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bridge

Interoperability of home appliances

Report 2023-2024

Data Management Working Group

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1. EXECUTIVE SUMMARY

1.1 INTEROPERABILITY OF HOME APPLIANCES

This second BRIDGE Report on interoperability of home appliances providesa common view on the issue and shows the the current state of affairs on this aspect within the BRIDGE projects.

In the area of energy flexibility in residential buildings, home appliances constitute the lowest, but probably one of the most important layers of the system. These appliances are indeed providing flexibility. The success of the energy management solutions, like algorithms or systems, is closely related to the capabilities of the home appliances, as well as, the ability to approach and exploit these capabilities. In that respect, a broader range of appliances providing flexibility and a common way to control these, allows wider deployment of energy management systems and increases the available flexibility of the energy systems.

This report refines the common ground on the interoperability of home appliances and provides insights from the BRIDGE projects on their approaches, challenges and solutions/products related to this topic. The identification of these products can help the other projects to deal with the problems related to interoperability of home appliances. This second report provides thus an update to the previous one and compares the outputs from last year with the current ones. It also extends the scope to the project products and external activities related to the subject of home appliance interoperability, and it draws on next possible subjects to be covered by the DMWG Action #5 Interoperability of home appliances in the following years.

This report refines the common ground on the interoperability of home appliances and provides insights from the BRIDGE projects on their approaches, challenges and solutions/products related to this topic. In this second report the potential new activities for the Action #5 Interoperability of home appliances are investigated and proposed.

2.INTRODUCTION

This report summarises the activities in the Action #5 of the Data Management Working Group (DMWG) of BRIDGE. It is the second report on this subject, since interoperability of home appliances was recognised as important at the 2021 General Assembly, leading to the action. The scope of this activity is related to all the other actions within the Data Management Working Group.

Action #1 provides the means to collect use cases in a structured way so that they can be compared and investigated in terms of flexibility scenarios as applied in BRIDGE projects. More specifically, it is about looking at the cases were home appliances are used in order to identify and compare their interfaces and functionalities.

Action #2 covers the data exchange aspects, including the activities related to data spaces. From the home appliances perspective, it identifies data to be exchanged with these appliances andf the digital languages (protocols, ontologies) that can be applied. The home appliances represent the endpoints in the defined DERA architecture – providing measurements and receiving steering signals.

Action #3 defines the overall framework, taking the central role in the working group. It defines the Generic Business Processes (GBPs) that synthetise the use cases into generic ones, identifying generic/harmonised roles, functions and interfaces that can be applied onto the data plane with use of standards that are then further investigated in Action #4. Both these actions further explain the use of home appliances for releasing flexibility and the standards that can be applied for that.

In this context, Action #5 focuses on the direct interaction with home appliances towards providing the features related to flexibility at the level of the prosumer role. This interaction involves data exchange and is executed to implement (part of) some given scenario, represented by a specific use case or a GBP. To follow the generic approach, the interactions with home appliances should also be generic in the sense that the flexibility-related functions (also referred to as *energy-related features*) provided by the appliances and the approaches to access these energy related features will be generic – supporting interoperability. The aim is to reduce the complexity and increase the universality of the control logic and to make the appliances interchangeable. The interoperability can be achieved by common approaches, set out by agreements or standards.

This second report presents the state of things in the BRIDGE projects with respect to the interoperability of home appliances, the problems and approaches to cope with them. It will be the base for future activities in Action #5 of the DMWG. Main part of the report is based on the inputs collected by a survey that was run among the BRIDGE projects.

The reports is structured as follows. The section **Contex and common ground** describes the context of the activities and defines the naming to be used in the survey and the report. The sections **General outcome of the survey** and **Detailed analysis of specific points** provide the results of the survey in both, diagrams and deeper analysis. Then, in section **Related activities towards harmonisation and standardisation** some chosen activities are named and referred to. And in two final sections **Next steps towards repository creation** and **Conclusions** the plans towards the repositories as well as the future activities of Action #5 are drawn.

3. CONTEXT AND COMMON GROUND

This section provides a common description of the problems related to the interoperability of home appliances, the context and the terminology used in the report.

In the area of energy flexibility in residential (but not only) buildings, home appliances constitute the lowest, but probably one of the most important layers of the system. The home appliances are indeed providing flexibility. The success of the energy management solutions, like algorithms or systems, is closely related to the capabilities of the home appliances, as well as, the ability to approach and exploit these capabilities. In that respect, a broader range of appliances providing flexibility and a common way to control these appliances, allows wider deployment of energy management systems and increases the available flexibility of the energy systems.

An energy-related **feature** of a **home appliance** is a function related to monitoring and control of the appliance, accessed for **energy management (algorithm)** using some **home appliance API** that includes communication interface and protocol. This API allows energy management to interact with the home appliance and to influence its energy behaviour to achieve the required flexibility, resilience and other optimization goals. This API is intended to be used for the **automated energy management** and not for direct control of the appliance by the end user (see Figure 1). Appliances that provide such an home appliance API for automation are also referred to as **Energy Smart Appliances (ESA)**.

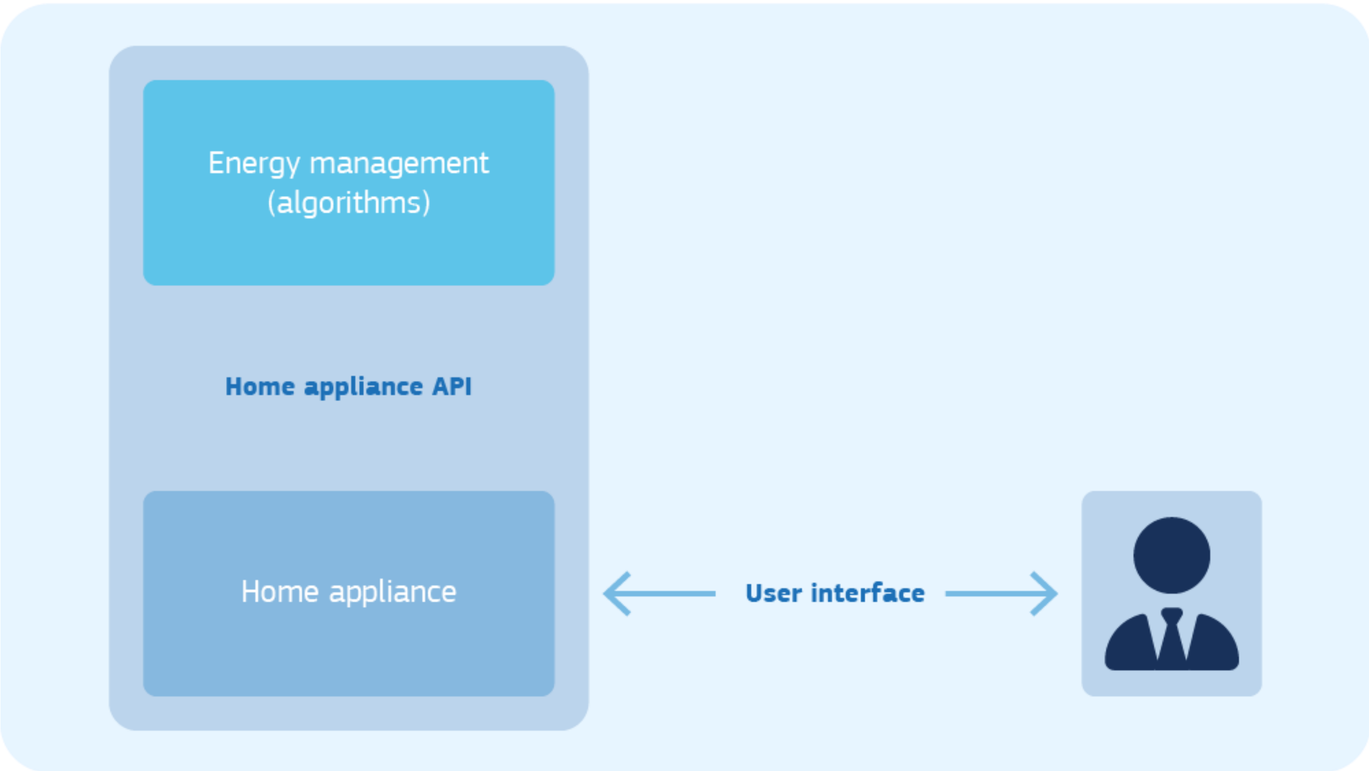

Figure 1 The interfaces of a home appliance

Even if the home appliance API does not involve interaction with the user, it is indeed used by the energy management to capture the state and possible actions that are possible to be executed on the complex entity, which is a combination of the home appliance and its user (see Figure 2, left).

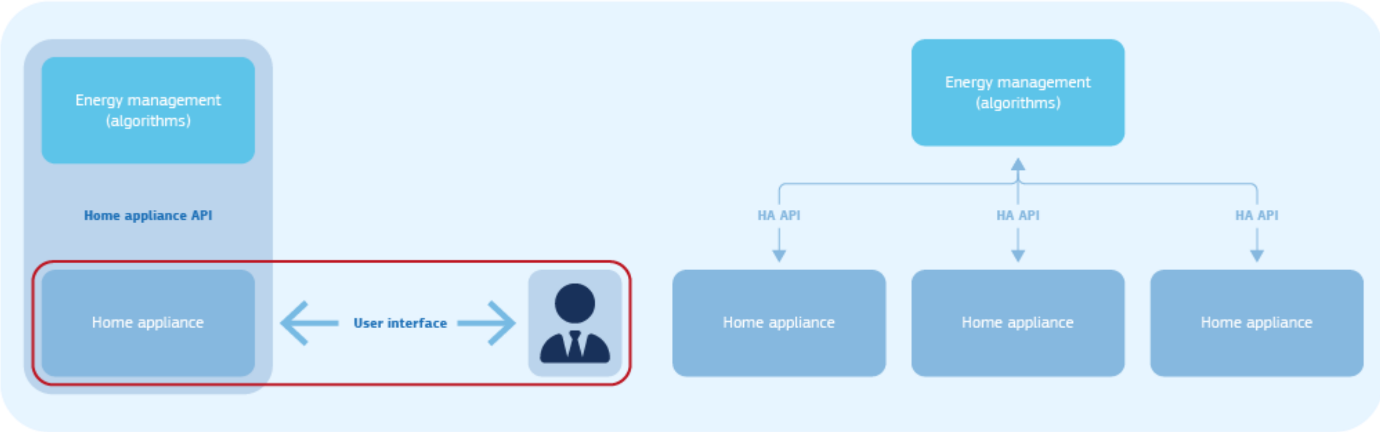

Figure 2 The detailed relation between the energy management and the home appliances

And it is very seldom the case that the energy management operates only on a single appliance. The more of them that are involved in the household, the more potential flexibility is available for the energy management. For better results, the energy management should interact with multiple home appliances and control them considering their synergies. But this complicates the relation between the energy management and the home appliances and scalability is desired (see Figure 2, right).

The different ways home appliances offer the home appliance API makes this relation even more complicated. The home appliance can provide the **API** directly or via an intermediary component (home gateway or cloud service). The intermediary component communicates with the home appliance using the **internal API**.

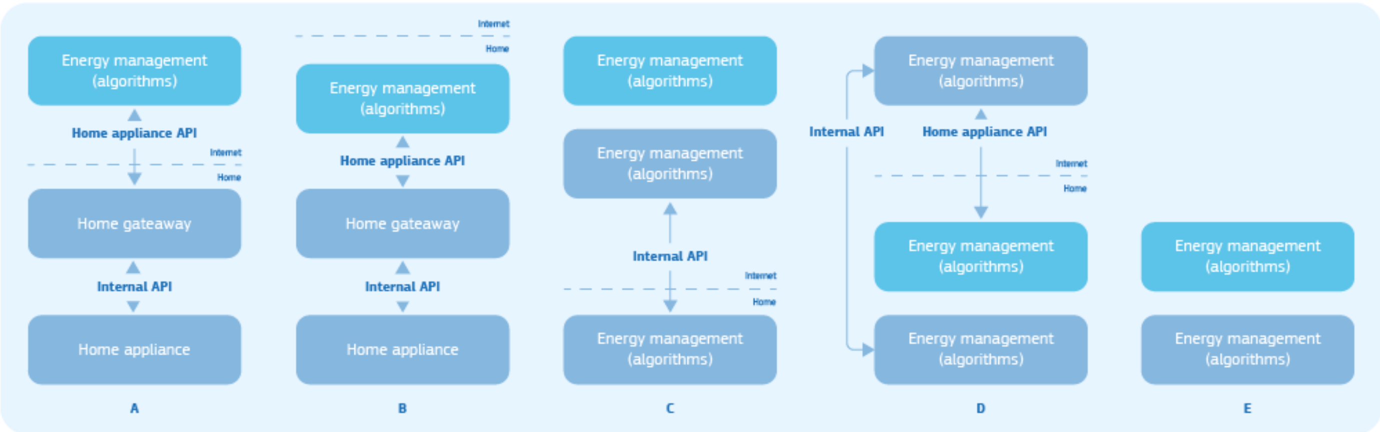

Figure 3 Possible ways for the interaction between the home appliance and energy management (algorithm)

Figure 3 presents the five main ways for interaction between the energy management (algorithm) and the home appliance. The examples a), b), c) and d) depict the approach with an **intermediary component** that communicates with the home appliance using an internal API and provides the home appliance API to the energy management (algorithm). It is important to mention that the internal API can be closed or open (as it can also be proprietary or standard) and that the energy management does not use it directly. The home appliance API is provided for the energy management, but it can also be open or closed, i.e., available for every owner of the supported home appliances or only for chosen users, like energy management providers.

In the examples a) and b) this intermediary component is a home gateway, located within the home where the home appliances are located as well. In c) and d) the intermediary component is a cloud service. To distinguish further, a) and c) depict the case where the energy management (algorithm) component using the home appliance API is located outside the home, while b) and d) depict the case where the energy management is located at home, for both options of the intermediary component.

The fifth example e) depicts the case where the home appliance provides the home appliance API directly, allowing the local energy management to access its energy-related features. In this case, accessing the home appliance is only possible from inside the home; if the energy management is be located outside the home, the home appliance has to actively connect to it and maintain the connection.

The (energy-related) **features** mentioned here cover **monitoring and control** of the home appliance. These features include a broad set of functions. They can include simple monitoring, like reading the energy consumption, or reading the state of the appliance. But, they can also cover simple control, like switching on or off, as well as complex control like shifting load in time or controlling the consumed (and/or produced) energy in other ways. The set of features depends on the **home appliance class** (or category). Examples of such classes include s washing machines, dryers, dishwashers, ovens, air conditioners. Some **specific features** can also be available only for a given **sub-class**, e.g., condenser dryer vs. heat pump dryer. For the sake of the home appliance interoperability analysis, it is important to know how the logic behind more complex features is distributed between the intermediary component and the home appliance itself. But the details on energy management (algorithm) are less important here, even if the intermediary components are part of the energy management solution, for instance, the home gateway device runs the energy management algorithms. It is nevertheless important to determine where the home appliance API is located and what functions it provides. This is also important for the interoperability of energy management components, so that these are also interchangeable.

In order to allow the energy management (algorithm) to achieve the best results, it should operate on home appliances that offer the most meaningful features. Moreover, similar features offered by different appliances from different manufacturers should be offered in a similar way, so that there is no need to change or implement the energy management (algorithm) specifically for each home appliance. Thus, besides providing meaningful features, **interoperability** of home appliances is crucial. The intermediary component can be a solution provided by a specific home appliance manufacturer, but it can also be a solution supporting multiple manufacturers and can be considered a **framework** or **platform**. This latter solution already supports interoperability.

Even if the energy management consists of multiple layers, for the sake of Action #5 we only consider it as a single layer that interacts with the home appliance using the home appliance API.

Finally, a controllable home appliance can consist of a non-controllable part (non-smart home appliance) and a device that provides control, like a smart plug. In this case, such a combination can be considered as one controllable home appliance. Furthermore, a solution (e.g., a software driver) providing complex energy related features, based on the knowledge about the appliance attached behind the smart plug, can be considered as the intermediary component.

There are ongoing activities that target the issue of interoperability involving many different device classes. On the level of the European Commission (DG ENER) it is, for instance, the Code of Conduct for energy smart appliances proposed by the Joint Research Centre[1], or the Horizon 2020 project InterConnect[2]. There are also approaches on the communication level that try to address the diversity in low-power home area networks (HAN), like Matter[3].

In order to capture the state of things in the BRIDGE projects a survey was conducted. The results are presented in the following two sections. The first one presents the anwers that can be easily analysed and presented in diagrams, while the second goes deeper into more complex and text answers.

[1] European Commission, Joint Research Centre. Code of Conduct for Energy Smart Appliances. Available at https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances
[2] Interconnect [online]. Available at: https://interconnectproject.eu
[3] Connectivity Standards Alliance. Matter, the foundation for connected things. Available at: https://csa-iot.org/all-solutions/matter/

4. GENERAL OUTCOME OF THE SURVEY

This section presents the outcome of the survey that was conducted among the projects. It presents the answers to questions that can be covered by a statistical summary and analysed. An interpretation of the outcomes is also provided.

The aim of the survey was to gather information regarding the control, monitoring, interoperability, and usage of home appliances in various projects. It covers topics such as the project's role as a provider or consumer of home appliance interoperability, the types of home appliances used, their energy-related features, API interfaces and protocols, interoperability challenges, security measures, awareness of relevant initiatives, and areas for improvement, among others. The complete set of questions is given in Annexe 1.

The survey received **24 responses**, covering the perspective of 23 projects and the BRIDGE Standards User Group (BSUG) – Action #4. Among respondents, 19 are controlling or monitoring home appliances, as presented in Figure 2.1. It is worth noting that last year there were 18 contributions to the survey and only 13 involved home appliances.

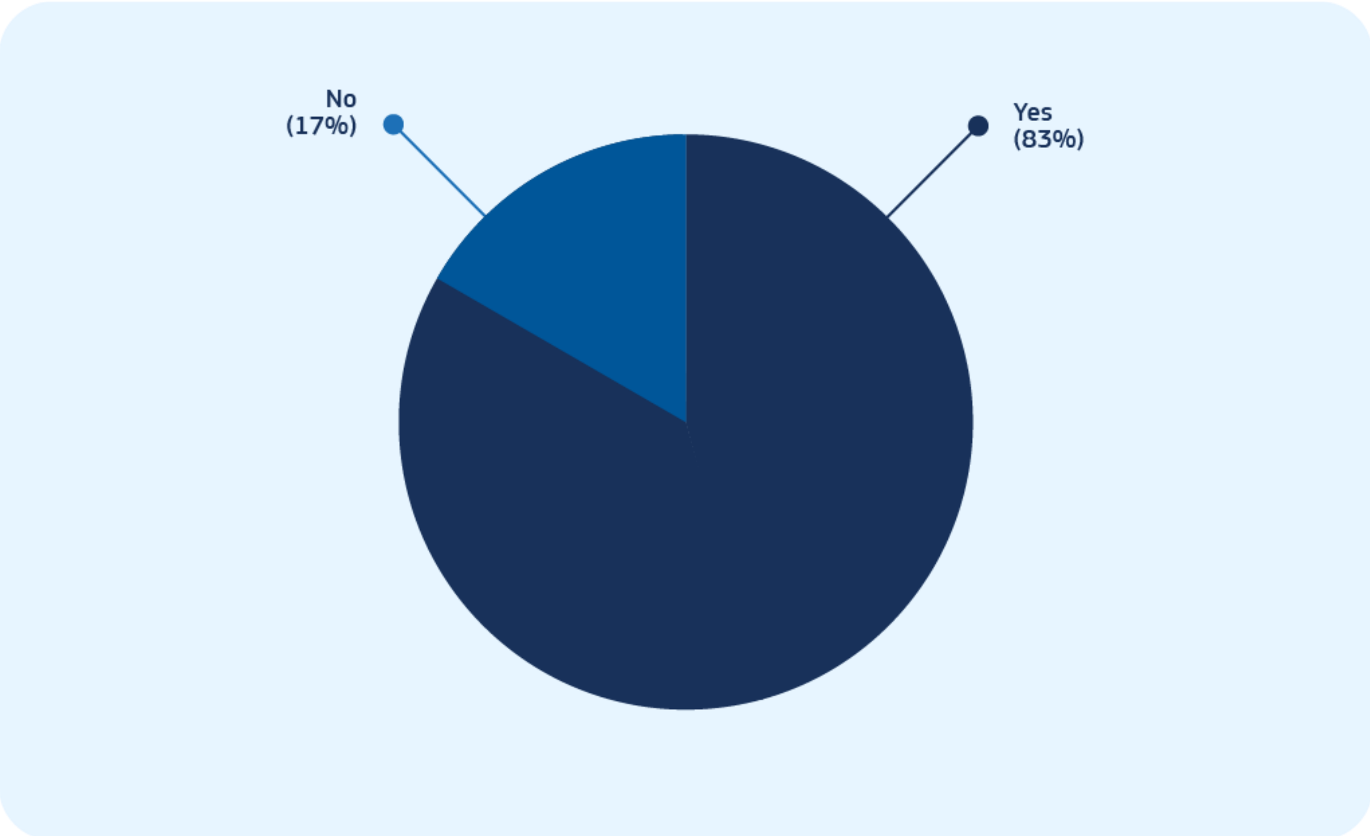

Figure 4 Q2: Do you control and/or monitor home appliances in your project?

The projects can be a consumer or a producer of approaches related to the interoperability of home appliances. If the focus in a project is related to energy management only and it is using home appliances for that purpose, then we define it as a consumer/user of the home appliances. Similarly, if the project focuses on developing approaches for supporting the use of different home appliances in different contexts, then we define it as a provider of home appliance interoperability approaches. Most of the projects are a mix of both of these aspects, however, if we first ask about the essential focus, the results are as presented in Figure 5. Slightly more projects identify themselves as providers, rather than consumers. A closer look at the distribution ratio between being the provider and the consumer is shown in Figure 6.

This distribution indicates an even greater focus on the provider side than on the consumer side. There are 3 strictly provider-oriented projects and more than one third of the projects are highly provider-oriented (≥80/20). Nevertheless, the biggest group of the projects is a compromise between providers and consumers. From the distribution, it can be deduced that more projects are focused on creating strategies to encourage the use of various household equipment in various situations. It can also be the case that some projects have been forced to develop interoperability-related approaches because of their lack on the market.

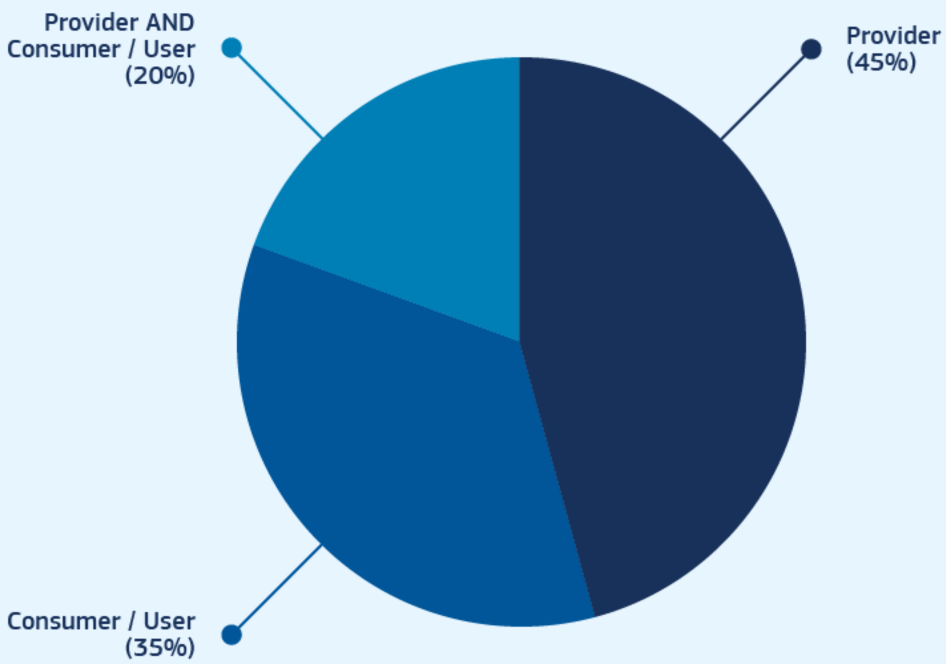

Figure 5 Q3: Do you consider your project as provider or consumer/user of approaches related to interoperability of home appliances?

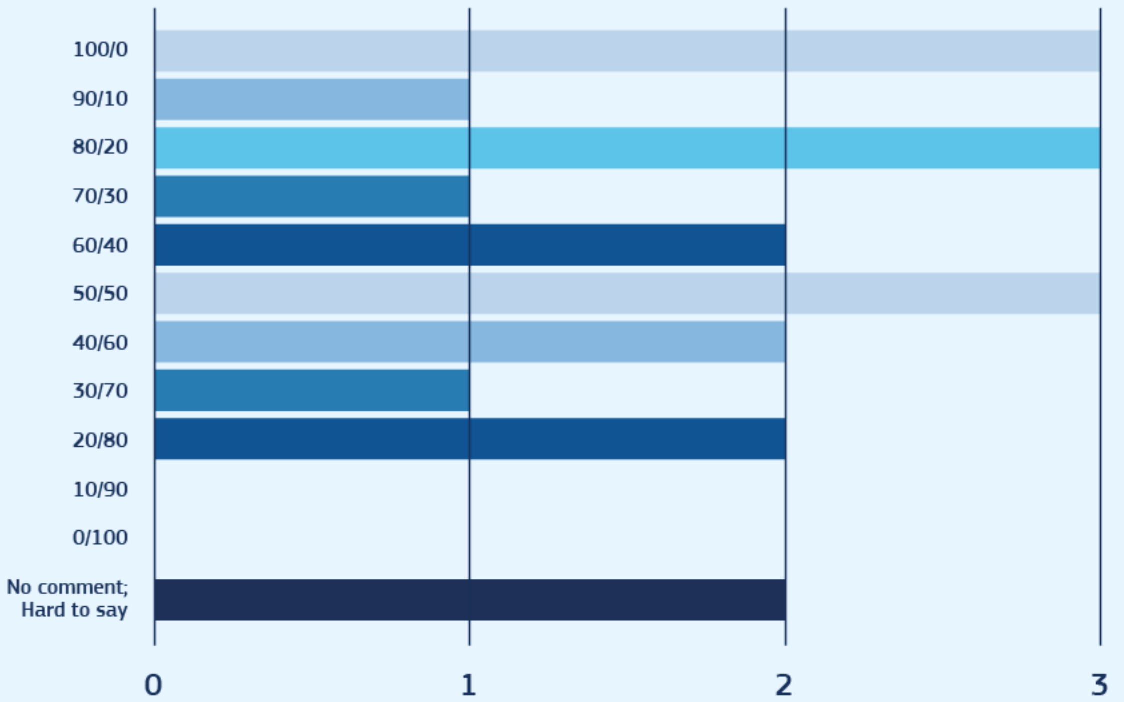

Figure 6 Q4: How would you define the split in the focus (provider vs. consumer/user)? (e.g., 40/60)

Most of the projects involve a wide range of products. Based on the responses of the survey, appliances were divided into three groups and the results are presented in Figure 7. Additionally, respondents declare what the energy-related features are used in a given project. The two dominant groups are white goods and HVAC. In the first group, the most frequently mentioned appliances are the shiftable loads, namely washing machines, dryers and dishwashers. Besides shifting, respondents also declare the possibility of pausing these home appliances. Lighting systems, TVs and refrigerators are not that controllable, in comparison to previous ones. Hence they are used less often, but they are also used by the projects. The second group includes HVAC-related products. Here, some of the projects are using comprehensive HVAC systems, where all the functionalities are involved. Other projects focus only on a few or single HVAC units, with heating equipment such as boilers or heat pumps leading the way. Here respondents indicate advanced functionalities, like setpoints, holiday programmes, scheduling, price-based signals management, etc. The last group consists of appliances related to EVs and storage. Batteries, as essential appliances in energy management systems, were the most frequently mentioned, followed by EVs and chargers. Here charging/discharging or scheduling are widely used functionalities. Furthermore, most of the home appliances collect the relevant measurements.

Advanced functionalities allowed use-case scenarios implemented in the projects to be defined. Most of the projects have developed flexibility scenarios by applying load shifting, peak load reduction, simply switching on/off, or scheduling home appliances. Additionally, some projects opt to include aggregators to manage the flexibility most optimally and create opportunities to trade flexibility on the local market. Objectives of the energy management that are frequently mentioned are: minimising the energy cost, maximising energy efficiency, maximising self-consumption, and maximising RES use. EVs, chargers, batteries and shiftable loads are also involved to enhance grid stability.

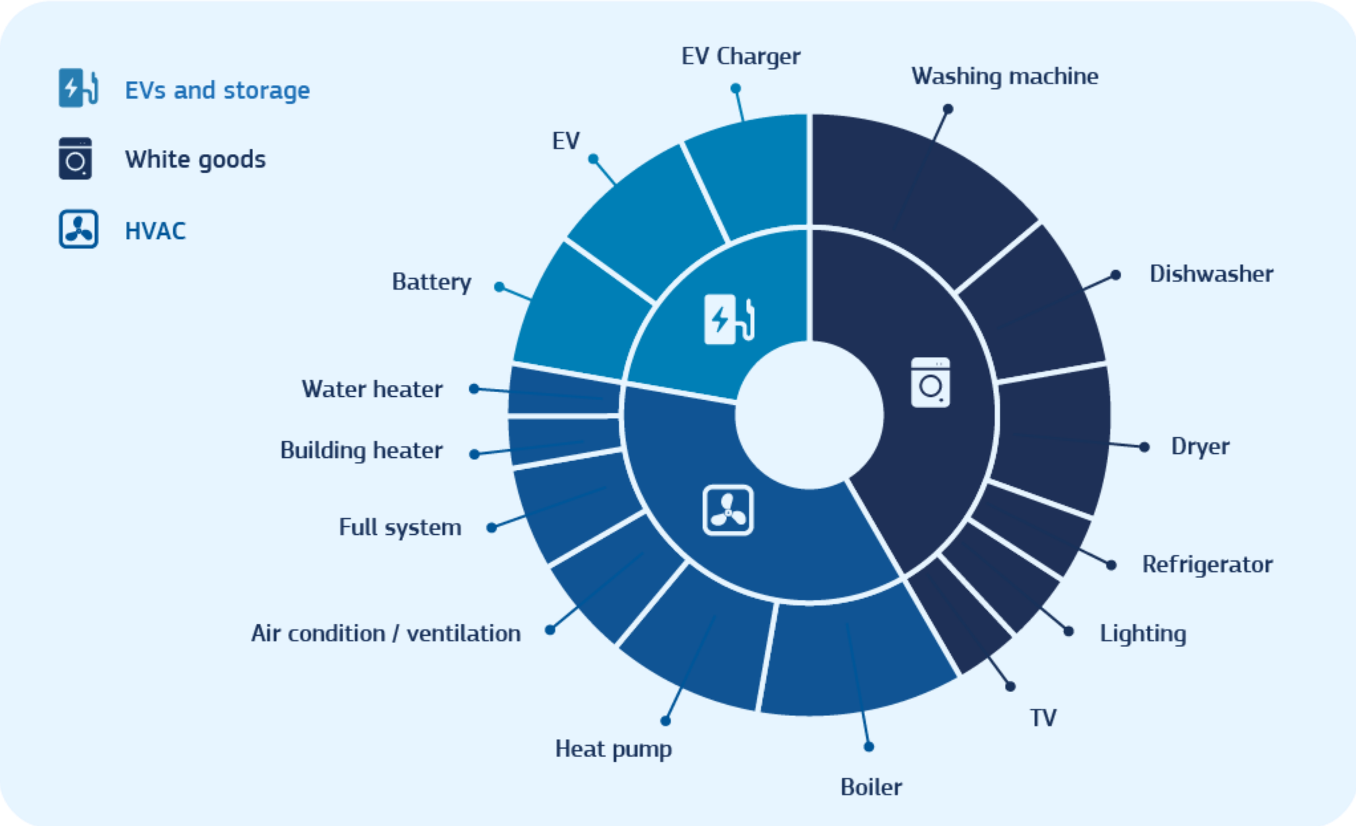

Figure 7 Q5: What are the home appliances that you are using in your project?

Home appliances delivered by manufacturers sometimes require customised extensions to be applicable in the energy management scenarios. The extent the projects are using the customised controls or those provided by the manufacturer is shown in Figure 8. More than half of the projects rely solely on customised extensions like a smart plugs. Only 15% are using pure manufacturers' appliances. That small number indicates that the market is still offering a limited number of appliances that are interoperable and have an open control system, to be used by the projects without workarounds.

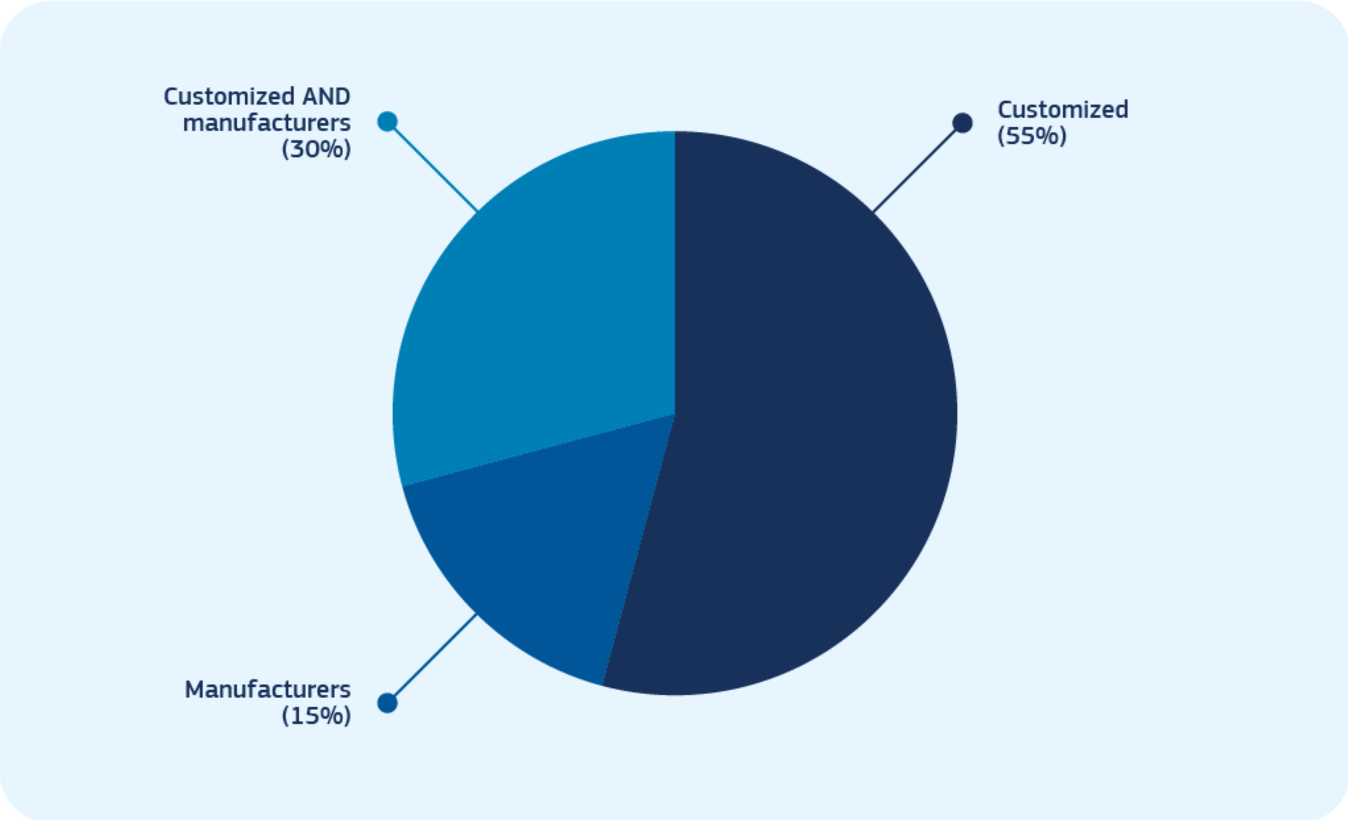

Figure 8 Q6: Do these home appliances provide manufacturers own control and monitoring or do you use customised extensions (like a smart plug)?

Figure 9 indicates that the vast majority of projects do not lock into a single manufacturer of home appliances. Different manufacturers mean different communication protocols, control and interfaces. This indicates just how important interoperability between home appliances really is.

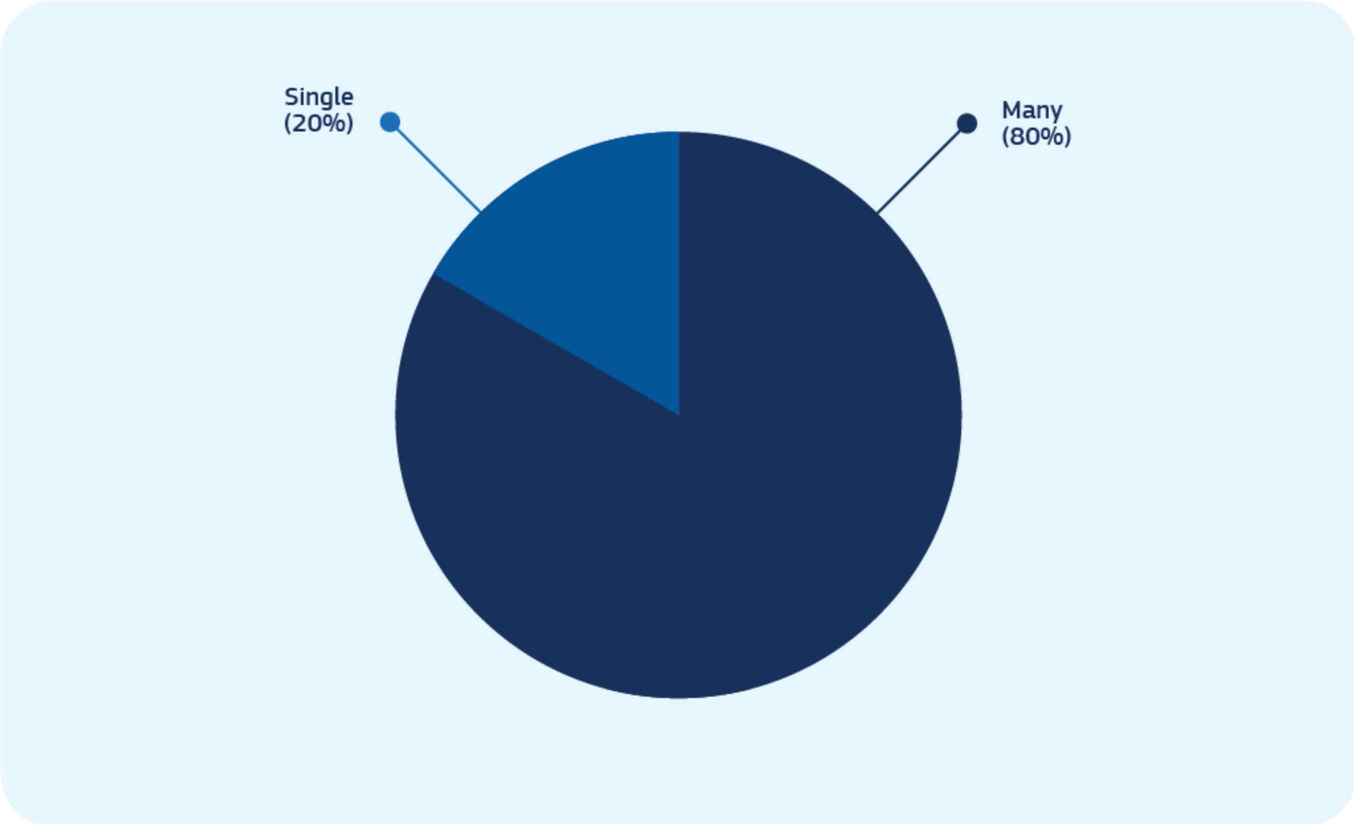

Figure 9 Q10: Do you use/support home appliances by a single manufacturer or by many manufacturers?

As indicated in Figure 10, most of the projects involve home appliances that are available on the market. The use of appliances readily available on the market could prove important when transferring pilots and demonstrators to the real world. Unfortunately, they can be more difficult to control and integrate. To avoid this, some projects opt for experimental home appliances, which typically offer more features than the home appliances available on the market. Figure 11 shows, on the other hand, that there is still a broad group of home appliances with closed monitoring and control systems.

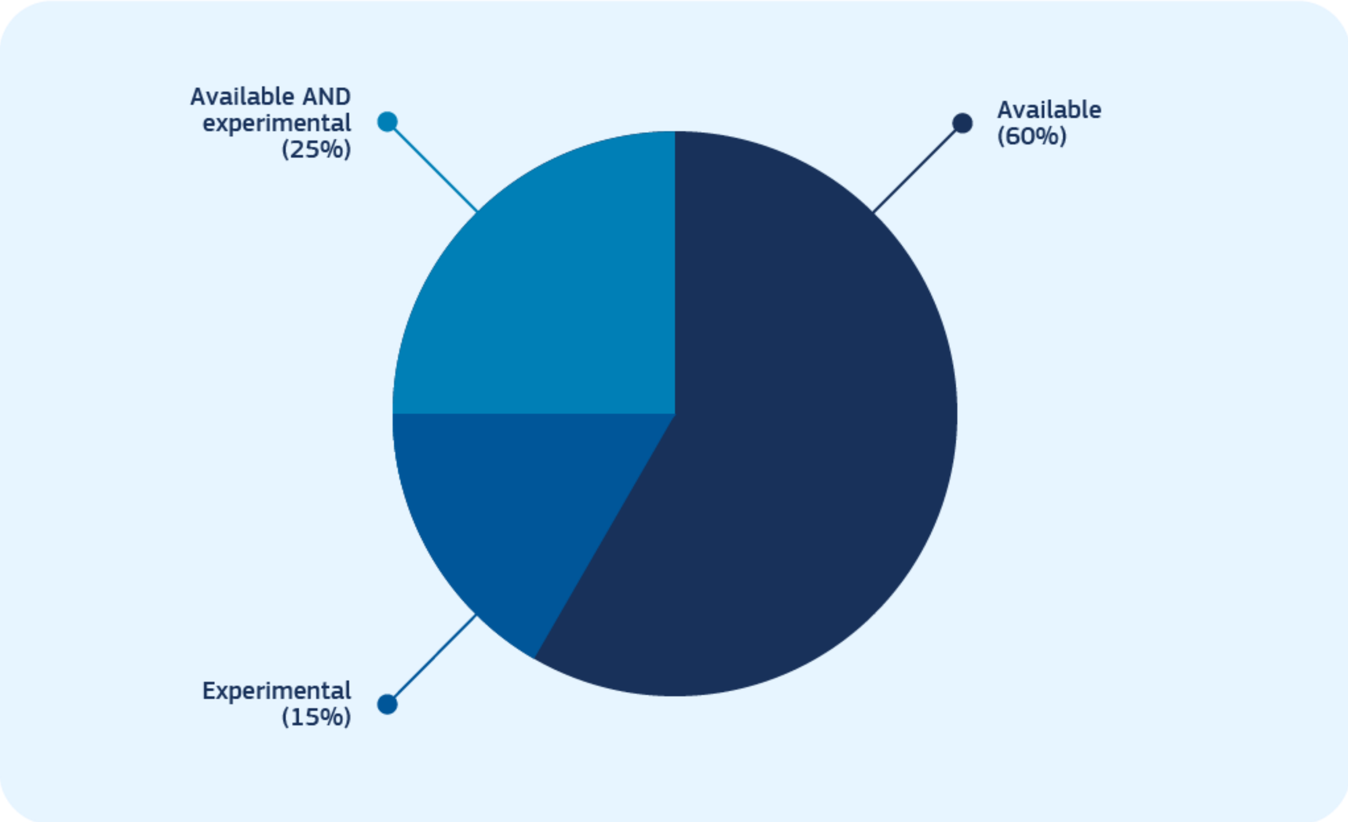

Figure 10 Q11: Are these home appliances available on the market or are experimental ones?

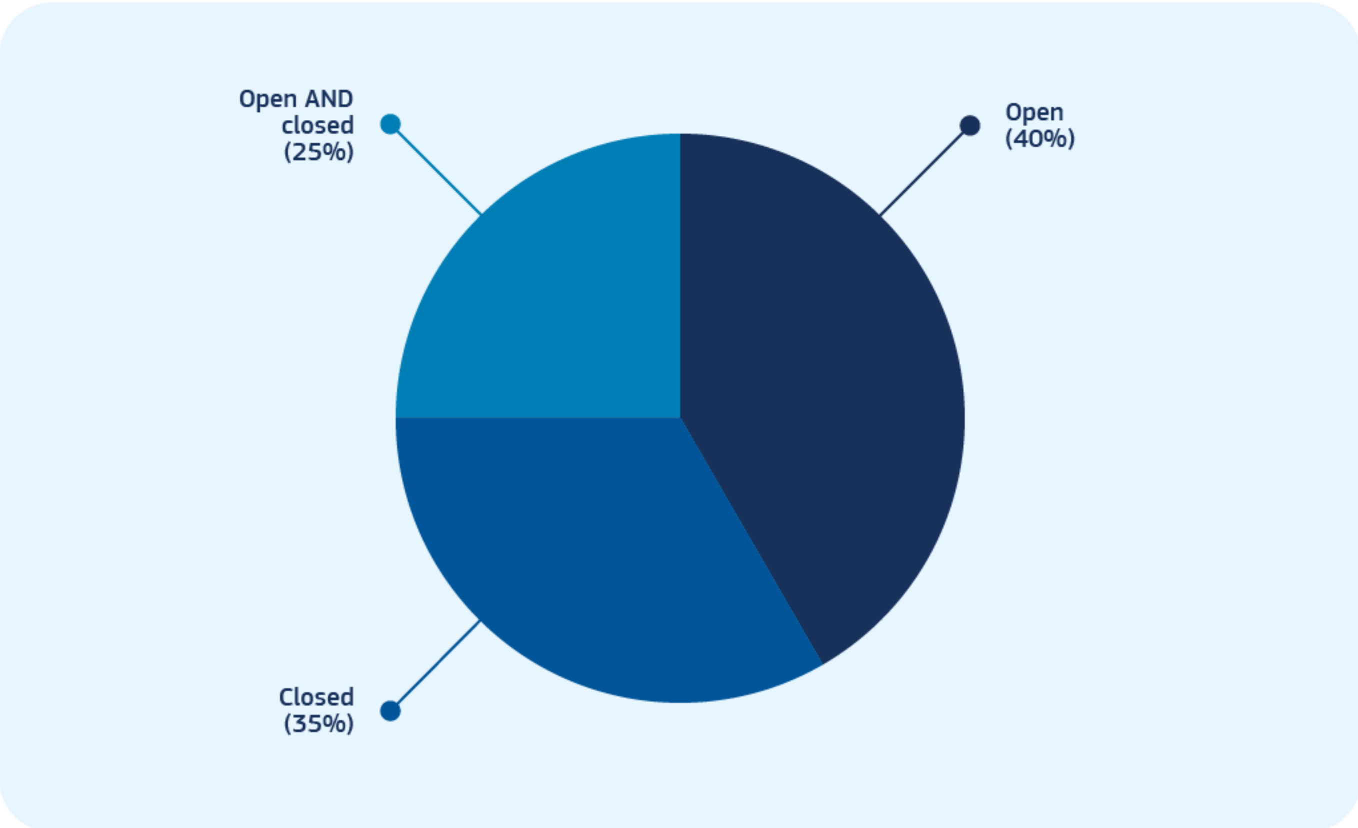

Figure 11 Q12: Do these home appliances provide open monitoring and control interfaces and protocols?

The location of home appliance APIs influences the architecture and design choices made in the context of home appliance integration and energy management systems. The most prefered location for home appliance APIs is presented in Figure 12, where responders could choose multiple locations. Almost half of the projects indicate cloud service as one of their locations, and more than one third indicate home gateway. It is worth noting that the report from last year showed an inverse relationship, meaning that the majority indicated the home gateway as the prefered location.

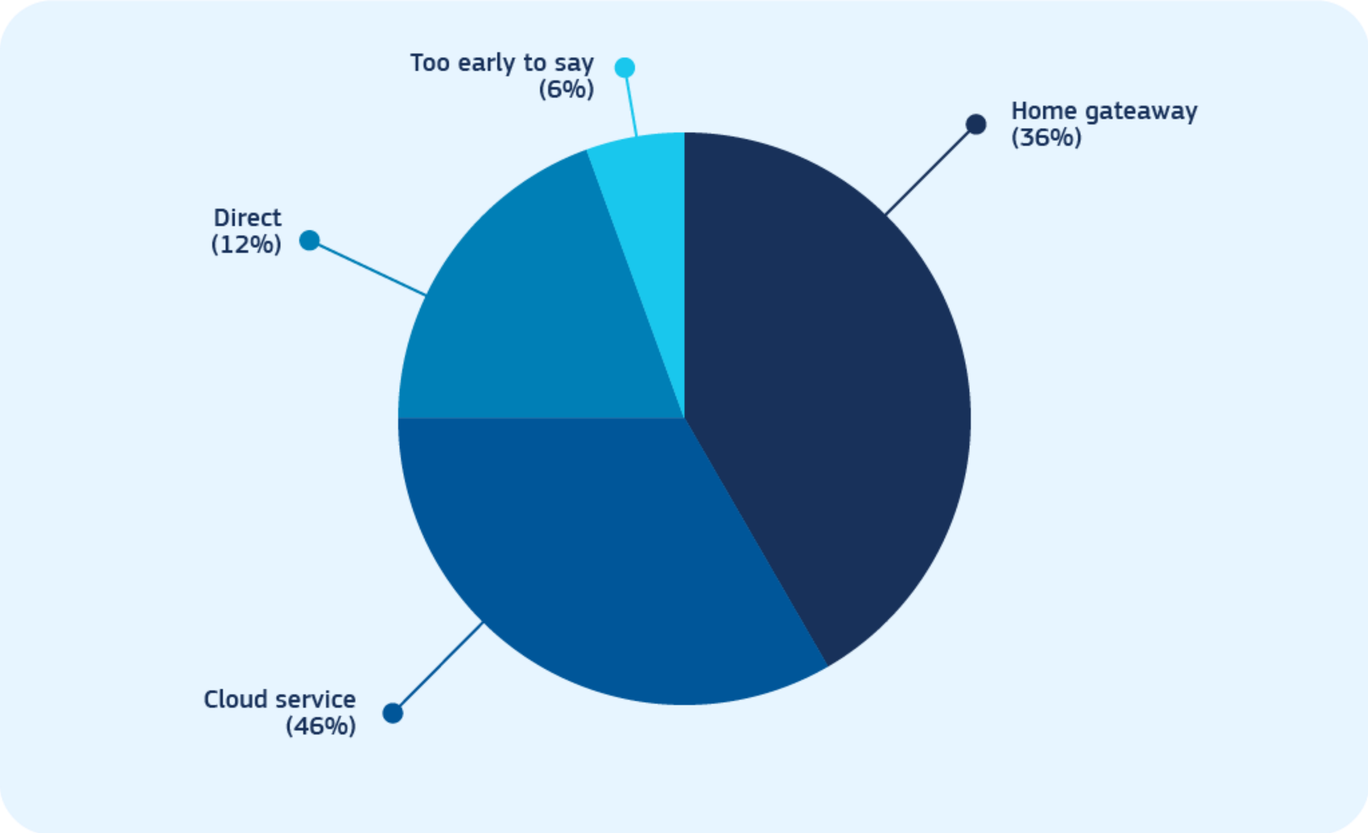

Figure 12 Q7: What is/are the home appliance API location(s) in your project?

The following section addresses the replies to the remaining questions that required more textual input.

5. DETAILED ANALYSIS OF SPECIFIC POINTS

This section goes into the details of the survey outcomes that could not easily be presented in the diagrams of the previous section. It also elaborates on some of the outcomes that were handled in a numerical way before, by sorting them according to specific subjects. These subjects will also be further investigated in the following years in the BRIDGE Data Management Working Group Action #5, and in conjunction with other BRIDGE activities.

5.1 USE OF STANDARDS

The standards of the protocols or interfaces vary widely across the projects. There are projects where participants try to use few standards, while others take an approach where they use multiple protocols to achieve synergy between them. The most commonly used standards are MQTT and REST API (RESTful API). A significant group of projects sticks to the well-known and established MQTT publish/subscribe interface for the messaging protocol of IoT devices. This is the default and preferred option for many projects due to the ease of integration with the cloud. Another group is using the RESTful API, which is not a standard but widely used due to clear architectural constraints. There is also a tendency to use both protocols. Less commonly used standards include MODBUS for client-server communication or Z-Wave to create a mesh network. In addition, some projects use WiFi or BLE as the standard protocol for local communication. Other less commonly used standards are openADR or OpenHAB. It is important to note that standards for protocols and interfaces are often undefined at the beginning of the project, and the decision on which ones to use is made at a later stage of the project.

5.2 SECURITY AND RELIABILITY

There are different approaches to provide security in the solutions developed by the projects. There are many standard approaches applied, including TLS/SSL, WSS, HTTPS, OAuth2, AWS Auth. There are also other approaches, like token based access control, password based access control. There are also projects that do not yet address this aspect or at all.

There are also different levels involving security, like security between each component or security at the cloud level for centralised approaches. This diversity is also related to the diversity of data exchange approaches. Depending on the level of distribution, the respective security approach needs to be applied, as security is to be addressed properly.

In data-based systems the lack of security or inproper security approach induces the potential risk on reliability, due to possible interferences from the attacker side or system malfunction that cause the data flows to be affected and not detected (or corrected) and may lead to general or partial system failure.

5.3 PRODUCTS

The BRIDGE projects reported outputs that can be considered as products supporting the interoperability of home appliances. The term *product* means here *output*, not necessarily a product in the sense of maturity. Additionally, these products refer to a diversity of aspects related to home appliance interoperability, which makes the following listing even more interesting, as it is not always obvious how some specific solutions can be supportive in this matter.

- The product of the **ACCEPT** project is the Building Information Management Layer (BIML) which is responsible for real-life, energy-related data collection, processing and storage. It focuses on the following major areas: the specifications of the off-the-shelf meters, sensors and actuators. They will enable the bi-directional communication with end-user appliances, the specifications and configuration of the IoT Gateway, and finally the software stack that enables the efficient and secure information flow and processing between the building, the occupants, and the market actors. It integrates devices regardless of their communication protocol in a uniform manner, enhancing the interoperability of the IoT Gateway.

- Demand-response and optimal market position tool employing NILM is the product of the **Communitas** project. The product aims to identify household appliances' consumption patterns through learning, offering recommendations, and managing device usage to reduce electricity costs and provide flexibility services. It supports interoperability by requiring communication with devices to obtain consumption data for learning consumption patterns, enabling real-time management and optimal scheduling based on generation and demand forecasts, focusing solely on electricity consumption. The product requires both a software infrastructure for data storage, processing, and pattern analysis, as well as devices for individual appliance consumption monitoring, along with forecasting consumption and controlling controllable loads via an external controller.
- The **ebalance-plus** projectcontributes with the household simulator and smartDSM data exchange middleware (with adapters). The first one can be used to model home appliances and evaluate the applicability of energy-related features in the context of energy management algorithms. The main aim is to do experiments with energy-related features and communication, and create digital twins and hardware or software tests. It can be combined with energy management algorithms. The second one is a data exchange platform that supports the application development or services that can also be adapters to translate the data-centric requests to device specific requests and commands, based on different communication technologies and protocols. Using the adapters, the different appliances can be connected to the complete system and can interact with it for monitoring and control purposes. For the full function, it requires the smartDSM platform, the adapters, the appliances and the algorithms to process the signals from the appliances and generate control signals for the devices (data-based signals).
- The **InterConnect** project delivers HEMS connect, which is a home energy management system that uses the semantic interoperable framework layer of the knowledge engine tool to ensure interoperability. It is being used mainly for flexibility services. To ensure proper work, it needs the home appliances to be smart appliances and it needs the knowledge engine.
- **InterStore** produces IEEE2030.5 software and IEEE2030.5 legacy protocol converter to assure interoperability between distributed energy resources (behind the meter) and energy management systems. It specifically applies to home storage systems, PV systems, chargers, etc. and needs to be coordinated by an energy management system.
- The **MASTERPIECE** project produced FIWARE IoT Agent JSON/MQTT. It aims to translate information from devices that use MQTT technology as a communication protocol to the NGSI-LD standard for context information management. The homogeneity provided by this agent ensures the interoperability of the information received from devices that communicate using MQTT, abstracting the consumer of this information from the heterogeneous implementation and protocols used by the assets and equipment. Furthermore, MASTERPIECE extended Node-RED's capability and compatibility with more communication protocols used by building electronics and equipment, such as ZWave and Modbus. This solution allows for the low-level integration of devices into an NGSI-LD platform, translating information and enabling bidirectional communication.
- The **REEFLEX** project presents ENERGY BOX, which is a gateway that allows monitoring and control of local devices and communication with external (non-local) systems. It can monitor and manage home appliances using different protocols and communication media such as Ethernet or ZigBee. It also allows appliances to communicate with remotooe control systems and to apply external operating commands. It requires locally manageable devices and an internet connection.
- The **SENDER** project creates Home Gateway to Interconnect the different home appliances of HVAC systems, lighting system, sensors and collect data from them to be sent to the cloud repository for further

processing. It allows monitoring the home appliances for a correct functioning of them, finding errors or problems. It connects mainly through ZigBee or Wi-Fi and exchanges data with appliances. The interoperability is from each appliance to the cloud, where the data is stored and processed, not between appliances.

- The **SiC4GRID** project aims to develop multi-level digital twins (cell, module and finally system level) for SiC-based power electronics (which will be also developed in the project) in wind and PV energy field, support the simulation of the system which will be an electrical converter for HVDC/MVDC applications (either in modular multi-level converter (MMC) topology – also in physical form – or in a solid state transformer topology). Additionally, the project will develop the corresponding models, receiving also feedback from mission profile to optimise the design, operation and performance of the converter. A GUI will be also developed to support the optimum system level design. Furthermore, a self-healing energy management system will be developed for automatic adjustment of parameters of the MMC converter based on feedback from wind generation forecast, failure mechanisms and reliability data. The energy management algorithms will overall support predictive maintenance and health monitoring.

The following table summarizes the products defined by the respective projects.

Project	Product	Implementation requirements	Accessibility	License
ACCEPT	Building Information Management Layer	software	closed	Apache License 2.0
Communitas	Demand response and optimal market position tool employing NILM	software; smart devices; external controller	to be defined	to be defined
ebalance plus	household simulator	software	to be defined	to be defined
	smartDSM data exchange middleware (with adapters)	smartDSM platform, the adapters, the appliances and the algorithms	to be defined	to be defined
InterConnect	HEMS connect	smart home appliances	closed	HEMS, under definition
InterStore	IEEE2030.5 software and IEEE2030.5 legacy protocol converter	none	yes	MIT

MASTERPIECE	FIWARE IoT Agent JSON/MQTT	NGSI-LD Context Broker (for minimum working case)	yes	AGPL-3.0 licence
	NodeRED and external libraries for ZWave, Modbus and NGSI-LD	NGSI-LD Context Broker (for minimum working case)	yes	Node-RED: Apache 2.0 Licence; Z-Wave JS library for Node-RED: MIT Licence; Modbus library for Node-RED: BSD 3-Clause Licence; NGSI-LD library for Node-RED: MIT Licence;
REEFLEX Project	ENERGY BOX	locally manageable devices; access to internet	closed	Varied licensing based on use.
SENDER	Home Gateway	raspberry Pi	to be defined	to be defined
SiC4GRID	multi-level digital twins for SiC-based power electronics (which will be also developed in the project)	Specific APIs and interfaces	To be defined	To be defined

5.4 ISSUES AND RECOMMENDATIONS

The Smart Grid Architecture Model (SGAM) is a conceptual framework used to represent the different layers and components of a smart grid system, facilitating its design and implementation. It categorises elements into domains such as business, operations, information and communication, providing a structured approach to understanding and analysing smart grid architectures. Despite the maturity of the model, not all projects are familiar with it (25%). For the question on the most problematic SGAM layer, 25% of respondents have no opinion, while the remainder reply that the more abstract layers tend to cause more problems. The layers that cause the most problems are thus communication, information and business. It actually reflects the well recognised state, where the diversity of communication technologies and lower level protocols are the main issue, and the information layer on top of them follows.

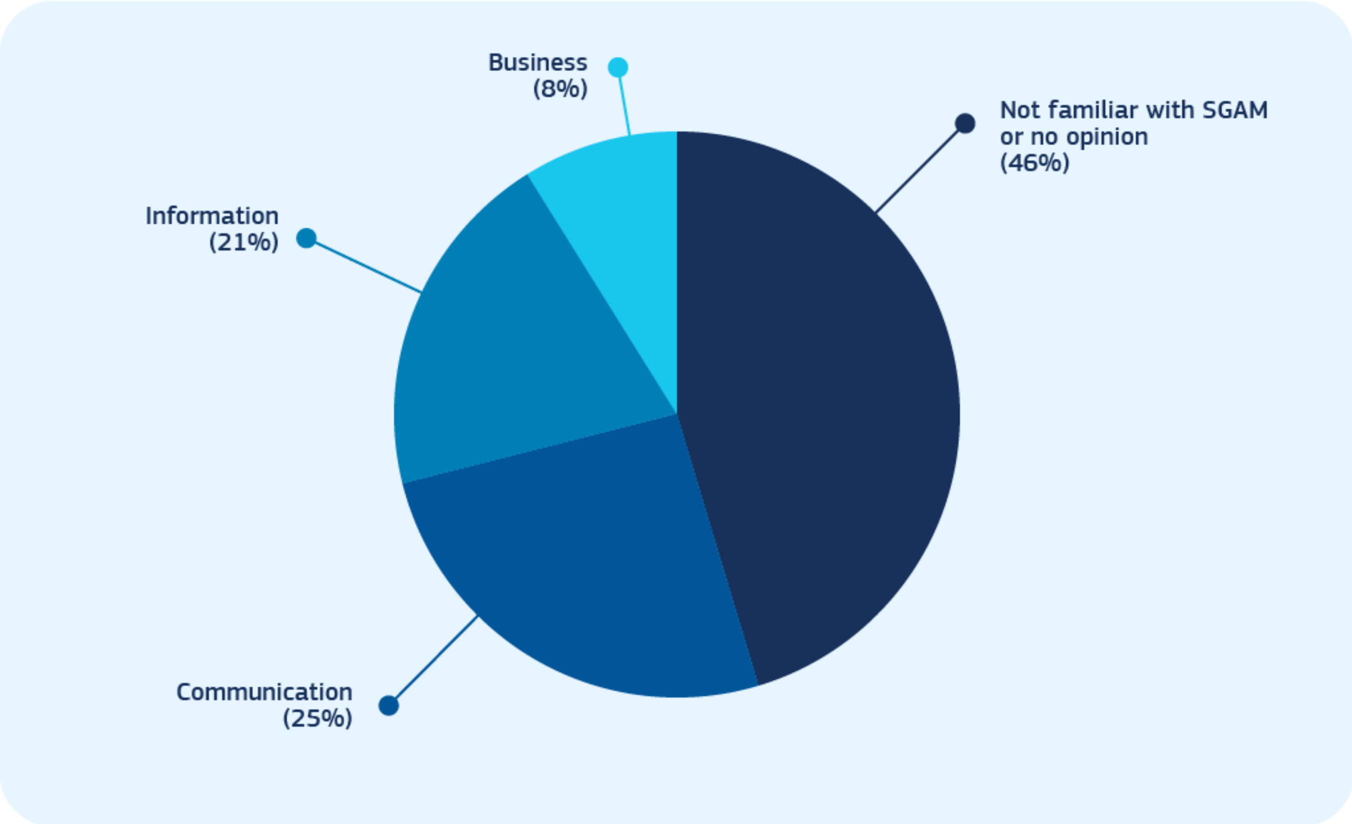

Figure 13 Q19: Related to the SGAM model, what is the layer that you see as the most problematic from the interoperability point of view?

The most problematic aspect of the communication layer is the interoperability of the communication protocols. There are multiple vendors of appliances. Each may require a different communication protocol.

In the case of the information layer to achieve interoperability, the semantics is the most problematic. Many different systems working together can lead to ambiguous terms. To overcome this issue, standardisation of the data model is needed.

In the business layer, an underdeveloped market and user behaviour and home infrastructure are given as potential difficulties.

There are also a number of features that project participants lack. In general, more intelligence in existing devices is desired. Firstly, better interaction with the energy management system and flexibility are advocated, namely automatically adaptive for load shifting, optimising energy consumption without user intervention. For this purpose, more advanced intelligent metering devices are required that provide detailed energy data. This should be accessible via control interfaces, but in such a way that the data remains secure, especially when access to this data is remote and extended to include, for example, weather data or price information. There is also a lack of functionality that is strictly device related. For example, advanced operational features in heat pumps, storage, electric vehicles or household appliances. Here it is worth highlighting the selection of operating profiles, price-based control, the establishment of setpoints or simply the postponement of operation.

5.5 REGULATIONS

Regulatory frameworks organise the rules that apply for energy management involving data. No responding project mentioned regulations as a problem or issue. This means that these rules are considered as fixed and projects apply them. Probably later on, as the approaches mature, there might be some interactions with the regulators.

6. RELATED ACTIVITIES TOWARDS HARMONISATION AND STANDARDISATION

6.1 JRC COC INTEROPERABILITY OF ENERGY SMART APPLIANCES

The JRC activity on proposing the Code of Conduct for Energy Smart Appliances[4] has resulted so far in the first version of the CoC text and an initial proposal for the methodology for verifying compliance.

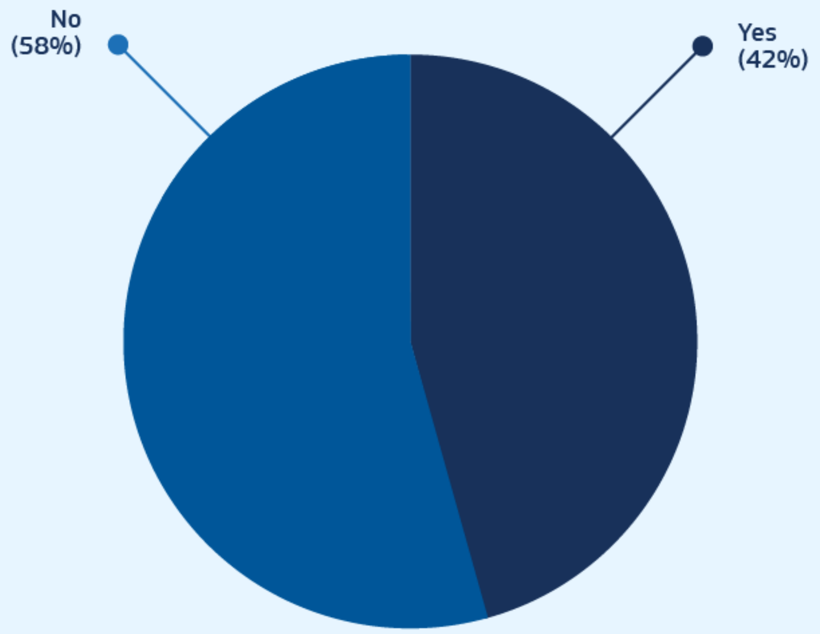

Figure 14 Q21: Are you aware of the JRC activity towards the Energy Smart Appliance Code of Conduct?

The code of conduct fosters interoperability and enhances the provision of demand flexibility from appliances by establishing guidelines for energy smart appliance (ESA) manufacturers. These guidelines are crucial for optimising consumption patterns in response to external stimuli, particularly in the increasingly decentralised energy landscape of the EU, where renewable energy sources are predominant. By encouraging ESA manufacturers to voluntarily sign the CoC, it outlines principles to ensure interoperability and the participation of relevant actors in the energy system. This initiative aims to unlock the potential of ESA in maximising demand side flexibility, thus aligning with EU energy and environmental policies.

[4] European Commission, Joint Research Centre. Code of Conduct for Energy Smart Appliances. Available at: https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances

The first version of the CoC has been agreed and will be launched. The launch event will take place during the EU Energy Day at the Hannover Fair on 23 April. This event is titled: *Energy Smart Appliances – harnessing the flexibility of interoperable energy smart appliances*.

6.2 MATTER STANDARD

Many of the projects and also external parties are working on hub-like approaches. These approaches focus on translating between different communication technologies and protocols – the hub is equipped with all the necessary communication modules and the translation is performed on the software level, involving the use of different data frames and higher level protocols. Matter is a standard / protocol that tries to organise this and to apply the IP addressing and communication on all devices in the home area network (HAN) by applying a common protocol layer on top of different communication technologies. However, this solution still requires the use of different hardware communication modules and the used technologies need to be IPv6 compatible (like Thread). But Matter provides a big step towards interoperability with its certification approach, where the certified devices are promised to work together out of the box. The latest version of the Matter has been published in October 2023[5].

6.3 DATA SPACES ACTIVITIES

Data spaces play a pivotal role in fostering interoperability by providing standardised frameworks and protocols for data exchange and integration among various systems and stakeholders. By facilitating seamless communication and collaboration between different entities, data spaces ensure that disparate systems can effectively interact and share information, ultimately enhancing interoperability across diverse domains.

More specifically, data spaces can enable energy smart appliances to seamlessly communicate with other upstream components of the energy system, such as smart grids and energy management systems, as well as downstream systems and devices, such as energy meters/sub-meters and actuators. This interoperability allows appliances to respond more effectively to market signals and grid conditions, thereby increasing their participation in demand response programmes and other energy market activities. Additionally, data spaces facilitate the exchange of data between of various energy system stakeholders, allowing end-users not only to participate in flexibility provision schemes, but to also access a wider range of energy services from different providers.

Under this category one can also put activities related to data semantics and ontologies. These allow specifying the meaning of the data exchanged with the home appliances as well as the relation between the different system components. There are currently several ongoing activities in this area and Action #5 will observe these in the following years.

[5] Connectivity Standards Alliance. Matter, the foundation for connected things. Available at: https://csa-iot.org/all-solutions/matter/

7. NEXT STEPS TOWARDS REPOSITORY CREATION

During the activities related to the Data Management Working Group several kinds of information have been collected that would be beneficial for current and future projects. There have been the use cases collected for Action #1 or code components collected for Action #4. In the two years of Action #5 there has also been similar information collected for creating the appliance database, as well as standards or project products related to interoperability of home appliances.

The approach for the following years is to bundle these activities that collect this information between DWMG actions, as well as to bundle the data sets to be related to more actions, maybe with an extended set of features to be stored.

Following this approach the joint Action #4 and Action #5 repository of relevant standards is planned. Similar, the code components repository will also be extended to cover the interoperability of home appliances products developed by the projects. Finally, activities towards integrating the database of home appliances within the EPREL database are planned.

This approach aims to collect and combine the data more efficiently while extending the impact to more projects and stakeholders.

8. CONCLUSIONS

This report summarises the second year of activities performed by the BRIDGE DMWG Action #5 on interoperability of home appliances. This action is still in its initial phase, but the activities already show the directions in which it will go in the following years. There are plans to investigate the approaches that work on the interoperability of home appliances on different levels, including security and reliability, use of standards, regulations.

What has again been confirmed by the results of the new survey is that the BRIDGE projects are at different stages of addressing the issue of home appliance interoperability. This comes from different project scopes and different stages of the projects' progress as well. The latter point may mean that there are new projects potentially not aware yet of the issues they may be facing soon, but the sooner they recognise that and the more informed they will be, the easier the problem may be to face. It is also crucial to provide common approaches that simplify the use of appliances in the energy management context, reducing the initial efforts needed by the projects to get introduced to the subject of home appliance interoperability. Ideally, there should be a list of devices that can be applied in the different scenarios and the projects can focus on the main goal: exploiting flexibility. But to achieve this stage it will still require some time. Action #5 will observe progress in this area.

The different focus of the projects is actually an interesting aspect that will be further observed by Action #5 – the scope of the projects determines their relation to the home appliance interoperability problem. As already stated in the previous report, Action #5 will interact with three (3) groups of projects. And each of the groups will be approached in a different way to limit the efforts while collecting data but still to maximise the collected knowledge and benefits.

There are projects that do not directly involve home appliances and are not interested in that aspect of energy management, since it is out of their scope. These projects can still set out use cases that might be relevant for Action #5 as the home appliances are often the bottom most layer that will be involved anyway, even if not directly considered in the first place. Thus, it is good to monitor their achievements to have an overview on the full picture, as they may probably define the context in which home appliances are used. These projects may be approached by generic DMWG surveys to capture their use cases.

The second group consists of projects that focus on energy management and need home appliances to implement it. These projects might be forced to address the issue of home appliance interoperability, but it is not their main goal and they might actually benefit from being able to reuse the solutions available. These projects can be considered as home appliance interoperability clients and testers, i.e., if provided with solutions available, these projects could investigate their applicability in specific scenarios and provide feedback to the developers of the solutions. These projects should be approached in their early phase of development with the solutions available so that they can make a meaningful choice, but also in the course of the project to collect feedback on the solutions applied.

Finally, the last group consists of projects that are providers of solutions for home appliance interoperability. Here, it is crucial to investigate their outcomes and make them available as soon as possible so that the interoperability clients can benefit. These projects should be monitored on their progress and their results should be linked and made available in a consistent and structured form.

In the following years there will be a need for a proper strategy to support both clients and providers of home appliance interoperability solutions. It is also important to monitor relevant activities and projects to follow the changes in the requirements and goals for energy management. This also involves further investigating the sometimes contradicting requirements coming from the different stakeholder groups, which need to agree in order to achieve the goals set either by the economics or regulations. Here the relation between three groups could be named: the manufacturers are to develop appliances that provide the given set of features, as required by the energy managers or aggregators and they both need to operate in the cost region acceptable to the end customers. Not all of these relations are critical for Action #5, but some may be interesting to observe in order to explain the reasons behind specific issues and/or progress in designing and implementing solutions for home appliance interoperability.

This year we further observed and participated in activities related to supporting home appliance interoperability, like the DG ENER and JRC European Code of Conduct for Energy Smart Appliances Interoperability[6]. This great example on how the manufacturers can be brought together to provide a common way for accessing their home appliances is somewhere between voluntary standardisation and regulatory activity. The CoC was launched in April 2024 at the Hannover Fair and we plan to monitor and support similar activities in the following years.

To summarise, in the next years we plan to work in the Action #5 on the following points towards the interoperability of home appliances:

- Develop the means and information exchange strategies to support both clients and providers of solutions for home appliance interoperability, including surveys and websites with relevant information, reuse and bundle where possible to increase impact,
- Identify and monitor relevant projects and activities that might generate requirements for home appliances and their interoperability in the dynamic context of energy management,
- Identify and monitor / support relevant activities towards harmonisation / standardisation,
- Contribute to a common information sharing strategy via DMWG repositories with:
    - Use cases,
    - Relevant outcomes / products from BRIDGE projects (code components),
    - Relevant standards and solutions,
    - Multi-class smart appliance database with list of energy-related features and interface description.

6 https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances

APPENDIX 1: SURVEY QUESTIONS

In order to collect the detailed information about the relation to home appliance interoperability in different BRIDGE projects, the following questionnaire was used. It was conducted as a Google Form survey.

Project-level Survey

Explanation on the possible answers

[x] – multiple choices possible

(x) – one of many

1. Please name your project (or projects if they share the way to use home appliances)

(short text input)

2. Do you control and/or monitor home appliances in your project?

(1) Yes
(2) No → go to 19

3. Do you consider your project as provider or consumer/user of approaches related to interoperability of home appliances?*

*if the focus of your project is related to energy management only and you are using home appliances for that purpose then you are a consumer/user of the home appliances. But if your project focuses on developing approaches for supporting the use of different home appliances in different contexts then you are a provider of home appliance interoperability. Of course, your project can also focus on both these aspects, but here it is crucial to define the strength of the focus, e.g., some projects may become providers because they needed to develop solutions allowing them to use different home appliances, but their main focus is on energy management.

[1] provider
[2] consumer/user

4. How would you define the split in the focus (provider vs. consumer/user), e.g., 40/60?

(short text input)

5. What are the home appliance classes* (and subclasses if applicable) you are using in your project? Please provide comma-separated.

(long text input)

*example home appliance classes are: “washing machine”, “dishwasher”, “water boiler”, etc. Subclasses define finer differences, like “condenser dryer” vs. “heat pump dryer”.

6. Do these home appliances provide manufacturer's own control and monitoring or do you use customised extensions (like a smart plug)?

[1] manufacturer's own control and monitoring
[2] customised (like additional HW for monitoring and control) – please explain

7. What is/are the home appliance API location(s) in your project?

[1] direct
[2] home gateway
[3] cloud service
[4] other (please specify)

8. What are the energy-related features of the home appliance classes that you use in your project? Please sort by home appliance class, like:
washing machine: shifting washing, pausing;
HVAC: setting temperature, reading energy consumption;
Fridge + Smart Plug: switching on/off, reading power parameters;

(long-text input)

9. For which use cases/scenarios implemented/considered in your project, do you use the energy-related features of the home appliances?
Please sort by use case, like:
Energy flexibility – VPP: switching on/off, shifting load;

(long-text input)

10. Do you use/support home appliances by a single manufacturer or by many manufacturers?
(1) single manufacturer
(2) many manufacturers

11. Are these home appliances available on the market or are experimental ones?
[1] Yes (available)
[2] No (experimental)

12. Do these home appliances provide open monitoring and control interfaces and protocols?
[1] yes (open)
[2] no (closed)

13. Which home appliance API interfaces and protocols are used in your project?

(long-text input)

14. Which internal API interfaces and protocols do these appliances use?

(long-text input)

15. How do you cope with interoperability? What is your approach to use appliances by different vendors and use their features? Provide short description, like use of adapters, appliance specific drivers, etc.

(long-text input)

16. Does your project use any specific framework/solution/product for controlling and monitoring the home appliances? Which one?

(short-text input)

17. Does your project provide any specific framework/solution/product for controlling and monitoring the home appliances? Which one?

(short-text input)

18. What are the security means applied in the home appliance API? What mechanisms are used for authentication, authorisation, confidentiality (data protection)? Are these available at home appliance level or e.g. at the cloud service level?

(long-text input)

19. Related to the SGAM model, what is the layer that you see as the most problematic from the interoperability point of view?

(1) Business
(2) Function
(3) Information
(4) Communication
(5) Component
(6) No opinion
(7) Do not know SGAM

20. Why do you see this layer as the most problematic?

(long-text input)

21. Are you aware of the JRC activity towards the Energy Smart Appliance Code of Conduct? (https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances)

(yes/no)

22. Is the JRC Code of Conduct relevant / helpful for your project partners? Please name the kind of partner and the benefits (manufacturer, integrator, scientific, etc.).

(long-text input)

23. What are the home appliance features that you miss for useful use cases? Please sort according to use case (e.g., usecase:device_class:feature1, feature2;)

(long-text input)

24. Are there any issues related to accessing the features of the home appliances you experienced or foresee?

(long-text input)

25. Are there any issues related to interoperability of home appliances you experienced or foresee?

(long-text input)

26. Can we ask you additional questions related to the survey? (e.g. per email)

(1) YES
(2) NO

27. Could you provide an Email address so that we can contact you directly for questions?

(short-text input)

APPENDIX 2: HOME APPLIANCE DATA QUESTIONS

In order to collect the information about the different home appliances used by the projects the following data was collected for each device.

1. Vendor/manufacturer
2. Model
3. Class and subclass (if applies)
4. Features provided directly by the appliance (please list them)
5. Is the home appliance used with additional hardware? (yes / no)
6. Features provided with the additional hardware (please list them)
7. Application in use case (what are the features used for)
8. Home appliance API level (direct / home gateway / cloud service / other)
9. Communication technology used by the internal API
10. Communication protocols used by the internal API
11. Is the internal API open?
12. Communication technology used by the home appliance API
13. Communication protocols used by the home appliance API
14. Do you apply any interoperability framework/product for that device? Please name it
15. What are the security approaches and protocols available/supported by the internal API? (for protecting the communication / authorisation / access control related)
16. What are the security approaches and protocols available/supported by the home appliance API? (for protecting the communication / authorisation / access control related)
17. Is the appliance available on the market? (yes / no)
18. Does the manufacturer allow you to install own software on the home appliance
19. Have you developed any home appliance specific driver / adapter for this device? (yes / no)
20. Are you interested in providing the adapter/driver for the appliance to the community? (yes / no)
21. What is the licensing scheme you plan for the driver/adapter?

APPENDIX 3: PRODUCT QUESTIONS

In oder to capture the information on the different project outcomes that can be considered products and can be reused by other projects the following questionnaire was used.

Description of a project product that supports home appliance interoperability

Project name:

Product name:

What is the aim of the product:

How does it support interoperability of home appliances:

Does it require additional infrastructure, systems, etc.:

Is it open and freely available:

What is the licensing scheme:

Contact person (name and email):

List of references

European Commission, Joint Research Centre. Code of Conduct for Energy Smart Appliances. Available at: https://ses.jrc.ec.europa.eu/development-of-policy-proposals-for-energy-smart-appliances

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