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

Specific monitoring plan for every PVSITES demonstration sites

Project report

NOBATEK, R2M, ACCIONA, FD2, FLISOM, VILOGIA, CRICURSA, TECNALIA

August 2017

Summary

This document describes the Measurement and Verification plans for each pilot site of the PVSITES project. These M&V plans aim at evaluating 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 environmental conditions and assess the performance of the implemented BIPV technologies themselves. The M&V plans are based on the monitoring guidelines that have been established in deliverable D8.7 "Common monitoring guidelines" and are defined in close relation with each pilot configuration in terms of BIPV implementation (location, technologies) and in close relation with the pilot sites managers to consider all the key factors that could affect monitoring implementation (accessibility, network connection, electrical configuration, etc.).

In addition to this, the defined M&V plans also consider the requirements associated with WP6 "Building Energy Management System for different building uses" activities related with building energy management system and optimization of active load management. For this WP, specific measurements are required for the demonstration and optimisation of PV production use.

Moreover, the IT infrastructure definition has been designed in order to cope with the requirements associated to the collection of monitoring data on the Building Control Center (BCC) managed by ACCIONA.

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 mainly prepared by PVSITES project partner NOBATEK, with additional contributions from R2M, ACCIONA, FD2, FLISOM, VILOGIA, CRICURSA and TECNALIA. The report was originally submitted to the European Commission as Project Deliverable D8.8 in August 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 task 8.4 “Monitoring of installations” and specifically related with subtask 8.4.1 “Detailed technical design of monitoring”. It specifies the Measurement and Verification Plans to be deployed for each pilot site and it establishes the specific details associated to each demonstration building.

This document proposes a general framework for the definition and design of a monitoring programme. It also gives tools for the implementation of the monitoring process and provides a full IPMVP framework for Measurement and Verification (M&V) programme aiming at the evaluation of impact of the BIPV introduction on the energy performance of the building. These guidelines contain generic recommendations and general description of the monitoring process that can be applied to different BIPV installation projects similar to PVSITES. In addition to this document, a further detailed description of the monitoring actions to be implemented in each demonstration site will be specified in another document.

The present document 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 pilot site. Moreover, the defined M&V plans consider the requirements associated with WP6 activities related with building energy management system and optimization of active load management. For this WP, specific electrical measurements are required for the demonstration and optimisation of PV production use.

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 and especially the WP6 requirements.

The second part of the document (Chapter 3) summarises the main items to be considered for each pilot site when analysing the pilot sites configurations.

The third part of the document (Chapter 4) provides the monitoring plans for the six pilot sites describing the 13 items to be considered in the whole monitoring process and recommended by the IPMVP:

-Energy conservation measures (ECM) intent,
-IPMVP option and measurement boundary,
-Baseline: Period, energy and conditions,
-Reporting period,
-Basis for adjustments: independent variables and static parameters,
-Analysis procedure,
-Energy prices,
-Meter specifications,
-Monitoring responsibilities,
-Expected accuracy,
-Budget,
-Report format,
-Quality assurance.

1.2 Relation with other activities in the project

Table 1.1. **Fehler! Verweisquelle konnte nicht gefunden werden.**depicts the main links of deliverable D8.8 to other activities (work packages, tasks, deliverables, etc.) within PVSITES project.

Table 1.1 Relation between D8.8 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.
D8.1	D8.1 provides a pre-dimensioning of BIPV systems for every demo site. This is the main input for the M&V plan definition.
D8.7	D8.7 introduces a first framework for the M&V Plans to be considered within PVSITES (monitoring guidelines).
D8.3	D8.3 will deliver the final design of the BIPV systems for each demo site.
WP6	Task 8.4 should feed in the planning tool developed within WP6 (Building Energy Management System for different building uses) with data measured on site (data series of PV production, solar radiation)

1.3 Reference material

D2.1 “Technical specifications for BIPV modules”, deliverable of the PVSITES project delivered at M06.

D8.1 “Energy audit of buildings and identification of BIPV possibilities in every demo site”, deliverable of the PVSITES project delivered at M15.

D8.7 “Common monitoring guidelines”, deliverable of the PVSITES project delivered at M15.

D8.3 “Design pack for every demo site”, deliverable of the PVSITES project, in preparation.

1.4 Abbreviation list

BCC: Building Control Centre

BEMS Building Energy Management System

BIPV: Building-integrated photovoltaics

BMS: Building Management System

CDD: Cooling Degree Day

CIGS: Copper Indium Gallium Selenide

COP: Coefficient of Performance

DHW: Domestic Hot Water

ECM: Energy Conservation Measure

EHG:	Ecole Hôtelière de Genève
EV:	Electrical Vehicle
HDD:	Heating Degree Day
ICT:	Information and Communication Technologies
IPMVP:	International Performance Measurement and Verification Protocol
M&V:	Measurement and Verification
PV:	Photovoltaics
WP:	Work Package
X1:	CIGS on steel modules by FLISOM
X2:	CIGS on large area flexible membrane by FLISOM
X4:	CIGS on steel modules by FLISOM
X5:	Glass-glass Si-crystalline modules with hidden bus bars and L-interconnections by ONYX
X7:	CIGS on curved surfaces by ONYX-FLISOM

2 MONITORING OBJECTIVES

This chapter reminds the objectives of the monitoring activities within the PVSITES project and highlights the main features to be considered within these monitoring activities.

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).
- European (even international) dimension as the project aims at driving BIPV technology to a large market deployment.
- Six pilot sites in three different countries with different building type targeted (residential, offices, carport, industrial).
- 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.
- A monitoring program based on the IPMVP protocol.
- A comparison with the simulated data 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.
- 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.

2.1 To assess the impact of the BIPV technologies on the building performances

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. For instance, 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.

2.1.1 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 and help in reducing specific peaks leading to the reduction of electricity bills. 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.

2.1.2 In terms of indoor comfort

The monitoring conducted within the project will also evaluate the impact on the indoor conditions for specific 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 indoor light level and the outdoor light level), or amount of heat entering a room. Occupancy information could be useful information in order to make the analysis of comfort conditions.

2.2 To 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 behavior. 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	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.	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	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)	Weather station installed in the vicinity of the BIPV installation	This parameter is optional. Wind speed impacts on module temperature and therefore may impact on modules performance as well.
Solar radiation	Global horizontal solar radiation measured in the plan of the PV cell with the ability to dissociate the direct solar radiation (DNI) from the diffuse solar radiation (DHI) This parameter can be used to calculate the global energy	Pyranometer positioned on an horizontal position and another one positioned in an inclined position can be	Maximum recommended precision: ±5% of reading

Parameter to be measured	Description	Mean of measurement	Observations
	exposure of the system (by day, month).	used for these measurements.	
Electrical power	The electrical power (DC current) before the inverter and Electrical power (AC current) after the inverter need to be measured	Wattmeter	Maximum recommended precision: ±2% of reading
Real energy produced	A sufficient time resolution allowing the detection of low production.	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) are analysed according to the different configurations retained for the six demonstration sites and this analysis leads 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 Sites analysis and key features to be considered for the monitoring activities

In line with the monitoring guidelines and methodology defined in D8.7, the sites to be monitored have to be deeply analysed before the definition of the monitoring plan. This is done through:

-Visits to the pilot sites: the visits give the opportunity to meet the local stakeholders and collect qualitative information that cannot be perceived through the documentation analysis.

-Discussions with the building owners, facility managers or people in charge of the building management.

-Collection of detailed information through the use of a questionnaire that people in charge of the building management fill in with as much detail as possible.

-Documentation analysis: architectural plans, electricity and fluids plans, description of HVAC systems, description of existing meters.

The following table provides a reminder on the pilot sites considered in the PVSITES project:

Table 3.1 Pilot sites of the PVSITES project

Pilot site	Location	Building typology	Partner in charge of the pilot site management	BIPV technology installed and demonstrated for each pilot site
1	Stambruges, BELGIUM	Residential single dwelling (including an office), new, private	FormatD2	PV integrated roof composed of CIGS on steel modules by FLISOM (model X1), with a double functionality as a constructive roofing solution and a renewable energy generation system.
2	Genève, Switzerland	Tertiary Building, school facilities+hotel, recently built, private	Flisom (Ecole Hôtelière de Genève)	2 façades systems composed of CIGS on large area flexible membrane & bendable elements (models X2 & X4) by FLISOM, with a double functionality as constructive façade solution and renewable energy generation system.
3	Dübendorf, Switzerland	Carport, public, roof renewal	Flisom (EMPA facilities)	PV integrated roof composed of CIGS on steel modules by FLISOM (model X1)
4	Granollers, Spain	Industrial and office building, Retrofitting, private	CRICURSA	PV integrated roof with CIGS on steel modules by FLISOM (model X4), with a double functionality as a constructive roofing solution and a renewable energy generation system.
5	Wattignies, France	Residential multi-storey, social housing	VILOGIA	BIPV ventilated façade made with glass-glass Si-crystalline modules with hidden bus bars and L-interconnections (model X5, by ONYX).
6	San Sebastián, Spain	Office building + laboratories, Retrofitting, private	TECNALIA	PV double-skin over the existing curtain walls with c-Si back contact laminated glass modules, by ONYX (model X7).

In line with the monitoring guidelines established in D8.7, the pilot sites have been visited in 2016 and all the information required to establish the M&V plan has been collected through questionnaires and discussions with the pilot site managers. After the pilot sites visits, a detailed report has been written for each demonstration site that has helped in feeding the D8.1 “Energy audit of buildings and identification of BIPV possibilities in every demo site”.

The following subsections provide the key features of the demonstration sites and the way BIPV is envisioned in terms of integration and self-consumption of PV production which are features to be considered for the monitoring activities.

3.1 Demo 1 – Format D2 house (Stambruges, BELGIUM)

PVSITES Demo 1, provided by the partner FORMAT D2 and located in the “Rue du Banc de Sable, 22 of Stambruges (Belgium)”, is simultaneously a residential and an office building for private and professional use (architectural studio).

The BIPV system proposed for this demo-site consists of a PV integrated roof composed of CIGS on steel modules by FLISOM (model X1), with a double functionality as a constructive roofing solution and a renewable energy generation system.

In terms of passive behaviour, the installed BIPV system will have an impact on the insulation characteristics of the house and therefore on its energy demand and on indoor environmental conditions. The BIPV system will allow covering part of the power demand reducing the electricity bill with a renewable energy source.

Figure 3.1 Format D2 house

3.2 Demo 2 – EHG (Genève, SWITZERLAND)

PVSITES Demo 2, provided by the partner FLISOM and located in the “Avenue de la Paix 12, 1202, Genève (Switzerland)”, is a set of buildings which houses the hotel school EHG (École Hôtelière de Genève). The site includes not only the school facilities but also a hotel to host the students.

The BIPV system proposed for this demo-site consists of 2 façades systems composed of CIGS on large area flexible membrane & bendable elements (models X2 & X4) provided by FLISOM, with a double functionality as constructive façade solution and renewable energy generation system.

In terms of passive behaviour, the installed BIPV system is expected to have an impact on the insulation characteristics of the pavilions and therefore on their heating energy demand and on indoor environmental conditions. Moreover, the BIPV surface is expected to get hotter than would a non-BIPV external element, and this would also impact the heat flux on these specific areas. Regarding the electricity produced by the BIPV system, it is planned to use it for the electricity demand associated with common usages of the buildings (lighting, computers etc). Therefore, only the global electricity consumption of the whole site is required in the demonstration strategy.


Figure 3.2 EHG pilot site (pavilion 1 and pavilion 2 on the left, main building on the right)

3.3 Demo 3 – Carport of EMPA facilities (Dübendorf, SWITZERLAND)

PVSITES Demo 3, provided by the partner FLISOM and located in “Überlandstrasse 129, 8600, Dübendorf (Switzerland)”, is a public carport of 500 m², part of the EMPA facilities (Swiss Federal Laboratories for Materials Science and Technology).

The BIPV system proposed for this demo-site consists on a PV integrated roof composed of CIGS on steel modules by FLISOM (model X1).

The carport performs the function of protection against rain, hail, snow, frost and the direct rays of sun. In principal, there is no power demand directly associated to the carport performance, because it is not illuminated nor has any other permanent power load. Nevertheless, PV power production will be addressed to supply the electrical sockets located in the basis of the posts, and used for recharging electrical vehicles or other applications.


Figure 3.3 Carport (EMPA facilities)

It should be highlighted here that some discussions and analysis are on-going at the time of writing of D8.8 about shifting to another demo site that will probably be another carport also located at EMPA facilities.

3.4 Demo 4 – CRICURSA building (Granollers, SPAIN)

The PVSITES Demo 4, provided by the partner CRICURSA and located in "Polígon Industrial Coll de la Manya, Camí de Can Ferran, s/n, 08403, Granollers (Spain)", is an industrial and offices building complex.

The BIPV system proposed for this demo-site will consist of a PV integrated roof with CIGS on steel modules from FLISOM (model X4), with a double functionality as a constructive roofing solution and a renewable energy generation system. The system will be installed on the roof of the recently built building which hosts workshops.

The impact of the BIPV system is expected to be on the heating demand as well as on the indoor environmental conditions (temperature mainly).

The generated electricity is expected to be used for the electricity usages of the offices building so the monitoring of the electricity consumption of the offices part of the site is of interest for the project.

Figure 3.4 Industrial and offices building complex in Spain, provided by CRICURSA.

3.5 Demo 5 – VILOGIA building (Wattignies, FRANCE)

PVSITES Demo 5, provided by the partner VILOGIA and located in the "12-14, rue du Docteur Laennec, 59139, Wattignies (France)", is a residential storey block.

The BIPV system will consist of a BIPV ventilated façade made with glass-glass Si-crystalline modules with hidden bus bars and L-interconnections (model X5, by ONYX). It is expected that the BIPV system will modify the thermal performance of the building (these can be improved or on the contrary can be an additional source of heat if the excess heat is not exhausted properly in the ventilated façade system). Therefore, an impact of the BIPV system on the indoor environmental conditions is expected as well as on heating consumptions.

The occupation and use patterns are typical of a residential block, with some common energy consumptions that can be partially covered by the PV production. So the electricity generated locally by the BIPV system is expected to be used by the common spaces of the building (indoor lighting of transit areas and other common loads such as entrance lighting and common electrical plugs, control access system, Elevator and Mechanical Ventilation).

Figure 3.5 Residential building (VILOGIA).

3.6 Demo 6 – TECNALIA building (San Sebastian, SPAIN)

PVSITES Demo 6, provided by the partner TECNALIA and located in "Paseo Mikeletegi 2, San Sebastian (Spain)", is one of TECNALIA facilities, an office building with engineering and chemical laboratories.

The BIPV system foreseen for the TECNALIA demo-site consists of a PV double-skin over the existing curtain walls with c-Si back contact laminated glass modules (model X7 by ONYX).

One of the objectives of the new BIPV system proposed for the chosen locations is to improve the indoor conditions of rooms closed by the curtain walls. Currently, these rooms are not well conditioned, being too hot in warm seasons and too cold in winter. Shadowing by the solar cells will significantly reduce the temperature in summer; the second skin over the existing cladding will help reducing the cold during the winter season. Moreover, the BIPV system may improve the glare and the control of daylighting in this specific area.

Figure 3.6 TECNALIA building.

The PV production is expected to be self-consumed for the electricity usages of the offices areas of the building. The offices areas have been defined as the most appropriate for energy optimisation. Therefore, the electricity consumptions (lighting and plugs) will be measured by floor in the offices area.

4 MEASUREMENT AND VERIFICATION PLANS FOR ALL THE DEMONSTRATION SITES

The visits and analysis of the pilot sites functioning have allowed to establish the Measurement and Verification Plans for all the demonstration sites. The M&V Plans include 13 items ensuring that each impacting parameter is taken into consideration and assigning the responsibilities to all the partners intervening in the monitoring process. These M&V plans have been agreed by the partners involved in the demonstration activities and monitoring process.

4.1 M&V plan for Demo 1 – Format D2 house (Stambruges, BELGIUM)

This section describes the M&V plan for the Demo 1 in line with the main features identified in the pilot site.

4.1.1 Energy conservation measures intent

The BIPV technology selected for the Belgian site is the CIGS on steel modules (manufacturer: FLISOM) that will be installed as a constructive roofing solution. A PV module surface of 102.3 m² will be installed on the SSW sloped roof of the house with an installed power of 8.9kWp[1].

For this integration typology, the impact is expected to be on the indoor environmental conditions of (the top floor of) the house as well as on the heating and cooling demand.

The BIPV system will allow covering part of the power demand reducing the electricity bill with a renewable energy source.

A storage system will be used for the house and will be included in the inverter (PV storage inverters provided by TECNALIA) associated with the BIPV system to optimize the interaction with the grid.

After the implementation of the BIPV solution, a commissioning phase is planned in order to check that the installation has been done correctly in order to guarantee that the installations fulfill the objectives of the pilot. This commissioning phase shall consist of a complete activation of the whole system (including the PV modules and the associated inverter) with an optimized set-up of the whole system.

4.1.2 IPMVP option and measurement boundary

Option C (Whole facility, see annex 1, §7.1) of IPMVP is applied for the impact assessment of the BIPV installation on the energy demand of the house. The following parameters will be measured:

- Heating demand of the building (comparison between the heating demand before and after the implementation of the BIPV technologies),

- Indoor conditions (those that are supposed to be impacted by the BIPV installation).

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[1] The figures provided here can differ from what was presented in deliverable D8.1 (Energy audit of buildings and identification of BIPV possibilities in every demo site) and can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

ECM scale (Option A, see annex 1, §7.1) will be used as well for this pilot site. The BIPV performance (production performance) will be evaluated independently (isolated measurement conducted on the system) and compared to the predictions.

4.1.3 Baseline: period, energy and conditions

4.1.3.1 Building analysis

4.1.3.1.1 Site context and data

As a complement to the information already provided in section 3.1, the following table summarises the main features of the Demo 1.

Table 4.1 Main features of Demo 1

Main features	Description
Address	Rue du Banc de Sable, 22 of Stambruges (Belgium)
Building typology	Residential + Architect's Office. It's a detached passive wooden house based on sustainable architecture principles
Surface	280 m² (219 m² heated floor)
Number of floors	3
BIPV installation location	SSW 30° sloped roof; orientation +14°, tilt 30°
Why do we install BIPV technology in this house in the frame of the architectural/efficiency objective?	The installation of BIPV technology in this house is completely in line with the sustainable architecture choices made for the design of the house and compliant with the requirements associated with rural style of the house.
Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building	Dominique DERAMAIX (Format D2)
Occupancy	The occupation pattern is typical of a residential building, with an extra consumption associated with the office activities during the working hours and periods.
Building plans (floor plans, electrical network, ventilation network…)	The plans are provided in annex 2 (§7.2)

4.1.3.1.2 Main equipment present in the building

The following table provides a synthesis of the equipment present in the house (Heating/Ventilation/DHW/solar panels/number of electrical board...) and energy used for each system. The table highlights also the existing possibilities for monitoring implementation.

Table 4.2 Main equipment of Demo 1

	Equipment	Energy used	Comments and possibilities of monitoring:
Heating	Direct electric radiator for heating (for bathrooms and office) and fire place for the house	Electricity and wood	Separate electricity meter on site; Wood consumption is collected manually by the house owner
DHW	Thermodynamic heat pump (air/water + extra electric resistance)	Electricity is used for this system with COP of 3.5	Separate electricity meter on site Thermal energy meter installed for measuring flow and temperature of hot water produced by the heat pump already on site
Ventilation	Electric double flux ventilation system (recovering the residual heat during the air renewal)	Electricity	Separate electricity meter on site
Lighting	LED Technology	Electricity	Separate electricity meter on site
ICT/BMS	Data are collected by a CMe3100 Elvaco unit and sent periodically by email.	Electricity	1st data stored = 1 January 2016

4.1.3.2 Baseline parameters

The baseline period to be considered for this site starts from the 1st of January 2016 and lasts until the start of the BIPV system installation planned for M28. The building will be occupied during this baseline period. The occupation profile should be identified and well described in order to be compared with the occupation profile of the reporting period. This can be done manually with a calendar with occupation per hour or per day during the whole monitoring period for instance.

4.1.3.2.1 Collected data

The baseline situation is established thanks to the data collected by the measurement infrastructure already on site and summarised in **Fehler! Verweisquelle konnte nicht gefunden werden.**. This measurement infrastructure is completed by the information related to the wood consumed by the house and collected manually by the house owner. The heating consumptions are monitored in order to identify if the integration of BIPV have an influence on the heating demand of the house (BIPV impact assessment). Additional measurements are also proposed for the purpose of WP6. The electricity consumptions are monitored in order to feed in the WP6 activities regarding the energy management strategy and therefore the characterisation of the manageable electrical loads in the house.

Table 4.3 Parameters measured during the baseline period in Demo 1

Parameters	Target	Scale	Means of measurement
Indoor environmental parameters	Temperature	Each room of the house	Temperature sensor already on site
	Relative humidity	Each room of the house	Humidity sensor already on site

Parameters	Target	Scale	Means of measurement
Energy consumptions	Heating consumptions: -Wood -Electricity	Building	Separate electricity meters already on site + manual follow-up of the wood consumed (monthly weighing)
	Electricity consumptions per electrical usage: -Lighting -Ventilation -DHW -Plugs and others (deduced from the general counter and the other usages)	Building	Separate electricity meters already on site. The global architecture of the electricity measurement infrastructure of the house is provided on Figure 4.1.
	DHW consumptions	Building	Thermal energy meter attached to the heat pump already on site
Outdoor environmental conditions	Temperature	Building	Weather station
	Humidity	Building	
	Wind velocity	Building	
	Rain intensity	Building	
	Hail intensity	Building	
	Global Inclined Solar radiation	Building	Pyranometer installed with the same orientation as the BIPV installation

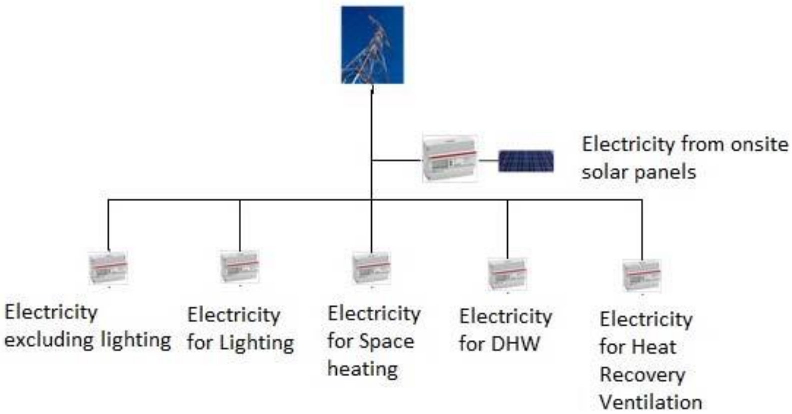

Figure 4.1 Global architecture of the electricity measurement infrastructure already installed on site

All these data, except outdoor temperature, outdoor humidity, wind velocity, rain intensity and hail intensity are collected with 10 min sample rate. The outdoor environment related data mentioned above are collected with 1 min sample rate.

Thanks to the communication gateways WebdynSun and Elvaco CMe 3100 and thanks to a mini-PC installed on site, all the data mentioned (except indoor temperature and relative humidity and wood consumption) are sent on an hourly basis to the ftp server hosted by Acciona. Concerning the indoor environmental data (temperature and relative humidity), they will be collected manually from a web interface made available by FD2.

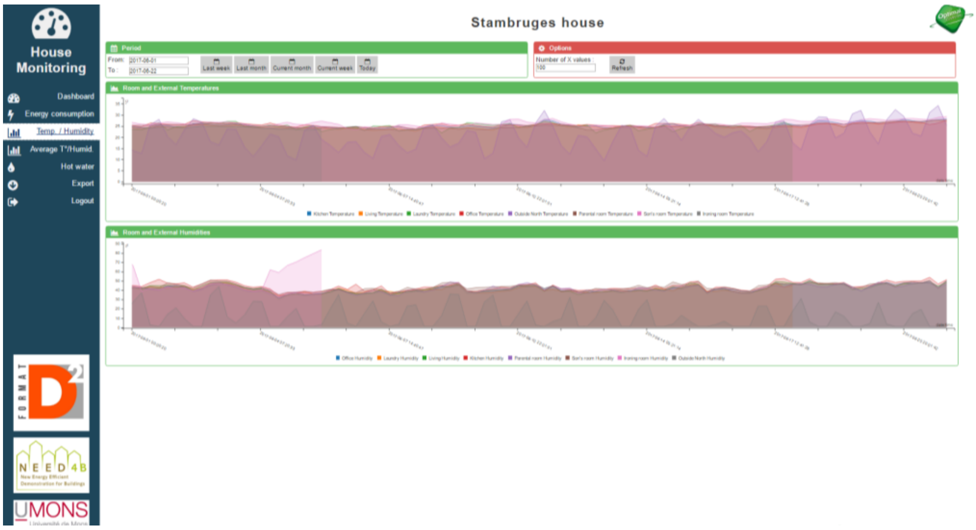

Figure 4.2 Web portal allowing extraction of the indoor environmental data (temperature and relative humidity)

As the local monitoring system is based on a Elvaco CMe 3100, the integration with ACCIONA BCC has been implemented using a file interchange method. A FTP server is available for the project, and Acciona BCC manages the FTP site were the different files with the data from FD2 are stored. BCC server runs a script that is continuously watching the FTP server: when a new file arrives, the script reads the file and stores the data included in the file into the database.

For reminder, the IT infrastructure of the monitoring systems and its communication with the Building Control Center (BCC) provided by Acciona is provided in annex 3 (§7.3).

It should be highlighted that the estimate of the impact of BIPV on passive behaviour of the house will be based on simulation.

As the data are collected since the 1st of January 2016, and the BIPV system is planned to be installed during the first months of 2018 we expect to have 1 year of monitoring data.

The following figures show a sample of data collected for the Belgian site.

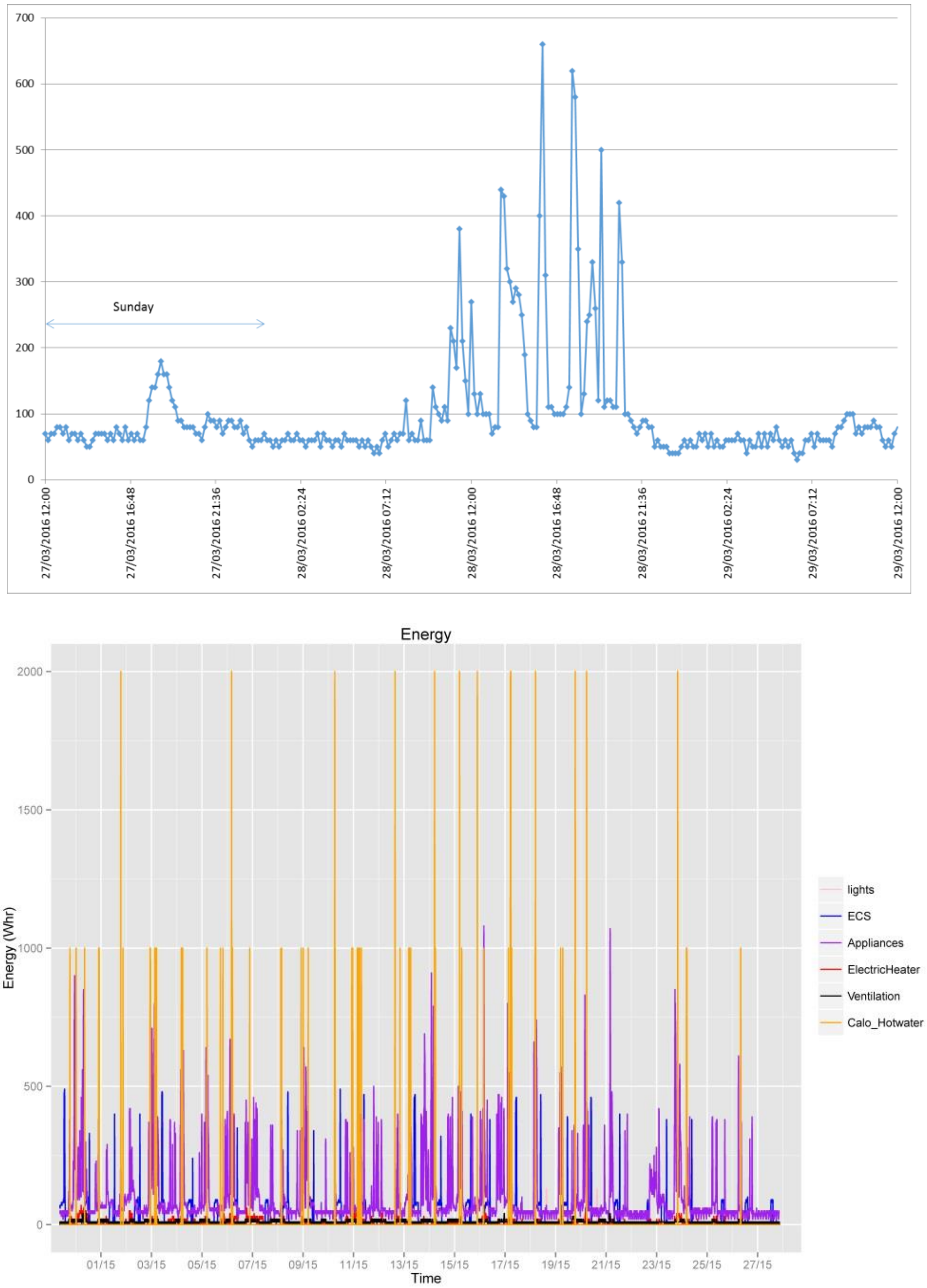

Figure 4.3 Energy consumptions of the house

4.1.3.2.2 Independent variables[2]

Outdoor temperature and solar radiation are considered as independent variables and will be used to calculate the heating (and eventually cooling) degree days and make the adjustment related with the heating consumptions.

4.1.3.2.3 Static factors[3]

The following table summarises the static factors to be considered for non-periodic adjustment.

Table 4.4 Static factors to be considered for Demo 1

Static factor	Value considered for the baseline
Indoor temperature set-up	The indoor temperature is not fixed by a thermostat because there is no central heating system. So, in winter, the occupant tries to keep an average of 21°C in the living-room and 18°C in the bedrooms. In summer, the temperature is on average 24°C in each room (max 27°C in living-room in July).
DHW temperature set-up	50°C
Area and volume of heated spaces	219 m² of heated floor
Building envelop characteristics	See D8.1 for details on the envelop characteristics
Building systems characteristics	See D8.1 for details on the systems characteristics
Occupation rate / number of occupants	3.5 (1 person present 1 week/2)
Ventilation rate	-day: 225m³/h -night: 150m³/h -showers or forced ventilation for night cooling: 380 m³/h

4.1.4 Reporting period

The reporting period will last at least one year from the end of the commissioning phase of the BIPV systems (expected M28) until the end of the project. The reporting period has to include at least a cold period, a warm period and a mid-season period.

During the reporting period, and in addition to the parameters mentioned for the baseline period the following parameters will be measured:

[2] 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.

[3] 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 4.5 Parameters to be measured during the reporting period (in addition to the parameters already mentioned for the baseline period)

Parameters	Target	Scale	Means of measurement
Energy consumptions	Electricity consumed from the grid (10 minutes frequency)	Building	Module (optical reader) connected to the energy provider meter in order to get the whole electricity consumed from the grid
BIPV performances	Energy and power generated	BIPV system output (Inverter output)	AC meter (bidirectional) at the output of the inverter (see Figure 4.4)
	Energy and power (DC current) between the inverter and the BIPV generator	BIPV system (Inverter)	DC meter at the input of the inverter (see Figure 4.4)
	Energy and power (DC current) between the inverter and the storage system	Storage and inverter	DC meter between the inverter and the storage system (see Figure 4.4)
BIPV conditions	Surface temperatures of the Back side of the PV modules The dust level on the tiles will be visually checked during the reporting period in order to identify potential degradation of the BIPV performances.	BIPV modules	Specific temperature sensor that can be attached directly to the surfaces to be monitored (back end of the module). For instance, PT1000 self-adhesive sensor.

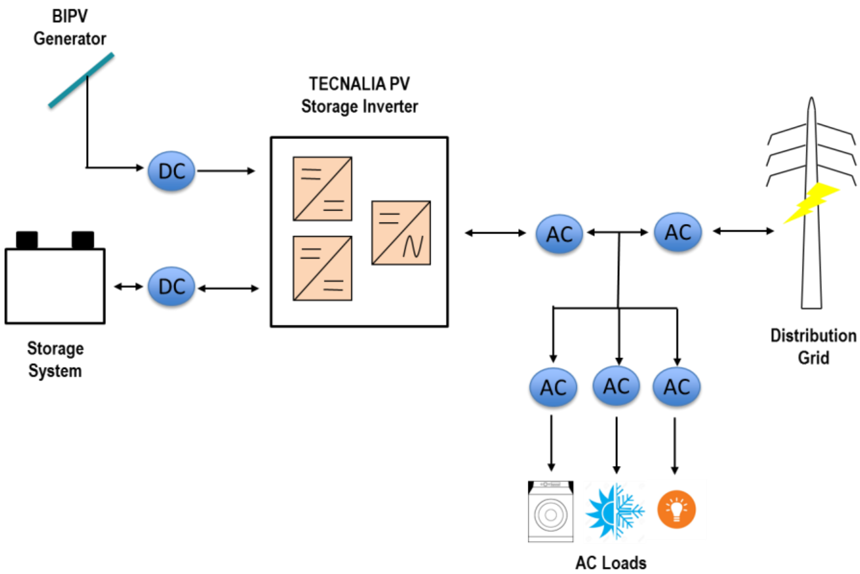

Figure 4.4 Electrical schema of the BIPV installation in Demo 1

A more intense follow-up will be conducted at the beginning of the operational phase of the BIPV system. This will allow the detection of issues in the functioning of the system and a reactive action to solve them.

All these data will be automatically collected by a centralized system installed during the baseline period and deposited on Acciona' FTP server using house internet connection. An access to an internet connection should be made available by the local pilot site manager.

4.1.5 Basis for adjustments

The consumption models will be established on the monthly data of heating consumptions using the independent variables mentioned above. 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.

The non-periodic adjustments (related with the static parameters evolution) will be done according to the following table:

Table 4.6 Non-periodic adjustments

Static factor	Value to be adjusted
Indoor temperature set-up	For the heating period, 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.
DHW temperature set-up	Adjustment on the DHW energy consumptions
Area and volume of heated spaces	Adjustment on the Heating consumptions
Building envelop characteristics	Adjustment on the Heating consumptions
Building systems characteristics	Adjustment on the Heating and electricity consumptions
Occupation rate / number of occupants	Adjustment on the Electricity energy consumptions
Ventilation rate	Adjustment on the Electricity energy consumptions

4.1.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicators:

-Comparison between the data collected for the baseline and the reporting periods in terms of energy consumptions including the required adjustments (independent variables+ static factors if needed). This can be done building a model (see Figure 4.5) on the basis of data collected during the baseline period and adjusting this model to the conditions of the reporting period.

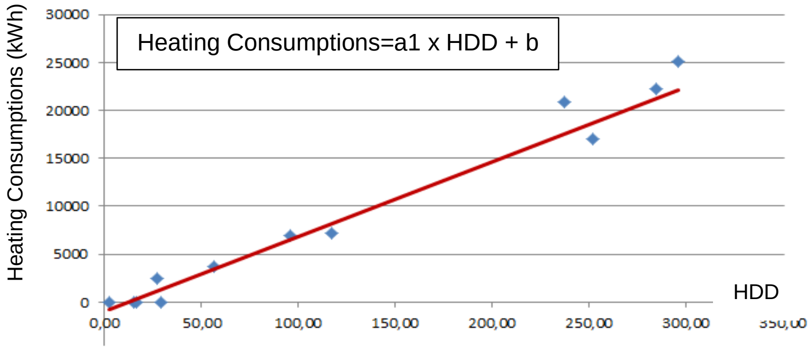

Figure 4.5 Example of regression analysis on baseline data

-Comparison between the data collected for the baseline and the reporting periods in terms of indoor comfort conditions on the basis of the calculation of number of hours of uncomfortable temperature during one full year and during the occupied hours only (for example 19°C >T° int. >26°C) (reference comfort temperature has to be defined for Belgium).

-Assessment of the BIPV performances in comparison with the predictions and assessment of the percentage of loads covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if self-consumed, the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.1.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.1.8 Meter specifications

The following table provides the different equipment which have been selected for the monitoring infrastructure to cover the M&V plan of Demo 1.

Table 4.7 Measurement devices for Demo 1

Sensor/meter	Measured parameter	Acquisition frequency	Cost (€)	Nb of units	Unit cost
Thermal energy meters ABB	Flow and temperature of hot water produced by the heat pump	10 min	Already installed on site		
Electricity meters ABB	Energy and power	10 min	Already installed on site		
Xbee sensor using wireless technology	Indoor relative humidity and temperature	≈3 min	Already installed on site		
Xbee sensors.	Outdoor relative humidity and temperature	≈3 min	Already installed on site		
Cme3100 Elcavo unit	Data collector		Already installed on site		
Electrical meter/power meter	Energy and Electrical power produced by the BIPV at the output of the inverter		195 €	1	195 €
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter		540 €	2	270 €
Optical reader FLUDIA	Electricity consumption from the grid		350 €	1	350 €
Self-adhesive sensor PT1000 with signal converters	Surface temperature of the BIPV modules (back side)		220 €	2	110 €
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity, rain and hail intensity	1 min	2 728 €	1	2 728 €
Pyranometer Kipp&Zonen SMP6-A	Global solar irradiation in the plane of the modules	10 min	1 580 €	1	1 580 €
Gateway WebdynSUN	Aggregator		433 €	1	433 €
PC for gateway configuration	Remote access		250 €	1	250 €
Additional devices	Cables, connectors, …		1 000 €	1	1 000 €
		TOTAL	7 296 €		

4.1.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the PVSITES project and assign the responsibilities to the partners involved in the demonstration.

Table 4.8 Monitoring responsibilities for Demo 1

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK + FD2
M&V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK + FD2
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + FD2
Equipment installation	Baseline	NOBATEK with the support of FD2
Equipment maintenance and replacement	Baseline + Reporting periods	FD2
Local communication verification	Baseline + Reporting periods	FD2 + NOBATEK
Data recording	Baseline + Reporting periods	NOBATEK + FD2 (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK + R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.1.10 Expected accuracy

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

- Uncertainty associated to the measurements,
- Adjustments (uncertainty on occupancy profiles for instance) and calculation process.

4.1.11 Budget

See above.

4.1.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,
- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can be calculated: energy production (kWh/kWp and kWh/m²), gap between the real production and the forecasted production (%)…),
- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.1.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the monitoring devices and provide support in case of problem and provide the information related with the static parameters.

4.2 M&V plan for Demo 2 – EHG (Genève, SWITZERLAND)

This section describes the M&V plan for the Demo 2 in line with the main features identified in the pilot site.

4.2.1 Energy conservation measures intent

The BIPV panels of CIGS on large area flexible membrane and bendable elements from FLISOM (models X2 & X4) are planned to be installed in this pilot site (Figure 4.6) with a total surface of 140m² resulting in 10 kWp installed[4].

Free areas in both façades will be used for implementing the BIPV systems (see D8.1 for the details about the BIPV system pre-dimensioning). This ECM is supposed to have an impact on the passive behavior of the buildings (heating/cooling demand and indoor environmental conditions). The BIPV system will allow covering part of the power demand of the whole site. Moreover, the configuration used (East and West orientation) will better match the daily consumption of the whole site.

Figure 4.6 West and East façades of the pavilion 1 and 2, respectively

The inverter and storage solution have not been selected yet for this site, but each building will host its own storage and inverter systems.

After the implementation of the BIPV solution, a commissioning phase is planned in order to check that the installation has been done correctly in order to guarantee that the installations fulfil the objectives of the pilot. This commissioning phase shall consist of a complete activation of the whole system (including the PV modules and the associated inverter) with an optimised set-up of the whole system.

4.2.2 IPMVP option and measurement boundary

As mentioned before, it is assumed that the impact of the BIPV system on the heating and cooling demand of the whole site (which is the only measurement that can be implemented) will be insignificant. Thus, option C is not relevant for the impact assessment on passive behaviour of the building.

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[4] The figures provided here can differ from what was presented in deliverable D8.1 (Energy audit of buildings and identification of BIPV possibilities in every demo site) and can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

Therefore, a mix between Option C (Whole building) and Option A (ECM scale) is applied by measuring:

-Local indoor environmental conditions that are supposed to be impacted by the BIPV installation that means the temperature in the rooms located behind the façades where the BIPV systems will be installed.

-The electricity consumption for the whole site (three buildings) in order to feed the WP6 (Building Energy Management System for Different Building Uses) and identify which are the opportunities to use the local energy produced for self-consumption of the whole site. This will allow to evaluate the share of electricity expenses that can be avoided through the self-consumption of PV production.

ECM scale (Option A) is used as well for the BIPV performance evaluation measuring independently the system (isolated measurement conducted on the system) and comparing these performances to the predictions.

4.2.3 Baseline: period, energy and conditions

4.2.3.1 Building analysis

4.2.3.1.1 Site context and data

The following table summarises the main features of the Demo 2.

Table 4.9 Main features of Demo 2

<table>
<tr><th>Main features</th><th colspan="3">Description</th></tr>
<tr><td>Address</td><td colspan="3">Avenue de la Paix 12, 1202, Genève, Switzerland</td></tr>
<tr><td>Building typology</td><td colspan="3">Set of 3 ground-level buildings which house administrative areas, a restaurant, a showroom, some classrooms and the hotel rooms. These 3 buildings are interconnected underground by a tunnel which hosts technical installations, a kitchen and a cafeteria.</td></tr>
<tr><td rowspan="2">Surface</td><td>Main building “Vieux-Bois”</td><td>Pavilion 1</td><td>Pavilion 2</td></tr>
<tr><td>1247</td><td>540</td><td>883</td></tr>
<tr><td>Number of floors (above ground level)</td><td>3</td><td>1</td><td>2</td></tr>
<tr><td>BIPV installation location</td><td>--</td><td>West façade</td><td>East façade</td></tr>
<tr><td>Why do we install BIPV technology in these buildings in the frame of the architectural/efficiency objective?</td><td colspan="3">The installation of BIPV technology in these buildings is compliant with the activities and energy use of the site (activities during the day mainly)</td></tr>
<tr><td>Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building</td><td>State of Geneva</td><td>Hotel School of Geneva</td><td>Hotel School of Geneva</td></tr>
</table>

<table>
<tr><th>Main features</th><th colspan="3">Description</th></tr>
<tr><td rowspan="2">Occupancy (Timing of weekly occupancy)</td><td>Administration: Monday-Friday from 7:30 to 20:30
Kitchen/restaurant: Monday-Friday from 8:00 to 16:00 + exceptions in the evening + weekend</td><td>Classrooms: Monday-Friday from 7:30 to 20:30
Kitchen/restaurant: Monday-Friday from 8:00 AM to 16:00 + exceptions in the evening + weekend</td><td>Monday-Friday from 7:30 to 20:30</td></tr>
<tr><td colspan="3">The school calendars will also be considered in order to take into consideration the inactivity of the site during summer, winter and Easter holidays.</td></tr>
<tr><td>Building plans (floor plans, electrical network, ventilation network…)</td><td colspan="3">Some plans provided by the site manager are shown in annex 4 (§7.4)</td></tr>
<tr><td>Date of the first visit</td><td colspan="3">20th October 2016</td></tr>
</table>

At the time of writing, several items still need to be collected from the pilot site manager concerning the way the indoor conditions are controlled (temperature set point, ventilation, lighting schedule, is the control different according to the day of the week and season considered?).

4.2.3.1.2 Main equipment presented in the building

The following table provides a synthesis of the equipment present on site and energy used for each system. The table highlights also the existing possibilities for monitoring implementation.

Table 4.10 Main equipment of Demo 2

<table>
<tr><th></th><th>Equipment</th><th>Energy used</th><th>Comments and possibilities of monitoring:</th></tr>
<tr><td><u>Heating</u></td><td>2 recent gas-fired boilers produce heat energy for heating for the whole site</td><td rowspan="2">Gas</td><td rowspan="2">Some thermal energy meters associated to the heating and DHW are already installed, but the perimeter covered by the measurements is not known. The data are collected on a central boiler regulator. The energy used for Pavilions 1 and 2 for heating and DHW can't be isolated from the energy consumed for the whole site.</td></tr>
<tr><td><u>DHW</u></td><td>Another gas-fired boiler supported by recovering non-used heat energy coming from the compressors and pumps of the heating system</td></tr>
<tr><td><u>Cooling</u></td><td>Direct Expansion (DX) Cooling Air Conditioning Systems in the main building;
Cooling heat pump in pavilion 1;
Cooling heat pump in pavilion 2.</td><td>Electricity</td><td>There is no separate measurement of the cooling energy consumed.
However, it is assumed that the impact of the BIPV system on the heat and cooling demand will be insignificant for this pilot.</td></tr>
<tr><td><u>Ventilation</u></td><td>5 simple ventilation units in the main building;
2 simple ventilation units in pavilion 1;
3 simple ventilation units in pavilion 2</td><td>Electricity</td><td></td></tr>
</table>

	Equipment	Energy used	Comments and possibilities of monitoring:
Lighting	Fluorescent tubes, manual switching on/off	Electricity	
ICT/BMS	One supervision system from Sauter that displays the energy meters associated with the heating and DHW systems.	Electricity	

The buildings are supplied by EDF grid through one single electricity delivery point located into the basement of the main building.

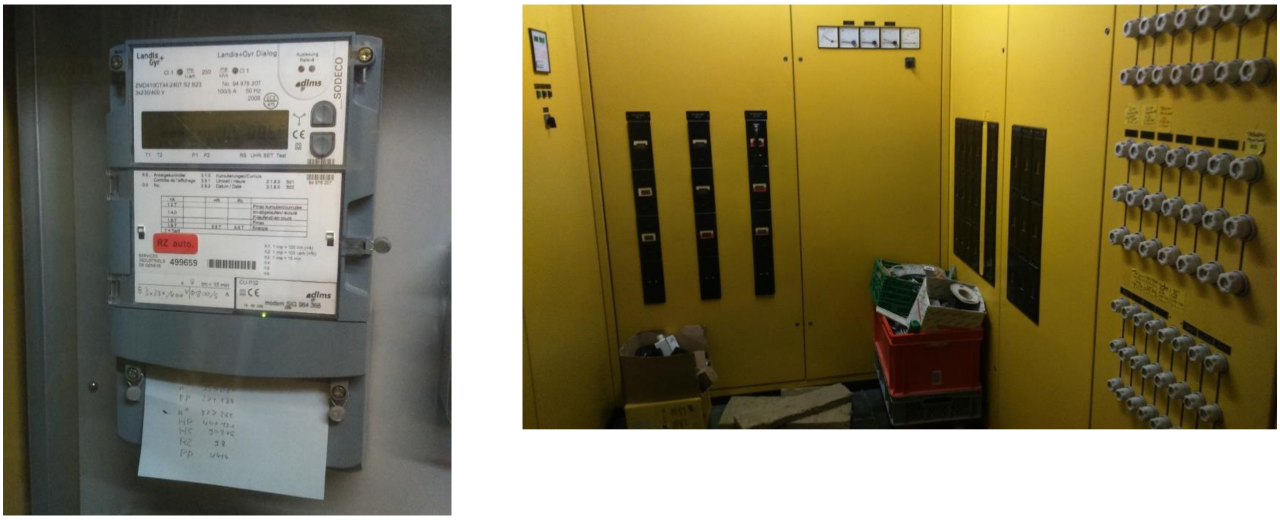

Figure 4.7 General electricity meter of the site (left) and room where this meter is located (right)

The cooling energy is distributed into classrooms by radiant panels located closely to the ceiling.

Figure 4.8 Cooling emitters in a classroom of Pavilion 2

4.2.3.2 Baseline parameters

4.2.3.2.1 Collected data

Concerning the baseline establishment, historical electricity consumption data for the whole site are already available with 15-minute frequency from the consumer portal provided by the EHG electricity supplier SIG. These historical data are currently manually collected and available for the period from 1st of January 2015 up to now.

The following figures show the daily electricity consumptions over a 1.5-year period for the whole site as well as electricity consumptions with a higher time resolution for a day of November illustrating the electricity consumption profile for a typical day.

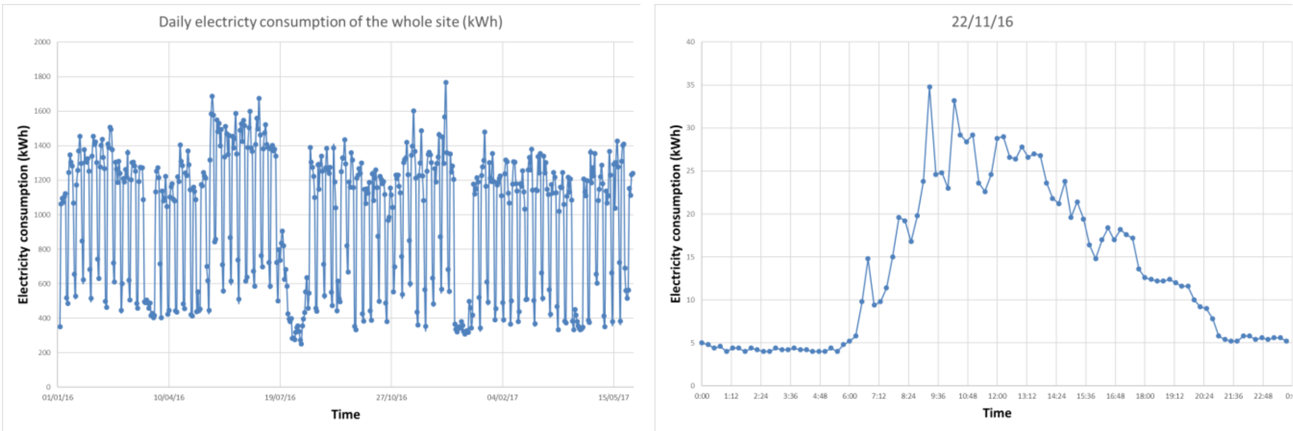

Figure 4.9 Daily electricity consumptions over a 1.5-year period (left) and electricity consumption with high time resolution for a day of November (right)

Fehler! Verweisquelle konnte nicht gefunden werden. summarizes the parameters to be m easured before and after installation of the BIPV system.

Table 4.11 Parameters measured during the baseline and the reporting periods for Demo 2

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Electricity consumptions	General consumption of all the 3 buildings The self-consumption of BIPV production is envisaged for the set of buildings (one delivery point for the whole site). So, a separate measurement of electricity consumption of buildings individually is not proposed.	The near real-time data from the EHG site general electricity meter is accessible on a web portal. A web service sending real-time data to an ftp server provided by EHG electricity supplier SIG can be used to automatically collect these data. Another option is to install an optical reader Fludia connected to the electricity meter.	Need to know if the web service described could be provided by SIG

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Indoor environmental parameters	Temperature and relative humidity into 1 classroom of each pavilion located behind the wall on which the BIPV system will be installed (in order to assess a potential impact of the BIPV on the general conditions)	Air temperature and relative humidity digital sensors[5] The temperature and relative humidity sensors are to be installed at 1,5 m of height from the floor, far enough from heat emitters and openings (doors, windows).	The classrooms in each pavilion need to be selected together with EHG. The sensors need to stay in place during the whole monitoring period
	Occupancy	Classrooms occupancy information collected from the site manager	
Outdoor parameters	Temperature	Temperature sensor	Need to define in which building (pavilion 1 or 2) the weather station will be installed
	Humidity	Humidity sensor	
	Wind speed at the location of the BIPV	Anemometer	
	Rain intensity	Ultrasound sensor	
	Hail intensity	Ultrasound sensor	
	Global solar radiation measured in the planes of the PV cells	2 pyranometers in the plane of the BIPV modules installed in each pavilion (vertical position, east and west oriented and free of shadow)	
Conditions on facades	Interior wall surface temperature on the walls on which the BIPV panels will be installed for each pavilion	Pt1000 or thermocouple temperature sensor	

All these data will be automatically collected by a centralized wire and wireless remote system (which includes laying of some communication cables inside the building) and deposited on a FTP server using building internet connection. An access to an internet connection should be made available by the local pilot site manager.

4.2.3.2.2 Independent variables

Occupancy calendar can be considered as an independent variable for the EHG site.

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[5] No need of black globe sensors as radiant heat transfer from the wall with BIPV panels to classrooms interior air is insignificant.

4.2.3.2.3 Static factors

The following table summarises the static factors to be considered for non-periodic adjustment.

Table 4.12 Static factors to be considered for Demo 2

Static factor	Value considered for the baseline
Indoor temperature set-up in administration part, in restaurant part and in other common spaces	20
Area and volume of heated spaces	Main building: 1247 m^2 Pavilion 1: 540 m^2 Pavilion 2: 883 m^2
Building envelop characteristics	Main building: old wall in rubbles / U=1-1.2 W/m^2*K Pavilion 1: walls in brick / U=0.4-0.6 W/m^2*K Pavilion 2: walls in brick / U=0.2-0.4 W/m^2*K
Building systems characteristics	Still needs to be filled out by the pilot site manager
Occupation rate / number of occupants per classroom	25
Occupation rate / number of occupants in restaurant	130
Ventilation rate	Still needs to be filled out by the pilot site manager

4.2.4 Reporting period

The reporting period will start after the end of the commissioning phase applied to the BIPV system (expected M28) until the end of the project. The reporting period has to include at least a cold period, a warm period and a mid-season period.

The parameters to be measured during the reporting period have been summarised in **Fehler! Verweisquelle konnte nicht gefunden werden.Fehler! Verweisquelle konnte nicht gefunden werden.**. In addition, in order to access the BIPV performances during the reporting period the M&V Plan includes the following measurements:

Table 4.13 M&V plan to access BIPV performances during the reporting period at EHG pilot site

Parameters	Boundaries/ measurand	Means of measurement	Associated constraints
BIPV performances	Electrical energy and power generated by the BIPV system + associated inverter	This will be discussed with FLISOM as FLISOM is in charge of selecting	The electrical configuration will be defined later by FLISOM and TECNALIA

Parameters	Boundaries/ measurand	Means of measurement	Associated constraints
	Electrical power and energy (DC current) before the BIPV inverter	commercial inverters for this demo site	
	Electricity entering and going out of the battery		
Conditions of the BIPV system	Surface temperature on the back side of the PV modules	Pt1000 or thermocouple temperature sensor	Need to access back side of the BIPV panels
Conditions on the facade	Air temperature between BIPV panels and exterior wall	Pt1000 or thermocouple temperature sensor	Need to access and position a sensor between the BIPV panels and the exterior wall surface
	Exterior wall surface temperature behind the BIPV panels	Pt1000 or thermocouple temperature sensor	Need to access and position a sensor on surface of exterior wall behind the BIPV panels

A more intense follow-up will be conducted at the beginning of the operational phase of the BIPV system. This will allow the detection of issues in the functioning of the system and a reactive action to solve them.

4.2.5 Basis for adjustments

The models will be established on the monthly data using the independent variables mentioned above. The baseline will be adjusted (according to these independent variables) to the conditions observed for the reporting period.

The non-periodic adjustments (related with the static parameters evolution) will be done according to the following table:

Table 4.14 Non-periodic adjustments for Demo 2

Static factor	Value to be adjusted
Indoor temperature set-up	According to the indoor temperature set-up some adjustment could be necessary on the indoor temperatures evolution assessment.
Building systems characteristics	Adjustment on the electricity consumptions
Ventilation rate	Adjustment on the Electricity consumptions

4.2.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicators:

-Comparison between the data collected for the baseline and the reporting periods in terms of electricity consumptions including the required adjustments (static factors).

-Comparison between the data collected for the baseline and the reporting periods in terms of indoor comfort conditions on the basis of the calculation of number of hours of uncomfortable temperature during one full year (for example 19°C >T° int. >26°C) (reference comfort temperature has to be defined).

-Assessment of the BIPV performances in comparison with the predictions and assessment of the percentage of loads covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if it is self-consumed, the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.2.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.2.8 Meter specifications

The following table provides the different equipment which have been selected for the monitoring infrastructure to cover the M&V plan.

Table 4.15 Measurement devices

Sensor/meter	Measured parameter	Cost (€)	Nb of units	Unit cost
WM-BUS sensors	Air temperature and relative humidity	400	4	100
PT1000 with signal converters	Indoor wall surface temperature	220	2	110
Electrical meter	Energy and power produced by the BIPV at the output of the inverter	390	2	195
Bidirectional Electrical meter	Electricity entering and going out of the battery	195	1	195
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter	540	2	270
Self-adhesive sensor PT1000	Surface temperature on the back side of the module	220	2	110
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity, rain and hail intensity	2728	1	2728
Self-supporting mast of 120 kg of weight with delivery cost	For the weather station and pyranometer	1 397 €	1	1 397 €
Pyranometer KIPP & ZONEN SMP6-A with mounting accessories	Outdoor global solar irradiation in the plane of the BIPV	3160	2	1580
Gateway WebdynSUN	Aggregator	537	1	537
Gateway WebdynRF WM-BUS	Communication gateway with temperature/relative humidity sensors	539	1	539
PC for gateway' configuration	Remote access	250	1	250
Additional devices	Cables, connectors,	2000	1	2000
	TOTAL	12 576 €		

4.2.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the project and assign the responsibilities to the partners involved in the demonstration.

Table 4.16 Monitoring responsibilities for Demo 2

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK
M1V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + FLISOM
Equipment installation	Baseline	NOBATEK with the support of FLISOM (+EHG)

Equipment maintenance and replacement	Baseline + Reporting periods	NOBATEK + FLISOM (+EHG local building manager)
Local communication verification	Baseline + Reporting periods	NOBATEK + EHG local IT manager
Data recording	Baseline + Reporting periods	NOBATEK + EHG local building manager (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK+R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.2.10 Expected accuracy

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

- Uncertainty associated to the measurements
- Adjustments and calculation process

4.2.11 Budget

See above

4.2.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,
- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can be calculated here (Energy production (kWh/kWp and kWh/m^2), gap between the real production and the forecasted production (%)…),
- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.2.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the monitoring devices and provide support in case of problem and provide the information related with the static parameters.

4.3 M&V plan for Demo 3 – Carport at EMPA facilities (Dübendorf, SWITZERLAND)

This section describes the M&V plan for the Demo 3 in line with the main features identified in the pilot site. Nevertheless, as explained in section 3.3, it should be highlighted here that some discussions and analysis are on-going at the time of writing of D8.8 about shifting to another demo site that will probably be another carport also located at EMPA facilities. As a consequence, the M&V plan proposed in this section will be almost entirely applicable for this new demonstration site.

4.3.1 Energy conservation measures intent

The BIPV system proposed for this demonstration site consists on a PV integrated roof composed of CIGS on steel modules from FLISOM (model X1).

It has been proposed to remove the asbestos cladding which is currently on the carport and replace it by the BIPV system.

The planned BIPV generator will be installed on both sides of the carport which have an 8° tilt orientation and are South-East and North-West oriented. The total surface to be installed is 150 m² with an installed power of 15 kWp[6].

Figure 4.10 Overview of the carport located in the EMPA facilities

[6] The figures provided here can differ from what was presented in deliverable D8.1 (Energy audit of buildings and identification of BIPV possibilities in every demo site) and can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

There is no need to establish a baseline for this demonstration site as the considered building has no energy demand because it is not illuminated nor has any other permanent load. Nevertheless, the electricity produced locally by the BIPV system to be installed could be used to supply the electrical sockets located in the basis of the posts and used for recharging the 20kW Electrical Vehicles (EV) charger present on site and installed on the south façade of the MOVE building.

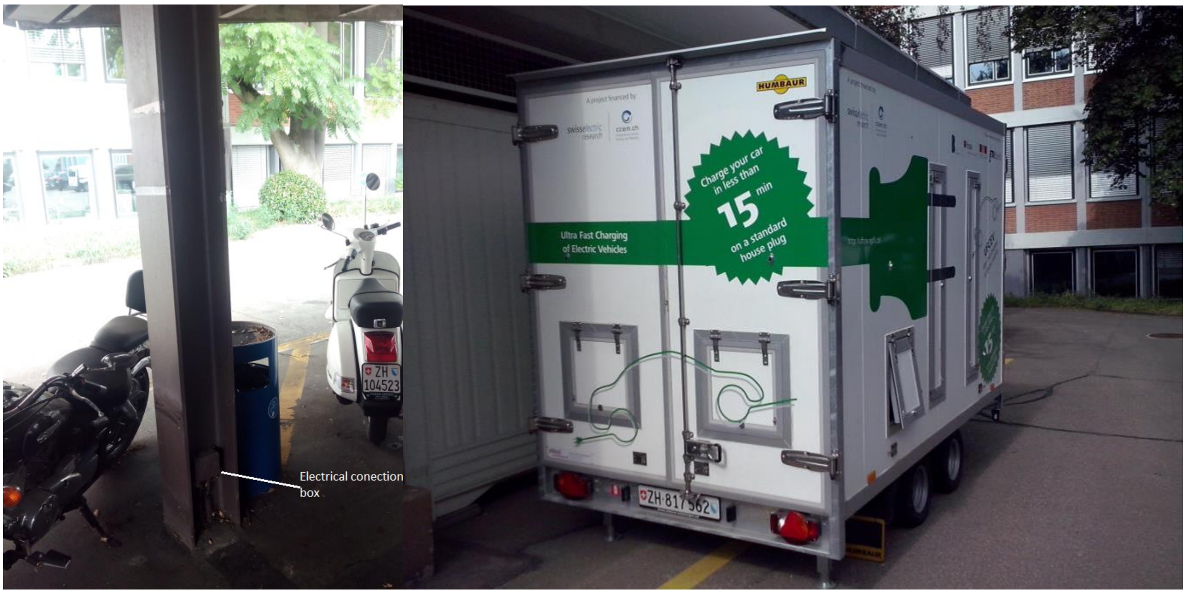

Figure 4.11 Electrical supply box (left) and 20 kW EV charger (right)

After the implementation of the BIPV solution, a commissioning phase is planned in order to check that the installation has been done correctly in order to guarantee that the installations fulfilling the objectives of the pilot. This commissioning phase shall consist of a complete activation of the whole system (including the PV modules and the associated inverter) with an optimized set-up of the whole system.

4.3.2 IPMVP option and measurement boundary

ECM scale (Option A or B) will be used in this case. The BIPV performance will be evaluated independently (isolated measurement conducted on the system) and compared to the predictions.

4.3.3 Baseline: period, energy and conditions

4.3.3.1 Building analysis

The carport is located at EMPA facilities, close to Flisom building. The current cladding is made of asbestos and it shows two inclined planes, one South-East oriented and the other North-West oriented. The total surface of the carport is 500 m², divided in two planes.

4.3.3.1.1 Site context and data

The following table summarises the main features of the Demo 3.

Table 4.17 Main features of Demo 3

Main features	Description
Address	Überlandstrasse 129, 8600 Dübendorf (SWITZERLAND)
Building typology	Carport (public)
Surface	500 m²
BIPV installation location	Roof integrated
Why do we install BIPV technology in this building in the frame of the architectural/efficiency objective?	The carport performs the function of protection against rain, hail, snow, frost and the direct rays of the sun. The complete replacement of the existing cladding by a new one including PV modules would not alter neither of these functions. Moreover, there is no power demand directly associated to the carport performance, because it is not illuminated nor has any other permanent power load. Nevertheless, PV power production could be used to supply the electrical sockets located in the basis of the posts, and used for recharging electric vehicles and other applications.
Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building	Public
Occupancy	The use and occupation pattern coincides with the timetable of an office building.
Date of the first visit	21st September 2016

4.3.3.1.2 Main equipment presented in the building

There is no lighting, nor any other electrical load in the carport. However, electrical supply is accessible in one side of the base. This electrical line is connected to the rest of interconnected buildings.

4.3.3.2 Baseline parameters

There is no need to establish a baseline as the considered building does not consume energy.

As already explained, the PV production could be used for the EV charger present on site. Nevertheless, all the energy generated will be finally injected into the local grid, but the energy management strategy will theoretically consider being working with a EV charger. Therefore, in order to feed in the WP6 regarding the Building Energy Management System (BEMS), the consumption of the EV charger will be monitored. Therefore, as an extension of the IPMVP approach, and as there is no consumption avoided to be demonstrated here, only KPIs will be calculated to identify the share of EV charger loads that can be covered by the PV production.

4.3.3.2.1 Collected data

The parameters given below **Fehler! Verweisquelle konnte nicht gefunden werden.** are proposed t o be measured before and after the installation of the BIPV system.

Table 4.18 Parameters to be measured

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Electricity consumptions	Energy load of the EV charger	Electricity meter installed on the EV charger by EMPA interlocutor → data to be sent automatically from a SQL database	Need to automatically send the data to the BCC
Outdoor environmental parameters	Temperature	Temperature sensor	Find a location to install a weather station in the vicinity of the future locations of the BIPV
	Relative humidity	Humidity sensor	
	Wind speed at the location of the BIPV	Anemometer	
	Rain intensity	Ultrasound sensor	
	Hail intensity	Ultrasound sensor	
	Global solar radiation measured in the plane of the PV cells	Pyranometer installed in the plane of the PV cells	

The electrical load of the EV charger has been manually collected during several weeks. The measured data will be sent automatically to the ftp server used for feeding the BCC system.

4.3.3.2.2 Independent variables

Not applicable here.

Nevertheless, as we consider that the PV production will be self-consumed by the EV charger and so will lead to energy savings as this energy will not be consumed form the grid, outdoor temperature and solar radiation can be considered as independent variables for the PV production.

4.3.3.2.3 Static factors

Not applicable here.

4.3.4 Reporting period

In addition to the parameters presented and measured during the baseline period and the reporting period as well, the following parameters related with the BIPV performance will be measured during the reporting phase.

Table 4.19 M&V plan to access BIPV performances during the reporting period at FLISOM pilot site

Parameters	Boundaries/ measurand	Means of Measurement	Associated constraints
Electricity energy and power	Electricity power and energy generated by the BIPV system	AC meter (bidirectional) at the output of the inverter	Possibility to collect it from the integrated datalogger from inverter used with the BIPV panels

Parameters	Boundaries/ measurand	Means of Measurement	Associated constraints
	Electrical energy and power (DC current) before the inverter	DC meter at the input of the inverter	
Conditions of the BIPV system	Surface temperature of the PV Modules on the back side of the modules	Specific temperature sensor that can be attached directly to the surfaces to be monitored (back end of the module). For instance, PT1000 self-adhesive sensor. Pt1000 or thermocouple temperature sensor	Need to access the back side of the BIPV panels

All these data will be automatically collected by a centralized wired remote system and/or inverter integrated datalogger or Fronius Sensor Card / Box and deposited on a FTP server using an internet connection. An access to an internet connection should be made available by the local pilot site manager.

4.3.5 Basis for adjustments

As there is no baseline establishment, no adjustment is defined.

Nevertheless, a major modification of the EV charge use could impact the self-consumption analysis and should be reported in order to consider it in the analysis.

4.3.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicator:

- Assessment of the BIPV performances in comparison with the predictions.

- Assessment of the percentage of EV loads covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if self-consumed the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.3.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.3.8 Meter specifications

The following table provides the different equipment which have been selected for the monitoring infrastructure to cover the M&V plan.

Table 4.20 Measurement devices for Demo 3

Sensor/meter	Measured parameter	Cost (€)	Nb of units	Unit cost
Clamp-on sensor or electricity meter	Energy and power used by the loads (EV charger)	500	1	500
Bidirectional electrical meter/power meter	Energy and Electrical power produced by the BIPV at the output of the inverter	195	1	195
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter	270	1	270
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity, rain and hail intensity	2728	1	2728
Pyranometer SMP6 Kipp&Zonen with mounting accessories	Global solar irradiation in the plane of the BIPV	3160	2	1580
Self-adhesive sensor PT1000 with signal converters	Surface temperature	220	2	110
PT1000 sensor with signal converter	Air temperature	110	1	110
Gateway WebdynSUN	Aggregator	433	1	433
PC for gateway' configuration	Remote access	250	1	250
Additional devices	Cables, connectors,	1000	1	1000
	TOTAL	8 866 €		

4.3.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the project and assign the responsibilities to the partners involved in the demonstration.

Table 4.21 Monitoring responsibilities

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK
M&V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + FLISOM
Equipment installation	Baseline	NOBATEK with the support of FLISOM and local stakeholders (EMPA)
Equipment maintenance and replacement	Baseline + Reporting periods	NOBATEK + local stakeholder + FLISOM

Task/Activity	Time period	Responsible
Local communication verification	Baseline + Reporting periods	NOBATEK+FLISOM
Data recording	Baseline + Reporting periods	NOBATEK + FLISOM (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK + R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.3.10 Expected accuracy

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

- Uncertainty associated to the measurements
- Adjustments and calculation process

4.3.11 Budget

See above

4.3.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,
- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can be calculated here (Energy production (kWh/kWp and kWh/m²), gap between the real production and the forecasted production (%)…),
- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.3.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the measurement infrastructure and alert and provide support in case of problem. The pilot manager should also alert in case of major modification in the EV charger use.

4.4 M&V plan for Demo 4 – CRICURSA building (Granollers, SPAIN)

This section describes the M&V plan for the Demo 4 in line with the main features identified in the pilot site.

4.4.1 Energy conservation measures intent

The BIPV technology selected for the CRICURSA building is the CIGS on steel modules from FLISOM (model X4), with a double functionality as a constructive roofing solution and a renewable energy generation system.

A surface of 224 m² will be installed resulting in an installed power of 19.2kWp[7] according to the following integration option: south sloped roof of the new factory building; orientation +2°, tilt 6° (see Figure 4.12 for the exact location of the BIPV system).

Using a roof integration will impact the indoor environmental conditions as well as heating consumptions of the building.

The PV production will allow to cover the energy load related with the heating and cooling system as well as other electrical loads (computers, different plugs, and so on). These loads represent the total consumption of the offices floor.

After the implementation of the BIPV solution, a commissioning phase is planned in order to check that the installation has been done correctly in order to guarantee that the installations fulfill the objectives of the pilot. This commissioning phase shall consist of a complete activation of the whole system (including the PV modules and the associated inverter) with an optimized set-up of the whole system.

[7] The figures provided here can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

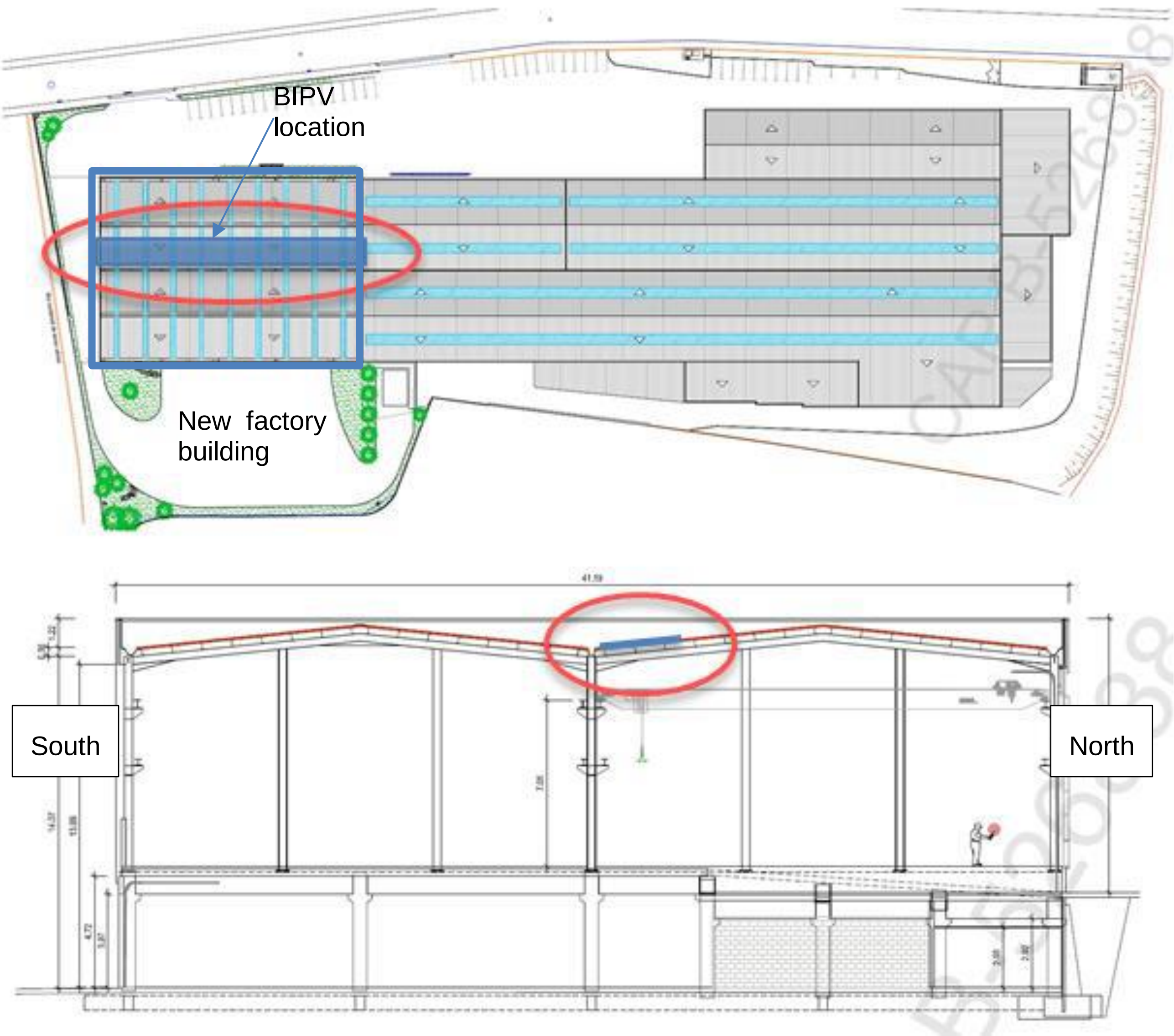

Figure 4.12 Location of the BIPV system in Demo 4

4.4.2 IPMVP option and measurement boundary

The new factory building is a heated area. Nevertheless, the heating distribution system does not allow the separate measurement of the heating consumption for this zone. In other words, thermal energy used to heat the zone of the factory affected by the BIPV solution is not isolated from the rest of the factory. Indeed, the heating for the new factory building is supplied by the gas-boiler Roca CPA-BT (or BTH) which produces hot water for the whole building and also hot water for showers and special machineries. Moreover, large ovens are present in the workshop producing a large amount of heat (internal gains) that could vary a lot according to the production rate of the company. The Factory production rate is thus a variable that increases the internal heat. Therefore, the only way to demonstrate energy reduction due to BIPV would be to isolate the zone measuring the heating consumption and considering production rate as an independent variable. However the heating distribution system does not allow this option. Even option D that would consider a simulation of the passive energy demand of the zone would require heating energy consumption measurement to calibrate the model. Therefore, it seems not possible to evaluate the impact of the BIPV installation on the heating consumption of this specific zone. As a consequence, the heating consumption will not be measured at all for this site. Nevertheless, using an option A approach by measuring local temperature parameters in the zone could provide informative data on the BIPV impact on the building passive behaviour performances.

Air renewal into the workshops of the new factory building is provided in the following way:

- Fresh air enters through holes (roof defects) at the left edge of the roof;
- Exhaust air is evacuated by the roof air extractors located in the middle of the roof and functioning on natural force (this is not an electrical system).

Except the temperature measurement in the vicinity of the roof, there is no other way to characterize the impact of the BIPV panels on the indoor conditions of the building and therefore on the heating demand. Therefore, it is proposed to use temperature and relative humidity sensors located in several points under the roof (as shown in Figure 4.13)

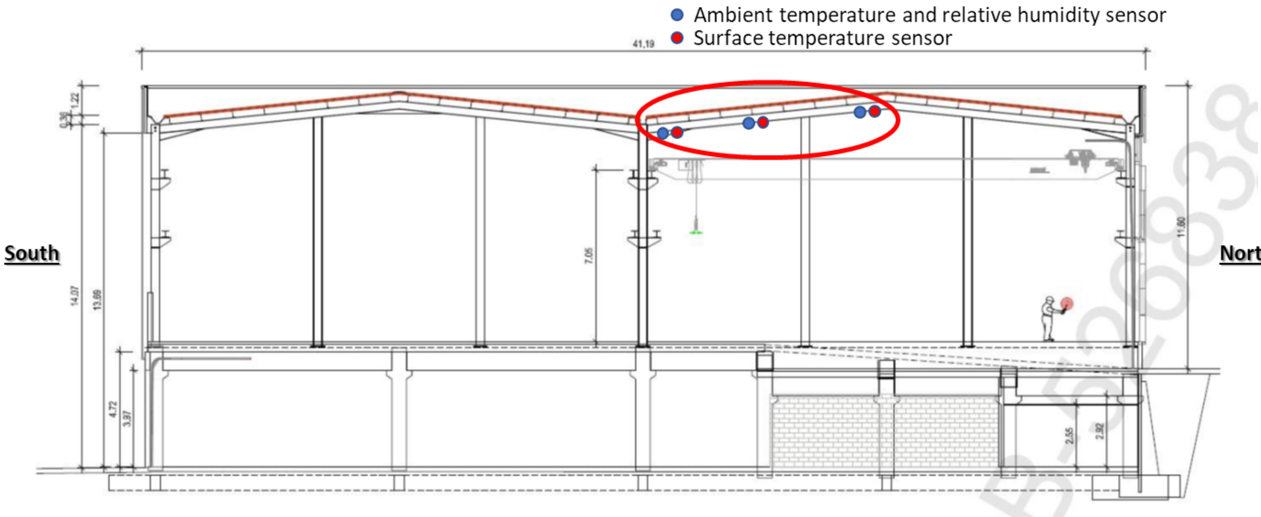

Figure 4.13 Installation plan for T/RH sensors

Therefore, the ECM scale approach (Option A) will be used for this pilot site. The BIPV performance will be evaluated independently (isolated measurement conducted on the system) and compared to the predictions.

4.4.3 Baseline: period, energy and conditions

4.4.3.1 Building analysis

4.4.3.1.1 Site context and data

The following table summarises the main features of the Demo 4.

Table 4.22 Main features of Demo 4

Main features	Description
Address	Polígon Industrial Coll de la Manya, Calle Camí de Can Ferran, s/n, 08403 Granollers(SPAIN)

Main features	Description
Building typology	Industrial building composed by an old part (offices zone+workshop zone+auxiliary services zone) and a recently built part (workshop+clean rooms)
Surface	13635 m²
Number of floors	2
BIPV installation location	South sloped roof of the new factory building; orientation +2°, tilt 6°
Why do we install BIPV technology in this house in the frame of the architectural/efficiency objective?	Regarding the main energy consumption in the production building, there are hundreds of machines in the factory with a huge amount of electrical and gas consumption. These loads cannot be covered by the BIPV system, because the power production of the PV modules is not representative in comparison with the high consumption of these machines. However, the loads of the offices zone and more specifically the electricity consumptions associated with the cooling and heating systems as well as those related with computers and plugs can be covered by the PV production.
Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building	CRICURSA
Occupancy	The detailed occupation rate is provided in annex 5 (§7.5.2). It is variable along the year as the production varies a lot along the year as well.
Building plans (floor plans, electrical network, ventilation network…)	Some simplified plans of the building are provided in annex 5 (§7.5.1)
Date of the first visit	09/06/2016

4.4.3.1.2 Main equipment present in the building

The following tables provides a synthesis of the equipment present in the building and energy used for each system. The table highlights also the existing possibilities for monitoring implementation.

Table 4.23 Main equipment of Demo 4

	Equipment	Energy used	Comments and possibilities of monitoring:
Heating	Large capacity (500kW) gas-boiler Roca CPA-BT (or BTH). This boiler also produces heating for the factory building (not offices and not new building) plus hot water for special machineries. Small capacity (217.1kW) Gas-boiler Roca supplies heating to changing rooms of old building 1.	Natural gas Natural gas	The gas supply for both gas-boilers is counted by a gas meter

	Equipment	Energy used	Comments and possibilities of monitoring:
DHW	Large capacity gas-boiler Roca CPA-BT (or BTH) produces hot water for showers Small capacity Gas-boiler Roca supplies DHW to changing rooms of old building 1	Natural gas Natural gas	
Ventilation	Small capacity Gas-boiler Roca supplies hot water to ventilation units (AHU) in clean rooms. Air extractors located in the workshop roof.	Natural gas Electricity and natural force	The electrical lines supplying the extractors are identified in the electrical boards.
Lighting	Natural and artificial non-controlled lighting		
ICT/BMS	SCADA system for temperature and ventilation regulation inside the Clean rooms.		

4.4.3.2 Baseline parameters

4.4.3.2.1 Collected data

Table below**Fehler! Verweisquelle konnte nicht gefunden werden.** summarises the parameters to b e measured before and after installation of the BIPV system.

Table 4.24 Parameters to be measured during the baseline and the reporting periods

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Electricity power and energy	Power and energy measured on the electricity lines of offices (IT servers + plugs)	Clamp-on sensors installed on the dedicated lines	
	Power and energy measured on the electricity lines of cooling system of the offices		
Indoor environmental parameters	Temperature and relative humidity in 3 points (see Figure 4.13): • 3 points under the roof below the upper and lower edge of the BIPV installation	Temperature and relative humidity sensor	
	Occupancy	Occupancy of workshops and offices zones of the building communicated by the facility manager	
	Temperature	Temperature sensor	

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Outdoor parameters	Humidity	Humidity sensor	Find a location to install the weather station close to the location of the BIPV system
	Wind speed at the location of the BIPV	Anemometer	
	Rain intensity	Ultrasound sensor	
	Hail intensity	Ultrasound sensor	
	Global solar radiation measured in the plane of the PV cells	Pyranometer installed in the plane of the PV cells	
Conditions on the roof	Temperature of the Interior roof surface	Pt1000 or thermocouple temperature sensor	

4.4.3.2.2 Independent variables

The occupation rate of the workshop in the new building can be considered as an independent variable for the indoor environmental conditions evolution. The occupation rate of the whole site is variable along the year and is detailed in annex 5 (§7.5.2).

4.4.3.2.3 Static factors

The following table summarises the static factors to be considered for non-periodic adjustment.

Table 4.25 Static factors to be considered for Demo 4

Static factor	Value considered for the baseline
Indoor temperature set-up in the buildings	The temperature in the factory is controlled by the ventilation and indoor temperature is 1 or 2 degrees less than outdoor temperature. In winter, a simple system of heating is used in the factory (if necessary, because the furnace works already as heating machines) that helps to increase the temperature by 8 to 10 degrees. In the offices, the temperature is 22ºC from 7:30 to 18:30. The setpoint is limited between 21 – 26 ºC, but in winter they used to set manually to 24 or 25 ºC.
Ventilation rate	258500 m^3/h

The building systems characteristics (power, set-up parameters…) should also be considered as static factors as they may also impact the parameters measured in the M&V plans. So they should be known and regularly monitored for the baseline period and the reporting period. For instance, any energy systems replacement or any modification in the energy use of the workshop (new machine for instance) should be monitored and reported during the monitoring period.

4.4.4 Reporting period

To access the BIPV performances during the reporting period, the following parameters will be measured in addition to those already measured and described in **Fehler! Verweisquelle konnte nicht gefunden werden.**:

Table 4.26 The M&V plan to access BIPV performances during the reporting period at CRICURSA pilot site

Parameters	Boundaries/ measurand	Measurement way	Associated Constraints
Electricity and power	Electrical power and energy (AC current) after the BIPV inverters	Electricity meters connected at the output of the inverters attached to the BIPV	See Figure 4.14
	The electrical power and energy (DC current) before the BIPV inverters	DC meters at the input of the BIPV inverters	See Figure 4.14
	Electricity entering and going out of the battery	Bidirectional AC electricity meter connected at the output of the inverter attached to the battery	See Figure 4.14 Possibility to collect it from the storage inverters that will be commercial type →to be checked when the definite selection will be done
Conditions of the BIPV system	Surface temperatures of the PV Modules →Surface temperature on the back side of the panels	Pt1000 or thermocouple temperature sensor	Need to access back side of the BIPV panels
Conditions of the roof	Air temperature between BIPV panels and lower internal layer of the roof	Pt1000 or thermocouple temperature sensor	Need to access and position a sensor between the BIPV panels and lower internal layer of the roof
	Surface temperature on the external side of lower internal roof layer behind the BIPV panels	Pt1000 or thermocouple temperature sensor	Need to access and position a sensor on the external side of lower internal roof layer behind the BIPV panels

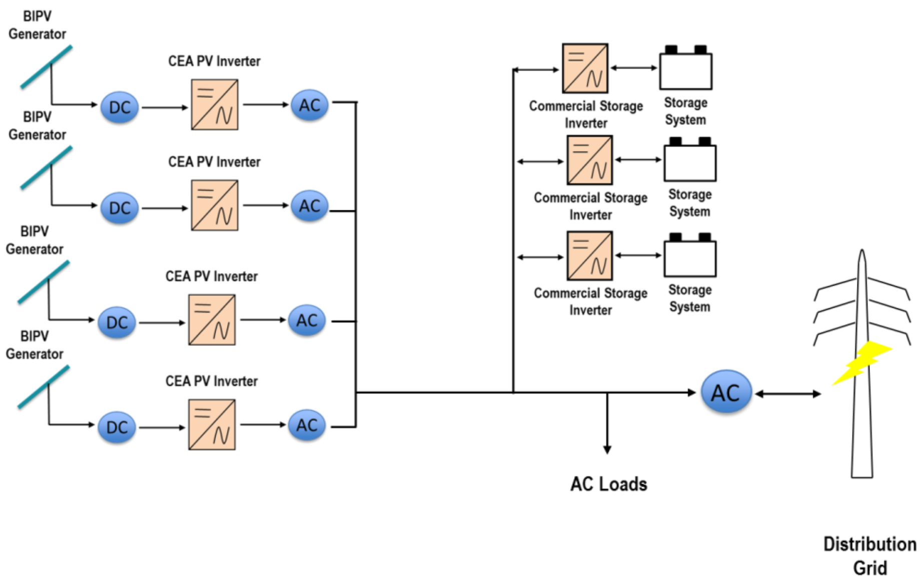

Figure 4.14 Electrical schema of the BIPV installation in Demo 4

All these data will be automatically collected by a centralized wire and wireless remote system (which includes laying of some communication cables inside the building) and deposited on a FTP server using CRICURSA internet connection.

4.4.5 Basis for adjustments

The non-periodic adjustments (related with the static parameters evolution) will be done according to the following table:

Table 4.27 Non-periodic adjustments for Demo 4

Static factor	Value to be adjusted
Indoor temperature set-up	According to the indoor temperature set-up some adjustment could be necessary on the indoor temperatures evolution assessment. This parameter has also an impact on the cooling demand of the offices and therefore the electricity consumptions measured in the offices may need an adjustment as well.
Building systems characteristics	Adjustment on the electricity consumptions
Occupation rate / number of occupants	Some adjustment may be necessary on the electricity consumptions according to the occupation rate of the offices building
Ventilation rate	Adjustment on the electricity energy consumptions

4.4.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicators:

-Comparison between the data collected for the baseline and the reporting periods in terms of energy consumptions including the required adjustments (independent variables+ static factors).

-Comparison between the data collected for the baseline and the reporting periods in terms of indoor conditions and roof characteristics.

-Assessment of the BIPV performances in comparison with the predictions.

-Assessment of the percentage of electrical loads of the offices covered by the PV production and assessment of the percentage of loads covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if self-consumed, the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.4.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.4.8 Meter specifications

The following table provides the different equipment which have been selected for the monitoring infrastructure to cover the M&V plan.

Table 4.28 Measurement devices for Demo 4

Sensor/meter	Measured parameter	Costs (€]	Nb of units	Unit cost
Clamp-on sensors for electricity lines of heating and cooling systems of offices (2levels) and plugs	Energy and power	1 500 €	3	500 €
PT1000 in 3 points on the surface with signal converters	Surface temperature	330 €	3	110 €
Wireless temperature/relative humidity in 3 points under the roof	Air temperature and relative humidity	300 €	3	100 €
Electrical meter	Energy and Electrical power produced by the BIPV at the output of the inverter	780 €	4	195 €
Bidirectional Electrical meter	Electricity coming from and going to the grid	195 €	1	195 €
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter	1080	4	270 €
Self-adhesive sensor PT1000 with signal converter	Surface temperature on the back side of the module	220	2	110 €
PT1000 sensor with signal converter	Air temperature of the air gap between the BIPV and the roof	110 €	1	110 €
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity	2 728 €	1	2 728 €
Self-supporting mast of 120 kg of weight with delivery cost	For the weather station and pyranometer	1 397 €	1	1 397 €
Pyranometer Kipp&Zonen SMP6-A with mounting accessories	Global solar irradiation in the plane of the BIPV	1 580 €	1	1 580 €
Gateway WebdynSUN	Aggregator	433 €	1	433 €
Gateway WebdynRF WM-BUS	Communication gateway with temperature/relative humidity sensors	533 €	1	533 €
PC for gateway' configuration		250 €	1	250 €
Additional devices	Connectors	500 €	1	500 €
	Cable (500 m cat 6A)	458 €	1	458 €
	TOTAL	12 394 €		

4.4.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the project and assign the responsibilities to the partners involved in the demonstration.

Table 4.29 Monitoring responsibilities for Demo 4

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK
M&V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + CRICURSA
Equipment installation	Baseline	NOBATEK with the support of CRICURSA
Equipment maintenance and replacement	Baseline + Reporting periods	NOBATEK + CRICURSA
Local communication verification	Baseline + Reporting periods	NOBATEK+ CRICURSA
Specific heat flux measurement	Baseline + Reporting periods	R2M
Data recording	Baseline + Reporting periods	NOBATEK + CRICURSA (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK +R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.4.10 Expected accuracy

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

- Uncertainty associated to the measurements
- Adjustments and calculation process

4.4.11 Budget

See Table 4.28

4.4.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,

- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can be calculated here (Energy production (kWh/kWp and kWh/m²), gap between the real production and the forecasted production (%)…),
- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.4.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the measurement infrastructure and alert and provide support in case of problem. The pilot manager is also in charge of collecting the static parameters that are needed for non-periodic adjustment.

4.5 M&V plan for Demo 5 – VILOGIA building (Wattignies, FRANCE)

This section describes the M&V plan for the Demo 5 in line with the main features identified in the pilot site.

4.5.1 Energy conservation measures intent

The BIPV system proposed for this demonstration site consists of a BIPV ventilated façade made with glass-glass Si-crystalline modules with hidden bus bars and L-interconnections (model X5, by ONYX).

A surface of 131 m^2 of PV modules will be installed with an installed power of 20 kWp[8].

It is expected that the passive effect of the system (ventilated façade) will improve the thermal performance of the building. Therefore an impact of the BIPV system on the indoor environmental conditions is expected as well as on heating consumptions.

The PV production will cover a portion of the electricity consumptions related with the common spaces of the building.

After the implementation of the BIPV solution, a commissioning phase is planned in order to check that the installation has been done correctly in order to guarantee that the installations fulfill the objectives of the pilot. This commissioning phase shall consist of a complete activation of the whole system (including the PV modules and the associated inverter) with an optimised set-up of the whole system.

4.5.2 IPMVP option and measurement boundary

For this site, the impact of the BIPV system installed as a ventilated façade on the building is assumed to be insignificant on the heating and cooling demand. As a consequence, the heating demand will not be measured for the building but instead an approach based on option A (ECM scale) is applied for the impact assessment of the BIPV installation on the building measuring:

-Indoor conditions (those that are supposed to be impacted by the BIPV installation) just behind the façade where the BIPV system will be installed.

ECM scale (Option A) will be used as well fort the BIPV performance evaluation measuring independently the system (isolated measurement conducted on the system) and comparing these performances to the predictions.

Regarding WP6 requirements, the measurements will be performed at the scale of the common spaces of the building identifying the share of electricity consumed for this specific usage that can be covered by the PV production and therefore estimate the expenses avoided through the self-consumption of PV production.

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[8] The figures provided here can differ from what was presented in deliverable D8.1 (Energy audit of buildings and identification of BIPV possibilities in every demo site) and can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

4.5.3 Baseline: period, energy and conditions

4.5.3.1 Building analysis

4.5.3.1.1 Site context and data

The following table summarises the main features of the Demo 5.

Table 4.30 Main features of Demo 5

Main features	Description
Address	12-14, rue du Docteur Laennec, Wattignies, 59139, France
Building typology	Residential, multistoreys building, social housing
Surface	3639 m²
Number of floors	8
BIPV installation location	Complete SSE façade, orientation -16°, tilt 90°. Only from the first floor to the top of the building will be occupied by the system in order to maintain the PV modules inaccessible from the ground for security aspects.
Why do we install BIPV technology in this house in the frame of the architectural/efficiency objective?	The building has a pending deep retrofitting, which will affect at least the south façade; thus, it is a propitious occasion to introduce a BIPV system which resolves the constructive requirements and improves the energy performance of the building.
Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building	VILOGIA is the owner of the building. Need to interact with the tenants (VILOGIA support required) in order to intervene in the dwellings.
Occupancy	The occupation pattern is the typical one of a residential building.
Building plans (floor plans, electrical network, ventilation network…)	The plans are provided in D8.3 “Design pack for every demo site” which is on preparation.
Date of the first visit	12/09/2016

4.5.3.1.2 Main equipment presents in the building

The building is composed by 3 apartment blocks number 12, 13 and 14 with 16 housings per block (2 housings per level).

The common spaces of the building are supplied by the EDF grid through four electricity delivery points (see Figure 4.15). In each apartment block, there is 1 electrical sub-meter (measuring elevator for entrance 12 and 13, elevator+mechanical ventilation for entrance 13). There is an additional electricity meter in entrance 13 for the general services consumptions including lighting of common spaces, electrical plugs located in the common spaces, control access system. Apart from the common spaces, each dwelling has its own delivery point.

Figure 4.15 Electricity distribution into the common spaces

The electricity meter for the common spaces of the whole building and sub-meters at block 13 level are shown below.

Figure 4.16 General building meters

The building is heated by a heat network (gas cogeneration wood) which is managed by DALKIA Company. It is a regulated heating system with a district heating distribution station (the station distributes 4 buildings). One of them is Residence La Fauvette.

Table 4.31 Main equipment of Demo 5

	Equipment	Energy used
Heating	Heat network A sub-station feeds in 4 buildings and among them the Demo 5. Heating of housings + commons spaces	Gas cogeneration wood
DHW	Heat network	Gas cogeneration wood
Other	Lift, control access system, lighting	Electricity

4.5.3.2 Baseline parameters

The baseline period to be considered for this site starts from the 1st of January 2016 and lasts until the start of the BIPV system installation planned for end of 2017. The building will be occupied during this baseline period. The occupation profile should be identified and well described in order to be compared with the occupation profile of the reporting period.

4.5.3.2.1 Collected data

Heating consumptions will not be measured because the district heating distribution system does not allow the separate measurement of the heating consumption of the building and of the zone that will be impacted by the BIPV installation. Instead, in order to assess the BIPV impact on the passive behavior of the building, the indoor environmental parameters into the housings and conditions on the façade behind the wall on which the BIPV system will be installed will be characterized at 3 points described in Figure 4.17:

- In a housing space (room, corridor) adjacent to the bottom of the area (first floor) planned for the installation of the BIPV panels;
- In a housing space (room, corridor) adjacent to the top of the area (seventh floor) planned for the installation of the BIPV panels;
- In a housing space (room, corridor) adjacent to an intermediary point (for example, fourth floor) between the top and the bottom.

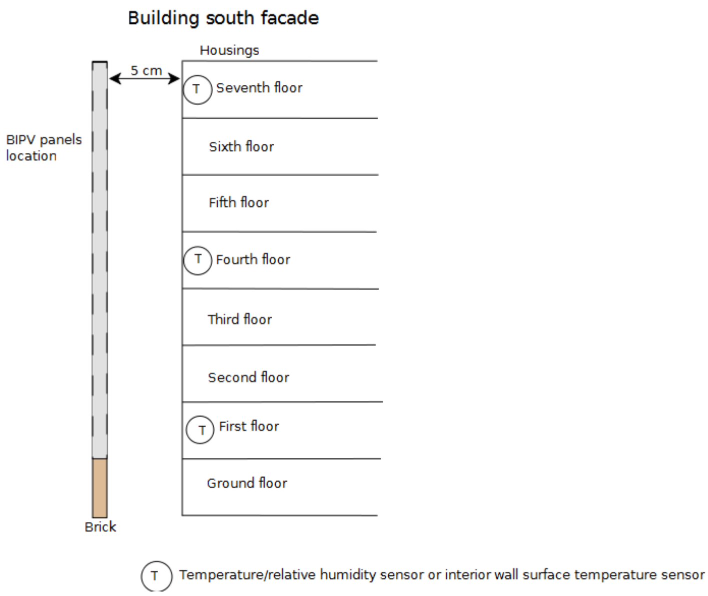

Figure 4.17 Installation plan for indoor T/RH sensors

Moreover in order to comply with the WP6 requirements and contribute to the energy management optimization strategy, the electricity consumed by common spaces will be measured because the self-consumption of the energy produced by the BIPV system is envisioned for this specific usage.

The yearly electricity consumption of common spaces for the three past years is the following:

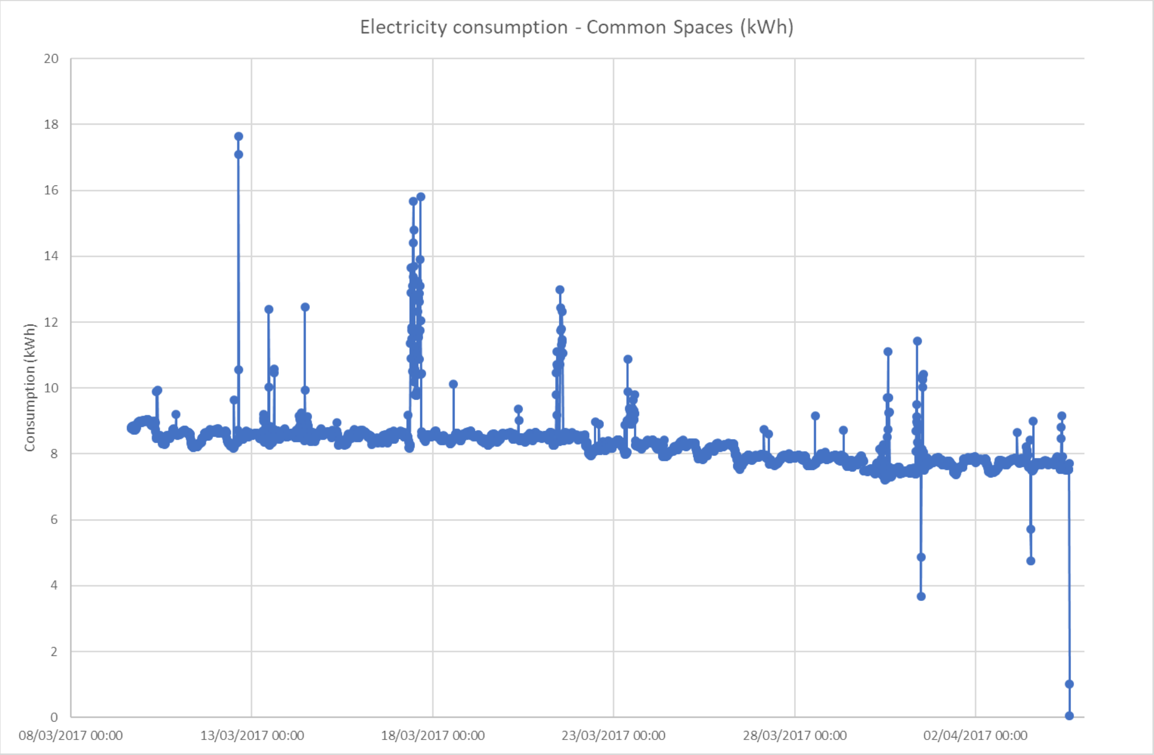

Figure 4.18 Electricity consumptions of the common spaces

The following table summarizes the parameters that will be measured for the baseline and the reporting periods.

Table 4.32 Parameters measured during the baseline and the reporting periods for Demo 5

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
Electricity consumptions (energy cumulated)	Building common spaces scale	Optical reader Fludia connected to the 4 electricity provider meters	Need to secure the location of the optical meters inside the common spaces electrical boards
Indoor environmental parameters	Temperature and relative humidity into 3 housings located close to the wall on which the BIPV system will be installed	Air temperature and relative humidity digital sensors[9] The temperature and relative humidity sensors are to be installed at 1,5 m of height from the floor, far	The tenants of the housings in which the sensors will be installed need to be recruited to participate in the experiment (VILOGIA action). The sensors need to stay in place during the whole monitoring period

[9] Black globe sensors are not required here as radiant heat transfer from the wall with BIPV panels to indoor air of housings is insignificant.

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Associated constraints
		enough from heat emitters and openings (doors, windows).	
	Occupancy	Occupancy information collected from the facility manager or concierge of the building	
Outdoor parameters	Temperature	Temperature sensor	Find a location to install a weather station in proximity to a future location of the BIPV
	Humidity	Humidity sensor	
	Wind speed at the location of the BIPV	Anemometer	
	Global solar radiation measured in the plane of the PV cells	Pyranometer in the plane of the BIPV modules (vertical position, south oriented and free of shadow)	
Conditions on the facade	Interior wall surface temperature	Pt100 or thermocouple temperature sensor	

All these measurements above combined with the historical data of energy (electricity) consumption of the building from the bills will allow establishing the baseline situation.

4.5.3.2.2 Independent variables

Regarding the indoor temperature conditions, the occupancy can be considered as an independent variable.

4.5.3.2.3 Static factors

For the Demo 5, the static factors to be considered as regards to the parameters measured in the M&V plan are the following: indoor temperature set-up in the dwellings or delivery temperature from the heating network, building systems characteristics, number of occupants in the dwellings in which the indoor temperatures are measured, ventilation rate in the dwellings. These parameters are currently being collected by the pilot site manager and will be regularly monitored during the whole monitoring period.

4.5.4 Reporting period

The reporting period will start after the end of the commissioning phase applied to the BIPV system (expected M28) until the end of the project. The reporting period has to include at least a cold period, a warm period and a mid-season period.

For the reporting period, in addition to the parameters defined in **Fehler! Verweisquelle konnte nicht gefunden werden.** and in order to access the BIPV performances during the reporting period, the Measurement & Verification Plan include the following measurements:

Table 4.33 M&V plan to access BIPV performances during the reporting period at Demo 5

Parameters	Boundaries/ measurand	Measurement way	Associated constraints
Electricity and power generated	Electrical energy and power generated by the BIPV system+associated inverter	Bidirectional AC Electricity meter at the output of the inverter	See Figure 4.19
	Electrical power (DC current) between the inverter and the storage system	DC meter at the input of the inverter	See Figure 4.19
	Electrical power (DC current) between the inverter and the BIPV generator	DC meter at the output of the inverter (battery side)	See Figure 4.19
Conditions of the BIPV system	Surface temperatures of the PV Modules on the back side of the modules	Pt100 or thermocouple temperature sensor	Need to access back side of the BIPV panels
Conditions on the façade	Air temperature between BIPV panels and exterior wall	Pt100 or thermocouple temperature sensor	Need to access and position a sensor between the BIPV panels and the exterior wall surface
	Exterior wall surface temperature behind the BIPV panels	Pt100 or thermocouple temperature sensor	Need to access and position an sensor on surface of exterior wall behind the BIPV panels

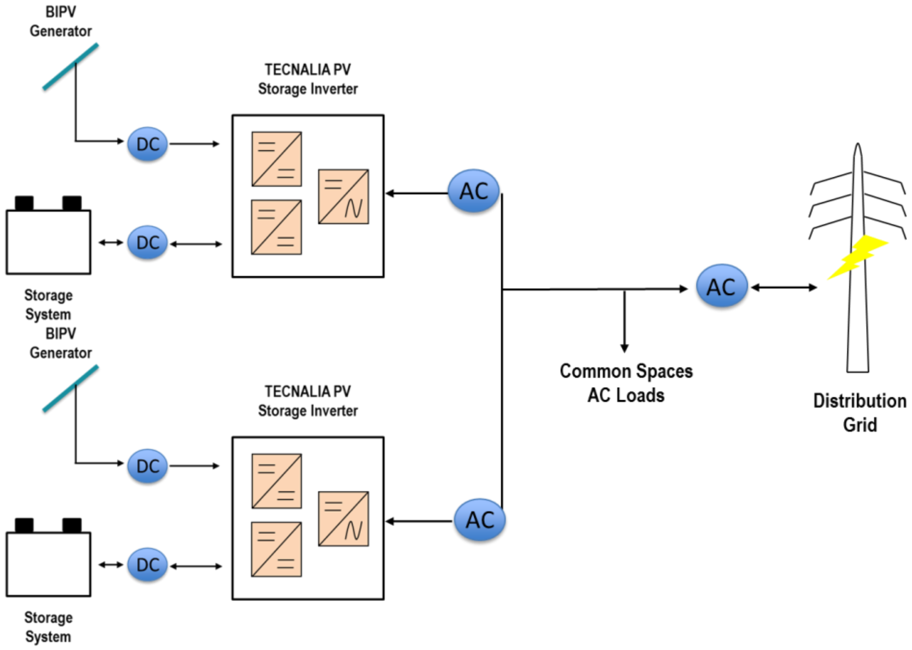

Figure 4.19 Electrical schema of the BIPV installation in Demo 5

All these data will be automatically collected by a centralized wire and wireless remote system (which includes laying of some communication cables inside the building) and deposited on a FTP server using building internet connection. An access to an internet connection should be made available by the local pilot site manager.

4.5.5 Basis for adjustments

The non-periodic adjustments (related with the static parameters evolution) will be done according to the following table:

Table 4.34 Non-periodic adjustments for Demo 5

Static factor	Value to be adjusted
Indoor temperature set-up	According to the indoor temperature set-up some adjustment could be necessary on the indoor temperatures evolution assessment.
Area and volume of heated spaces	Adjustment on the indoor temperature evolution assessment
Building systems characteristics	Adjustment on the electricity consumptions
Number of occupants	Adjustment on the indoor temperature evolution assessment

4.5.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicators:

-Comparison between the data collected for the baseline and the reporting periods in terms of energy consumptions including the required adjustments (independent variables+ static factors).

-Comparison between the data collected for the baseline and the reporting periods in terms of indoor conditions and temperature conditions of the wall on which the BIPV system will be installed.

-Assessment of the BIPV performances in comparison with the predictions.

-Assessment of the electrical loads of common spaces covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if self-consumed the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.5.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.5.8 Meter specifications

The following table provides the different equipment selected for the monitoring infrastructure to cover the M&V plan of Demo 5.

Table 4.35 Measurement devices for Demo 5

Sensor/meter	Measured parameter	Costs (€]	Nb of units	Unit cost
Optical reader FLUDIA	Energy consumed by the common spaces	1500	6	250
HOBO sensors (sensor+datalogger)	Air temperature and relative humidity in the area behind the wall where the BIPV will be installed	450	3	150
PT1000 sensor with signal converter	Interior wall surface temperature	330	3	110
Bidirectional electrical meter	Energy and Electrical power produced by the BIPV at the output of the inverter	390	2	195
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter	1080	4	270
Self-adhesive sensor PT1000 with signal converter	Surface temperature of the BIPV modules (back end)	220	2	110
PT1000 sensor with signal converter	Air gap between the BIPV and the wall	110	1	110
PT1000 sensor with signal converter	Surface temperature of the exterior of the wall	110	1	110
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity, rain and hail intensity	2728	1	2728
Weather station data collection software		333	1	333
Pyranometer KIPP&ZONEN SMP6-A	Global solar irradiation in the plane of the BIPV	1580	1	1580
Self-supporting mast of 120 kg of weight with delivery cost	For the weather station and pyranometer	1397	1	1397
Gateway WebdynSUN	Aggregator	433	1	433
Gateway WebdynRF WM-BUS	Communication gateway with temperature/relative humidity sensors WM-BUS	533	1	533
PC for gateway' configuration		250	1	250
Additional devices	Cables, connectors,	1000	1	1000
	TOTAL	12 444 €		

4.5.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the project and assign the responsibilities to the partners involved in the demonstration.

Table 4.36 Monitoring responsibilities for Demo 5

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK
M&V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + VILOGIA
Equipment installation	Baseline	NOBATEK with the support of VILOGIA or local pilot site manager
Equipment maintenance and replacement	Baseline + Reporting periods	NOBATEK + local stakeholder
Local communication verification	Baseline + Reporting periods	NOBATEK+VILOGIA
Data recording	Baseline + Reporting periods	NOBATEK + VILOGIA (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK+R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.5.10 Expected accuracy

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

- Uncertainty associated to the measurements
- Adjustments and calculation process

4.5.11 Budget

See Table 4.35 above.

4.5.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,
- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can be calculated here (Energy production (kWh/kWp and kWh/m^2), gap between the real production and the forecasted production (%)…),
- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.5.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the measurement infrastructure and alert and provide support in case of problem. The pilot manager is also in charge of collecting the static parameters that are needed for non-periodic adjustment.

4.6 M&V plan for Demo 6 – TECNALIA building (San Sebastian, SPAIN)

This section describes the M&V plan for the Demo 6 in line with the main features identified in the pilot site.

4.6.1 Energy conservation measures intent

The BIPV system foreseen for the TECNALIA's demos-site consists of a PV double-skin over the existing curtain walls with c-Si back contact laminated glass modules, by ONYX. The BIPV system will therefore perform as double-glazing ventilated façade.

A surface of around 138m² will be installed with an installed power of 20 kWp according to the following installation option: SSE & S polygonal façades[10].


Figure 4.20 SE Curtain wall where the BIPV system will be installed (left) and room potentially impacted by the BIPV installation

This integration typology allows to improve the indoor environmental conditions of the room behind the curtain wall which are currently not satisfactory (too hot in warm seasons and too cold in winter). Shadowing the curtain wall by the solar cells will significantly reduce the temperature in summer; the second skin over the existing cladding will improve reduce the cold during the winter seasons.

Moreover the PV production will allow covering a portion of electricity usages of the offices areas of the building. The offices areas have been defined as the most appropriate for energy optimisation. Therefore the electricity consumptions (lighting and plugs) will be measured by floor in the offices area.

[10] The figures provided here can differ from what was presented in deliverable D8.1 (Energy audit of buildings and identification of BIPV possibilities in every demo site) and can still suffer changes due to the design process which is in progress and that will be reflected in next deliverables D8.2 (Result of modeling and BIPV strategies for every demo site) and D8.3 (Design pack for every demo site).

4.6.2 IPMVP option and measurement boundary

ECM scale approach (Option A) is applied for the impact assessment of the BIPV installation on the building:

- Indoor conditions (those that are supposed to be impacted by the BIPV installation that means lighting conditions, temperature conditions of the room located behind the curtain wall on which the BIPV will be installed).

- Isolated measurement conducted on the BIPV system and compared to the predictions.

- Electricity consumptions for specific zones and usages will be measured in order to assess the share of electricity consumptions that can be covered by the PV production and therefore estimate the expenses avoided thanks to the self-consumption applied to the building.

4.6.3 Baseline: period, energy and conditions

4.6.3.1 Building analysis

4.6.3.1.1 Site context and data

The following table summarises the main features of the Demo 6.

Table 4.37 Main features of Demo 6

Main features	Description
Address	Paseo Mikeletegi 2, San Sebastian (Spain).
Building typology	Tertiary building hosting offices, engineering and chemical laboratories and one part of the basement dedicated to special machines
Surface	6000 m²
Number of floors	4
BIPV installation location	SSE & S polygonal façades (curtain wall)
Why do we install BIPV technology in this building in the frame of the architectural/efficiency objective?	The installation of BIPV in this building will help in improving the indoor environmental conditions in the room located behind the curtain walls and cover a part of the electrical load of the offices energy use.
Owner of the building and specific requirements in terms of interaction with the building and the occupants of the building	TECNALIA Contact point: Building manager
Occupancy	The occupation pattern is the typical of an offices building. It should be highlighted that the lighting system is turned on all day long (from 8:00 till 17:00).
Building plans (floor plans, electrical network, ventilation network…)	The plans are provided in annex 6 (§7.6)
Date of the first visit	02/06/2016

4.6.3.1.2 Main equipment present in the building

The following table provides a synthesis of the equipment present in the building (Heating/Ventilation/DHW/solar panels/number of electrical board...) and energy used for each system. The table highlights also the existing possibilities for monitoring implementation.

Table 4.38 Main equipment of Demo 6

	Equipment	Energy used	Comments and possibilities of monitoring:
Heating	2 gas boilers	Natural gas	The occupants do not have the possibility to adjust the temperature set-point themselves. This is done manually through a centralised management system by the building manager.
Cooling (no cooling in the basement, only in the 3 other levels.	2 gas chillers 2 additional electrical chillers	Natural gas Electricity	
Ventilation			
Lighting	Turned on all day long (from 8:00 till 17:00).		
ICT/BMS	Supervision interface associated to the HVAC system		The data measured are not stored in the system
Other	Special machines located in the basement are the most important electricity consumers of the building. The electricity consumption for lighting and plugs represent only 30% of the whole electricity consumptions.		

4.6.3.2 Baseline parameters

The cooling/heating distribution system does not allow the separate measurement of the heating and cooling consumption for the zone that is supposed to be impacted by the BIPV installation. Therefore heating consumptions of this specific zone will not be measured. Moreover, the surface of the installed BIPV system is too small to have a significant and measurable impact on the whole heating/cooling consumption and if we choose to measure the energy consumption associated with heating/cooling of the whole building, we will not be able to detect the impact of the BIPV system on these consumptions.

4.6.3.2.1 Collected data

In the frame of the Measurement & Verification plan, the parameters summarised below**Fehler! Verweisquelle konnte nicht gefunden werden.** are proposed to be measured to access the building performances (indoor environmental conditions and energy consumption parameters) before and after the installation of the BIPV system.

Table 4.39 Parameters to be measured during the baseline and the reporting periods for Demo 6

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Constraints associated
Electricity consumptions	Electricity consumption by usage (lighting, plugs) for the offices area of the building for the 2^{nd} and 3^{rd} floors (area defined as the most appropriate for energy optimization, see WP6 requirements)	Electricity meters with clamp-on sensors suited for the cable section of 6 mm^2 installed on the corresponding lines	Available space in the electrical distribution boards for the installation of the electricity meters needs to be checked
Indoor environmental parameters	Air temperature in the rooms on the 2^{nd} and 3^{rd} floors behind the curtain wall on which the BIPV system will be installed	Temperature digital sensor	
	Operative temperature taking into account radiation through the transparent facade	Pt100 or thermocouple sensor +black globe	
	Luminance	Lux meter	
	Indoor radiation level	1^{st} class[11] thermopile pyranometer	
Occupancy	In the rooms on the 2^{nd} and 3^{rd} floors behind the curtain wall on which the BIPV system will be installed	Presence detector in the rooms of 2^{nd} and 3^{rd} floors behind the façade and global occupancy information from the facility manager for the open spaces	
Outdoor parameters	Temperature	Temperature sensor	Find a location to install a weather station in the vicinity of the future location of the BIPV system
	Relative humidity	Humidity sensor	
	Wind speed at the location of the BIPV	Anemometer	
	Global solar radiation measured in the plane of the PV cell	Pyranometer in the plane of the BIPV modules	

[11] According to ISO 9060. Solar energy -- Specification and classification of instruments for measuring hemispherical solar and direct solar radiation

Parameters	Boundaries/ measurand	Means of Measurement/calculation	Constraints associated
	Exterior light level	Lux meter	
Conditions on the facade	Indoor window surface temperature	Pt100 or thermocouple temperature sensor	
	Solar factor or G-value which provides the share of solar energy that finally ends up in the interior	Will be calculated as difference between outdoor solar radiation and interior radiation levels in the rooms at the 2nd and 3rd floor close to the glass façade on which the BIPV system will be installed	
	Daylight factor which is the ratio of the internal light level at a given point in a room to the exterior light level measured on a horizontal plane is constant, regardless of the time of day.	Will be calculated on the basis of exterior light level and indoor luminance in the rooms at the 2nd and 3rd floor close the glass façade on which the BIPV system will be installed	

4.6.3.2.2 Independent variables

Regarding the indoor temperature conditions, the occupancy, outdoor temperature and light level can be considered as an independent variables.

4.6.3.2.3 Static factors

For this demonstration building, the static factors to be considered are the indoor temperature set-up of the building, the area and volume of the room located behind the curtain wall for the 2nd and 3rd floor, the number of occupants of these specific zones, and the ventilation rate used in these zones. Commonly there is no occupancy in these areas and there is a ventilation system but without specific temperature controls.

4.6.4 Reporting period

The reporting period will start after the end of the commissioning phase applied to the BIPV system (expected M28) until the end of the project. The reporting period has to include at least a cold period, a warm period and a mid-season period.

To access the BIPV performance during the reporting period, the M&V plan should at least include the following measurements:

Table 4.40 M&V plan to access the BIPV performances during the reporting period in Demo 6

Parameters	Boundaries	Means of measurement	Constraints associated
Electricity energy and power	Electrical power and energy (AC current) after the BIPV inverter generated by the BIPV system One inverter associated to each façade should be considered (→total of 2 measurements	AC meter connected to the output of both inverters or directly by the inverters themselves	Possibility to collect it from the inverters used with the BIPV panels to be checked See electricity configuration (Figure 4.21
	Electrical power and energy (DC current) before the BIPV inverter One inverter associated to each façade should be considered (→total of 2 measurements)	DC meter at the input of the inverters x 2	See electricity configuration (Figure 4.21
	Electrical power and energy entering and going out of the Battery inverter	Bidirectional AC meter between the BIPV inverters and the storage inverter	Possibility to collect it from the storage inverters that will be commercial type →to be checked when the definite selection will be done See electricity configuration (Figure 4.21
Conditions of the BIPV system	Surface temperatures of the PV modules	PT100 self-adhesive sensor.	

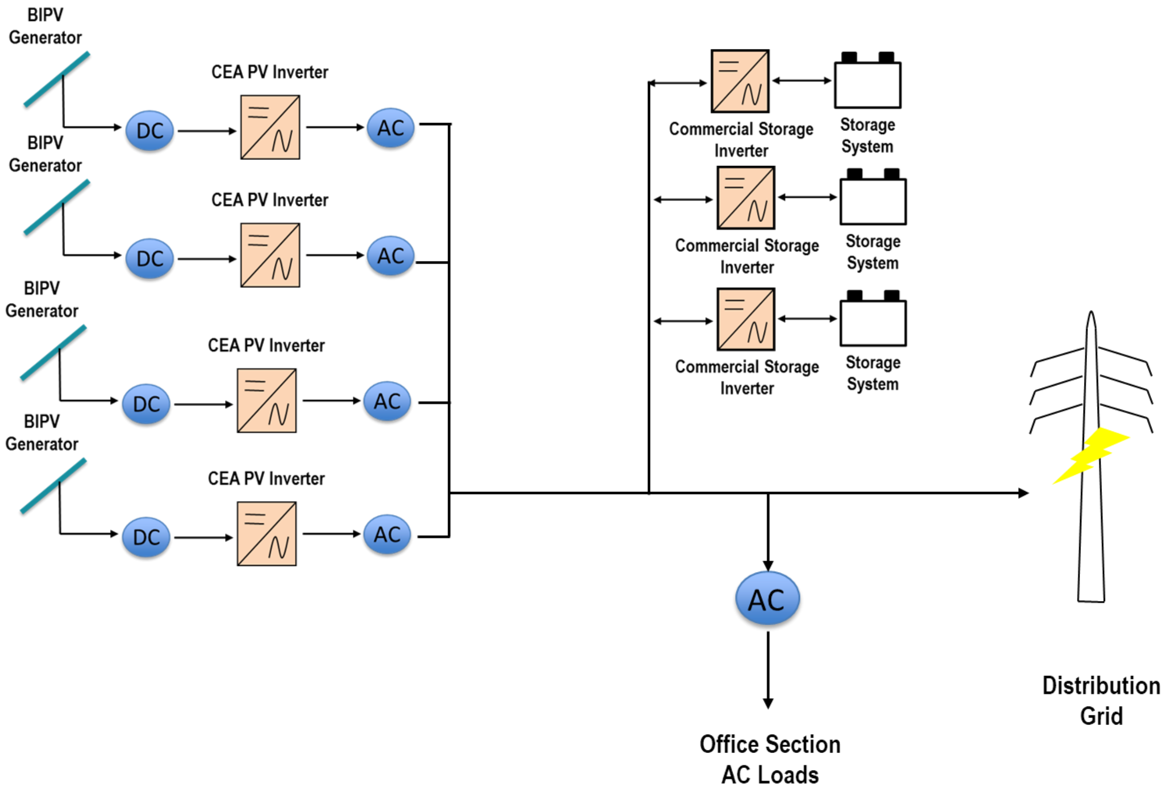

Figure 4.21 Electrical schema of the BIPV installation in Demo 6

All these data (except occupancy dataloggers data which are not planned to be transmitted) will be automatically collected by a centralized wire and wireless remote system (or a dedicated PC), which includes laying of some communication cables inside the building. Once collected, the data will be deposited on a FTP server using TECNALIA internet connection.

4.6.5 Basis for adjustments

The non-periodic adjustments (related with the static parameters evolution) will be done according to the following table:

Table 4.41 Non-periodic adjustments for Demo 6

Static factor	Value to be adjusted
Indoor temperature set-up	According to the indoor temperature set-up some adjustment could be necessary on the indoor temperatures evolution assessment.
Area and volume of heated spaces	Adjustment on the indoor temperature evolution assessment
Building systems characteristics	Adjustment on the electricity consumptions
Number of occupants	Adjustment on the indoor temperature evolution assessment

4.6.6 Analysis procedure

The analysis procedure is based on the calculation of the following indicators:

-Comparison between the data collected for the baseline and the reporting periods in terms of energy consumptions including the required adjustments (independent variables+ static factors).

-Comparison between the data collected for the baseline and the reporting periods in terms of indoor conditions and temperature conditions of the wall on which the BIPV system will be installed.

-Assessment of the BIPV performances in comparison with the predictions.

-Assessment of the percentage of electrical loads of the offices area (2nd and 3rd floors) covered by the PV production. This analysis extends the IPMVP approach which is focused per se on energy savings assessment. Nevertheless, if self-consumed the PV production can be considered as energy savings as this electricity is not taken from the grid and avoid energy expenses in some way.

4.6.7 Energy prices (optional)

The energy price criteria will not be considered in the frame of the monitoring process in the PVSITES project. Only energy values (kWh) will be considered in the impact assessment as well as temperature.

4.6.8 Meter specifications

The following table provides the different equipment which have been selected for the monitoring infrastructure to cover the M&V plan of Demo 6.

Table 4.42 Measurement devices for Demo 6

Sensor/meter	Measured parameter	Cost (€)	Nb of units	Unit cost
Direct electricity meters Schneider A9MEM	Energy consumed by the offices areas (2 floors, lighting+others)	2000	4	500
WM-BUS sensors	Air temperature and relative humidity	300	3	100
PT100 or thermocouple sensor +black globe	Operative temperature	600	1	600
Pyranometer + rotating support (vertical position)	Indoor solar irradiation	1650	1	1650
Luxmeter/Presence detector datalogger	Luminance indoor and presence in the room located behind the BIPV façade	526	2	263
PT1000 with signal converter	Indoor window surface temperature	110	1	110
Electrical meter	Energy and power produced by the BIPV at the output of the inverter	1189	4	297
Wattmeter ACCUENERGY	Electrical power and energy (DC current) before the inverter	1080	4	270
Self-adhesive sensor PT1000 with signal converter	Surface temperature on the back side of the module	220	2	110
Weather station Vaisala WXT536 with mounting/connection accessories	Outdoor temperature, relative humidity, wind direction and velocity, rain and hail intensity	2728	1	2728
Weather station data collection software		333	1	333
System RaZON+ (mini solar tracker)	Direct and diffuse solar irradiation	8733	1	8733
Self-supporting mast of 120 kg of weight with delivery cost	For the weather station and pyranometer	1397	1	1397
Pyranometer KIPP&ZONEN SMP6-A	Outdoor global solar irradiation in the plane of the BIPV	1580	1	1580
Gateway WebdynSUN	Aggregator	433	1	433
Gateway WebdynRF WM-BUS	Communication gateway with temperature/relative humidity sensors	533	1	533
PC for configuration		250	1	250
Additional devices	Cables, connectors,	1000	1	1000
	TOTAL	24 661 €		

4.6.9 Monitoring responsibilities

The following table summarises the different tasks and activities associated with monitoring in the project and assign the responsibilities to the partners involved in the demonstration.

Table 4.43 Monitoring responsibilities for Demo 6

Task/Activity	Time period	Responsible
M&V plan proposal	Baseline + Reporting periods	NOBATEK
M&V plan validation	Baseline + Reporting periods	PVSITES consortium
Equipment proposal	Baseline + Reporting periods	NOBATEK
Equipment validation	Baseline + Reporting periods	NOBATEK + ACCIONA + TECNALIA
Equipment installation	Baseline	NOBATEK with the support of TECNALIA (local building manager)
Equipment maintenance and replacement	Baseline + Reporting periods	NOBATEK + TECNALIA (local building manager)
Local communication verification	Baseline + Reporting periods	NOBATEK+ TECNALIA
Data recording	Baseline + Reporting periods	NOBATEK + TECNALIA (static factors)
Data sharing	Baseline + Reporting periods	NOBATEK + ACCIONA (BCC)
Data analysis	Baseline + Reporting periods	NOBATEK + R2M
Project reporting	Baseline + Reporting periods	NOBATEK + ACCIONA

4.6.10 Expected accuracy

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

- Uncertainty associated to the measurements
- Adjustments and calculation process

4.6.11 Budget

See Table 4.42 above.

4.6.12 Report format

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

The report will include at least the following information:

- Energy consumptions (monthly) for the considered period,
- The list of independent variables and static factors for the considered period,
- After ECM implementation, comparison between the reporting period situation and the baseline period situation and performance results of the BIPV system. Here several KPIs can

be calculated here (Energy production (kWh/kWp and kWh/m²), gap between the real production and the forecasted production (%)…),

- Specific items to be considered (issues encountered on site, events occurred during the period and that could modify the monitoring analysis).

4.6.13 Quality insurance

In the frame of the data collection, two storage systems will be used to guarantee that no data will be lost during the monitoring phase. Moreover, a periodic verification will be conducted on the collected data in order to check that the monitoring system (sensors + data collection infrastructure) is functioning correctly.

In the case of missing data, it is acknowledged that interpolation between measured data will be used.

The pilot site manager is completely involved in the monitoring process in order to regularly check the measurement infrastructure and alert and provide support in case of problem. The pilot manager is also in charge of collecting the static parameters that are needed for non-periodic adjustment.

5 CONCLUSIONS

This report describes the measurement and verification plans for all the demonstration sites of the PVSITES project. These M&V plans are built on the basis of the monitoring guidelines established in D8.7 and follow the 13 items recommended by the IPMVP approach.

These M&V plans have been used for the installation of the monitoring devices that has started during the first period of the project and which is currently in progress.

The passive behavior of the buildings and therefore the impact of the BIPV systems on the performance of the buildings is difficult to assess as the energy systems do not usually allow the separate measurement of the parameters of interest. Nevertheless the proposed M&V plans try to include this aspect and propose some measurements solutions to make such an assessment.

Regarding the monitoring activities, the M&V plans presented in this deliverable have been prepared on the basis of the works conducted so far on the BIPV design and implementation and on the energy management strategy developed as part of the WP6. Some modifications or adjustments may appear on the BIPV design and implementation in the current activities and this may have an impact on the measurements to be deployed. Moreover, as the instrumentation activities have tried as far as possible to address the WP6 needs, some evolutions are also expected in the measurements to be deployed to answer this WP6's needs.

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: 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.

Option D: Calibrated simulation. It involves the use of computer simulation software to predict facility energy for one or both of the terms in Equation 1). A simulation model must be "calibrated" so that it predicts an energy pattern that approximately matches actual metered data.

Avoided Energy Use (or Savings) = (Baseline Energy ± Routine Adjustments to reporting-period conditions ± Non-Routine Adjustments to reporting-period conditions) - Reporting-Period Energy. 1)

7.2 Appendix 2: Plans of Demo 1

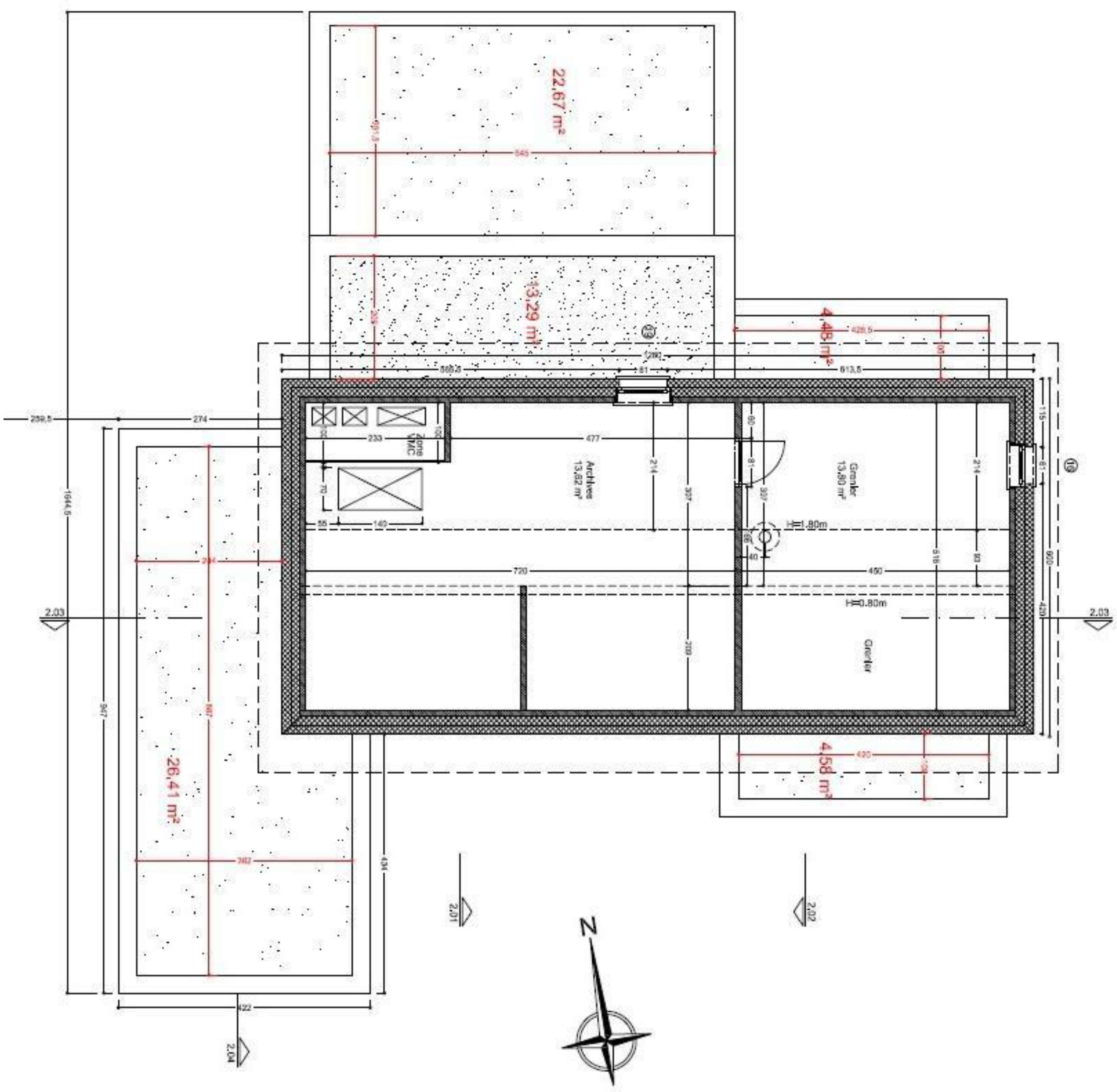

Figure 7.1 Floor plan of the Belgian Demo-building.

Figure 7.2 Temperature and humidity sensors location in the house

7.3 Appendix 3: IT infrastructure of the monitoring system

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

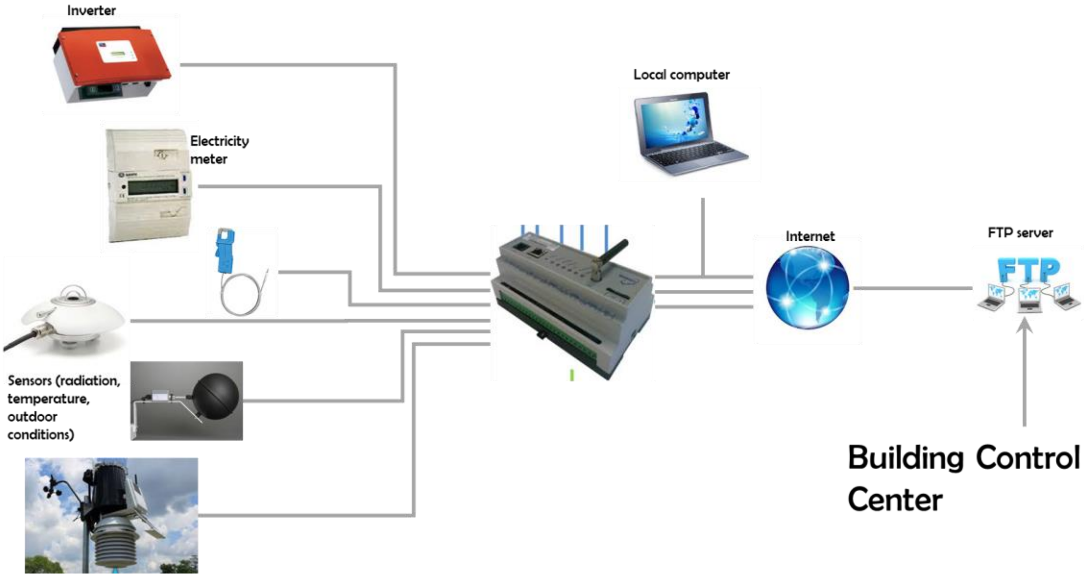

Figure 7.3 General communication concept between the monitoring infrastructure on site and the BCC

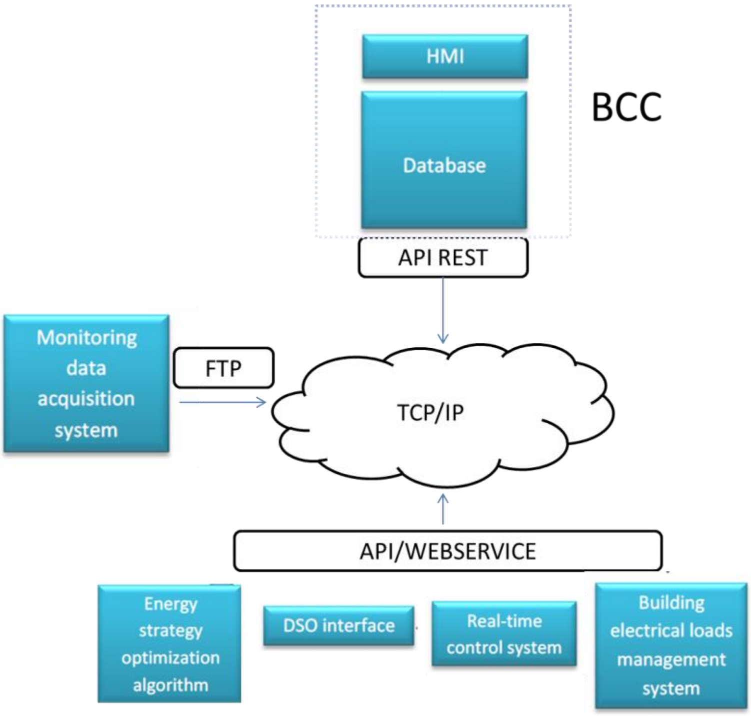

Figure 7.4 BCC integration in the PVSITES Architecture.

7.4 Appendix 4: Plans of Demo 2

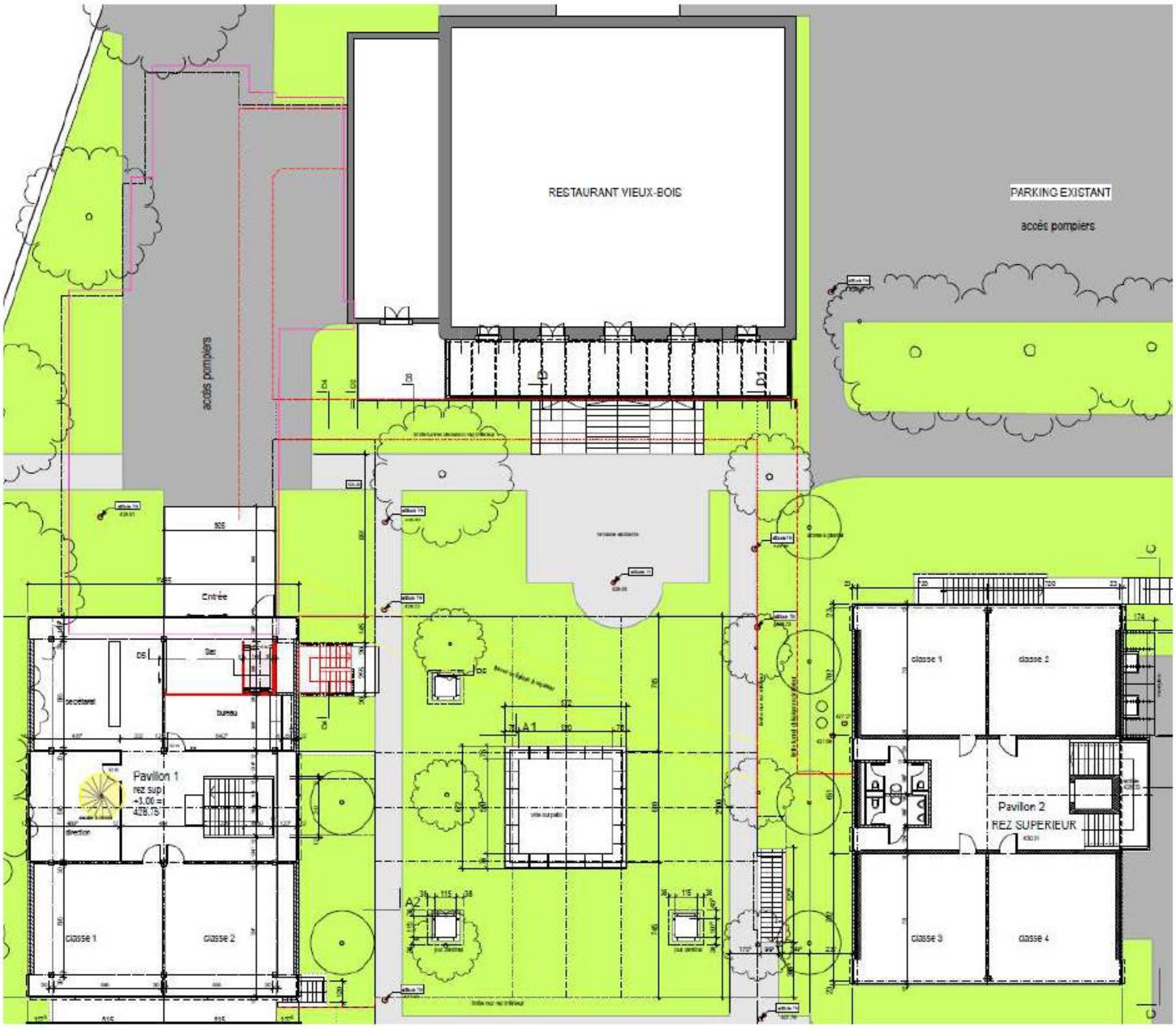

Figure 7.5 Plan of EHG pilot site

7.5 Appendix 5: Demo 4

7.5.1 Plans of Demo 4

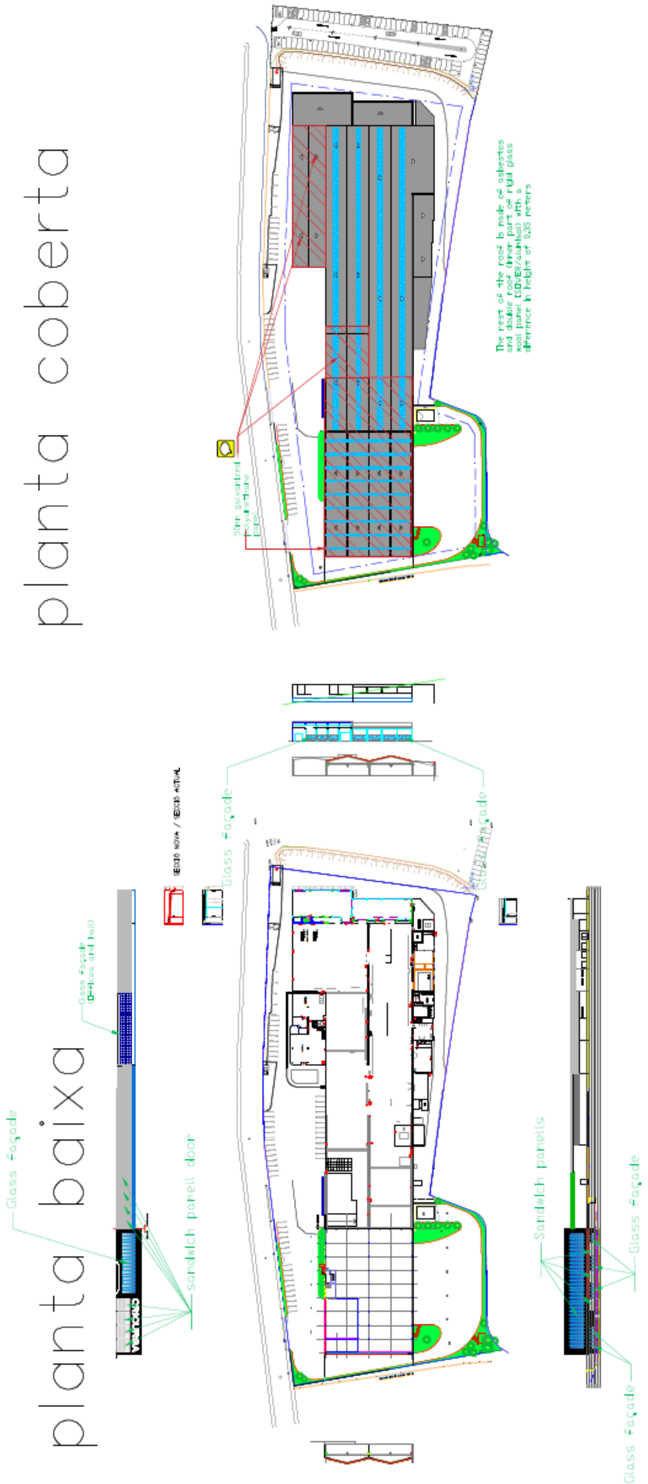

Figure 7.6 Plans of CRICURSA pilot site

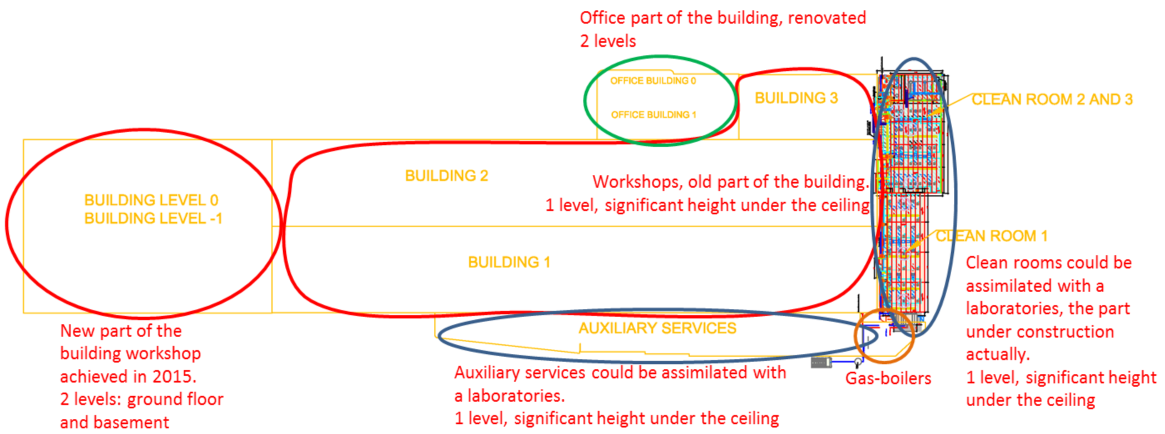

Figure 7.7 Simplified plans of CRICURSA pilot site

7.5.2 Occupation rate in Demo 4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Offices Monday to Thursday from 7:00 AM to 19:00 Friday from 7:00 AM to 15:00	32	32	32	32	32	32	32	10	32	32	32	32
Factory Plant (From Monday to Friday 24 hours per day)	30	30	30	30	30	30	30	30	30	30	30	30
Factory Plant (Weekend and Holidays) 24 hours per day	10	10	10	10	10	10	10	0	10	10	10	10

7.6 Appendix 6: Plans of Demo 6

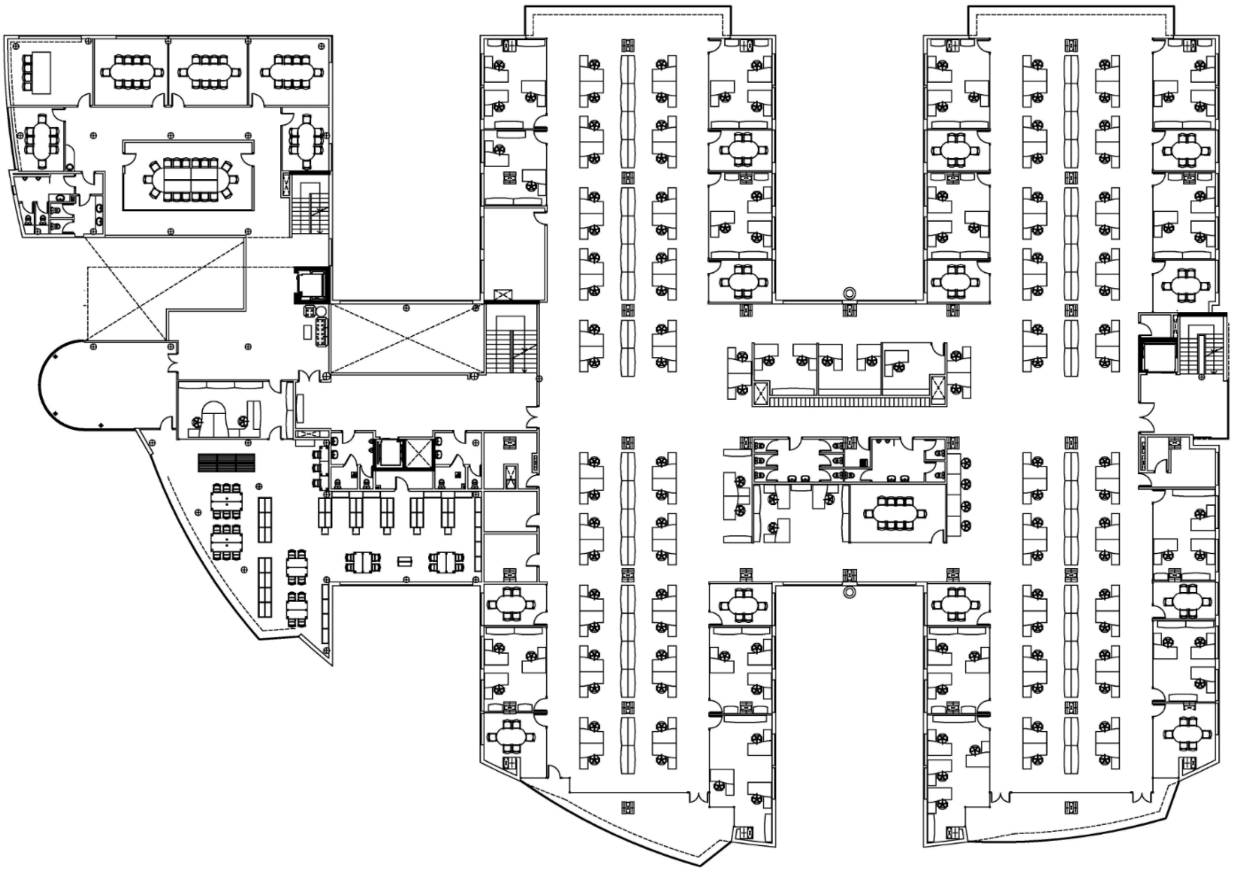

Figure 7.8 Plans of TECNALIA pilot site (1st floor)

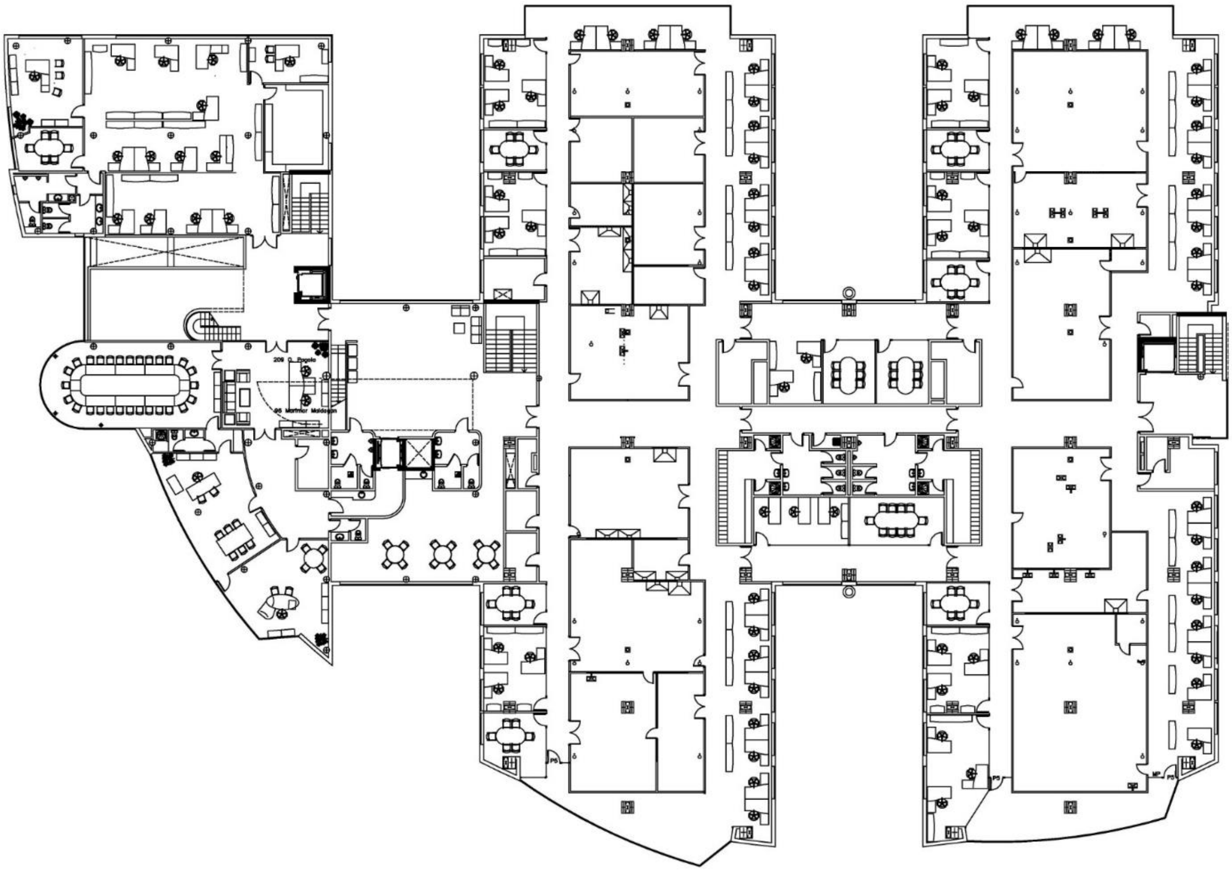

Figure 7.9 Plans of TECNALIA pilot site (2nd floor)