This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768

Common monitoring guidelines for the demonstration sites

Project report

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April 2017

Summary

This document describes the monitoring guidelines that are to be followed by each pilot site of the PVSITES project in terms of measurement to be conducted in order to evaluate the impact of the BIPV technologies on the performance of the buildings or a portion of the buildings in terms of energy consumptions and indoor conditions and assess the performances of the implemented BIPV technologies themselves. This deliverable is one of the documents associated to the task 8.4 “Monitoring of installations” and specifically related with subtask “Detailed technical design of monitoring”.

These guidelines are based on the International Performance Measurement and Verification Protocol (IPMVP) methodology aiming at defining a rigorous approach to assess the impact of the ECMs (Energy Conservation Measures) implemented in the pilot sites. These guidelines propose a methodology that involves all the partners engaged in the implementation and evaluation process of the BIPV technologies: it starts from the visit of the pilots, continues with the definition of a measurement and verification plan for each pilot site and ends with an analysis of the collected data.

Acknowledgements

The work described in this publication has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 691768.

The present report was prepared by PVSITES project partner Nobatek, with additional contributions from R2M, Acciona, FormatD2, Flisom, Vilogia, Cricursa and Tecnalia. The report was originally submitted to the European Commission as Project Deliverable D8.7 in April 2017.

Disclaimer

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

This deliverable is one of the documents associated to the task 8.4 “Monitoring of installations” and specifically related with subtask 8.4.1 “Detailed technical design of monitoring”. It specifies the monitoring strategy to be used for establishing a performance monitoring allowing to deliver the performances of the BIPV technologies implemented in each pilot site and assess the impact of these BIPV technologies on the energy performance and indoor conditions of each building.

Performance monitoring is a key point when dealing with the evaluation of technologies in real situations and is fully integrated within the PVSITES project. The information to be delivered from such monitoring approach are not only the general performances of the BIPV solutions that will be installed in the pilot sites but also the comparison of these performances with the simulated one and the impact of the BIPV integration on the energy demand or comfort conditions of the building. These monitoring results aim at feeding the analysis of economic viability of BIPV solutions in terms of energy bill reduction in conjunction with investments for instance.

In order to ensure the right quality of this assessment, the monitoring should be based on a clear evaluation methodology. Therefore, this document more precisely describes the monitoring guidelines supporting the monitoring and evaluation approach that are to be followed by each pilot site of the PVSITES project. These guidelines define a set of actions and steps proposed as a common performance evaluation process to be implemented. The guidelines are based on two main items:

- A monitoring procedure providing a very detailed process made of several steps and requirements.
- The IPMVP protocol as the framework for the monitoring programme content, ensuring both quality of the assessment to be done and homogeneity between each pilot site.

In the first part of the document (Chapter 2), the general objectives of the monitoring are reminded taking into account all the requirements coming from the other activities conducted within the project.

The second part of the document (Chapter 3) proposes a monitoring procedure allowing to give a common approach to the whole consortium regarding monitoring activities.

In Chapter 4, the different component items of the IPMVP methodology are reminded and transposed to the PVSITES project in order to define what are the key points that need to be monitored and studied more specifically. This chapter will be directly used and will be the basis for the definition of the detailed Measurement & Verification Plan for each demonstration site (D8.8 ‘Specific monitoring plan for every demonstration site’).

1.2 Relation with other activities in the project

Table 1.1 depicts the main links of deliverable D8.7 to other activities (work packages, tasks, deliverables, etc.) within PVSITES project.

Table 1.1 Relation between D8.7 and other activities in the project

Project activity	Relation with current deliverable
D2.1	D2.1 provides the general roadmap for the standardization of BIPV products, focusing on EU directives and compliance with CE marking requirements. It also proposes a first monitoring approach and lists the parameters to be measured in order to assess the BIPV system performance.
D8.8	D8.7 introduces a first framework for the M&V Plans to be considered within PVSITES (monitoring guidelines) and the document D8.8 to be delivered later will provide the specific details related with each pilot site and the associated M&V Plans.

1.3 Reference material

D2.1 Technical specifications for BIPV modules, deliverable of the PVSITES project delivered at M6.

1.4 Abbreviation list

API: Application Program Interfaces

BCC: Building Control Centre

BIPV: Building-integrated photovoltaics

BMS: Building Management System

CDD: Cooling Degree Day

ECM: Energy Conservation Measure

IPMVP: International Performance Measurement and Verification Protocol

HDD: Heating Degree Day

M&V: Measurement and Verification

PV: Photovoltaics

2 MONITORING OBJECTIVES

2.1 Context and objectives integration

It is of crucial importance to clearly understand the context and objectives of the PVSITES project to take them into account for the monitoring plan. Numerous key parameters have to be integrated in the monitoring program in order to cover all the objectives:

- Demonstration project with real technologies implementation (demonstration of a large portfolio of building-integrated solar technologies and systems) - WP2 related,
- European (even international) dimension as the project aims at driving BIPV technology to a large market deployment – WP1 related,
- Six pilot sites in three different countries with different building type targeted (residential, offices, carport, industrial) – WP8 related,
- A monitoring program aiming at assessing the performances of the BIPV technologies implemented in each pilot site and assessing the impact of these BIPV technologies on the energy performance and indoor conditions of each pilot site – WP8 related,
- A monitoring program based on the IPMVP protocol – WP8 related,
- A comparison with the simulated data about BIPV production in order to assess the performance gap associated to the BIPV technologies, identify if possible the sources of the gap and conduct corrective actions to reduce this gap – WPs 3 and 8 related,
- The whole monitoring approach should lead to a set of lessons learnt and guidelines that will serve the investors in getting some security related to the installation – WP8 related.

2.2 Assess the impact of BIPV technologies

One major aim of the demonstration phase of the PVSITES project is to assess the impact of the integration of BIPV technologies on the energy performance of buildings and the indoor conditions that may be affected by such integration.

BIPV elements, according to their integration type, can influence the passive properties of envelops and buildings in various ways. Semi-transparent BIPV technologies can affect the natural lighting of a room and reduce the free heating input leading to an increase in energy (heating) demand.

2.2.1 In terms of energy performances

PVSITEs aims at assessing the way BIPV integration affects the energy demand of the buildings in which they are integrated. This includes not only the heating and cooling demand but also the electricity demand and the way the electricity produced can cover a portion of the whole electricity consumption of the building. In this frame, various measurements can be envisioned:

- Direct measurement: energy consumption measurement, U-value measurement, ….
- Indirect measurement: ventilation consumptions if the BIPV integration may have an impact on the way the ventilation is functioning in the building. Heating, cooling and lighting consumptions can also be considered here.

It should be highlighted that in the frame of PVSITES, the estimated impact of BIPV on passive behaviors will be based on simulation. The thermal flux measurements will not be conducted on the demonstration building.

2.2.2 In terms of indoor comfort

The monitoring conducted within the project will also evaluate the impact on the indoor conditions for certain configurations in which the environmental conditions may be affected. This potential impact is measured through the measurement of parameters directly impacted such as indoor temperature (and the related parameter which is relative humidity) in different locations (e.g., near or away from surfaces), or share of natural light entering a room (ratio between the external irradiation and the outdoor irradiation), amount of heat entering a room. Occupancy information could be useful information in order to make the analysis of comfort conditions.

2.3 Assess the BIPV performance

A photovoltaic component for building integration (BIPV) is a complex technological system in which different requirements have to be met (electrical and building-related) in order to ensure the overall desired performance of the component in the building. Actual performance of a PV system can differ from its expected behaviour. This is the main reason why the performance of PV systems should be monitored, analyzed and, if needed, improved on. In order to evaluate these performances, test procedures have to be carefully defined.

In the absence of standards for monitoring activities directly addressing BIPV components, the monitoring approach that has been proposed in D2.1 includes the following elements to be measured:

Table 2.1 Parameters to be measured in order to assess the BIPV system performance

Parameter to be measured	Description	Unit	Mean of measurement	Observations
Module surface temperature	This measurement is conducted through the use of specific temperature sensor that can be attached directly to the surface to be monitored (back end of the module). The module performance directly and strongly depends on its temperature during operation.	°C	PT100 self-adhesive sensor	Maximum recommended precision: ±1K
Ambient temperature	The air temperature should be measured at a location which is representative of the conditions met by the BIPV system	°C	Weather station installed in the vicinity of the BIPV installation	Maximum recommended precision: ±1K
Wind velocity	If applicable, the wind velocity should be measured at a location which is representative of the conditions met by the BIPV system (it should be located close to the BIPV system (surface) without creating shade)	m/s	Weather station installed in the vicinity of the BIPV installation	This parameter is optional

Solar irradiation	Global horizontal solar irradiation measured in the plan of the PV cell with the ability to dissociate the direct solar irradiation (DNI) from the diffuse solar irradiation (DHI) This parameter can be used to calculate the global energy exposure of the system (by day, month).	W/m²	Pyranometer positioned on an horizontal position and another one positioned in an inclined position can be used for these measurements.	Maximum recommended precision: ±5% of reading
Electrical power	The electrical power (DC current) before the inverter and Electrical power (AC current) after the inverter need to be measured	kW	Wattmeter	Maximum recommended precision: ±2% of reading
Real energy produced	A sufficient time resolution allowing the detection of low production.	kWh	Electrical meter/power meter	

All these parameters will give insight on the environmental conditions of the BIPV installations as well as provide details about the energy production regarding these environmental conditions in real conditions. In parallel to these measurements, punctual and periodical visual observation (monthly observation for instance) will be conducted in order to check visual aspect of the BIPV modules (dust deposit for instance).

Both approaches (impact of BIPV technologies on the building and BIPV performances) will be analysed according to the different configurations retained for the six demonstration sites and this analysis will lead to a specific Measurement and Verification (M&V) Plan taking into account the specificities of each pilot in terms of BIPV technologies, BIPV implementation and location, energy usage, building typology and configuration).

3 MONITORING PROCEDURE

A chronological procedure is proposed for the implementation of the monitoring program of the PVSITES project. A chronological approach enables a clear definition of the main steps to be taken for the implementation of the methodology which is detailed hereafter.

The main steps of the procedure are:

1. Site analysis
2. Proposition of a measurement and verification plan
3. Monitoring equipment installation
4. Data collection and analysis
5. Reporting

The following sections describe in a more detailed way the objective and content of each step.

3.1 Site analysis

The sites to be monitored have to be deeply analysed before the definition of the monitoring plan. This is done through:

- Site documentation analysis: thanks to the support from the local pilot site managers, information about the building will be collected (architectural plans, electricity and fluids plans, description of HVAC systems, description of counters, description of the way the building and its systems are managed and piloted) and information about the existing measurement devices as well as BIPV installation plan (location, power…). In order to proceed to the collection of this information, a specific questionnaire has been elaborated in order to collect preliminary information from the pilot sites and is provided in an Annex (see section 7.1).

- Site visit: the partners involved in the monitoring aspects will visit the pilot sites and collect the required information to feed the monitoring program. These visits allow integrating clearly all the technical details and issues that cannot or have not been taken into account from the documentation analysis. It also allows for meeting with local stakeholders who deliver interesting “qualitative” information.

Regarding the PVSITES project, the visits of the pilot sites give also the opportunity to identify or confirm the location for the installation of the BIPV system. This gives also the chance to identify the possible locations for the installation of the devices that should be installed outdoor for the BIPV performance assessment (weather station for instance). After the pilot site visits, a clear and very detailed report should be written in order to aggregate the information and share it with the other partners involved in the tasks associated with pilot sites and demonstration.

3.2 Proposition of a measurement and verification plan

Once both pilot sites and project objectives regarding each site are clearly defined and agreed, a formal monitoring plan is established and proposed to the consortium in order to identify if all the targets of demonstration are covered. This formal monitoring plan is called Measurement & Verification plan (M&V Plan) according to the IPMVP (International Performance Measurement and Verification Protocol) which is the methodology that will be used as the main framework to set-up the monitoring activities within PVSITES. The M&V Plan integrates 13 items ensuring that each impacting parameter is taken into consideration and assigning the responsibilities to all the partners intervening in the monitoring process. This M&V plan should be agreed between stakeholders involved in the monitoring process (from implementation up to data analysis and use) and pilots’ managers. This is important in order to guarantee that each partner understands his role and is aware of all the influencing parameters that should be monitoring continuously.

The D8.7 introduces a first framework for the M&V Plans to be considered within PVSITES (monitoring guidelines) and the document D8.8 to be delivered later will provide the specific details related with each pilot site and the associated M&V Plans.

3.3 Monitoring equipment installation

The equipment which are selected and mentioned in the M&V Plans of each pilot site are calibrated and installed on site by the partners responsible for this specific task. The installation is properly conducted with an emphasis on the verification of communication between equipment and the correct data acquisition for all the devices installed on site.

Equipment installation has to be conducted by qualified professionals and the necessary authorizations, especially for electricity and fluids monitoring.

The building owner and the local stakeholders (housekeeper, tenants, building manager, maintenance responsible…) should also be involved in the installation process when necessary.

In the case of PVSITES, the monitoring equipment will be installed in two different phases:

- A first phase before the implementation of the BIPV technologies in order to establish the baseline of the sites and monitor the reporting period for comparison.

- A second phase after the implementation of the BIPV systems on site in order to measure the BIPV performances. For the monitoring of this phase, additional measurement devices (in comparison to the first phase) will be installed in relation with BIPV performance assessment.

3.4 Data collection and analysis

The data collection starts as soon as the equipment are installed. In some cases, the existing BMS already installed on site can provide historical data that can serve to establish the baseline situation. Energy bills can also be collected and used for the baseline assessment. The data collection should last at least the duration required to perform the evaluation. As regards to the BIPV impact assessment, this could require a data collection during one year prior to the installation of the BIPV solutions and one year after the installation of the BIPV technologies. The collection period will be enough to cover all different seasonal conditions.

Data collection should be achieved through the use of a redundant storage solution in order to avoid data losses.

In the case of the PVSITES project, all the data collected on site will be automatically sent to an FTP server. PVSITES data will be stored in daily files (*.csv or *.txt) that will be uploaded and actualized every 15 minutes. The structure of the data contained in the file or data format will be defined. It will include at least a variable tag, value, description and a timestamp for each value.

Data coming from other PVSITES modules will be shared with Building Control Centre in one of the following ways (schema provided in Figure 3.3).

- Through file interchange in a common server (FTP)
- Through webservices provided by PVSITE module
- Through Application Program Interfaces (API's) provided by PVSITE module.

The Building Control Centre developed by ACCIONA (see annex 2, section 7.2) will provide an API REST so that the PVSITES stored data is available for other PVSITES modules.

The BCC is a platform that provides different services, among them, the ability to manage data collection from different BMS (Building Management System) and measurement infrastructures (Figure 3.1).

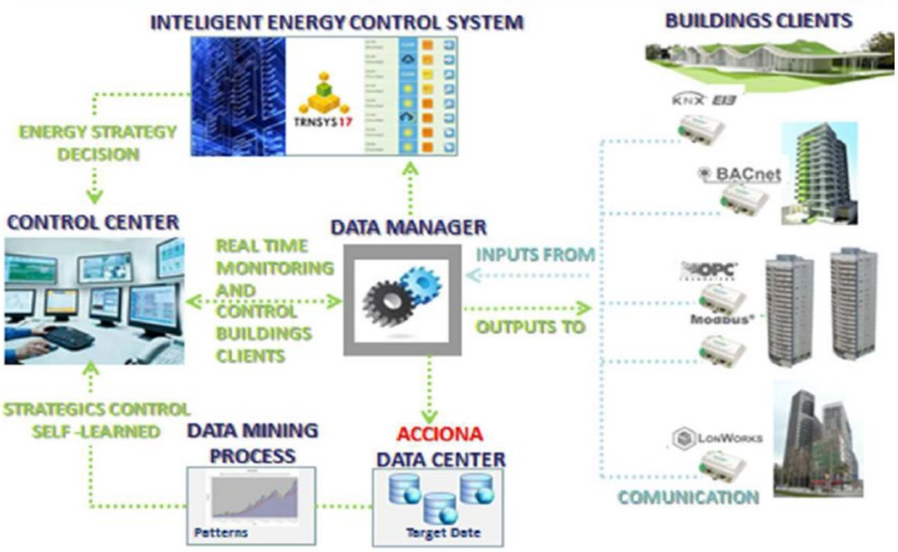


Figure 3.1 Flows used within the BCC

On the demo sites, the data are collected through a local aggregator device (Webdyn Gateway) from the measurement infrastructure and then sent to an FTP server from which the BCC will gather the whole information according to the schema provided in Figure 3.2.

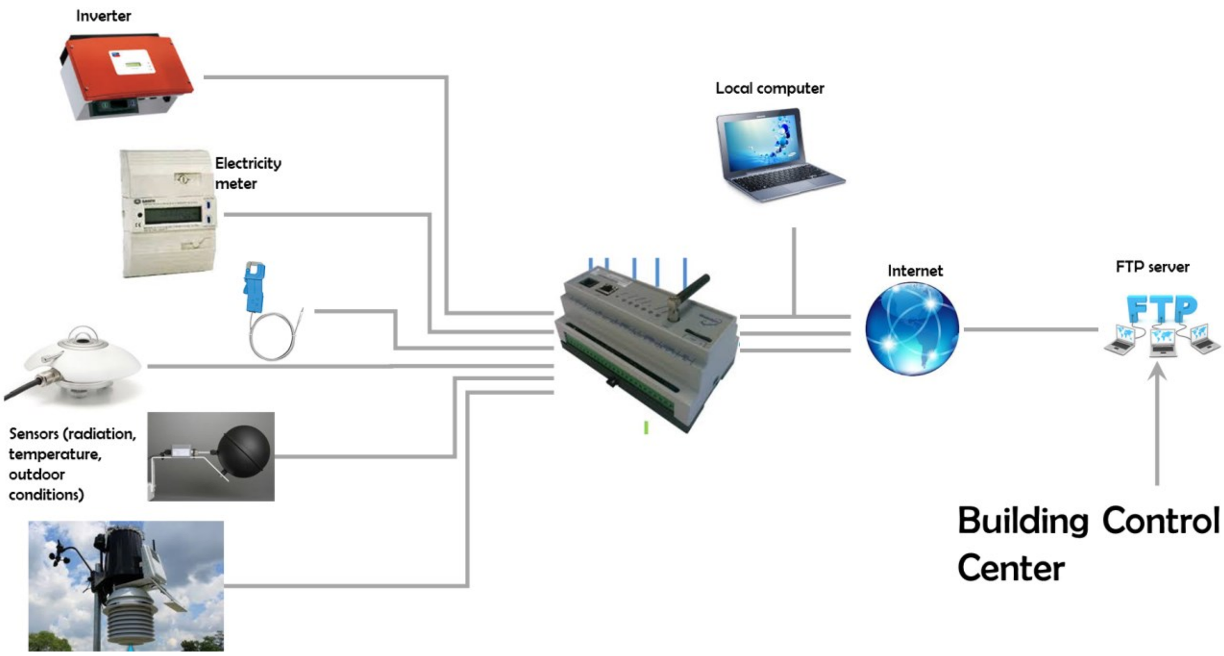


Figure 3.2 General communication concept between the monitoring infrastructure on site and the BCC

The BCC (recovering and storage solution) is taken into account as early as possible in order to identify the associated requirements and needs when defining the M&V plan so that the IT communication between the field level measurement infrastructure and the BCC will be operational and efficient.

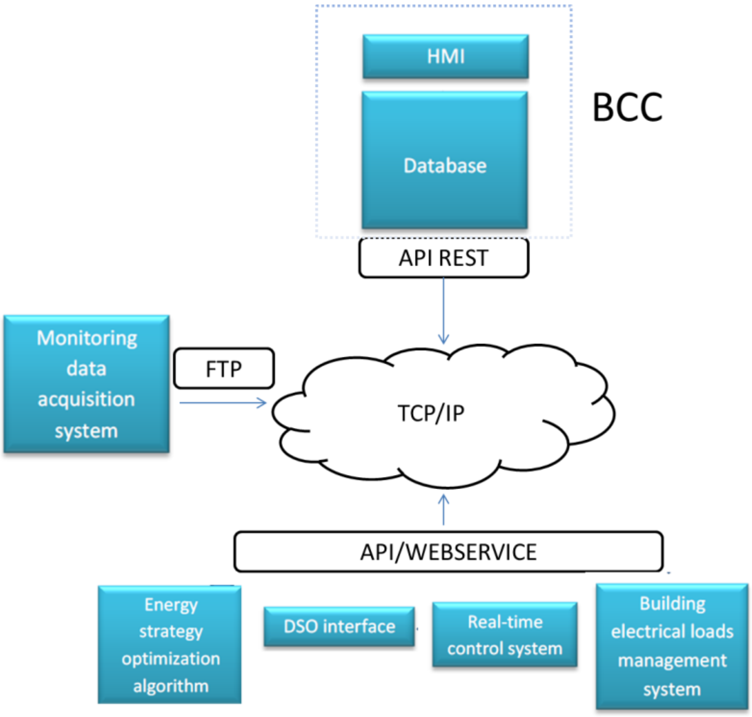


Figure 3.3 BCC integration in the PVSITES Architecture.

Concerning the data analysis, it will be conducted at several levels:

- First, a comparison between the data collected on the same parameters before and after the installation of BIPV will be conducted. This will allow highlighting some evolutions in the building functioning.
- An absolute performance assessment will be done on the BIPV parameters.
- A comparative analysis will be conducted between the expected performances of the BIPV installations and the real situation. Regarding the BIPV electricity generation the comparison will occur with the predictions from the manufacturers with respect to efficiency and production (for given solar radiation), while for the BIPV influence on passive behaviour, loads and comfort this comparison will be done against the predictions generated via simulation or detailed diagnosis possibly supported by specific measurements.
- A comparison between the building functioning will also be done with the results obtained within the simulation activities (WP3, WP4 and WP7). It should be noted that this comparison will be made on the basis of the evolutions trends and not on the quantitative values obtained.

Important remark about data analysis:

Concerning the comparison between simulation and measurements of the demonstration buildings, it is important to highlight very early that it will be very challenging (for instance because of the uncertainty associated to simulation and prediction as regards to the retained hypothesis). A specific attention will be paid to this comparison and the following objectives will be continuously considered (from the most optimistic to the most basic ones):

- Validate models by comparing evolution of parameters (Temperature, Electricity production, Cooling or heating consumption, lighting electricity consumption…).
- Overall comparison between what is predicted and what is measured: weekly, monthly, annually comparison of electricity production… maximum of temperature or power production reached.

- Analysis and comparison of the measurements (from a panel to another, from a panel on a demo building, against a panel on a test bench or in lab).
- Analysis of the measurements regarding overall indoor comfort conditions and local effets.
- Interpretation and assumption regarding reasons for divergency.

Therefore, it should be mentioned that comparison of simulated data with diagnostic and characterisation measurements should be more accurate and achievable than continuous monitoring. This is why punctual measurements such as blower door tests or Infrared thermography images can also be used to complete the continuous measurement of energy consumptions and indoor conditions.

The conducted analysis must also lead to a set of specific lessons learnt that could help in expanding the approach to a larger application of the monitoring guidelines exposed in this document.

3.5 Reporting

The reporting will be conducted periodically with the following purposes:

- Detect anomalies in the BIPV solutions functioning or in the building behavior,
- Understand real performances in different climatic seasons and operation conditions,
- Detect problems in data collection or measurement devices functioning,
- Get intermediary results that could be used to improve the systems themselves.

The reporting will be shared with the partners involved in the demonstration of the PVSITES project.

The report format and the frequency of reporting that will be used within the project are further detailed in the M&V plans for each pilot site.

4 COMMON GUIDELINES - IPMVP FRAMEWORK

The IPMVP (International Performance Measurement and Verification Protocol) is used as a framework for the PVSITES monitoring program. IPMVP allows integrating a global analysis for the monitoring program, from requirements to reporting. It brings coherence to the measurements realized and insures the quality of the results [1].

IPMVP can be implemented through a Measurements and Verification (M&V) Plan for the project and for each of the pilots. An M&V Plan is based on 13 items to be fulfilled in order to set up a clear and coherent monitoring plan. These 13 points are used in the following sub-chapters to present the PVSITES monitoring guidelines.

4.1 Energy conservation measures intent

The PVSITES project aims at installing the BIPV technologies investigated in the project and assess the impact of it on the energy performance of the building.

The BIPV technologies, by their very nature, will replace a portion of the envelope of the building. Moreover, they will produce electricity that can be self-consumed in order to cover a portion of the overall electricity consumption of the building. Both measures should be considered within the monitoring approach.

4.2 IPMVP option and measurement boundary

Options A, B and C are appropriate for the monitoring within PVSITES project. For reminder, the key characteristics of each option are provided in Annex 3 (section 7.3).

Option D in the case of the BIPV performance assessment in comparison to the simulated performance can also be used.

As stated in [2], option C of IPMVP may be most appropriate for applications in which renewable energy contributes a large part of the building load, or when renewable energy systems are installed as part of a larger suite of energy efficiency measures. However, in some cases the perimeter influenced by the installation of the BIPV systems can't be isolated in terms of measurements and therefore Option C is the only one applicable.

In most of the demonstration buildings of the PVSITES project, the BIPV installations will not contribute to a large part of the building load. Therefore the measurement perimeter will be adapted.

4.3 Baseline: Period, energy and conditions

The baseline period will be established using different kinds of information:

- Energy consumptions measurements (per energy type) through the energy meters available from the energy providers. This information will be made available by the pilot managers through the provision of energy bills.

- Energy consumptions measurements collected within the project thanks to additional measurements devices installed by the partners.

- Indoor conditions measured in the perimeter investigated in the study through additional measurement devices installed by the partners.

The measurement period should be preferably one year or should include at least a cold and a warm period in order to be representative in terms of external conditions.

The collection of static parameters (such as indoor temperature set point, area and volumes of heated spaces, number of occupants, regulation settings) and independent variables (such as the outdoor temperature or heating degree days) is also required during this baseline period in order to enable the adjustments of the reference.

The baseline establishment should be detailed in the M&V plan of each pilot site and includes all the items previously described.

A detailed description of the building has to be included in this section of the M&V plan in order to clearly identify which are the influent parameters affecting the parameters that will be measured.

A proposition for the content of this section in the M&V plan is the following:

- Building analysis
  - Site context and data
  - Main equipment present in the building
- Baseline parameters
  - Collected data
  - Independent variables[1] (outdoor temperature or HDD (Heating Degree Days)/CDD (Cooling Degree Days))
  - Static factors[2] (indoor temperature set-point, building envelop characteristics, building systems characteristics, area and volume of heated space, occupation rate, number of occupants, ventilation rate).

4.4 Reporting period

The reporting period should preferably last 1 year and include at least a warm and cold period.

The parameters to be measured in the frame of the PVSITES demonstration are listed in the following table. The area concerned by each measurement should be clearly defined for each site in relation with the simulation activities. If sampling is used for some of the measurements, this sampling should be clearly defined and explained and should be as representative as possible so that extrapolation can be made and a correct and reliable impact assessment can be achieved.

[1] According to the IPMVP, an independent variable is a parameter that is expected to change regularly and have a measurable impact on the energy use of a system or facility. For example, a common independent variable governing building energy use is outdoor temperature. Likewise in a manufacturing plant the number of units produced in a period is often an independent variable significantly affecting energy use. Another common independent variable is the number of seconds, hours or days in each metering period.

[2] According to the IPMVP, static factors are parameters which are not usually expected to change such as the facility size, the design and operation of installed equipment. These factors should be monitored during the reporting period and non-periodic adjustments should be made in case of evolution of these factors.

Table 4.1 Raw parameters to be measured for each pilot site

Parameters	Boundaries
Heating consumptions	At the whole building scale
	At the level of the area impacted by the BIPV installation (if possible to isolate the area)
Electricity consumptions	At the whole building scale
	At the level of the area impacted by the BIPV installation (if possible to isolate the area)
	At the level of the energy usage that can self-consume the energy produced by the BIPV
Indoor environmental parameters: temperature, humidity, occupation, luminance	At the level of the area impacted by the BIPV installation (if possible to isolate the area)
Electricity generated	Electricity generated by the installed BIPV system
Outdoor parameters: **Temperature, Wind speed at the location of the BIPV, Solar irradiation at the location of the BIPV**	In the vicinity of the building and for solar radiation in the conditions BIPV modules.
BIPV system conditions and performances	Surface temperature of the BIPV modules Energy produced at the key locations of the PV installations (inverter output, inverter input, between the inverter and the storage system, between the PV system and the grid)

Concerning the data acquisition frequency, it will be mainly driven by the need associated by the WP6 requirements. It should be checked that the same frequency is used for both the baseline and the reporting periods so that comparison can be made.

NB: some punctual measurements can be conducted in order to evaluate specific parameters.

- U-value measurement: as an example, we can mention here envelop parameters measurements that could be conducted punctually before the implementation of the BIPV solution on the portion of the envelop concerned by the replacement and after the BIPV implementation. A U-value measurement through the use of a thermal fluxmeter potentially coupled with an infrared camera can be proposed over a small area of the roof or façade considered. This measurement won't be implemented in the frame of the PVSITES project.
- Heat flow rate will be measured in real conditions before and after the BIPV installations.
- Blower door and Infrared thermography tests: blower door tests could be used as well in order to evaluate the impact of the ECM on the ventilation rate and leakage. This test can be conducted before and after the installation of the BIPV solution and the results compared in terms of Q4 value. Coupling the air leakage tests with Infrared thermography measurements allows for the identification of thermal bridges and can provide qualitative visualization of leakage if present in the building. These measurements should be performed according to the standard NF EN 13829.

4.5 Basis for adjustments

The model will be established on the monthly energy consumptions (heating, cooling, lighting…). The adjustment that will be used is based on the avoided energy use method. The baseline will be adjusted to the conditions observed for the reporting period.

4.5.1 Independent variables

Concerning heating consumptions, the Heating Degree Days (HDD) will be used as independent variable to build the model and conduct the required adjustments. For cooling consumptions, CDD (Cooling Degree Days) will be used. Regarding electricity consumption associated with lighting, occupancy and luminance level are two independent variables to consider in the models set-up. For BIPV production, solar radiation will be the main independent variable to consider.

In other cases, other independent variables may be used in order to adjust the measurement for instance the occupancy, or the parameters set-up.

4.5.2 Static parameters

The M&V plan should provide the list of the static parameters to be considered for each pilot site (this will be specified in the M&V plans). The monitoring of these static parameters should be part of the regular monitoring of the site and any evolution of these static parameters should be reported regularly by the building managers. As a general rule, non-periodic adjustments related with static parameters evolution should be made proportionally according to the parameter evolution. This will depend on the static factor to be considered. The following parameters can be identified as static factors:

Table 4.2 Static factors and potential non-periodic adjustment

Static factor	Value to be adjusted
Indoor temperature set-up	If the indoor temperature is greater than the comfort temperature, there will be no adjustment. If the indoor temperature is lower than the comfort temperature, an adjustment will be done on the heating consumptions.
Area and volume of heated spaces	Proportional adjustment on the Heating consumptions
Building envelop characteristics	Proportional adjustment on the Heating consumptions
Building systems characteristics	Adjustment on the Heating and electricity consumptions
Occupation rate / number of occupants	Proportional adjustment on the Electricity energy consumptions and heating consumptions
Ventilation rate	Proportional adjustment on the Electricity energy consumptions

4.6 Analysis procedure

The following analysis and monitoring indicators are proposed in order to comply with the objectives of the PVSITES project. Of course, these indicators will be selected according to the use case associated to each pilot site.

- Final energy consumption per square meter (kWh/m²) for the whole building or for a restricted area of the building expressed for a full year and for representative weeks (the coldest week, the warmest week for instance),

- Electricity consumption (overall or for specific usage (lighting for instance)) per square meter (kWh /m²) for the whole building or a restricted area of the building expressed for a full year and for representative weeks (activity week and holiday week),

- Heating consumption per square meter (kWh/m²) for the whole building or for a restricted area of the building expressed for a full year and for representative weeks (the coldest week, the warmest week for instance) – the value will be adjusted according to the static parameters,

- Comfort level (number of hours when the indoor temperature is outside the comfort range i.e. <18° and >28°C). For each demo-site, the temperature range may be adjusted according to comfort and safety regulation. A complementary key performance indicator could be defined as follows :

  (Number of hours when the temperature is outside the comfort range) x delatT.

- Energy production per square meter of BIPV installed (kWh/m²) or kWh/kWp for a full year and for representative weeks (winter week and summer week).

- Comparison between same indicators calculated for the baseline and the reporting periods including the required adjustment.

A more specific analysis will be conducted on the measurements conducted on the BIPV systems:

- A correlation will be established between the electricity produced and the temperature measured on the PV modules.

- A correlation will be established between the electricity produced and the irradiation level measured on site in the vicinity of the installation.

- A correlation will be established between the electricity produced and the wind speed measured on site in the vicinity of the installation.

- An analysis will be conducted on the potential coverage of this production as regards to specific usages (how the production can be used for self-consumption on site?).

- A comparison between the real performances measurements and the simulated one.

4.7 Energy prices

The energy prices can be used to promote the energy savings realized through the local energy production on site and its self-consumption. In this frame, it is interesting to assess the self-consumption or the self-production rates.

Energy prices can also be used to value the savings/waste generated by the introduction of the BIPV in the building as an energy conservation measure consisting in replacing a portion of the envelop.

The M&V Plan should mention the energy prices (dynamic and incentives/tariff for injection into grid) for each energy type and consider the energy prices evolution if required (formula to be provided). The selling and buying prices should also be considered for the electricity generation. This information is site/country specific and should be provided by the local partner responsible of the demonstration site.

4.8 Meter specifications

This information is site specific and is to be mentioned in the M&V Plan of each site. It will include the description of metering points and periods (of importance in cases of not continuous energy consumption metering).

For each site, the references of each meter shall be mentioned including the type, brand and model, the mean of communication, and the mean of power supply.

4.9 Monitoring responsibilities

The M&V Plan should mention the tasks to be conducted in the frame of the monitoring and the persons appointed for each task in a way similar to what is proposed in the following table.

Table 4.3 Definition of monitoring responsibilities

Task/Activity	Time period	Responsible
M&V Plan proposal	Baseline + reporting periods	NOBATEK + Pilot Site manager
M&V Plan validation	Baseline + reporting periods	PVSITES consortium
Equipment proposal	Baseline + reporting periods	NOBATEK + Pilot Site manager
Equipment validation	Baseline + reporting periods	NOBATEK + ACCIONA + Pilot Site manager
Equipment installation	Baseline	NOBATEK with the support of pilot site manager
Equipment maintenance and replacement	Baseline + reporting periods	Pilot Site manager + NOBATEK
Local communication verification	Baseline + reporting periods	Pilot Site manager + NOBATEK
Data recording (including static parameters and independent variables)	Baseline + reporting periods	NOBATEK + Pilot Site manager (static factors)
Data sharing	Baseline + reporting periods	NOBATEK + ACCIONA (Building Control Centre)
Data analysis	Baseline + reporting periods	NOBATEK + R2M
Project reporting	Baseline + reporting periods	NOBATEK + ACCIONA

4.10 Expected accuracy

The uncertainties associated to the M&V process are related with:

- Uncertainty associated to the measurements
- Adjustments and calculation process

For the equipment to be installed, its uncertainty will be specified (cf. M&V Plan of each site).

4.11 Budget

This information is site specific and shall be mentioned in the M&V Plan of each site. It shall include the definition of budget required for savings determination (Initial set-up costs and ongoing costs throughout the reporting period). Nevertheless, this information won't be fully exploited in the frame of the PVSITES project.

4.12 Report format

In the case of the PVSITES project, the following elements should be mentioned in the reporting:

- Impact of the BIPV technologies on the energy performance of the building and indoor environmental conditions (taking into account the indicators mentioned earlier),
- Performances of the BIPV installations (taking into consideration the influencing parameters analysis),
- Discrepancies between forecasted and real results for the BIPV performances,
- Lessons learnt, site by site but also common conclusions.

The reporting will be done on a six-month basis providing the monthly values of the parameters which are monitored.

4.13 Quality assurance

In the frame of the IPMVP application, it is recommended to have a CMVP (CERTIFIED MEASUREMENT AND VERIFICATION PROFESSIONAL) person involved in the process of M&V.

A double saving strategy will ensure a proper storage of the collected data. This will be ensured by the use of the Building Control Center from ACCIONA and a local storage at NOBATEK.

When possible or required, a cross checking will be conducted between the measured data and the bills collected from the building owner.

Moreover, a periodic validation allowing to check if the data is recorded properly is also recommended.

In the case of missing or outliers data, it is agreed to determine the missing data by interpolation with the adjacent data (this is only applicable for short periods of time).

Some periodic maintenance visits are planned in the pilot sites in order to check that the monitoring infrastructure is functional.

5 CONCLUSIONS

This report describes the monitoring guidelines supporting the monitoring and evaluation approach of the PVSITES project. These guidelines define a set of actions proposed as a common performance evaluation process to be implemented in monitoring processes for BIPV projects. It is also the basis for the definition of the monitoring programs for each pilot site.

These guidelines define a set of actions and steps proposed as a common performance evaluation process to be implemented. The guidelines are based on two main items:

- A monitoring procedure providing a very detailed process made of several steps and requirements.
- The IPMVP protocol as the framework for the monitoring programme content, ensuring both quality of the assessment to be done and homogeneity between each pilot site.

These guidelines should be read, understood and agree by all the partners involved in the demonstration and BIPV technologies assessment within the PVSITES project.

6 REFERENCES

[1] EVO, International Performance Measurement and Verification Protocol, Concepts and Options for Determining Energy and Water Savings, Volume 1, EVO 10000-1, 2012.

[2] EVO, International Performance Measurement and Verification Protocol, Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications, Volume III, August 2003,

7 APPENDICES

7.1 Appendix 1: Questionnaire elaborated at the beginning of the project to collect the information from the pilot site

[Name of the demo]

Description of the demo project: [Describe main issues of the demo project and resulting building.]

Responsible partner for the demo is [XXXXXXXXX]

[INSERT PHOTO DEMO]

Insert any picture related to the Demo illustrate it

General details of the demo:

Characteristics of the building	
Building type	[residential/office/industrial/public service/ x/ y]
Location	[city, country]
Area	[will describe the scale of the project]
Number of floors	[write the number of storeys]

Info DEMO leader

ROLE	ORANIZATION	CONTACT NAME	LOCATION	E-MAIL	PHONE

Info Partners/Stakeholders:

ROLE	ORGANIZATION	CONTACT NAME	LOCATION	E-MAIL	PHONE

Info Demo

QUESTION	ANSWER
What are the systems for HEATING/COOLING generation currently used in the building? What is the energy source used by these systems?	[Chiller, VRV, Heat Pump, boiler…all the possible information to describe the system]
What is the system for DHW generation currently used in the building? What is the energy source used by this system?	
Is the building being energy monitored and controlled (BMS, PLC, SCADA etc…)	[Yes/no. Please, try to describe the systems etc. Please join the BMS system architecture. Please specify the measures/counters controlled by BMS/SCADA: • Energy Counts (general electricity counter, heating counter, gas counter…) • Indoor climatic conditions • Outdoor climatic conditions • Occupancy sensors]
If a BMS/SCADA is present, are the historical energy data stored into a database application? What is the date for the first data stored?	[YES/NO, data stored from…]
Can we collect these historical data (DBB accessible? data export from BMS Supervision software to an .csv/.txt/.xml file?)?	[Yes/NO, Means of data collection]
If a BMS is installed in your building, can we please get access to the measurement plan associated to this BMS?	

Is the building currently being energy measured?	[information about:
	- Metering equipment and sensors list. Please specify:
	    o Electricity meters installed and what they measure.
	    o Gas meters installed and what they measure.
	    o Thermal energy meters installed and what they measure.
	- Field buses,
	- Manufacturers and protocols used (BACnet, MODBUS, etc…).]

Is there any comfort sensor installed in the building (temperature sensors? Humidity sensors?)? And is it possible to get historical data from these sensors (data from last year for instance)?	[YES/NO, Which sensors? .csv or .txt files]
Do you have any diagram to know what measurement devices do you have installed?	[It could be interesting to have a diagram to analyse]
Do you have historical energy consumption measured data for electricity, for heating, for cooling for the past few years (2014, 2015)?	
Do you have historical data related to indoor environmental conditions available?	
Do you have building energy consumption bills for the past few years (2014, 2015)?	[Electrical, gas…] [If some energy bills are available for your building and for the past few years (2015 would be the best), could you please make them accessible through the restricted area of the PVSITES website?]
Do you have an open internet access to connect from the outside and to which our monitoring devices or the BMS will be connected in order to be able to collect the measured data remotely?	[LAN, Firewall restrictions, public IP, FTP, web services, describe building ICT system]
Is there a weather station installed close to the building?	YES/NO, What are the data measured by this weather station?

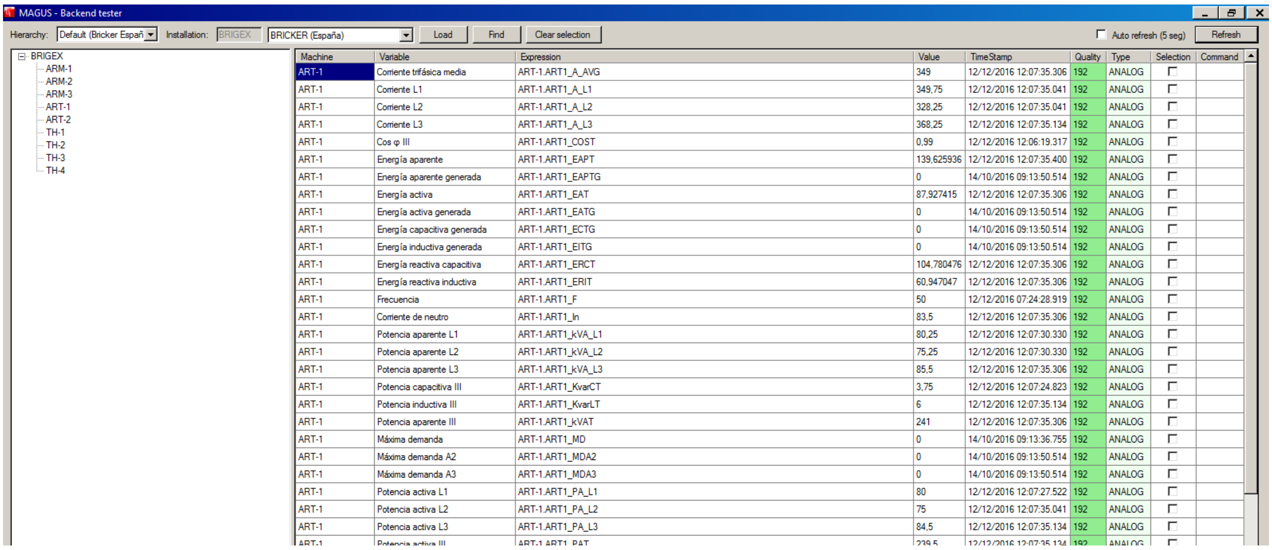
7.2 Appendix 2: Description of the Building Control Centre

ACCIONA Building Control Centre is a Monitoring and Control solution designed for buildings. It is a computer-based system with an open architecture as it allows building integration through different backend solutions (existing BMS, embedded PC, PLC etc.) and supports standardized communication protocols (OPC, BACnet, MODBUS). Communications are secured via encryption tools (VPN). Buildings are monitored and controlled through an energy SCADA system that provides a set of tools for real time monitoring energy performance, visualization, graphical analysis, historical data and reporting services.

BCC is designed to manage, control and monitor building technical services (power, HVAC, lighting etc.) and the energy consumptions and different building loads. It provides the information and the tools that aid building managers and maintenance staff to understand the energy usage of their buildings and to control and improve their buildings' energy performance.

BCC can integrate data from different sources, from connecting to a Backend module (PC, PLC, data logger etc.) installed on site, or connecting to other servers (FTP) or using different type of services (Web Service, API). This flexibility makes easier the integration tasks and allows BCC to communicate with many type of equipment or systems.

Different types of users or groups of users can be defined, with different types of access to the building information (Owner, Manager, maintenance and operation staff, etc.)



Machine	Variable	Expression	Value	TimeStamp	Quality	Type	Selection	Command
ART-1	Corriente trifásica media	ART-1.ART1_A_AVG	349	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Corriente L1	ART-1.ART1_A_L1	349,75	12/12/2016 12:07:35.041	192	ANALOG		
ART-1	Corriente L2	ART-1.ART1_A_L2	328,25	12/12/2016 12:07:35.041	192	ANALOG		
ART-1	Corriente L3	ART-1.ART1_A_L3	368,25	12/12/2016 12:07:35.134	192	ANALOG		
ART-1	Cos φ III	ART-1.ART1_COST	0,99	12/12/2016 12:06:19.317	192	ANALOG		
ART-1	Energía aparente	ART-1.ART1_EAPT	139,625936	12/12/2016 12:07:35.400	192	ANALOG		
ART-1	Energía aparente generada	ART-1.ART1_EAPTG	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Energía activa	ART-1.ART1_EAT	87,927415	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Energía activa generada	ART-1.ART1_EATG	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Energía capacitiva generada	ART-1.ART1_ECTG	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Energía inductiva generada	ART-1.ART1_EITG	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Energía reactiva capacitiva	ART-1.ART1_ERCT	104,780476	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Energía reactiva inductiva	ART-1.ART1_ERIT	60,947047	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Frecuencia	ART-1.ART1_F	50	12/12/2016 07:24:28.919	192	ANALOG		
ART-1	Corriente de neutro	ART-1.ART1_In	83,5	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Potencia aparente L1	ART-1.ART1_kVA_L1	80,25	12/12/2016 12:07:30.330	192	ANALOG		
ART-1	Potencia aparente L2	ART-1.ART1_kVA_L2	75,25	12/12/2016 12:07:30.330	192	ANALOG		
ART-1	Potencia aparente L3	ART-1.ART1_kVA_L3	85,5	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Potencia capacitiva III	ART-1.ART1_KvarCT	3,75	12/12/2016 12:07:24.823	192	ANALOG		
ART-1	Potencia inductiva III	ART-1.ART1_KvarLT	6	12/12/2016 12:07:35.134	192	ANALOG		
ART-1	Potencia aparente III	ART-1.ART1_kVAT	241	12/12/2016 12:07:35.306	192	ANALOG		
ART-1	Máxima demanda	ART-1.ART1_MD	0	14/10/2016 09:13:36.755	192	ANALOG		
ART-1	Máxima demanda A2	ART-1.ART1_MDA2	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Máxima demanda A3	ART-1.ART1_MDA3	0	14/10/2016 09:13:50.514	192	ANALOG		
ART-1	Potencia activa L1	ART-1.ART1_PA_L1	80	12/12/2016 12:07:27.522	192	ANALOG		
ART-1	Potencia activa L2	ART-1.ART1_PA_L2	75	12/12/2016 12:07:35.041	192	ANALOG		
ART-1	Potencia activa L3	ART-1.ART1_PA_L3	84,5	12/12/2016 12:07:35.134	192	ANALOG		
ART-1	Potencia activa III	ART-1.ART1_PAT	239,5	12/12/2016 12:07:35.134	192	ANALOG		

Energy Reports can be sent to the different users according to their privileges via email.

A website is available for the user for data visualization.

7.3 Appendix 3: Main characteristics of the four options of the IPMVP protocol

Option A: Retrofit isolation-Key parameter measurement. Energy quantities involved in the savings calculation can be derived from a computation using a combination of measurements of some parameters and estimates of the others.

Option B: Retrofit Isolation-All parameter measurement. This option requires the measurement of all energy quantities, or all parameters needed to compute energy savings.

Option C: Whole facility. Savings are determined by measuring energy use at the whole facility or sub-facility level. This option involves use of utility meters, whole-facility meters, or sub-meters to assess the energy performance of a total facility. The measurement boundary encompasses either the whole facility or a major section. This Option determines the collective savings of all ECMs applied to the part of the facility monitored by the energy meter. Also, since whole-facility meters are used, savings reported under Option C include the positive or negative effects of any non-ECM changes made in the facility.