Residential Renovation
towards nearly zero energy CITIES

R2CITIES

"**R**enovation of **R**esidential urban spaces: Towards nearly zero energy **CITIES**"

D4.5 M&V Plan for Valladolid demo site

WP 4, Task 4.3

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Executive Summary

The present document establishes the Measurement & Verification plan for the Valladolid demo site. The M&V plan is based on IPMVP, although extended due to the district nature of the project. Thus, this document contains the District Performance Indicators (DPIs) which allow the assessment of the energy savings in the whole neighborhood. It can also be found the baseline, reporting period and key metered parameters to carry out the energy evaluation as a whole. Nevertheless, for achieving the objectives of the project, it is required to know the features of the energy supplies of the buildings inside the district so as to determine the best actions to aim with the retrofitting strategies. As well, the model needs to be calibrated, adjusted and validated, therefore, the M&V plan sets up the fundamental of these steps which are used in the evaluation of the refurbishment project.

1. Introduction

1.1. Purpose and target group

This report focuses on the definition of the Measurement and Verification (M&V) plan for the Valladolid demo site. As remarked in the previous deliverable D4.1: “Report on the Measurement and Verification analysis” [1], Measurement and Verification Operational Guide [2] from the Office of Environment and Heritage of the State of New South Wales (Australia), which is also based on the IPMVP [3] is selected as basis protocol for the M&V plan after comparing multiple ones. Thus, once laid the fundamentals, the plan for the Valladolid demo site is established within the present document and the related documents for the remaining demonstrators (D4.6 and D4.7). Although the present approach is based on IPMVP, it needs to be adapted because IPMVP does not consider neighborhoods, but buildings. Therefore, the existing guidelines have been adjusted to the project requirements at district level.

Then, the framework for the M&V plan selects the IPMVP option within the available ones, describes the demo site, its Energy Conservation Measures (ECM(s)) and the expected benefits, as well as the Key Performance Indicators, baseline and reporting period in order to evaluate the energy savings through real validation. In that sense, the current deliverable applies with the following objectives of the project.

- Scientific objective: “To define the requirements, baseline and boundary conditions for an integrated and systemic renovation of residential districts”
    - Key Performance Indicators analysis for nearly zero energy districts audit
    - Key measurement elements for the energy management plan
    - Typologies-classification of residential scenarios at district level
    - Definition of the energy diagnosis and evaluation methodology
- Scientific objective: “Execution, supervision of the construction works and its monitoring and evaluation”
    - Assurance of the quality and time for delivery
    - Set up a model for monitoring commitment
    - Evaluation methodology for the process and the final energy performance
    - Align the M&V with the EC CONCERTO [4] technical monitoring database and approaches

On the other hand, observing the methodology workflow in Figure 1, the guidelines given in the current deliverable cover the diagnosis phase together with the execution and evaluation phase. In the first one, the indicators and key parameters are defined within the plan. With regard to the execution phase, how the energy and costs savings are going to be evaluated is detailed. Therefore, for achieving these goals, several steps must be fulfilled as follows:

1. Definition of the refurbishment project, demonstrator energy and comfort features and the expected benefits through the retrofitting strategies.
2. Implementation of the M&V protocol according to the deliverable D4.1 “Report on the Measurement and Verification analysis” [1], which is based on the IPMVP
    - Selection of the boundaries and IPMVP option

- Selection of the DSIs (District Sustainable Indicators) related to the energy assessment
- Description of the ECM(s)

3. Definition of the Baseline period
   - Set-up the time slot
   - Selection of the key parameters according to KPIs
4. Definition of the Reporting period
5. Assessment process: Calculation of the results and energy savings
6. Monitoring and metering requirements

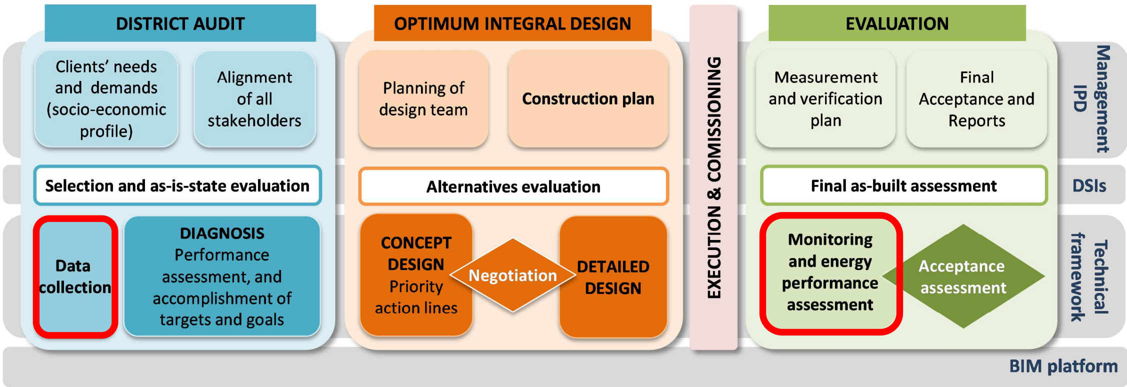

Figure 1: R2CITIES methodology workflow

1.2. Contribution of partners

Table 1: Contribution from partners to D4.5

Participant short name	Contributions
CARTIF	Deliverable leader, development of the main features of the M&V plan, demo information, baseline and reporting period, as well as the Key Performance Indicators and the metering specifications for the Valladolid demonstrator.

1.3. Relation to other activities in the project

Table 2: Relationship with other activities

Deliverable	Relationship
D1.1	Audit of the facilities, energy components and additional information about the Valladolid district. Moreover, overall energy District Sustainability Indicators (DSIs) definition.
D2.2	Definition of the Energy Conservation Measures (ECM(s)) applicable at district level and evaluation method to select and analyse the most appropriate combination of technologies.

D2.12	Common monitoring platform where the key parameters for M&V have to be gathered.
D3.2	Optimum integral design of each demo site selecting the ECM(s) to be applied.
D3.4	Detailed retrofitting project in the Valladolid district.
D4.1	Selection of IPMVP as fundamental protocol for the M&V plan.
D4.2	Definition of the specifications for monitoring and metering systems for the demonstrator.
D4.8	Energy savings evaluation report
D5.1	Valladolid demo activities report.

2. M&V project plan preparation

A well-defined and implemented M&V plan is intended to provide the basis for documenting performance of a system, installation, building or in this case, district, in a transparent manner that can be subject to independent, third party verification. A good M&V plan balances the savings uncertainty associated with energy improvement projects against the cost to execute the plan [5].

Following the description presented in Deliverable 4.1 "Report of the measurement and verification protocol analysis" [1], a complete M&V plan should include discussion of the key topics included in Table 3, as described in Chapter 5 of 2010 IPMVP [3].

Table 3: Recommended M&V plan table of contents

Topic
1. Project Intent
2. Selected IPMVP Option and Measurement Boundary
3. Baseline: Period, Energy and Conditions
4. Reporting period
5. Basis for Adjustment
6. Analysis procedure for calculating results
7. Energy Prices for cost savings calculations
8. Meter Specifications
9. Monitoring Responsibilities
10. Expected Accuracy
11. Budget
12. Report Format
13. Quality Assurance

A full description of these topics for the Valladolid demo site is provided in the following sections.

3. Project Intent

This section explains the retrofitting project to be carried out within the Valladolid demo site. The strategy to be applied at district level covers the reduction of the building energy demand in a 40%, which combined with a contribution of Renewable Energy Sources (RES) in part of the district to cover at least 80% of the remaining demand allows to reduce consumptions from fossil fuels at around a 60% and the related CO_2 emissions at around a 60%, such as it is established in the R2CITIES project objectives (for further details, see Building Energy Specification Table (BEST) in DoW).

Approximately 21,000 square meters of the district "Cuatro de Marzo", in the city of Valladolid have been chosen for implementing several ECM(s): (i) a biomass boiler based district heating solution, as well as (ii) an envelope retrofitting solution (external wall insulation) together with the doubling of the windows, and (iii) ICT solutions.

These interventions have been selected through the application of the R2CITIES methodology, whose aim is to demonstrate an open and easily replicable strategy for the renovation of the neighbourhood, considering the energy point of view as one of the main pillars, with the cost-effectiveness of the interventions as the other one.

3.1. Project description

In order to achieve the aforementioned savings, the "Cuatro de Marzo" neighbourhood (Figure 2), located in the city of Valladolid, has been selected for demonstration purposes. As a result of the District Diagnosis carried out in D1.1 "District Level Audit and Diagnosis Methodology" [6], the main targets and goals for the intervention where identified, serving as basis for the development of the Concept Design of the solutions to be implemented in the district. Considering the objectives of the R2CITIES project in terms of cost effectiveness, energy savings and CO_2 emissions reduction, the evaluation and selection of different scenarios of combined ECM(s) under the methods and tools established in the R2CITIES methodology was carried out in D3.2 "Concept design of each demo site report" [7] to set the requirements that the Detailed Projects will have to meet. Those selected ECM(s) are presented in the present deliverable as the basis for the development of the M&V Plan for Valladolid demo site.

The intervention plan for Valladolid demo-site involves a Public Grant, in which the selected ECM(s) will be considered as minimum requirements to be addressed in the detailed projects that will define the real interventions in the 26 buildings to be renovated (260 dwellings in total). The detailed projects, along with the development of the engineering documents, will be carried out under Task 3.4.

As a result of the aforementioned evaluation (concept design), it was concluded that, to meet the R2CITIES objectives, the intervention should address the reduction of the energy use of 100 dwellings (10 buildings) through the intervention in the envelope, together with the replacement of the current heating system based on individual gas-fired boilers by a district heating system based on biomass. For the remaining 160 dwellings (16 buildings), the intervention is only applied at envelope level to reduce the thermal demand and consumption.

These two level interventions not only allow reaching the requirements related to energy savings, comfort improvement and CO2 emissions reduction, but also ensure the economic affordability of the overall intervention, being the most cost-effective solution to be implemented according to the economic feasibility analysis carried out in D1.2 “Financial Investment Plan Report” [8].

For improving the energy efficiency, the following interventions are planned at two levels:

- External wall insulation based on External Thermal Insulation Composite Systems (ETICS) of 60 mm thickness in all buildings.
- Replacement of the windows in order to reduce the thermal losses with double-glazed windows glass 6/16/6 in all buildings.
- District Heating system based on biomass boiler only in 10 out of the retrofitted buildings (26 buildings).
- ICT implementation of control strategy for the room thermostats and radiator valves, according to certain comfort conditions in all buildings.
- Building Integrated Photovoltaics (BIPV). This measure is optional and only in buildings that so decide, integration of a ventilated photovoltaic façade for electricity generation will be deployed.

Considering these retrofitting strategies, the final district energy use reduction is estimated in a 60%, i.e. 1,824,165 kWh/a[1] in the total area of 21,000 m^2 covered by the retrofitting solutions, in comparison with the as-it-is status. It has to be taken into account that the energy savings are related to thermal energy through the reduction of the thermal losses with the doubling of window glasses and the external wall insulation, decreasing the energy demand, as well as the substitution of the thermal primary energy from the current individual heating system with the central biomass heating one.

In contrast to the thermal energy savings, and out of the scope for the energy savings evaluation, the integration of BIPV is optional, leaving the final decision to the owners because of the parallel business model defined within the project. Although electric consumption is out of scope the ECM(s) that will be implemented in “Cuatro de Marzo” district, these ECM(s) cause interactive effects on the electric energy consumption due to change of the individual heating by a district heating network. In this regard and with aim at characterizing these effects, it will be monitored both the electric consumption of the individual boilers in the dwellings during baseline period and the electric consumption of biomass based district heating during reporting period.

These energy goals have been estimated by means of simulation procedures and the methods and tools defined in the District Audit methodology carried out in D1.1 “District Level Audit and Diagnosis Methodology” [6]. Therefore, for the real evaluation and assessment of the final state, the Measurement and Verification plan, which is based on IPMVP and detailed in this deliverable, covers the definition of the verification procedures. Thus, a first stage of

[1] kWh/a is an equivalent unit to kWh/yr or kWh/y that can be found in different parts of R2CITIES deliverables.

monitoring is related to the definition of the baseline period. After that, the retrofitting strategies are implemented, and their output is measured through the reporting period.

Given the fact that R2CITIES project deals with energy efficient renovations at district level, some adjustments have to be done to address the M&V activities at district level. In this regard, a strategy for aggregating individual results combined with sampling procedures is established to achieve an appropriate and balanced solution in terms of accuracy and cost-effectiveness. Finally, the validation is done by means of a set of indicators (named District Sustainability Indicators in the project framework) defined in the M&V plan which assesses the energy savings achieved in the demo site, as well as the cost savings.

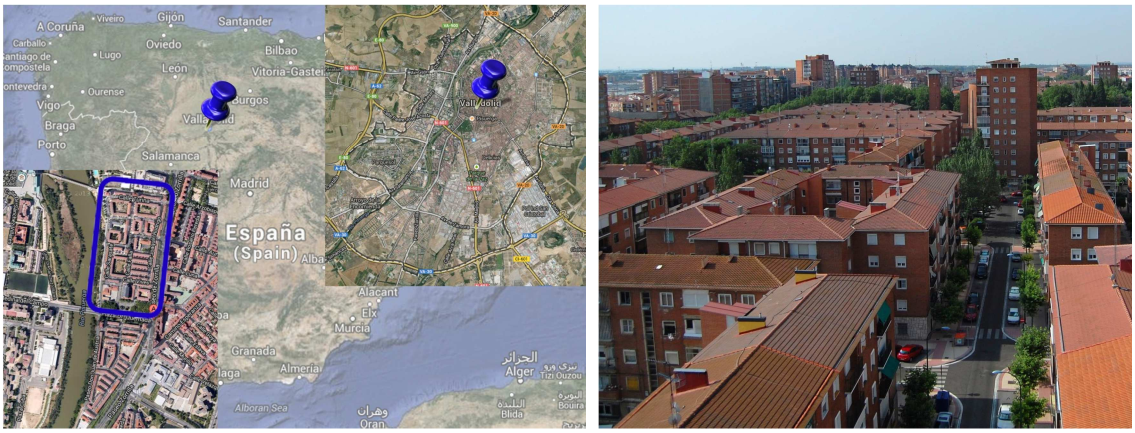

Figure 2: Cuatro de Marzo district location

3.2. Expected project benefits

The expected benefits originated by the above mentioned interventions on the envelope and on the energy systems of the demo site fall under three main categories:

- Energy savings and/or self-production of energy: it is the amount of energy saved (i.e.: not consumed) if compared to the previous scenario and/or the amount of energy produced by means of the innovative/renewable systems installed within the project.
- Costs savings: it is the quantification of the economic benefits directly related to the energy savings/self-production.
- CO_2 savings: it is the environmental benefit originated by the energy savings and/or self-production of energy, and it is estimated through the estimation of the greenhouse gas emissions based on developed emission factors, related to the corresponding energy carriers.

In basis of the data collected and a first simulated analysis, reported in Deliverable 1.1 “District Level Audit and Diagnosis Methodology” [6] for the as-is-state evaluation and in D2.2 “Report on high-value energy products” [9] and WP5 (Demonstration) activities for the evaluation of different alternatives of intervention, an estimation of the energy savings is calculated. First of all, a base scenario was determined as representing the district and for the calculation of the current status. Later on, a set of scenarios were determined. Once evaluated all the scenarios, the final solution is proposed based on the commitment between necessary investment and energy savings.

The final selection of the buildings will be carried out in the following months, once the process of publication and management of the public promotion of the intervention will be completed. Under this public grant, R2CITIES interventions will be promoted by the Municipality of Valladolid (though the Municipal Society for Ground and Housing, VIVA) to all the Communities of owners. Therefore, this approach could be subject to modifications and it will be detailed within the Task 3.4: "Detailed design and development of the engineering documents".

According to the diagnosis carried out in D1.1: "District Level Audit and Diagnosis Methodology" [6], the energy performance of the district was analysed with specific energy simulation software. The tool used was Energy+, which allows to carry out a dynamic analysis of the district and its dwellings, assessing its hourly evolution over a type year. Results provided by these simulations allow to obtain an accurate estimation of the energy consumption of the district (Table 4). Within the table, the information related to the district and the two subtypes of linear blocks is depicted.

Table 4: Energy audit

ENERGY AUDIT RESULTS	**District** "Cuatro de Marzo"	**Subtype 1** Linear block N-S	**Subtype 2** Linear block E-W
[EN3] Net fossil energy consumed (kWh/m^{2}a)	166.11	168.20	162.98

If the energy demand/consumption of the as-it-is status, obtained from the energy audit, is split into each single use, the results for heating and DHW are depicted in the next bullets. This information is useful from the energy savings point of view, because the renovation strategy is centred in the thermal energy with the aim of reducing the consumption for heating and DHW.

- Heating demand: 2,289,630 kWh_{th}/a
- DHW demand: 386,190 kWh_{th}/a
- Heating consumption: 2,828,350 kWh_{th}/a
- DHW consumption: 454,300 kWh_{th}/a

The aforementioned subtypes are represented in Figure 3 through the blocks of buildings which compose them. There, the blocks 02 and 03 illustrate the intervention in terms of District Heating, whereas the remaining blocks are the non-biomass solution.

Figure 3: Scenario definition for the evaluation of expected savings

The selected scenario after the evaluation of the different alternatives of implementation of ECM(s) considers 10 buildings in a patio block in which the centralized biomass district heating network will be installed along with the other aforementioned measures and 16 buildings in linear blocks in which only the envelopment and ICT measures will be implemented. This scenario is thus divided into:

- Block 01 - Linear block (five storey) N-S oriented (blue)
- Block 02 - Linear block (five storey) N-S oriented in patio block (blue)
- Block 03 - Linear block (five storey) E-W oriented in patio block (green)
- Block 04 - Linear block (five storey) E-W oriented (green)

Furthermore, Table 5 shows the expected results for the scenario explained before. Then, the thermal energy consumption for each set of blocks is detailed.

Table 5: Expected results for the solution scenario

EXPECTED RESULTS	**District** "Cuatro de Marzo"	**Subtype 1** Linear block N-S	**Subtype 2** Linear block E-W	**Subtype 1** Linear block N-S	**Subtype 2** Linear block E-W
		envelope + ICT (12,600 m^2)		envelope + ICT + centralized district heating (8,400m^2)	
[EN7] Net fossil energy consumed (kWh/m^2a)	70.54	100.07	107.11	19.50	22.57
Expected energy savings (%)	57.53%	40.54%	36.32%	88.04%	86.16%

- Within the scenario, the proposed solutions imply an increase of the usage of renewable generation sources. In this way, the district heating and the BIPV (optional) could provide the following results.
  - Increase of RES thermal production from 0 kWh_{th}/a to 701,023.64 kWh_{th}/a
  - Increase of RES electricity if, and only if the BIPV is finally installed, production from 0 kWh_e/a to 172,555.06 kWh_e/a

Energy savings calculation implies a reduction of 57.53% of the energy. These savings mentioned before are related to the inclusion of all the solutions in the selected blocks. Last, but not least, for the evaluation of the costs savings and some other DSIs, such as the payback period or return of investment to be addressed in the framework of WP1 activities, in particular in the Task 1.2 and Task 1.3, it is pointed out the investment (see Table 6) of the individual equipment for the retrofitting.

Table 6: Cost for individual actuation

INDIVIDUAL ACTUATIONS	COST PER CONDITINED AREA
ETICs 60mm (dark cladding)	39.63 €/m^2
BIPV + ETICS 60mm rest façade area	47.73 €/m^2
New external window (glass 6/16/6)	30.74 €/m^2
Biomass boiler in the patio blocks (only applicable to patio block buildings)	52.79 €/m^2
Thermostatic valves + programmable thermostats	2.18 €/m^2

3.3. Energy conservation measures

This section describes the energy conservation measures to be carried out in the buildings during the retrofitting process. Two chapters are identified, the passive solutions for façade and the active ones for the energy generation and distribution.

3.3.1. Passive solutions

Façade insulation

The first detailed solution refers the external wall insulation through External Thermal Insulation Composite Systems (ETICS). This is one of the most important energy efficiency strategies into urban spaces because its aim is to minimize the energy demand both in warm and in cold seasons, at the same time the comfort conditions are improved because the thermal losses are reduced. As aforementioned, the existing constructive composition of the demo buildings does not include any thermal insulation, either internal or external.

In this way, the façade solutions are implemented to limit the thermal exchanges between exterior and interior due to outdoor and indoor climate conditions difference. Then, the thermal bridges are reduced, but also the aesthetic of the building is improved resulting in a much better appearance. An example is illustrated in Figure 4. Another important concern about this strategy is the avoidance to the owner to leave the home during the renovation of the façade.

With regard to the technical features of the insulation system, the thickness of the insulation layer is 60 mm, which allows energy saving of buildings, a fixing system that fortifies the connection to the existing wall and a final layer to protect the system against external agents and give the wished aesthetic appearance to the facade. In such regard, the aim is to reduce the heat losses in winter and heat gains in summer by reducing significantly the U-value from 1.25 W/m^{2}K of the as-it-is status of the existing façade to 0.39 W/m^{2}K in the retrofitted one. Last but not least, the material of the insulation system is not decided and it will be detailed in the Task 3.4. However, the constraint that it must apply is the final U-value.

Figure 4: Example of exterior wall insulation

Replacement of windows

The second passive solution is the replacement of the windows of the dwellings. In fact, it is not a real replacement, but doubling the current ones. At the current status, windows are single-glazed systems equipped with aluminium or PCV frame without thermal break, resulting in poor acoustic and thermal insulation that means higher energy requirements. By doubling the glass with a new window of high-performance, the final air leakage, thermal transmittance and solar heat-gain coefficient are improved so as to get better indoor climate conditions (luminescence, temperature,…), as well as reducing thermal losses.

For the implementation of the solution, double-glazed window 6/16/6 with thermal break, two sheets of 6 mm and air chamber of 16 mm thickness has been chosen. This proposal suggests a solution to reduce the U value of the openings, thus the energy loss by conduction through the windows are avoided. On the other hand, it is selected a glass with a high solar factor to allow entry of radiation in winter, benefiting savings in heating demand. Then, the U-value is reduced from 5.7 to 2.8 W/m^2K and solar factor from 0.85 to 0.73.

Through the combination of the wall insulation and the window replacement, the final solution improves the overall thermal performance of the building façade. The energy demand for heating and cooling is, then, reduced whereas the indoor comfort conditions are, at the same time, improved.

3.3.2. Active solutions

Centralized biomass boiler

In the previous subsection the façade solutions have been explained, but those are related to thermal losses avoidance. However, they need to be combined with renewable energy generation solutions. In such way, the centralized biomass boiler is the selected Renewable Energy System (RES). In fact, the region where Valladolid is placed offers a high degree of biomass fuel, resulting in easy availability of this source of energy to feed the biomass boiler. In fact, there exists a potentiality for development of biomass fuel industry that could result in a positive impact on the availability of supply.

At the current status, individual gas boilers are installed into the dwellings, however, a centralized system is more efficient because it ensures operational continuity without frequent start and stop processes. Thus, the solution involves a single biomass boiler, thought to cover the heating demand of a group of dwellings (100) compiled in 10 adjoining buildings. The biomass boiler will provide energy both for heating and for DHW. Thus, the installation will bring the biomass boiler and storage silo in a suitable place and underground distribution system until the buildings. Once the building is reached, the façade will be used for the distribution of the energy to the individual distribution station (in substitution of the current individual gas boiler) inside the dwelling. Nevertheless, the dwelling distribution (radiators, DHW) will not be refurbished, although the ICT control measures will be carried out (see below). These stations will contain an individual meter per dwelling, but the business model for billing depends on the owner's community (individual or common payments).

The biomass boiler is going to cover a heat space of 8400 m^2 with a useful power of 315 kW that means 448 MWh/year. However, this boiler is not capable of covering the total demand due to load peaks, but the 80%. For such purpose, and only the remaining 20% of the demand, a secondary support gas boiler is required with a useful power of 235 kW and 112 MWh/year. To compare with the as-it-is situation, the energy demand is 572 MWh.

<u>(Optional) Ventilated photovoltaic façade (BIPV)</u>

The last intervention at envelope level is the ventilated photovoltaic façade. It is important to start saying this solution is optional because the final decision depends on the owners due to budget limitations. The goal of this innovative solutions is the substitution of the primary energy generation from the current supplier to this renewable source so as to feed the biomass generation and distribution system.

As brief description of the solution, ventilated photovoltaic facades are a promising way to integrate photovoltaic systems into building structure allowing them to produce clean and free energy from the sun without compromising comfort and aesthetics (when combined with other claddings or construction materials). This multifunctional solution does not include only on-site energy generation, but it also provides protection against severe weather conditions, improving the thermal indoor conditions too. For example, in summer, it provides shadow in order to avoid overheating in the interior of the dwelling. Moreover, the ventilated air chamber and the application of insulating material can increase the acoustic absorption and reduce the amount of heat absorbed by buildings. During winter months the ventilated façade acts as a barrier to the internal thermal loads, ensuring well-being inside the building.

As a preliminary proposal, the module selected for the integration is an opaque glass based on amorphous silicon technology with a nominal power of 60 Wp/sqm. The initial dimensions proposed for the PV glass are 1245 x 635 mm and 6.85 mm thickness. However, if the system is finally installed, it would be possible to select other glass dimensions that could fit better with the modulation of the existing façade.

As the final decision has still to be made, in case the proposed system is installed, the BIPV system characteristics will be deeply detailed in further documents.

ICT energy management

Finally, the last retrofitting strategy is the inclusion of ICT measures in combination with the biomass generation and distribution system. Although ICT measures are not directly involved with energy generation, their contribution to improve the energy performance of these systems is proven. Through the ICT measures it is guaranteed a better management of the energy use in the buildings and dwellings, as well as a set of comfort conditions.

Three solutions are related to ICT measures and described as follows:

- Programmable room thermostats will limit the thermal energy consumption by switching the heating system on and off as required to reduce comfort temperatures and prevent rooms from overheating.
- Thermostatic radiator valves (TRV) will allow saving up to 20% (in combination with the previous solution, see results of NETxAutomation[2]) of thermal energy for heating demand. TRV are self-regulating valves fitted to control the room temperature by changing the flow of hot water to the radiator;
- Smart meters give consumers near real time information on energy consumption and the ability to manage their energy use, finding ways to save energy. According to Sapienx[3] studies, smart meters allow saving around 5% of the energy consumption.

[2] NETxAutomation Web site: http://www.netxautomation.com/

[3] Sapienx Web site: http://www.sapienx.es/

4. Demo description

The “Cuatro de Marzo” district is placed on Valladolid, latitude 41° 38’ N and longitude 4° 44’ W. It is a compact residential area of dwellings of medium - poor constructive quality in a progressive ageing, offering a high level of retrofitting possibilities. This district was built on a net area of 209,247 m^2 and usable area of 175,611 m^2. All the blocks were built up following the same constructive systems. Their foundation consists of single and continuous concrete footings, whereas the structural system is formed by load-bearing walls, together with hollow brick slabs. The envelope is made of brick cavity walls without insulation layer and has single glazed metal-framed windows and balconies. Nevertheless, some residents have installed a second window outside the original one and the majority of them have enclosed the balconies too, in order to reduce heat losses. The partition walls are made of a single layer of brick. Finally, the roof system consists of a tiled pitched roof and has no insulation layer.

Considering all the buildings, the total number is of 189 buildings with a total amount of dwellings of 1950. The number of inhabitants affected by the renovation is of 3,750 with a density of population of 26,793 in/km^2. Additional information about the demo site is related to the climatic conditions, being a climatic zone D2 with Heating Degree Days and Cooling Degree Days of 3.121 °C and 394 °C, respectively. With regard to the energy features, the thermal gross area is 166,140 m^2 and the volume 457,230.24 m^3. Figure 5 represents the sectors in which the district is divided. They will be compiled in “group units” to deploy the retrofitting strategies.

At the moment of writing the current deliverable, the process of publication and management of the public promotion of the intervention is not completed, therefore, the “group units” are not decided yet (detailed information will come in Task 3.4). However, they will contain the topologies highlighted in Table 7, whose size is similar, although the number of buildings for each type is different. Moreover, Figure 6 sets an example of the type 1 building and its distribution in the whole district, whereas Figure 7 illustrates the type 2 buildings.

Table 7: Type of buildings

Building types	Number of buildings	Typology	Inhabitants	Net built area (m^2)	Net usable area (m^2)
Type 1	100	Line N-S block building	1923	1,043.40	875.25
Type 2	83	Line E-W block building	1597	1,043.40	875.25

Figure 5: Sectioning of the neighbourhood

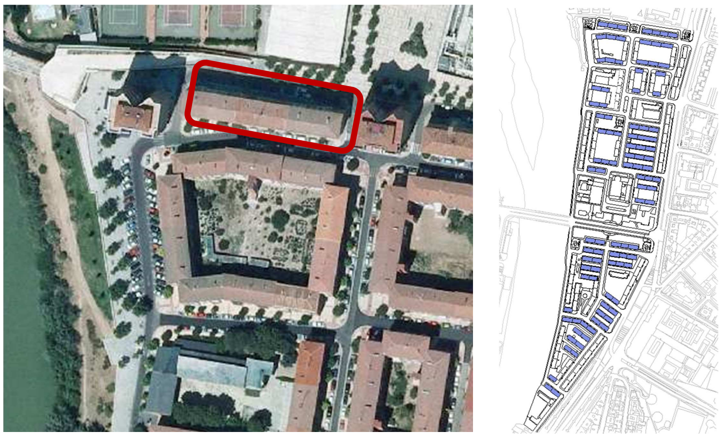

Figure 6: Type 1 buildings

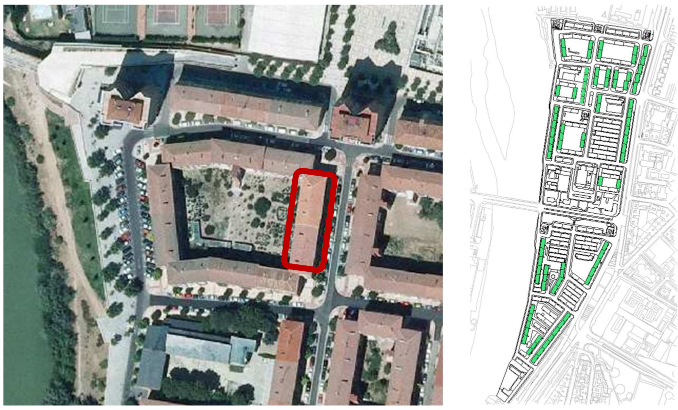

Figure 7: Type 2 buildings

Anyway, the decision of the amount of net area to be refurbished is made. Thus, 100 dwellings will be provided with central biomass boiler and the remaining solutions and 160 dwellings will incorporate the solutions without biomass, which means 10 buildings (10 dwellings per building in both types) with biomass and 16 more without it. For the biomass intervention, it is required, due to economic issues, that all the buildings would be adjacent, setting up a “group unit” to make installation feasible, as for instance the patio blocks. For the second “group unit”, it is a set of individual buildings without taking care about the situation into the district. Then, the total area of the intervention for the biomass solution is 8,400 m^2, while the “non-biomass” solution covers 12,400 m^2, being the total approximated renovated area 21,000 m^2.

With regard to the technical details of the whole district, the following information gives an overview of the indicators for the energy demand of the neighbourhood as they are shown in the Deliverable D1.1 “District level audit and diagnosis methodology” [6]:

- Density of final energy demand (EN1A) – 107.75 kWh/m^{2}a
- Density of final energy consumption (EN1B) – 133.02 kWh/m^{2}a
- Peak load of electricity demand (EN2A) – 8.37 kW
- Load profile of electricity demand (EN2B) – 8.37 kW
- Peak load of thermal (heat and cold) energy demand (EN3A) – 26.43 kW
- Load profile of thermal (heat and cold) energy demand (EN3B) – 10.82 kW
- Degree of accordance with national laws and standards (EN4) – 27.28%

- Degree of congruence of calculated annual final energy demand and monitored consumption (EN5) – 81.00%
- Degree of energetic self-supply (EN6) – 0.00 kWh

Finally, an audit of the current installations along the buildings of the neighbourhood is summarised in the bullets below, where information of the as-it-is status is remarked. Although some of this information is extended in the next chapter, here, it is given an overview of the current situation.

- Exterior walls – No insulation
- Windows – Single glazing
- Balcony – Continuous slab without insulation
- Roof – Flat roof slab and pitched roof without insulation
- Basement ceiling – No insulation
- Ventilation system – No installation, natural ventilation
- Heat source – Individual gas boilers for each apartment (1,950 units)
- Heat distribution – Radiators (12,180 units)
- Cooling – No cooling systems

4.1. Envelope characteristics

The low constructive characteristics of the elements of the envelope are responsible of the high energy demand and low comfort conditions that are present in these buildings. The lack of insulation in the external walls along with the low performance windows provoke the existence of a high level of thermal losses through the walls, increased by the existing thermal bridges and air leakage points. Table 8 describes the different constructive elements in the buildings (note the characteristics are common for all the buildings in the district) with the associated U-value and the materials of its construction.

Table 8: U-value for façade elements

	U-value	Materials
ENVELOPE		
External wall	1.25 W/m^2C	Brick-air-brick-plaster
Roof	2.14 W/m^2C	Tile-wooden strips- long thin brick
Slab	2.63 W/m^2C	Floor tile-reinforced concrete-reinforced concrete-plaster
Internal partition	2.13 W/m^2C	Gypsum-brick-gypsum
WINDOWS		
Frame	2 W/m^2C	--
Glass	5.7 W/m^2C / FS = 0.85	6 mm single glazed aluminium window

4.2. Energy supplies

From the energy perspective, the understating of the demand and consumption of primary energy helps to design the most suitable retrofitting strategy taking into consideration the existing energy sources. To start up, the overall energy demand obtained from simulation is depicted in Table 9. As shown, the main consumption is due to heating, whereas the Domestic Hot Water presents much lower value. The energy for these purposes is provided by the individual gas boilers installed in each building, being the main point of refurbishment so as to reduce the gas consumption through better thermal insulation, as well as district heating system based on biomass. On the other hand, the electricity consumption is due to lighting systems, but it represents a low percentage of the total energy consumption.

ENERGY SIMULATION TOTAL BLOCKS	[Base Case]
HEATING demand	77.09 kWh/m^{2}a
HEATING consumption	87.99 kWh/m^{2}a
LIGHTING consumption	6.80 kWh/m^{2}a
DHW consumption	20.30 kWh/m^{2}a
Gas consumption	108.29 kWh/m^{2}a
Electricity consumption	6.80 kWh/m^{2}a

Table 9: Energy demand/consumption of the district

The energy demand does not include cooling because no intervention is foreseen from the cooling side (the buildings have not installed cooling systems). This delivered energy, as mentioned, comes from individual gas boilers with a total number of 1950 units (with 12,180 terminal units in form of water radiators) along the neighbourhood and electricity company. In the as-it-is status of the district, there is neither biomass nor district heating/cooling nor renewable energy (solar, soil, ground water, external air…).

The domestic gas energy supplier is Gas Natural Fenosa[4] whose fuel is domestic gas-grid-bound whose contracted power is upper than 5,000 kWh/a and lower or equal 50,000 kWh/y and tariff 8.88 €/month + 0.05078 €/kWh + 21% VAT. For the electricity, the supplier is Iberdrola[5] with a contracted power of 4.4 kW and a tariff of 35.65 €/kW/y + 0.147565 €/kWh + 21% VAT.

[4] Gas Natural Fenosa Web site: http://www.gasnaturalfenosa.es/

[5] Iberdrola Web site: http://www.iberdrola.es/

5. Selected IPMVP option and measurement boundary

As mentioned before, the R2CITIES objective is the reduction of the thermal energy demand, as well as the CO_2 emissions through the implementation of Energy Conservation Measures (ECM(s)) at district level. In order to assess the results, a first study about the state of the art in existing methodologies for M&V was carried out in the deliverable D4.1 "Report of the measurement and verification protocol analysis" [1]. As a result, IPMVP (International Performance Measure and Verification Protocol) is selected as reference, although it requires being adapted into the district requirements. Therefore, it cannot be followed "to the dot" without fulfilling all the thoroughness due to the R2CITIES peculiarities.

5.1. IMPVP district considerations

This section depicts the considerations to take into account for the IPMVP as selected protocol for the M&V plan in the case of the Valladolid demo site. IPMVP is limited to the building scenario. However, in the R2CITIES project, the level of study is increased at district level, therefore, IPMVP needs to be extended for applying its premises into districts. In such way, three adaptations are considered and explained in the next sections. It is important to note that in the current deliverable only the proposal is realised, meanwhile the D4.8. "Feedback of the M&V plan implementation and proposed improvements" will report the results in the evaluation of the M&V plan and its adjustments according to the district specifications.

5.1.1. Data mining techniques

First of all, due to the widening and the complexity for the measurements and simulation possibilities into a district, some data mining techniques are considered in order to estimate the data-point at a whole. Thus, no one option from IPMVP is suitable in these cases, being necessary the modification of any so as to apply with the district requirements. Then, for achieving a complete view of the performance of the district, the following data mining techniques are used.

- "Sampling": It is a common technique within statistics, quality assurance and survey methodology and it is based on the selection of a subset of samples within a "population" (in statistical terms). In this case, the population is the total amount of dwellings, whereas the subset is a representative number of monitored residences. This, through statistic methods, the characteristics of the whole set can be estimated. In the section 5.4, the technique is explained with more detail and how it is applied within the M&V plan for Valladolid.
- "Clustering": It is a technique within the Artificial Intelligence field which determines automatically clusters of elements with similarities among them. Thus, the dwellings of whole district could be grouped into clusters taking into consideration their type, features and so on. This technique is described in the following sections, as well as its appliance within R2CITIES.

The combination of both data mining techniques provides information of the energy performance of the whole district by means of representative measurements. For that reason, it is critical the selection of the representative dwelling for sampling according to the cluster of buildings.

5.1.2. Performance indicators

Secondly, districts can be considered as a system of complex interconnections, interactions, relationships and flows. Therefore, a comprehensive approach is essential for effective assessment with regard to global performance. Nevertheless, IPMVP defines the Key Performance Indicators to evaluate the energy performance. Yet, these indicators are described according to the building approach, meanwhile R2CITIES goes a step forward considering the district as a whole and, thus, specifying the District Sustainability Indicators, as stated in the D2.2: "Report on high-value energy products" [9]. Thus, these new "concept" for indicators considers group of buildings and their interactions with the urban infrastructures as a unique energy unit. In that way, the measurement boundary has to be defined in order to cover the buildings that demand and use energy from generation and distribution systems, providing a common framework for the entire demo.

Moreover, according to the D2.2 "Report on high-value energy products" [9], this new specification requires a methodology for district retrofitting, such as illustrated in Figure 8. There, there are multiple levels of definition following logical steps. Each indicator should be identified at each specific stage, starting from the diagnosis at district level to the final energy savings, economic and social assessment stage.

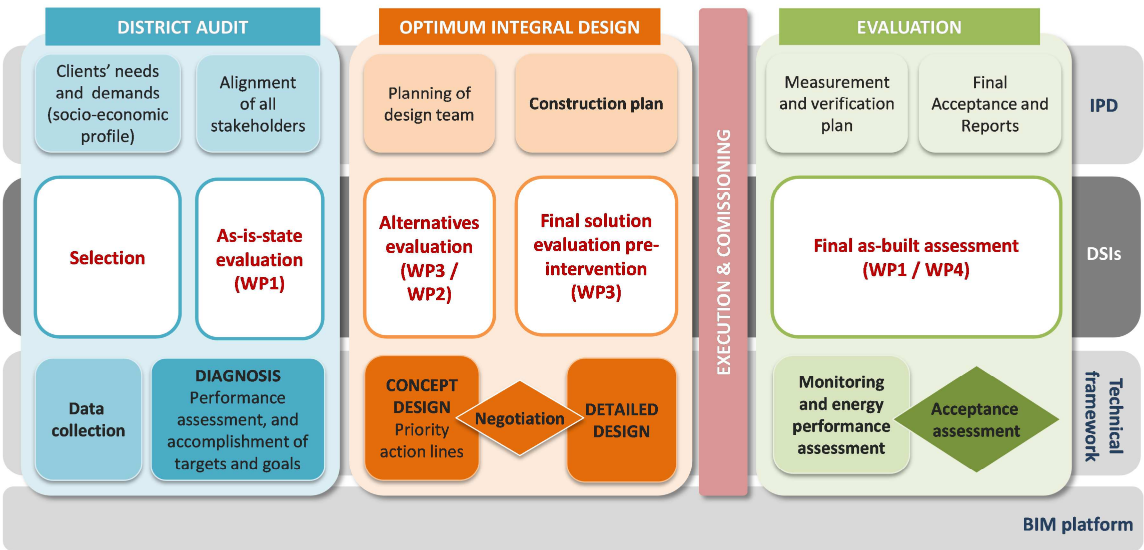

Figure 8: R2CITIES methodology for District Retrofitting

Next sections will detail the DSIs, as well as the measurement boundaries to be applied within the R2CITIES project at district level.

5.1.3. CONCERTO extension

The CONCERTO [4] is a Europe wide initiative proactively addressing the challenges of creating a more sustainable future for Europe's energy needs. As result of CONCERTO Premium, an Indicator Guide was produced where a complete set of economic, technical and environmental indicators was defined. This guide is followed as reference within R2CITIES for the definition of the performance indicators. However, CONCERTO is limited to buildings, being necessary the adaptation into districts through the aforementioned District Sustainable Indicators.

Furthermore, CONCERTO establishes the monitoring guidelines as recommendations for energy efficiency project. In this way, CONCERTO specifies the minimum requirements that allow the energy analysis, mainly centered into the delivered and consumed energy, as well as the energy sources and the uses. For such purpose, R2CITIES takes these guidelines as basis of metering, taking into consideration building monitoring is a manageable process, but the whole district is not affordable. Thus, the data mining techniques detailed before bridge the gap between buildings, districts and CONCERTO guidelines in a cost-effective manner.

5.2. Measurement boundary

Savings may be determined for an entire facility or simply for a percentage of it, depending upon the purposes of the reporting.

- If the purpose of reporting is to help the management of the equipment affected by the energy savings strategy, a measurement boundary should be drawn around that involved equipment. Then, all significant energy requirements of the equipment within the boundary can be determined. This approach is used in the Retrofit Isolation Options A or B.
- If the purpose of reporting is to help the management of the total facility energy performance, the meters measuring the energy source provided to the whole facility can be used to assess performance and savings. The measurement boundary, in this case, encompasses the Whole Facility Option C.
- If baseline or reporting period data are unreliable or unavailable, energy data from calibrated energy performance simulation software can play the role of the missing data of the data-points in the whole facility. The measurement boundary can be depicted accordingly, bringing the Calibrated Simulation Option D.

Some of the energy requirements of the systems or equipment being assessed may arise outside a practical measurement boundary. Nevertheless, all energy effects of the ECM(s) should be considered. Those energy effects that are significant should be determined from measurements, whereas the remaining are estimated or ignored.

Any energy effect that occurs beyond the notional measurement boundary is named interactive effect. It is important to find a way out to estimate the magnitude of these interactive effects in order to determine savings. Alternatively, they may be ignored as long as the M&V Plan includes justification of each effect and its likely magnitude.

In the case of Valladolid demo site, it is determined the measurement boundary given by the total thermal energy consumption at district level, whose calculation is realized by means of individual consumption of the dwelling gas consumption. Thus, the ECM(s) will only affect the thermal consumption, meanwhile electricity consumption is out of the scope of the M&V plan, although considered as crossed effects within the M&V plan.

As in the Valladolid demo site, the total number of retrofitting solutions is 260 dwelling from which, 100 will have a district heating system based on biomass, ICT measures and façade ECM(s) and the rest 160 dwelling will only integrate the façade solutions and ICT measures. The assessment boundary is represented by the blocks with the thermal consumption involved.

As observed in Figure 9, which follows the UNE regulations in boundary representation [10], assessment boundary for the baseline period of measurement points are both individual gas meter and the electric consumption by individual boiler. These measurements are carried out in the representative dwelling for the sampling and clustering techniques. Finally, it is important to note the other electric consumptions are out of scope

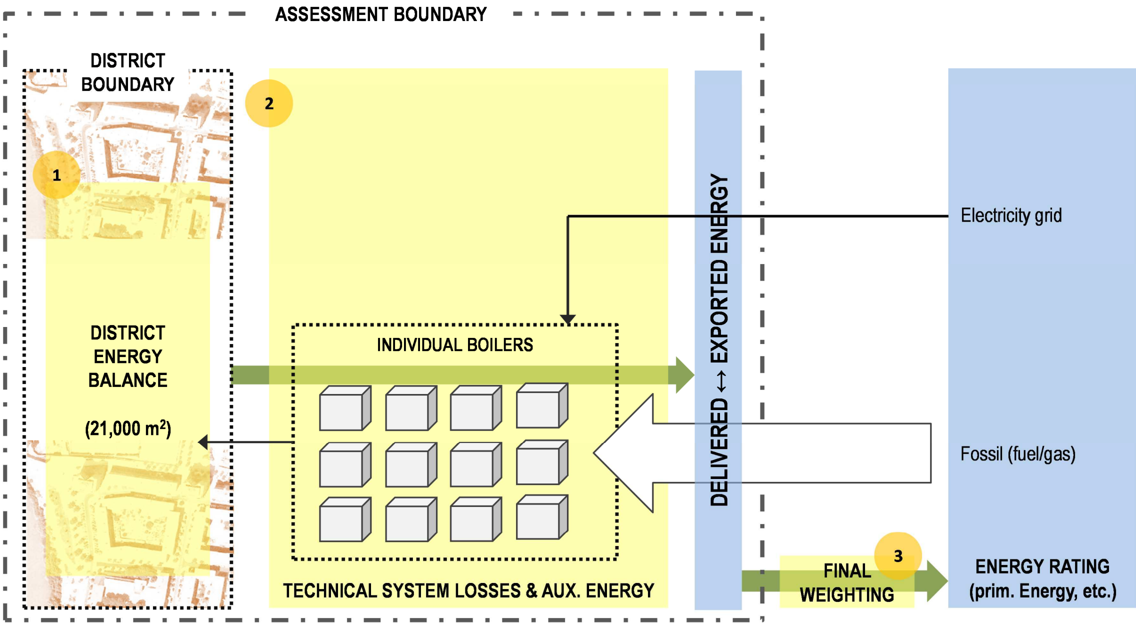

Figure 9: Valladolid assessment boundary for baseline

On the other hand, as observed in Figure 10, assessment boundary for reporting period is the same that baseline period although there are new measure points that are DHW and heating from district heating. Besides that, if the PV energy production would be installed the, measured PV energy would be the other boundary point. However, in the current case, the electricity consumption for feeding both the District Heating and the individual systems are metered so as to determine the interactive effects.

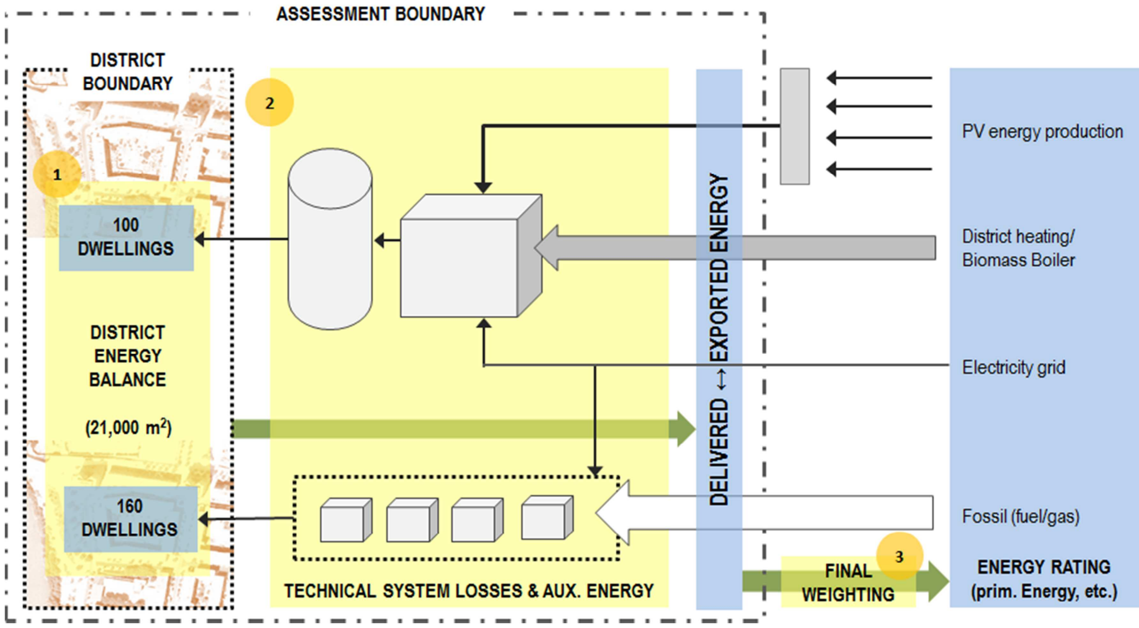

Figure 10: Valladolid assessment boundary for reporting

5.3. Valladolid M&V Option

So as to select the suitable option for the M&V plan, IMPVP suggests some open points to be answered before, as illustrated in Figure 11. Red line is the path followed during the decision process in order to take the option most appropriate for the application of IPMVP to the "Cuatro de Marzo" district. The selected option is C, but with some modifications to address the district level of the M&V Plan.

The explanation of the reasons for defining the selected option is as follows:

- The aim is the measurement of the final energy performance in the whole retrofitted area and not the individual ECM(s).
- The energy savings due to the façade renovation and windows substitution are around 40% in comparison with the current status, above the 10% specified by IPMVP.
- There is no evaluation scenario for the assessment of the individual implemented ECM(s) in the Valladolid neighborhood, but the global energy savings at district level.
- The main challenge for the implementation of IPMVP in R2CITIES is the lack of energy consumption data for the whole district because, in the as-it-is status, the heating is individualized and not all the homeowners have available the gas bills during the last year. As well, the refurbishment involves 260 dwellings. However, through the data mining techniques, the remaining consumptions can be obtained.
- According to IPMVP, if the option C is selected, the whole district energy consumption during both baseline and reporting period has to be measured. However, the monitoring of 260 dwellings (approximately 21,000 m^2) is too difficult and expensive, and a cost-effective approach should be considered. Thus, in R2CITIES project this option should be modified.

- For the Measurement and Verification R2CITIES plan, some dwellings will be selected by considering exhaustive statistical analysis and applying different sampling and aggregation techniques that allows characterizing the energy savings of whole district from sample dwellings.

Once the open-points for the selection of the IMPVP option (bullets before) are solved and observing the red-line path, the option C is the most adequate for the M&V plan to be applied in the Cuatro de Marzo district.

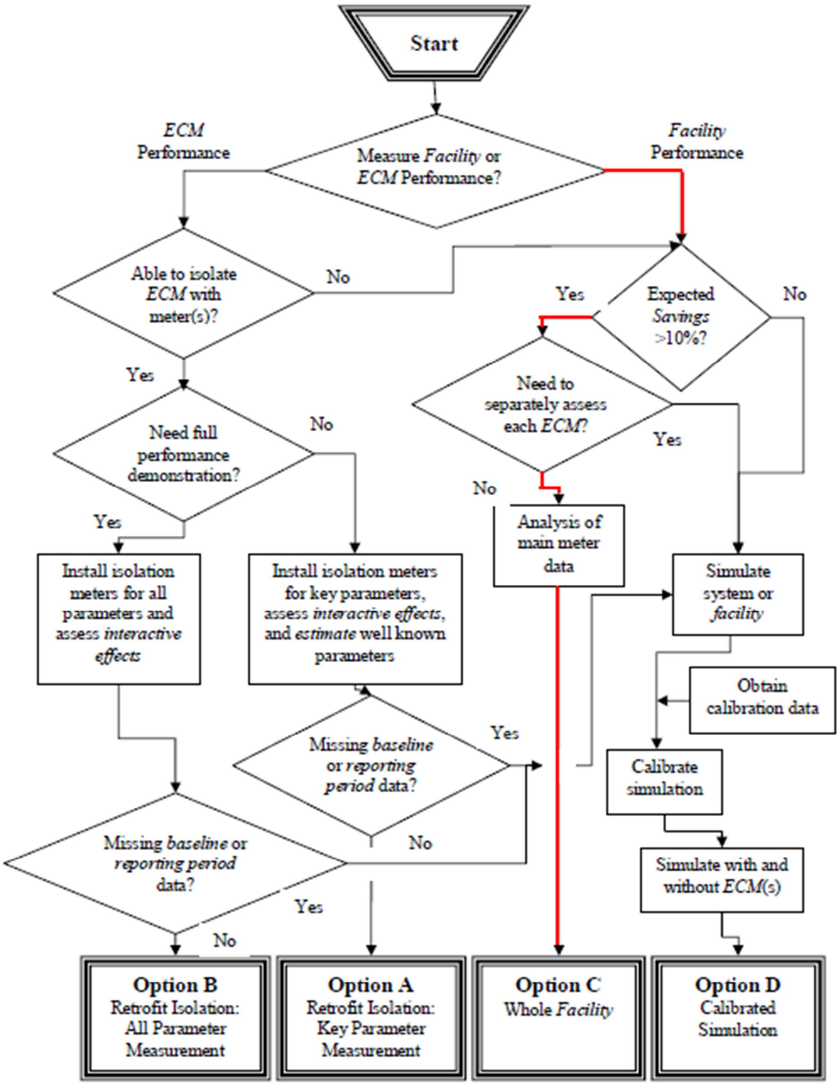

Figure 11: Option selection under IPMVP

5.4. Selection of Representative dwellings

Energy renovation programs at district level require careful evaluation of the representative dwellings that will take part in the model validation procedure because of the high costs to implement the ECM(s) and to monitor the operating variables to assess the expected reductions on energy use in the post-retrofit case.

In this regard, all Measurement and Verification protocols, such as IPMVP, are focused on building level and recommend measuring all dwellings affected by an intervention. In R2CITIES, in the case of "Cuatro de Marzo" district, a rough estimation of the cost of deployment of the necessary metering and monitoring equipment, estimated at around 2,000 € per dwelling, will lead to an unaffordable cost for monitoring the whole district to be retrofitted. For the total of 260 dwellings, the cost is around 520,000 €[6].

Following these premises, some adjustments have to be done to IPMVP protocol (as explained in D4.1: "Report on the Measurement and Verification analysis" [1]) to address the M&V plan at district level, in order to meet the objectives regarding the cost-effectiveness of the monitoring programme without compromising the quality and accuracy of the measurements. As it will be explained later on in this section, the existence of similar typologies of the buildings and dwellings allows the definition of an appropriate procedure to apply sampling techniques to reduce this cost and therefore, make the intervention feasible.

In particular, a sampling approach together with a strategy for aggregating individual results in order to use these data to assess the district model under the option C has been defined.

Sampling involves conducting measurements on a subset of a population to estimate the characteristics of the entire population. In the present M&V context, this is based on the sampling of a subset of dwellings within a larger population, with the aim to develop a trend or energy model from the collected data.

A typical sampling process involves:

- Defining a population
- Defining a sample size
- Defining the sampling approach
- Collecting and analysing sample data

In the case of Valladolid demo site, the **population** is defined as the total number of dwellings occupying the total area of 21,000 m^2 that will be covered by the intervention under the framework of R2CITIES project, i.e. **260 dwellings**.

Regarding the definition of the **sample size**, as explained above, some considerations related to the characteristics of the district should be taken into account. As it is presented in the Deliverable D1.1 "District Level Audit and Diagnosis Methodology" [6], the "Cuatro de Marzo" district is a homogeneous residential area consisting of medium constructive quality buildings in a progressive ageing. The district has only two main different typologies of buildings: linear blocks (organised around courtyards or lined up to the streets) and towers. In addition to the building typology, the orientation is crucial to study the energy performance of different building subtypes. For both typologies, linear block and tower, North-South and East-West orientations have been considered. In this way, four building subtypes have been defined for Valladolid demo site.

[6] This amount could be reduced due to economies of scale. But somehow, the final result is unaffordable following a cost-effective approach at district level.

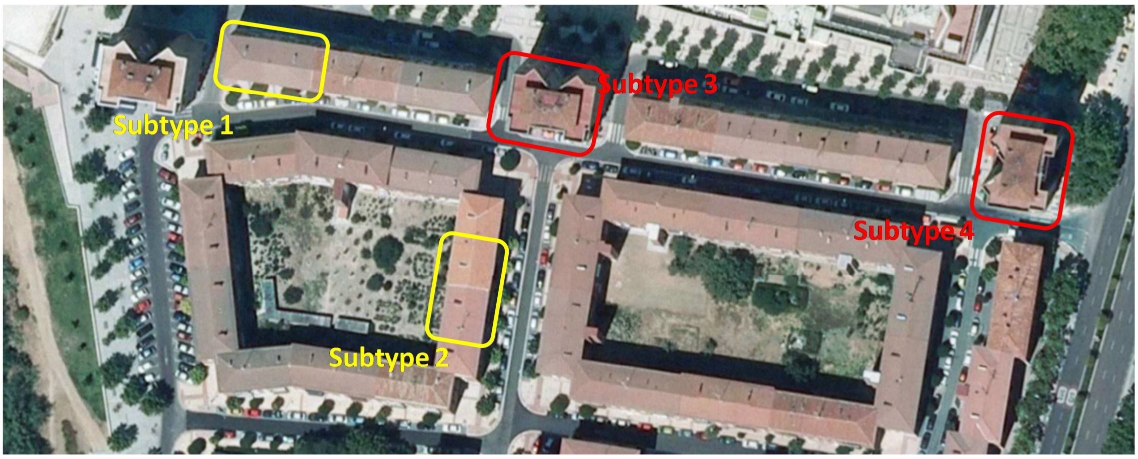

Figure 12: Cuatro de Marzo different building subtypes

Considering the typological and constructive homogeneity of the district, this not only allows developing systemic and integrated solutions, being easily replicable along the whole district, but also allows defining a **small sample size** for the appropriate description of the population in terms of coverage and accuracy. In addition, this approach meets the cost-effectiveness objective with regard to the monitoring needs, ensuring a good precision and confidence level.

Sampling approaches can be classified in three main types:

- Random samples: each element of the population has a certain chance to be selected as a part of the sample.
- Non-random samples: various types of non-random samples exist, based on judgment, purposive or snowball selection or chain sampling; often there are subjective choices within the selection procedures. This sampling strategy typically does not generate representative results.
- “Cluster sampling”: is a grouping strategy. The main objective is grouping the population, in this case dwellings, in such a way that dwellings in the same group (called a cluster) are more similar (in some sense or another by using a specific mathematical measure based on a particular statistical distribution, called distance) to each other than to those in the other groups (clusters). This type of sampling approach comes from data mining and is a common technique for statistical data analysis.

In accordance to the necessary accuracy of the assessment methods and the need to assure the cost-effectiveness of the intervention, the specific sampling approach will be defined and implemented in WP5. Given the characteristics of the retrofitting intervention in the Valladolid demo site and taking into consideration that dwellings can be characterized by different features (orientation, location, size, occupied/not, etc.) a clustering procedure can be applied to identify an appropriate number of representatives of the whole district, following a mathematical approach. The **collection and analysing of sample data** are addressed in the following sections.

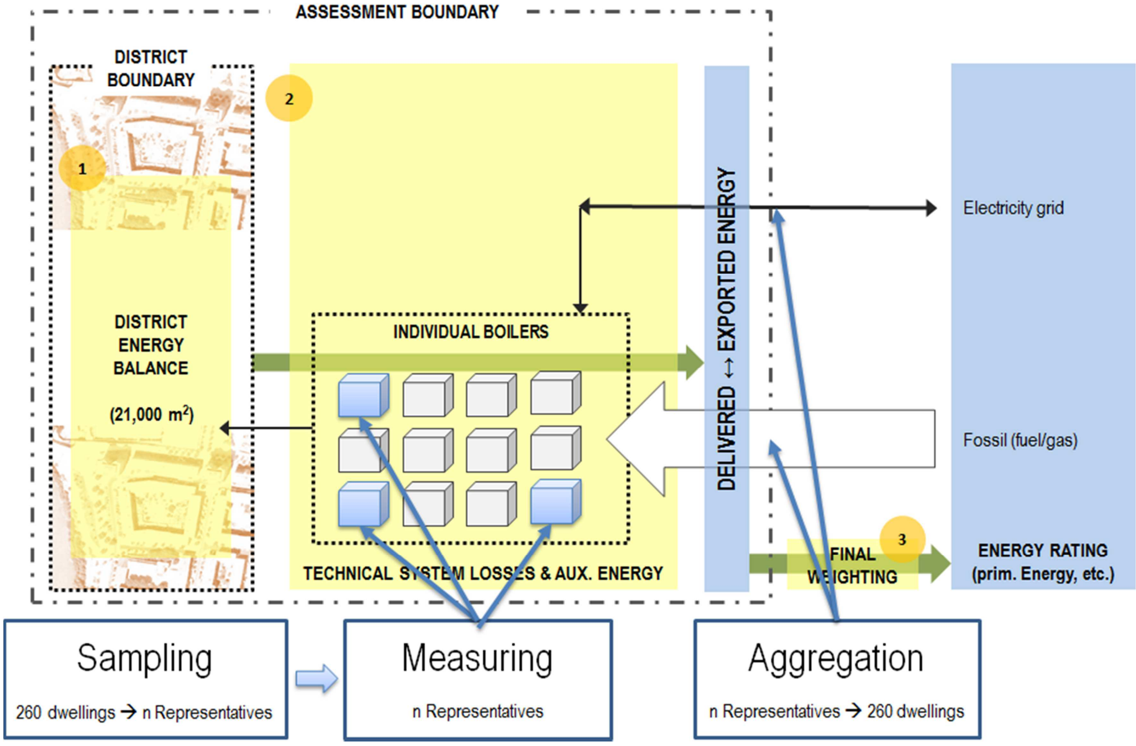

Figure 13: Sampling procedures in baseline definition

As a final summary, in Figure 13, it can be identified the procedure of Sampling – Aggregation needed to assess the district level in R2CITIES project M&V plan in Valladolid demo site, for the baseline definition stage. In this stage, from a population of 260 dwellings, *n* representatives must be selected. Direct measures (electricity and fuel) will be taken from those *n* representative dwellings. To build the baseline, an aggregation approach will be followed (weighted sum).

On the contrary, as it can be seen in Figure 14, the procedure to build the necessary data to generate the post-retrofit energy performance model requires a different strategy. R2CITIES interventions in Valladolid are twofold: the first option consists on façade retrofitting combined with the creation of a new district heating (100 dwellings) and the implementation of BIPV as optional ECM; and the second one consists only on retrofitting a set of dwellings. In the first approach, direct measures from both the PV and the district heating systems will be gathered. For the remaining 160 dwellings, the initial strategy will be maintained, being necessary to build the reporting data through aggregation techniques based on the remaining n_1 representatives of the original 160 dwellings.

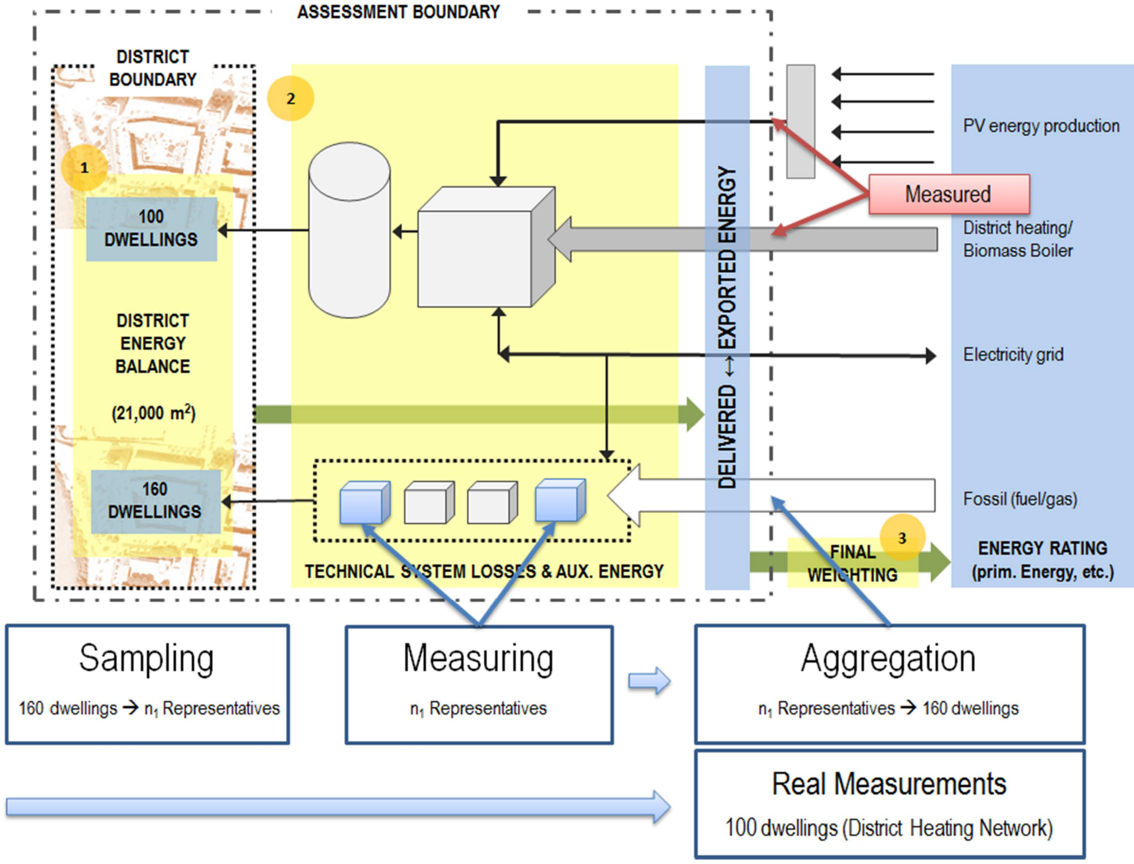

Figure 14: Post-Retrofit reporting period

5.5. Valladolid Energy District Sustainability Indicators

As it was explained in deliverable D1.1 "District Level Audit and Diagnosis Methodology" [6], which details the proposed methodology for energy efficient district renovation, each Technical Indicator, named District Sustainability Indicators (DSI), should be identified at each specific stage, starting from the Energy audit (Deliverable D1.1) at district level to the final energy saving assessment stage given by the M&V plans (Deliverable D4.5, D4.6 and D4.7).

Thus, the selected technical indicators to be calculated at this stage have been taken from CONCERTO Premium guidelines [4]. The description of key performance indicators that in energy assessment and energy savings at district level are defined as Energy District Sustainability Indicators is:

1. **(Final) energy demand and consumption (ENV1 – FEN)**

The final energy demand/consumption of a building corresponds to the energy entering the building (e.g. energy content of light oil, electricity, district heat) in order to be used in different areas of application (space heating, space cooling, domestic water heating, electrical appliances). The energy demand is based on the calculated figures whereas the energy consumption is based on metered figures. To enable the comparability between buildings, the total energy demand is related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered time interval (e.g. year).

This indicator can be used in order to assess the energy efficiency of a building, i.e. the thermal quality of the building envelope, the efficiency of the heating system, the cooling system, the electrical appliances etc.

Unit: $kWh/(m^2\, a)$

$$EN_{i,t} = \frac{\sum_{EC}\sum_{AA=AA1}^{AA4} In_{EC,AA,i,t}}{Cap_i}$$

where

$EN_{i,t}$	Final energy demand/consumption of the sample building i based on annual data of year t $[kWh/(m^2\ a)]$
$In_{EC,AA,i,t}$	Input (>0) energy flow into the sample building i for application area in year t regarding energy carrier (or source) $[kWh/a]$
Cap_i	Floor area of the sample building i $[m^2]$

During the baseline period, the indicator will be obtained from the monitoring systems installed in every single representative dwelling chosen for monitoring. Moreover, the measured data will be used for the model calibration, more precisely, the final energy for heating and DHW. On the other hand, while reporting period, this indicator will be calculated in the centralized biomass generation system and in the meters installed in the individual boilers in those that will not be changed by a centralized system.

2. **Primary energy consumption (ENV2 – FEN)**

$$PEN_{I,t} = \frac{\sum_{i\in I} PEN_{i,t} * Cap_i}{\sum_{i\in I} Cap_i}$$

where:

$PEN_{I,t}$	Primary energy consumption set I of buildings based on annual data of year t [kWh/(m^{2}a)]
$PEN_{i,t}$	Primary energy consumption of building i based on annual data of year t [kWh/(m^{2}a)]
Cap_i	Floor area of building i [m^2]

Where $PEN_{i,t}$ is calculated as:

$$PEN_{i,t} = \sum_{EC}\sum_{AA=AA1}^{AA4} \frac{\left(\left(In_{EC,AA,i,t} * PEF_{EC}\right) + Cap_i * \frac{PEF_{[i]}}{EL_{[i]}}\right)}{Cap_i}$$

where:

$PEN_{i,t}$	Primary energy consumption of building i based on annual data of year t [kWh/m^{2}a]
$In_{EC,AA,i,t}$	input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]
$PEF_{[i]}$	Primary energy factor for a building of the same type as i [kWh/m^2]
Cap_i	Floor area of building i [m^2]
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]

3. Net fossil energy consumed (EN7 – NFEC)

The net fossil energy consumed (NFEC) expresses the reduction of the energy generated by fossil fuels to be achieved within the project, because it measures the energy delivered to the district by means of fossil sources prorated by the percentage of renewable energy sources. Therefore, the difference between baseline and reporting period will give the value for the reduction of using these generation systems.

$$NFEC = \sum_i E_{delivered,i} * (1 - \psi_i)$$

where:

$E_{delivered,i}$	Final energy delivered for each individual energy source [kWh/m^{2}a]
ψ_i	Percentage of the energy coming from renewable sources for each energy source

5.6. Interactive effects

IPMVP defines the interactive effects as energy effects generated by an ECM, but it does not consider the measurements within the boundary. Thus, in the case of the Valladolid demo site, the electricity savings are out of the scope, although the ECM to be implemented could cause electricity savings due to the possibility of including a BIPV solution, as well as the modification of electricity consumption in the buildings.

In the first case, the inclusion of the BIPV solution offers the generation of electricity from a renewable system, instead of using the current system. Therefore, the interactive effect, in this case, would be the decrease of usage of fossil fuel for the electricity generation. Then, if integrated, the energy generated by the PV should be metered.

Secondly, if not BIPV is included, the interactive effect comes from the substitution of the individual gas boilers, with their circulation pump. In the refurbished scenario, the biomass boiler uses its own circulation pump, but also the individual distribution stations at dwelling level presents a circulation pump. Thus, the balance of the electricity consumption is evaluated through the baseline and reporting period as interactive effect of the biomass solution.

5.7. Additionality

Regarding the additionally, it is important to take into account that one of ECM(s) planned in Valladolid demo case is the implementation of BIPV (Building Integration Photovoltaic). At the current moment of the project, this ECM is not decided and its installation depends on the owners. If finally this installation is made, it will be necessary to update the M&V plan because its implementation influences in the electricity consumption savings.

6. Valladolid baseline definition: period, energy and conditions

This section describes each contributor to the energy consumption that characterizes the baseline and the subsequent model calibration, measurement period, data collection, independent variables definition, static factors and description of the ECM(s) to be implemented at district level, as well as the equipment inventory.

6.1. Baseline period

The baseline period should be established to:

- Represent all operating modes of the facility. This period should span a full operating cycle from maximum energy use to minimum.
- Fairly represent all operating conditions of a normal operating cycle. For example, though a year may be chosen as the baseline period, if data is missing during the selected year for one month, comparable data for the same month in a different year should be used to ensure the baseline record does not under represent operating conditions of the missing month.
- Include only time periods for which all fixed and variable energy-governing facts are known about the facility. Extension of baseline periods backwards in time to include multiple cycles of operation requires equal knowledge of all energy-governing factors throughout the longer baseline period in order to properly derive routine and non-routine adjustments (see Section 8.1) after ECM installation.
- Coincide with the period immediately before commitment to undertake the retrofit. Periods further back in time would not reflect the existing conditions before retrofit and may therefore not provide a proper baseline for measuring the effect of just the ECM. ECM planning may require study of a longer time period than the one is chosen for the baseline period. Longer study periods assist the planner in understanding facility performance and determining what the normal cycle length actually is.

As defined before, the baseline period will be generated by means of data mining techniques, sampling and clustering. Then, a set of representative dwellings (initially estimated in 4, but it will be detailed in Task 3.4) is ideally chosen during the heating period of 2014 – 2015 (October 2014 – March 2015) as representation of the working period of the selected ECM(s).

According to the DSIs and boundaries, the main variables to be monitored in each one of the individual dwellings are:

- DHW consumption
- Heating consumption
- Gas consumption from bills
- Individual gas boilers electricity consumption

6.1.1. Static factors

Table 10 presents the main characteristics of the static factors in Valladolid demo which influence the overall energy use within the boundaries of district. For getting the values, it has been considered the same number of buildings of type 1 and type 2 in the retrofitting strategy (13 of each type within the 26 total buildings). As aforementioned, both types represent the same useful area per single building, being each storey 176.25 m^2 of useful area with the 96.23% of conditioned area (thermal area), apart from the basement with a useful area 170.25 m^2 and the respective 92.57% conditioned. Moreover, the occupancy is taken as an average of 4 people per dwelling, which means 40 people per building. Last, the conditioned area expressed in the BEST tables is divided into heated and cooled area.

Table 10: Static factors for Valladolid

Type of Building	Useful area [m^2]	Heated area [m^2]	Cooled area [m^2]	Occupancy [people]
Type 1	11,378.25	10,868	0	520
Type 2	11,378.25	10,868	0	520

6.1.1.1. Occupancy

The occupancy profile (See Table 11) in Valladolid was obtained from energy audit done in Work Package 1 (D1.1: “District level audit and diagnosis methodology” [6]) and it was used in the simulation model.

Table 11: Occupancy profile

<table>
<tr><th>Occupancy</th><th>Diary</th><th>Weekend</th></tr>
<tr><td>8:00 – 15:00</td><td>33% existing occupancy</td><td rowspan="3">100% existing occupancy</td></tr>
<tr><td>15:00 – 20:00</td><td>50% occupancy</td></tr>
<tr><td>20:00 – 8:00</td><td>100% existing occupancy</td></tr>
</table>

It is important to note the assumption of similar occupancy in all the dwellings and buildings is done. Thus, this occupancy pattern is similar in the district during both baseline and reporting period. It is observed that in the central hours of the day, the half of the people take the homes up, with the exception of the weekends. The proposed profile indicates an approach about the heating requirements and it does not take into account empty dwellings because the heating premises have to be established in order to maintain certain indoor comfort conditions.

Furthermore, the occupancy is obtained from inhabitants census in combination with owners surveys (D1.1 “District level audit and diagnosis methodology” [6]) about the presence in the dwelling according to the day time, being a very difficult variable to be measured and necessary to establish the assumptions mentioned before. Moreover, an accurate monitoring of the variable is complicated to achieve during baseline and reporting periods. Besides that, the occupancy does not affect to the thermal consumption in a high percentage due to the internal loads, represented by each person. Furthermore, the presence could affect to the thermostatic valves (their set-point modification), but the individual and global consumption is going to be measured. Thus, the occupancy can be considered as constant for both periods. Then, the Heating Degree Days (HDD) will be taken into consideration as the independent variables to analyse the energy consumption.

6.1.1.2. Equipment

An energetic audit has been realized in the WP1 "Diagnosis and indicators of performance", so as to obtain the information about the facilities of the dwelling from each demo site. In fact, the constructive characteristics, energy equipment and other information have been described in the D1.1 "District level Audit and Diagnosis Methodology" [6]. Then, the present deliverable presents a summary of such facilities concerning the M&V plan. For more information, see D1.1 "District level Audit and Diagnosis Methodology" [6].

6.2. Independent variables and the basis for adjustments

Regularly changing parameters that affect facility's energy use are called independent variables. As it is stated in the IPMVP, common independent variables in buildings are weather and occupancy. Weather has many dimensions, but for whole-facility analysis, weather is often just outdoor dry-bulb temperature. Occupancy is defined in many ways, such as hotel room occupancy, office-building occupancy hours, occupied days (weekdays/weekends), or restaurant-meal sales. However, in the case of the Valladolid demo site, a residential district, the occupancy is taken following the approach considered for the evaluation process.

Mathematical modelling can assess independent variables if they are cyclical. Regression analysis and other forms of mathematical modelling can determine the number of independent variables to consider in the baseline data. Independent variables should be measured and recorded at the same time as the energy data.

To sum up, for the "Cuatro de Marzo" district, the degree days, defined in the next section, are considered as independent variable for the necessary adjustments between baseline and reporting period data. The occupancy is not considered as it is assumed as constant during the baseline and reporting period, whose effect is the same in both periods. Besides that, the internal loads presented by the occupancy do not represent great variations in the thermal consumption. Therefore, the occupancy can be neglected in the evaluation process.

6.2.1. Degree Days

Climatic changes or weather conditions are one of the key reasons of variability in energy use of a building or at a higher level, a district. In this way, the weather conditions are considered within the independent variables.

When analysing European countries, different applications of the methodology are found, and with different threshold and even set temperatures, which hampers a unified calculation. In

1996, the European Commission asked for an assessment of climatic correction methods applied in various member states. Eurostat [11] presented the findings to the Energy Statistics Committee and the Member States in principle approved a common method for heating-temperature correction. The method is described in “Panorama of Energy” [12]. It employs the first described formula and defines 15°C as the heating threshold temperature and 18°C as the heating set temperature. The average daily temperature is defined as the arithmetic mean of the minimum and maximum air temperature of that specific day.

Concerning correction of heating energy consumption within R2CITIES, and in line with CONCERTO Premium [4] and stated in the D4.1: “Report on the Measurement and Verification analysis” [1], this definition is adopted:

$$HDD_{18/15} = \sum_{1}^{z}(18°\mathrm{C} - t_a)\,;\ \ with\ \ t_a = \frac{t_{min} + t_{max}}{2}$$

where

HDD_{18}	heating degree days for a time period with z days when ambient air temperature under the heating set temperature (18ºC)
z	number of heating days in the time period
t_a	daily average ambient air temperature

If the daily average temperature exceeds the reference base temperature, t_{ht}, the heating degree-day measure is set equal to zero since there is no heating requirements expected on this day.

7. Reporting period

According to the recommendations of the IPMVP, the reporting period should encompass at least one normal operating cycle of the equipment or facility, in order to fully characterize the savings effectiveness in all normal operating modes. The length of any reporting period should be determined with due consideration of the life of the ECM and the likelihood of degradation of originally achieved savings over time.

After the installation of the ECM(s), the passive solutions for façade and the active ones for the energy generation and distribution, **12 months (from January 2016 to January 2017)** of actual building energy use data and coinciding actual independent variable data will be collected to verify the performance and assess the energy savings and costs. This period does not include the installation of the required meters and the activities during reporting period can be divided among monitoring/measurement. Thus, the winter period, where the ECM(s) are operational, is measured for the energy savings assessment in comparison with the baseline. Considering IPMVP, this represents the reporting period measured energy. The difference between the actual measured energy use in this reporting period and the calculated adjusted baseline energy, only now re-calculated using the actual independent variables measured each month in the “reporting period,” represents the energy savings (or “avoided energy use”).

If the frequency of savings measurement after initial proof of performance is reduced, other on-site monitoring activities could be intensified to ensure savings remain in place. IPMVP-adherent savings can only be reported for the reporting period that uses IPMVP adherent procedures. If IPMVP-adherent savings are used as a basis for assuming future savings, future savings reports do not adhere to IPMVP.

8. Basis for Adjustment

The objective of M&V is to reliably determine energy savings. Nevertheless, within the reliability, the energy saving reports contains a reasonable level of uncertainty. This uncertainty of a savings report can be managed by controlling random errors and data bias. Random errors are affected by the quality of the measurement equipment, the measurement techniques, and the design of the sampling procedure. Data bias, on the other hand, is affected by the quality of measurement data, assumptions and analysis.

Energy savings computations involve a comparison of measured energy data, and a calculation of "adjustments" to convert both measurements to the same set of operating conditions. Both the measurements and the adjustments introduce some error. These errors may arise for example due to meter inaccuracy, sampling procedures or adjustment procedures. These processes generate statistical "estimates" with reported or expected values, and some level of variation. In other words, true values are unknown, only estimated with some level of uncertainty. All physical measurement and statistical analysis are based on statistical calculations and estimation of central tendencies, such as mean values, and quantification of variations such as range, standard deviation, standard error, and variance.

Errors occur in three ways: modelling, sampling, and measurement as follows.

- Modelling. Errors in mathematical modelling due to inappropriate functional form, inclusion of irrelevant variables, exclusion of relevant variables, etc.
- Sampling. Sampling error arises when only a portion of the population of current values is measured, or a biased sampling approach is used. Representation of only a portion of the population may occur in either a physical sense (i.e., only 20 of 1,000 light fixtures are metered), or in the time sense (metering occurring for only ten minutes out of every hour).
- Measurement. Measurement errors arise from the accuracy of sensors, data tracking errors, drift since calibration, imprecise measurements, etc. The magnitude of such errors is largely given by manufacturer's specifications and managed by periodic re-calibration.

What will be analysed regarding to the energy lifecycle (consumption, production and storage) in relation to the ECM(s) is closely related to the decisions to be made in each pilot case.

The adjustments should be computed from identifiable physical facts about the energy governing characteristics of equipment within the measurement boundary. Two types of adjustments are possible: Routine or Non-Routine, although R2CITIES considers the first one because the non-routine adjustments takes into account those parameters which do not vary over time, in this case the occupancy (considered constant). Moreover, it is assumed a constant occupancy during baseline and reporting period with the same presence rate. Therefore, the adjustment, with regard to this variable, is exactly the same in both periods and it can be neglected.

8.1. Routine Adjustments

For any energy-governing factor, such as weather, it is expected the evaluation methodology could change routinely during the reporting period. A variety of techniques can be used to define the adjustment of this methodology. Techniques may be as simple as a constant value (no adjustment) or as complex as multiple parameter non-linear equations, each one correlating energy with one or more independent variables. Valid mathematical techniques must be used to derive the adjustment method for each M&V Plan.

For a generic and global point of view, all changes in the equipment (boiler, façade, etc…) of Valladolid district should be taken into account as it will have an impact on energy profile. We can already predict that there will be a need for different kinds of adjustments. The following parameters (Table 12) could have a considerable impact.

Table 12: Adjustment parameters

Parameters	Indicator
Weather (outside temperature)	HDD (Heating degree days)
Occupancy	Occupancy

In fact, the occupancy could seem to be one of the variables with a high level of impact, affecting directly the energy consumption at district level. However, as stated before, it can be neglected in the case study because it is supposed constant both in baseline and reporting period. Thus, the adjustment, regarding this variable, is the same in both periods and, when comparing before and after renovation, its effects will be cancelled. Furthermore, the measurement of this variable is complex due to the need of metering all the individual dwellings to be retrofitted, which is out of budget.

Then, for the energy savings assessment, the HDD will be the unique parameter to be taken into consideration, being necessary the monitoring of the outdoor temperature through a weather station that will be available near the district.

9. Analysis procedure for calculating results

This section specifies the data analysis procedures, algorithms and assumptions to be used in each savings report. R2CITIES is looking for (re)usable models for the definition of energy efficiency for buildings/facilities/urban areas that can be used before and after the ECM(s) that are put into a place.

Mathematical modelling is used in M&V to find a mathematical relationship between dependent and independent variables. The dependent variable, in this case the energy, is modelled as being governed by one or more independent variable(s) (X_i, also known as "explanatory" variables). This type of modelling is called regression analysis, in which the model attempts to "explain" the variation in energy that results from variations in the individual independent variables. The model quantifies the causation. For example, when independent variable increases by one unit, energy consumption increases by "b" units, where "b" is called the regression coefficient.

The most common models are linear regressions in the form of:

$$Y = b_o + b_1X_1 + b_2X_2 + \cdots + e$$

where:

- *Y* is the dependent variable, usually in the form of energy use during a specific time period (e.g., 30 days, 1 week, 1 day, 1 hour, etc.)
- X_i (i = 1, 2, 3 … p) represents the "p" independent variables such as weather, production, occupancy, metering period length, etc.
- b_i (i = 0, 1, 2, … p) represents the coefficients derived for each independent variable, and one fixed coefficient (b_0) unrelated to the independent variables
- *e* represents the residual errors that remain unexplained after accounting for the impact of the various independent variables. Regression analysis finds the set of b_i values that minimizes the sum of squared residual-error terms (thus regression models are also called least-squares models).

In the case of the Valladolid demo site, such as defined in sections before, the dependent variable is the thermal consumption at district level. On the other hand, one single independent variable is considered, which the HDD is. Therefore, the linear regression model is as follows:

$$Energy\ consumption(monthly) = b_o + b_1HDD(monthly)$$

The values of b_0 and b_1 have to be determined during the baseline period. Within this time span, the climate conditions (more concrete the temperature) will be metered and the HDD will be calculated. Then, the correlation between the monthly thermal energy consumption and the HDD will provide the coefficients of the linear regression equation.

Furthermore, the model is valid if, and only if, the following constraints are fulfilled.

- $R^2 = \frac{\sum(Y_{ie}-Y_m)^2}{\sum(Y_{im}-Y_m)^2} > 0.75$, where i_e is the estimated value, i_m represents the measured value and *m* is the mean value of all the measurement data.
- Variation of root mean square error coefficient $C_V < 0.05$
- Data with standard variation ±2 could be deleted.

Last, although initially other variables are neglected, such as CDD and occupancy, during the evaluation procedure, the correlation between these variables and the energy consumption will be calculated. This study could demonstrate whether the approach is right or another variable should be included in the equation. In the second case, obtaining the coefficients follows a similar process than the explained before (correlations).

9.1. Baseline Period

During baseline, the monitoring will be carried out in multiple representative dwellings (estimated initially in 4, but it will be determined by the sampling and clustering techniques requirements), being the information to be stored the following:

- Monthly DHW consumption
- Monthly heating consumption
- Air outdoor temperature basis for the calculation of the monthly HDD

These parameters, together the indoor conditions for comfort, will establish the baseline period for the measurements during the time span already defined. Thus, the measurements taken from the representative buildings will feed the data mining models so as to estimate the global consumption at district level. Also, the electricity consumption of the individual gas boilers will be taken into consideration for the interactive effects aforementioned. Last, the HDD will provide the input for the determination of the linear regression model.

9.2. Reporting period

During reporting period, the district heating system based on biomass will provide the energy for covering the demand of the DHW and heating at the whole district. Therefore, the parameters to be collected along this period are the following:

- Monthly DHW consumption
- Monthly heating consumption
- Air outdoor temperature basis for the calculation of the monthly HDD

Besides these parameters, the electricity consumption of the biomass boiler, distribution circuits and the individual dwelling stations will be measured. These data-points will provide the comparison with the baseline period with regard to the electricity consumption and the crossed effects of the ECM(s) in the electricity consumption. Furthermore, the indoor conditions will also indicate the comfort level of the homeowners as consequence of the implementation of the ECM(s).

In order to work out the energy savings after the reporting period, the following equation describes the necessary inputs for the assessment process.

$$Savings = Baseline\ energy\ from\ the\ data\ mining\ model\ without\ ECM(s) - Reporting\ period\ energy from\ data\ mining\ model\ with\ ECM(s) \pm Routine\ adjustments \pm Residual\ error\ of\ the\ estimation$$

This equation represents the energy savings by comparing the thermal energy consumption during the baseline and reporting period whose value is obtained through the data mining techniques described before. Nevertheless, the estimation of these values generates a residual error which should be taken into account, if relevant. Finally, the energy savings require a routine adjustment, such as detailed in the previous section.

Once evaluated the monthly energy savings, it could be obtained the annual values as the sum of these savings. Moreover, in consequence with the energy savings, the CO_2 savings and economic savings could be determined, when possible, from the energy ones. In the case of the economic analysis, it is out of the scope of this deliverable and the study is realized into the WP1 “Diagnosis and Indicators of performance”, more concrete D1.2 “Financial Investment Plan Report” [8] and D1.3 “Technology Payback analysis” [13] through the Return of Investment and Payback periods, among other indicators. About the CO_2 savings, the DSI to be applied is the “Greenhouse gas emissions (ENV3)” that is expressed in $kgCO_2/m^2a$, which is considered as environmental indicator as expressed in the D1.1 “District level audit and diagnosis methodology” [6].

10. Energy prices for cost savings calculations

The energy prices provide the information for the calculation of the cost savings from the energy assessment. Although the economic analysis is out of the scope of this deliverable, even work package, the tariffs feed the WP1 “Diagnosis and indicators of performance”. Therefore, it is needed the knowledge of these values for the energy in the current status.

Thus, as aforementioned and stated in D1.1 “District level audit and diagnosis methodology” [6], for the gas-grid-bound in the case of Spain, the tariff is 8.88 €/month + 0.05078 €/kWh + 21% VAT, meanwhile in the case of the electricity the widely used tariff is 35.65 €/kW/y + 0.147565 €/kWh + 21% VAT. It is important to mention that the tariffs could be modified according to the local suppliers.

11. Meter specifications

For the procedure of analysis and evaluation of the results, it is required a metering concept. Thus, for achieving the objectives established by the M&V plan, a monitoring platform associated to the Valladolid demo is under design as depicted in Figure 15, where the multiple sources needed for the metering specification are illustrated. Here, it is important to note, that this is just an overall overview and more detailed information is included in D4.2: "Monitoring need for the Valladolid demo case" [14]. In this metering procedure, the buildings are considered as independent data sources, even dwelling, although the global data from the single building is collected in the same way and stored in a common persistent platform. Then, each individual building data is metered, integrated in the data logger and stored with the remaining measurements so as to feed the data mining techniques. Nevertheless, the information for the M&V plan is related to the individual dwelling energy consumption without considering the comfort parameters, which are gathered for other purposes (see D4.2 [14]), such as control. Moreover, the information related to energy provided by the district heating must be compiled in so far as it is the main energy generation system after the retrofitting intervention and it will be used for the comparison between the as-it-is status and the new one. Last, but not least, the weather station plays an important role in the M&V plan because the adjustment through the HDD and CDD requires the collection of external conditions variables. This Weather station is external to the monitoring system because it will be collected the information from the Architecture School of Valladolid.

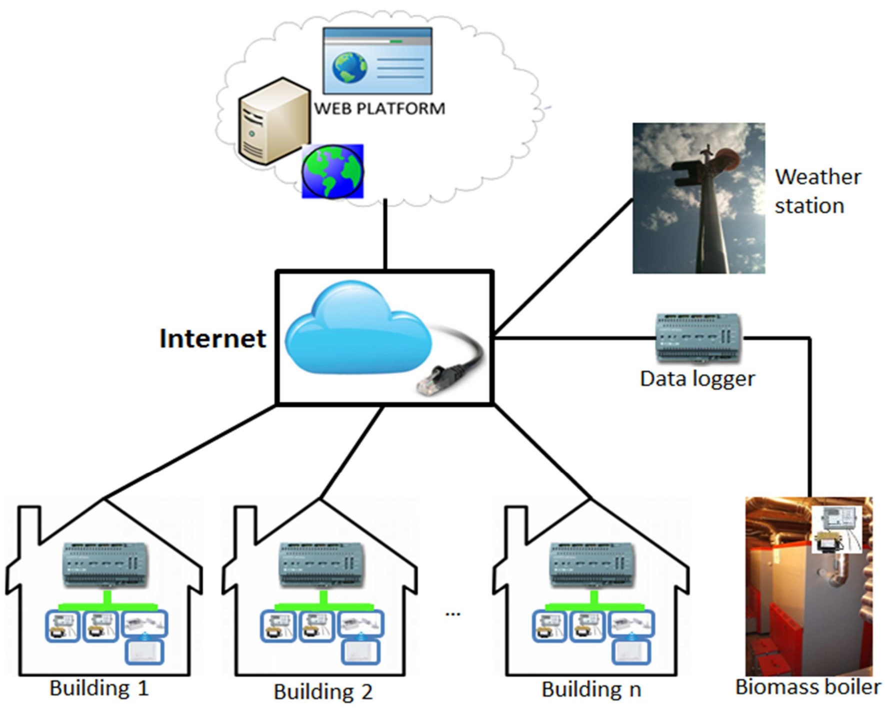

Figure 15: Metering procedure

11.1. Monitoring and measurement

This subsection defines the monitoring, metering and measurement procedures for the operational verification of the ECM(s) implementation performance. This means that the periodic energy consumption can vary over time, the energy savings are directly related to the energy consumption and sufficient data will be collected from the installed metering devices to cover all thermal energy consumption. However, the assessment measurements during the reporting period will be done on the performance of the facility as a whole (or parts of or devices in the facility) and not on specific ECM performance as it was defined in section 5.1.

The reporting period after taking/implementing/installing/activating the ECM(s) is identified above from January 2016 to January 2017. In this time span, measurements will be done on a small time-scale basis, e.g. every 5 minutes or 30 minutes and collected extensively. In addition, aggregation of the measured values over longer periods can be done afterwards or on the fly. At a monthly basis the results can be aggregated to take into account the relevant deviations (like the weather in different seasons).

Before executing the measurements during the reporting period, it should be verified that the ECM(s) are installed and operating properly and that they have the potential to generate savings. As stated in IPMVP [3], the process before gathering the metering in the reporting period, operational verification during the commissioning of ECM may involve inspections, functional performance testing, and/or data trending with analysis. These activities will be reflected in WP5: “Demonstration”.

For the assessment process, the variables to be monitored in the Valladolid district during the reporting period are the following ones.

- DHW consumption for the whole district gathered from the biomass generation system output in the case of buildings with the biomass solution, but also the individual consumption in those buildings with the “non-biomass” solution where heat meters are required.
- Heating consumption for the whole district gathered from the biomass generation system output in the case of buildings with the biomass solution, but also the individual consumption in those buildings with the “non-biomass” solution where heat meters are required.
- Gas consumption from the support boiler for covering the peak demands for heating in the biomass solution.
- Gas consumption from bills in the case of the buildings with the “non-biomass” solution.
- Electricity consumption of the individual gas boilers, the district heating biomass boiler, the distribution system and the individual dwelling stations.

11.2. Collecting data, equipment requirements and metering specifications

Once the global procedure is described, more detailed concepts are collected in this section. First of all, extracted from D4.2 “Monitoring need for the Valladolid demo case” [14], the metering concept per building is drawn in Figure 16. There, the information, which is based on the variables described in the previous chapter, taken from the building is remarked. Thus, for the energy goals of the M&V plan, inside every single building and dwelling, heat meters are going to be deployed so as to measure the heating and Domestic Hot Water energy consumption through devices compliant with LonWorks[7] protocol. The heat meters are Kamstrup Multical 602 that are able to measure the liquid flow into the pipes, but also the energy consumption in kWh with help of the temperature probes.

Moreover, the comfort measures, such as indoor temperature, are taken with wireless devices which minimize the impact of the installation and are compliant with enOcean[8] protocol. This protocol reduces the requirements for installation because no cable is necessary and the devices are self-powered by energy harvesting. This means the sensor is fed through mechanical or environmental conditions, as for instance vibrations, pressure, light or temperature change. Thus, the maintenance is reduced without the use of batteries which have to be replaced.

Furthermore, the data-points will be available on Internet by means of the data logger that collects the measurements from the dwellings and building. Thus, a gateway from enOcean to LonWorks translates the information to establish a common language for all the measurements. Then, the iLon Smart Server[9] data logger collects the information and provides open access through Internet, such as SOAP (Simple Object Access Protocol) or FTP (File Transfer Protocol) protocols.

Additionally to the installation plan draft, a weather station is required for those data-points related to the outdoor conditions, such as the external temperature, or even the global radiation if BIPV is finally included in the retrofitting process. Although it appears associated to the building in the scheme, the information will be taken from an external data source accessible via Web Services protocols over Internet. As stated before, the Weather Station is located near the district, around 1.7 km from the district (see Figure 17). This distance is considered within the range where the climatic conditions do not vary and the data-points will be included in the common monitoring platform together with the energy measurements.

[7] LonWorks technology: http://www.echelon.com/technology/lonworks/

[8] EnOcean technology: http://www.enocean.com/en/home/

[9] iLon Smart Server: http://www.echelon.com/products/controllers/smartserver/

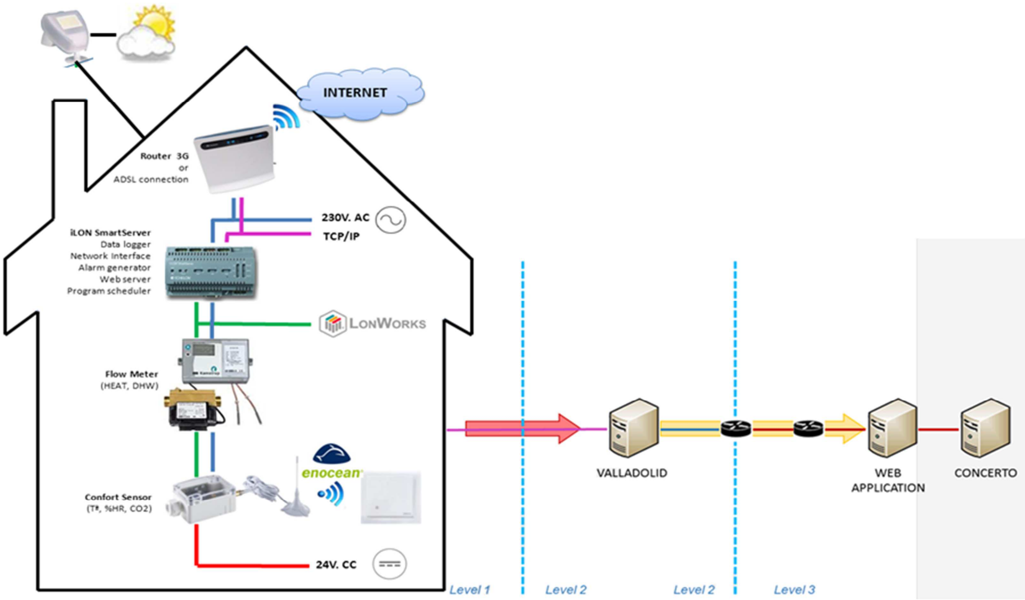

Figure 16: Metering concept

Figure 17: Distance from Weather station to Cuatro de Marzo district

As mentioned before, the monitoring specification requires some variables both for baseline and for reporting period. During the reporting period, the data-points are enough for DSI assessment of the facilities at district level. However, during baseline, it is required the appliance of the well-established data mining procedures to determine the energy performance of the district. First of all, due to budget limitations and the cost-effectiveness objective that must be fulfilled within R2CITIES project, only a set of representative dwellings will be monitored, therefore, not all the information is collected about the energy performance of the demo site. Secondly, the energy consumption can be compiled from the energy bills (electricity and gas), but not all the invoices are available.

11.3. Key measurement parameter(s)

Once defined the specifications, procedure and equipment for the monitoring phase of the project, the variables that should be collected are highlighted in this section. The list of key measurement parameters are reflected in Table 13, where the variable, resolution, meaning and when is usable are remarked. Some clarifications, as aforementioned, the gas consumption is taken from the current bills, although not all the information can be compiled, therefore, some of these data will be obtained through the data mining techniques. Moreover, the resolution is defined to 15 minutes because the M&V plan does not need "real-time" measurements, but the integrated values along the time. Then, considering that the energy meters are able to collect the accumulated energy in the distribution circuit, measuring these flows in a period of 15 minutes is more than enough for avoiding losses of data. Finally, the temperature is not varying excessively in a period of 15 minutes, therefore, this resolution is valid for the M&V plan, although the final value for the assessment will be the monthly sum of the instantaneous measurements.

It is noticed that these requirements are those minimum for the M&V plan, but monitoring & visualization (see D4.2 [14]) will define the final resolution period.

Table 13: Metering requirements for the M&V plan

Data-point name	Resolution	Description	Time period
Gas consumption	Monthly	Total gas consumption from bills for each building/dwelling according to the current gas consumption for DHW and heating	Baseline
Gas DHW energy flow	15 minutes	Individual energy of each dwelling used for DHW purposes	Baseline
Gas heating energy flow	15 minutes	Individual energy for each dwelling used for heating purposes	Baseline
Individual gas boilers electricity cons.	15 minutes	Electricity consumption of the individual gas boilers in the as-it-is status.	Baseline
Boiler energy consumption	15 minutes	Input of the boiler for the generation of the energy demand required at district level	Reporting
DHW energy flow	15 minutes	Output of the boiler at district level for	Reporting

		DHW purposes	
Heating energy flow	15 minutes	Output of the boiler at district level for heating purposes	Reporting
Boiler energy generation	15 minutes	The total energy generated by the biomass boiler and provided to the buildings through the distribution system	Reporting
Support boiler consumption	15 minutes	Total energy generated by the gas support boiler for the energy demand peaks	Reporting
Biomass boiler electricity cons.	15 minutes	Electricity consumption for feeding the biomass boiler and its distribution circuits	Reporting
Individual stations electricity cons.	15 minutes	Electricity consumption of the individual dwelling stations	Reporting
Outdoor temperature	15 minutes	External temperature for calculation HDD or CDD	Baseline and Reporting

11.4. Estimated parameter(s) and justification for estimates

As depicted before, since all the information about the whole district is unavailable, either bills or measurements an estimation procedure has been designed. Thus, in order to bridge the gap between buildings and districts, it is required some techniques for the estimation of the data-points. Here, data mining techniques are designed so as to determine the energy performance (mainly thermal (gas) consumption) as a whole. In this way, sampling and clustering procedures aggregate a set of representative measurements in groups for metering. However, this estimation does not lack of accuracy because, statistically, if the population (set of dwellings) are selected appropriately and the groups are defined accordingly, the residual error can be reduced until being neglected. For these reasons, the correlation among elements of a group must be high (approximately 1) and among elements of different groups must be low (approximately 0).

12. Monitoring responsibilities

For carrying out the suitable monitoring process, a set of responsibilities and collaborative work among R2CITIES partners is necessary. Thus, Table 14 defines the actions to be taken for the specified partner.

First of all, there is needed the collection of the current invoices and selection of dwellings to be monitored, task to be done by VIVA. With regard to the installation plan of the monitoring system for the demo site, CARTIF is in charge of selecting the equipment, installing it into the dwellings and buildings and committing the devices to start metering information.

Afterwards, ABB ought to design the common monitoring platform for the project in order to store the data-points, as well as assuring the data quality through the interpolation of data-points where needed, as for example when data gaps appear. CARTIF will be responsible for its implementation and deployment, in accordance to ABB specifications, for the demo site of Cuatro de Marzo district in Valladolid.

Once deployed, CARTIF will evaluate the data and analyze the information according to this M&V plan and the defined KPIs for the demo site. Last, but not least, ONYX and ACC are responsible for the simulation and selection of the ECM(s) most appropriate for the district.

Table 14: Metering responsibilities

Task description	Partner	Responsibility
Bills collection	VIVA	The energy consumption is required for the baseline definition, then, VIVA is compiling the energy bills from neighbours
Installation	CARTIF	Installation and commitment of the devices and sensors for the proper monitoring of the facilities in the demo site.
Monitoring platform	ABB/CARTIF	Development and deployment of the common monitoring platform for collecting and visualizing data.
Interpolate data-points	ABB/CARTIF	When data gaps, the platform interpolates the measurements in order to establish a continuous stream of information.
Data analysis	CARTIF	The analysis of the information, data quality and evaluation of the KPIs for the demo site
ECM(s)	ACC/ONYX/CARTIF	Simulations and deployment of the ECM(s) at district level for the retrofitting strategy

12.1. Technical monitoring

As described below, the CONCERTO [4] is a Europe wide initiative proactively addressing the challenges of creating a more sustainable future for Europe's energy needs; whose result is a technical monitoring guide. Then, one of the objectives of R2CITIES is to use the guidelines and indicators provided by CONCERTO, as well as giving feedback to the CONCERTO database. Thus, to start up, a summary of the Concerto technical monitoring guide [4] is highlighted in order to establish the common framework to be applied. First of all, CONCERTO specifies those minimum parameters to enable the energy analysis. The overall generated, delivered and consumed energy have to be measured. This M&V plan complies with these minimum requirements through the selected data-points in Table 13. Moreover, it ideally sets up a common period for metering for all the data-points, which is applied in R2CITIES with energy flow measurements each 15 minutes. As well, monthly energy consumption of at least two years should be provided. In this way, the demo site already has the monthly invoices, although some of this information is obtained by means of "sampling and clustering". Furthermore, the energy should be expressed per unit of gross/heated/cooled area, such as R2CITIES is doing for the definition of the measurements, as well as the ECM(s) performance.

Nevertheless, the energy data comparison among different years has a different impact depending on the climate conditions. Therefore, the energy information should be normalized with the HDD and/or CDD. In the M&V plan these values are considered for the adjustment in the overall equation for energy savings.

Furthermore, CONCERTO defines a timeframe to be applied, as shown in Figure 18 [4]. Three stages are described: definition of the monitoring concept, implementation of the monitoring measures and monitoring of the energy supply and consumption. At this moment, the project is running in the stage 1 where the monitoring concept and the integration of the meters will be rendered, whereas the next two stages will be carried out in advance. However, R2CITIES span is of 4 years, reducing the first stage in one year for applying with the guidance of CONCERTO.

On the other hand, CONCERTO establishes where to meter, being the main point the Renewable Energy Sources (RES), as well as the energy uses (i.e. DHW, heating, electricity consumption…) separately. That guideline includes the zones if the building has multiple areas with different requirements of energy. Even more, the building should be treated as a whole, instead of individual dwellings. With this aim, R2CITIES applies with these needs as far as the biomass boiler will be monitored and the distribution circuits at building level for the different usages, whereas the buildings have not got multiple areas, being all of them residential. However, CONCERTO remains at building level, although R2CITIES goes a step forward because it evaluates districts. In this way, as discussed below, R2CITIES proposes measurements at District Heating level instead of single buildings, as well as a set of District Sustainable Indicators in order to apply with the district requirements. Therefore, R2CITIES takes the CONCERTO guidelines as basis of metering, taking into consideration building monitoring is a manageable process, but the whole district is not affordable. Thus, the data mining techniques detailed before bridge the gap between buildings, districts and CONCERTO guidelines in a cost-effective manner.

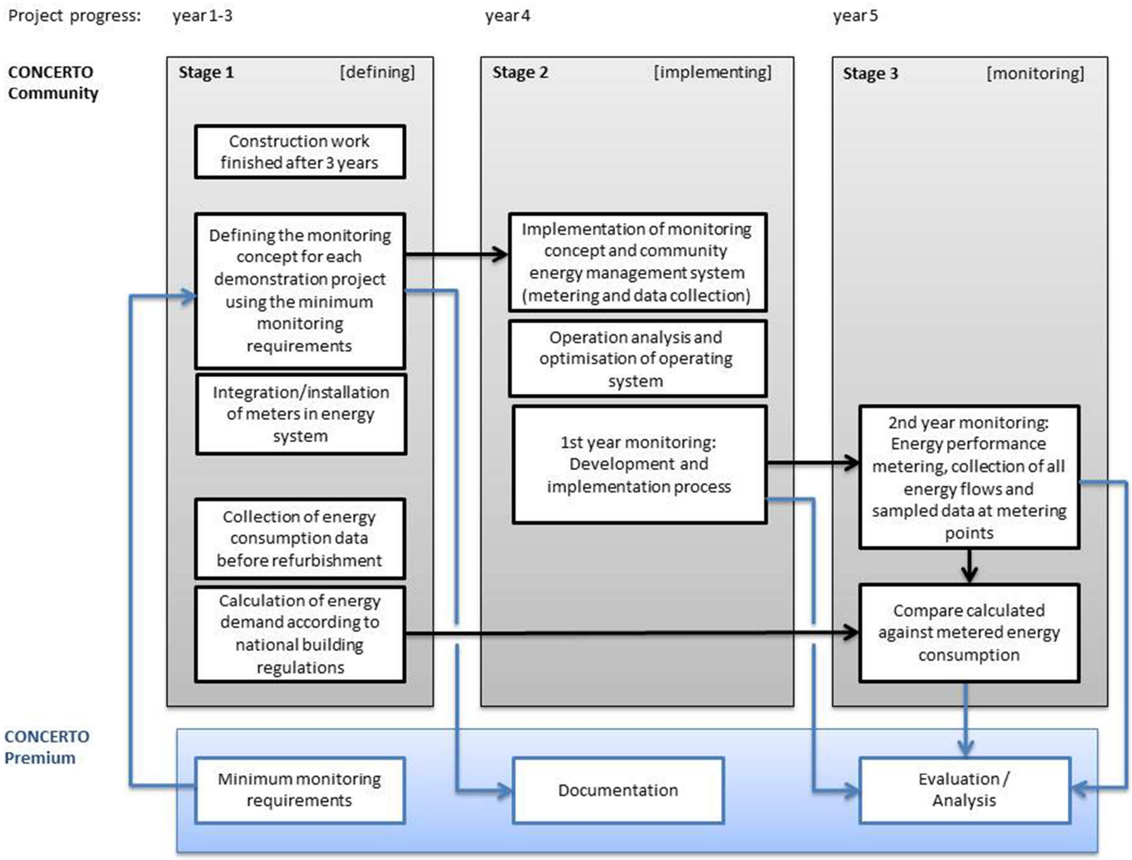

Figure 18: Timeframe according Concerto

Finally, so as to contribute with CONCERT premium database, R2CITIES will compile the information of the monitoring system, before and after refurbishment, as well as energy analysis in order to feed the Excel sheets provided by CONCERTO10. Within the database of CONCERTO, also the KPIs are fed into it, although R2CITIES defined the DSIs. The results of this feedback will be detailed in the D4.8: "Feedback of the M&V plan implementation and proposed improvements".

Moreover, R2CITIES will contribute, if required, to the development of new monitoring requirements for the new platform that will be promoted by the EC[11] for sharing and comparing results among Smart Cities Projects funded in the last calls. R2CITIES will accomplish with the new specifications of the feeding mechanism that the new Technical Monitoring Database could define.

[10] Concerto Premium finalised in December 2013. The new program will start in the following months.

[11] R2CITIES must accomplish with the new requirements for sharing data of the new Platform. At the moment of development of this Deliverable, excel templates were devoted from Concerto Premium initiative for feeding Concerto Technical Monitoring Database (TMD) to share and compare results.

13. Expected accuracy

The measurement of any physical quantity includes errors or deviations because the meters are not perfect equipment, with no 100% of accuracy. In this way, errors are defined as the difference between the metered value and the real one. In any energy savings determination process, the prevention of these errors helps the evaluation of more accurate calculation of the savings.

Some are the characteristics within a savings determination process which should be carefully reviewed to manage accuracy or uncertainties. These features are explained in the following bullets, as well as the reasons for arising.

- Instrumentation – measurement equipment errors are due to calibration, inexact measurement, or improper meter selection installation or operation.
- Modelling – the inability to find mathematical forms that fully account for all variations in energy use. Modelling errors can be owing to inappropriate functional form, inclusion of irrelevant variables, or exclusion of relevant variables.
- Sampling – use of a sample of the full population of items or events to represent the entire population introduces error as a result of: the variation in values within the population, or biased sampling. Sampling may be done in either a physical sense (i.e., only 2% of the lighting fixtures are measured) or a temporal sense (instantaneous measurement only once per hour).
- Interactive effects (beyond the measurement boundary) which are not fully included in the savings computation methodology.

Table 15 shows the accuracy of equipment which will be installed in Valladolid demo for each parameter to be monitored.

Table 15: Equipment accuracy

Data-point name	Sensor /meter	Precision
DHW energy flow	KAMSTRUP MULTICAL 602	±0.5%
Heating energy flow	KAMSTRUP MULTICAL 602	±0.5%
Outdoor temperature	Weather station. WMR200	±1ºC
Indoor temperature	ELTAKO-FCO2TF63	±1ºC

14. Report format

M&V Reports should be prepared and presented as defined in the M&V Plan. Complete M&V reports should include at least:

- Observed data of the reporting period: the measurement period start and end points in time, the energy data, and the values of the independent variables.
- Description and justification for any corrections made to observed data.
- Energy price schedule used.
- All details of any baseline non-routine adjustment performed. Details should include an explanation of the change in conditions since the baseline period; all observed facts and assumptions, and the engineering calculations leading to the adjustment.
- Computed savings in energy and monetary units.

M&V reports should be written to their readers' levels of understanding. Energy managers should review the M&V reports with the facility's operating staff. Such reviews may uncover useful information about how the facility uses energy, or where operating staff could benefit from more knowledge of the energy-consumption characteristics of their facility.

15. Quality assurance

So as to assure the data quality, during the monitoring phase, a set of alarms will be implemented within the common monitoring platform in order to keep informed about out of well-established range values or even malfunctioning of the metering system. Some examples of alarms are those which send a mail to the administrator when a variable is out of an operational range (i.e. relative humidity minus 0), lack of connectivity of the data collector at the moment of gathering sensor network information and so on. Moreover, in the case of the Valladolid demo site, both cloud-based and local backup is envisaged for the case of missing data. Then, in the presence of any data commitment error, the data can be recovered and populated over the common platform.

16. References

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