



Orchestration of Renewable Integrated Generation in Neighbourhoods

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D2.2 Laboratory validation reports

WP2 - Design and validation of ICT hardware and software platforms

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Introduction / Executive summary

The purpose of this deliverable is to document the testing procedures performed to the metering and actuation equipment used in the ORIGIN project. Although the laboratory based testing tries to replicate the working conditions of the equipment, this type of testing does not always accurately replicate the conditions experienced in the operating environment. Similarly, theoretical analyses may not account for all factors influencing the operation of equipment. Also the 3 deployment sites are in different geographical locations and therefore have differing climates and the usage characteristics of the equipment in each site will vary.

Specification of the Laboratory validation

Description of the used validation test procedures

The validation process is comprised of three layers of testing procedures with distinct objectives: the first level testing has the objective of assuring that each individual software or hardware component complies with its specification in terms of function and communications; the second level has the objective to assure that each one of the specified hardware solutions works as an integrated solution in the field; the third level intends to test the specified solutions in real scenarios, collecting real data.

At a first level, the functional specifications, integration and communication of the hardware and software solution components are tested and validated. For all the ISA developed equipment this level of testing is necessarily performed inside the conception and development phase, according to the internal quality processes derived from ISO 9001 and CMMI Level 2 certifications that ISA holds¹. In pair with the described testing, every piece of hardware equipment ISA produces is subject to a battery of tests regarding functionality and communications to ensure that no malfunctioning equipment is sent to the field. A failure in any of the performed tests implies that the piece of hardware is rejected or serviced in order to pass all the tests. All the solutions and equipment, being products or prototypes, delivered to the Origin project are subject to the described testing processes with no exception. For the software-based solutions, as the data server used in the Origin project, a similar quality assurance process is performed before any new version of the component is publicly published for usage. In summary, this first level ensures that:

- All developed hardware devices and respective developed firmware conform to the specifications in terms of:
 - Accomplishment of all the specified functionalities
 - Measurement accuracy and range
 - Wireless or wired communication capabilities in terms of signal levels of transmission and reception
 - Wireless or wired communication protocols

¹ <http://www.isasensing.com/uk/certificados/2/?pagina1=2/>

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- Stability and reliability
- All the developed software conforms to the specifications in terms of :
 - Functionalities
 - Security
 - Communication protocols
 - Stability and reliability

At a second level, the solution’s components are installed in a simulated test bed composed of real hardware, similar to the ones to be installed in the pilots, and tests are performed to assure that all the hardware is integrated and their working mode is validated in a scenario that intends to reproduce the real scenarios found in the project’s pilots.

The third level intends to test the solution from the end user point of view, taking into account some of the solutions’ particularities in real use scenarios, such as battery life or comparison with similar solutions.

Description of the testing environments and performed tests

This section describes the used environments to test the Origin solutions. Two distinct test beds were used: one in ISA premises, one in University of Strathclyde. While the ISA test bed, composed of two parts (one for iHub and one for Cloogy solution testing), was assembled with the main objective of testing the integration and communications of all the components of the solution, University of Strathclyde’s test bed had the main objective of testing the solutions applications in real measurement scenarios. The University of Strathclyde’s test bed consists of three parts: The hot water storage test for the temperature and flow meters; the three phase lab test for the custom built electrical metering equipment and the single phase lab test for the Cloogy transmitter’s battery life cycle.

iHub solution integration testing

Testing of the iHub solution was performed using the test bed depicted in Figure 1. This test bed represents a model of the scenario that is deployed on the project’s pilots and is composed of the same components that will be deployed in the pilots:

- iHub device – acts as a concentrator/gateway for the communications with the field devices and as a data logger. This device delivers the collected data from the field devices to the data server;
- MBus to Modbus bridge – is a gateway to enable the possibility for the iHub device to read information from the heat meters installed on the field;
- iMeter – is an electrical meter, capable of reading several electrical energy related variables such as energy, power, voltage, frequency, power factor and others;

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- SMAAlert – is a device capable of controlling external devices by using its digital outputs. Despite not being used in the scope of the project, this device is also capable of generating alerts through the GSM network using SMS messages;
- I/O Module – is a device used for reading analog variables (4..20mA values) from external devices such as temperature probes;
- RTU Netmeter – is a device used for counting electrical pulses applied on its terminals. The pulse counting is transmitted to the iHub periodically;
- iPoint – is a set of devices (iPointTH and iPointCO2) used to measure the air quality, in terms of Temperature, Humidity and CO2 concentration.
- Data Server – Is the data server where the collected data is uploaded and stored to be accessed by the other Origin’s components by visits web services. The data server is connected to the iHub through its Ethernet interface, using an internet access.

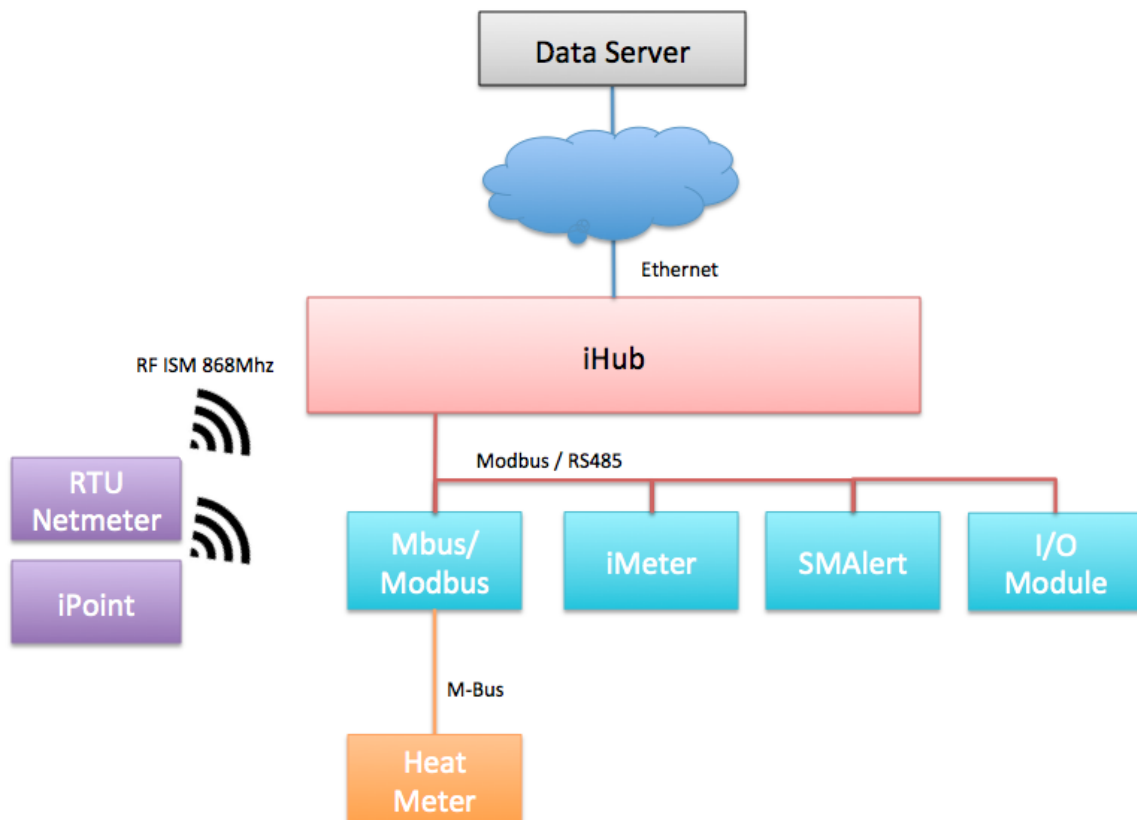


Figure 1 - iHub test bed for integration and communication validation

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The implemented test bed comprises several communication technologies to integrate all the components. As the iHub provides only two distinct communication channels with the field devices, the ISM 868MHz radio and the Modbus over RS485, all the other communication channels such as the M-Bus, the Analog 4..20mA or the pulse outputs must be adapted to any of the field communication channels of the iHub. Table 1 describes some of the possible protocol conversions to be used with the iHub solution to cover possible distinct variable types that can be found on the Origin pilots.

Table 1 - iHub protocol conversions

Device	Communication Protocol	Used Converter	iHub Channel
Heat Meter	M-Bus	Mbus to Modbus converter	Modbus / RS485
Temperature probe	Analog 4..20mA	I/O Module	Modbus / RS485
Gas Meter	Pulse Output	RTU Netmeter	RF ISM 868MHz
Water Meter	Pulse Output	RTU Netmeter	RF ISM 868MHz

Prior to the Origin project, distinct data platforms were used to handle iHub based solutions and Cloogy based solutions. As having a single data server, with a single API for the other project's components to interact, was considered a very positive point to have, the Cloogy data server platform was enhanced during the development phase of the Origin project to support both the solutions in use on the project: the iHub solution and the Cloogy solution. Although this implementation was heavily tested during the development phase (according to the ISA's certified quality processes), this testing scenario also had the purpose to validate the data server integration.

As no new hardware components were developed for the iHub solution on the Origin project, the main focus of the performed tests was to validate the integration with the 3rd party components and the integration with the data platform. The data platform had no capabilities of integrating iHub solutions before the Origin project, in terms of configurations provisioning and data collecting. In summary, tests performed in this test bed had the objective of the full validation of the integration of all the components in a single solution, capable of configuring and reading variables from all the installed devices and deliver the samples to the data platform.

The integration testing process was composed of the following steps:

Table 2 - iHub solution integration test steps

Test step	Description
1	Instantiation of the test bed, deploying the hardware according to the Figure 1 scheme
2	Configuration of the test bed hardware in the data server platform
3	Verification of the configurations committed to the iHub from the data server
4	Verification of the remote devices status on the iHub maintenance interface
5	Verification of the existence of data collected from the test bed devices in the data server

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The tests performed on this scenario demonstrated that the platform is well integrated as a whole and capable of accomplishing the specified monitoring in the project’s pilots.

Cloogy solution integration testing

For the Origin project, several enhancements and upgrades were performed on the basic Cloogy solution (also known as “off-the-shelf” Cloogy solution) during the development phase to meet the monitoring requirements specified for the project. The basic Cloogy kit, which is sold by ISA as a commercial product, is composed of the following hardware components:

- A Cloogy hub, capable of communicating with field devices using Zigbee 2.4GHz
- A current transmitter to be used with a single phase/circuit, using Zigbee 2.4GHz communications
- A power plug using Zigbee 2.4GHz communications

In terms of hardware enhancements performed on the Cloogy solution to meet the Origin project requirements, we can note:

- Enhancement of the Cloogy hub hardware with an ISM 868MHz radio in addition to the pre-existent Zigbee 2.4GHz radio, capable of communicating with the additional hardware components developed for the project. Although this radio uses the same ISM 868MHz, the communication protocol was developed to be more optimized and is not compatible with the iHub ISM 868MHz radio;
- Enhancement of the current transmitter to be capable of measuring three distinct single phase circuits using three separate current clamps;
- Creation of a new gateway from M-Bus to ISM 868MHz to read heat meters using the M-Bus protocol in the Cloogy solution;
- Creation of a new Cloogy Triple temperature reader device (RTU Tri-temp) capable of reading up to three temperature points to be used to measure water temperatures in hot water thermal tanks;
- Creation of a new Cloogy iPointTH device for measurement of air temperature and humidity with capability of battery powering or by optional external mains adapter;
- Creation of a new Cloogy iPointCO2 device for measurement of air CO2 concentration.

All the above-mentioned enhancements to the Cloogy solution, along with the implicit hardware design and firmware developments, the implied software support in the data server and the implementation of new features in the Cloogy data server will be used in the project. Only the

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Cloogy Power Plug remained the same as in the “off-the-shelf” version, all the other components used in the Origin project were developed or adapted specifically to meet the specifications of the project.

Although the available time inside the project was not abundant for the specification, development and production of the four newly designed devices and all the developed enhancements to fulfil the project’s requirements, as it is part of the quality processes of ISA, were fully tested inside the development process before any of the project’s devices were reproduced. No unit has been delivered to any Origin pilot without being tested by the production process. These test processes assure that the equipment delivered to the project all comply with the specifications as described in the project deliverable D2.1.

In order to assure that all the newly developed Cloogy components and enhancements work in an integrated way, a test bed was prepared in ISA’s labs composed by one device of each one of the solution components. Figure 2 depicts the implemented test bed, used for the Cloogy components integration validation as stated.

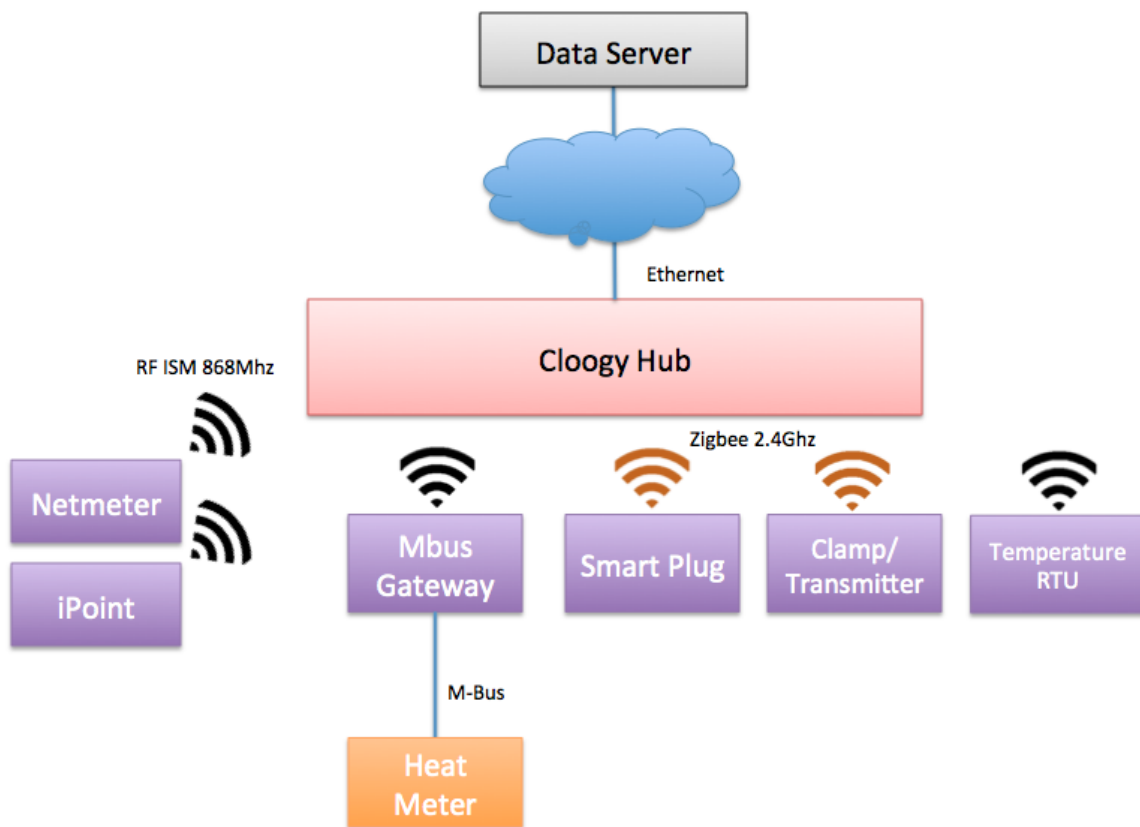


Figure 2 - Cloogy testbed for integration and communication validation

The test bed was composed of the following components:

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- Enhanced Cloogy Hub – Acts as a concentrator/gateway for all the other components. This hub is fitted with both Zigbee 2.4GHz radio (acts as a Zigbee network coordinator) and the newly developed ISM 868MHz radio. It also connects to the data server using a wired Ethernet connection;
- Cloogy Netmeter – Counts electrical pulses applied to its inputs and transmits the count to the Cloogy Hub at pre-specified time intervals. This device’s functionalities are similar to the ones found in the iHub’s RTU Netmeter, but using the improved version of the ISM 868MHz radio (which is incompatible with the iHub version);
- iPoint – It is a set of devices that can be used to measure air parameters such as temperature, humidity (by the iPointTH) or CO2 concentration (by the iPointCO2). These devices have similar functionalities as the iHub’s iPoints but using the improved version of the ISM 868MHz radio (which is incompatible with the iHub version);
- Mbus Gateway – This is a device used to read the M-Bus interface available on the Origin’s heat meters. This device is capable of reading the heat energy, water flow, hot temperature and cold temperature. It transmits the acquired samples using the ISM 868 MHz radio.
- Smart Plug – This is the smart plug used to measure electrical appliances consumptions (energy, current, voltage, frequency, power factor, ...) with capability to actuate it. The smart plug uses the Zigbee 2.4GHz network to communicate with the Cloogy Hub;
- Current Clamp/Transmitter – This device is used to measure the consumptions of up to three single phase circuits of one triple phase circuit. The device communicates with the Cloogy hub using the Zigbee 2.4GHz network.
- Temperature RTU – The temperature RTU (also named as Tri-Temperature RTU) is used to measure water temperatures inside thermal storage tanks. This device transmits data to the Cloogy hub using the ISM 868MHz.
- Data Server – This is the data server where the collected data is uploaded and stored to and can be accessed by the other Origin’s components via its web services. The data server is connected to the Cloogy Hub through its Ethernet interface, using an internet access.

After the test bed was assembled, the integration of the distinct hardware sensors was tested according to the following steps:

Table 3 - Cloogy solution integration test steps

Test step	Description
1	Instantiation of the test bed, deploying the hardware according to the Figure 2 scheme
2	Configuration of the test bed hardware in the data server platform
3	Verification of the configurations committed to the Cloogy

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	hub from the data server
4	Verification of the remote devices status on the Cloogy hub maintenance interface
5	Verification of the existence of data collected from the test bed devices in the data server

Hot water storage testing

The ORIGIN metering equipment being installed in the host communities (Findhorn, Tamera and Damanhur) contains several devices for monitoring domestic hot water use. Before this equipment is installed in the host communities it must be tested to ensure that the data being recorded is accurate and that it operates as expected when used in this application.

In order to test the equipment a hot water testbed rig was designed for installation in the University of Strathclyde DSM laboratory. This hot water rig was designed to emulate the systems used for hot water storage in the host communities. An overview of the system is shown in Figure 3.

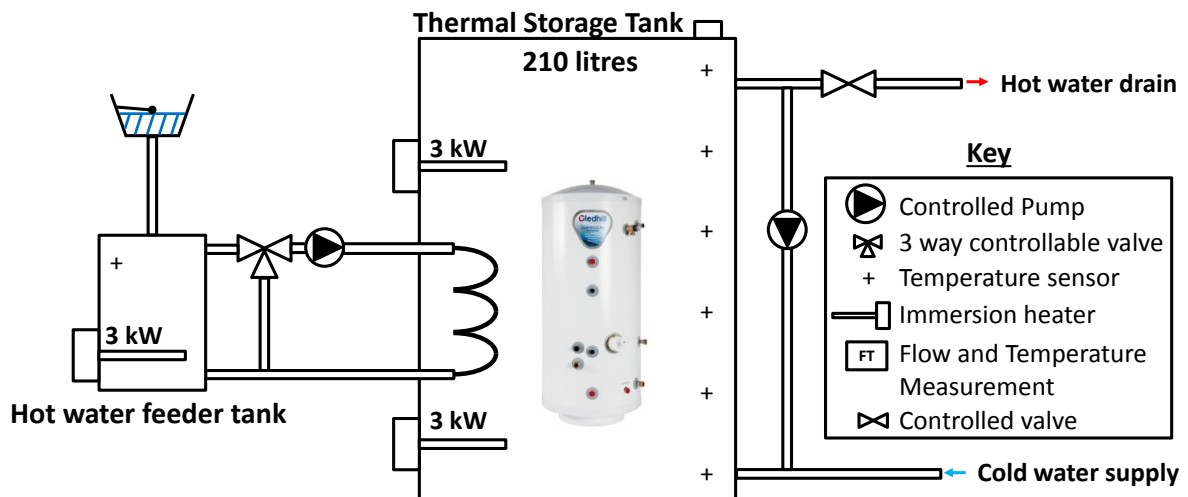


Figure 3 Hot water storage rig for laboratory testing of hot water metering equipment

All of the valves, heating elements and pumps will be controlled via a labview interface. The thermocouple temperature and flow meter inputs will be read into the labview interface and the recorded data will be used to inform the algorithm that controls the operation of the hot water rig. Labview allows the user to define a pre-set operating cycle so that the hot water rig will operate independent of user supervision over long time periods. This allows the user to pre-set a typical domestic hot water usage scenario, run it for several days and at the end of the cycle evaluate whether the monitoring equipment (that is being installed in the host communities) has operated correctly under expected operating conditions.

The hot water feeder tank emulates heating of the primary thermal storage tank from a solar thermal collector source. The solar resource available to heat the hot water feeder tank is emulated by controlling the immersion heater operating cycle via labview. The temperature sensor provides feedback to the labview algorithm with regards to the temperature of the water. The feed-in cycle from the hot water tank can also be controlled by actuating the three way valve and pump in combination. The three way controlled valve allows the user to mix the hot water feeder tank to maintain a uniform temperature in the tank or to heat the primary thermal storage tank. The pump

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can also be controlled to operate at different rates to emulate different types of solar thermal collector.

As in a typical modern domestic hot water tank there are two immersion heaters that can be used to ‘top up’ the temperature of the water when domestic hot water demand is high and/or on overcast days when there is negligible heating from the solar thermal collector. As with the installations in the host communities temperature sensors will be fitted to the primary thermal storage tank to measure temperature stratification in the tank.

The pump on the right hand side of tank allows the user to mix the water in the thermal storage tanks to ensure a uniform temperature throughout the tank. The controllable valve is controlled via the labview algorithm to emulate domestic hot water consumption.

Custom built electrical metering equipment testing

Other than the Cloogy monitoring equipment, the following equipment based on the iHub solution is also going to be installed in the host communities:

1. iPoint temperature and humidity sensor
2. iPoint CO2 sensor
3. Current clamps and multi-phase meter (iMeter meter solution)

As with the hot water monitoring equipment this electrical metering equipment will be validated before installation in the host communities.

The iPoint temperature and humidity sensor and iPoint CO2 sensor will be validated against existing temperature, humidity and CO2 sensors installed in the University of Strathclyde DSM lab. The test will also ensure that the equipment is capable of uploading the recorded data to ISA’s servers and that the data can then be viewed via the online web interface.

The iMeterRail Meter solution is designed to be used in the Soillse Boiler room to monitor multiple electrical phases. This meter is capable of monitoring several electrical parameters (as listed below):

- Energy
- Power
- Voltage RMS
- Current RMS
- Frequency
- Power Factor

The iMeterRail operates in conjunction with current clamps as shown in Figure 4.

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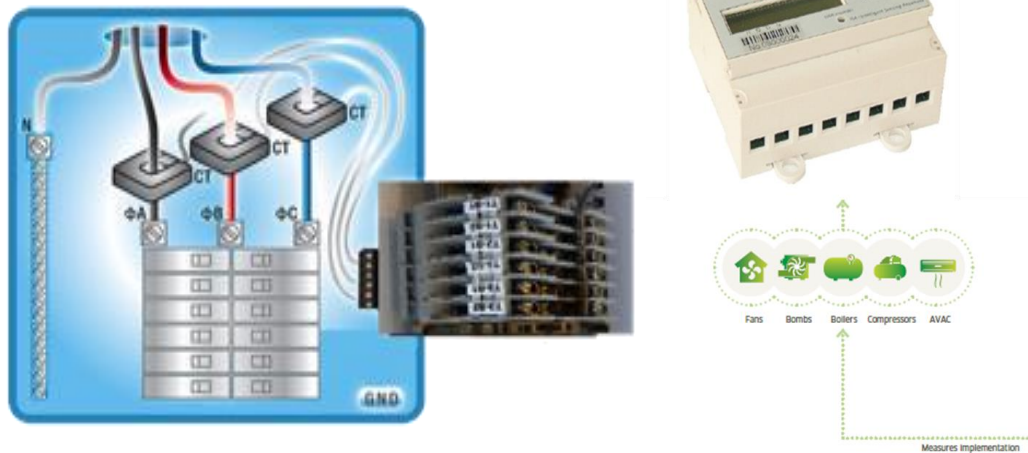


Figure 4 iMeterRail solution

The iMeterRail solution will be validated in the power electronics lab in the University of Strathclyde. The equipment will be tested under a range of loading conditions using secondary metering equipment to ensure that the device is accurately recording the relevant electrical parameters. This test will also be undertaken to ensure that the correct metering information is sent to ISA’s servers and that it can be accessed via the online web interface.

Cloogy battery life tests

The standard basic Cloogy home energy metering system [1], on which the Cloogy systems installed in the Origin project is based, is an off the shelf solution that allows home owners to measure their household energy consumption. As described in detail in this project’s deliverable D2.1, the Cloogy system employs a current transformer clamp based solution for metering energy consumption within homes. The clamp is connected around the neutral wire in the dwelling’s electrical meter box. A wireless transmitter analyses the currents consumed by the house, records the measurements made by the clamp and transmits the data wirelessly to a Cloogy hub using the low power wireless transmission technology Zigbee 2.4GHz. The hub is connected to the internet, usually by the usage of a broadband internet router, and transmits the data to an online data platform. The data platform has multiple channels to provide data to its end users such as a web based interface where the home owner can view the data from its household electrical consumptions. This platform also permits the integration with external or third party user interfaces (including mobile applications) by using its REST web service interface. An overview of the system is shown in Figure 5.

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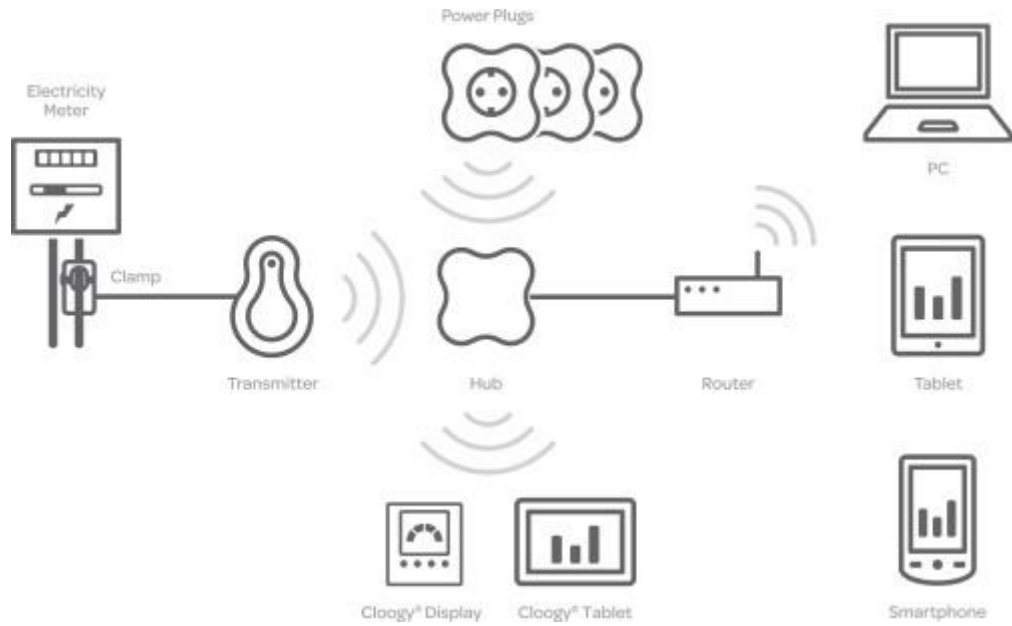


Figure 5 Diagrammatical representation of standard basic Cloogy home energy metering system

As happens with all the battery-based devices, the Cloogy clamp transmitter has a finite battery life. Ahead of installation of the Cloogy kit in the host communities it is necessary to determine the expected life of the transmitter to establish the frequency of battery replacement tasks and schedule access to premises to minimise disruption to both the collection process and the householders routine. In order to evaluate the battery life a Cloogy kit was installed in the Demand Side Management lab at the University of Strathclyde. The transmitter was connected to the neutral wire within the electric switchboard input to the lab as shown in Figure 6 and the hub was setup at a distance of 12 meters away from the transmitter within the lab (this is the maximum permissible distance within the confines of the lab) as shown in Figure 7. This setup emulates a typical household installation of the Cloogy home energy metering system.

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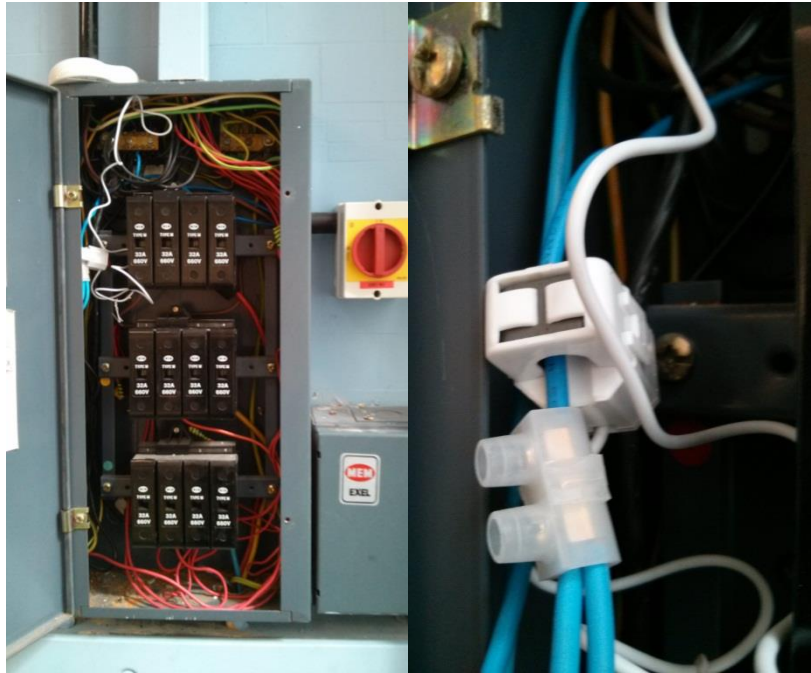


Figure 6 Transmitter battery capacity test



Figure 7 Hub lab setup battery capacity test

Configured in this way, the clamp monitored the total electrical consumption within the lab. The battery charge level within the transmitter was checked using a ZTS battery tester [2] once per week over the course of 43 days. Over this period the battery charge fell by 20% as shown in Table 4.

Date of battery level sampling	Remaining battery charge (%)
16/07/2013	40
23/07/2013	37
30/07/2013	33
06/08/2013	30
13/08/2013	27
20/08/2013	23
27/08/2013	20

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Table 4 Battery charge test

From the results recorded using the battery tester it can be assumed by extrapolation that the full batteries will power the Cloogy clamp for approximately 215 days. It is worth noting that during the test it was discovered that opening the Cloogy online browser interface prompts the transmitter to send data at an increased rate and this causes the batteries to be discharged at a faster rate. This increased rate of energy consumption may cause users within the community who regularly check their household energy consumption to decrease the life of their transmitters faster than those who do not.

The batteries supplied with the Cloogy transmitter are AA, 1700MAh capacity alkaline batteries and were partially discharged before the lab testing began. If required, the transmitter battery life could be significantly increased if the 1700mAH batteries were replaced with higher capacity batteries.

Tests regarding the accuracy of the Cloogy measurements were performed in the UK field test in a later section of this report.

Cloogy UK Lab Test

The Cloogy system was designed for use in mainland Europe which, despite having the same electrical system characteristics (both 230V at 50Hz)²³ have a different mains connector from the UK. While most problems associated with using a Cloogy in a UK domestic premises are likely to be circumvented using combinations of travel adaptors, testing this assumption prior to deploying to homes in the trial communities alleviates the need for potential troubleshooting in the field that could have been carried out in a lab environment. Figure 8 depicts the usage of travel adaptors for using the Cloogy power plug.

² Regulated by the european norm EN 50160 (in Britain BS 50160) - Voltage characteristics of electricity supplied by public electricity networks

³ UK electrical system characteristics legislation: <http://www.legislation.gov.uk/uksi/2002/2665/regulation/27/made>

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Figure 8 - Example of usage of UK/EU adapters for Cloogy power plug

Cloogy UK Field Test

The purpose of this test was to assess whether the Cloogy metering clamp represented the true value of electrical load on a given home incomer. It was decided to benchmark it against a similar system created by a UK company which is in widespread use.

The purpose of this test was to compare and benchmark the results of electrical load on a given home incomer, obtained by the Cloogy metering clamp with a similar home energy consumption monitoring system, created by a UK based company also having its products in widespread use.

AlertMe

AlertMe [3] is a hub/broadband based home automation and monitoring solution devised by Cambridge, UK based AlertMe Ltd. This technology works in a similar manner to the Cloogy in that it

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features a home hub that communicates wirelessly with various low power environmental and metering sensors positioned around a dwelling. The AlertMe home hub relays measurements taken from these to a cloud based storage facility via home broadband which can then be queried through a web interface by a variety of clients including the AlertMe range of in home displays and tablet and phone based apps. The AlertMe system is used as the basis for a web based heating controller marketed by UK energy provider British Gas as well as home monitoring platforms sold in the Netherlands and the US.

In the Findhorn community, a series of identical detached premises in a development known as Soillse will be participants in the ORIGIN project. These 6 properties have their domestic electricity meters all housed in a common outbuilding as shown in figure 4.



Figure 4 Soillse boiler room incomers in the Findhorn Community

This is convenient for testing activities as it removes the necessity of entering several premises to install or modify metering equipment. The seventh meter shown in figure 4 is for the outbuilding itself – the only loads in this building were wet appliances and lighting.



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Figure 5 Soillse boiler room AlertMe installations

Figure 5 shows the AlertMe current clamp transmitters set out on the floor of the boiler house – one transmitter was used per incomer with all data being wirelessly transmitted to a single AlertMe home hub and then forwarded via broadband to AlertMe’s cloud storage service. Data collected was accessible through AlertMe’s web based user interface or programmatically through a REST (REpresentational State Transfer) web service API.



Figure 6 AlertMe incomer clamps on Soillse incomers

Energy usage is measured in the AlertMe systems in the same way as it is for the Cloogy: non-invasively through a clamp based current transducer as shown in Figure 6.

Test acceptance criteria

In order for the solutions be considered apt for the deployment on the Origin’s project pilots, it is considered that some criteria must be met. In terms of hardware components, firmware of the hardware components and software developed by ISA, the quality process of the conception and development already establishes the needed criteria to ensure that all the specification and quality of the components is met. The equivalent happens with the production process of all the ISA’s components. All the conception/development tests and production tests must be passed with no exception for all the ISA produced hardware components to be assembled at the Origin’s pilots as part as the monitoring solution.

In terms of integration of the monitoring solution, all the components must be able to integrate together as expected in the final solutions. The integration tests, performed at both test beds assembled at ISA must indicate that all the components work together as expected. Also, the data server must be able to handle configurations and data from both the used solutions in the project (the iHub and the Cloogy solution).

Regarding the application tests some criteria parameters were specified to ensure that the solution is fit to fulfil some key field parameters. One of the important parameters is the battery life, so the battery life of the battery based devices, such as the Cloogy Current clamp which represents the most critical battery based component, should be long enough to minimize the impact and

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disruption on the dwellings where the devices are going to be installed. It is considered that a battery life should not be less than 4 months (120 days). Also the values provided by the Cloogy monitoring solution should be approximated to the ones provided by similar solutions such as the AlertMe. The sum-squared difference should not exceed 10% of the measured values.

The following table synthetizes the test acceptance criteria for the tests performed on the Origin monitoring solutions:

Table 5 - Test criteria acceptance table

Test	Performed tests	Acceptance criteria
Cloogy solution hardware components	Hardware and firmware tests performed during the conception and development process. Tests performed during the production process.	All tests passed
iHub solution hardware components	Hardware and firmware tests performed during the conception and development process. Tests performed during the production process.	All tests passed
Data server platform	Compatibility tests with both Cloogy and iHub solutions regarding configurations provisioning and data retrieval/storage	All test passed
Cloogy solution integration	Assembly of a Cloogy test bed with all the available components	Platform should be able to configure and read the variables from all the solution components
iHub solution integration	Assembly of a iHub test bed with all the available components	Platform should be able to configure and read the variables from all the solution components
Battery life	Battery life of the Cloogy Clamp transmitter	Battery life should be more than 120 days
Comparison of measured consumptions with similar solutions	Comparison of values of consumptions acquired by Cloogy with the ones acquired by AlertMe	Values from both solutions should have an error of less than 10%

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Laboratory and Field Test Results

This section describes the results of the tests performed to the solutions, described in the previous sections

Test	Acceptance criteria	Test results
Cloogy solution hardware components	All tests passed	All tests passed
iHub solution hardware components	All tests passed	All tests passed
Data server platform	All test passed	All test passed
Cloogy solution integration	Platform should be able to configure and read the variables from all the solution components	Configurations sent to hubs with success Data platform was able to read data from the devices
iHub solution integration	Platform should be able to configure and read the variables from all the solution components	Configurations sent to hubs with success Data platform was able to read data from the devices
Battery life	Battery life should be more than 120 days	Battery life tests estimated approximately 215 days of battery life
Comparison of measured consumptions with similar solutions	Values from both solutions should have an error of less than 10%	Values from both solutions had an error of less than 10%

Conclusion of the laboratory validation

The tests performed on the Origin's monitoring solution, composed by both Cloogy and iHub based solutions, demonstrated that the hardware components are compliant with the specifications needed for the monitoring of the Origin pilots, as described in the project's deliverable D2.1 and also that all the components are capable of working in an integrated way not only inside each one of the two distinct solutions (iHub and Cloogy) but also as a common solution to form a solid common monitoring platform.

In terms of applicability, the components under test demonstrated they are adequate for the monitoring of residential dwellings (for the case of Cloogy based solution) and community buildings (for the case of iHub based solution).

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Deliverable	D2.2 – Laboratory validation reports

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