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RESPOND
DEMAND RESPONSE FOR ALL

Integrated Demand REsponse SOlution Towards Energy POsitive NeighbourhooDs

WP1 PILOT SITE CHARACTERIZATION

T1.3 INTEROPERABILITY ISSUES AT PILOT LEVEL

D1.3 RESPOND STRATEGY TO SUPPORT INTEROPERABILITY

The RESPOND Consortium 2018

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EXECUTIVE SUMMARY

This document on "RESPOND strategy to support interoperability" reports on the results achieved in Task 1.3 – "Interoperability issues at pilot level" during the first six months of the RESPOND project. The goal of this task was to perform systematic technological analysis of the legacy ICT infrastructure at three pilot sites, in terms of supporting interoperability with RESPOND platform. The analysis included home automation, smart home devices, building management systems, energy assets and metering equipment that might be involved in operation scenarios envisioned in RESPOND system. The analysis was performed at household, building and district level.

Besides, we provide an overview of the currently available interoperability solutions for smart home and energy management domains. We start with the communication protocols and continue with the existing specifications and standards, aimed to enable devices to communicate using the common messaging format. In addition, we make an introduction to the devices and services provided by consortium members.

Based on the data collected from pilot site questionnaires, a list of interoperability requirements has been compiled. Finally, we present RESPOND generalized approach to support interoperability and conclude the report with the recommendations to be followed in other related work packages and tasks.

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ABBREVIATIONS AND ACRONYMS

AES	Advanced Encryption Standard
BMS	Building Management System
CDM	Canonical Data Model
DHW	Domestic Hot Water
EMS	Energy Management System
HVAC	Heating, ventilation and air conditioning
HW	Hardware
ICT	Information and Communication Technology
IP	Internet Protocol
ISM	Industrial, Scientific and Medical radio bands
M2M	Machine to Machine
SW	Software
TCP	Transmission Control Protocol
URI	Uniform Resource Identifier
XML	Extensible Markup Language

1. INTRODUCTION

Recent advances in wireless communications and microelectronic manufacturing have enabled mass production of low cost miniature devices with sufficient computing capabilities that can be used for innovative home automation solutions. Since residential sector is one of the most energy demanding, there is a strong interest in exploitation of connected smart devices to improve energy efficiency, comfort and the quality of life. Over the years, device manufacturers have embraced different communication technologies that are shown to be mutually incompatible. Furthermore, there are cases where even devices using same technology (e.g. Zigbee) produced by different manufacturers are mutually incompatible, impeding easy upgrade of the system with new devices/features resulting in undesirable vendor lock-in. Although there exist different working groups/alliances that propose standards aimed to solve the aforementioned problems (Zigbee and Z-Wave Alliance, etc.), the issue of interoperability is still open in home automation and energy management area.

In this report, we provide systematic technological analysis of the legacy ICT systems at pilot sites, in terms of supporting interoperability with RESPOND platform. The analysis will include metering equipment, energy assets, smart home devices and Building Management Systems (BMS) / Energy Management Systems (EMS) that are already present at the pilot sites, as well as those that will be deployed over the course of the project. This report will take into account the best practices and currently available interoperability solutions and open standards, in order to make RESPOND truly interoperable platform that could be easily integrated with any other ICT system, and not only limited to pilot sites.

1.1 AIMS AND OBJECTIVES

Interoperability is defined as the ability of a system to work with or use the parts of equipment of another system. In the context of RESPOND project, the architecture of the system is designed to support interoperability from the beginning. RESPOND project aims to complement and enhance the existing smart home and building management systems, in order to improve the energy efficiency and optimize the costs by seamless integration of cooperative DR programs. Since there potentially exist different legacy and mutually incompatible devices, one of the most important goals of the RESPOND solution is to ensure interoperability among different system components. Indeed, interoperability represents one of the main pillars for the successful deployment of the RESPOND system.

In order to categorize different features that contribute to interoperability, a layered interoperability model is presented, as shown in Figure 1, which comprises the common interoperability layers: technical, syntactic, and semantic layers. The first one – technical interoperability layer focuses on establishing communication channel between the systems. Next, the syntactic interoperability layer enhances the interoperability by introducing a common data format for the message exchange between different systems. Finally, on the semantic interoperability layer, the data are presented semantically, categorized using context ontologies and linked to other semantic data

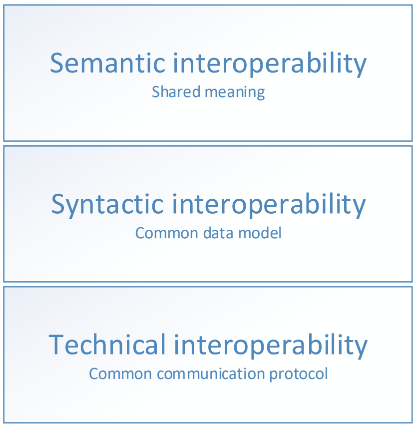


FIGURE 1 INTEROPERABILITY LAYERS

In the sequel, we describe in detail each of the interoperability layers:

Technical interoperability, which is usually associated with hardware/software components that enable communication between smart devices, is focused on the communication protocols and the infrastructure needed for those protocols to operate. It represents the lowest level of interoperability that is required to hold for the system to be interoperable at all. It includes a combination of software and hardware that enables the physical communication channel and the lower layer of the protocol stack. For home automation, TCP/IP is considered as the solution for technical interoperability. Nevertheless, home automation devices often lack hardware/software support for TCP/IP communication. Therefore, in order to provide technical interoperability for legacy home automation devices, it is necessary to employ appropriate hardware solution. Whereas technical interoperability is not enough *per se*, it is required before any other type of interoperability can be considered.

In the context of RESPOND system, technical interoperability will be fulfilled by installing new equipment provided by technical partners DEVELCO and Energo Monitor at the pilot sites. Some of these devices will empower legacy equipment with new features (e.g. remote monitoring of power consumption measured by legacy power meter). On the other hand, some of newly installed devices will allow remote measurement and control that was not previously available (e.g. temperature and humidity measurement and remote control of heating devices by means of smart relays). Finally, the Energy gateway (e.g. OGEMA) will be used to connect to other legacy systems that are not supported by consortium members' provided equipment.

Syntactic interoperability is usually associated with common data format, used to describe the messages transmitted between system devices. This interoperability layer empowers two or more systems with the capability to interpret the message content of exchanged data. There exist different methods for implementing syntactic interoperability. It can be performed directly between two or more devices using their native protocols, or by employing protocol converters. For the purpose of interoperability in RESPOND project, it will be implemented in a middleware, through protocol adapters that abstract diverse protocols of legacy and newly installed equipment and unify the data via CDM. The benefit of such approach is that each protocol needs to be converted only into common format and back, that results in a linearly growing number of adapters (2N). The technical partners that provide equipment will be in charge of the translation of their proprietary format into jointly agreed CDM, whereas legacy systems will be integrated via energy gateway that will communicate with the rest of the system by using the same common messaging format.

Semantic interoperability is concerned about the meaning of the data and sharing of that meaning. It ensures that the precise meaning of exchanged information can be understood by any other application that was not initially developed for that purpose. In such a way, systems are able to combine received information with other information resources (e.g. ontology) and to process it in a meaningful manner. On this layer, data can be presented semantically, categorized using context ontologies and linked to other semantic data. The advantages of semantics can primarily be seen when building intelligence that employs this information.

1.2 RELATION TO OTHER RESPOND ACTIVITIES

In Task 1.1, which has been done in parallel to Task 1.3 (this report), a systematic characterization of households, buildings and districts from perspective of typical technology and legacy devices was performed. The legacy equipment at all three pilot sites were studied from their energy and communication point of view (working profiles, communication technologies, data formats, etc.) in order to identify possible interoperability issues. The collected information has been used as a basis for the definition of interoperability requirements and RESPOND strategy to support interoperability, provided later in Section 4. The results and recommendations provided in this report will be directly exploited in WP5 – System integration and interoperability in Tasks T5.1 (Home automation interoperability interfaces) and T5.2 (Smart grid connectivity).

1.3 REPORT STRUCTURE

In this report, we propose a set of measures to ensure the interoperability of various parts of RESPOND system, with the focus on preselected pilot sites. First, in Section 2 we review relevant communication protocols aimed to support technical level interoperability in smart home domain. In addition, we consider various open standards that will serve as a starting point and further extended in order to ensure syntactic and semantic level interoperability, as well as smart home solutions provided by RESPOND consortium members. Next, in Section 3 we provide, in tabular form, the relevant interoperability aspects at three pilot sites, collected during initial pilot characterization. Then, as a result of the analysis of interoperability issues at pilot sites, in Section 4 we outline the main interoperability requirements. Finally, the report is concluded by presenting the RESPOND generalized approach and recommendations that will be applied in related work packages and tasks.

2. INTEROPERABILITY IN SMART HOME DOMAIN

In this section, we will present an overview of existing solutions used to support interoperability in home automation and energy management area. In addition, we will provide more details about equipment and services provided by consortium members Develco and Energo Monitor in order to get a clear overview of potential interoperability issues on their sides.

2.1 RELEVANT COMMUNICATION PROTOCOLS IN SMART HOME DOMAIN

In this section, we will provide a review of different communication protocols that ensure interoperability at technical level by enabling seamless message exchange among different devices in home automation and energy management scenarios.

Zigbee is a wireless technology developed as a global open standard that is supposed to answer unique requirements of low cost and low power consumption for M2M communication. It is based on IEEE 802.15.4 standard for Personal Area Networks (PAN) that works in unlicensed band including 2.4GHz, 900 MHz and 868 MHz, depending on local regulations. The standard 802.15.4 that Zigbee is based on, allows devices to communicate using different topologies (point-to-point, star and mesh) with batteries that can last for years. Although Zigbee shares frequency band with other wireless technologies (Bluetooth and WiFi), it takes full advantage of interference avoidance techniques and features unique channel agility mechanism. Moreover, there exist products in the market that have both WiFi and Zigbee integrated and are capable of working effectively in buildings and homes.

The transmission distance of Zigbee is limited to 10-100 meters, depending on channel propagation characteristics and output power. To overcome this limitation, Zigbee employs mesh networking mechanisms (see Figure 2) that allow it to transmit data over longer distances with the help of intermediate devices that relay data through a series of hops to distant ones.

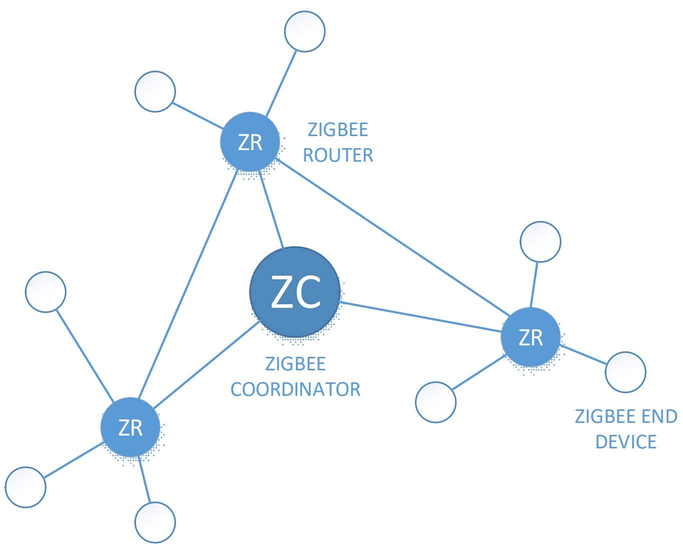


FIGURE 2 ZIGBEE MESH NETWORK

Zigbee is typically used in low data rate applications (up to 250 kbps) that require long battery life and security mechanisms (Zigbee uses 128 bit AES encryption). It builds on the physical layer and media access control layer that are defined in IEEE 802.15.4 and further specifies the network and application layer. Zigbee devices can perform one of the following roles:

- *Zigbee Coordinator*: there is precisely one coordinator in each network. It is the most capable device and usually mains powered. It forms the root of the network and may bridge to other networks, Furthermore, it stores the information about the network topology and acts as a respository for security keys.
- *Zigbee Router*: although it runs an application function, it can also pass the data from other device. Due to significant amount of work it performs, it is usually powered by batteries of larger capacity or by AC mains.
- *Zigbee End Device*: can be less capable device that contains just enough functionality to pass data to parent node, without the possibility to relay data from other devices in the network. Their main functionality allows them to change to sleep mode significant amount of time, resulting in longer battery life.

Zigbee Alliance is an organization that gather some of the most innovative and well-known organizations in the world such as: Philips, Huawei, Schneider Electric, Texas Instruments, etc. They are working together on developing Zigbee standard and further improving it to fit various operation scenarios such as smart homes, building automation, e-health. Their collaboration guarantees the long-term interoperability of Zigbee based solutions.

Z-Wave is a wireless communication protocol used mainly for home automation. Similarly to Zigbee, it uses low power transmission in combination with mesh networking to achieve long battery life and long coverage, suitable for smart home applications. In contrast to Zigbee, Z-Wave has more strictly controlled product ecosystem that aims mostly at smart home automation space. There is no guarantee that two Zigbee devices are interoperable, unless the interoperability is previously planned. On the other hand, a Z-Wave application will always integrate with another Z-Wave devices, since they use a proprietary radio transmitter. Moreover, Z-Wave uses exclusively sub-1 GHz frequency band (868 MHz in EU, and 915 MHz in US), that results in better interference management in contrast to Zigbee that usually operates in 2.4 GHz band where it coexists with other wireless networks (WiFi and Bluetooth).

Z-Wave is designed to provide reliable low-latency communication at data rates up to 100kbps that is more than sufficient for smart home and smart metering applications. Communication distance between two network nodes is approx. 40 meters indoors (100 m outdoors), with the ability of the message to hop up to 4 times between nodes. Although in Zigbee there is no such limitation in the number of hops, 4 hops is more than enough for typical home automation scenario. As for the security, Z-Wave also uses 128 bit AES encryption. Moreover, since 2016, Z-Wave alliance demands more strict security standards for devices receiving Z-Wave certification that provides advanced security for smart home devices and gateways by mandating new pairing procedures involving unique PIN or QR codes on each device.

Wireless M-Bus is a communication protocol primarily aimed to provide wireless connectivity for smart metering systems. It is the European standard (EN 13757-4) that specifies the communication between utility meters (electricity, gas, water, etc.) and data loggers, concentrators or smart meter gateways (see Figure 3)

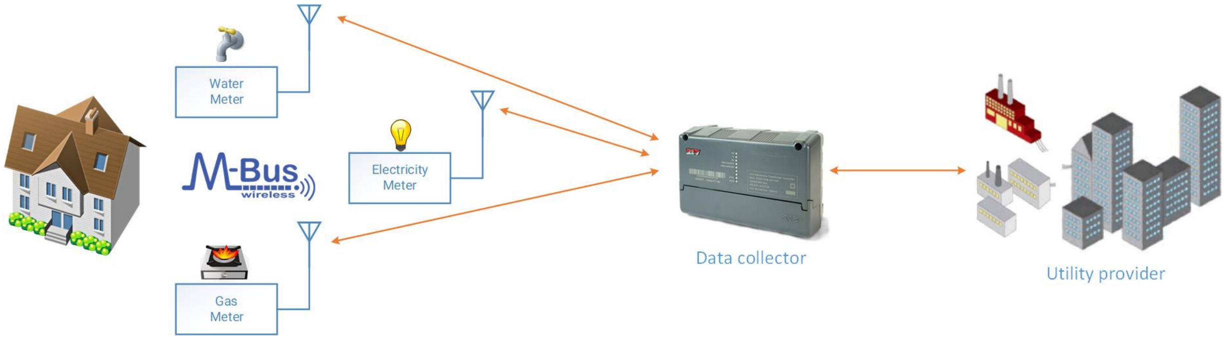


FIGURE 3 WIRELESS M-BUS COMMUNICATION

Since smart grid environments require long range and robust wireless communication, they usually employ sub-GHz frequency bands, such as: 169 MHz, 434 MHZ and 868 MHz. Besides, these bands can be used without licence in Europe, they are free from interference and have better propagation characteristics than already crowded 2.4 GHz band. By using these frequency bands, radio waves can propagate well in areas such as underground and in building that have several walls and obstructions between the metering device and the gateway.

Wireless M-Bus has gained significant traction in Europe due to its relative simplicity. It works in a basic star type of network that offers longer transmission distances. Since it is not IP or mesh enabled, its software stack requirements can be kept to minimum. Besides, it has lower cost since it uses standard ISM bands and no industry alliance certification is required. Nevertheless, its main drawback is that it is either lacking encryption, or when encrypted, the keys are not available for users/system integrators, because they are controlled by the device owner/manufacturer.

2.2 EXISTING SPECIFICATIONS AND STANDARDS FOR SYNTACTIC INTEROPERABILITY

Once the technical interoperability has been achieved by a suitable combination of communication network technologies and gateways, the next step is to ensure that all the devices communicate using the common messaging format. This is performed on the syntactic interoperability layer by defining the canonical data model (CDM). In the sequel, we provide a list of standards that may potentially serve as a starting point for the definition of RESPOND CDM.

oBIX (open Building Information Exchange) is an initiative by Organization for the Advancement of Structured Information Standards (OASIS) which defines XML and Web Services-based mechanisms for building control systems. Extending to all smart systems embedded in buildings, oBIX targets those that have traditionally been using proprietary control standards, as well as non-control system sensing, such as: heating, ventilation and air conditioning (HVAC), elevators, life/safety systems, access control, intruder detection, etc. oBIX aims to improve operational effectiveness, giving facility managers and building owners increased knowledge and control of their properties. In such a way, it offers a major step forward in fulfilling the vision of truly intelligent buildings. oBIX represents data as objects in a hierarchical structure as shown in Figure 4 . The top level object is called "root object'" and is the parent of all other objects. Data can be addressed in a hierarchical way, such as /Floor1/Room3/Lights.

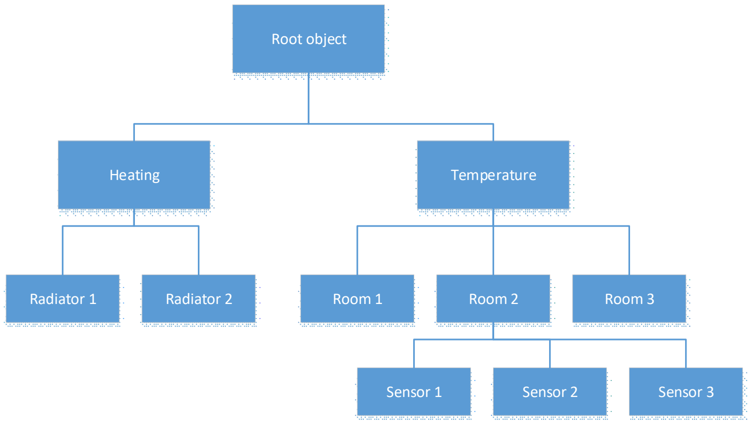


FIGURE 4 OBIX STRUCTURE

The Common Information Model (CIM), a standard developed by the electric power industry that has been adopted by the International Electrotechnical Commission (IEC), aims to enable application software to exchange information about an electrical network. The standard that defines the core packages of the CIM is IEC 61970-301, with a focus on the needs of electricity transmission, where related applications include energy management system, SCADA, planning and optimization. The CIM itself is defined in Unified Modeling Language (UML) notation and consists of classes and their attributes, and the relationships among them (see Figure 5). A key purpose of the CIM is to provide a common language to describe exactly what data is being exchanged among a utility's business systems.

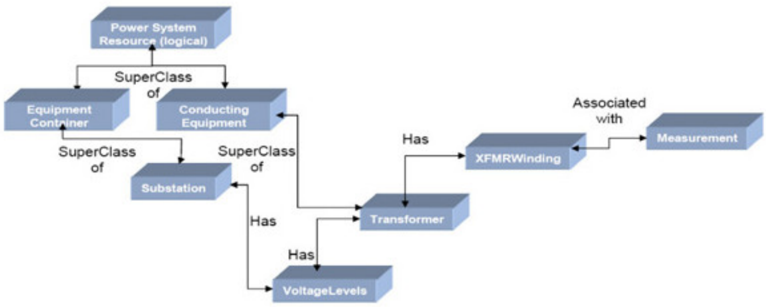


FIGURE 5 CIM DATA MODEL OBJECTS AND RELATIONSHIPS

EEBus SPINE (Smart Premises Interoperable Neutral-message Exchange) defines a protocol and messages on application layer (ISO-OSI layer 7) that work transparently to the used transport protocol. Any communication technology that provides bi-directional message exchange can be used more or less directly. SPINE supports different use cases that concern control and monitoring of smart appliances like White Goods, HVAC systems and related devices like batteries, etc. It is mainly focused on the areas of smart energy, smart home and connected devices, that makes it a perfect candidate for the RESPOND project's CDM. Some of the application scenarios envisioned by RESPOND project proposal cannot be directly covered by

SPINE. Nevertheless, modular and extensible nature of SPINE makes it suitable for covering those cases as well, by extending the original specification.

Once the CDM to be used in RESPOND has been chosen, it is necessary to provide translation from and to different proprietary formats. In the sequel, we introduce some of the stakeholders involved in the RESPOND project and provide examples of data formats generated by their platforms.

2.3 SMART HOME SOLUTIONS IN RESPOND

Develco Products[1] is a B2B company providing white label products within the fields of smart home, energy management, home security, and assisted living. On the pilot sites where devices manufactured by technical provider Develco will be installed (Denmark and Ireland), a gateway device (Squid.link) supporting different communication protocols (Zigbee, Z-Wave, Wireless M-bus) will be used in order to ensure the long-term interoperability with smart devices that may be installed in the future (see Figure 6).

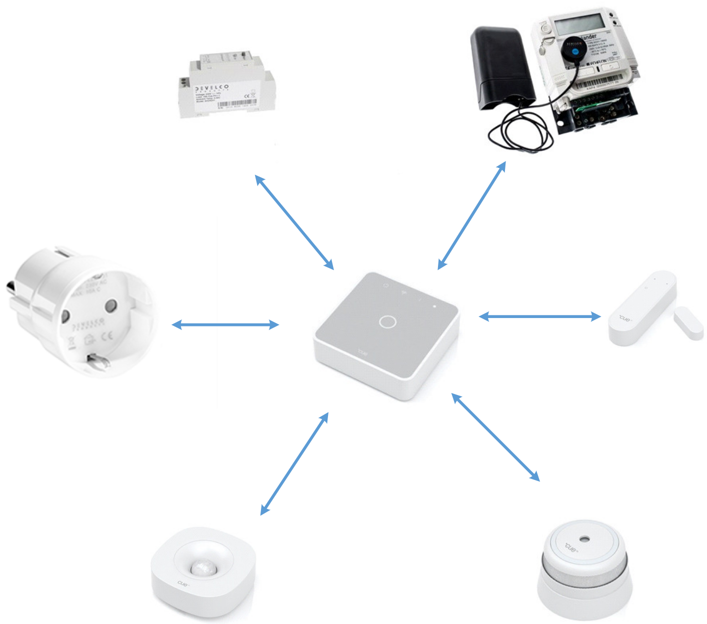


FIGURE 6 DEVELCO'S SQUID.LINK GATEWAY AND SMART HOME DEVICES

The software architecture of Squid.link Gateway offers numerous customization possibilities including: internet interface, cloud connection, application API and communication protocols. Due to its software architecture, the Squid.link Gateway allows integration with 3rd party cloud services.

An example of message sent by a Develco device is shown as follows:

[1] https://www.develcoproducts.com

```
{ "type": "get",
"path": "zb/dev/4/ldev/smartplug/data",
"data": [ {
"key": "summationdelivered",
"name": "Consumed Energy",
"type": "integer",
"unit": "Wh",
"access": "r",
"value": 13633 } ]
```


Energomonitor[2] is a utility and photovoltaics monitoring solution start-up company based in Czech Republic. It concentrates on monitoring of electricity, gas and water consumption. Within the RESPOND project, Energomonitor will deploy its sensors and meters at the Madrid pilot site. Homebase device (see central device in Figure 7), which is used to collect data from different devices (smart plug, smart meters), uses proprietary communication protocol. Consequently, it is not possible to use it to collect data from devices produced by other vendors. Nevertheless, its integration into RESPOND system will be enabled though the API that is provided by Energo Monitor cloud service where all the data collected by Homebase device are permanently stored.

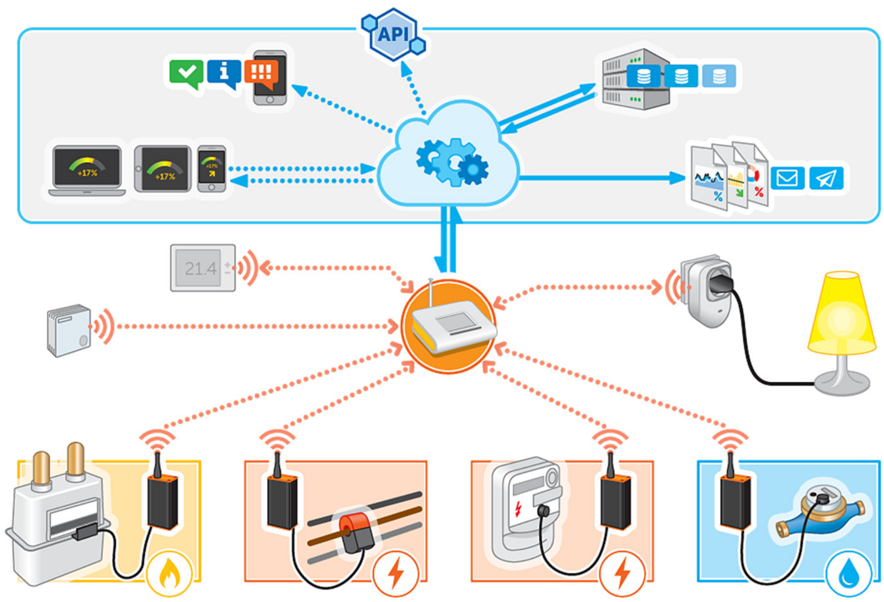


FIGURE 7 ENERGO MONITOR PLATFORM ARCHITECTURE

[2] https://www.energomonitor.com

Data measured by the devices will be sent to the RESPOND platform via MQTT protocol and in JSON format. As an example, we provide a message sent by a Thermosense device:

```
{ "t": 1450435970,
"a": {"ch": 5, "d": 8},
"s": [ {"a": {"m": 16}, "v": 17.5}
] }
```

This message would sent measurement made by a Thermosense at Friday, 18 December 2015 at 15:52:50, where 17.5 C and -35dBm were measured. In this message ”t” refers to the Unix timestamp when data was measured (1450435970: Friday, 18 Dec 2015 10:52:50 GMT); ”a” are global attributes; ”ch” is the channel to which sensor is paired; ”d” is the device identifier (8 is an ETM thermosense); ”s” is subset, list of dictionaries with data itself; ”m” is the medium number (16 refers to temperature in degrees Celsius) and ”v” the value itself 17.5.

3. INTEROPERABILITY ASPECTS OF PILOT SITES

To demonstrate the full potential of RESPOND solution, three project pilot sites have been selected where RESPOND will be deployed and validated as part of project activities. This section reports the list of legacy system components at three pilot sites derived from the analysis of information collected through RESPOND pilot sites characterization and interoperability questionnaire. In addition, we outline an initial deployment plan for the equipment to be installed over the course of the project. Finally, as a result of the analysis, in Section 33 we provide the list of functional and technical requirements that have to be fulfilled in order to support interoperability.

3.1 MADRID PILOT (SPAIN)

This pilot site is located in Madrid and consists of 3 residential buildings where 24 dwellings out of 69 have been preselected to participate in RESPOND project. Each of the dwellings have its individual consumption of electricity and gas along with the energy demand related with the common areas. At this moment, there is no generation system in the building, but the residents association will consider installing a new solar thermal system to reduce the expenses of Domestic Hot Water (DHW), as shown in Table 3.1-2. Currently, in the dwellings, there is no system for monitoring of energy demand by household devices, besides the electricity and gas meters deployed by the energy company (see Figure 8).

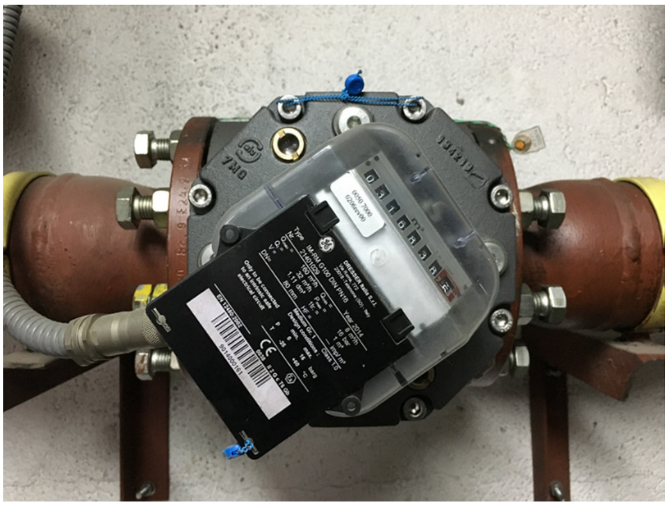
During the course of the project, there is a plan to deploy appropriate smart metering equipment and home automation devices provided by consortium member Energo Monitor. These newly deployed devices will enable the disaggregation of the energy consumption of different household equipment, as well as adjustments of the consumption when desired (e.g. with smart plug). In Section 3.1.1, we provide the list of legacy and newly deployed devices.

Calorimeter

Water meter

Power meter

EMS Trend (central boiler)



Gas meter (central boiler)

FIGURE 8. LEGACY METERS AND EMS FOUND AT MADRID PILOT SITE

3.1.1 LEGACY ICT SYSTEMS AND DEPLOYMENT PLAN

TABLE 3.1-1: MADRID PILOT - METERING EQUIPMENT

General information					Data read / data acquisition				
Legacy device / to be installed during the project	Meter / sensor type	Sensor name / vendor	Per individual household or common?	Type of power supply	Data accessible remotely or only locally?	Available interface for data acquisition?	Communication protocol for data acquisition?	Time resolution	Additional comment
Energy related sensors (consumption - electricity, water, gas, heating; production/storage status metering...)									
Legacy	Calorimeter	etf TCM 311/Apator	Per individual household	Battery	locally + remote capabilities	Direct connection	Mbus	N/A	http://www.apator.com/uploads/files/Produkty/Cieplomierze/elf/i-en-009-2017-elf-13-01.pdf
Legacy	Power meter	cx1000-6 es/Sagecom	Per individual household	Mains	Both	Direct connection		Hourly	http://www.arkossa.com/descargas/catalogos/cx1000.pdf
Legacy	Water meter	Istameter radio net 3/Ista (cold water)	Per individual household	Battery	Remotely	Ista Radio system	Radio	Daily	https://www.ista.com/uk/solutions/technology/water-meters/istameter-m-water-meter-range/#c4454 https://www.ista.com/fileadmin/twt_customer/countries/content/Tutorial/Documents/ista_symphonic.pdf

Legacy	Water meter	Istameter radio net 3/Ista (hot water)	Per individual household	Battery	Remotely	Ista Radio system	Radio	Daily	https://www.ista.com/uk/solutions/technology/water-meters/istameter-m-water-meter-range/#c4454 https://www.ista.com/fileadmin/twt_customer/countries/content/Tutorial/Documents/ista_symphonic.pdf
Legacy	Gas meter	IM-RM G100 DIN/Dresser	Common	N/A	Locally	Direct connection		N/A	http://www.gimim.com/files/products/docs/20/239/Cat-rotativo-Tipo-C-RM-iMRM.pdf http://www.meterbuy.com/fileadmin/user_upload/Data_sheets/141110_Imbema_-_Datasheet_Dresser_Roots_Series_C_Rotary_Meter_Brochure_R1.pdf
To be installed	Power meter	Plugsense/Energomonitor	Per individual household	Mains	Remotely	Energomonitor API		seconds, configurable	
To be installed	Power meter	Powersense/Energomonitor	Per individual household	Battery	Remotely	Energomonitor API		seconds, configurable	
To be installed	Power meter	Optosense/Energomonitor	Per individual household	Battery	Remotely	Energomonitor API		seconds, configurable	
To be installed	Gas meter	Relaysense gas/Energomonitor	Per individual household	Battery	Remotely	Energomonitor API		seconds, configurable	
To be installed	Water meter	Relaysense water/Energomonitor	Per individual household	Battery	Remotely	Energomonitor API		seconds, configurable	

Environmental sensors (indoor/outdoor temperature, light intensity, humidity, gas, smoke sensor...)									
To be installed	Thermometer	Thermosense/Energomonitor	Per individual household	Battery	Remotely	Energomonitor API		seconds, configurable	
To be installed	Visibility Sensor	QAE2120.010 / Siemens (6x)	Common (thermosolar)		Locally	SIEMENS web service			
Other sensors (occupancy, etc.)									
Legacy	Human Presence Detector	N/A	Common	Mains	N/A				

TABLE 3.1-2: MADRID PILOT - ENERGY ASSETS

General info							Energy dispatch control (from generation to storage, local consumption or grid)				
Legacy device / to be installed during the project	Energy asset type	Energy asset name / vendor	Type of energy generated / stored?	Generation [kWp] / storage capacity [kWh]	Per individual household or common?	Grid connectivity	Is there associated control unit?	Accessible remotely or only locally?	Available interfaces for device control / data reading?	Communication protocol for device control / data reading?	Additional comment
Generation assets (solar generator, wind generator, diesel generator, geothermal...)											
To be installed	Solar Device	WOLF TOPSON	Thermal Energy	10 kWp	Common	only local consumption	PLC	both	BMS/EMS	KNXNetIP	To be installed during the project. Final

		CFK-1									details to be decided

TABLE 3.1-3: MADRID PILOT - SMART HOME DEVICES

General info					Device control / data set-points			
Legacy device / to be installed during the project	Device type	Device name / vendor	Per individual household or common?	Type of power supply?	Device accessible remotely or only locally?	Available interfaces for device control?	Communication protocol for device control?	Additional comment
Lighting system and other								
To be installed	Display	Portasight/Energomonitor	Per individual household	Battery	Web accessible	API		
To be installed	Smartplug	Plugsense/Energomonitor	Per individual household	Mains	Web accessible	API		
To be installed	Thermostat	Thermosense/Energomonitor	Per individual household	Battery	Web accessible	API		
To be installed	Gateway	Homebase/Energomonitor	Per individual household	Mains	Web accessible	API		

TABLE 3.1-4: MADRID PILOT - BMS/EMS

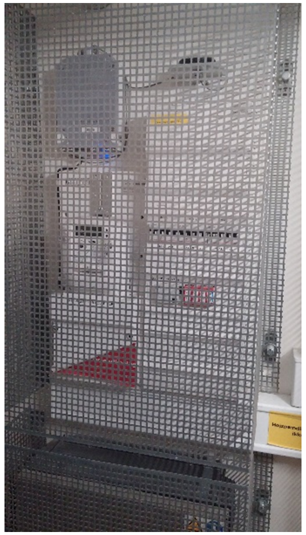
General info			Data monitoring & Control actions through BMS/EMS						
Legacy device / to be installed during the project	BMS/EMS name/vendor	Per individual household or common?	Accessible remotely or only locally?	Available interfaces with BMS/EMS ?	Communication protocol / means for interfacing with BMS/EMS?	Monitored data points provided via BMS/EMS	Time resolution of monitored data	Available control actions (data set-points) via BMS/EMS	Additional comment
Legacy	Trend IQ251 +TREND NDP Control Display Panel (Central boiler)	Common	Both		LAN				https://partners.trendcontrols.com/trendproducts/cd/ru/pdf/en-ta102315-uk0yr1008.pdf
To be installed	Siemens (Thermosolar) RMS705B	Common	Both	both	Web service siemens OZW772.01				To be installed during the project. Final details to be decided

3.2 AARHUS PILOT (DENMARK)

This pilot site is located in Aarhus, and it consists of 4 buildings, where 20 apartments have been preselected for demonstration of RESPOND solution. All apartments have individual monitoring of electricity consumption (see Figure 9), whereas individual consumption of heating and water is not measured. Nevertheless, there is a possibility for installation of calorimeters and water-flow meters. The public housing estate is equipped with photo voltaic panels, that contribute with yearly production of approximately 590 MWh. The produced electricity is completely supplied to the apartments for local electricity use.

Electricity meter, 3 phase, ABB B23 113-100

Danfoss TLX PV inverter



PV inverter and generation monitoring point

FIGURE 9 LEGACY EQUIPMENT AT AARHUS PILOT SITE

To provide a fine grained higher resolution of monitoring, home automation and smart metering equipment provided by consortium member DEVELCO will be deployed on this pilot site. It is envisioned that RESPOND platform will provide integration and adequate analysis of monitoring data in order to perform adequate control actions on building systems.

3.2.1 LEGACY ICT SYSTEMS AND DEPLOYMENT PLAN

TABLE 3.2-1: AARHUS PILOT - METERING EQUIPMENT

General information					Data read / data acquisition				
Legacy device / to be installed during the project	**Meter / sensor type**	**Sensor name / vendor**	**Per individual household or common?**	**Type of power supply**	**Data accessible remotely or only locally?**	**Available interface for data acquisition?**	**Communication protocol for data acquisition?**	**Time resolution**	**Additional comment**
Energy related sensors (consumption - electricity, water, gas, heating; production/storage status metering...)									
Legacy	Power meter	ABB B23 113-100	Per individual household	mains	Both	Direct connection	M-Bus/pulse	Currently: day	http://new.abb.com/products/ABB2CMA100165R1000
To be installed	Calorimeter	Kamstrup MC 602	Per individual household	Battery	locally	Wireless	Zigbee	N/A	
To be installed	Power meter	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	10 sec	
To be installed	Calorimeter	Develco Products	Per individual households	Battery, mains	remotely	Open API, REST API	Zigbee, Wireless M-Bus	30 sec	Heat Meter from Kamstrup - Multical 602

To be installed	Power meter	Develco Products	Per individual households	Mains	remotely	Open API, REST API	Zigbee	10 sec	Smart relay with sub meter, Monitoring power consumption. Remote controlling On/Off relay to switch off electrical appliances
Environmental sensors (indoor/outdoor temperature, light intensity, humidity, gas, smoke sensor...)									
To be installed	Thermometer	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	300 sec	
To be installed	Humidity Sensor	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	300 sec	

TABLE 3.2-2: AARHUS PILOT - ENERGY ASSETS

General info							**Energy dispatch control** **(from generation to storage, local consumption or grid)**				
Legacy device / to be installed during the project	**Energy asset type**	**Energy asset name / vendor**	**Type of energy generated / stored?**	**Generation [kWp] / storage capacity [kWh]**	**Per individual household or common?**	**Grid connectivity**	**Is there associated control unit?**	**Accessible remotely or only locally?**	**Available interfaces for device control / data reading?**	**Communication protocol for device control / data reading?**	**Additional comment**
Generation assets (solar generator, wind generator, diesel generator, geothermal...)											
Legacy	Solar Device	REC Group REC 255	Electrical Energy	622 kWp	Entire estate	Both	Danfoss TLX	both	BMS/EMS	RS485, GSM model	

TABLE 3.2-3: AARHUS PILOT - BMS/EMS

General info			Data monitoring & Control actions through BMS/EMS						
Legacy device / to be installed during the project	**BMS/EMS name/vendor**	**Per individual household or common?**	**Accessible remotely or only locally?**	**Available interfaces with BMS/EMS?**	**Communication protocol / means for interfacing with BMS/EMS?**	**Monitored data points provided via BMS/EMS**	**Time resolution of monitored data**	**Available control actions (data set-points) via BMS/EMS**	**Additional comment**
Legacy	Energy Key	Entire estate	Web based			Energy	res 15 min /daily update	only monitor	http:// ALBOA.energykey.dk can export data in custom csv-file
Legacy	Evishine	PV	Web based			energy	online monitoring and production	only monitor	https://evishine.dk/ALBOA

3.3 ARAN ISLANDS PILOT (IRELAND)

This pilot site is located at Aran Islands, where a total number of 24 dwellings have been preselected for demonstration activities of RESPOND system. In order to reduce the island's dependency on fossil fuels, Aran Islands embarked ambitious program that included increased levels of insulation, electrification of the heating and transportation (heat pumps, storage heaters, electrical vehicles, photo-voltaic and solar-thermal arrays), as shown in Figure 10. Currently, smart metering exists in terms of temperature sensors and power meters, whereas a number of consumption devices (e.g. for heating) can be controlled wirelessly. To complement legacy devices, home automation and smart metering devices provided by consortium partner DEVELCO will be considered for full blown deployment of RESPOND system.

Mitsubishi Electric air to water heat pump

Daikin air conditioner

FIGURE 10 LEGACY EQUIPMENT AT ARAN ISLANDS PILOT SITE

3.3.1 LEGACY ICT SYSTEMS AND DEPLOYMENT PLAN

TABLE 3.3-1: ARAN ISLANDS PILOT - METERING EQUIPMENT

General information					Data read / data acquisition				
Legacy device / to be installed during the project	Meter / sensor type	Sensor name / vendor	Per individual household or common?	Type of power supply	Data accessible remotely or only locally?	Available interface for data acquisition?	Communication protocol for data acquisition?	Time resolution	Additional comment
Energy related sensors (consumption - electricity, water, gas, heating; production/storage status metering...)									
Legacy	Calorimeter	Apator etf TCM 311	Per individual household	Battery	locally + remote capabilities	Direct connection		N/A	Calorimeter
Legacy	Power meter	Meterus 83330	Per individual household	mains	Both	Direct connection		Quarter-hour	Power meter
To be installed	Calorimeter	Kamstrup MC 602	Per individual household	Battery	locally	Wireless	Zigbee	N/A	
To be installed	Power meter	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	10 sec	
To be installed	Calorimeter	Develco Products	Per individual households	Battery, mains	remotely	Open API, REST API	Zigbee, Wireless M-Bus	30 sec	Heat Meter from Kamstrup - Multical 602
To be	Power meter	Develco	Per	Mains	remotely	Open API, REST	Zigbee	10 sec	Smart relay with sub meter, Monitoring power

installed		Products	individual households			API			consumption. Remote controlling On/Off relay to switch off electrical appliances
Environmental sensors (indoor/outdoor temperature, light intensity, humidity, gas, smoke sensor...)									
To be installed	Thermometer	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	300 sec	
To be installed	Humidity Sensor	Develco Products	Per individual households	Battery	remotely	Open API, REST API	Zigbee	300 sec	

TABLE 3.3-2: ARAN ISLANDS PILOT- ENERGY ASSETS

General info							Energy dispatch control (from generation to storage, local consumption or grid)				
Legacy device / to be installed during the project	**Energy asset type**	**Energy asset name / vendor**	**Type of energy generated / stored?**	**Generation [kWp] / storage capacity [kWh]**	**Per individual household or common?**	**Grid connectivity**	**Is there associated control unit?**	**Accessible remotely or only locally?**	**Available interfaces for device control / data reading?**	**Communication protocol for device control / data reading?**	**Additional comment**
Generation assets (solar generator, wind generator, diesel generator, geothermal...)											
Legacy	SolarDevice	WOLF TOPSON CFK-1	Thermal Energy	10 kWp	Common	only local consumption	PLC	both	BMS/EMS	KNXNetIP	Solar Device
Legacy	pv panel 2kW, heat pump 5kW	Heat pump-Daikin	Thermal Energy	2 kWp	per household	connected		locally	manual		pv panel 2kw, heat pump 5kw

4. SYSTEM INTEROPERABILITY REQUIREMENTS

In this section, we report the list of interoperability requirements derived from the analysis of information collected through pilot sites characterization questionnaire, as well as from the RESPOND DoW objectives. Questionnaire answers provided in tabular form have been analysed and translated into formal, verifiable inputs for projects work packages according to the information processing schema depicted in Figure 11.

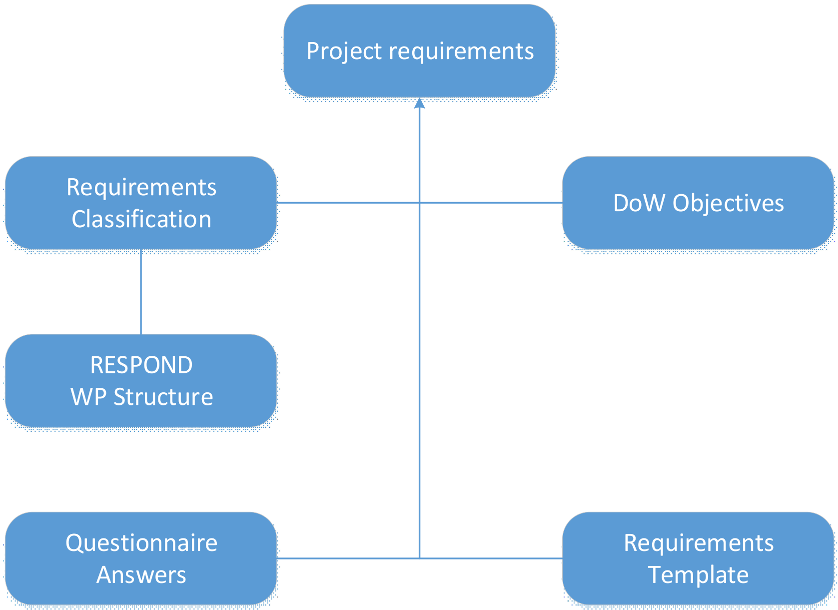


FIGURE 11 INPUTS FOR INTEROPERABILITY REQUIREMENTS DEFINITION

The classification of information into standard categories followed the schema reported below:

- [**Headline**]: Short description of requirements
- [**Req Description**]: Full description of the requirements
- [**Classification**]: WP/Task identifier accountable for the requirement
- [**Type**]: Task or other sub-activity accountable for the requirement alternatively can be category, i.e. functional/performance/other/...
- [**Rationale**]: Purpose of the requirements definition, can be a sub-activity of the Work Package, DoW (Description of Work) reference, a verbose motivation, etc.
- [**Acceptance criteria**]: Method/technique to be employed for requirement demonstration/validation
- [**Priority Level**]: Classification of relevance, to be taken into account for first and second phase of a task

The overall objective of this interoperability characterization is that of providing identifiable, reusable and verifiable inputs for the execution of related project work packages, from modelling requirements, architectural application layers definitions to demonstrator ICT specifications and indicators analysis.

[Headline]	[Req Description]	[Classification]	[Type]	[Rationale]	[Acceptance criteria]	[Priority Level]
Architectural model composition to support interoperability	The Architectural model shall natively support the interconnection and composition of devices and systems produced by different manufacturers	WP2–Use case deployment and follow up	T2.1-System architecture design	The RESPOND system should support a variety of different devices to allow long-term interoperability and to prevent vendor lock-in	Design validation/Demonstration	1
Information model definition to support semantic interoperability	RESPOND should considering Information Modelling standard processes	WP4–ICT enabled cooperative demand response model	T4.1-Semantic information model	A way to specify and exchange energy and building assets information should be defined, preferably by using well defined standard (e.g. EEBus SPINE)	Demonstration	1
Integration architecture	RESPOND overall architecture should be based on open and standard integration frameworks and communication protocols	WP2–Use case deployment and follow up	T2.1-System architecture design	Web services and Service Oriented Architecture are the preferable choice as integration frameworks. Also, SOAP and WSDL-based APIs or REST protocols should be considered for synchronous communication.	Demonstration	2

				Asynchronous communication should be based on OSGI publish/subscribe mechanisms		
Home automation interoperability	RESPOND should support well known communication protocols for home automation	WP5-System Integration and Interoperability	T5.1-Home automation interoperability interfaces	Communication with home automation system should be based on well-known communication protocols (Zigbee, Z-Wave, etc.)	Design validation/Demonstration	1
Smart metering interoperability	RESPOND should support well known communication protocols for smart metering	WP5-System Integration and Interoperability	T5.2-Smart grid connectivity	Communication with smart metering devices (Electicity, water and gas consumption) should be based on well-known communication protocols (Zigbee, Wireless M-bus, etc.)	Design validation/Demonstration	1
BMS/EMS interoperability	RESPOND should support newly deployed as well as already available legacy BMS/EMS systems	WP5-System Integration and Interoperability	T5.1-Home automation interoperability interfaces	Communication with BMS/EMS systems should be done in a protocol agnostic manner by supporting different open protocols (BACnet,	Design validation/Demonstration	1

				KNX)		
Grid interoperability and services 1	RESPOND should try to comply with the main coming standards and initiatives relevant to Smart Grids and advanced metering infrastructures especially concerning: data exchange, ICT security, distribution management and tariff and load control	WP4–ICT enabled cooperative demand response model	T4.1-Semantic information model	The main outputs from technical working-groups of CEN/CENELEC/ETSI should be considered. For instance: - TC57 WG21 (interface/protocols for systems connected to grid) - SG-CG M490 (mandate of the smart grid coordination group to define a SG reference architecture) - IEC 61850 (comm. networks and systems for s/stations automation) - CIM / IEC61968 (energy distribution management), .. - CEER Publications - OASIS Energy Interoperation Committee	Demonstration	1

				Specification Also, the AMI security profile from SG Security Working Group (UCAIug) & The NIST Cyber Security Coordination Task Group may be considered for the cyber security issues.		
Grid interoperability and services 2	RESPOND should try to align with current standardization efforts in the field of energy standard information exchange	WP4–ICT enabled cooperative demand response model	T4.1-Semantic information model	In order to implement energy working demand-response processes, it is important that energy consumers/producers and utilities share standardized data on energy characteristics, energy availability, energy price, flexibility offers, operational schedules, building information, etc. For instance EEBus SPINE, eMIX, oBIX, CIM, etc. are example of initiatives to consider as reference for RESPOND.	Demonstration	2

Energy Gateway	RESPOND should start from ongoing initiatives concerning energy gateways' standardization or preliminary commercialization	WP2–Use case deployment and follow up	T2.1-System architecture design	Various ongoing initiatives can be considered for possible reference in RESPOND. For instance HGI (Home Gateway initiative), OGEMA, etc. and the products being commercialized by some vendors	Design validation / Demonstration	2
MQTT Broker for interconnectivity	Interconnectivity architecture of RESPOND shall be based on a integration message brokering layer	WP2–Use case deployment and follow up	T2.1-System architecture design	MQTT broker allows information to flow between disparate applications across multiple hardware and software platforms. In RESPOND, multiple implementation of a single application layer are expected (i.e. multiple gateways) and MQTT middleware provides communication with loose component coupling.	Design validation	1

5. RESPOND GENERALIZED APPROACH

In order to support interoperability and easy integration of all system components, RESPOND platform will be designed to be cloud-based and service-oriented (see preliminary architecture in Figure 12). Such design will allow for easy extensibility with new devices and data sources if there is a need in the future. As can be seen, smart home devices, smart meters and EMS/BMS systems use proprietary protocols that have to be translated to the canonical data model. CDM will serve as the common application programming interface (API) providing a way for HW/SW abstraction and interaction between RESPOND internal services. CDM for the RESPOND project will take as a starting point EEBus SPINE and further extend it according to RESPOND specific requirements to support long term interoperability.

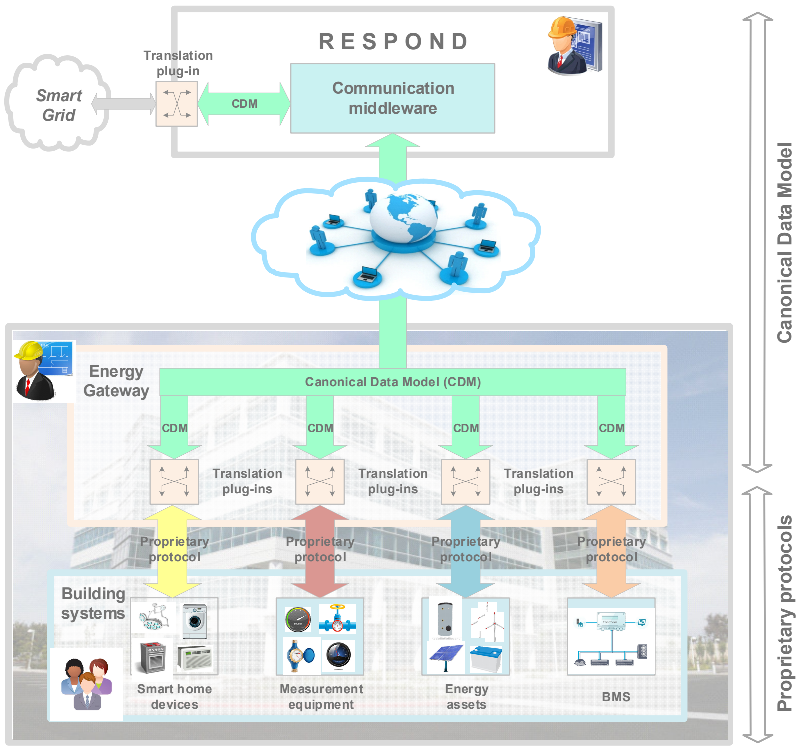


FIGURE 12 RESPOND SYSTEM PRELIMINARY ARCHITECTURE

In order to ensure interoperability with hardware and software systems (especially with the legacy ones), OGEMA (Open Gateway Energy MAnagement) will also be deployed. OGEMA is an open source software platform that supports standardized building automation and energy management applications and links them to the customer's loads and generators. The software is designed to be installed on a gateway computer between the customer and the smart grid. Since the platform is manufacturer and hardware independent, OGEMA allows energy flows within customer premises to be optimized with high degree of modularity. OGEMA is designed to be easily extendable by means of plugins (i.e. communication drivers) which support different communication protocols and enable translation from and to proprietary data formats (Zigbee, Z-Wave, Modbus, BACnet, KNX).

Applications installed in OGEMA can obtain access to consumer devices, user displays, smart meters as well as data provided by external services such as energy pricing information and grid parameters. OGEMA is designed to act as an operating system that enables applications to access different types of connected hardware and external services without having to deal with the physical aspects of the connection.

OGEMA implementations are able to run on a variety of devices including PC, as well as embedded computers with low energy requirements (e.g. Raspberry Pi 3). The framework is Java based and requires a Java Virtual Machine to be installed on the targeted platform, as can be seen in Figure 13, where OGEMA technology stack is presented.

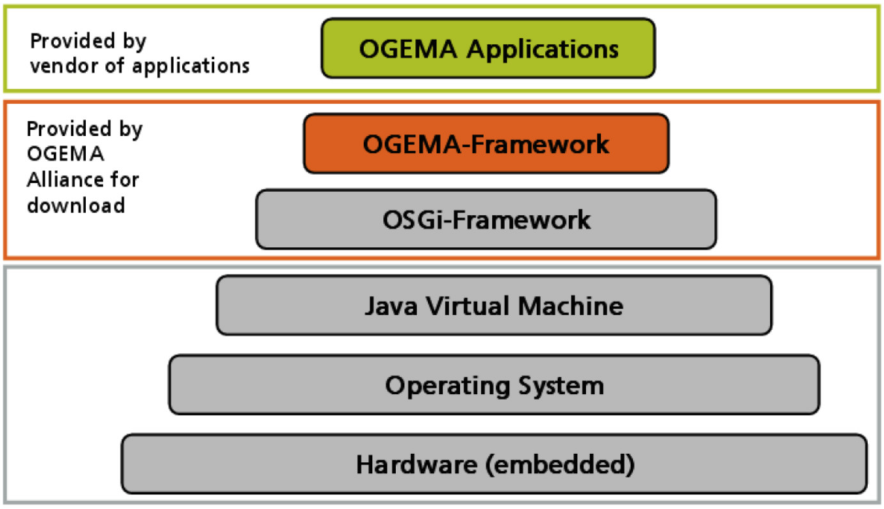


FIGURE 13 OGEMA TECHNOLOGY STACK[3]

Next, in order to support its service oriented nature, RESPOND will be leveraged upon an open source MQTT messaging broker that will be responsible for orchestration of system components and communication among them. The MQTT broker (e.g. Mosquitto) will ensure scalability with millisecond latency for high data throughput scenarios. At the same time, Open API concepts will be deployed in order to provide bidirectional interface towards the smart grid and third party services. Besides the external data intake (e.g. weather data, energy pricing data, etc.), open API will enable further exploitation and replication of RESPOND data analytics and core services for development of new business models.

Finally, semantic interoperability represents one of the main issues in heterogeneous environments, where devices and systems have problems sharing data with unambiguous and shared meaning. In order to abstract from details of specific solutions and protocols, it is necessary to create an abstraction layer that will provide a commonly agreed semantics to enable interoperability. To achieve this, RESPOND will not develop new semantic information model. Instead, it will exploit existing data models and specification, and possibly further extend them according to the RESPOND specific requirements.

[3] http://www.ogema.org//wp-content/uploads/2014/12/OGEMA_2.0_introduction_v2.0.2.pdf

6. CONCLUSIONS AND RECOMMENDATIONS

In this report, we have presented the approach that will be taken over the course of the RESPOND project, in order to support interoperability. Although the approach is concerned primarily with the pilot sites, it is general enough to be easily replicable beyond the RESPOND project.

Firstly, at the technical layer, it is necessary to ensure that the devices using diverse networking technologies can communicate to each other by employing suitable gateways. At Denmark and Ireland pilot sites where Develco's equipment will be installed, technical interoperability will be ensured via the Squid.link gateway that support common communication protocols found in home automation applications. On the other hand, at Spain pilot site, equipment provided by another consortium member – Energo Monitor will be installed. The equipment to be deployed at this pilot site employs proprietary wireless protocol for communication with the communication gateway – Homebase. Both gateways will primarily be used to collect data from newly deployed devices, provided by consortium partners. Nevertheless, since the Develco's gateway supports widespread communication technologies, it also allows devices from other manufacturers to be easily connected to the RESPOND system. Finally, legacy EMS/BMS systems and other legacy equipment already present at the pilot sites will be integrated by means of OGEMA gateway.

With such a large number of devices that will be integrated into RESPOND platform, it is necessary to ensure that all of them use the common messaging format. This requirement will be fulfilled at the syntactic interoperability layer by using the commonly agreed CDM based on EEBus SPINE data model and its potential extensions, where the translation from and to proprietary messaging format will be performed at the gateway devices. In order to keep the message payload low, more detailed, static information about the devices themselves will be available from the corresponding ontology, compatible with the chosen CDM (e.g. SAREF).

Finally, to ensure the interoperability with other external systems and services (smart grid, meteo service), open API and a set of plugins will be provided.