Orchestration of Renewable Integrated Generation in Neighbourhoods

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D8.3 Replication Pack

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Table of Contents

1. Executive Summary

This document describes the whole process to follow in order to replicate the ORIGIN platform in other existing public spaces and communities. The ORIGIN project has followed a series of steps during its 3 years of development, including some initial analysis steps (audits, monitoring needs in the buildings and energy networks, detection of efficiency opportunities and shiftable energy loads); the identification of points of interest to generate energy efficiency outputs; definition, design and implementation of analysis and prediction modules; communication and control protocols for managing the energy grid; installation and commissioning in the communities; user-interfaces and user engagement; and the design and implementation of an ICT architecture to support all these services.

Throughout the project this process has been documented and reviewed with replication purposes in mind. A paper titled Orchestration of Renewable Generation in Low Energy Buildings and Districts using Energy Storage and Load Shaping was presented at 6th International Conference on Building Physics for a Sustainable Built Environment. This paper presents the overall approach taken in the ORIGIN project. We also now have an overall view of the steps to deploy the ORIGIN platform in other spaces. These steps have been shared at a workshop held at Findhorn on June 4th 2015 as part of the Harnessing Community Energies ORIGIN conference. Further workshops are planned in Tamera on 10th September and in Turin on 24th September to disseminate these steps more widely.

This document is structured as follows: section 2 introduces the ORIGIN concept and the possible replication routes; section 3 and 4 specifies the procedure to design and deploy the field equipment for monitoring and controlling the energy network according to the site needs; section 5 and 6 covers the high level platform, this is, the servers and software needed to enable the ORIGIN operation; section 7 and 8 describes the requirement for an end user engagement strategy and the metrics, interface, performance and review process and section 9 specifies the community-level business models available for the interaction between suppliers and consumers, focusing on structure and pricing.

2. Deploying the ORIGIN platform

2.1. Current System

The current ORIGIN energy management system provides Findhorn, Tamera and Damanhur with an energy management tool to monitor and orchestrate energy consumption and generation at a community and household level. Communities and their residents can:

- shift and/or save energy demand,
- increase the share of environmentally friendly and/or local electricity generation
- optimize the cost-benefit relation for their community energy supply system

In the first year of the project the energy networks of the 3 communities were mapped (milestone 1) and the hardware and monitoring kit identified through an energy audit process was installed /ready to be installed (milestone2). In year 2, the communities' energy use was monitored (milestone 3) and the prediction and control algorithms were developed (milestone 4). In year 3, the full energy control system has been functioning (milestone 5).

As detailed in D5.8, the ORIGIN architecture can be split into macro functional modules and some or all of these modules can be implemented in a future system. The ORIGIN energy management approach is configured to serve energy supply and energy demand services for communities, clusters of buildings as well as private customers and small commercial customers. The services are based on IP containing algorithms for prediction of demand and supply as a basis to allow for optimization of energy management actions across the considered energy networks.

2.2. Future System

To use ORIGIN in a new location then it is important for the community to understand what they want to achieve from the system and then look at the economics of the different scenarios detailed in D5.8 and choose the scenario that meets their needs.

Scenario 0 – Standalone optimisation

Scenario 1- Basic monitoring

Scenario 2 – Basic informational system

Scenario 3 – Actuated system

For the purposes of this report we have detailed the replication process for scenario 2 and 3 as scenario 0 and 1 are a subset of scenario 1. In deliverable 7.5, a number of possible business models were identified for the ORIGIN system. Scenario 2 replicates the demand response informational system business model. Scenario 3 corresponds to the demand response actuated system.

A SWOT analysis was performed in D7.5 and the informational demand response business model was the first ranked although the actuated system was not far behind and may be more suitable in new communities where disruption due to installation of monitoring kit can be minimised.

For the different scenarios, the following chart highlights the necessary steps in the replication process. The starting point for a community is to decide on which scenario they would like to adopt and this will be decided based on a number of considerations which include costs, grid set up, availability of local renewable energy and community preferences.

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
	Stand alone optimization	Simple monitoring	Informational System	Actuated System
Audit				
Hardware specification				
Software specification				
Hardware installation				
Software installation				
user engagement strategy				
Metrics and interface				
Performance and review				

Key:

	Required
	Not required

3. Auditing the new location

The audit process is detailed in D1.1 and in the section below. The templates in D1.1 can be used to gain the required building level information and from this the required equipment for measuring household consumption can be established and load shifting opportunities can be identified.

The first step to establish the ORIGIN Platform in a new location is the local auditing phase. For the advanced monitoring module mentioned in D5.8, this is performed ideally in each of the buildings or dwellings of a community. For the Basic monitoring module mentioned in D5.8, this might only be performed for strategic dwellings or the community as a whole. This auditing establishes the foundations for the planning and deployment of the monitoring system. This auditing must be performed locally by a person that has a good understanding of the ORIGIN Platform as a whole, including the available technologies and new technologies that can be added/integrated into the monitoring system.

During this phase the main objective is to identify the valuable monitoring points that could lead to good inputs for the optimization system. The auditor must survey the electrical loads of the building and their characteristics. With the help of the responsible person or owner of the audited building/dwelling, the auditor should also try to understand and evaluate the usage profile of each appliance/load and assess their energetic share in the building/dwelling consumption. In summary, for the monitoring survey of the audit the key points are:

- Identify the main electrical appliances and their characteristics;
- Identify the main thermal loads and their characteristics;
- Understand the usage profile of the identified electrical appliances and thermal loads;
- Assess the energetic impact of each electrical appliance and thermal load;
- Indicate the potential monitoring points in the building/dwelling.

The most common items to be monitored are:

- Electrical monitoring
    - Main feed from the electrical supplier;
    - Any generation source that might be available such as solar PV panels or wind turbines;
    - Sub-monitoring of distinct relevant circuits (e.g. lighting, sockets, air conditioning, etc.);
    - Monitoring of specific high-consumption appliances such as washing machines or dish washers
    - Monitoring of electrical heaters
- Thermal monitoring
    - Any thermal source available such as boilers or solar thermal panels;
    - Thermal storages in terms of storage temperatures in several points at different heights if possible;

    - Thermal consumptions from the thermal storage to the distinct systems such as floor heating, air heating, sanitary water supply.
- Comfort monitoring
    - Air temperature and humidity at relevant rooms or points;
    - Air CO_2 concentration

Other variables, not present in the list above, can also be monitored and should be studied if they are relevant to the energy consumption optimization or if it might represent a good input to the ORIGIN optimization system.

Alongside the monitoring point survey, the auditor must also evaluate the points where the installation of actuators is possible and may represent a potential control point for automated load shifting controlled by the ORIGIN Platform. Appliances that might potentially be controlled manually/scheduled by the user, such as electronically controlled washing machines or dishwashers that do not permit starting by simple actuation on their power supply, should also be considered in this survey as the ORIGIN Platform permits the issuing of messages to its users to highlight appliances that maybe turned off/on. In the control evaluation the auditor should consider the following key points:

- Identify and characterize potential points to install actuators to be used for automated load shifting.
- Identify and characterize potential points to be controlled by the user.
- Identify any limits and constraints to be considered when performing automated load shifting imposed by the controlled appliances and/or their users.

The most common points to apply actuators are:

- Washing machine
- Dish washer
- Immersion heaters for hot water thermal storages
- Electrical motors and pumps
- Air conditioning and heat pumps
- Electric vehicle charging stations

Another important aspect to consider during the field audit is the availability of a reliable broadband Internet connection at each site. As stated in section 5 “Setting up the platform core”, the recommended ICT architecture places the Field Devices Server outside the community. The ORIGIN Platform will require Internet connection to achieve its objectives of energy monitoring and optimization, so the existence of Internet connection is mandatory. If the Internet connection is not available, the auditor must ask for the building owner/responsible to install an Internet connection before the installation phase of the ORIGIN equipment. In terms of requirements for the Internet connection the minimum specifications are:

- Permanent and reliable Internet connection;
- Minimum upload and download speed of 256kbit/s;

- Minimum monthly data volume is dependent on the number of devices but should not be less than 500MB/month;
- Availability of wired Ethernet LAN Internet feed for the data concentrator/hub;
- Possibility of establishing an outbound TCP connection over IPv4 to the ORIGIN server on the cloud.

The auditor should also pay special attention to the restrictions that may impact the installation of the ORIGIN devices. For example, there might be restrictions of available space on the electrical boards, restrictions on the distance that the wireless devices may be positioned to remain in the communication range of the data concentrator or other legal restrictions that may exist in the country.

After the field audit, in order to simplify the planning and deployment phases and as it is very common to find similar buildings/dwellings in a community, buildings or dwellings with similar characteristics should be grouped together. This grouping permits that instead of needing one installation plan for each community building/dwelling; a single one can be performed per group type and applied to all the buildings/dwellings of the group. Also, if the auditor cannot perform the auditing visit to a specific dwelling (e.g. the dweller was away during the audit period) it is possible to apply with a high degree of confidence an installation plan for the group of dwellings where the specific dwelling belongs. Fig. 1 shows a grouping example, where there are 2 main groups (actuated and not actuated buildings). For the first group there are 3 sub-groups defined by their appliances, size, floors, domestic hot water systems or space heating technologies.

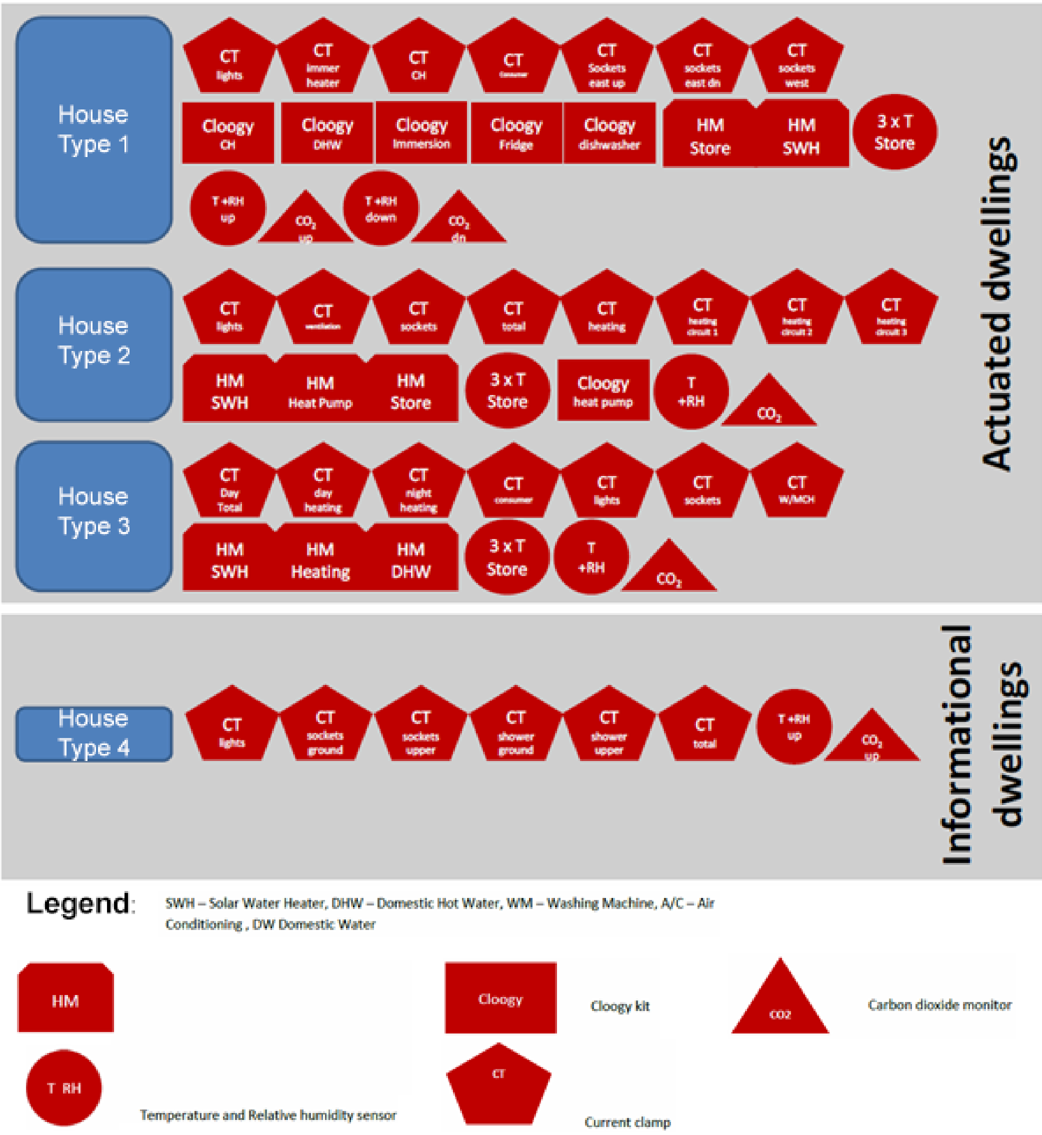


Fig. 1: Example of telemetry grouping.

Typically a full audit of a simple dwelling can take from 10 to 20 minutes. For more complex buildings (usually the main community buildings) the audit can be longer and take 1 hour or more depending on the complexity of the electric circuits. For complex buildings, diagrams of the existing circuits are useful for the auditor to help in the audit itself and potentially also during the planning of the installation.

For the ORIGIN Platform to be as accurate as possible in its energy generation and demand prediction, a local weather station may be required to be installed if there is not sufficient weather data available locally. If this is the case, the auditor should find a suitable location for the installation of a weather station. In general terms, this location should be

- as close as possible to the monitored community;

- ideally, in an area with a radius of 30 to 100 meters without major obstacles; (trees, buildings etc.) to obtain more representative wind data;
- Unshaded during the full daylight period for better solar radiance data quality;
- easy to access, as some of the measurement devices may need periodic maintenance to be performed.

4. Installing and commissioning of field equipment – hardware installation

After the auditing process of the community, the next step is to prepare an installation plan to be applied to each one of the community buildings and dwelling groups. During this process, the monitoring and actuation requirements obtained from the local auditing phase are translated to specific monitoring and actuation devices that accomplish the proposed objectives. The ORIGIN monitoring and actuation system devices enable the possibility to monitor or actuate the most relevant variables that might be considered on most building and dwelling energetic systems. However, if a relevant system could not be monitored or actuated with the existent and tested devices, new third party sensors and actuators can be procured and integrated into the ORIGIN monitoring and actuation platform.

In its essence, this installation plan should contain the details of which electrical and thermal circuits will be fitted with sensors (e.g. electrical circuits or appliances, thermal storages, sources or loads) and also which appliances or circuits will be fitted with automated actuation mechanisms. For each one of the specified circuits or actuation points, a specific device should be appointed for the purpose.

With the installation plan finished, it is possible to proceed to the procurement and buying of all the needed devices to be installed on the site. Along with the device procurement it might be also necessary to use certified local technical teams (electricians and/or plumbers) to assist and/or perform some of the installation tasks. Although it is possible for a lay person to install most of the domestic devices in their dwellings, it is recommended that this task is performed by the technical teams arranged for the installation tasks. The selected electricians for the technical team should be able to install the electrical monitoring devices in the buildings/dwellings and also be capable to perform the needed connections of the communication interfaces of the wired sensor devices (such as the electrical meters). For the installation of some of the thermal monitoring devices, such as heat meters, it is necessary that this task is performed by a plumber, as it is necessary to cut water pipes and fit the meter in the hot water/heating circuits.

The existence of a local person responsible in the community for the deployment and maintenance phases is mandatory. The profile of this person should be technical and he/she should ideally be able to assist the technical teams during the deployment phase. The responsible person should act as the go-between for the ORIGIN team and the local technical team and be responsible for gathering and maintaining all the installation reports (indication of the installed equipment identification and needed configuration elements). The local responsible person should also be in charge of establishing an accurate deployment action plan/schedule according to the specified installation plan with the local technical teams and ensure the follow-up of the action plan.

Depending on the capabilities of the chosen installation technical teams, it might be valuable to offer a small technical training session. In this training session, provided by an ORIGIN member with deep knowledge of the ORIGIN monitoring platform, all the devices' characteristics and their installation procedures are described in detail to the technical teams. The duration of this training session depends on the experience of the technical teams, but is likely to last one to two working days.

After all the devices are bought and ready for the installation and the technical teams are also ready for the deployment phase, the installation work may begin according to the established deployment action plan. Installation reports should be delivered to the ORIGIN team after the end of the installation of each community building or dwelling. This installation report does not need to follow a strict format but should contain all the needed information for the installed monitoring devices and data concentrators to be provisioned into the monitoring data server. It's very useful to include in these reports the "Device Deployment Report" which lists devices and installation details for each hub (shown in Fig. 2). This template generates CSV installation files, which can be used at a later stage with the ORIGIN testing tools for commissioning purposes (see section 5.1.3).

ORIGIN concept

ORIGIN-Project

Template for device deployment lists generation

COOPERATION

City / Area	Tamera
Location / device name	1: Stirling Machine & Solar Kitchen

Hub Type	iHub
Hub ID	7777-1184-3996-7238-6804
MAC	00-04-A3-22-71-80
IP Address	192.168.200.2

Generate CSV file

Name	**ID**	**Description**
iMeter Rail	216	
CT 1	217	Current transformer for phase 1
CT 2	218	
CT 3	219	
RTU NetMeter	220	
RTU SmartLogger	221	
RTU TempSensor	222	
RTU Mbus Conv.	223	
Temp Sens	224	
Reed Switch	225	
iMeter Rail	226	
CT 1	227	
CT 2	228	
CT 3	229	
RTU NetMeter	230	
RTU SmartLogger	231	
RTU TempSensor	232	

Fig. 2: Device Deployment Report for a hub installed in a building.

In order to maximise the early detection of deployment and field configuration problems, the installation reports should be phased in when the installations are completed as they trigger the setting up of the devices on the ORIGIN data server. Once set up, the data collection of the installed sensors can be started and any errors corrected.

At the final phase of the deployment phase, after the field devices are installed and configured, an ORIGIN member should perform a commissioning visit to the community. The main objective of this commissioning process is to ensure that everything is operating according to plan. During this visit, the ORIGIN member, in conjunction with the local community representative, if possible, should check that all the devices are installed according to specification and that their data is being collected without problems to the ORIGIN data server in the cloud. If a problem is detected during this visit, it should be solved or scheduled to be solved by the installation technical team.

For facilitating the assistance, troubleshooting and maintenance tasks it is recommended that remote network access is provided from the ORIGIN team to the community's network where the field units (iHubs and Cloogy hubs) are connected. Remote access permits that, when any problem occurs in the field devices or units, the ORIGIN technical team can quickly perform remotely a set of tests to diagnose the problem and, if possible, solve it also remotely without the need of sending a person to the community with all the inconveniences associated (delays and costs). The remote access can be provided by a VPN (virtual private network) access or alternatively by a remote desktop or shell (e.g. ssh) access to a computer in the network of the units.

5. Setting up the platform core – software installation

The ORIGIN Community Energy Management System (CEMS) is composed of a group of functional modules which when combined brings the full functionality of the ORIGIN system. As functional modules, they can be physically implemented in many different final hardware configurations depending on the requirements. The original ORIGIN pilots were built into 3 physical servers:

- Field Devices Server: for managing the field devices (ISA Cloud).
- Attached Modules Server: for the high computing modules (forecasting and predictions).
- Core Server: for the ORIGIN core, database, communication and interfacing, and the User Interface webserver.

For new deployments, the ORIGIN CEMS could be installed in a server into the community. This solution requires a good technical maintenance service, carefully dimensioned equipment and a professional Internet access with a high upload bandwidth. For most cases, internalizing this server maintenance is inefficient, so other solutions such as a hosting service is recommended. A hosting service has to provide the storage, computing and bandwidth requirements for the new community. Once arranged, the host manages the server maintenance and offer a Service-Level Agreement which outsources these responsibilities and provide a high quality service with very competitive prices. The Field Devices Server can also be managed internally by the communities, but it requires management efforts to keep all field devices updated and working, so this is a candidate server to be outsourced. ISA offers very competitive prices for managing this server, with a pricing plan based on the number of installed hubs.

For associated communities there is also the possibility of sharing these servers. The ORIGIN CEMS support several communities in a common platform, sharing storage and computing resources. This schema uses the available resources more efficiently and greatly decreases the management costs.

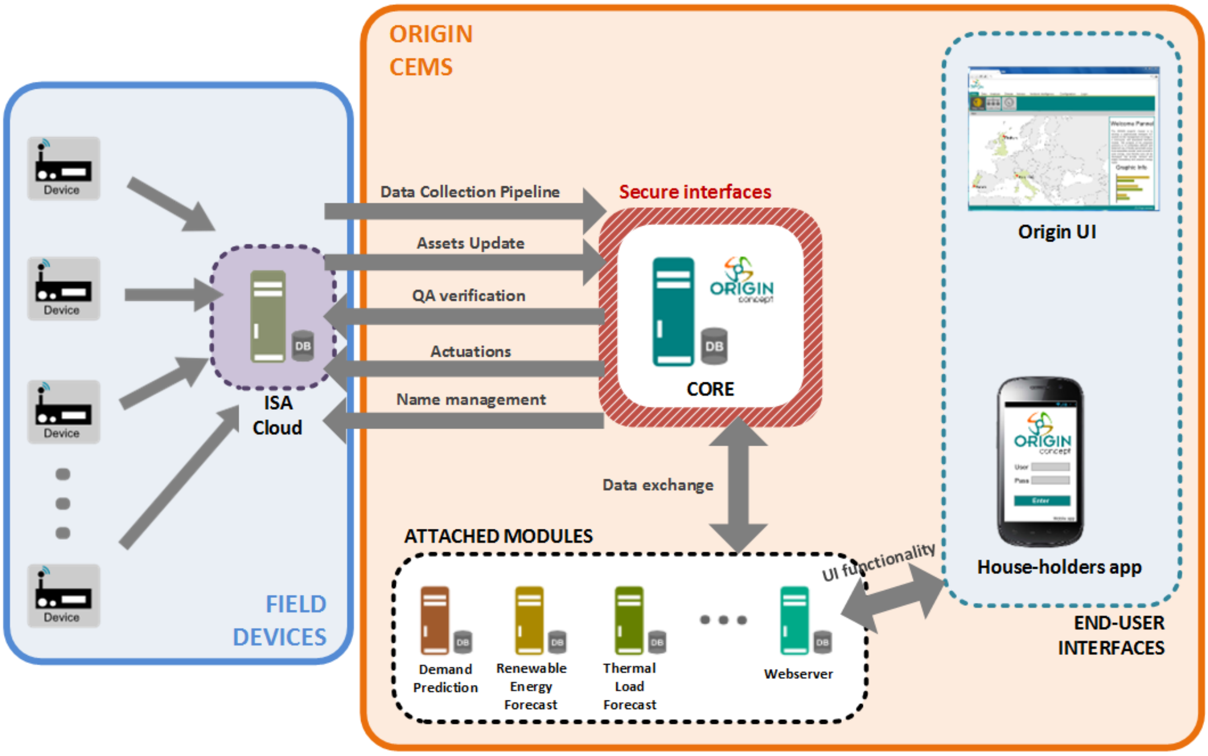


Fig. 3: ORIGIN platform high-level architecture

5.1. Field Devices Provisioning

5.1.1. Configuration in ISA Cloud

After defining the servers' infrastructure and installing the ORIGIN platform, all the devices should be recorded onto the "Field Devices Server", (likely to use the **ISA cloud**), by using its back-office pages. The platform back-office is a web-based interface that permits the recording of the different buildings or dwellings and the equipment installed. Fig. 4 depicts an example screen of the data platform's back-office showing the status of a number of units.

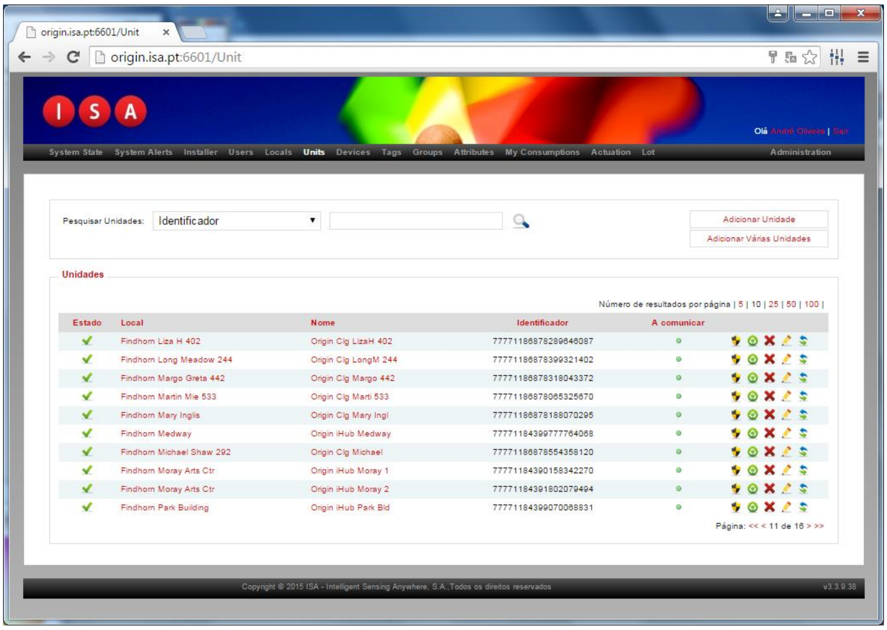


Fig. 4: Data Platform Back-office interface

The data platform's back-office uses a comprehensive hierarchical scheme to record the field devices that facilitates understanding and access to any of the installed field variables. The main entities detailed in the back office are presented in the following list, ordered from the broader element to the finer and more detailed ones:

- Local – This entity represents a 'local' on the field. It might represent a single building or dwelling of the community. In some cases it may also represent a distinct zone of the community. Each local may have a number of units associated with it;
- Unit – The unit entity represents a data concentrator, which is in most cases an iHub or Cloogy Hub. The unit may belong to a specific local and may have a number of devices associated with it;
- Device – The device represents a monitoring device, such as an electrical meter or a temperature/humidity sensor. Devices are associated with a specific unit and may present a number of tags;
- Tag – This entity represents a single measurement variable obtained from the field. The tag is the entity that contains the data collected from the field. This entity is associated with a device.

Each one of the listed entities present specific properties that must be configured during the recording process, the most relevant properties for each one of the entities is shown on the next list:

- Local
    - Local name (e.g. Findhorn A Smith house number xxx);
    - Zip code (e.g. IV36 3TZ);
    - Country (e.g. United Kingdom);
- Unit
    - Unit type (e.g. Cloogy Hub);

    - Unit name (e.g. ORIGIN Clg A Smith);
    - Unit serial/ID (e.g. 77771186878554358120);
    - Server address (e.g. ORIGIN.isa.pt:6603)
    - Local service webpage credentials (e.g. admin/password)
- Device
    - Device type (e.g. Cloogy Transmitter 3 Phases);
    - Device name (e.g. Consumer unit 1);
    - Device serial/ID (e.g. 3ZUVF7C3JVXBM0)
- Tag
    - Tag type (e.g. Apparent Energy Phase A);
    - Tag name (e.g. Immersion heater);
    - Tag sampling rate (e.g. 5 minutes);

When a unit recorded in the platform connects to the data server, it will be supplied with the configurations of the unit itself and of all the devices and tags that were connected to it previously in the back-office. For most of the field devices, the only needed configuration is performed at the back-office level and no configuration tasks are needed at field level. However, for some devices like the ones based on Modbus communication interface, some configurations need to be applied locally and matched at the back-office level.

In the platform back-office it is possible to check if the configurations have already been deployed to a specific unit and also if there are some field devices that are not providing valid data as shown on Fig. 5. It is also possible to perform some administrative operations on each unit such as issue a reboot or force the re-sending of the configurations.

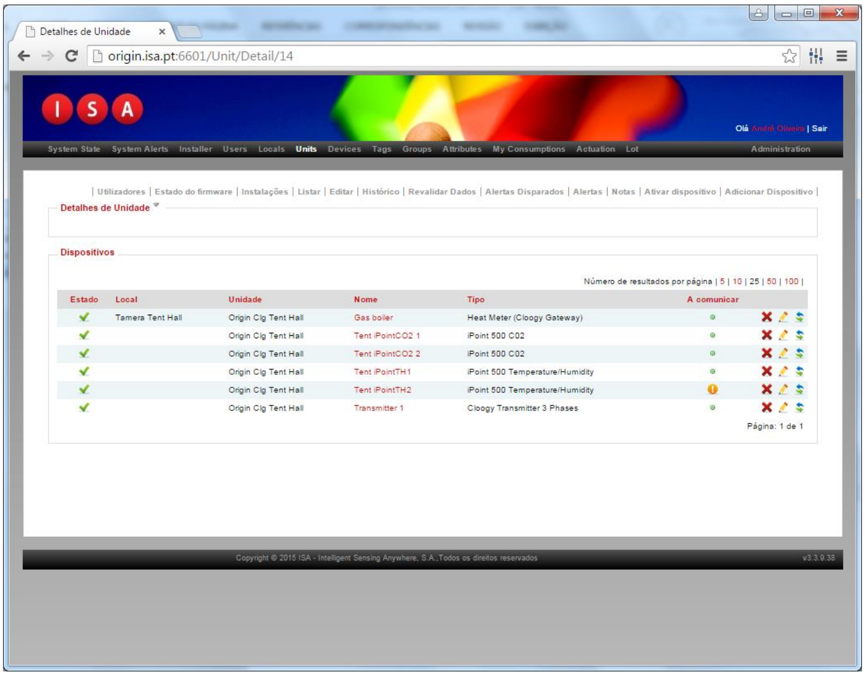


Fig. 5: Back-office view of a unit devices showing one device not providing valid data

It is also possible to inspect the collected data for each one of the configured tags (variables) for each device and validate if the collected data is within the expected value ranges and if data collecting is being performed with no failures. Fig. 6 shows the back-office view of the data collected from a specific device.

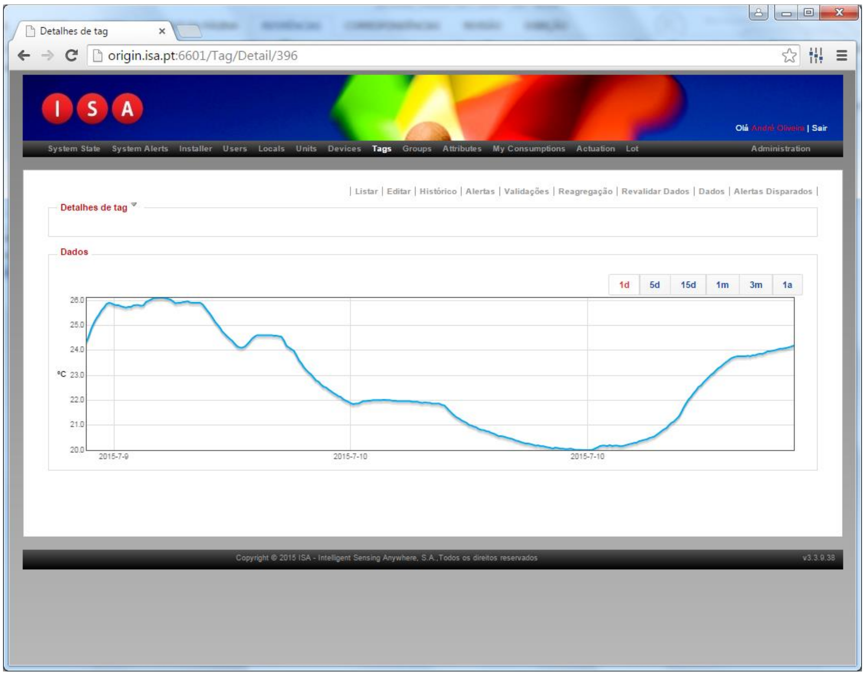


Fig. 6: Back-office view of a tag's data

As stated previously, in order to enable early detection of installation problems, it is recommended that installation reports are provided progressively to the ORIGIN team by the installer team as soon as a local or unit is installed in the field. This way, if any problem is detected after the unit is recorded and configured it can be quickly reported to the installer team so the problem can be solved. The installation reports should contain the essential information that enables the unit and devices to be correctly provisioned into the platform. The following list denotes the minimum parameters that the installation report must contain:

- Identification of the local of installation (e.g. name of the community building or dwelling owner);
- Identification of the installed units (e.g. unit serial numbers and a friendly name to easily identify the unit or where the unit was installed inside the building/dwelling);
- For each installed sensor/device:
  - Type of device (e.g. iHub Temperature/Humidity sensor, Cloogy Plug, etc.);
  - Unit where the device is connected;
  - Device Identification (e.g. serial, ID or Modbus/mbus id)
  - Identification of where the device is installed inside the building/dwelling
  - Identification of what is being measured in each device variable

5.1.2. Configuration in ORIGIN Core

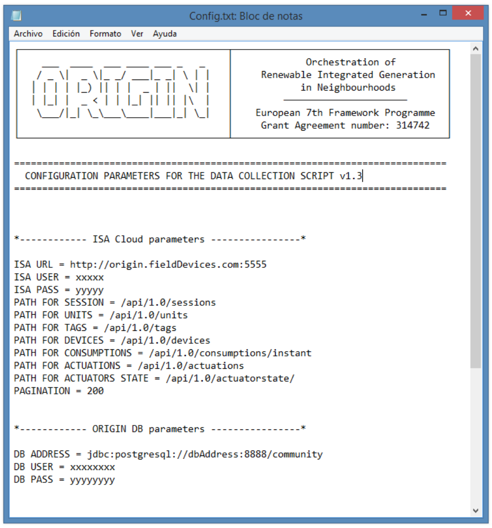
At this point the Field Devices Server is working and collecting data from the field devices, but this data is stored locally and is still not available in the ORIGIN CEMS. ISA cloud acts as an independent collecting and management server which deals directly with the field devices, working isolated from ORIGIN CEMS. This architecture works as an intermediate buffer and brings a common homogenous method to interact with field devices, adds a degree of security and backup, and separates the management tasks between "field" and "IT platform". Then, ORIGIN CEMS gets the telemetry data and adds value with the internal analysing modules.

The first step is to configure the connectivity details to bring up the communication channels between the Field Devices Server and the ORIGIN CEMS. As stated in Fig. 3, there are five modules interacting between both systems:

- **Data Collection Pipeline**: Retrieves new measurements for each sensor. It is executed periodically each 30 minutes by default, and gets new measurements from the Field Devices Server, using the last reading timestamp for each sensor.
- **Assets Update**: The Field Devices Server is the single management point for buildings and devices. Any device added or removed from this server will be propagated through the Assets Update module to the ORIGIN core on a daily basis. Once the asset is configured in the Field Devices Server, it can't be modified, because the only allowed actions are addition and deletion of assets. If a critical modification is required, the asset should be deleted and created again.
- **QA verification**: checks the assets library in the Field Devices Server, and performs various quality tests to check their correct operation.
- **Actuations**: module for executing automatic actuations (switching loads on/off) in the community, according to the orchestration decisions from the ORIGIN platform.
- **Name management**: similar to the Assets Update module, this module operates in the opposite direction. Users have a limited amount of managing actions over the field devices and houses from the ORIGIN User Interface, a non-disruptive management more focused in changing names and descriptions (an information only used by end-users). These changes are propagated to the Field Devices Server through this module.

The configuration for these modules is stored in 2 configuration files:

- **Config.txt**: main configuration file. It contains the connectivity information for these five modules, this is, the configuration for each end of the generated pipelines between the Field Devices Server and the ORIGIN Core. Here the responsible person will define the address of the Field Devices Server, with its credentials and ways to work with the ISA Cloud API. It specifies the address to the ORIGIN database, which can be installed in the same server or in a different location, and its credentials. There are other configuration parameters in this file such as paths for configuration files or logs, which can be easily configured.



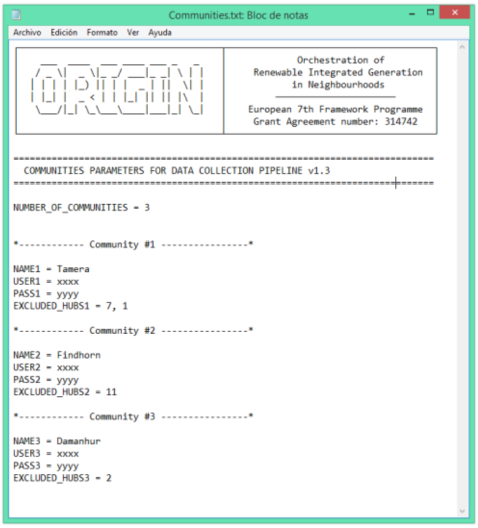


Fig. 7: Left - Main configuration file. Right - Configuration for communities.

- **Communities.txt**: this file lists the communities supported by this ORIGIN CEMS (one or more). This file contains the name of the community, credentials for accessing the Field Devices Server for this community, and a list of excluded hubs. Excluded hubs are those with no relevant telemetry information for the platform, such as communication hubs in the network backbone, hubs without sensors, etc. If the platform supports more than one community, the number of communities must be specified in this file, as well as an entry for each community with all this information.

All modules with periodic execution have configured a default execution period. This is managed by the CRON daemon in the ORIGIN core, so this period can be easily modified if needed. Anyway all the periods are defined to interoperate efficiently between the different acquisition and analysis modules, so this action is not recommended. This CRON configuration includes email address for reporting execution errors, so the supervisor mail should be written here.

```
origin_iti@itl:~$  sudo crontab -l
# ===========================================================
#             CRONTAB SCHEDULE FOR ORIGIN PLATFORM
# ===========================================================
#
# Please don't modify this file. This configuration is set by
# the supervisor and any change can impact negatively in the
# system's performance.
#
# m h  dom mon dow   command
#
MAILTO="supervisor@origin-energy.eu"
10 * * * * /var/DATA/DCpipeline/DCpipeline.sh
40 * * * * /var/DATA/DCpipeline/DCpipeline.sh
00 01 * * * /var/DATA/DCpipeline/findNewDevices.sh
05 00 * * * service ntp restart > /dev/null
00 02 * * 7 /var/DATA/DBbackup/bin/dbbackup.sh
MAILTO=""
00 00 * * * /var/log/nginx/report.sh
*/5 * * * *
/var/DATA/www/originui/portal/ActuationScript/launchActuation.sh
```

Fig. 8: Left - Main configuration file. Right - Configuration for communities.

Finally, both telemetry servers (Field Devices Server and ORIGIN Core) must agree on the available type of measurements or type of sensors. This list can be managed directly in the ORIGIN database, and will contain all the types of installed sensors. The snapshot in Fig. 9 shows the default types list. The "*type_id*" column must fit the type ID code from the Field Devices Server, as well as the "*measurement_units*". Please pay special attention to magnitudes. It's a common mistake to swap between kW and W, m^3 and litres, or even between metric and imperial units. The "cumulative" column indicates if a measurement is instantaneous (as power or temperature) or cumulative (as energies, consumptions in general or costs). This is used for the "Monitoring" section of the ORIGIN User Interface, for managing the charts in a more intuitive way for end-users.

type_id	description	measurement_units	cumulative
12	Relative Humidity	%	
11	Battery Level	%	
123	THD Current Phase C	%	
122	THD Current Phase B	%	
121	THD Current Phase A	%	
120	THD Voltage Phase C	%	
119	THD Voltage Phase B	%	
118	THD Voltage Phase A	%	
160	Battery Level Error	%	
56	Temperature Probe 2	C	
55	Temperature Probe 1	C	
54	Temperature Probe 0	C	
57	Temperature Cold	C	
58	Temperature Hot	C	
115	Temperature Hot 4	C	
110	Temperature Cold 4	C	
114	Temperature Hot 3	C	
109	Temperature Cold 3	C	
113	Temperature Hot 2	C	
108	Temperature Cold 2	C	
117	Temperature Hot 6	C	
116	Temperature Hot 5	C	
112	Temperature Cold 6	C	
111	Temperature Cold 5	C	
86	Apparent Power Phase C	kVA	
85	Apparent Power Phase B	kVA	
84	Apparent Power Phase A	kVA	
1	Carbone Dioxide Concentration	pH	
10	Active Power Total	kW	
73	Active Power Phase C	kW	
74	Active Power Phase B	kW	
72	Active Power Phase A	kW	
31	Status On_Off	status	
149	Operation Mode	status	
21	Power Factor	na	
77	Power Factor - Phase C	na	
76	Power Factor - Phase B	na	
75	Power Factor - Phase A	na	
61	Channel 2	na	
60	Channel 1	na	
59	Channel 0	na	
66	Channel 7	na	
65	Channel 6	na	
64	Channel 5	na	
63	Channel 4	na	
62	Channel 3	na	
91	Counter 2	na	
19	Voltage RMS	V	
97	Voltage DC	V	
80	Voltage RMS Phase C	V	
79	Voltage RMS Phase B	V	
78	Voltage RMS Phase A	V	
20	Frequency	Hz	
2	Wind Direction	deg	

```
     22 | Wind Speed                    | m/s               |
     18 | Atmospheric pressure          | hPa               |
    161 | Absortion Time                | s                 |
     32 | Instant Current RMS Phase-C   | A                 |
     29 | Instant Current RMS Phase-B   | A                 |
     27 | Instant Current RMS Phase-A   | A                 |
     89 | Apparent Energy Phase C       | kVAh              | t
     88 | Apparent Energy Phase B       | kVAh              | t
     87 | Apparent Energy Phase A       | kVAh              | t
     83 | Reactive Power Phase C        | kVAr              |
     82 | Reactive Power Phase B        | kVAr              |
     81 | Reactive Power Phase A        | kVAr              |
     96 | Diffused Solar Radiation      | W/m2              |
     94 | Global Solar Radiation        | W/m2              |
      8 | Temperature                   | C                 |
     95 | Direct Solar Radiation        | W/m2              |
     68 | Reactive Energy Total (-)     | kVArh             | t
     67 | Reactive Energy Total (+)     | kVArh             | t
      6 | Active Energy Total +         | kWh               | t
     53 | Energy Counter                | kWh               | t
    105 | Energy Counter 4              | kWh               | t
    104 | Energy Counter 3              | kWh               | t
     71 | Active Energy Phase C +       | kWh               | t
     70 | Active Energy Phase B +       | kWh               | t
     69 | Active Energy Phase A +       | kWh               | t
    103 | Energy Counter 2              | kWh               | t
    107 | Energy Counter 6              | kWh               | t
    106 | Energy Counter 5              | kWh               | t
    124 | Active Energy Total -         | kWh               | t
    153 | Gas Boiler Energy             | kWh               | t
    152 | Biomass Energy                | kWh               | t
     25 | Thermal Solar Energy          | kWh               | t
     23 | Water Counter                 | m3                | t
    100 | Water Counter 4               | m3                | t
     99 | Water Counter 3               | m3                | t
     98 | Water Counter 2               | m3                | t
     93 | Gas Counter 2                 | m3                | t
      7 | Gas Counter 1                 | m3                | t
    102 | Water Counter 6               | m3                | t
    101 | Water Counter 5               | m3                | t
     14 | Rainfall Amount               | mm                | t
    187 | Instant Current DC            | A                 |
```

Fig. 9: Snapshot of the "deployed_sensor" table in ORIGIN DB.

Now the configuration for the ORIGIN core is finished, and the next step is to import the assets configured in the Field Devices Server (in the previous section) and start getting measurements. The "Assets Update" module provides the first assets update, but it runs automatically every day at 00:00, so for commissioning purposes it should be manually forced to start when the administrator needs. This can be done from the User Interface, just go to Maintenance Area > Equipment > Update and click on the "Update" button. After finishing it will display a summary message with the results of this operation.

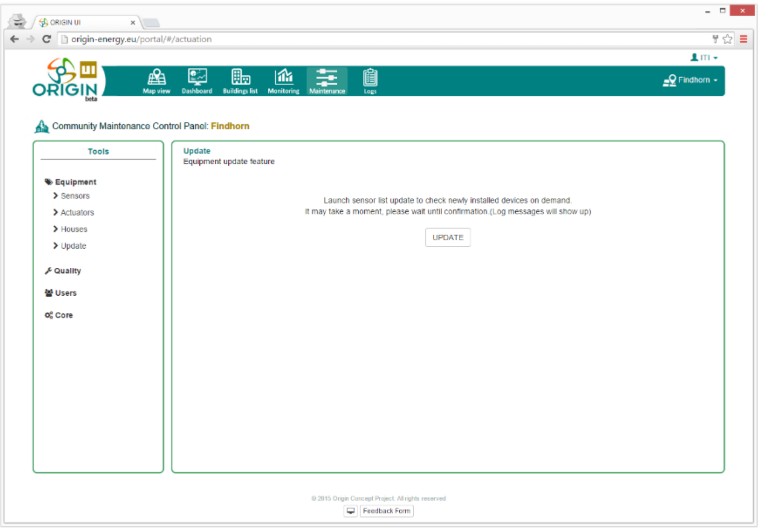


Fig. 10: ORIGIN UI, update devices from ISA cloud.

After this action, the ORIGIN CEMS will be up to date with the new field devices and buildings. The next automatic execution of the “Data Collection Pipeline” module will retrieve all existing measurements from these devices. The equipment update will still be launched automatically every day at 00:00 to reflect changes in the field equipment. The Data Collection Pipeline will be launched every 30 minutes to get all new measurements from the field devices through the Field Devices Server.

5.1.3. Validating the installation

Having reached this point, some validation steps are done to check the correctness of the installations performed and ensure that good quality data is collected, delivered and stored in the data platform.

- Validation of the installation of the monitoring hardware in each one of the monitored points. This task (done in the previous section) implies a local inspection of the hardware installed at the monitoring points, where all the connections to the probes and power supplies are verified. The installation of the probes (if any) is also verified.

- Verification of the monitoring hardware configuration. This task (done in the previous section) implies the check of the hardware configuration, ensuring that it is suitable for the installed probes (e.g. correct current transformer ratio configuration, correct heat meter address configuration, etc.).

- Verification of the communications. This task implies the verification of the communications between the monitoring hardware and the respective hubs/data loggers. All the installed sensors should be able to communicate with the respective hub and thus should be detected by it. This task should be performed by accessing the hub (through its maintenance/technical interface) and verifying that the remote sensors are being detected.

- Validation of the complete communication chain from the monitoring hardware through the Field Devices Server (ISA Cloud). This task implies the verification in the data server that the data collected from the installed sensors is being stored properly, and all the installed hardware is correctly configured in the platform. This implies the verification of the data in the data server back office. ORIGIN has generated also a commissioning script to get automatically a tree of configured buildings and devices, current status, and a very useful evaluation of their readings, which results in a powerful tool for installers during the commissioning stage. This script, called the "Quality Assessment Script" or "QA script", can be launched from any computer with Internet connection (not necessarily from the ORIGIN platform) and Java VM. The QA script makes an intensive exploration through the Field Devices Server to check if all devices have been configured properly, or if there are devices out-of-order, with missing readings, working out of their operation range, malfunctioning devices locked into a fixed value or fixed at zero, sensors with too much high variance, and battery status. These tests are configurable. If during the installation stage the installers generated the lists of deployed devices using the ORIGIN template (see Fig. 2) then these lists can generate CSV files to be analysed by the QA script, which will compare the installed devices with the administratively configured devices in the server (see Fig. 11).

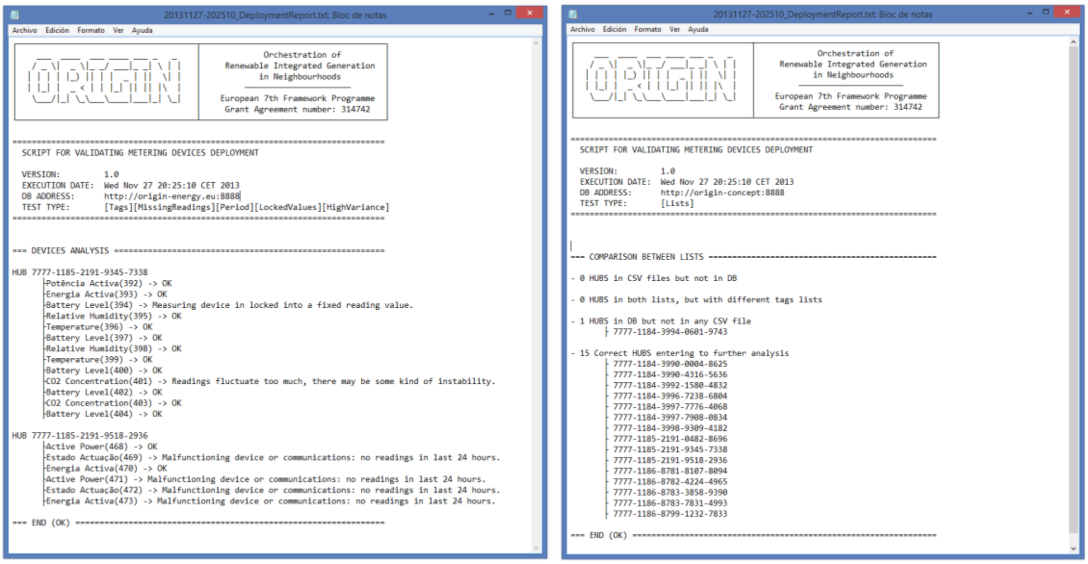


Fig. 11: Sample output from the QA script. Left: Analysis of measures. Right: Assets checkup with installation lists.

- Validation of the communication pipelines between the Field Devices Server and the ORIGIN core. Any error with the pipelines will be registered in the log folder (set in the config files) or sent by mail to the supervisor (configured in the cron daemon). Then, the ORIGIN User Interface can be used for checking if all devices are present in the ORIGIN core, through the Maintenance > Quality toolbox. With the "Sensors" tool, we will obtain a list of all sensing points present in the ORIGIN core. Clicking on any of these sensors it will display its related information (name, house, type, units, last reading). If a sensor name is incorrect or we prefer to set a more "human readable" name, we can change it from here, and the "Name management" module will propagate this change to the Field Devices Server.

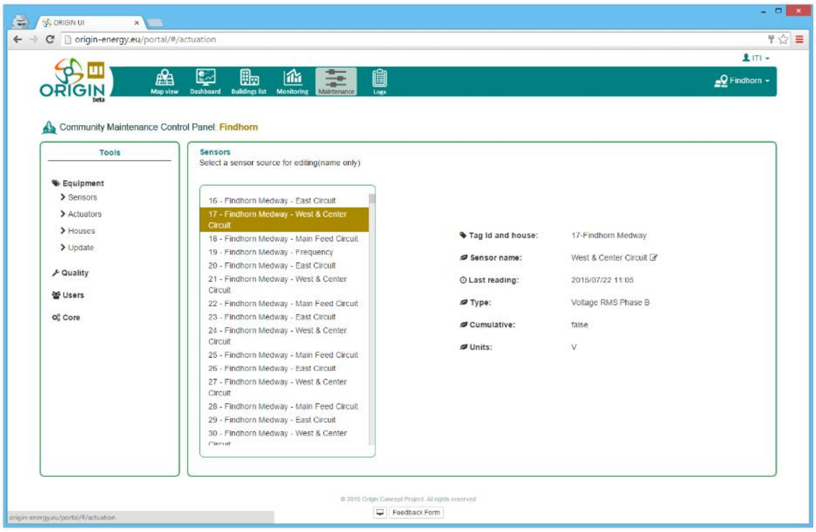


Fig. 12: Screenshot of the tool for checking sensors.

Similar to this we can find the "Actuators" tool, listing all actuating devices in the community. Selecting an actuator it will show its name, building and current status (ON, OFF or unknown). There is also a button for switching its relay (use it carefully), which can be used to check the correct remote actuation over this device. The actuator name is also editable.

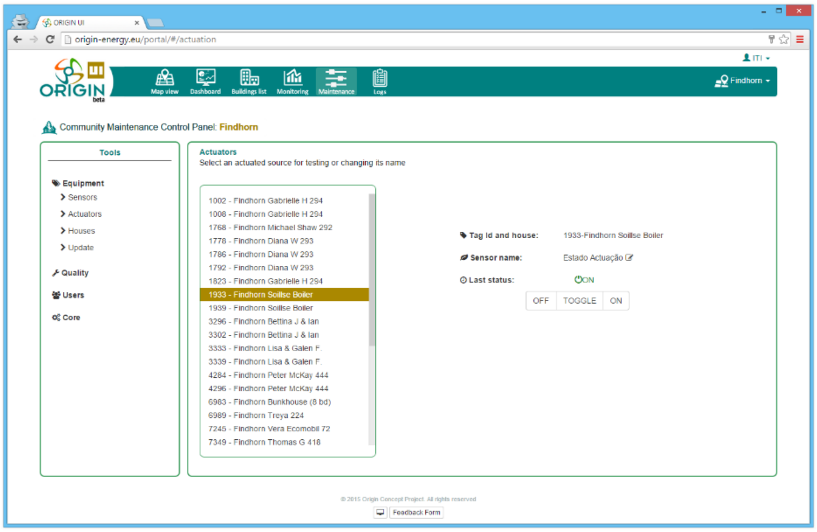


Fig. 13: Screenshot of the tool for checking actuators.

Finally, the "Houses" tool lists all the configured buildings, displaying information about their name and ID. Again, the house name is editable.

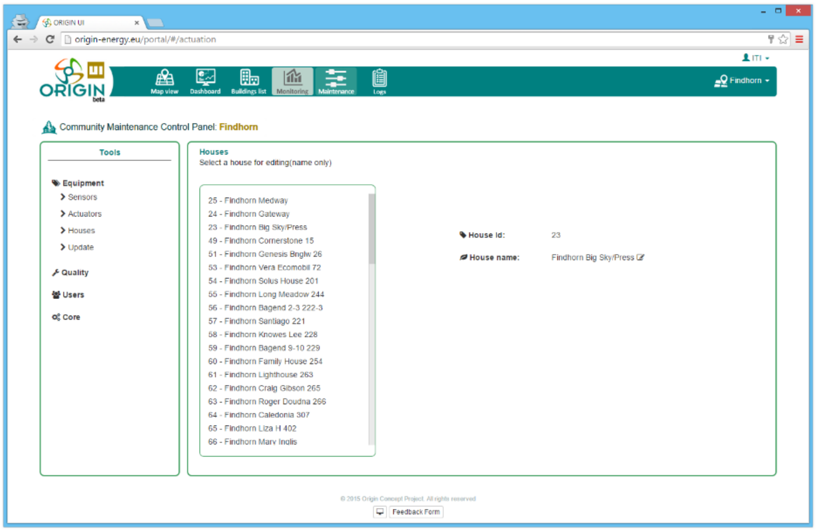


Fig. 14: Screenshot of the tool for checking buildings.

After these validation steps, the pilot is considered fully functional and ready for data acquisition, according to the specifications. From now, the sensors status and the data acquisition operation can be checked from the ORIGIN User Interface, using the “Quality” toolbox. The “Offline sensors” tool displays a list with all the sensors and actuators for this community, with a colour code to visually report the last time this device sent its readings. The bottom filter is used to list only devices with a specific colour code, and selecting a device will display additional data such as the timestamp of this last communication.

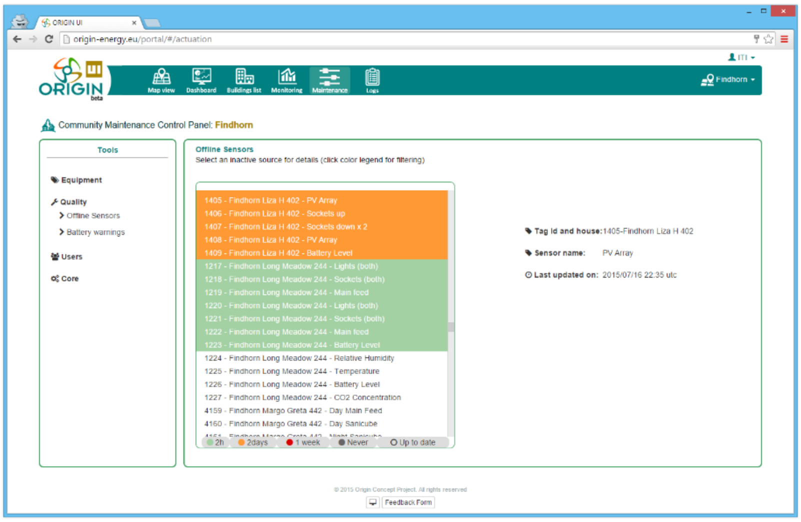


Fig. 15: Screenshot of the tool for checking offline sensors.

Another relevant tool for managers is the “Battery warnings” tool, which will list all those devices whose battery level is below the 10% threshold.

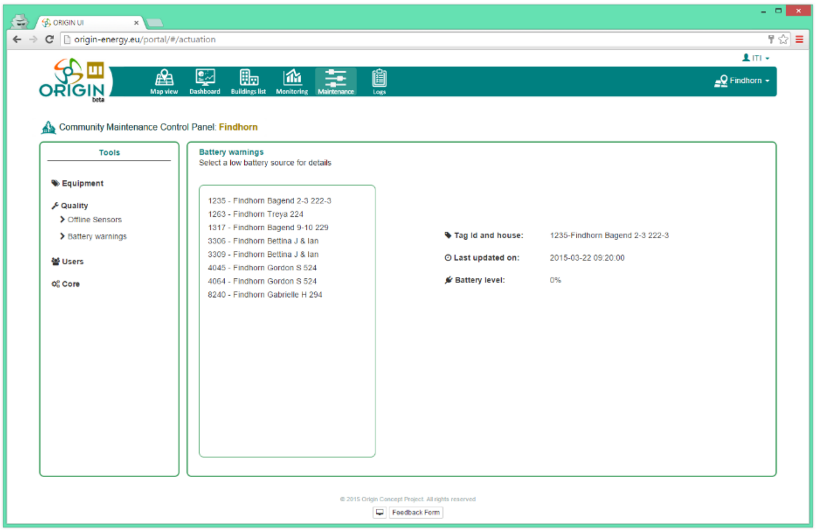


Fig. 16: Screenshot of the tool for battery warnings.

5.2. Users Management and privacy matters

The ORIGIN User Interface is a powerful and very intuitive tool for enabling the users to know their energy consumption and interact with them to improve their energy behaviour. There are 4 different available roles:

- Big screen: this role is used for display in communities e.g. on big community screens and only has access to information and grouped telemetry from the community as a whole, not from its individual buildings. Users with this role will see a cleaner User Interface that works without the user's interaction. The Big screen user accesses directly to the dashboard. It will do some automatic scrolling and will change between different time scales for some gadgets, enabling an unassisted view of the dashboard.
- Community member: this role is intended for the house-owners and is the most used. Each community user has access to only the information about his assigned buildings (assigned by the manager, for example his house and some community buildings). Telemetry and private data from community members will be used only inside the ORIGIN CEMS and will be processed automatically by the analysing modules. Higher-level roles will have access this data for management purposes, so the community users must sign a privacy agreement to confirm they know and allow this. Passwords are not stored in the system (only their hash), so no one, even administrators, have access to it.
- Community manager: this role has access to all the buildings in the community and to the management area. The community manager is responsible for managing the users, and can manage the field devices through different tools for testing their behaviour and batteries. They must sign a privacy agreement which prevents them from extracting personal data out of the ORIGIN CEMS for other purposes than community management.
- Project manager: it has the same privileges as the community manager, plus access to internal core modules (to start and stop them) and access to multiple communities in shared ORIGIN CEMS servers. They must sign a privacy agreement which prevent them from

extracting private data out of the ORIGIN CEMS to other purposes than community management.

Users must have a unique username and mail address within a same ORIGIN Core server. Mail address is mandatory to enable the password recovery and receive critical system mailing. Each user will have an attached role, and “Community Members” will have a list of allowed buildings.

Only *Community Managers* and *Project Managers* can manage users. Allowed actions are to create, modify and remove users. Any removed user will receive an email alert reporting this action.

In the commissioning stage, managers can add new users from Maintenance > Users > Create user. If the role “Community Member” is selected, then a list of available buildings will be shown, and the accessible buildings for this user can be selected. Please take care with this selection: the user will have access to all metering info from these buildings, not just from the Dashboard screen, but also from the Monitoring section.

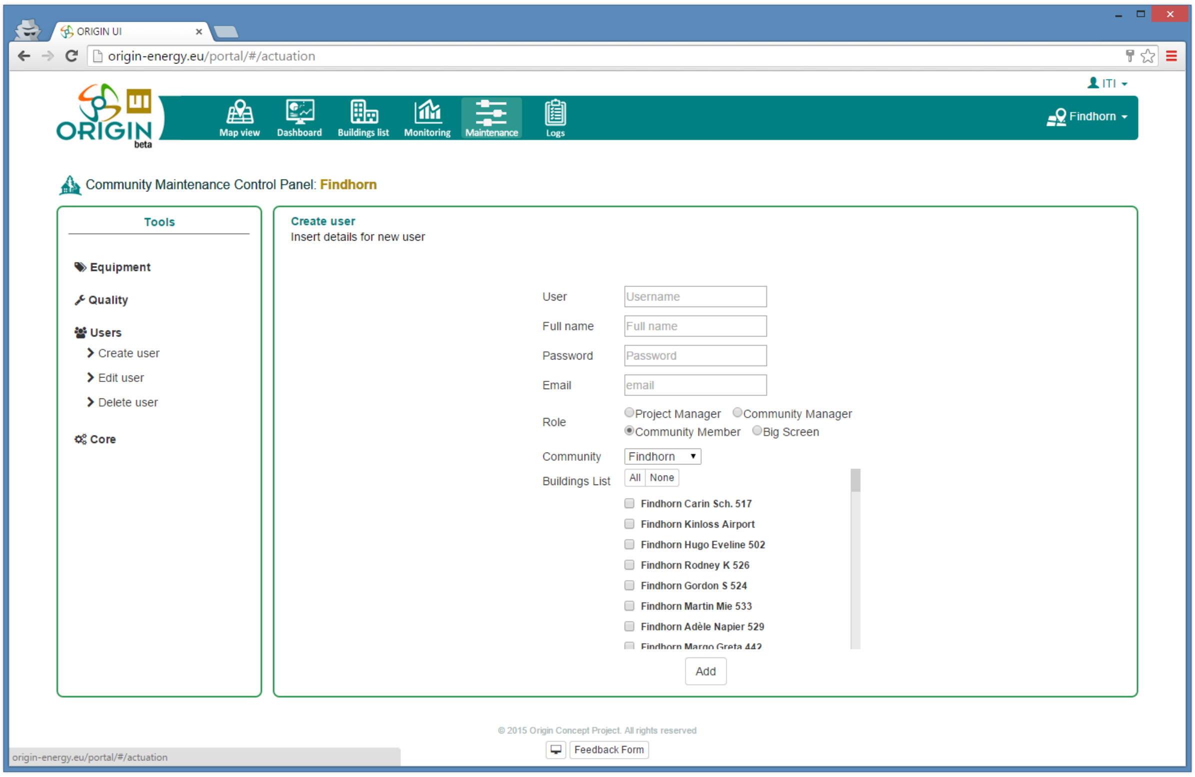


Fig. 17: ORIGIN UI, add new users.

5.3. Setting up the attached modules

In order to achieve the maximum scalability and flexibility, the prediction, scheduling and optimisation sections of the ORIGIN system has been set up as a series of interconnected modules. The modular approach enables one section of the system to be modified/improved without affecting other sections. It also enables the ORIGIN system to be scaled up. For example, modules such as the weather prediction module can be set up on completely independent machines. As the ORIGIN system grows (as new sites are added that utilise the same hardware), computationally heavy modules (e.g. weather prediction) can be moved to powerful machine/machines without affecting the rest of the system.

The following are the main modules that constitute this part of the ORIGIN system:

- Weather Prediction Algorithm
- Renewable Generation Prediction Algorithm
- Demand Prediction Algorithm
- Gap Analysis Algorithm
- Opportunities Prediction Algorithm
- Optimisation and Control Algorithm
- Tariff Generation Algorithm
- Performance Metrics Calculation Algoritm

5.3.1. Weather Prediction Algorithm

The ORIGIN weather prediction system uses a novel approach that is based on not only the past weather observation from the ORIGIN installation site but also weather observations and predictions from a network of sites surrounding the ORIGIN installation site. The following steps are necessary in order to set up the ORIGIN weather prediction system at a new installation:

- Site survey & selection of nearby weather observation/forecast sites
- Setting up of configuration files
- Launch weather model training & weather forecasting

Site survey & selection of nearby weather observation/forecast sites

This involves locating the ORIGIN installation site on a map and then locating weather forecast and observation sites surrounding the ORIGIN installation site. The rule that should be followed in selecting surrounding sites should be to select weather forecast and observation locations that can "intercept" a weather front approaching the installation site from any direction. It should be able to intercept the weather front at different intervals during the approach. Figures 18 & 19 illustrate this concept using actuation weather data collection setup for Findhorn.

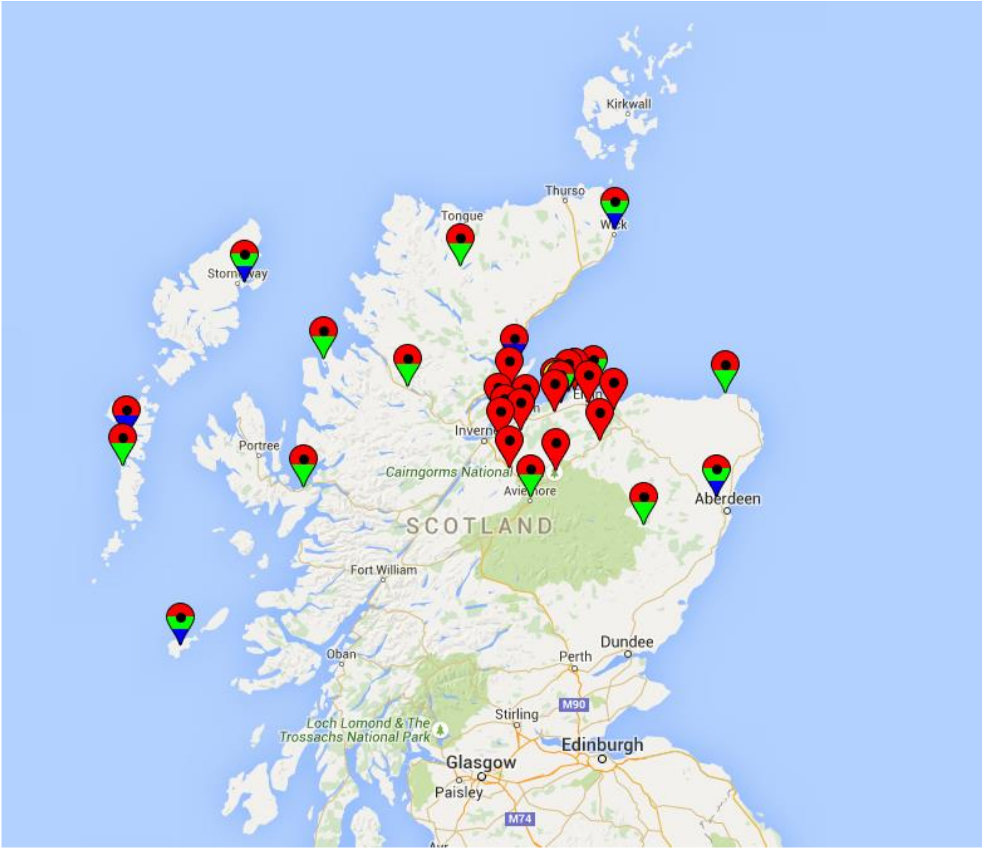


Fig. 18: Complete network of weather data collection stations around Findhorn, UK.

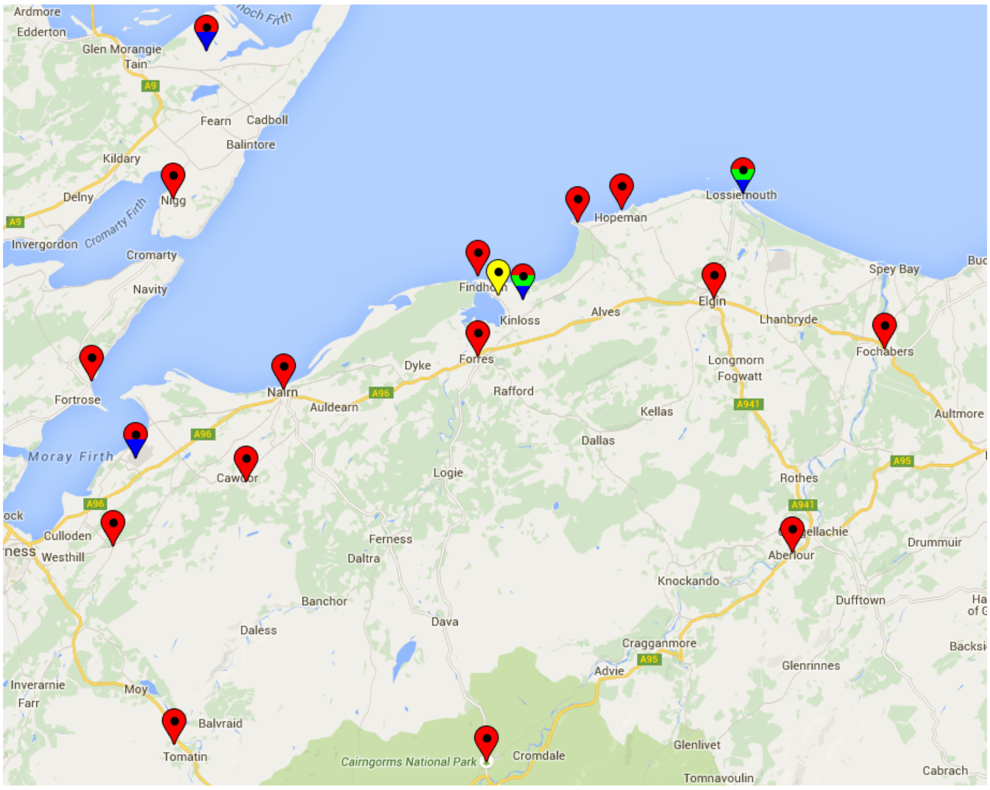


Fig. 19: Zoomed in view of weather data collection sites around Findhorn, UK.

Key for figures 18 & 19:

-  - Findhorn
-  - Met Office forecast site
-  - Met Office observation site
-  - METAR observation site
-  - Met Office forecast & observation site
- - Met Office forecast and METAR observation site
-  - Met Office forecast, Met Office observation and METAR observation site

Setting up of configuration files

There are two XML configuration files that for the weather forecasting module:

- /weather/forecast/folder/Z_JavaPrograms/RFADataSection/Scripts/RFADataSecConfigFindhorn.xml
- /weather/forecast/folder/Z_JavaPrograms/RFADataSection/Scripts/weather_grab_config_findhorn.xml

RFADataSecConfigFindhorn.xml

This is the overall configuration file for the weather data collection module and it sets the following parameters:

- Name of the ORIGIN site (e.g. Findhorn)
- Operaring system (e.g. Linux or Windows)
- Base folder
- Path to second configuration file (weather_grab_config_findhorn.xml)
- Delimiter for CSV files
- Name of the log file
- Java object output path
- Name of the weather observations Java object
- Name of the weather forecast Java object
- Output path for the CSV weather dataset
- A list of weather parameters to be recorded from each weather data source (please see figure 19 for the list of weather parameters collected from the UK Met Office).

```
▼<met-office>
  ▼<forecast>
      <item>WeatherType</item>
      <item>WindDirection</item>
      <item>MaxUvIndex</item>
      <item>Pressure</item>
      <item>Visibility</item>
      <item>Temperature</item>
      <item>ScreenRelativeHumidity</item>
      <item>WindSpeed</item>
      <item>WindGust</item>
      <item>PrecipitationProbability</item>
      <item>FeelsLikeTemperature</item>
      <item>AQIndex</item>
    </forecast>
  ▼<observation>
      <item>WindDirection</item>
      <item>ScreenRelativeHumidity</item>
      <!-- <item>PressureTendency</item> -->
      <item>WeatherType</item>
      <item>Pressure</item>
      <item>Temperature</item>
      <item>WindSpeed</item>
      <item>Visibility</item>
      <item>WindGust</item>
    </observation>
  </met-office>
```

Fig. 20: XML configuration section for the UK Met Office weather parameters.

weather_grab_config_findhorn.xml

This file specifies URLs and other details for data collection for each site in the network of weather data collection sites.

At the beginning of the file, each weather data collection source (e.g. Met Office, Forecast.io etc.) is defined as a URL. The URL is defined with place holders for any required API keys for accessing that particular resource and the unique ID for accessing the data stream for a particular site. For example, the Forecast.io is as follows:

- <base-resource-url id="1"><![CDATA[https://api.forecast.io/forecast/{API_KEY}/{UNIQUE_ID}?units=uk&exclude=minutely]]></base-resource-url>

As shown in figure 21, the second section of the file defines the name, map coordinates and uniqueIDs for each weather resource for each site that weather data is being collected for.

```
<nearby-site name="Kinloss">
  <location>57.649,-3.561</location>
  <forecast name="forecast">
    <forecast-resource name="met_office">
      <url type="xml" base-resource-id="2">3066</url>
    </forecast-resource>
    <forecast-resource name="forecast_io">
      <url type="json" base-resource-id="1">57.649,-3.561</url>
    </forecast-resource>
  </forecast>
  <observation name="observation">
    <observation-resource name="met_office">
      <url type="xml" base-resource-id="3">3066</url>
    </observation-resource>
    <observation-resource name="metar">
      <url type="metar" base-resource-id="4">EGQK</url>
    </observation-resource>
  </observation>
</nearby-site>
```


Fig. 21: XML required for configuring Kinloss as a nearby weather data collection point for Findhorn.

Launch weather model training & weather forecasting

The weather forecasting module is control by a Linux shell script that does the following (in this order):

- Call RFADataSection.jar (located in /weather/forecast/folder/ Z_JavaPrograms/RFADataSection/Program folder) together with the two XML configuration files. This program downloads all the weather data and appends the latest data to a rolling four week CSV dataset.
- Call RFAWeatherModelInterpreter.jar program that uses the four week rolling weather dataset together with weather models for creating the required weather forecasts.
- Call RFAWeatherForecastDBWriter.jar program to write the weather forecast to the ORIGIN database.
- Call RFATrackModelBuilding.jar to track the progress of weather model building. This program looks at processes running in the machine to see if weather models are being built. If so, it will write a blank file called "controlFindhornModelBuilding.sh". If there is no weather model being built, this means the latest run of weather model building is complete. Therefore, it will write instructions for putting the latest weather models live to controlFindhornModelBuilding.sh file.
- Call controlFindhornModelBuilding.sh. If a weather model is being built, this file will be blank and running this file will not execute any instructions. If a weather model has been built, then this file will put that weather model live and start building a new weather model.

The shell script that controls the weather forecasting should be launched once every hour using the CRON daemon in Linux as follows:

- 1 * * * * /weather/forecast/folder/Z_JavaPrograms/RFADataSection/Scripts/hourly_run_findhorn.sh

5.4. Setting up the ORIGIN User Interface

The ORIGIN User Interface is intended for end-users and platform managers. It brings monitoring capabilities for house-holders but also gives powerful tools to manage the assets, internal modules and actuations.

The ORIGIN User Interface needs two components to go live: the webservices server and the website server. The first one interacts with different components of the ORIGIN platform to get information from modules, scripts and the database, and can execute actions on the different modules or even with the Field Devices Server. This webservices server then offers a homogeneous and secure high-level API to bring these services to outside of the ORIGIN platform: the user web browser. The website server hosts the ORIGIN User Interface and manages user requests. The technology used by the ORIGIN User Interface moves the power to the client's side, so it requires less computation/memory resources in the server, and the webservice queries are launched by them, so it requires a strong security framework to ensure privacy.

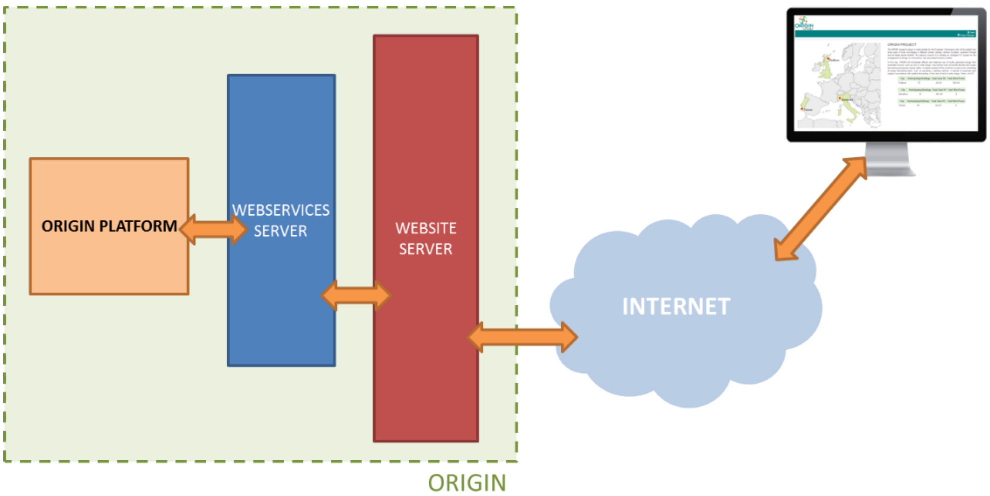


Fig. 22: Building blocks architecture for the User Interface.

5.4.1. Webservices server

This module is written in Java + Apache CXF and generates a REST API. Any needed configuration has to be done in the configuration file "*ConfigData.java*", so any change in these settings must be recompiled.

For new deployments the relevant settings will be:

- Access settings for ORIGIN database. This includes address, database name, user and password.
- Access settings for Webservices server. IP address, port, relative paths.
- Access settings for Field Devices server. Address, port, relative paths and credentials.

- Security. Default settings are appropriate for new deployments, but these settings can be modified if needed. This section include encryption algorithms, transformations, key sizes and token expiration times.

5.4.2. Website server

This module is developed with HTML5, CSS3, and AngujarJS (a JavaScript framework), with PHP for interacting with ORIGIN maintenance scripts. It provides the User Interface accessible to ORIGIN community members.
Any changes are applied by updating/uploading the last versions of the code files to the server's file system. Web server does not need to be restarted, but users normally need to clean their browser cache in order so load the changes in the UI.

For new deployments the relevant setting will be:

- Access settings for Webservices server: IP address and ports.

```
'use strict';
/* Controllers */
/* CHANGE THE WEB SERVICES IP WITH THE FOLLOWING VALUES ACCORDINGLY*/
/* Production server IP or name and port XXX.XXX.XXX.XXX:YYYY*/
/* Test server IP or name and port  XXX.XXX.XXX.XXX:YYYY */
/* WHERE TO FIND IT: $rootScope.serverWS = 'XXX.XXX.XXX.XXX:YYYY' in naviController*/
angular.module('myApp.controllers', [])
//controller for language key
.controller('transCtrl', function ($scope,$rootScope, $translate,theUser) {
    $scope.changeLanguage = function (key) {
    $translate.use(key);
  };
  $scope.$watch(function () { return theUser.lang }, function (newVal, oldVal) {
      $scope.changeLanguage(theUser.lang);
        });
})
.controller( 'naviController',function($scope,$rootScope,theUser,$cookieStore,localStorageService,
$state,$alert,$http,tmhDynamicLocale,logout){
    $rootScope.serverWS = 'XXX.XXX.XXX.XXX:YYYY';
    $rootScope.serverWSTESTING = 'XXX.XXX.XXX.XXX:YYYY';
    $rootScope.ciph=ZZZ;
    $rootScope.onhold=false;
    ...
```

Fig. 23: Snapshot of the configuration file for webservices settings.

- Security. These settings must match the security settings of web services, such as encryption algorithms, key sizes.
- Language translation files: language support can be enabled by adding the corresponding JSON files in the translation folders.
- Paths to other modules scripts: in order to provide the maintenance and log sections, paths to scripts such as those related with the "Actuations" and the "Assets Update" modules should be properly configured in corresponding .php files.

```php
<?php
echo exec('../DCpipeline/findNewDevices.sh');
$searchthis = "There are";
$matches = array();
$handle = @fopen("../DCpipeline/outputDevices.txt", "r");
if ($handle)
{
    while (!feof($handle))
    {
        $buffer = fgets($handle);
        if(strpos($buffer, $searchthis) !== FALSE)
            $matches[] = $buffer;
    }
    fclose($handle);
}
echo $matches;
?>
```

Where to find the script

Where to find the log with script's output

Fig. 24: Snapshot of the configuration file for path settings.

6 Realising the orchestration capabilities

To orchestrate the energy flows in a community, the ORIGIN platform manages what has been described in D5.8 as an informational (user led) module and or an Automatic Actuation module

The Automatic actuation module provides a list of operable loads, which can be controlled automatically by the core as needed.

The information module can give:

User Awareness information: historical energy consumption information, future energy surplus forecast information, performance information relative to other community members etc.

Recommendations: users receive recommendations to enable them to schedule their energy use so that it aligns more successfully with local renewable generation but they have to decide to take action.

Dynamic tariff information – a tariff system can be used to reward end users who change their energy consumption to match locally generated renewable energy surplus where possible..

Some of these methods could be more successful than others depending on the community. An internal dynamic tariff system does not make sense in communities where people do not pay for the energy of their home (community payment, flat rates, etc.). Recommendations and user awareness are powerful tools for most of the situations, but only where the users can have an impact with their energy behaviour. Communities where the main loads are shared (washing-machine rooms, district heating, shared spaces etc.) are intrinsically efficient and don't allow much intervention from users, where their action can even interrupt the operation of the facilities and be counterproductive. These loads are more efficiently controlled by the automatic actuation module.

6.1 Automatic actuation

The ORIGIN Optimization module generates optimization schedules over a pool of loads. Which loads are included in this pool depends on the community needs, and can include community and private loads such as space heating, hot water, electric vehicle charging, water pumping, public lighting and so on. For actuating domestic hot water and heating, the actuation schedule is generated once a day. For actuating other loads (e.g. electric vehicle charging), an actuation schedule is produced and/or updated once every hour.

time	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9
1. Normal operation no ORIGIN control																ON	ON	ON							
2. ORIGIN Control enabled but no shift applied																ON	ON	ON							
3. ORIGIN Control enabled and load precharged								ON	ON							ON	ON	ON							
4. ORIGIN Control enabled and load delayed																							ON	ON	ON
5. ORIGIN Control enabled and load avoided																									

1. Normal operation: no ORIGIN load shift / control hardware (cloogy plug) installed
2. Control enabled but no shift: here the cloogy must be made to operate to the 'normal schedule' this requires the cloogy to be 'OFF' except for the normal charge period.
3. Control enabled and precharged: here the cloogy must be made be 'OFF' except at the precharge period, plus operate again at the normal charge period.
4. Control enabled and charge delayed: here the cloogy must be 'OFF' except at the coasted charge period.
5. Control enabled and charge avoided: here the cloogy must be 'OFF'.

Fig. 25: Example of automatic actuations.

This scheduling is saved in the database and the actuation module is responsible for executing it. As there are no real-time requirements (the actuation is defined with a “best-effort” approach where delays up to 15 minutes are acceptable), the actuation module reads periodically this scheduling every 5 minutes to update the physical loads in the community. To improve time and battery life, minimize unnecessary communications with wireless devices and improve the error management, the actuation module connects only with those loads that should be actuated in that moment, and manages internally an “administrative status” for each load. For each execution, the actuation module generates a list of loads which should be switched on, and a list of loads which should be switched off. This bears in mind the scheduling, the administrative status and the communication/actuation errors with this device. A device that was not contacted successfully will be retried in the next execution, in 5 minutes, so this will be the minimum delay on an error. These actuations are not critical but there is a need of knowing exactly what has been actuated and what not, so all this information is properly processed and stored in the database, and is available for viewing in the “Maintenance Area” of the ORIGIN User Interface.

The actuation module acts as a bridge between the ORIGIN platform and the physical actuation devices in the community. On the community’s side, a Cloogy device is connected to the load which will be actuated. The Cloogy works as a remote operable relay, and is controlled by the Actuation module to switch on/off the attached load. Following this architecture, the loads in this pool will be addressed by their connected Cloogies, so the actuation module uses the tag ID of each Cloogy to operate the load. The actuation module generates a communication channel with each operable relay, paying special attention to problems that can arise in this situation, encompassed by communication errors and physical errors. Communication errors are more common in wireless environments, and are caused by connectivity problems (devices disconnected from their hubs, battery leakage etc.). Physical errors are registered when, after the successful reception of the order, the actuation module checks the remote relay status and it has not changed.

For communication with field devices, the Actuation module includes a modular communication stack to include new devices and vendors with open APIs. This makes the ORIGIN platform compatible with legacy systems in the communities, and brings the possibility of including new devices of their choice.

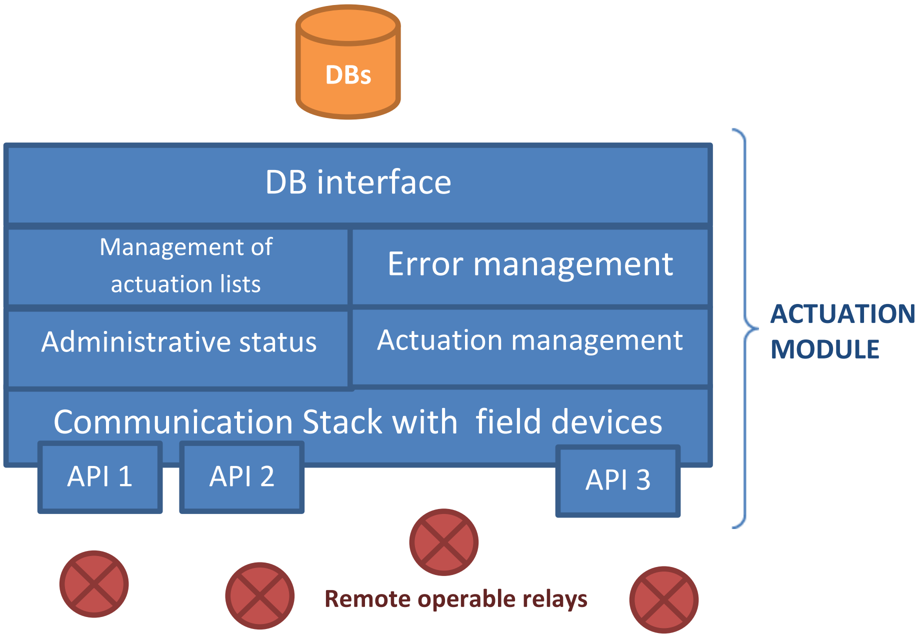


Fig. 26: Actuation module architecture.

Automatic actuation is always a controversial method; human interaction is preferred in many situations. However, a well-analysed and configured scenario with automatic actuation can lead to efficiencies and removes the human dependence and the human errors. If automatic actuation is enabled in a community, it's highly recommendable to enable an "emergency button" to switch on/off the whole automatic actuation module, bypassing the system if any problem is detected. There is a software button available in the "Maintenance" section of the ORIGIN User Interface.

7 End User Engagement Strategy

One of the key learnings from the ORIGIN project has been the importance of engaging with the communities to ensure that any ORIGIN based system is used and adopted. Therefore for any of the scenarios identified in section 2.2 it is vital that an engagement strategy is identified in conjunction with the proposed community. This strategy is developed at the start of the project. The engagement strategy would include:

1. Identification of a local ' ORIGIN' champion
2. Proposed training in the 'ORIGIN' system – how, who, when
3. Options for community engagement eg community display screens, newsletters etc
4. Ongoing updates / feedback on what has been achieved by the ORIGIN system and the users

Deliverable 5.4 gives examples of the ongoing engagement strategies used in Tamera, Damanhur and Findhorn

8 Metrics, Interface, Performance and Review

For future replication, it is important to identify the desired ‘energy ‘ metrics that are needing addressed and then highlight these metrics on a user interface. The interface can then be used to monitor performance and to review progress.

The ORIGIN user interface screen can show historical, actual and forecast energy information see figures 27 and 28 for examples. Depending on the complexity of the system chosen the interface can show community and or building level information. There are a number of gadgets which display information and the user can select the ones he /she finds most useful. Some of the gadgets present historical information and some present forecast information. The historical gadgets show information for yesterday, the current month and since the system went live. They include anenergy balance visually showing how the energy is being used: Energy imported from the grid,'green' energy exported and 'green' energy consumed on site, a greenometer showing how much of the energy consumed is ' green' and a leaf showing shows the % CO2 saved. The forecast gadgets include a localised weather forecast, a plant and a traffic light system showing availability now and energy forecasts in the form of a clock, a table and in a graphical form indicating the availability of renewable energy taking into account forecast demand. A text recommendation can also highlight optimum times for using renewable generation over the next 48 hours. From this, the communities can make informed choices about their energy behaviour As mentioned previously, the actuated system is also able to automatically schedule suitable loads to match periods of high renewable energy supply. The system can also be used to offer tariff reductions for periods forecast to have high energy availability and these periods can be highlighted using the user interface

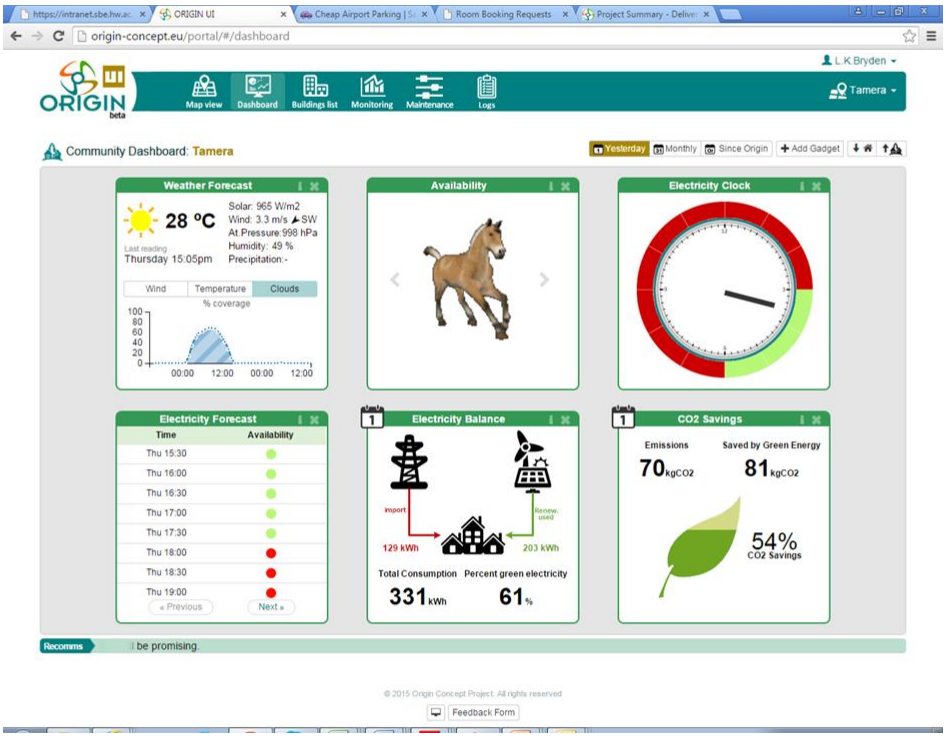


Figure 27 – Tamera user interface showing current weather and renewable generation availability, forecast renewable generation, historical consumption and generation information and CO2 savings

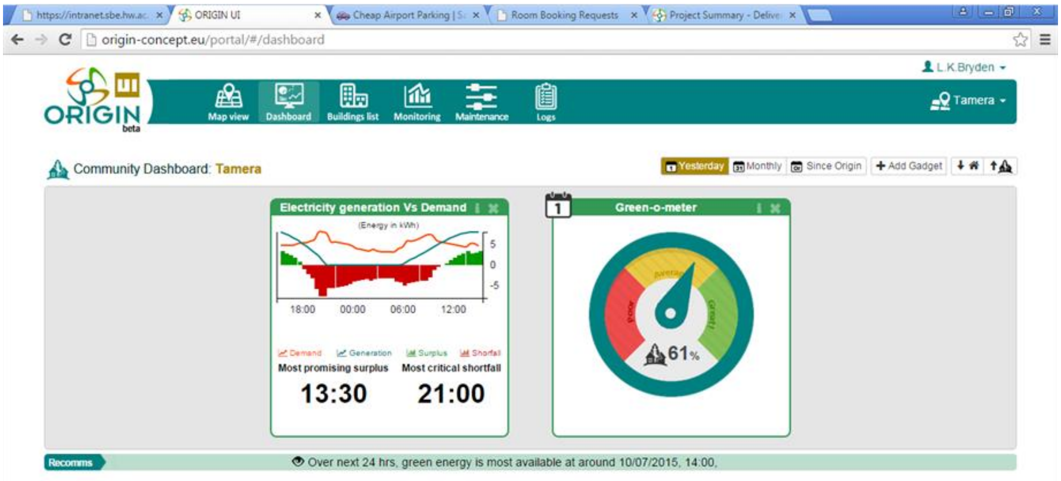


Figure 28 – Tamera user interface showing forecast renewable electricity generation versus predicted demand and corresponding surplus /deficit and a greenometer indicating how much of the electricity used was from the local renewable source

For replication purposes, the ORIGIN user interface has been developed so that it can be customised in conjunction with the community's wishes /needs. This means the community / end users are more likely to understand and be able to engage with the gadgets chosen to represent the key 'energy' related metrics and this is more likely bring about the desired 'energy' behaviour change.

9 Business model for the new site

A central element is the selection of an appropriate business model for providing and using the ORIGIN approach. The project team used the Canvas approach to identify promising business opportunities for communities and public utilities which as small utilities often take care of the energy supply for citizens within small municipalities. With a SWOT approach each business model was evaluated and assessed by using a scoring model. The most appropriate business models are the informational demand response model (which is already valuable today) and the actuation demand response model (which will be a valuable option for future applications). These business models can be combined with the business model for forecasting renewable energy prediction. In order to assess the applicability he market drivers for ORIGIN as well as current trends as a basis for customer demand were analyzed.

The following tables explains in brief the two demand response business models from the point of view of communities and public utilities:

9.1 Business Model "ORIGIN Demand Response System – informational" in communities

Using the ORIGIN CEMS for demand response services is possible in two different ways: informational and actuated. These two opportunities are split up into two business models because the actuated ORIGIN CEMS requires different resources to realise the service. The core functionality of the informational demand response system is to inform users how and when to consume energy based on local information about generation and load behaviour (Table 1). Communities could provide such a solution for free in public buildings but in general are not in the role of buying or providing such a solution to citizens due to a large lack of Know How, resources and a completely different role for citizens. Nevertheless, communities often are involved in public utilities which are responsible to take care for supplying local citizens with energy. So their market role is adequate for providing ORIGIN demand response systems. Their customers, often members of the community, could buy the solution as a cloud based service in the residential and commercial sector. An important prerequisite is a smart metering infrastructure which should already be in place in order to inform customers about their energy consumption. Then hardware costs are reduced significantly. Sensors could easily be connected to the ORIGIN solution. However, other independent market actors such as energy service providers from the ICT or energy sector could offer the ORIGIN solutions as well to private and commercial customers.

*Table 1: **Business Model "ORIGIN Demand Response System – informational" for communities being represented by public utilities.***

Key partners	Key activities	Value proposition	Customer relation	Customer segments
▪ ORIGIN service provider ▪ If necessary	▪ If necessary purchase hardware including user	Inform users about own consumption and when to consume energy	▪ Technical support (online or direct)	For service providers: ▪ Housing

hardware supplier ▪ Platform/server operators ▪ App service provider ▪ If necessary retailers	interface ▪ Sales/marketing ▪ Implementation/ maintenance ▪ Data collection, mining, metering ▪ Provide cloud tool and / or app	based on local information about electricity generation ▪ Reduced energy costs for end customers ▪ Improved CO2 footprint for communities and end customers ▪ Increased independency from national grid ▪ Increased revenue of RE asset ▪ Efficient grid load	▪ Personal assistance ▪ Online communities ▪ Automated services ▪ Key account management	industry, communities, utilities/ contractors, RE suppliers ▪ Private customers For public utilities, housing industry: ▪ End customers, prosumers, tenants
	Key resources		**Channels**	
	▪ If necessary hardware: ICT infrastructure, user interface ▪ Online and / or app features ▪ Sales/marketing ▪ After sales support		▪ Direct contacts to customers ▪ Online communi-cation (e.g. via display, apps) ▪ Sources such as community journals, news, Internet	

Cost structure	**Revenue streams**
▪ Product and business development for providing the solution to citizens and other customers ▪ Data security and data safety ▪ Website / app design ▪ Marketing and sales ▪ Maintenance and service	▪ Licensing (annual), royalty ▪ Increased income from local RE production ▪ Optimized procurement ▪ Returns from additional energy service sales ▪ Reduced additional costs for end customers

9.2 Business Model "ORIGIN Demand Response System – actuated" in communities

The actuated ORIGIN demand response system differs from the informational demand response system by actuation of devices through dynamic tariffs. The goal is to achieve a pareto optimal solution which enables each market actor involved to be better off than before. Informational demand response is also part of the system and is based on the demand and prediction algorithms (DPA) in order to shift loads and safe energy (Table 2). Again, communities could provide such a solution for free in public buildings but in general are not in the role of buying or providing a demand response system to citizens due to a large lack of Know How, resources and a completely different role for citizens. This is why public utilities may take over this role for their customers which often are members of the community. Like for the informational system a smart metering infrastructure should already be in place in order to reduce hardware costs significantly and to provide and meter dynamic tariff designs. Sensors and actuators could easily be connected to the ORIGIN solution and to devices such as heat pumps, CHP, electric vehicles or washing machines. However, other independent market actors such as energy service providers from the ICT or energy sector could offer the ORIGIN solutions as well to private and commercial customers.

Table 2: ***Business Model "ORIGIN Demand Response System – actuated" for communities being represented by public utilities.***

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Customer relation</th><th>Customer segments</th></tr>
<tr>
<td rowspan="3">▪ ORIGIN service provider
▪ If necessary hardware supplier
▪ Platform/server operators
▪ App service provider
▪ If necessary retailers</td>
<td>▪ If necessary purchase hardware including user interface
▪ Tariff design
▪ Sales/marketing
▪ Implementation/ maintenance
▪ Data collection, mining, metering
▪ Processes for tariff design and communication
▪ Provide cloud tool and / or app</td>
<td rowspan="3">Tariff based actuation of devices such as heat pumps and informational DR based on DPA in order to shift loads and safe energy
▪ Increased revenue of RE asset/loads
▪ Reduced energy costs of consumers
▪ Improved CO2 footprint
▪ Increased self-sufficiency
▪ Efficient grid load
▪ Optimized procurement</td>
<td>▪ Technical support (online or direct)
▪ Personal assistance
▪ Online communities
▪ Automated services
▪ Key account management</td>
<td rowspan="3">For ORIGIN service providers:
▪ Housing industry, communities, utilities/ contractors, RE suppliers
▪ Private customers
For public utilities, housing industry:
▪ End customers, prosumers, tenants</td>
</tr>
<tr><th>Key resources</th><th>Channels</th></tr>
<tr>
<td>▪ If necessary hardware: ICT infrastructure, sensors, actors, user interface
▪ Online and / or app features
▪ Sales/marketing
▪ After sales support</td>
<td>▪ Direct contacts to customers
▪ Online communi-cation (e.g. via display, apps)
▪ Sources such as community journals, news, Internet</td>
</tr>
<tr><th colspan="2">Cost structure</th><th colspan="3">Revenue streams</th></tr>
<tr>
<td colspan="2">▪ Product and business development for providing the solution to citizens and other customers
▪ Data security and data safety
▪ Website / app design
▪ Marketing and sales
▪ Maintenance and service</td>
<td colspan="3">▪ Licensing (annual), royalty
▪ Increased income from local RE production
▪ Optimized procurement
▪ Returns from additional energy service sales
▪ Reduced additional costs for end customers</td>
</tr>
</table>