functionalities applied in the large scale roll out of smart metering in EU Member States; European Smart Grids Task Force Expert Group 1 – Standards and Interoperability, October 2015

- Real time electricity consumption information: smart meters will record electricity consumption, typically in intervals of an hour or less (15 minutes is the recommendation) and communicate this information back to grid operator/electricity supplier or third party depending on the member state. In use cases, where flexibility is offered to an external party, the external party could get access to the smart meter data in order to verify whether the customers' appliance(s) have reacted according to the instructions it received. The approach to use the smart meter for verification (settlement), however, has a number of drawbacks:
  - roll-out and uptake of some residential demand response programs will be coupled to the roll-out of smart meters
  - typical requirements of smart meters are not always compliant with the requirements of grid operators (e.g. measurement resolution)
  - the smart meter does not distinguish the power consumption of the smart appliance(s) and the other power consumers in the house, which makes it very ambiguous what the contribution of the energy smart appliance actually was

Customer and home energy managers (CEMs/HEMs):
The CEM/HEM functionality is presented in many residential smart grid architectures and can fulfil the following functions:

- aggregation of flexibility: In case several energy smart appliances are present, the CEM/HEM can bundle the flexibility. This reduces the overhead for external parties using the aggregated flexibility instead of the individual appliance flexibilities.
- coordination of local renewable sources and energy smart appliances: Especially in the local optimal energy consumption use case (see 7.5.1.3), where no external party takes the responsibility to coordinate the smart appliances with the availability of locally produced renewable energy, a CEM/HEM can take the role of the controller
- translation of price signals into direct interface commands: The CEM/HEM can take the role of the external controller which translates variable price information into direct interface instructions (see 7.5.4.2) for one or several connected energy smart appliances.

The CEM/HEM functionality can be implemented as physical controller in the house or as an external service.

Recommendation:
Home Energy Manager systems (HEMs), Customer Energy Manager systems (CEMs), Building Automation Control Systems (BACS) and smart meters are outside of scope of this study. From the above discussion it is clear that energy smart appliances, smart meters and CEMs/HEMs should be interoperable. It is highly recommended that interoperability with CEMS/HEMS and smart meters is accounted for during the development of a common data model for energy smart appliances. On the other hand, the lack of (existing) standardization for mainly CEMS/HEMS and BACS and the broad diversity of smart standard meter implementations should not be a limiting factor in the roll-out of smart appliances and associated services. By defining a set of interoperability requirements at appliance level to start with, it is attempted to break the "chicken and egg" discussion what should be implemented first. To speed up the uptake of demand response from the energy smart appliances and avoid possible barriers related to the roll-out of smart meters, and CEM/HEM, the recommendation is that individual appliances should be able to participate in demand response services without the presence of a CEM/HEM or a smart meter.

Part II: Technical requirements

In Part II the technical requirement (options) for a smart appliance will be discussed. In some cases several options are discussed and a final recommendation can be found in 0. Where possible, the requirement options are in line with the principles described in the 'Delivering a New Deal for Energy Consumers' communication of the Commission. The following extracts in the communication were considered as relevant and used as guidelines in the remainder of this section:

- '*give consumers a wide choice of action*';
- '*the choice on participating in demand response must always stay with the consumer*';
- '*standards and interoperability are important also for the in-home communication between a smart appliance and energy management systems so that demand-response-ready, in-home equipment can be easy to install and operate. Industry needs to finalise and apply such standards quickly and should be supported in this*';
- '*the data collection and processing party in the context of smart metering systems or other services empowering consumers to act should provide direct access to these data to the customer and any third party designated by the consumer*';
- '*for value-added services, only third parties authorised by the consumer must have access to consumer's consumption and billing data*';
- '*making sure smart home appliances and components are fully interoperable and easy to use … with the recommended functionalities to maximise their benefit to consumers*'.

Part II is organized as follows:

- 7.7 Appliance categories: although quite some requirements can be defined horizontally, some requirements are different for periodical appliances compared to thermal appliances. Before detailing the requirements, the global difference in approach is explained in this section
- 7.8 Functional requirements
- 7.9 Interoperability requirements
- 7.10 Interface requirements
- 7.11 Information requirements

7.7. Appliance categories

Although quite some requirements can be defined horizontally, some requirements are different for periodical appliances compared to thermal appliances. Before detailing the requirements, the global difference in approach is explained in this section.

7.7.1. Periodical appliances

This section discusses the general flexibility properties of periodic appliances, i.e., dishwasher, tumble dryer, washer dryer, washing machine. The flexibility in the electricity consumption of periodic appliances is created by shifting the execution of the program the user selected within a user defined time window. This specific type of flexibility allows detailing a number of general requirements.

When configuring the program, the user must be able to select a program deadline in the future, where this program deadline is the time the program must be finished the latest[33].

The time window in between the configuration time of the user, and the time the program must be started the latest to meet the user deadline, is called the 'flexibility window'.

7.7.1.1 Option 1: Periodical appliances with a fixed program

The direct flexibility interface allows the appliance to be started remotely at any point in time in the flexibility window. The command the appliance accepts is a start command, which contains the program start time. Once the program is started, it cannot be interrupted. The power profile of the program cannot be altered. If no start command is sent to the appliance, or in case of communication failures, the appliance starts the program automatically at the end of the flexibility window.

7.7.1.2 Option 2: Periodical appliances with an interruptible program

This approach is the same as the approach described in the previous section (fixed program) but adds additional functionality to support "pausing" and "resuming" of the program execution. The appliance can indicate in which parts of the program/profile it can be interrupted and how long the "pause" is allowed to be.

<u>Recommendation</u>: The recommendation is to choose for periodical appliances with an interruptible program for the following reasons:

- Foreseeing interruptibility does not mean that an appliance or a specific program must be interruptible: in case an appliance or a specific program is not suitable for interruption, this can be indicated in the communicated power profile. This makes interruptibility possible without being mandatory.

[33] The requirement that the program must be finished before the user deadline serves as a specific comfort requirement.

- It makes it possible for the appliance to contribute in demand response programs which need emergency power reduction or switch/off appliances, typically used to cope with grid incidents.

7.7.2. THERMAL APPLIANCES

This section discusses the general flexibility properties for thermal appliances, fitting in category IIa and IIb:

- refrigerators and freezers
- commercial refrigeration
- continuous storage water heaters
- electric radiators with(out) inertia
- (non-)residential heat pumps with(out) thermal storage
- (non-)residential air conditioners with(out) thermal storage

The above appliances are aiming at a specific target temperature (air or water temperature) within certain operational comfort limits (minimum and maximum temperature) or they are aiming at storing a certain amount of heat in a thermal storage (typically water tank). In both cases the flexibility in the electricity consumption of the appliance is created by the operational comfort limits: when the appliance will be switched OFF, it will take some time before the minimum temperature limit is reached. The other way around, when the appliance will be instructed to consume maximum power, it will take some time before the maximum temperature limit is reached.

Example 1: Figure 19 shows a very simple example of the presence of flexibility in a thermal appliance which can only be switched On and OFF by means of a hysteresis controller: The left part of the figure shows the normal behaviour of without using the flexibility: the controller has an upper and a lower temperature limit. When the temperature in the house/room reaches the lower temperature limit, the heating is switched ON and the house/room starts warming up. When the upper limit is reached, the heating is switched OFF. The upper and the lower temperature limits are the so-called comfort limits, set by the controller or the end user. The right part of the figure shows the situation where the flexibility of this heating system is being used. While the heating is switched OFF and the house/room is cooling down, an external command switches the heating back at time = t_1. This is possible/allowed as long as the actual temperature in the house/room stays between the upper and lower limits. After some time the upper temperature is reached and the heating is switched OFF. Similarly at time = t_2, the heating is switched OFF while it was in its normal warming up cycle. This example can be applied to simple heating systems, refrigerators and freezers.

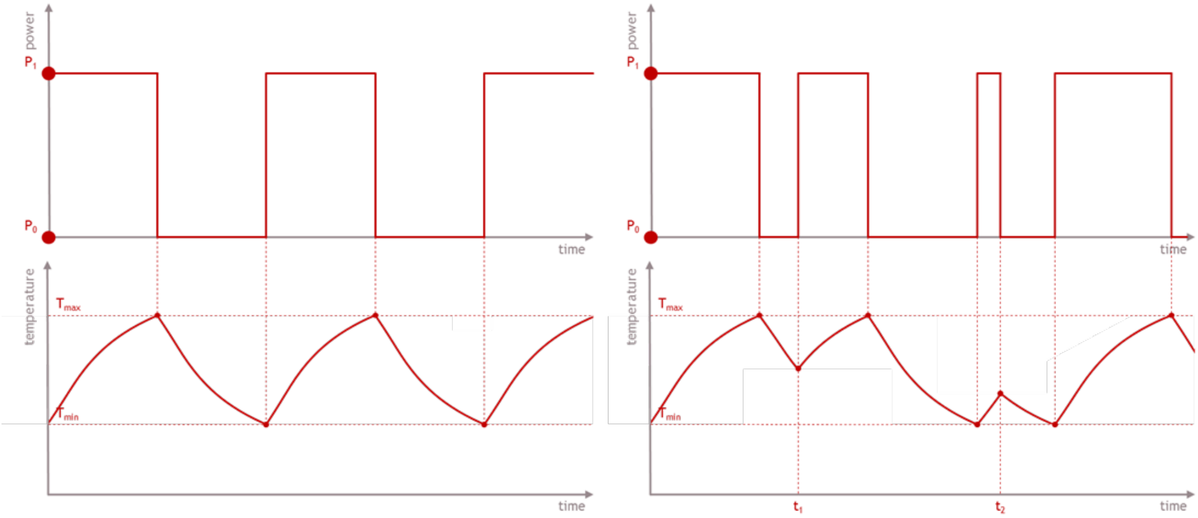


Figure 19: The presence of flexibility in a thermal appliance which is being switched ON/OFF by a hysteresis controller. The left part figure shows the normal operation without using flexibility, the right part of the figure shows the behaviour when flexibility is activated.

Example 2: Figure 19 shows a more advanced example of the presence of flexibility in a thermal appliance with power modulation in combination with a more advanced controller. The thermal appliance can operate in a power range between P_1 and P_2 or switched OFF. The left figure part of the figure shows the normal operation of the thermal appliance: the controller will continuously make small corrections to the power in order to stay as close as possible to the target temperature. The right part of the figure shows the operation of the thermal appliance when flexibility is activated. Before t_1, the operation of the thermal appliance is exactly the same, but at t_1 a request to increase to maximum power comes in and the temperature starts increasing which is accepted as long as the upper temperature limit is not reached. At t_2, the power is set to minimum power, at t_3 the power is switched OFF and at t_4 the power is switched ON again. Again, all commands are accepted as long as the comfort limits (upper and lower temperature limits) are not exceeded. At t_5, the controller continues its "normal" operation. This example can be applied to more advanced heat pump and air conditioning systems.

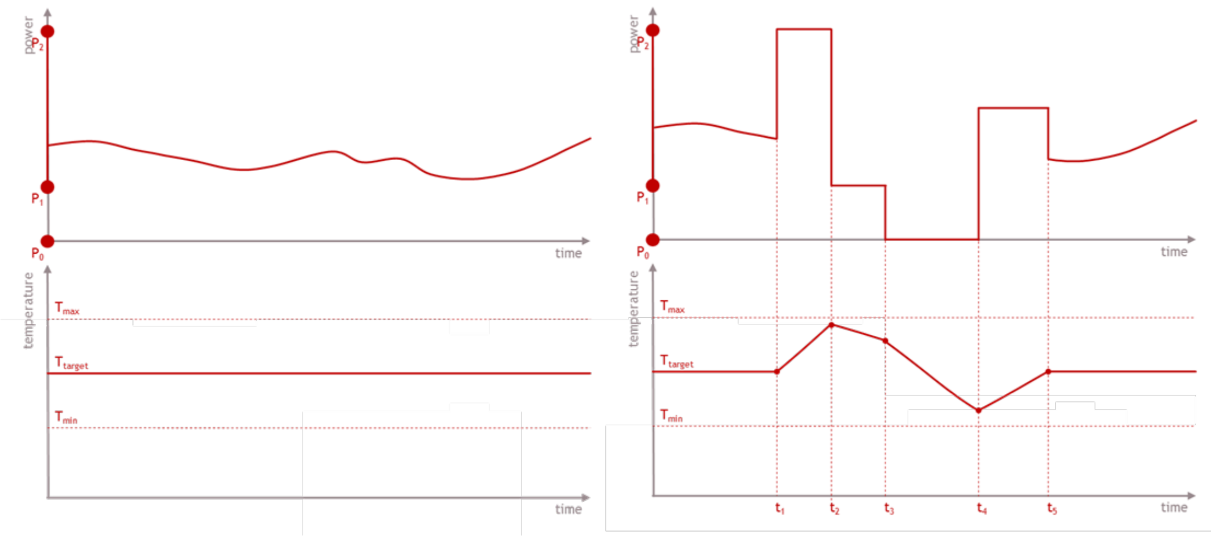


Figure 20: The presence of flexibility in a thermal appliance that supports power modulation and a more advanced controller. The left part figure shows the normal operation without using flexibility, the right part of the figure shows the behaviour when flexibility is activated.

The same principles can be applied to storage water heaters. In that case the comfort limits are not only determined by the temperature but also by the amount of hot water which is stored in the hot water tank.

7.8. FUNCTIONAL REQUIREMENTS

This section describes the functionalities which have to be present in an energy smart appliance. Every subsection with 3 numbers (1.1.1) is a requirement, every subsection with 4 numbers (1.1.1.1) is a requirement option. In case there are several requirement options, a final recommendation is made in the last subsection.

In general, all appliances remain subject to existing regulations and directives. E.g. upgrading an appliance with energy smart functionality, can increase the electromagnetic emissions, especially in the case when wireless communication technologies are used. In this case, this remains subject to the existing EMC directive.

7.8.1. THE USER SHOULD HAVE THE POSSIBILITY TO ENABLE AND DISABLE THE ENERGY SMART FUNCTIONALITY IN THE USER SETTINGS (HORIZONTAL)

At all times, the user of the smart appliance should have the possibility to enable and disable the energy smart functionality in the user settings. Although the appliance is capable to contribute in demand response programs, the final decision to do so is always with the end user.

7.8.2. THE ENERGY SMART FUNCTIONALITY IS DISABLED BY DEFAULT (HORIZONTAL)

Smart appliances should be sold with the energy smart functionality disabled by default. Even when the “resource discovery” feature (see 7.9.1) detects the presence of a customer energy manager, service provider or any other device which can handle energy smart commands, the energy smart functionality stays disabled. Enabling the energy smart functionality always requires a manual interaction or confirmation by the end user in the user settings.

User settings of the smart appliance can be set/changed on the appliance (buttons and/or display) or via remote controlled access (e.g. web interface, smartphone app). Further refinement of this requirement could include that the first time enabling cannot happen via remote controlled access for security reasons.

7.8.3. THE USER ALWAYS HAS THE POSSIBILITY TO OVERRULE AN EXTERNAL ENERGY SMART COMMAND (HORIZONTAL)

When the energy smart functionality is enabled, the smart appliance is subject to external commands/instructions from a customer energy manager or an external party. The user should always have the possibility to overrule the energy smart commands.

<u>Example</u>: The user has an air-conditioning unit which participates in a demand response program via an external party. The external party sends an instruction to switch the air-condition unit OFF. The user considers this action as inconvenient at that particular moment in time and must have the possibility to switch the air-conditioning unit on again.

<u>Remark</u>: The possibility to ignore external energy smart actions/instructions does not mean, however, that the user is protected against obligations in a contract with an external party. In the above example, the contract between user and external party can stipulate, e.g., that energy smart actions can be ignored for maximum 20% of the time, otherwise a penalty has to be paid. The requirement stipulates that it is always the end decision of the user to comply or ignore to the

conditions of the contract. The requirement avoids that an external party can force undesired energy smart actions at any moment in time.

7.8.4. The smart appliance should fall back to standalone operation when the energy smart functionality fails (horizontal)

In case of communication faults, a failing communication network, failure of the DR infrastructure, or any other detectable failure related to the energy smart functionality, the appliance must automatically fall back to standalone operation, i.e., the same operation as if the energy smart functionality is disabled.

7.8.5. A smart appliance should have a minimum amount of flexibility (vertical)

The definition of flexibility heavily depends on the kind of smart appliance. This will be specified individually per appliance category.

Periodical appliances in category I:
For periodical appliances, the amount of flexibility is determined by 2 elements:

The user must be able to select a deadline of up to at least 24h in the future from the moment of program configuration.

Thermal appliances in category IIa:
For appliances in category IIa (with internal flexibility), the flexibility can be expressed as the energy content which can be stored between the upper and lower comfort limits . For each type of appliance a minimum energy level should be defined (TBD).

Thermal appliances in category IIb:
Appliances in category IIb don't have an internal flexibility. For these appliances a reference setup should be defined and a measurement procedure to define how much energy can be stored between the lower and upper limits.

7.8.6. A smart appliance should have flexibility quantification functionality

Especially in the use case where flexibility is offered to an external party, there is a need for the external party to know how much flexibility is available at a certain moment in time and the near future. Also in other use cases, this functionality allows optimal scheduling of the appliance in order to optimize to specific business case goals or KPI's. The functionality can be implemented in different levels of complexity. Some (simple) options can be implemented as horizontal measures, the more complex options require a vertical policy approach.

7.8.6.1 Horizontal option 1: Real time power flexibility, with actual power status

On request, the appliance communicates its current power consumption and which power consumption range is possible for the appliance at the current moment in time. The current power consumption can be based on estimations or based on measurements, as long as it meets a to-be-defined accuracy. It has to be investigated whether the accuracy can be defined horizontally or needs to be vertically.

Example 1: A dishwasher is in its warming-up cycle which can be interrupted. On request, the dishwasher responds that its current power consumption is 1800W and that its power range consists of 2 discrete possibilities: 0W or 1800W [0W,1800W]
Example 2: A variable power heat pump responds to an external request that its power consumption is 6kW and that it can be switched off or modulated between 3 and 8kW [0W, 3000W-8000W]

Advantages:
- Can be implemented as a horizontal requirement
- Simple and cost effective

Drawbacks:
- Not suitable for energy planning purposes because it only focuses on the current situation

7.8.6.2 Horizontal option 2: Estimated power flexibility for the near future and actual status

This option is based on the previous one but it gives an estimate for the future of how long the adapted power level can be maintained.

Example 1: A dishwasher is in its warming-up cycle which can be interrupted. On request, the dishwasher responds that its current power consumption is 1800W and that its power range consists of 2 discrete possibilities: 0W which can be maintained for 2h, 1800W which can be maintained for 20 minutes
Example 2: A variable power heat pump responds that its power consumption is 6kW and that it can be switched off for 40 minutes or modulated between 3 and 8kW for maximum 4.5kWh in total.

Advantages:
- Can be implemented as a horizontal requirement
- Simple and cost effective
- Short term energy planning possible.

Drawbacks:
- This approach seems more suitable for thermal appliances, home batteries and EV charging poles than for periodical appliances.
- It is not straightforward for some types of appliances (typically for the thermal appliances) to estimate this time. This will complicate the definition of a verification procedure.

7.8.6.3 Vertical option for periodical appliances: The appliance communicates an estimated energy consumption profile

The presence of flexibility depends on the status of the periodical appliance. There are 3 possibilities:
1. The periodical appliance is OFF and no program is scheduled: the appliance communicates that there is no scheduled energy consumption.
2. The periodical appliance is OFF, but it is scheduled: the appliance communicates the estimated energy consumption profile with a given, to be defined accuracy. It also indicates which parts of the profile can be interrupted and how long they can be paused. Further, the periodical appliance communicates the scheduled deadline of the program.
3. The periodical appliance is ON and executing the scheduled program: The appliance communicates the same information as in 2., but additionally indicates what its current status is in the scheduled profile.

7.8.6.4 *Vertical option for thermal appliances: The appliance communicates a power flexibility graph*

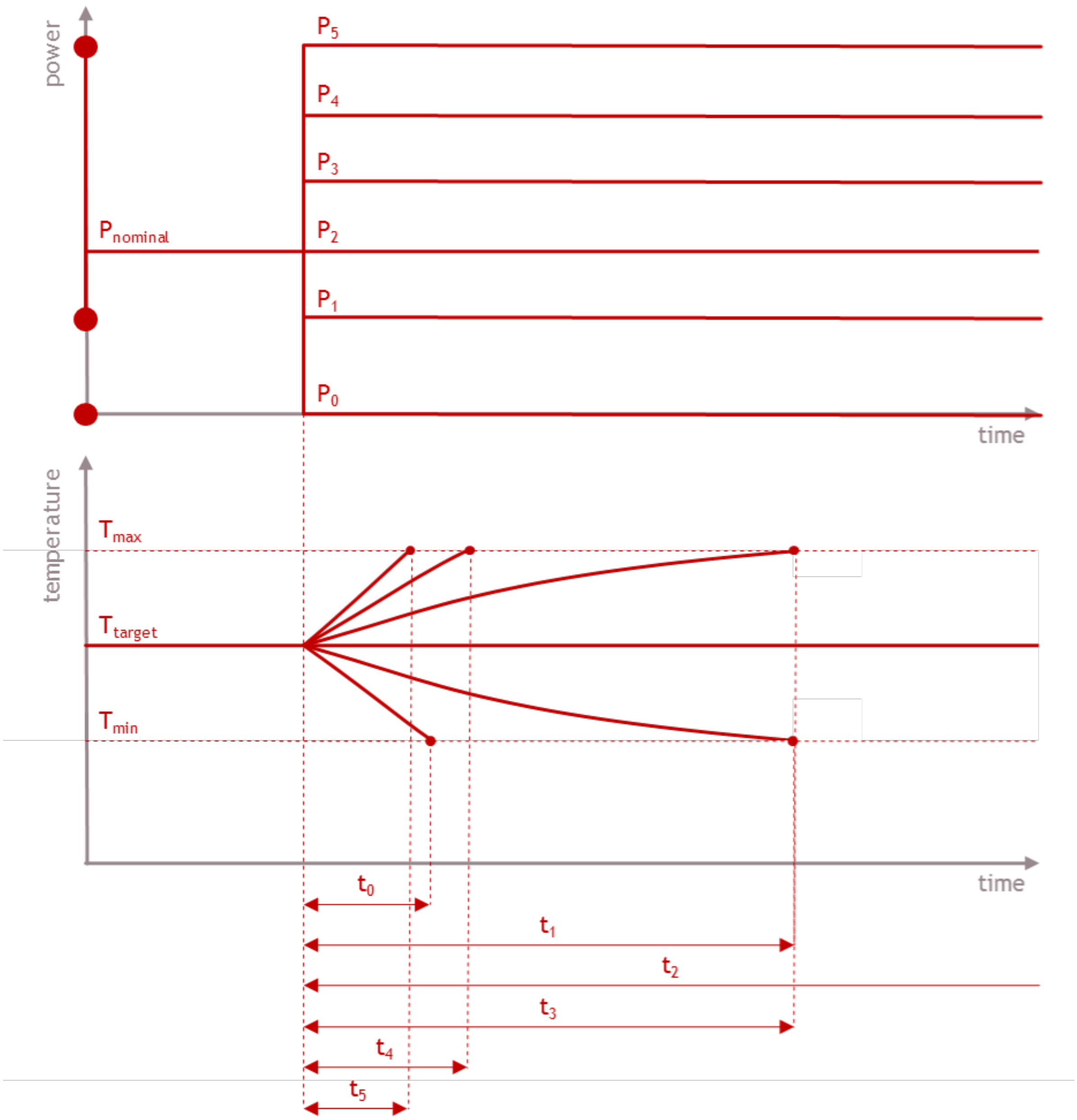


Figure 21: Effect on the temperature (lower plot) for different values of the power consumption (upper plot).

In many thermal applications (e.g. heating of a house), a specific amount of power is needed in order to keep the temperature at the target temperature. shows the example of a house, heated by a heat pump which can be switched OFF or modulated between 30% and 100%. In order to keep the house at the target temperature, the heat pump is modulated at 47.5% ($P_{nominal}$ = P_2 = 47.5% of the maximum power). This is shown in the first part of . At some point in time, the heat pump gets a command to switch to different power consumption (P, P_1 … P_5 in the upper plot of). The lower plot shows the effect on the actual temperature in the house. It is clear that the closer the new power stays to the nominal power, the longer it takes before the upper or lower temperature limit is reached. This information can be represented in a new type of “power flexibility graph” as presented in .

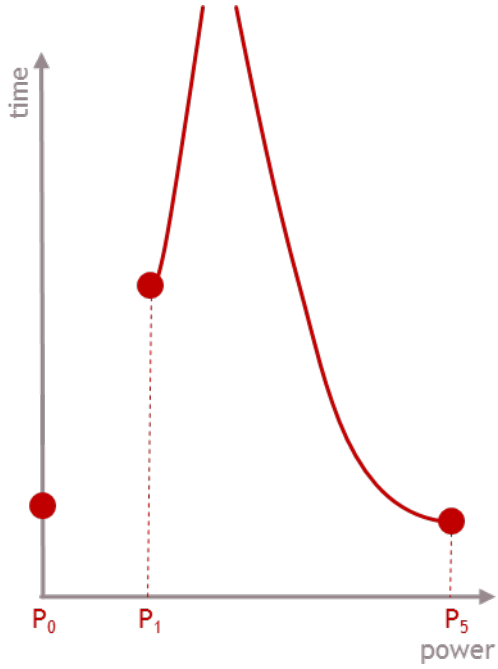


Figure 22: Example "power flexibility graph" for house with a heat pump.

For a specific moment in time, the "power flexibility graph" expresses how long an appliance can keep running as function of the power consumption before the upper or lower temperature limit is reached. It is important to mention that this is a dynamic graph: this means that the shape of the graph not only changes as function of conditions (in the case of the above example: the set target temperature, the set upper and lower temperature limits, outside temperature) but also as function of the used flexibility: in the example of , the heat pump can be switched on for a certain time t_5 at maximum power. When the heat pump gets the command to consume the maximum power, the remaining time that the heat pump can run at that maximum power get shorter till the upper limit is reached.

Figure 21 and Figure 22 show an example how this principle works for a house heating system. For "storage based thermal systems", the internal calculation method to determine the "power flexibility graph" may differ and require additional information (e.g. amount of energy stored, expected hot water use, …) but from an interface point of view the same principles can be used.

7.8.6.5 Recommendation

Due to the very different modes of operation and in order to optimally use and plan the available flexibility, the recommendation is to specify a different functionality for periodical and thermal appliances. Horizontal option 1 is only able to communicate the current status and power range and consequently does not allow to make a good scheduling of appliances on the longer term. Horizontal option 2 is a bit better, but still does not catch the flexibility present in periodical appliances very well. In order to optimally use/plan the different types of appliances it is recommended to select the vertical option, as described in 7.8.6.3, for periodical appliances and to select the vertical option, as described in 7.8.6.4, for thermal appliances.

7.8.7. A SMART APPLIANCE SHOULD HAVE A SETTLEMENT SUPPORT FUNCTIONALITY (HORIZONTAL)

In the use case where flexibility is offered to an external party, there is typically a contract in place between the owner of the smart appliance(s) and the external party. The external party has a need to verify whether an appliance has reacted according to the instructions it received. This verification mechanism is typically called the "settlement procedure". The lack of or impossibility to perform this is a large barrier for residential demand response in many member states[34].

A requirement for integrated settlement support in the energy smart appliance will speed the adaptation of residential demand response mechanisms throughout Europe, by providing a harmonized methodology across the EU for settlement, effectively removing above described barrier for the adoption of residential demand response. It also avoids that settlement requirements are defined nationally, in turn increasing the number of products that must be designed, tested and produced.

7.8.7.1 Option 1: Settlement via external measurement device

From an appliance point of view, the simplest option is to perform the settlement via an external measurement. The external measurement can be performed by a special submetering device, which is compliant with the specifications of the external party.

Advantages:
- No requirements for the smart appliance
- The measurement equipment can be chosen accordingly to the needs and requirements of the external party and/or the local country regulations.

Drawbacks:
- Extra equipment is needed to use the smart appliance
- The approach slows down the roll-out of a harmonized approach across the EU

7.8.7.2 Option 2: Settlement via smart meter

Instead of an individual measurement per appliance, the settlement could be organized via the smart meter.

Advantages:
- No requirements for the smart appliance

Drawbacks:

[34] Settlement procedures, e.g., for the BRP balance, are today typically based on those meters in the system that support quarter hour measurements and remote metering. When no such measurements are available, e.g., for those regions without smart metering for residential consumers, settlement is often based on assigning consumption and production relative to BRP market share. This is an important barrier to deploy residential demand response. Furthermore, it can be argued that to adapt the settlement procedures to support resindential demand response, quarter hour measurements at the level of the household are insufficient, and that submetering of the DSF capable appliances is required.

- Roll-out and uptake of residential demand response is coupled to the roll-out of smart meters.
- Typical requirements of smart meters are not always compliant with the requirements of grid operators (e.g. measurement resolution)
- The smart meter does not distinguish the power consumption of the smart appliance(s) and the other power consumers in the house, which makes it very ambiguous what the contribution of the smart appliance actually was.

7.8.7.3 Horizontal option 3: Real time power readout

On request, the appliance communicates its current power consumption. The current power consumption can be based on an estimation or based on a measurement as long as it meets a given, to be defined, accuracy. It is the responsibility of the external party to request the actual power consumption measurement and collect the required verification information.

Advantages:
- The measurement data can be used for other purposes e.g. energy efficiency monitoring, submetering, …

Drawbacks:
- Additional measurement hardware or power estimation needed
- Depending on the settings, procedures and needs of the external party, a lot of requests might come in to receive a single measurement sample. This might result in high communication overhead.

7.8.7.4 Horizontal option 4: Logging of the historical power consumption profile and instructions

The appliance keeps measurements and records its historical power consumption in memory with a given, to be defined, resolution and time scale. Optionally, it records the external instructions it received. On request, the appliance communicates the historical data to the external party. For appliances with long periods of time with the same power consumption it makes sense to use a format which support a variable time steps.

Advantages:
- The measurement data can be used for other purposes e.g. energy efficiency monitoring, submetering, …
- Settlement information can be communicated afterwards and in larger blocks, reducing the real time requirements of the communication protocol and communication overhead because the data can be communicated in larger blocks.

Drawbacks:
- Additional measurement hardware or power estimation needed
- Extra memory needed for storing historical data

7.8.7.5 Recommendation

For this requirement, there are several horizontal options: external measurement, via smart meter, real time power readout and logging of the historical power consumption profile and instructions. Due to the fact that:

- the market evolution (direct vs indirect demand response) is unpredictable
- settlement support is an important element of direct demand response business cases
- direct demand response is currently the most interesting business case for industrial customer,

it is recommended to support direct demand response business cases with an external party. Further, it is not fair towards potential customers that additional measurement equipment is needed for certain business cases and for that reason the recommendation is that the appliance keeps measurements and records its historical power consumption in memory with a to be defined resolution and time scale. Optionally, it records the external instructions it received. The recorded measurement data can be used for other purposes as for example energy efficiency monitoring, a feature which can be used even when the appliance doesn't need the recorded data for settlement support.

7.8.8. A SMART APPLIANCE SHOULD MAKE ENERGY CONSUMPTION DATA AVAILABLE TO THE USER (HORIZONTAL)

While realizing energy smart functionality, useful data concerning the energy consumption of the energy smart appliance is gathered. This data can be used to inform the user and stimulate the user to take energy efficiency measures. Energy efficiency is a main goal of the Ecodesign Directive and so –although not strictly energy smart related –, requirements concerning the availability of data with an impact on energy efficiency can be included. The availability of the energy consumption data is also in line with the 'Delivering a New Deal for Energy Consumers' communication of the Commission. Due to the recommendation in 7.8.7.5, energy consumption is recorded anyway and it makes sense to make this information available for the user.

7.8.9. A SMART APPLIANCE SHOULD HAVE A MAXIMUM SURPLUS ENERGY CONSUMPTION (VERTICAL)

Despite the fact that demand side flexibility is not about energy efficiency but about the shifting of energy consumption, as described in task 6, energy smart functionality can have an impact on the total energy consumption.

Standby losses of energy smart appliances, e.g., due to extra communication components, fall under the specific Ecodesign process dealing with standby losses[35], and are not further discussed specifically for energy smart appliances.

The use of the energy smart functionality may result in operating points that deviate from the most energy efficient operation point, e.g., by cooling deeper or heating higher. This implies possible surplus energy consumption compared to when the appliance offers no flexibility. From a system perspective, this can be justified provided that the energy smart functionality allows for increased share of RES, leading to reduced CO_2 emissions and/or sufficient added value for the flexibility,

[35] http://www.eceee.org/ecodesign/products/standby/

despite the surplus energy consumption. Requirements that limit or give the user control on the size of these losses should be defined, so the user is not confronted with unexpected excessive surplus energy consumption and/or the user can tailor the surplus consumption in function of his/her specific use of the flexibility and the resulting added value. The nature and size of the surplus energy consumption are strongly dependent on the type of the appliance and the technology used. Hence, requirements regarding such surplus consumption can only be set vertically.

7.8.9.1 Option 1: information requirement

The customer should be informed that enabling demand side flexibility in a smart appliance might result in increased electricity consumption. The increased electricity consumption is typically caused in thermal appliances by extra losses due to the fact that the appliance is not exactly operating at the target temperature or at the target schedule. The manufacturer has to indicate how much the increase will be for the different flexibility settings.

Advantages:

- No additional settings for the end user

Drawbacks:

- No protection for the end user on the surplus energy consumption due to the activation of flexibility

7.8.9.2 Option 2: maximum surplus energy consumption

The surplus energy consumption of energy smart functionality may not exceed a predefined maximum limit.

Advantages:

- Unexpected excessive surplus consumption is avoided
- No extra complexity for the user

Drawbacks:

- When set too high, the requirement loses its purpose. When set too low, the flexibility is limited too much. It is a complex exercise to define a good limit per appliance category.

7.8.9.3 Option 3: user configurable maximum surplus energy consumption limit

The appliance offers an extra configuration setting that allows the user to define the maximum surplus energy consumption.

Advantages:

- The energy losses can be tailored in function of the preferences of the user and in function of the added value of energy smart appliance’s flexibility for the demand response business case of the user.

Drawbacks:

- Extra complexity for the user.

7.8.9.4 Option 4: conservative default value for configurable surplus energy consumption limit

The energy smart appliance is shipped with a predefined conservative default value for the user configurable maximum surplus energy consumption limit.

Advantages:

- Ensures that the user must make an informed and conscious choice to increase the consumption due to losses, rather than remaining unaware of the potential increase of the energy consumption.

7.8.9.5 Recommendation

For this requirement, several options were several options proposed: “information requirement”, “maximum surplus energy consumption", “user configurable maximum surplus energy consumption", “conservative value for configurable maximum surplus energy consumption". In order to protect the customer, without limiting the potential flexibility of the energy smart appliance, the recommended option is “conservative value for configurable maximum surplus energy consumption". How the “surplus energy consumption” will be measured and the definition of the “conservative value” has to be defined as a vertical requirement per appliance.

7.9. INTEROPERABILITY REQUIREMENTS

7.9.1. THE COMMUNICATION INTERFACE SHOULD HAVE “RESOURCE DISCOVERY” FUNCTIONALITY (HORIZONTAL)

Resource discovery mechanisms are mechanisms to discover devices in a network: based on a list of the functions looked for, the discovery service replies with a list of network addresses and other identification information of the devices in the network that offer the requested functionality. Examples of such systems are Bonjour/zeroconf, SSDP, DIAL, etc.

To improve the interoperability of energy smart appliances, a requirement should be defined that energy smart appliance must support one or several of an agreed on list of resource discovery protocols.

As discussed in task 1, there are two main communication/control architectures for energy smart appliances: the cloud model and the central energy manager model. The existing resource discovery protocols are typically usable in a central energy manager model, i.e., energy smart appliances and CEM controller are all part of the same physical local communication network. Discovery of appliances by a cloud based controller or server is typically with proprietary and/or custom mechanisms. The extension of the resource discovery standards with cloud based discovery mechanisms is a technical gap that should be addressed to improve the interoperability of energy smart appliances.

7.9.2. THE COMMUNICATION INTERFACE SHOULD SUPPORT A COMMON DATA MODEL AND APPLICATION PROTOCOL (HORIZONTAL)

To guarantee interoperability at semantic level, the communication interface of a smart appliance should support a common data model. Supporting a common data model means that the application protocol provided at the communication interface makes use of a data model that complies with imposed reference ontology. A compliant data model can be mapped one-to-one to the reference ontology. A candidate for such reference ontology is SAREF/SAREF4ENER[36]. The mapping of a specific data model to the reference ontology should be standardized. Compliance test should be part of the performance standards.

The common data model must support all actions/instructions and responses/events over the communication interface defined in the requirements in this document. An appliance type (vertical) must support the (minimum) set of actions/instructions and responses/events defined in the requirements in this document specific for the type of appliance, meaning a subset of the common data model. These subsets per appliance type should be defined in standards.

Regarding the application protocol used over the direct flexibility interface, there are several options:

- Option 1: the communication interface should support at least one specific standardized application protocol.
- Option 2: the communication interface should support at least one standardized application protocol selected from list of standardized application protocols.
- Option 3: the communication interface may use any application protocol.

The appliance may offer additional application protocols and data models.

Recommendation:
The best guarantee for the customer to achieve interoperability is a single data model and a single standardized application protocol (Option 1) which must be supported.

A possible way forward would be the adoption of data model and application protocol proposal from the industry itself, within a TBD timeframe. In case no consensus can be achieved in the defined timeframe, the data model and application protocol can be subject of a standardization mandate.

[36] The Smart Appliances REFerence ontology (SAREF) ETSI TS 103 264 V2.1.1 (2017-03) is conceived as a shared model of consensus that facilitates the matching of existing semantic assets in the smart appliances domain, reducing the effort of translating from one asset to another, since SAREF requires one set of mappings to each asset, instead of a dedicated set of mappings for each pair of assets.
Different semantic assets share some recurring, core concepts, but they often use different terminologies and adopt different data models to represent these concepts. Using SAREF, different assets can keep using their own terminology and data models, but still can relate to each other through their common semantics. In other words, SAREF enables semantic interoperability in the smart appliances domain through its shared, core concepts.
SAREF4ENER (ETSI TS 103 410-1) is the SAREF extension for the energy domain.

7.9.3. THE COMMUNICATION INTERFACE SHOULD SUPPORT CYBERSECURITY AND PRIVACY REQUIREMENTS FOR CONNECTED DEVICES (HORIZONTAL)

A connected appliance is vulnerable to cyber threats and attacks. Any vulnerability, such as an unsecured connection or product, can be exploited with effects ranging from nuisance and small-value losses to large-scale breaches of sensitive personal data or routing the appliance into remotely controlled bots used for large-scale network attacks. The energy smart appliance therefore must comply with the prevailing EU cyber security and data protection legislation.
In this context the European Commission is reviewing the cybersecurity strategy to strengthen Europe's resilience. One of the actions, listed in the communication[37], the European Commission will accomplish by September 2017, is the development of measures on cyber security standards, certification and labelling, to make ICT-based systems, including connected objects, more cyber-secure.

7.9.4. THE COMMUNICATION INTERFACE SHOULD SUPPORT AN UPGRADABILITY FUNCTIONALITY (HORIZONTAL)

Appliances have a typical lifetime length that surpasses that of software manifold. For an appliance to be interoperable, it is required that the software of those appliances can be remotely updated to prevent avoidable and early decommissioning of appliances due to outdated software.

7.9.5. THE COMMUNICATION INTERFACE SHOULD SUPPORT COMMUNICATION WITH LOCAL AND EXTERNAL ENERGY MANAGEMENT SYSTEMS (HORIZONTAL)

In 7.5.1, a number of use cases were presented, in some use cases the appliance receives instructions from local customer energy management system, in other use cases directly from an external party. It is important that both options are supported by the smart appliance. This requirement has the following implications:

- The appliance should be able to communicate with a local controller or customer energy management system without making use of the public internet.
- In case the appliance connects to a manufacturers cloud platform, it should be possible to use the direct flexibility interface functionalities via the cloud platform as well. This should be configurable in the user settings.

[37] Communication from the European Commission on the Mid-Term Review on the implementation of the Digital Single Market Strategy, COM(2017) 228 final, 10.5.2017

7.10. INTERFACE REQUIREMENTS

7.10.1. THE SMART APPLIANCE SHOULD HAVE A DIRECT FLEXIBILITY INTERFACE (HORIZONTAL)

In section 7.5, the direct flexibility interface, indirect flexibility interface and internal measurement interface for demand response use cases were discussed. It was indicated that a direct flexibility interface is suitable for explicit demand response and local optimal energy consumption use cases and that it can be converted to the other types of interfaces by means of an additional controller. A direct flexibility interface is considered as the most versatile interface type which makes the smart appliance compliant with most foreseeable demand response business models. For that reason, a smart appliance should have direct flexibility interface functionality.

7.10.2. THE SMART APPLIANCE SHOULD FALL BACK TO STANDALONE OPERATION WHEN THE ENERGY SMART FUNCTIONALITY FAILS (HORIZONTAL)

In case of communication faults, a failing communication network, failure of the DR infrastructure, or any other detectable failure related to the energy smart functionality, the appliance must automatically fall back to standalone operation, i.e., the same operation as if the energy smart functionality is disabled;

7.10.3. THE DIRECT FLEXIBILITY INTERFACE SHOULD SUPPORT A MINIMUM INSTRUCTION SET (VERTICAL).

In this section a minimum instruction set for the direct flexibility interface will be defined. As explained earlier in the document, a different approach is recommended for the different appliance categories. This results in a different minimum instruction set which should be supported.

7.10.3.1 Minimum instruction set for periodical appliances

<u>Get flexibility status command</u>:
The periodical appliance supports a command which communicates its flexibility status to an external party/controller. The flexibility status information depends on the status of the periodical appliance. There are 3 possible situations:

- The periodical appliance is OFF: There is no program running and no program is scheduled by the user. In this case the appliance communicates it has no flexibility.
- The periodical appliance is SCHEDULED: There is no program running but the user has scheduled a program for the future. In this case the appliance communicates:
  - the power profile of the selected program: the power profile consists of the power consumption as function of the time (see example in Figure 23)
  - the power profile can be split in parts (e.g. warming up, washing, …): for each part it can be indicated whether it is interruptible and how long it can be interrupted
  - the program deadline
- The periodical appliance is ON: There is a program running at the moment the flexibility information is requested. In this case the appliance communicates:
  - the power profile of the selected program: the power profile consists of the power consumption as function of the time (see example in Figure 23)
  - the power profile can be split in parts (e.g. warming up, washing, …): for each part it can be indicated whether it is interruptible and how long it can be interrupted
  - the program deadline

  - o the actual status of the program: the appliance communicates the progress of the program which is running.

Start command:
The direct flexibility interface for periodical appliances has a start command, which contains the program start time: between the moment the user configures the appliance and the time the program must be started the latest to meet the user deadline, the appliance accepts a start command and the appliance starts at the time indicated. In case:

- the indicated time is in the past: the appliance starts immediately
- the indicated time is after the latest start time, the appliance starts at the latest start time
- the start command comes without a start time: the appliance starts immediately
- no start command is sent: the appliance starts automatically at the latest time possible to finish before the deadline.

Pause command:
During the execution of a program and under the condition that the program is "interruptible" at that particular part of the program, the periodical appliances accepts a pause command. The pause command can contain a specified time, the program should be paused. In case:

- the program is not interruptible at that particular part of the program: the pause command will be ignored
- the pause command comes without a specified pause time, the program resumes when:
  - o a resume command is received
  - o the maximum allowed interruption time for that particular part of the program is reached
  - o the user configured deadline would be exceeded in case the program would be interrupted any longer
- the pause command comes with a specified pause time which is longer than the maximum allowed interruption time: the program resumes when the maximum allowed interruption time is reached.
- The pause command comes with a specified pause time which would result in exceeding the user configured deadline of the program: the program resumes at the latest moment in time to ensure that the selected program is finished at the selected user deadline.

Resume command:
When the execution of a program has been interrupted by means of a pause command, the periodical appliance accepts a resume command to resume the execution of the program.

Get historical power consumption data:
Due to the settlement support requirement and the recommendation that an appliance should record its historical power consumption (see 7.8.7), the periodical appliance supports a command to communicate this data.

User interaction warning:
Due to the requirement that the user always has the possibility to overrule external commands (see 7.8.3), at any moment in time the user has the possibility to interact. Examples:

- the user can start the execution of a program earlier than scheduled
- the user decides to resume program execution while it was paused by means of an external command
- the user aborts a program which was running or scheduled

The periodical appliance has a mechanism (e.g. event subscription mechanism) to inform external users of the flexibility that the appliance is deviating from the original schedule.

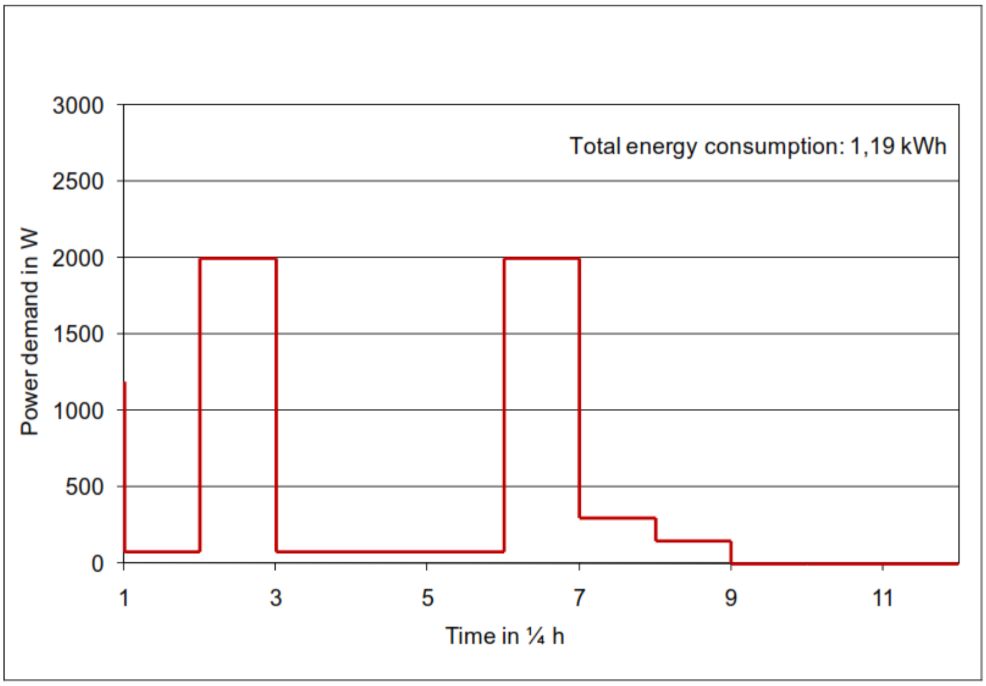


Figure 23: General pattern of a power demand curve of an average dishwasher operating in a normal cleaning program (source: Stamminger et al., 2009). The program consists of several steps, during which the power consumption is constant.

7.10.3.2 Minimum instruction set for thermal appliances

Get flexibility status command:
The thermal appliance supports a command which communicates its flexibility status to an external party/controller. The flexibility status information contains the following information:

- the power range of the appliance: the power range defines in which range the power of the appliance can be set. This can be:
  - discrete power range: this means that the appliance can be set to a discrete number of power settings. Simple example is a simple heater which can be switched On or OFF. The power range could exist of 2 discrete numbers: [0W, 3000W]
  - continuous power range: this means that the appliance can be set to any value in a continuous range e.g. [0W-8000W]. The appliance can be set to any value in the range between 0 and 8000W
  - mixed discrete and continuous power range, which is the combination of both above possibilities: a realistic example would be a heatpump which can be modulated between 2000W and 6000W or can be switched OFF. This can be represented as [0W,2000W-6000W]
- the actual power consumption
- the power flexibility graph: the concept of the power flexibility graph is explained in 7.8.6.4 and an example is shown in . For each power in the "power range", the "power flexibility graph" expresses how long the appliance can keep running before user comfort limits are reached. Accuracy, resolution and format are to be defined.

Set power command:
The thermal appliance has a "set power command" which requests the appliance to consume a specified power. The appliance acknowledges the command with the expected time it can maintain that power before comfort limits are violated. The appliance returns to its normal operation when:

- it receives a "resume normal operation" command
- when the user configured comfort settings are reached. Example: the appliance is a heatpump based residential heating system. The appliance accepted a "set power command" to switch OFF (0W). At the moment in time that the user configured lower temperature limit is reached, the appliance returns to its normal operation mode.
- when the physical limits of the appliance are reached. Example: the appliance is a storage water heater. The appliance accepted a "set power command" to switch to maximal power (e.g. 4000W). At the moment in time that the storage water tank is full with hot water at the maximum temperature, the appliance returns to its normal operation

As long as no comfort limits are reached, the appliance can accept a consecutive series of "set power commands".

Resume normal operation command:
The thermal appliance has a "resume normal operation command" which sets the appliance back in its normal mode of operation.

Get historical power consumption data:
Due to the settlement support requirement and the recommendation that an appliance should record its historical power consumption (see 7.8.7), the thermal appliance supports a command to communicate this data.

User interaction and resume to normal operation warning:
Due to the requirement that the user always has the possibility to overrule external commands (see 7.8.3), at any moment in time the user has the possibility to interact, for example the user changes the temperature setting in the house. Further, the thermal appliance has a mechanism (e.g. event subscription mechanism) to inform external users of the flexibility that the appliance resumed to normal operation. Resuming to normal operation can be caused by user interaction, reaching comfort or physical limits of the appliance.

7.10.4. In case the smart appliance supports an indirect flexibility interface, it should comply with minimum interoperability requirements (horizontal)

In section 7.5, the direct flexibility interface, indirect flexibility interface and internal measurement interface for demand response use cases were discussed. It was indicated that the direct flexibility interface is considered as the most versatile interface type which makes the smart appliance compliant with most foreseeable demand response business models, while the indirect flexibility interface can only be used for a restricted subset of the business cases which is difficult to adapt to the remaining business cases. For that reason, it was recommended to make the direct flexibility interface "mandatory", while it is recommended to make the indirect flexibility interface "optional".

In case, however, the appliance implements an indirect flexibility interface, it is important that the price information has an EU standardized common format, aligned with (a) format(s) supported by smart meters. Already today there are quite some protocols which support the communication of price information. Examples are the Energy Interoperation (EI) 1.0 which is the basis of OpenADR (IEC 62746-10-1). Also EEBus/SPINE and SEP 2.0 have a Pricing Function Set in order to provide the tariff structures communicated by the server. It is designed to support a variety of tariff types, including flat-rate pricing, Time-of-Use tiers, consumption blocks, hourly day-ahead pricing, real-time pricing, or any combination of the former mentioned tariff types. The Pricing Function set supports application-specific tariffs for devices (e.g. EV, DER), and special event based prices like critical peak price). Also in IEC 62056, a series of smart meter standards, supports the communication of price information.

7.10.5. In case the smart appliance supports an indirect flexibility interface, the appliance should make optimal use of price variability (vertical)

In case the electricity consumption of the smart appliance is subject to variable electricity prices via an indirect flexibility interface, the appliance should be capable of scheduling its periods of high electricity consumption at moments that the electricity price is low. This can only be specified in vertical requirements. The technical details of this requirement still have to be defined.

7.11. Information requirements

7.11.1. The energy smart functionality should be explained in the technical documentation and/or user manual of the appliance (horizontal)

The user should be informed about the following topics in the user documentation:

- detailed explanation of all implemented energy smart functions
- the possible impact of enabling the energy smart functionality on comfort and energy efficiency. Example: in case of a heat pump for heating a house, the user should be warned that deviations of the target temperature are possible when flexibility is requested. The user should be warned as well that the activation of flexibility might result in slightly increased electricity consumption.

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