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RESPOND

DEMAND RESPONSE FOR ALL

Integrated Demand REsponse SOlution Towards Energy POsitive NeighbourhooDs

WP2: Use case deployment and follow-up

T 2.2 Seamless integration of RESPOND technology tiers

D2.2 Integration of key RESPOND technology tiers

The RESPOND Consortium 2018

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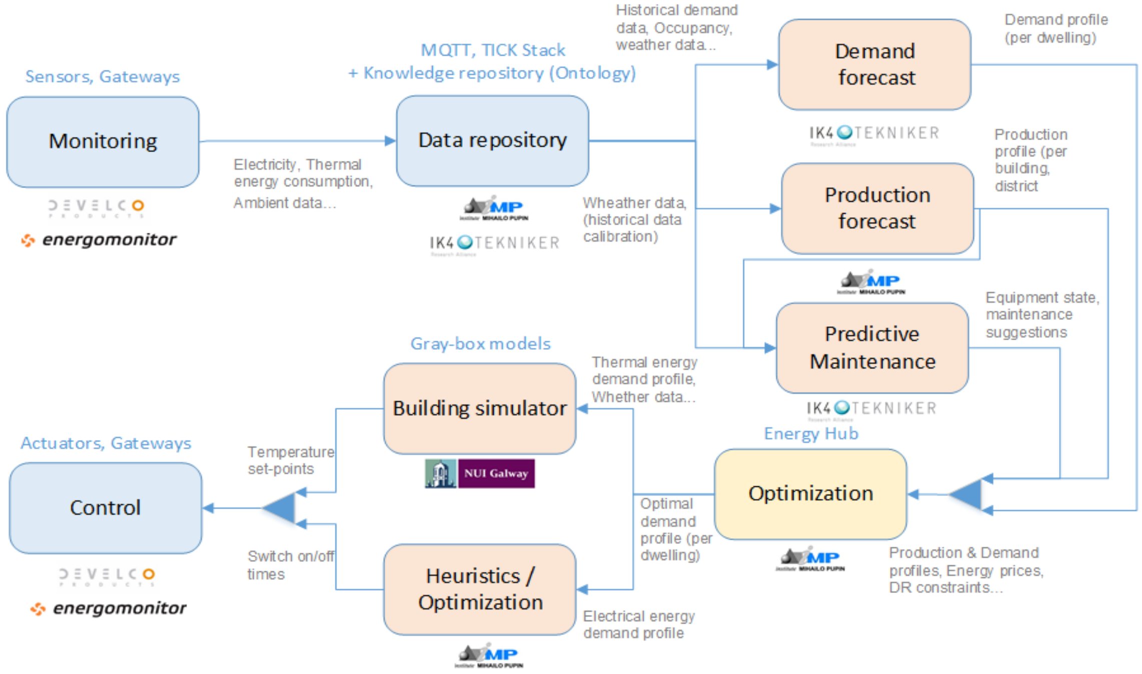
EXECUTIVE SUMMARY

The main objective of this report is to **present the integration strategy of all the technology tiers of RESPOND solution**. It belongs to the *WP2: Use Case Deployment and follow up* and it is a direct output of *Task 2.2: Seamless integration of RESPOND technology tiers* Which started in month 1 and ends in month 12.

As can be seen in the figure below, **RESPOND Platform main objective** is collecting, storing and processing data obtained from different field level devices (including both newly installed for RESPOND project and legacy systems), and sending the control actions to actuators. The collected data is further processed by means of analytic services which will be developed during RESPOND project. In the following figure, the flow of data between different components of the RESPOND platform from sensor to actuators, i.e. the so-called Control loop is shown.



Data flow in RESPOND control loop

Deliverable 2.2 main objective is to define the **matching between the existing systems** and **underlying technology concepts** (analytical services) with **system reference architecture** defined previously in task 2.1. All of this allows to define the seamless integration of RESPOND key technology tiers that is going to be carried out in WP4 and WP5.

The outputs of the present deliverable have also a **key role in the early deployment and interfacing with ICT infrastructure in pilots** (Task 2.3) together with WP4 (ICT enabled cooperative Demand Response model) and WP5 (System integration and interoperability).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

DEXCell	DEXCell Energy Manager
DHW	Domestic Hot Water
DR	Demand Response
EMS	Energy Management System
HW	Hardware devices
ICT	Information and communication technology
Legacy system	Set of HW/SW components already in place before the project
MQTT	Message Queue Telemetry Transport
PM	Predictive Maintenance
PV	Photovoltaic
REST API	Method of allowing communication between a web-based client and server that employs representational state transfer (REST) constraints
STC	Solar Thermal Collector
SW	Software systems

INTRODUCTION

1.1 AIMS AND OBJECTIVES

This task deals with the **communication and integration among the key technology tiers** of RESPOND platform, i.e. the set of technical modules developed in the following working packages. In this regard, it has been analysed the integration of all underlying concepts featured by core services of RESPOND platform, such as DR optimisation, energy production models, energy demand forecasting, etc., and suggest their relations and interaction necessary to conduct cooperative demand management and optimal control strategy.

As a result, the **interfaces between internal system components and core services**, as well as **towards external HW/SW systems** (such as smart home devices, legacy systems, third party services, etc.) have been specified. All relevant communication details, among all possible layouts of the RESPOND key technology tiers, have been reported in this document to allow the seamless integration of RESPOND solution in the following WPs (particularly in WP4 and WP5).

One of the main challenges has been to **match the existing systems and underlying technology concepts with system reference architecture designed in Task 2.1** [1]. To do so, the existing technology available in pilot sites has been taken into consideration along with the new MQTT based architecture, which will be able not only to integrate the new RESPOND technology tiers, but also the legacy systems present in the pilot sites. In addition, the inputs from WP1 in terms of exact deployment options and project requirements have been considered for the activities performed in this task.

Last but not least, one of the key objectives of this task has been the **definition of the strategy for integration of RESPOND platform enabling early deployment** and interfacing with ICT infrastructure at pilot sites.

1.2 RELATION TO OTHER PROJECT ACTIVITIES

With regards to the interaction between Task 2.2 and the rest of RESPOND project activities, the main interactions are listed below:

- As for the integration of technology tiers, **WP4 works about "ICT enabled cooperative demand response model"** have been taken into consideration.
- Regarding the interfaces among internal system components, core services and external HW/SW systems, main interaction has been done with **WP5 about "System Integration and Interoperability"**.
- In relation with early deployment definition and the matching with the system reference architecture designed in Task 2.1, a continuous collaboration with the rest of WP2 ongoing tasks has been carried out: **"T2.1 System architecture design"** and **"T2.3 Design of the initial deployment plan"**.

Last but not least, key results of the task will be used as an input by T2.4 about the early deployment at pilot sites, as well as T2.5 about the demand response platform deployment, and WP5 about system integration and interoperability.

1.3 REPORT STRUCTURE

The existing report is organized as follows. First, the key technology tiers developed in WP4 are described in detail in order to identify its requirements in terms of inputs/outputs and internal dynamics. Secondly, the previous assessment is used to match the reference architecture defined in D2.1, providing as a result the specification of the required interfaces among them as well as with the external systems (HW and open interfaces). The third part of the report addresses the early deployment at pilot sites, taking into consideration the in-depth assessment carried out in WP1 and T2.3 about the existing conditions and requirements for each site. Finally, a set of conclusions about the seamless integration of the RESPOND technology tiers as well as a description of the further research topics identified is provided.

2. MATCHING OF KEY TECHNOLOGY TIERS USING REFERENCE ARCHITECTURE

2.1 SUMMARY OF REFERENCE ARCHITECTURE FROM TASK 2.1

This section aims at summarising the RESPOND reference architecture. For further details on the architecture, the read of *D2.1 RESPOND system reference architecture* is advised. The following figure shows an overview of the RESPOND reference architecture. This architecture comprises different modules and services which are briefly introduced next.

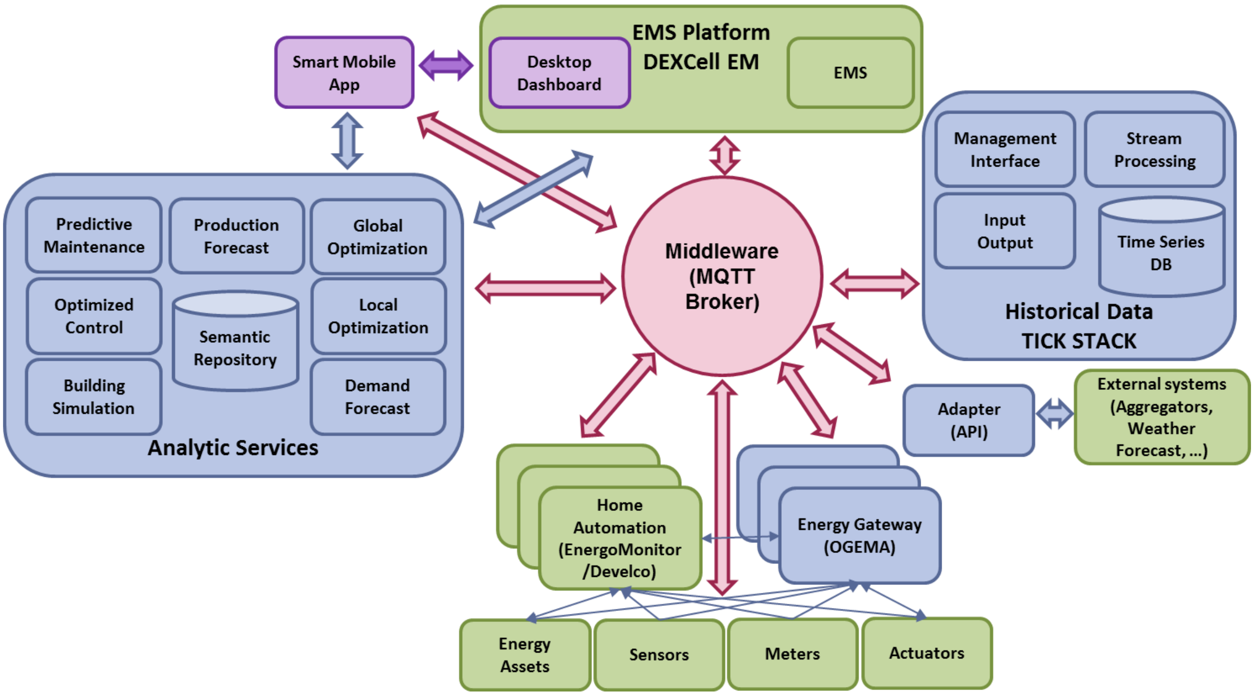


Figure 7: RESPOND reference architecture

The **field communication** part of the architecture enables the communication of devices like sensors, meters, actuators and energy assets, as well as home automation systems with the middleware. For that purpose, gateways developed by ENE (HomeBase gateway) or DEV (Squid.Linkk gateway) are leveraged. In cases where devices cannot be connected with the middleware via these gateways, an Energy Gateway (such as OGEMA) will be implemented.

The middleware is formed by the MQTT broker. This component receives data and distributes it to other components via the publish/subscription method.

External services such as aggregators or weather forecasting services, can provide valuable information that can be used for other RESPOND services, mainly the analytical services. It is necessary to develop the protocol adapter from the neutral MQTT format to the format used by the external system, and vice versa.

The analytical services module is a set of services that can communicate via MQTT with the rest of the system. This module leverages one or several analytic repositories for transformed data. Historical data stores all data passing through the MQTT broker. A semantic repository is used to store metadata based on an ontology that integrates different existing ontologies. It will identify data coming from different sources and support the analytic services through inference rules. Analytic services could also communicate with DEXCell REST API.

The User Interaction with services and other modules is also a key point in the proposed architecture. Efforts in visualization must be oriented towards the user engagement, which is an added value for the project. Furthermore, DEXCell capabilities will be leveraged for fulfilling other visualization needs.

2.2 INTERFACES

As can be seen in previous section, RESPOND aims at collecting, storing and processing data obtained from different field level devices and sending the control actions to actuators. The collected data are further processed by means of analytic services which will be developed during RESPOND project. In the following figure, we show the flow of data between different components of the RESPOND platform from sensor to actuators, i.e. the so-called Control loop.

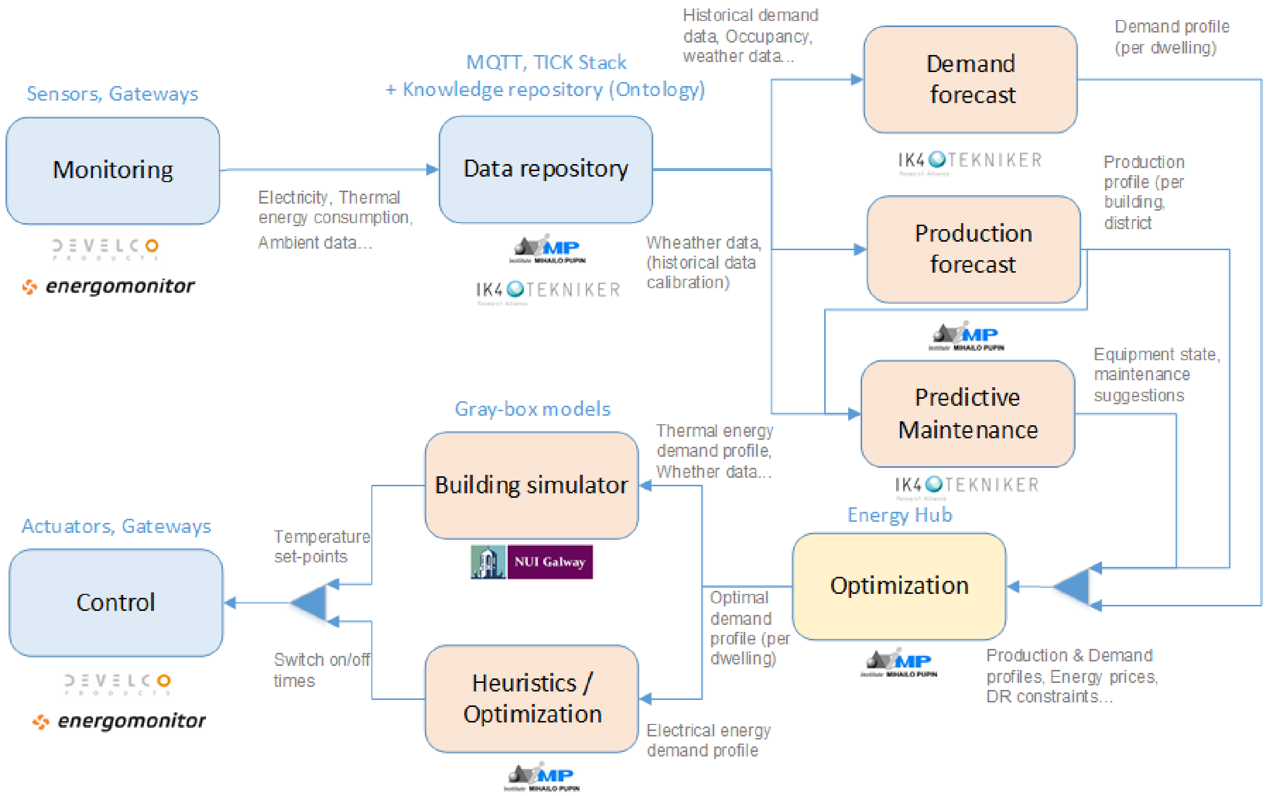


Figure 8. Data flow in RESPOND control loop

As can be seen, the data flows through the system in the following way:

- **Sensors and smart meters** send their measurement through the gateway devices (Develco's Squid.link and Energomonitor's Homebase) that act as a local data collecting hub in each designated area (dwellings and common areas). Different kinds of measurements (electricity and thermal energy consumption, ambient temperature and humidity, air quality, etc.) are sent via MQTT protocol with payload formatted according to Canonical Data Model that has been described in D2.1.
- **The data received at the MQTT broker** that has been deployed as part of RESPOND data repository are parsed and stored in Influx database, particularly optimized for storage are fast retrieval of large amount of time-series type of data. InfluxDB, which will act as a central location for the storage of data collected by field level devices, also provides a web-based interface that can be used to query the data by other system components
- **Production forecast analytic service** will use the production model with the relevant data (e.g. forecast of solar insolation at specific location) obtained by external services in order to predict the electrical energy production for a given time frame (on the order of hours and days). This service will query both InfluxDB API to get the historical data and also an external web service API to get the forecast of solar insolation.
- **Demand forecast service** aims to predict the energy demand for individual dwellings as well as districts by employing historical and currently monitored data (demand, weather data, ambient temperature, occupancy of different areas, etc.) obtained by getting responses from InfluxDB API and external weather service API.
- **Predictive maintenance** aims to predict the performance of the energy producing equipment (such as PV panels) as well as the monitoring devices in order to allow cost-effective decision making. Production forecast will be used as an input on the module.
- **The outputs** from production and demand forecast services together with the predictive maintenance, in the form of energy production and demand predictions (energy profile as a function of time) are **fed into global (for districts) and local (for individual dwellings) optimization component**. Besides, the optimization service considers other relevant data, such as DR constraints and energy pricing, which are obtained by querying the appropriate external service API interfaces. As the output, optimization service produces the optimal demand profile for each individual dwelling.
- The **optimal demand profile obtained** from the optimization service **is further processed and** transformed into control actions by employing **building simulator**, which focuses mainly on thermal energy modelling and rule-based optimization service. These three services preform the transformation from optimal energy demand profile into control actions (temperature set-point and actuator state) that are **finally carried out by different actuator devices** (smart plugs and thermostats) which are deployed in the field.

The analytic services will be implemented according to the micro-service concept, a variant of service-oriented architecture which structures a system as a collection of loosely coupled independent services.

The advantage of system decomposition into smaller services is that it improves the modularity and makes the system easier to understand and develop by autonomous teams, as it is case in RESPOND project. This concept parallelizes development by enabling autonomous teams to develop and deploy their services independently. In micro-service architecture, services are often processing that can even be deployed on separate machines, have their own persistent data storage, and communicate over a network by using technology-agnostic protocol such as HTTP. They are easy to replace and can be implemented using different programming languages, databases, and server environments that better fit their purpose.

The preliminary specification of inputs and outputs of envisioned REPSOND's analytic services is detailed in the previous section about RESPOND's technology tiers, which in fact represent internal tiers and building blocks of the platform. However, the platform also leverages external services, such as weather service (for meteorological forecast) and energy pricing service which are briefly described in the following while the final specification will be derived during the development of each particular service.

External weather service API

The data related to weather conditions at the pilot site (temperature, insolation, humidity, wind, etc.) will be fetched from external weather data services, such as Openweathermap.org, Wunderground.com, etc.

For instance, current weather data for London can be fetched by sending HTTP GET request to the url.

Request:
```
https://samples.openweathermap.org/data/2.5/weather?q=London,uk
```
Response:

```
{
"coord":{"lon":-0.13,"lat":51.51},
"weather":[{"id":300,"main":"Drizzle","description":"light intensity
drizzle","icon":"09d"}],
"base":"stations",
"main":{"temp":280.32,"pressure":1012,"humidity":81,"temp_min":279.15,"temp_max":28
1.15},
"visibility":10000,
"wind":{"speed":4.1,"deg":80},
"clouds":{"all":90},
"dt":1485789600,
"sys":{"type":1,"id":5091,"message":0.0103,"country":"GB","sunrise":1485762037,"sun
set":1485794875},
"id":2643743,
"name":"London",
"cod":200
}
```


Besides, weather forecast for the given location can be fetched by sending HTTP GET request.

Request:
```
https://samples.openweathermap.org/data/2.5/forecast?q=London&mode=xml
```
Response:

```
<weatherdata>
<script/>
```

```
<location>
       <name>London</name>
       <type/>
       <country>US</country>
       <timezone/>
       <location altitude="0" latitude="39.8865" longitude="-83.4483"
       geobase="geonames" geobaseid="4517009"/>
</location>
<credit/>
<meta>
       <lastupdate/>
       <calctime>0.0028</calctime>
       <nextupdate/>
</meta>
<sun rise="2017-03-03T12:03:03" set="2017-03-03T23:28:37"/>
<forecast>
       <time from="2017-03-03T06:00:00" to="2017-03-03T09:00:00">
       <symbol number="600" name="light snow" var="13n"/>
       <precipitation unit="3h" value="0.03125" type="snow"/>
       <windDirection deg="303.004" code="WNW" name="West-northwest"/>
       <windSpeed mps="2.29" name="Light breeze"/>
       <temperature unit="kelvin" value="269.91" min="269.91" max="270.877"/>
       <pressure unit="hPa" value="1005.61"/>
       <humidity value="93" unit="%"/>
       <clouds value="scattered clouds" all="32" unit="%"/>
       </time>
       <time from="2017-03-03T09:00:00" to="2017-03-03T12:00:00">
       <symbol number="800" name="clear sky" var="01n"/>
       <precipitation unit="3h" value="0.0225" type="snow"/>
       <windDirection deg="293.503" code="WNW" name="West-northwest"/>
       <windSpeed mps="3.55" name="Gentle Breeze"/>
       <temperature unit="kelvin" value="269.23" min="269.23" max="269.957"/>
       <pressure unit="hPa" value="1007.39"/>
       <humidity value="90" unit="%"/>
       <clouds value="scattered clouds" all="36" unit="%"/>
       </time>
. . . . . .
```


External energy pricing API

In a similar manner, energy pricing for a given time period can be fetched form external energy pricing API:

Request:

```
https://api.genability.com/rest/public/rest/public/tariffs/823?populateProperties=t
rue&populateRates=true&lookupVariableRates=true
```

Response:


```
{
    "status": "success",
    "count": 1,
    "type": "Tariff",
    "results": [
{
            "tariffId": 3284480,
            "masterTariffId": 823,
            "tariffCode": "R-1",
            "tariffName": "Residential",
            "lseId": 310,
```

```
            "lseName": "National Grid - Massachusetts",
            "priorTariffId": 3279572,
            "tariffType": "DEFAULT",
            "customerClass": "RESIDENTIAL",
            "customerCount": 1006774,
            "customerLikelihood": null,
            "territoryId": 328,
            "effectiveDate": "2017-05-01",
            "endDate": null,
            "timeZone": "US/Eastern",
            "billingPeriod": "MONTHLY",
            "currency": "USD",
            "chargeTypes": "FIXED_PRICE,CONSUMPTION_BASED,MINIMUM",
            "chargePeriod": "MONTHLY",
            "hasTimeOfUseRates": false,
            "hasTieredRates": false,
            "hasContractedRates": true,
            "hasRateApplicability": true,
            "isActive": true,
            "rates": [
                      {
                          "tariffRateId": 17838923,
                          "tariffId": 3284480,
                          "tariffSequenceNumber": 22,
                          "rateGroupName": "Customer Charge",
                          "rateName": "Customer Charge",
                          "fromDateTime": "2017-05-01T00:00:00-04:00",
                          "toDateTime": null,
                          "chargeType": "FIXED_PRICE",
                          "chargeClass": "DISTRIBUTION",
                          "chargePeriod": "MONTHLY",
                          "rateBands": [
                              {
                                  "tariffRateBandId": 11575434,
                                  "tariffRateId": 17838923,
                                  "rateSequenceNumber": 1,
                                  "hasConsumptionLimit": false,
                                  "hasDemandLimit": false,
                                  "hasPropertyLimit": false,
                                  "rateAmount": 5.5,
                                  "rateUnit": "COST_PER_UNIT",
                                  "isCredit": false,
                                  "prevUpperLimit": null
                              }
                          ]
                      },
```


3. RESPOND KEY TECHNOLOGY TIERS

Before starting with the description of each technology tier that makes up the Respond solution, it is important to explain that in RESPOND project as a technology tier we understand those analytic services that are underlying concepts featured by core services of RESPOND platform such as DR optimisation and energy production model (developed by Pupin), Energy Demand Forecasting and Predictive Maintenance (developed by Tekniker) and Building Simulation model (developed by NUIG).

On the following tables a detailed explanation has been provided to each technology tier defining the following aspects for each of them:

1. Description of the application
2. Involved developers
3. Inputs
4. Outputs
5. Functionalities
6. Additional comments

3.1 DR OPTIMISATION

Description of application
As stated the framework for modelling of energy infrastructure is based on the concept of energy hub, which represents a flexible and scalable form suitable for the formulation and solution of generic optimization problems related to energy management. Given its holistic approach, it accounts for available energy supply carriers, energy conversion options and existing storage units. The chosen approach was adapted from [1] and can be schematized as depicted in figure 1. The basic modelling block features energy input, sequentially followed by conversion and output stages. Once the energy flows enter the hub (Pin) they can be either stored immediately at input stage (Qin), if storage facilities are available, or dispatched through the dispatch element (Fcin) to the converter stage (C) as Pcin. Once the energy conversion is performed the output (Pcout) can then be exported (Pexp) and the net remaining output (Pout) is forwarded (via the dispatch element Fout) to the output stage where it is either stored (Qout) or immediately employed to satisfy the load demand (L). This modelling framework allows for integrated optimization of energy supply flows and demand side flexibility thus offering a holistic energy management paradigm. If the case is about more elaborate and complex topologies, which cannot be represented with a single conversion and/or dispatch stage, the flexibility of the energy hub approach comes into play by placing several blocks in a sequence, as shown also in figure 1. The input to a successive block is taken to be equal to the output of the preceding block, so that for two consecutive blocks the first sees the second as a load.

Developers

[1] Almassalkhi M., Hiskens I.A. "Optimization framework for the analysis of large-scale networks of energy hubs". Proceedings of the Power Systems Computation Conference, Stockholm, August 2011.

Name	Responsibility
Marko Batic	Matlab prototype
Marko Jelic	Java prototype

Inputs	
Parameter name	**Description**
L_e [kW]	Electricity demand, historic/measured/forecasted
A_i [kW]	Appliance rated power
W_i [range]	Appliance operating window
L_h [kW]	Heating demand, historic/measured/forecasted
L_c [kW]	Cooling demand, historic/measured/forecasted
C_e [€/kWh]	Price of Electricity
C_{exp} [€/kWh]	Price of exported electricity
C_h [€/kWh]	Price of Heat
E_{PV} [kWh]	Energy from photovoltaic plant, historic/measured/forecasted
E_{STC} [kWh]	Energy from solar thermal collector, historic/measured/forecasted
SOC_{batt} [%]	State of Charge of battery bank
S_{hwt} [~J]	Hot Water tank volume and temperature
N_{ee} [%]	Efficiency electrical to electrical
N_{eh} [%]	Efficiency electrical to heating
N_{ec} [%]	Efficiency electrical to cooling
N_{hh} [%]	Efficiency heating to heating

Outputs	
Parameter name	**Description**
Pe [kW]	Electricity supply
Ph [kW]	Heating supply
Vij	Dispatching factors from carrier i to carrier j (electricity, heating, cooling)
Le [kW]	Suggested profile of Electricity demand
Lh [kW]	Suggested profile of Heating demand
Lc [kW]	Suggested profile of Cooling demand
SAi	Suggested start operation time for appliance i

Functionalities	
Function	**Description**

Energy planning	Offers planning of energy infrastructure in terms of both retrofit and design. It suggests optimal topology and sizing of energy assets for a given demand, energy pricing and geographical context.
Operation dispatching	Offers optimal energy dispatching of supplied and locally produced energy towards energy demand, available storages or exchanges with the distribution network.

Additional comments:

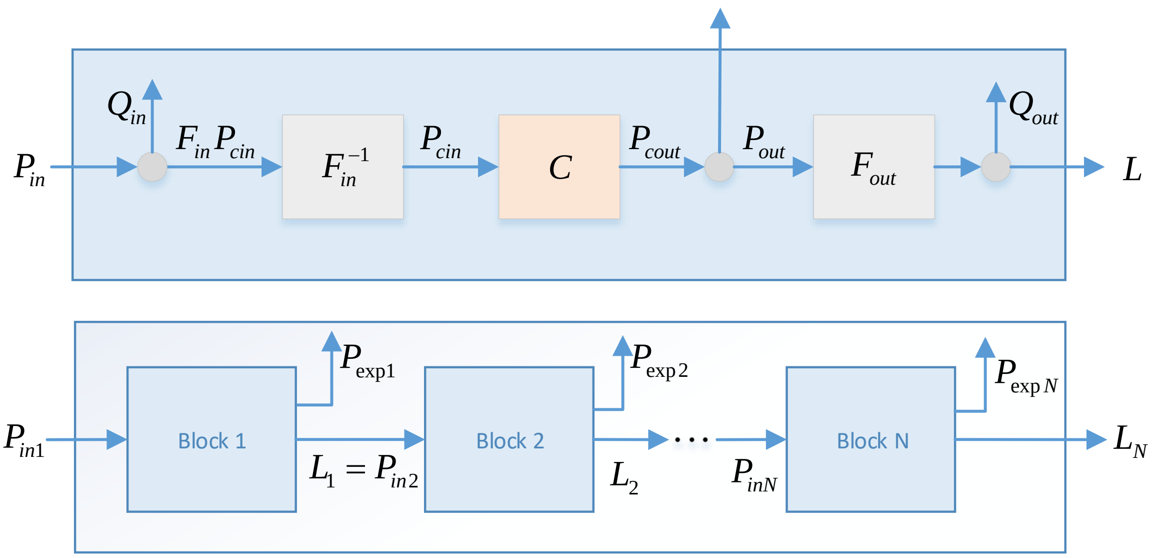


Figure 9: Block schematic of energy hub and multi-block schematic of energy hub

3.2 ENERGY PRODUCTION MODELS

Description of application
This service will be responsible for delivering energy production forecast from the RES available at the demo sites, which will be further consumed by the optimization service in order to determine optimal dispatch of the produced energy between satisfaction of immediate loads, energy storage or export to the power grid. In the context of RESPOND project and its demonstration sites, the two main types of energy generation devices are the photovoltaic (PV) panels, enabling production of electricity from solar energy, and the solar thermal collectors (STC) which also harness solar energy but for production of thermal energy. For the implementation purposes, both deterministic and stochastic approaches will be considered.

Developers	
Name	**Responsibility**
Marko Batic	Deterministic models
Nikola Tomasevic	Stochastic models

Inputs PV	
Parameter name	**Description**
GT [kW/m2]	Global horizontal radiation on the earth's surface averaged over the time step
Ta [^{o}C]	Ambient (Surrounding) Air Temperature
a_p [%/°C]	Temperature coefficient of power
Y_{PV} [kW]	Rated capacity of the PV array
$T_{c,NOCT}$ [°C]	Nominal operating cell temperature
LFT [yrs]	PV lifetime
β [°]	Slope of the surface
γ [°]	Azimuth of the surface
A_{PV} [m^2]	Surface area of the PV module
f_{PV} [%]	PV derating factor
λ [°]	Longitude
ϕ [°]	Latitude
Z [hr]	Time zone
ρ[%]	Ground reflectance - albedo

Outputs PV	
Parameter name	**Description**
P_{pv} [kW]	Power output of the PV

Inputs STC		
Parameter name	**Description**	
GT [W/m2]	Global solar irradiance radiation at the collector aperture	
ta [K]	Ambient (Surrounding) Air Temperature	

Ti [K]	Heat transfer Fluid Temperature at the collector inlet	
To [K]	Heat transfer Fluid Temperature at the collector outlet	
AG [m2]	Collector Gross area	
AA [m2]	Collector Absorber area	
Aa [m2]	Collector Aperture area	
cf [J/(kg K]	Heat transfer Fluid specific heat capacity	

Outputs STC	
Parameter name	**Description**
$\dot{Q}_U$ [W]	Power output per collector unit

Functionalities	
Function	**Description**
Forecasting of energy production from photovoltaic panels (PV)	
Forecasting of energy production from solar thermal collectors' panels (STC)	

Additional comments:

The provided inputs and outputs represent a superset of parameters used by both deterministic and stochastic models. The key difference is that the stochastic approach considers employment of a data-driven technique, e.g. machine learning, which leverages its training process only on measurements from historical energy production of specific source recorded together with applicable meteorological conditions.

3.3 Building Simulation Model

Description of application
The Building energy simulator is based on a modelica model, it is a grey-box model based on [A. Giretti, M. Vaccarini, M. Casals, M. Macarulla, A. Fuertes, R.V. Jones, Reduced-order

modeling for energy performance contracting, Energy and Buildings, Volume 167, 2018, Pages 216-230, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2018.02.049.].

The model has been implemented as a thermal model using the basic components of the Modelica Standard Library and some special components of the IBPSA Project 1 Library in the Dymola simulation environment.

The building model is made of four main components:

- The envelope,
- The heating/cooling systems,
- The internal gain,
- The weather.

Summarising, the proposed reduced building model is described by 23 parameters (described below). A statistical tool has been created to estimate the main building energy parameters. The information needed to populate the tools are taken from available technical information, surveys and interviews. The remaining uncertain parameters are evaluated based on specific values, and then adjusted throughout the calibration process.

The reduced set parameters and the availability of reliable information for most of them, make the reduced order grey-box modelling calibration quite simple compared to the White box model. In the proposed modelling approach, only 8 out of 23 parameters are significantly affected by uncertainty and should be fine-tuned through calibration. Furthermore, most of them have a specific footprint on the energy consumption, hence some calibration guidelines can be established, improving the calibration process structure. Once the building simulation model is calibrated with a standard procedure, it will be ready for translate optimization scenario into thermal control actions.

Developers

Name	Responsibility
Federico Seri	NUIG
Alessandro Piccinini	NUIG

Inputs

Parameter name	Description
V_{ol}	Building volume
A_{pq}	Opaque envelope area divided as per orientation (e,w,n,s)
A_{win}	Window area divided as per orientation (e,w,n,s)
G_v	Solar shading coefficient
R_{ea}	Outdoor air - envelope coupling resistance
R_{ie}	Averaged resistance of the opaque envelope
C_e	Heat capacity of the opaque envelope

R_m	Thermal resistance between the walls and furniture and the interior air
C_m	Heat capacity of the interior walls and furniture
V_{air}	Internal air volume
L_{ea}	Air infiltration resistance
V_{rt}	Mass flow rate through forced ventilation
R_{ih}	Thermal resistance between the heating/cooling system and the interior
C_{ih}	Heat capacity for the heating/cooling system
E_{ff}	Efficiency of the heating/cooling system
P_{ow}	Installed heating/cooling power
H_{ys}	Hysteresis range of the thermostat
O_{cc}	Average monthly occupancy level
O_{per}	Average monthly occupancy level
S_{etp}	Indoor temperature set-points
W_{ea}	Weather data file
G_p	Heat gain per person
G_{eq}	Heat gain due to fixed equipment and systems

Outputs	
Parameter name	**Description**
TotTh	Total thermal Energy consumption of the the heating/cooling system
Tia	Indoor air temperature
TotEle	Total Electrical consumption

Functionalities	
Function	**Description**
Optimizing heating/cooling systems	
Thermal load shifting	
Energy consumption forecasting for different indoor temperature set-points	

Additional comments:

Since the grey box model is in a developing phase, during the project could be done some modification with the adding or the changing of some of the model in terms of physical equation, parameters and functionalities.

The input/output of the building energy simulator will be customized based on the RESPOND optimization scenarios requests (i.e. calculate the indoor temperature set-points to save a certain amount of kWh on the next hour).

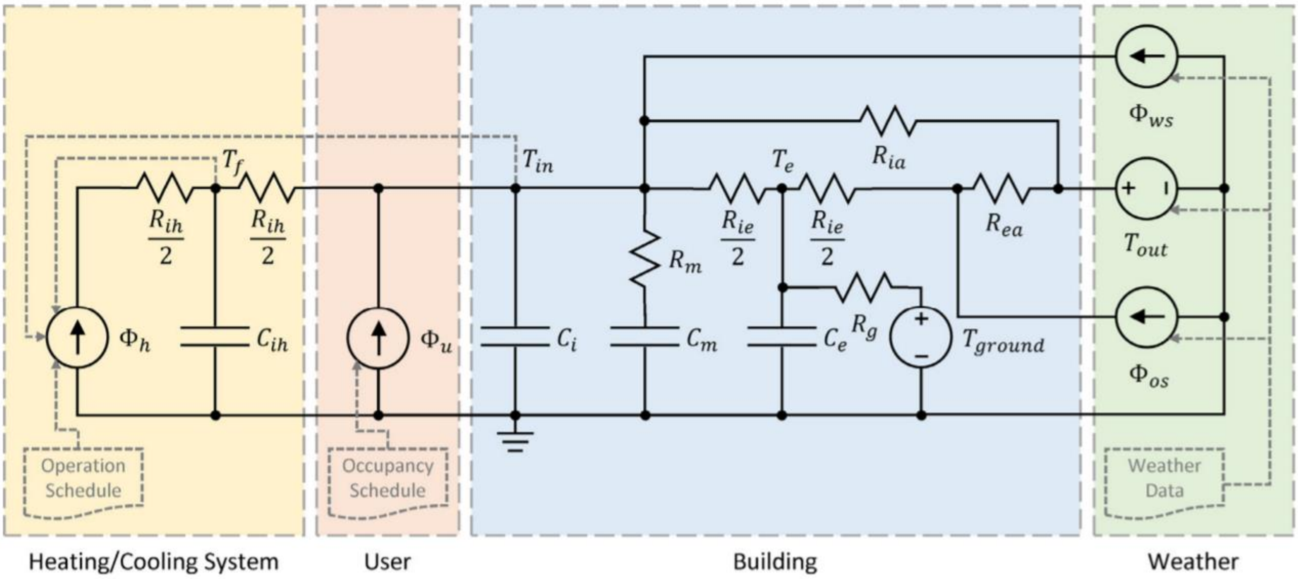


Figure 10 The RC-network of the Grey-box model

3.4 ENERGY DEMAND FORECASTING

Description of application
The goal of this service is to estimate the energy demand (both electric and thermal energy) that will occur in a house or at a neighbourhood level in a given time in the future. The energy demand is strongly influenced by dwellers' habits. Likewise, dwellers' habits are affected by the culture, the income of the house and the location of the building to name a few. This means that, even though two houses are next to each other, their energy demands may vary considerably. Therefore, it is necessary to forecast the energy demand forecast for each dwell. The demand forecast service will receive inputs coming from different sources to produce as accurate predictions as possible. Among the relevant input there are weather forecast (e.g. cloud cover, external temperature), the date, the time, the season of the year, the consumption (thermal or electric, depending on what forecast is aimed), the indoor conditions and whether it is a laboral day or not. Energy demand forecasting could be done also for individual appliances. In this case the models will be simpler based mainly on historical trends.

Developers	
Name	**Responsibility**
Iker Esnaola	Model development
Alvaro García	Software integration

Ignacio Lázaro	Data acquisition and management

Inputs	
Parameter name	**Description**
ExtTemp [ºC]	External temperature, historic/measured/forecasted
ExtHumy [%]	External relative humidity, historic/measured/forecasted
WindSpeed [m/s]	External wind speed, historic/measured/forecasted
IndTemp [ºC]	Indoor temperature, historic/measured
IndHum [%]	Indoor relative humidity, historic/measured/forecasted
CO2 [ppm]	CO2 levels, historic/measured/forecasted
Occ	Occupancy
DayType	Type of day in terms of laborality
dateTime	Date and time
Month	Month of the year
ElecCons [KWh]	Electric Consumption, historic/measured
TherCons [KWh]	Thermal Consumption, historic/measured
ElecPrice [€/KWh]	Electricity Price
TherPrice [€/KWh]	Thermal Energy Price

Outputs	
Parameter name	**Description**
ElecConsFor [KWh]	Electric Consumption Forecast
TherConsFor [KWh]	Thermal Consumption Forecast
IndTempFor [ºC]	Indoor Temperature Forecast

Functionalities	
Function	**Description**
Electric Consumption Forecast	Offers the predicted electric consumption of a house/building/neighborhood for a given period of time
Thermal Consumption Forecast	Offers the predicted thermal consumption of a house/building/neighborhood for a given period of time
Temperature Profile Forecast	Offers the predicted temperature of a house for a given period of time

Additional comments:

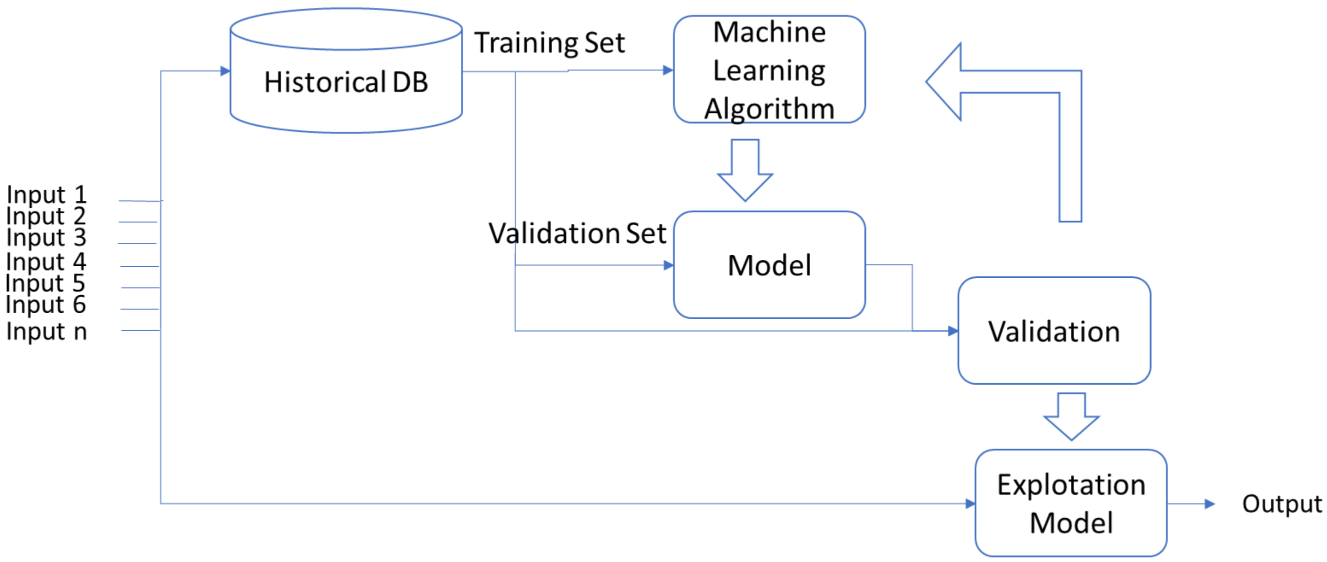


Figure 11. Energy demand forecasting flow

3.5 Predictive Maintenance

Description of application
Often, the culprit of having a high consumption in residential facilities is to have defective or deficient equipment in operation, whose energy leaks are easy to ignore, causing low performance equipment, which represents a significant percentage of operating costs. The change of strategy, from Preventive Maintenance (PM) to a Predictive Maintenance (PdM) approach, provides a new way to reduce costs. PdM is an early-warning system to know when an equipment/device is malfunctioning and should be replaced or repair. It reduces overhead, avoid unplanned downtime and provide information about the equipment conditions in real time. Trend projection and planned downtime could be used to optimize the schedule of the equipment shifting loads for a better use of the resources or shift loads when a downtime is planned.

Developers	
Name	**Responsibility**
Iker Esnaola	Model development
Susana Ferreiro	Maintenance strategy definition
Santiago Fernandez	Model development
Alvaro García	Software integration

Ignacio Lázaro	Data acquisition and management

Inputs	
Parameter name	**Description**
ExtTemp [ºC]	External temperature, historic/measured/forecasted
ExtHum [%]	External relative humidity, historic/measured/forecasted
IndTemp [ºC]	Indoor temperature, historic/measured
IndHum [%]	Indoor relative humidity, historic/measured/forecasted
CO2 [ppm]	CO2 levels, historic/measured/forecasted
Occ	Occupancy
DayType	Type of day in terms of working/non-working days
dateTime	Date and time
Month	Month of the year
ElecCons [KWh]	Electric Consumption, historic/measured
TherCons [KWh]	Thermal Consumption, historic/measured
Ppv [kW]	Power output of the PV, historic/measured
$\dot{Q}_U$ [W]	Power output per solar thermal collectors panels, historic/measured

Outputs	
Parameter name	**Description**
OpMode	Normal / Abnormality
TrendPred	Evolution of the operation and prediction of the future 'Operation mode'
Command/Prescription	What should be done? Actions to be taken based on the 'Operation mode' and 'Trend Prediction'

Functionalities	
Function	**Description**
Anomaly detection	The function will recognize abnormal conditions in the operation of the monitored system, considering the normal operation mode inferred from historical data. "Normal operation" conditions will be defined for the system, and the changes will be detected.

Trend prediction	The function will provide the trend and projection of the future operation mode for the system.
Decision support	The function will make a prescription and recommendations to help for the decision-making in terms of deciding what type of action should be taken, considering actual and future operation mode of the system.

Additional comments:

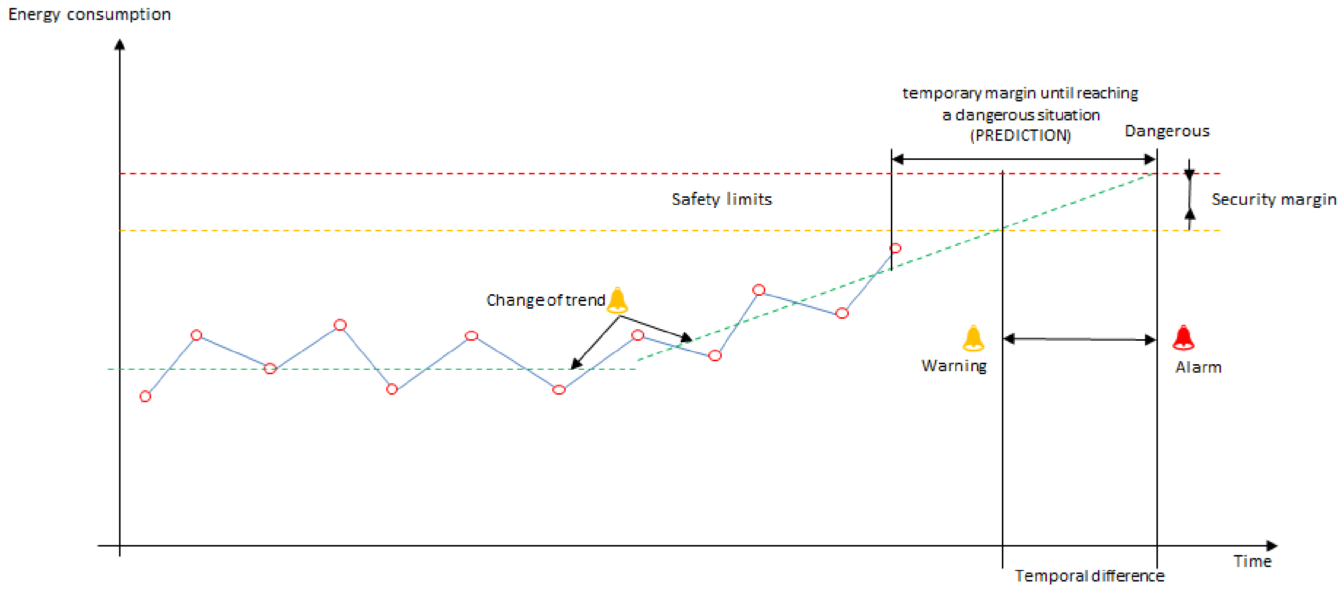


Figure 12. Prediction flow

4. EARLY DEPLOYMENT AT PILOT SITES

4.1 AVAILABLE ICT INFRASTRUCTURE AT PILOT SITES

Based on deliverable 1.3, Respond strategy to support interoperability, this section reports the list of legacy system components at the three pilot sites derived from the analysis of information collected through RESPOND pilot sites characterization and interoperability questionnaire.

Madrid pilot (Spain)

This pilot site consists of 3 residential buildings where 19 dwellings and 5 common areas participate in RESPOND project.

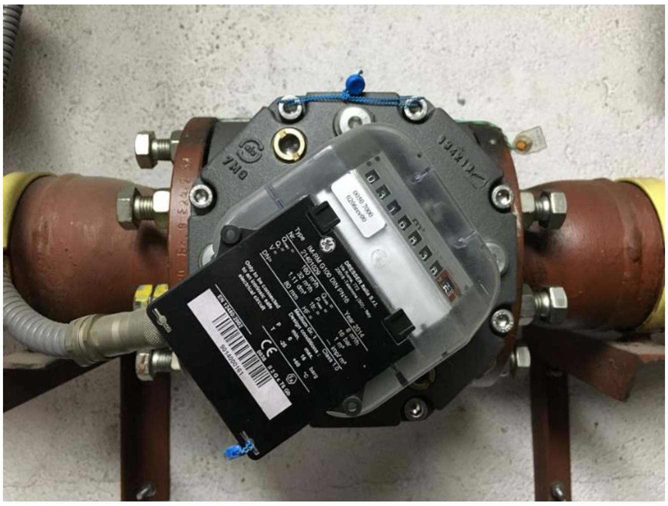
Each of the **dwellings** had its individual consumption of electricity and gas along with the energy demand related with the common areas. In the dwellings, there was no system for monitoring of energy demand by household devices, besides the electricity and gas meters deployed by the energy company :

Calorimeter

Water meter

Power meter

EMS Trend (central boiler)



Gas meter (central boiler)

Figure 7. Legacy meters and EMS found at Madrid pilot sites

The **common area** has already installed the following equipment that is devised to be considered in DR actions:

- Trend IQ251 central heating boiler
- Cx2000-9/Sagecom Electricity meter
- Istameter radio net 3/Ista water meters
- IM-RM G100 DIN Dresser gas meter

In the tables 1-2, we report the Legacy ICT Systems that were available at the Spanish pilot.

Table 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
Other sensors (occupancy, etc.)									
Legacy	Human Presence Detector	N/A	Common	Mains	N/A				

Table 2: 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

Aarhus pilot (Denmark)

The pilot located in Aarhus consists of 4 buildings where 20 apartments were preselected for demonstration of RESPOND solution and the installations have been done in 16 **apartments**.

All apartments have individual monitoring of electricity consumption (see following figure), 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 8. Legacy equipment at Aarhus pilot site

The **common area** has already installed the following equipment that is devised to be considered in DR actions:

- REC Twinpeak 2S 72 PV Panels
- Danfoss TripleLynx Inverter

In the tables 3-5, we report the Legacy ICT Systems that were available at the Danish pilot.

Table 3: 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

Table 4: 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 5: 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

Aran Islands pilot (Ireland)

The pilot located at Aran Islands consist of 11 houses at the moment where demonstration activities of RESPOND system will take place. 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 the following figure. 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 9. Legacy equipment at Aran islands pilot site

In the tables 6-7, we report the Legacy ICT Systems that were available at the Irish pilot.

Table 6: 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

Table 7: 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

4.2 IMPLEMENTATION IN PILOT SITES

Based on deliverable 2.3 and also taking advantage of the content that will make up deliverable 2.4 This section is a brief summary to report the equipment that we have installed in the three pilots.

Madrid pilot (Spain)

This section reports the equipment that we have installed in the Spanish pilots. Currently, the deployments have been done in 11 dwellings and 5 common areas.

We have deployed appropriate smart metering equipment and home automation devices provided by consortium member Energomonitor. These newly deployed devices 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).

Energomonitor Homebase

Energomonitor Optosense

Energomonitor Airsense

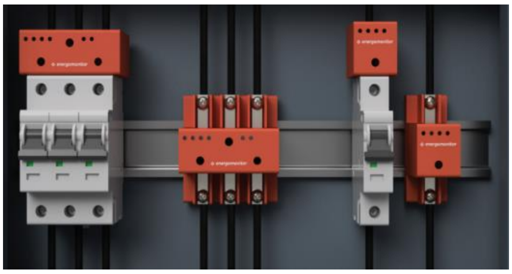
Energomonitor Relaysense Gas

GasEnergomonitor Relaysense Water

Energomonitor Thermosense

Energomonitor Portasight

Energomonitor Plugsense



Energomonitor Powersense DIN Rail

As a summary of the content that appears on deliverable 2.3 the devices installed on the houses are mainly:

- Gateway
- Monitoring of electric energy consumed
- Monitoring of the humidity, temperature and CO2 of the room in which it is installed
- Monitoring of gas consumed
- Monitoring of water consumed
- Monitoring of the temperature of the room in which it is installed
- Monitoring of the humidity and temperature of the room in which it is installed
- Monitoring of the dishwasher's power consumption, and controlling the dishwasher's activation according to DR actions
- Monitoring of the washing machine's power consumption, and controlling the washing machine's activation according to DR actions
- Monitoring of the air conditioner's power consumption

With regards to the common areas, the devices installed are:

- Gateway
- Monitoring of electric energy consumed
- 6 Siemens QAE2120.010 temperature sensors
- 2 electronic heat meters Siemens UH50
- Siemens RMS705B solar regulation control unit
- Siemens OZW722.01 web server for remote communications
  Energomonitor Optosense

At the beginning of RESPOND project, there was no generation system in the building, the installation of a new solar thermal system to reduce the expenses of Domestic Hot Water (DHW) is in progress:

- The thermosolar system performance will be monitored by the temperature sensors and the heat meters. All of them are expected to be connected to the control unit that will be available for remote access through the web server. All Siemens devices will use KNX communication protocol. Furthermore, a heat meter is intended to be placed in the primary thermal circuit in order to measure the real solar production, while the other one will be located in the return circuit to quantify circuit loses. As regards for the temperature sensors, they will be installed in the cold-water input, solar panels input and output, thermosolar circuit water tank, SHW water tank and SHW output. This way, in addition to enabling the adjustment and measurement of thermosolar system's performance, it will provide trials participants with thermosolar SHW availability and production, in order to modify their consumption timeframes.

Besides, as described again in deliverable 2.3, the new deployment meters, energy and smart home assets and BMS/EMS are the following:

- 3 power meters in 3 households
- 1 gas meter
- 1 water meter
- Thermometer
- Visibility sensors
- Solar Device
- Display
- Smartplug
- Thermostat
- Gateway
- Siemens (Thermosolar) RMS705B

Energomonitor sensors send data to the Energomonitor homebase. Both the Portasight Display and Plugsense are capable of two-way communication. The homebase then communicates with the MQTT Broker. The data bridge processes data via the MQTT broker which has been prepared on Pupin's side. Control is facilitated via the RESPOND Control bridge for demand response (DR) actions via the Energomonitor Plugsense.

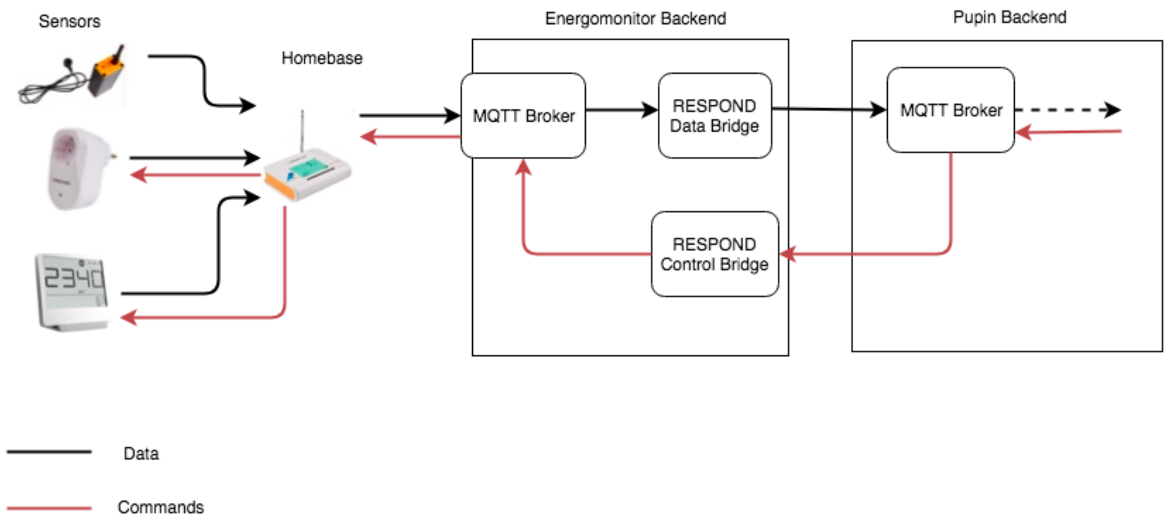


Figure 10. Energomonitor ICT implementation

Aarhus pilot (Denmark)

This section as described in deliverable 2.3 reports the equipment that we have been installed in the Danish pilots. Currently, the deployments have been done in 16 houses are deployed, except for thermostats.

To provide a fine grained higher resolution of monitoring, home automation and smart metering equipment provided by consortium member DEVELCO have been 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.

On each house the following equipment have been installed:

- Develco Squid.Link Gateway
- Develco Kamstrup Interface
- Kamstrup MC 602 Calorimeter
- Develco External Meter Interface
- Thermostat
- Develco SmartPlug 1
- Develco SmartPlug 2
- Develco window sensor
- CO2 sensor (manufacturer not decided yet)

And on the common areas the installed equipment is:

- Gateway
- Develco Prosumer Meter

What is expected also to be installed for the new metering equipment for each house is the following:

- Calorimeter
- Power meter
- Calorimeter
- Power meter
- Thermometer
- Humidity Sensor

<u>Develco installation</u>

The gateway is installed in a central place inside the house. This is to obtain the best RF ranges to all the installed devices.

The **Kamstrup heat meter is installed in the basement** and the radio module inside the heat meters is transmitting Wireless Mbus metering data to the gateway in a fixed interval of every 5 minutes. The

Wireless MBus protocol is a one-way communication and the gateway is acting as a data concentrator collecting heat metering data.

The **Electricity meter is also installed in the basement**. To collect electricity meter data with a high resolution an External meter interface with an optical probe is attached to the flashing LED on the electricity meter. The LED on the electricity meter is blinking 1000 timers for each kWh. The External meter interface calculates the number of pulses and sends the data (Watt and kWh) to the gateway every 1 minute. The communication with the gateway is via ZigBee. ZigBee MESH network functionality is used to obtain the best ranges performance.

To **control the heat in each room a Blue tooth Smart thermostat is installed on each radiator**. The thermostat transmits the current temperature and the temperature set point to the gateway every 10 minutes. Blue tooth low energy is used but no MESH functionality is supported. The communication is point to point. The Smart thermostat has not yet been installed in the houses but initial tests have showed that we have a RF ranges problem and the gateway has problem communication with the radiators on the first floor due to the heavy conceit separating the two floors. One of the plans is to install an extra gateway on the 1 floor to communicate with the Smart thermostats upstairs. The gateway on the first floor then sends its data using the build-in WiFi supported by both gateways.

Humidity and VOC sensor are both small battery driven devices that has been mounted on the wall in the rooms upstairs and downstairs. The sensors measure the temperature, humidity and air quality every 5 minutes and transmit the data to the gateway. The communication with the gateway is via ZigBee. ZigBee MESH network functionality is used to obtain the best ranges performance. Since the sensor is a battery driven device is does not support the ZigBee MESH routing functionality. The device is called a ZigBee end device and the radio is turn off most of the time to save battery power.

The Smart Plug and Smart Cable are installed on the dishwasher, washing machine and tumbler dryer measuring the current power (Watt) and the total accumulated power (kWh) since the plug/cable was installed. Data is transmitted to the gateway every 1 minute. The communication with the gateway is via ZigBee. Since the Smart plug and Cable is connected to the mains power (230 VAC) is has it ZigBee radio open all the time and ZigBee MESH network functionality is supported. Some of the Smart plugs are installed in different location in the house and the only functionality is to build a stable RF network with the best ranges' performance.

The prosumer meter is installed on the PV system and a dedicated gateway is installed next to the PV. The PV system is not connected to one specific house but it is connected to the local grid providing electricity to all the houses and apartments in the housing association. Data is transmitted to the gateway every 1 minute. The communication with the gateway is via ZigBee. The gateway is transmitting all the PV data to the MQTT broker via the build-in 3G modem connection. WiFi and Ethernet are not supported.

That at the pilot site in Denmark different wireless technologies is used to collect data from all the devices installed in the different pilot houses. The Develco Products Squid.link gateway is the central devices in the ICT infrastructure providing and creating the different wireless networks.

For the **WAN network the gateway communicates with the MQTT broker via the build-in 3G modem in the gateway**. Each gateway is equipped with an M&M data SIM card. WiFi and Ethernet connection is also supported but will only be used if the 3G connection is unstable.

For the LAN network, communication with the devices installed in the houses, the following wireless technologies is used ZigBee, Wireless MBus and Blue tooth.

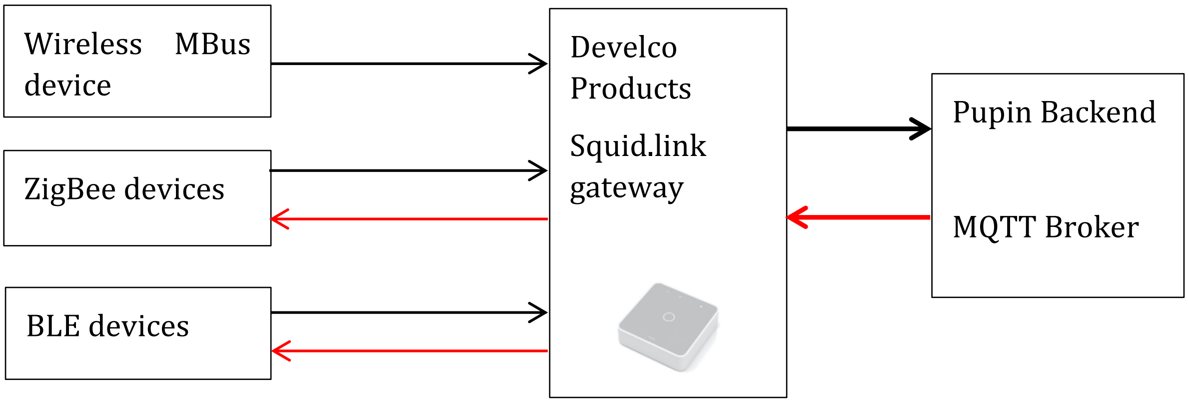


Figure 11 Develco ICT implementation

5. Conclusions

In this document, integration of key technology tiers is described. As a result, the **interfaces between internal system components and core services**, as well as **towards external HW/SW systems** (such as smart home devices, legacy systems, third party services, etc.) have been specified. All relevant communication details, among all possible layouts of the RESPOND key technology tiers, have been reported in this document to allow the seamless integration of RESPOND solution in the following WPs (particularly in WP4 and WP5).

One of the main challenges has been to **match the existing systems and underlying technology concepts with system reference architecture designed in Task 2.1** [1]. To do so, the existing technology available in pilot sites has been taken into consideration along with the new MQTT based architecture, which will be able not only to integrate the new RESPOND technology tiers, but also the legacy systems present in the pilot sites. In addition, the inputs from WP1 in terms of exact deployment options and project requirements have been considered for the activities performed in this task.

Thanks to the inputs of all the partners involved in the task, the following deliverable has achieved the following goals:

- A **detailed analysis of the integration of all underlying concepts** for each analytical service has been provided: description of the application, involved developers, inputs, outputs, functionalities, additional comments. Therefore, during the second-year integration activities of DR enabling components in WP3, WP4 and WP5 will be done thanks to the technology tier description of each technology done in this deliverable.
- Based on the inputs from WP1, the **matching of key technology tiers using reference architecture** has also been described.
- The **interfaces** between internal **system components**, **core services** and **external HW/SW systems** has been provided.
- The **strategy for integration of RESPOND platform that will enable early deployment** and interfacing with ICT infrastructure at pilot sites has been described.

Results of this deliverable will be used as an input for all the tasks in WP4 and WP5, together with task 2.5 (Demand response platform development). Taking into consideration that analytic systems are currently under development, and the ICT architecture is also being implemented (using specification from T2.1), some minor changes might be expected on the future with regards to the technology tiers and its integration. This is not the case for field devices, which will remain constant across the project. but the initial definitions have been clarified. Therefore, results of this deliverables can be considered a first attempt of the ICT integration, but it might be subject to minor changes during project development.

REFERENCES

RESPOND DOCUMENTS

[1] Deliverable 2.1: “RESPOND system reference architecture”, 2018.

[2] Deliverable 1.3: “RESPOND strategy to support interoperability” 2018

[3] Deliverable 2.3: “Initial deployment plan” 2018