Residential Renovation
towards nearly zero energy CITIES

R2CITIES

"Renovation of Residential urban spaces: Towards nearly zero energy CITIES"

D4.7 M&V Plan for Genoa demo site

WP 4, Task 4.3

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Collaborative Project – **GRANT AGREEMENT No. 314473**

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Table of Content

List of Figures

List of Tables

Executive Summary

Deliverable 4.7 M&V Plan for Genoa demo site aims to provide the general overview of the measurement and verification plan that will be applied in the Genova demo site developed in the framework of R2CITIES project.

This report deeply describes how the 13 topics of the M&V plan will be addressed in Genova.

In particular for all the mentioned sections below a deep analysis in the Genova demo context has been developed in this report:

- Project Intent
- IPMVP option and measurement boundary
- Baseline: period, energy and conditions
- Reporting period
- Basis for Adjustment
- Analysis procedure for calculating results
- Energy prices for cost savings calculations
- Meter specifications
- Monitoring responsibilities
- Expected accuracy
- Budget and resources
- Report format
- Quality assurance

This deliverable will be used as input for the Deliverable “D4.8 Feedback of the M&V plan implementation and proposed improvements” where the validation of the overall approach followed as M&V plan will be.

1 Introduction

1.1 Purpose and target group

This report focuses on the definition of the Measurement and Verification (M&V) plan for the Genova demo site. As remarked in the previous deliverable (D4.1: Report on the Measurement and Verification analysis), IPMVP is selected as basis protocol for the M&V plan after comparing multiple ones. Thus, once laid the fundamentals, the plan for the Genova demo site is established within the present document and the related documents for the remaining demonstrators (D4.5 and D4.6). The approach is based on IPMVP, although adapted, because IPMVP does not consider neighborhoods, but buildings, therefore, the existing guidelines have been adjusted to the project requirements at district level.

1.2 Contribution of partners

Here below are listed the R2cities partners that are involved in the development of the Genova demo site identifying which will be the main contributions expected.

Participant name	Contributions
D'Appolonia (DAPP)	Demo activities coordination Input on the selection of the most suitable interventions in particular in term of heating systems Input to the preliminary and definitive project Coordination and analysis of the results related to the ECMs implemented Analysis of the User acceptance before and after the realization of the interventions. Feedback on the M&V plan deployed D'Appolonia is involved in the demo activities since the beginning and will coordinate all the activities that will follow in order to implement measure and validate the saving that will be achieved in the demo thanks to R2CITIES. Margherita Scotto will be the main contact from D'Appolonia for the M&V phase of R2CITIES project in the Genova demo.
The Municipality of Genova (GEN)	Owner of the demo site; Input on the selection of the most suitable interventions; Contact with ARTE that has the current data available in terms of consumption for the demo); Finalization of preliminary and definitive implementation project (technical and administrative aspects); Tender publication and assessment of the demands that will be applied;

	Overall overview during the work implementation; Tenants and energy manager feedback on the intervention done. The team of the municipality that is and will be involved in the Genova demo site is composed by three different departments dealing with: Smart cities development, maintenance plan for the buildings owned by the municipality and finally the social housing department.
The University of Genova (UNIGE)	Input on the selection of the most suitable interventions in particular in term of envelope performances and internal comfort conditions; Diagnosis and energy/sustainable audit of the demo; Input for the preliminary and definitive project (technical aspects, Drawings, numerical simulation with standard and innovative instruments (for instance with BIM simulations); Co-coordination (together with the other Italian partners) and analysis of the results related to the ECMs (Energy Conservation Measures) deployed and to the research activities in the "in situ laboratories". Renata Morbiducci and Marco Vassale will be the main contact from University of Genova for the M&V phase of R2CITIES project in the Genova demo.
ABB	Input on the selection of the most suitable interventions in particular in term of sensors for the monitoring phase Input to the preliminary and definitive project (technical aspects) ICT platform development for data storage In particular with the project it will be involved Andrea Melis who is the ABB Project Manager for R2CITIES project. Ivano Scarrone is the ABB Project Leader for R2CITIES Project.
Officinae Verdi (Verdi)	Officinae Verdi will follow the project choices and in particular is providing inputs to the preliminary and definitive project (financial aspects). Giusy Calvanese will be the main contact from VERDI for the M&V phase of R2cities project in the Genova demo.

Table 1: Contribution from partners to D4.7

1.3 Relation to other activities in the project

Deliverable	Relationship
D1.1	Audit of the facilities, energy components and additional information about the Valladolid district. Moreover, overall KPIs definition.
D2.2	Definition of the Energy Conservation Measures susceptible for application

	at the whole district level, and more specifically, for the Genova demosite.
D3.2	Optimum integral design of each demo site selecting the ECMs to be applied.
D2.12	Common monitoring platform where the key parameters for M&V have to be gathered.
D4.1	Selection of IPMVP as fundamental protocol for the M&V plan.
D4.2	Definition of the monitoring system for the demonstrator.

Table 2: Relationship with other activities

2 M&V project plan preparation

A well-defined and implemented M&V plan provides the basis for documenting performance 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 [1].

Following the description presented in in Deliverable 4.1 "Report of the measurement and verification protocol analysis", a complete M&V plan should include discussion of the key topics included in the table below as describe in Chapter 5 of 2010 IPMVP [2].

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

Table 3: Recommended M&V plan table of contents

A full description of these topics for the Genoa demos-site is provided in the following sections.

[1] Lawrence Berkeley National Laboratory, "M&V Plan", http://mnv.lbl.gov/keyMnVDocs/mnvplan

[2] International Performance Measurement and Verification Protocol: " Concepts and Options for Determining Energy and Water Savings Volume 1" Prepared by Efficiency Valuation Organization www.evo-world.org April 2007

3 Project Intent

3.1 Project description

R2CITIES aims to develop and demonstrate an open and easily replicable strategy for designing, constructing and managing large scale district renovation projects for achieving nearly zero energy cities. To this purpose, a demonstration and dissemination framework of very innovative strategies and solutions for building energy renovation at district level is being developed.

The demo selected by the Municipality of Genova is a part of the Pegli 3 District. The part selected is called "Lavatrici- in English Washing Machine". Pegli 3 is located in the west part of Genoa, the original Zone Urban Plan of the district (by application of the Italian Law for council housings 167/62, 1976) includes many hectares with a capacity of many thousands of habitants.

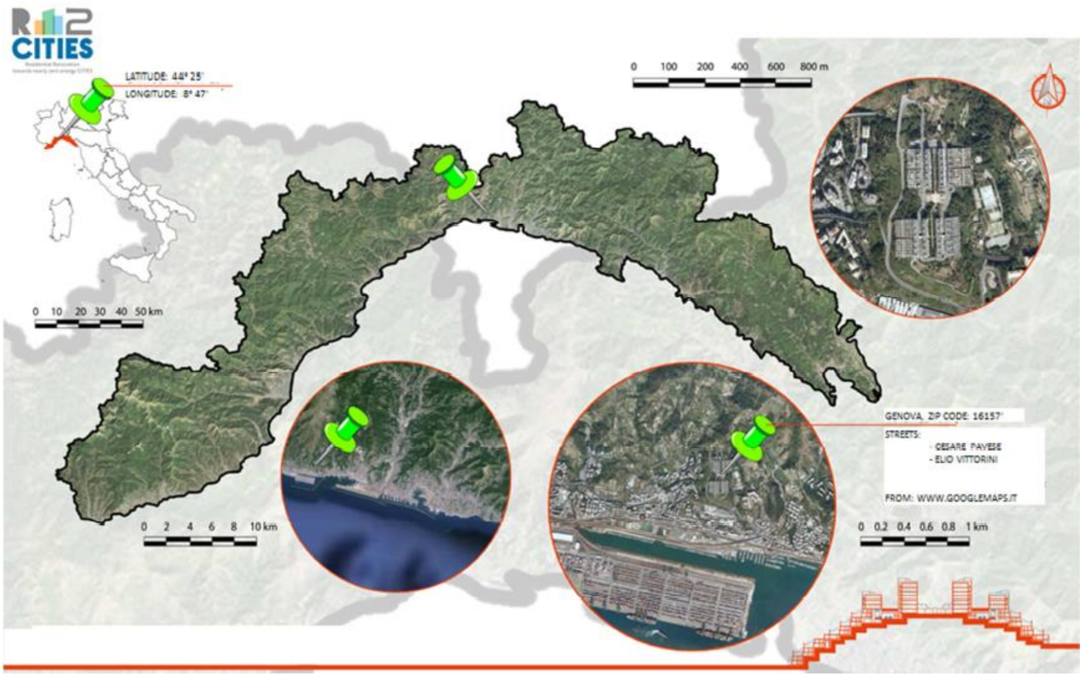

Figure 1: Location of Pegli 3 district and of the Washing Machines

It is divided into several sectors where several social services were included (i.e. schools, spaces for sports, supermarkets, highways, etc). There are inbuilt sectors, an area built with private funding, one build by ARTE (Azienda Regionale Territoriale per L'Edilizia - Regional body dealing with the construction and refurbishment of public buildings) and finally the part that will represent R2CITIES demo site: the "Washing Machines". The figure indicates the location of Pegli 3 and of the "Washing Machines", and Figure 2shows the aerial view of the area.

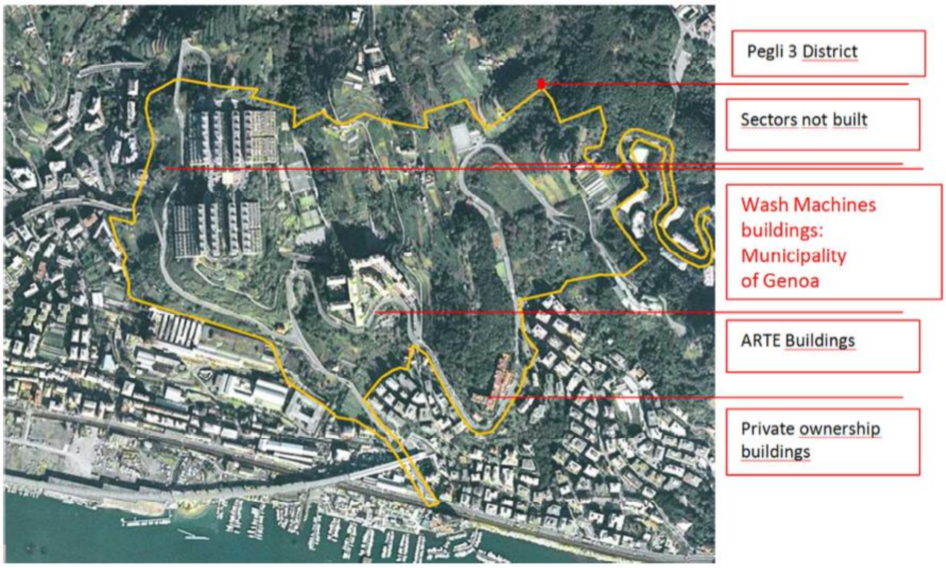

Figure 2: Aerial View of the Pegli 3 district

The "Washing Machines" complex was built on an area of more than 40.000 m^2. The total volume of the 4 blocks is around 230.000 m^3 corresponding to 64.000 m^2.

The housing district brings itself considerable energy and environmental criticalities, due to the large size and the partly public character of the buildings. For these reasons the requalification of the constructions is considered a tool to reduce the very high costs for management that could help to elevate the level of social and environmental quality of entire neighborhood.

The current energy status (BEST Tables) in the entire district is not adequate to the energy efficiency limits of the Italian regional energy efficiency law and in general for the idea of "nearly zero energy building/district". Efficiency is low both in terms of transmittance (W/m^2 K) and energy demand per square meter of total used conditioned floor area (kWh/m^2yr, including system losses). The same consideration is valid for the hydrometric performances in terms of interstitial and surface condensations.

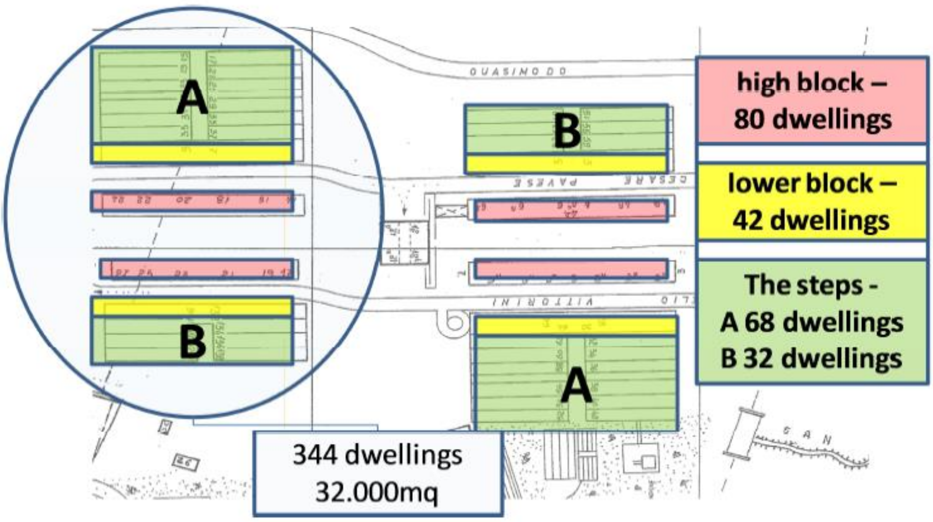

Figure 3: Genoa demo site

The Washing Machines were built from the 1983 and the 1989. They are built using the "banches et tables" constructive technique. The main technical data of buildings are:

- type of structure: cast reinforced concrete (depth of horizontal and vertical sets: 0.15 m);
- typology of dwellings: simple floor with balcony (facades oriented to East or West), simple floor with double faces (facades oriented to East/West), duplex floors (facades oriented to East or West);
- typology of common spaces: several spaces with different shapes for common activities; different elevators and staircases areas for every typology of building;
- main characteristics of constructive elements: foundation on pilots or continue; flat roof; vertical walls with different main typologies:
    a) precast wall panels filled with internal discontinue thermal insulation layer (external East/West walls),
    b) reinforced concrete wall with or without layer of hollow units and with or without internal layer of thermal insulation (South/North walls),
    c) vertically perforated modular wall with or without an internal layer of thermal insulation (no-heating or internal East/West walls); windows with metal frame and double air glazing; South and North Façades without windows;
- current maintenance conditions: in general not sufficient ordinary maintenance, problems of heat losses, thermal bridges, water infiltrations and no-controlled external air/wind infiltrations, common areas not adequately exploited.

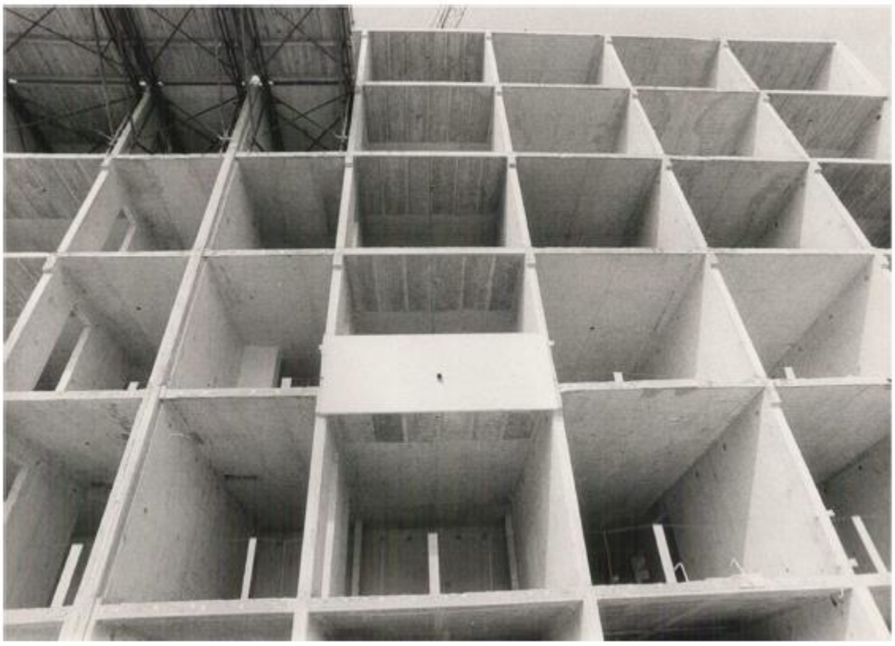

Figure 4: The Washing Machines, the "banches et tables" French constructive technique

The most suitable and cost-effective solutions to achieve a “nearly zero energy” Pegli 3 District are related to the southern “high blocks”, encompassed within the Washing machines cluster, with an overall covered surface of about 18,000 m^2. The interventions firstly identified regard envelope and control systems.

The selection of project interventions and area has been defined and settled up during the first months of the project after the completion of the diagnosis phase that is reported in D1.1 (District level audit and diagnosis methodology) and according to the project overall methodology carried out in D3.1 (Integrated methodology development for energy efficient district renovation). Indeed the initial planning was having two options in terms of covered area and additional interventions possible.

The two options for the district area were: two high blocks (as finally chosen) or alternatively the combination of 1 high block plus 1 low block plus a steps module.

In terms of possible interventions the initial list was including:

- Decrease of the heating/cooling losses and the general thermo hygrometric inefficient of the construction: Thermal insulation increase; Thermal bridges elimination or reduction; Windows substitution/insertion (medium cost technique.
- Solar energy production for electric energy consumption of the common/leisure area: Photovoltaic panels installation on the roof and in the South façades.
- Transformation of common/leisure area in "common/leisure sustainable area" with automation system for thermal, hygrometric, lighting and security control.
- Windows with automation system; External solar protection with automation system for solar control; Automation system installation in the common area for thermal, hygrometric, lighting and security control.

To be sure to reach the target aims of the project, during the design phase the Genova team has started to investigate the possibility to include some interventions at plant level, able to ensure important consumption reductions with reduced budgets. These plant interventions include the installation of thermostatic valves, heat metering at each flat and the installation of natural gas fed condensing boiler in parallel to the existing boilers.

Below are listed all the intervention finally defined for their implementation in the Demo site. All the detailed information about these interventions can be found in section 5.2:

- replacement of windows;
- boiler substitution;
- energy consumption monitoring and control system;
- single zone electro valves installation.
- thermostatic valves and individual metering system installation;

Such intervention will renovate an overall area of 18.000m^2 in the district.

In the table below are listed, for each intervention, the values of the parameters that provide the increasing of the system efficiency.

	Unit	Current values	Foreseen values
Replacement of windows	W/(m^{2}K)	4,04 – 1,99	< 1,4

	dB	> 35	< 35
Heating system renovation	η	0,87	1,02
Thermostatic valves and individual metering system installation	η	0,66	0,91

Table 4: Comparison between actual and foreseen values of the efficiency related parameter

The intervention that will be applied in the Genova demo will affect the global consumptions that are used on the area to cover first of all the heating needs. Extraordinary maintenance interventions were not planned on the area and the ordinary maintenance will not influence the results that will be achieved thanks to the interventions that will be realized in the framework of R2CITIES.

The selected area includes 162 (160 existing plus 2 dwellings that are under construction in an old common area) dwellings where for sure some occupancy changes will occur in the next years but as it will be detailed in the following sections the ambition of the intervention in Genova will be to reduce the energy consumptions at district level and upcoming modification in the user profile will not affect the total final result.

Moreover some research activities will be developed in some dwellings, denominated the "in situ laboratories", in order to deep another passive solutions and their potential for energy savings and increased comfort (in the case of a higher budget). These two levels of intervention will allow to perform a replicability a feasibility analysis in terms of cost-effectiveness of the proposed solutions.

The experimental activities will be carried out in two different types of dwellings:

- The EMPTY dwellings (no tenants);

- The OCCUPIED dwellings (with tenants).

The experimental/monitoring activities are different for the two typologies of empty dwellings as described below.

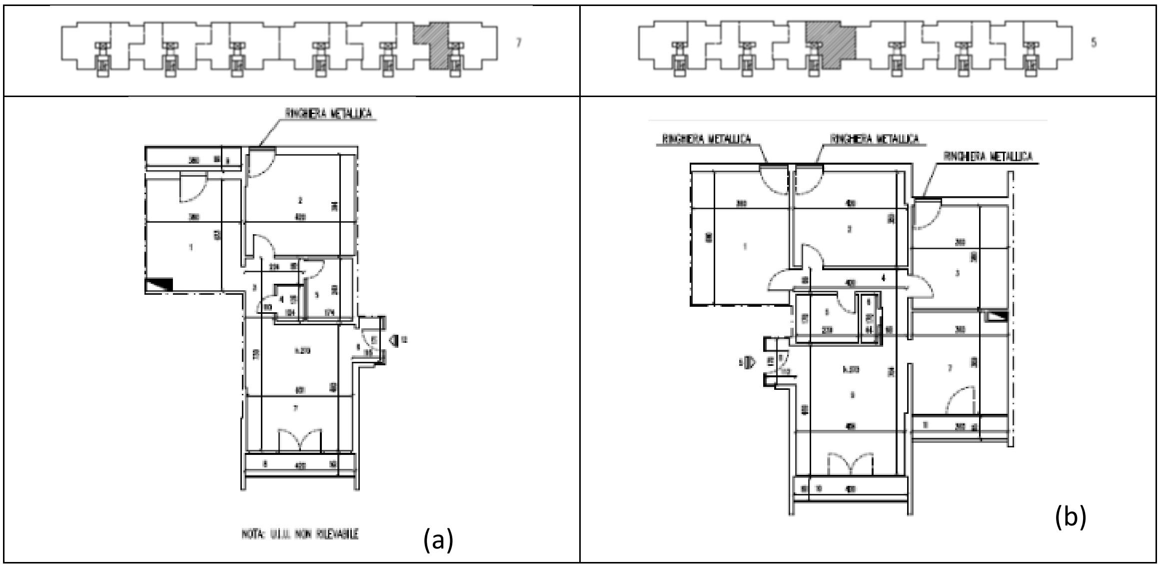

Figure 5: The two plants of dwellings for the in situ laboratories: (a) Dwelling A; (b) Dwelling B

In Empty Dwelling A the following interventions and subsequent monitoring, data collection and processing are provided:

- The same interventions of the pilot area (18.000 m^2);
- Transformation of balconies into greenhouse spaces to increase the saved energy and to improve the internal comfort conditions (see the figure below sketch a);
- Automation system on the standard Italian solar protection (shutters) to increase the internal thermohygrometric and lighting comfort conditions and to simulate the normal living internal conditions (see the figure below sketch b);
- Realization of a new system for natural ventilation to increase the internal thermohygrometric comfort and air quality conditions (see the figure below sketch c);
- Realization of a new system for lighting to increase the saved energy and to improve the internal comfort conditions (see the figure below sketch d);
- Automation system for thermal, hygrometric, lighting and security control to increase the saved energy and to improve the internal comfort conditions.

Figure 6: Interventions in "Dwellings A": (a) Transformation of balconies into greenhouse spaces; (b) Automation system on the standard Italian solar protection; (c) Realization of a new system for natural ventilation; (d) Realization of a new system for lighting.

In Empty Dwelling B the following interventions and subsequent monitoring, data collection and processing are provided:

- The same interventions of the pilot area (18.000 m^2);

- Automation system on the standard Italian solar protection (shutters) to simulate the normal living internal conditions (see the figure below sketch a).
- Painting of internal opaque walls with nanotechnology coatings to test the real contribution on the thermal insulation increase, on the thermal bridges reduction and on the improvement of the internal comfort conditions (see the figure below sketch b);
- Realization of a new system for lighting to increase the saved energy and to improve the internal comfort conditions (see the figure below sketch c);
- Automation system for thermal, hygrometric, lighting and security control to increase the saved energy and to improve the internal comfort conditions.

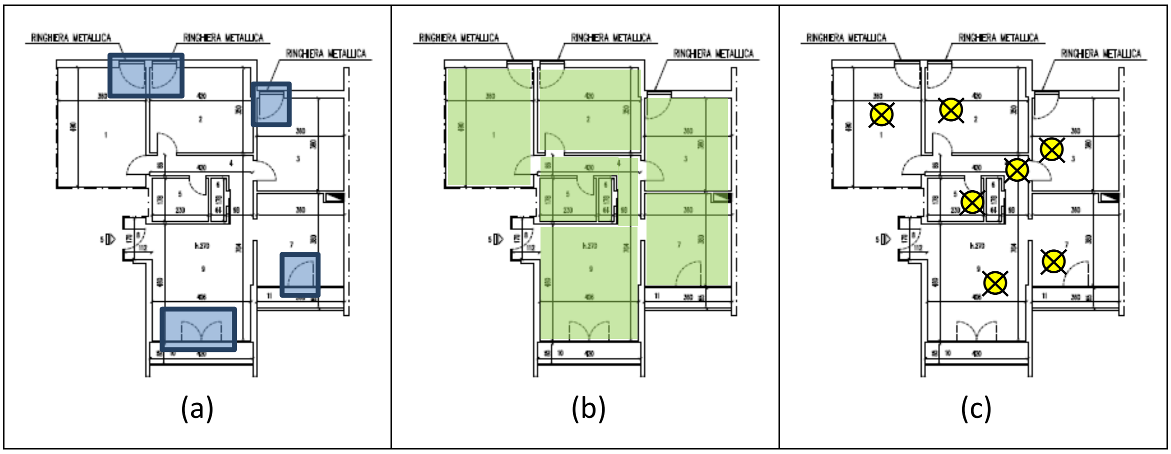

Figure 7: Interventions in "Dwellings B": (a) Automation system on the standard Italian solar protection; (b) Painting of internal opaque walls with nanotechnology paint coatings;(c) Realization of a new system for lighting to increase the internal lighting comfort

With reference to the two occupied dwellings (**Occupied Dwelling A and B**), the following interventions and subsequent monitoring, data collection and processing are planned:

- The same interventions of the pilot area (18.000 m^2);
- Automation system for thermal, hygrometric, lighting and security control monitoring to compare the differences between the two EMPTY dwellings and the two OCCUPIED dwellings.

3.2 Expected project benefits

In this section the expected project benefits are estimated in terms of energy costs and CO_2 emission savings. The analyses described below have been possible after definition of the interventions that will be implemented and the estimations of related costs.

The estimated costs for the envisaged systems are hereby summarized:

- replacement of windows: € 1,000,000-1,200,000 (1,000,000-1,200,000 is the budget needed in case all windows will be substituted. There will be the possibility that after dwelling per dwelling survey some windows will be evaluated in a good status and will not need to be replaced)
- heating system renovation: € 400,000 – 600,000. This intervention includes:
  - boiler substitution;

  - energy consumption monitoring and control system installation;
  - single zone electro valves installation;
  - variable flow pumps for heat distribution installation;
- thermostatic valves and individual metering system installation: € 100,000;

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: 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; the costs savings are therefore obtained applying the actual cost for fuel or electricity borne by the managing authority of the pilot site to the energy savings identified above (these unit costs are usually derived from the different energy bills for electricity, natural gas or fuels);
- CO_2 savings: it is the environmental benefit originated by the energy saving/self-production; each kWh of energy, liter of fuel, or whatever the energy carrier considered corresponds through an emission factor to greenhouse gas emissions; so, GHG emissions are saved whenever those units of energy are saved and/or self-produced.

The summary of the quoted benefits is listed in the following Table for each category of intervention.

Replacement of windows	Energy Saving: 206,000 (123,600) kWh/year
	Costs Saving: 18,950 (11,400) €/year
	CO_2 Saving: 41,200 (24,700) kgCO_2/year
Heating system renovation	Energy Saving: 154,500 (85,000) kWh/year
	Costs Saving: 14,200 (7,800) €/year
	CO_2 Saving: 30,900 (17,000) kgCO_2/year
Thermostatic valves and individual metering system installation	Energy Saving: 257,500 (167,300) kWh/year
	Costs Saving: 23,700 (15,400) €/year
	CO_2 Saving: 51,500 (33,500) kgCO_2/year

Table 5: Summary of the quoted benefits

The energy savings reported in the table above are calculated considering the average total consumptions for heating purposes of the last four seasons equal to around 1,030 MWh.

Each single ECM will bring energy savings through improved efficiency of energy generation, distribution and consumption: the replacement of windows intervention is expected to generate 20% of savings, the heating system renovation about 15% and installation of thermostatic valves and individual metering system about 25%.

Savings generated through the concomitant implementation of three ECMs are however different from the ones generated by single ECM implementation.

Savings from interventions on the envelope reduce the heat demand, whereas those on the plants increase the efficiency in the conversion of fuel into heat. Thus savings reported on brackets in the table above are those generated considering interaction between all interventions (e.g. the efficiency of heat generation will be improved thanks to the intervention on the heating systems. In the meanwhile the general condition of the heating area will be improved thanks to the windows replacement lowering the heating needs. The combination of these two circumstances will generate an overall saving lower than the sum of single interventions). These are known as “interactive effects”. A more detailed description of them and how those can be handled in both Measurement and Verification stages can be found in Deliverable 4.1 “Report of the measurement and verification protocol analysis”.

In total, the whole interventions are expected to produce a saving of about 50 % of current heating consumptions.

	Unit	Actual value	Foreseen value
Global energy demand	MWh/year	592	474
Global energy consumption	MWh/year	1030	510

Table 6: Comparison between actual and foreseen values of demand and consumption of Genova demo site

4 IPMVP option and measurement boundary

The IPMVP (International Performance Measurement and Verification Protocol) is used as a framework for the R2Cities monitoring program. IPMVP allows integrating a global analysis for the monitoring program, from requirements to reporting. It brings coherence to the measurements realized and ensures results quality.

As suggested by Vol 1 of IPMVP (Concepts and Options for Determining Energy and Water Savings), the protocol can be implemented through a Measurements and Verification Plan (M&VP) for the project and for each of the pilots. A M&VP is based on 13 points to be fulfilled in order to set up a clear and coherent measurement and verification plan.

4.1 M&V Option

As described in the D4.1 the available options to evaluate the saving due to a retrofitting intervention are four: A, B, C and D with some different boundary conditions as briefly detailed in the table below.

IPMVP Option	How savings are calculated	Typical Applications
A. Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameters which defines the energy use of the ECM's affected systems and/or the success of the project. Mesurement frequency ranges from short-term to continuous. Parameters not selected for field measurement are estimated.	Engineering calculation of baseline and reporting period energy from: - short-term or continuous measurements of key operating parameters; and - estimated values Routine and non-routine adjustments as required	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the light based on facility schedules and occupant behavior.
B. Retrofit isolation: All Parameter Measurement Savings are determined by field measuremet of the energy use of the ECM-affected system. Measurement frequency ranges from short-term to continuous.	Short term or continuous measurement of baseline and reporting period energy, and/or engineering computations using measurement of proxies of energy use. Routine and non-routine adjustments as required	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the base year this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.

IPMVP Option	How savings are calculated	Typical Applications
C. Whole Facility Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month base year period and throughout the post-retrofit period.
D. Calibrated Simulation Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end use metering.	Multifaceted energy management program affecting many systems in a building but where no base year data are available. Post-retrofit period energy use is measured by the gas and electric utility meters. Base year energy use is determined by simulation using a model calibrated by the post-retrofit period utility data.

Table 7: M&V Option details

For the Genova demo site it was decided to apply the IPMVP option C for determining savings. This decision was taken under the following considerations:

- We are in this framework determining and measuring saving at facility level (Option A and B are then excluded);
- The expected savings (50%) will be large compared to the random unexplained energy variations which usually occur at the whole facility level;
- There will be no need to separately assess each ECM;
- Continuous measurement of the entire facility's energy use will be taken throughout the reporting period of 12 months;
- All routine and non-routine adjustment to the baseline period will be incorporate;
- Will be analysed the effect due to more than one ECM (at this moment the focus in on improvement of thermal insulation with the replacement of windows, on heating system improvement with the replacement of the current heating central boiler and on regulation of heating distribution efficiency improvement).

Historical whole-facility baseline energy use and related data will be collected and continuously measures of the whole facility energy uses after ECM installation will be conducted.

Energy consumptions during the reporting period will be estimated developing a statistical representative trend of the whole facility performance taking into account independent variables (routine adjustments) like outdoor temperature and static factors (non-routine adjustments).

4.2 Measurement boundary

In order to employ IPMVP techniques to effectively evaluate the before versus after effects of an ECM, a consistent boundary which serves as a common reference point for conducting measurement and for claiming savings should be established. In that respect, a measurement boundary is a notional border drawn around equipment and/or systems that are relevant for determining the savings achieved by the ECMs.

Measurement boundaries are defined to include site areas affected by the ECMs for the purpose of conducting M&V and to isolate or segregate unaffected areas. Excluding those areas which may introduce uncertainty enables to focus on the specific effects of the ECMs.

Considering the actual ECMs implementations in the Genova demo site (improvement of thermal insulation with the replacement of windows, heating system improvement with the replacement of the current heating central boiler and regulation of heating distribution efficiency improvement) the measurement boundaries identified at whole facility level are the following:

- the project considers interventions on 162 dwellings belonging to two high bars and the substitution of the centralized heating system with a more efficient one placed in a dedicated building; these different zones represent the physical boundary of the interventions where the savings will be appreciate;
- from the energy system point of view, the meter considered the boundary of the system is the natural gas meter connected to the boiler providing energy to the dwellings; other meters counting the energy supplied to single dwellings or group of dwellings could be used to have a more precise value of the energy supplied locally but not represent a measurement boundary of this system.

4.3 Genova Energy District Sustainability Indicators

For the whole-facility method (Option C), the variables that have to be taken into account are already described. In the scope of the M&V plan in R2CITIES, each Technical Indicator is depicted as District Sustainability Indicators (DSI). Those DSIs should be identified at each specific stage, starting from the Energy audit (Deliverable 1.1) at district level to the final energy savings assessment stage given by the M&V plans (Deliverable 4.5, 4.6 and 4.7).

Each DSI can be strongly useful for the energy calculation model. Anyway, for a more precise simulation, more data are necessary. For example, it is important to determine the schedule activities and structural characteristics, such as:

- Building dimensions (e.g. net floor area, height, vertical area, net and gross volume)
- Transparent components characteristics (area, kind and dimension of window glasses, framework materials, shutter materials)

- Opaque structures (walls, floors, roofs) characteristics (area, thickness and material of each component, kind of thermal bridges, ambient boundary conditions and temperatures).

The Performance Indexes importance lies in the evaluation of the success of the particular process analysed; in the present case, DSIs concern the specific energy consumption for district/building/flat/common areas.

DSI are evaluated through the same calculation method, i.e. using measures coming from both baseline and post retrofit data measurement campaigns.

Here follows a list of the key measurement parameters. These values have to be considered for a more precise building energy performance evaluation.

CONCERTO KPI	DSI EVALUATION EQUATION	MEASURED DATA
1) Density of final energy demand (or consumption)	$DEN_{EC,I,t} = \frac{\sum_{AA=AA1}^{AA4} In_{EC,AA,I,t}}{Cap_I}$	• Annual m^3 of natural gas consumption • calorific power of natural gas used • total m^3 of the set of buildings
2) Efficiency of energy supply units	$Ef_{s,EC,t,avg} = \frac{1}{EN_{s,EC,t}}$	• MWh calculated downstream the centralised boiler • m^3 of natural gas consumption Thanks to these data it's possible to calculate both the average efficiency of the supply unit (season average) and the maximum efficiency of the supply unit (month efficiency).
3) Power of energy supply units in operation	$Po_{s,EC,t,avg} = \frac{Out_{EC,s,t}}{8760 * Cap_{s,EC}}$	• MWh calculated downstream the centralised boiler • maximum power of the centralised boiler (from technical data of the plant)
4) Peak load and load profile of electricity demand	$LP_{I,EC=electricity,t,\Delta t_k} = \frac{\sum_{AA1}^{AA4} In_{EC,AA,I,\Delta t_k}}{\Delta t_k * 8760}$	• electrical energy flow into the building
5) Peak load and load profile of thermal (heating/cooling) energy demand	$LP_{i,AA,t,\Delta t_k} = \frac{\sum_{EC} In_{EC,AA,i,\Delta t_k}}{\Delta t_k * 8760}$	• thermal energy flow into the building
6) Degree of congruence of calculated annual final	$DC_{I,t} = \frac{\sum_{i \in I} Cap_i * DC_{i,t}}{\sum_{i \in I} Cap_i}$	• m^3 of natural gas consumption for heating

energy demand and monitored consumption		

Table 8: Genova demo site key performance indicators

Not all DSIs listed in Table 8 will have relevance within the M&V plan of Genova demo site:

- DSIs number 1) and 5) will be the ones that effectively will contribute to calculate the savings of the implemented ECMs being gathered both in the baseline and the reporting period;
- DSIs number 2), 3) and 6) will give an idea of the effective best performance of the heating generation and distribution system thanks to the new equipments installed;
- DSI number 4) will add information of electricity consumption per single dwelling never known and gathered before.

4.4 Interactive effects

The energy use for the whole district outside the boundary described in the previous paragraph will be affected principally in terms of electric energy consumption reduction of the auxiliaries serving the boiler and the heating distribution system.

A more efficient boiler and energy distribution system, the substitution of windows with more efficient ones will decrease the electric energy consumption of auxiliaries like pumps, electrical engines, fans, etc. directly connected to the equipment.

4.5 Additionality

Due to the ambition of R2CITIES project additionality related to the combination of different energy ECMs is an intrinsic aspect. The renovation interventions are related to 18.000 square meters and saving for at least 50% are expected.

In this project at least three ECMs will be implemented. Considering the improvement of the thermal insulation by replacements of windows, the improvement of the efficiency of the thermal regulation and distribution system and the substitution of the present natural gas centralized boiler with a more efficient one, the total saving obtained implementing the interventions is less than the sum of the savings obtained through each separate intervention.

Thermal insulation improving means reduction of thermal demand for winter heating of each single dwelling considered by the intervention; the savings obtained are related to the less energy demand to obtain the same internal comfort conditions.

Boiler substitution means higher efficiency of energy conversion and consequently less combustible consumptions; savings are related to less energy consumptions to satisfy the energy demand increasing the efficiency of the equipment; improvement of efficiency of thermal regulation at dwellings level means less energy losses, more regular temperature profiles inside each dwelling, a more rational use of thermal energy supplied than basically less primary energy consumptions.

With respect to single intervention, implementing all solutions means increasing energy conversion efficiency to satisfy less energy requested by the user; the resultant saving is then less than the sum of the single savings resulting from each improvement applied to the initial condition of the system.

5 Baseline: period, energy and conditions

In order to edit the baseline mode, the natural gas consumption (only for heating) has been considered as dependent variable and the external air temperature as independent variable.
The natural gas consumption data has been taken directly by the plant manager and derives from the measurement used to assign to each dwelling the bill. Because, in Genova, the heating season lasts from the 1st of November to the 15th of April, these data have been taken monthly (six times per year) and are expressed in [m^3 natural gas consumed/month of measurement].

The external air temperature data has been taken from both the public website www.wundergroung.com (referred to a near meteo station situated in Genova – Sestri Levante) and from A.R.P.A.L (Agenzia Regionale Protezione Ambiente Ligure) website: www.arpal.gov.it (referred to a near meteo station situated in Genova – Pegli). As the external air temperature data are expressed in daily mean value, they has been subsequently transformed in a monthly mean value.

5.1 Baseline and post-retrofit measurement periods

The baseline period used as reference period compared to which savings of the reporting period will be calculated includes data of energy consumptions for winter heating from November 2010 to April 2014. These data refers to boiler total consumptions for each month of the heating period and can be subdivided on each dwelling supplied by the heating system; they have been collected by ARTE that manages heating supplied to dwellings and buy natural gas from a local seller.

The heating power is supplied through a 628 kW natural gas fed boiler located in an part of the building from which departs the hot water distribution pipelines. A natural gas meter measures the gas volumes consumed taken from the natural gas supplier; this measure is the reference measure for the savings calculation obtained.

Referred to this period has been also calculated the total energy demand of the 162 dwellings considered as the sum of the single dwelling thermal energy demand; these figures come out from the energy internal demand due to the type of insulation present, the number of tenants of the dwelling, the behaviour of the tenants, the type of use of the dwelling, the external ambient temperature. The single dwelling thermal energy demand has been estimated because no thermal meter is present at dwelling level and the total energy demand obtained by the sum of each figure has been compared to the total energy supplied by the boiler also to understand the efficiency of the heat distribution system.

As previously mentioned, the foreseen retrofit measures will provide less thermal energy demand for winter heating and a more efficient system of heating production.

The measurement period will last for two years; the main measure will be the total natural gas consumption due to boiler operations. The savings will be calculated as the difference in consumption between the adjusted base line energy curve and the reporting period measured energy curve in terms of energy from natural gas consumed.

The adjustment of the baseline will be made through the independent variable represented by weather conditions and in particular by the external ambient temperature that affect the internal heating demand during winter period.

The new baseline of the reporting period, adjusted through this parameter, will represent the curve to which compare the line of the consumption of the reporting period for savings calculation.

5.2 Energy conservation measures (ECM)

Replacement of windows

Description: the replacement of windows represents a medium cost passive solution and it contributes to reduce building energy losses as windows almost always represent the largest source of unwanted heat loss and heat gain in buildings. In particular, this intervention consists in replacing older windows that are poorly designed and installed with innovative and high performance windows made of energy-efficient and durable materials, meeting local building codes.

Exact Location: windows should be changed on the east facing façade of the western high block and on the west facing façade of the eastern high block.

Size of the intervention: each façade has approximately 400 m^2 windows, although it is estimated that part of them (around 30%) has already been substituted with good quality, double glazed windows that would not be replaced.

Savings: the expected savings of this intervention are around 123,600 kWh/year

Overall cost: the total cost is estimated at 1,000,000 € (in case all windows were to be substituted).

Heating system renovation

Description: the renovation of the heating system mainly includes the substitution of the actual natural gas fed boiler with a more efficient condensing one. In parallel other equipment will be installed to make the hot water distribution system more efficient:

- a new centralized energy consumption and monitoring control system, described in the paragraphs below, will be installed; all data and information collected in a central server will be visualised in remote computers;
- the distribution system will be provided by a variable flow pumps and by an heat exchanger that will separate the primary hot water circuit of the boiler from the rest of the distribution system; the variable flow pumps will give the possibility to better regulate the hot water flow rate at district level accordingly to the frequent variations in heating demand during each days of the heating season.
- for each heating column distribution present in each buildings single electro valves will be installed; this will determine a more efficient and rational heating distribution at

building level, giving the possibility to separately manage different zones of the heating distribution system excluding some of them or make them working at different hot water flow rates level;

Exact Location: the interventions described will be realized in the building already destined to the actual heating power plant; the equipment installed won't need any additional space.

Size of the intervention: the new condensing boiler is 200 kW of thermal power installed

Savings: the expected savings of this intervention are around 85,000 kWh/year

Overall cost: total cost is estimated at 400,000 €

Thermostatic valves and individual metering system installation

Description: In order to increase the overall efficiency of the heating system and to give the possibility to each tenant to pay only for the heat effectively consumed, thermostatic valves and heat meter will be installed for each of 162 dwellings

Exact Location: each of 162 dwellings included in the project

Size of the intervention: 162 heat meters will be installed and a number of thermostatic valves not yet decided

Savings: the expected savings of this intervention are around 167,300 kWh/year

Overall cost: total cost is estimated at 100,000 €

5.3 Operating cycle

For each of the ECMs implemented is possible to define an operating cycle depending on is physical intrinsic characteristic and on equipment utilization.

The savings related to each EMC implemented are relevant during each heating season (from 1st November to 15th of April); for each season is possible to appreciate the improvement given by ECMs implemented and directly measure the energy savings even in big variation of the external temperature.

From one heating season to the following there will be little variation in savings obtained by each ECM other condition remaining constant; this is due to natural progressively decay of performances different for each ECM.

The boiler efficiency for example is supposed to decay during its life operating cycle that is expected to be more than 20 years; the same can be expected for the new windows installed and for the automatic valves placement that allow to better regulates the heat distribution to all dwellings considered.

A good maintenance plan through the operating life cycle of all equipment can reduce these decreases of efficiency keeping high the energy savings value.

5.4 Baseline conditions

In this section with reference to the baseline conditions there are not specific note to be reported since there are not baseline conditions and variables that do not include independent variables.

The required conditions of internal dwelling comfort are mostly related to the external ambient temperature during the heating winter period.

Problems related to old and less efficient heating centralized systems regard different comfort levels between different dwellings within a same building of groups of building; this is due not only to different comfort conditions required by each tenant but also to the lacking of a good control and management system of heating power that leads to dwelling internal temperatures under or well above the value prescribed by law. This leads to different values of internal temperature for dwellings placed in a middle position of a building rather than dwellings placed just under the roof, at first floor or with different walls getting outside; with the absence of a regulating system inside each dwelling, the same heating flow is supplied to each of them resulting in different comfort level depending on different condition described.

The implementation of new heating control system through electric automatic valves installation for each dwelling will limit the problem described giving the same level of comfort for each type of dwelling allowing a more precise heating distribution.

6 Reporting period

In the framework of R2CITIES project the timeline for the demo implementation has been based on different deadlines as report in the picture below. Due to the national framework a two steps approval process was established (preliminary and definitive project) and according to the estimated timeline the tender to select who will perform the works with detailed interventions defined should be ready for the end of October 2014 corresponding to M16. Than works for the district renovation are supposed to last one year from M22 to M34 thus allowing having one year after the conclusion of the refurbishment for the monitoring of benefits that the intervention had provide.

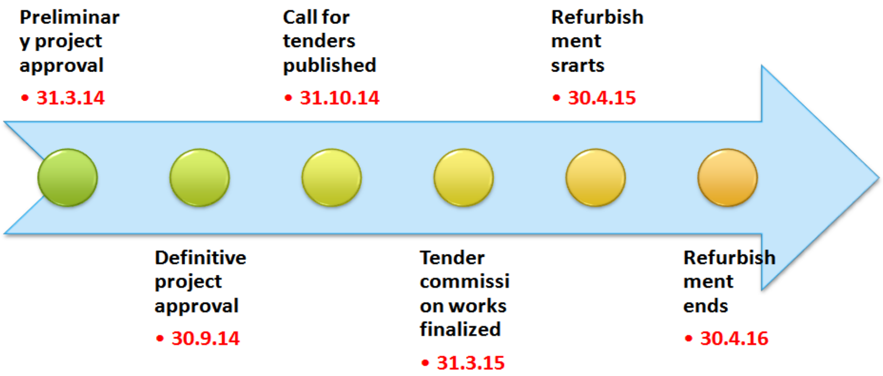

Figure 8: Genova timeline

The reporting period that will last 12 Months will began at May 2016 corresponding to M35 and will last up to April 2017 corresponding to M46. In this way in the Genova demo site it will be possible to gather the information related to one whole year and in particular to one whole heating year. The heating year in Genova is regulated by the regional law and it normally last from the 1st November to the 15th April. May 2017 will be then used for the assessment of savings achieved analyzing the data against the data available from the baseline period.

6.1 Monitoring and measurement

Before executing the various measurements during the reporting period, it should be verified that the ECMs are installed and operating properly and that they have the potential to generate savings. Operational verification may involve inspections, functional performance testing, and/or data trending with analysis.

For the assessment process, the variables to be monitored in the Genova demo site during the reporting period are the following ones.

- Heating demand/consumption for the whole district gathered from the natural gas generation system output and from the single individual metering equipment installed.
- Gas consumption from bills and metering equipment installed upstream the boiler.

7 Basis for Adjustment

The baseline energy curve is based on energy consumptions, expressed in terms of MWh of natural gas, obtained during the period of data collection specified in the section above. These consumptions are directly related through - the efficiency of the boiler, the efficiency of the distribution system and the efficiency of the regulation system-- to the estimated thermal energy demand of the dwellings directly as influenced by their specific characteristic described in D1.1.

To properly document the impact of the ECM it's necessary to compare the m^3 of natural gas consumptions before and after the ECM implementation. Because this data depends on the external temperature (before ECMs implementation) and several other factors (after ECMs implementation) and because each year has different climatic conditions, it's not possible to directly compare the consumption values. For this reason it's necessary to build a mathematical algorithm that can express the energy behavior of the building cleared from all the variables that can alter it. This mathematical expression is known as "adjusted energy baseline model". The "baseline energy" use pattern before ECMs installation defines the relationship between energy use and production. Following ECMs installation, this baseline relationship is used to estimate a new baseline called the "adjusted baseline" that takes into account factors called "static factors" and independent variables. The saving, or "avoided energy use" is the difference between the adjusted-baseline energy and the energy actually metered during the reporting period.

The adjustment to the baseline curve in the reporting period will be made taking into account the set of condition listed below:

- changing type or way of utilization for some dwellings (static factor);
- other ways to improve thermal insulation realized by single tenants independently (static factor);
- changes in weather conditions (different average external temperature compared to that one measured during the baseline period)

7.1 Independent variables and the basis for adjustments

Independent variables refer to regularly changing parameters affecting the energy use of the site. These may be environmental or operations based, including

- nature based, e.g. ambient temperature, humidity, rainfall, wind speed/direction;
- site specific, e.g. occupancy, operating hours;
- system specific.

From an M&V perspective, identifying and incorporating independent variables is an important step to ensure a like-for-like comparison. The impact of the variables on energy use may be random, cyclical or changing according to predetermined patterns.

The independent variables that affect the adjusted baseline, reference of the reporting period, are those related to the weather different conditions between baseline period and reporting period. These parameters affect the curves of energy requirements of the dwellings and consequently the energy production of the thermal power plant.

As described in D1.1 (paragraph 4.8) for given physical characteristics of the envelope of the buildings different external weather conditions (in particular external temperature) lead to minor or greater energy requirements to maintain the same internal degree of comfort for each day of the thermal conditioning period.

For heating consumptions of Genova demo site, the only independent variable considered that has an effect on the energy use is the external air temperature (that affect directly HDD parameter) as the only system of regulation of the centralised boiler is a climatic unit.

This data has been used as the only independent variable in the construction of the baseline model through a simple linear regression with the dependent variable: natural gas consumption.

As described below has been identify the relationship between the consumption measured in the last four season and the equivalent external ambient temperature to create an algorithm that keep in relation consumption and external ambient temperature.

7.1.1 Degree Days

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

When looking at 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[3] 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" [4]. 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, this definition is adopted:

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

[3] European Commission – Eurostat, http://epp.eurostat.ec.europa.eu

[4] Panorama of Energy, Energy Statistics to support EU policies and solutions, Eurostat and European Commission (2007), ISBN 92-79-03894-X.

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.

8 Analysis procedure for calculating results

To calculate the adjusted energy baseline model it is necessary to use a simple linear regression method in which the dependent variable is the monthly m^3 of natural gas consumption (for heating) and the monthly mean value of HDD. Both these data are expressed in monthly step and constitute a set of four heating season (2010-2014) each of which is composed by six month for a total of 24 couple of data.

Month – year	m^3 natural gas consumption	°C external air temperature	HDD
nov-10	16053,45	12,53	164,1
dic-10	28527,00	6,58	354,02
gen-11	31292,00	7,87	314,03
feb-11	21235,00	10,21	218,12
mar-11	19974,00	11,10	213,9
apr-11	7785,00	15,47	75,9
nov-11	12020,00	13,90	123
dic-11	22426,00	11,63	197,47
gen-12	15905,00	9,58	261,02
feb-12	32324,00	6,38	325,36
mar-12	17693,00	13,58	137,02
apr-12	11798,00	13,93	122,1
nov-12	15673,00	13,40	138
dic-12	24297,00	8,87	283,03
gen-13	28504,00	7,77	317,13
feb-13	25631,00	7,29	299,88
mar-13	21815,00	9,29	270,01
apr-13	13805,00	12,20	174
nov-13	16 154	13,20	144
dic-13	24 958	11,32	207,08
gen-14	19 771	9,55	261,95
feb-14	23 788	10,32	215,04
mar-14	15 268	12,52	169,88
apr-14	11 349	15,47	75,9

Table 9: Genova data

The baseline measurement campaigns as well as the post retrofit data campaigns are influenced by not-adjustable independent variables (internal/external and environmental conditions). It is necessary to measure also these variables and to associate to each campaign its environmental condition measure.

As an example, some variables could be the following:

- Not-adjustable

  - Occupation (Air quality CO_2)
  - Air quality
  - Environmental temperature
  - Environmental humidity
  - Solar incidence
  - Wind force and direction
  - Rain
- Adjustable
  - Indoor temperature
  - Indoor humidity
  - Windows openings, shutters
  - Indoor lighting
- Energy consumptions:
  - For the district/building/flat/common areas
  - Primary Energy Consumption (gas, electricity, Renewable Energy Sources, etc.)
  - For each application (heating space, Domestic Hot Water, etc.)
  - Energy for lighting, appliances.

From the above list of measures, the external temperature has the highest influence on the ambient conditioning process and is the most responsible of variations in energy consumptions.

The energy saving data coming from both baseline and post retrofit measurement campaign conditions in fact are not directly comparable, but it is necessary to adjust the baseline DSI with correction curves that bring them to the same conditions in which the actual measure campaign is performed. The correction curves put in a correlation the DSI with the external variables in order to determine a Corrective Factor. In this way, if the external variable changes, the DSI is modified accordingly (obtaining adjusted baseline DSI). For each of the tentative parameters above it will be necessary to define, in each savings report, which measures will be compulsory and which will be option.

Mathematical modelling is used in M&V to find a mathematical relationship between dependent and independent variables. The dependent variable, usually 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. For example, if one of the "Xs" is production level, the model would assess whether the variation of energy from its mean is caused by changes in production level. The model quantifies the causation. For example, when production 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:

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

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_{it} (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 Genova 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:

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

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 ie is the estimated values, im 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.

The energetic linear regression model at district level is obtained from the thermal model of the district, which is calibrated with the monitoring data.

9 Energy prices for cost savings calculations

“Cost savings” should not be confused with “cost avoidance”. The term “cost savings” infers that energy cost post-retrofit will be lower than those within the baseline period. This approach does not take into account changes in factors that determine energy use (e.g. changes in site activities, effects of independent variables such as production or weather, etc.), or price risks such as changes to energy contracts or tariff rates.

The effects of these factors may result in a situation in which energy cost rises despite a reduction in energy use. Although there would not be “cost savings”, “cost avoidance” could be claimed.

This concept is very important in relation to the assumptions used for the economic analysis. The right amount of economic benefit can be obtained operating the comparison between two scenarios: (Energy consumptions forecast with implemented ECMs) – (Energy consumptions forecast with no implemented EMCs). The rightfulness of this position is in contrast with the need of forecasting a future quantity, thus introducing uncertainties in the analysis.

The cost saving could be evaluated once that the tariff conditions for gas supply are known. Tariffs are variable based on the relative suppliers but for the first evaluation in Genova an average valued was considered and such value is: 0.9 €/m^3 VAT included.

10 Meter specifications

Before the ECM intervention, the metering point of natural gas consumption is located in the boiler room. The consumption here metered will be subsequently divided into each-dwelling consumption through a proportional method that assigns a number of thousandths to each flat. The sum (of this number) for each dwelling should give thousand because it represents the totality of consumption. The metering period covers an heating season that in Genoa lasts from the 1st of November to eh 15th oh April.

When evaluating buildings and systems used therein from an energy point of view, energy flow rates are taken into account for heating, cooling, illumination and heating of drinking water.
Herein, in order to evaluate the buildings energy performance, it is necessary to distinguish between energy requirement and energy demand. Energy requirement is the amount of energy needed in order to meet requirements for indoor temperature, indoor humidity, illuminance, etc. Energy demand is the amount of energy the present systems must use in order to satisfy energy requirements. The type of energy demand required for benefits delivery, distribution and energy generation is known as energy demand for generation or final energy demand. Energy demand defines the amount of energy that is used from energy supply companies (oil, gas, etc.). In other words, the energy demand is the primary energy needed.
In order to evaluate the building energy performance and the benefits due to the energy efficiency interventions, it is necessary to evaluate and monitoring the present energy needs and the consumptions before and after the operations.
The kinds of energy that have to be monitored are:

1. Electric
2. Thermal

As above-mentioned, the building energy flow rates are strongly influenced by indoor and outdoor conditions. Therefore, these parameters have to be considered.
Here follow, the indoor parameters:

1. Temperature
2. Humidity
3. CO_2 concentration (that could be related to the occupancy or to the schedule activities)

Here follow, the outdoor parameters:

1. Twilight
2. Brightness
3. Rain
4. Temperature
5. Day/night
6. Wind speed

The building energy performance evaluation can be analysed applying the whole-facility method (C method) that is the most appropriate approach in the studied case. Option C is a whole-building verification method. Savings are based on actual energy consumption as measured by the utility meter(s). Estimated savings will likely vary over the contract term, even when adjusted for weather and other factors. Option C verification methods determine savings by studying overall energy use in a facility. The evaluation of whole-building or facility-level metered data is completed using techniques ranging from simple billing comparison to multivariate regression analysis.

10.1 Collecting data, equipment requirements and metering specifications

1. Electric consumption monitoring

The electric energy meter puts residents in multi-unit residential and commercial buildings in control of their own cost by using a dedicated meter to measure the energy used in each individual unit for several utilities. This kind of meter lets residents pay only for what they use. Knowing how and where electricity costs arise will also help improve the environment by cutting the need for “unnecessary” electrical energy production. A specific example is the multitude of devices with “stand-by” consumption connected to the mains supply but not in use. These include transformers for mobile phone chargers, TVs and computers, halogen lamps or other ones, etc.

Figure 9: Electric energy meters

The meters are ideal for many applications and installations and they support a wide voltage range as well as a wide temperature range. The display is pixel-oriented and can display up to four quantities at the same time. Navigating the meter is easily done via the push-buttons below the display. To configure the meter settings, the set button must be accessed. This button is protected against unauthorized use when the “glass lid” on the front of the meter is closed and sealed. The average power consumption of the common meter is very low, less than 0,8 VA.

2. Thermal consumption monitoring

The thermal energy meter is the system for measuring the amount of energy used by individual households for heating their homes. The processing of data relating to the difference between the temperature of the water supply and the return, along with the data relating to the volume of water used by each user, are used to calculate the amount of energy actually consumed.

The system consists of a thermal energy meter, a motorized valve controlled by a programmable chronothermostat located inside the apartment. In this way, the user can adjust the temperature of the household and determine the hours of heating. The user is, therefore, able to manage the system according to his/her specific needs.

In this case, for Genoa demo site, ABB does not provide a thermal energy meter device because this kind of metering is already included in the thermal system replacement. ABB will provide each dwelling with the thermal regulation and temperature control systems, in order to manage the heating system according to the need. The temperature data is transmitted directly on the KNX bus.

3. Equipment for indoor parameters evaluation

The Air Quality Sensor is a CO2 room air sensor. It measures the CO2 concentration, temperature and relative humidity of a room. The power is supplied via the KNX, and an additional auxiliary supply is not required. The connection to the KNX technology is implemented via a bus connection terminal in the device interior.

Here follows a picture of the device:

Figure 10: Air quality sensor

4. Equipment for outdoor parameters evaluation

A dedicated sensor, that could be located on the roof, acquires the weather data and transmits them directly on the bus. The Weather Sensor records wind velocity, rain, brightness in three directions, twilight, temperature, date and time (GPS radio receiver). The Weather Sensor only functions in combination with the Weather Unit that elaborates data and makes them usable for the monitoring and potential commands. External influences such as wind, rain, brightness and temperature are quite significant in determining many building management processes. For example, a heating system that is controlled depending on the external temperature ensures a pleasant temperature and also the energy-efficient control of the boiler.

Here follows a picture of the weather sensor:

Figure 11: Weather sensor

The measured weather values can be directly transmitted on the bus in a cyclical way (every 5, 10, 30 seconds or 5, 10, 30 minutes up to max. every 24 hours) or after a change of a Lux values, but it is also possible to consider both of them at the same time.

The baseline measurement campaign, as well as the post retrofit data campaign, are influenced by not-adjustable independent variables (indoor and outdoor conditions). It is necessary to measure also these variables and to associate each campaign with its ambient condition measures. This way, it is possible to compare the amount of electric and thermal energy consumed before and after the energy efficiency improvement interventions.

10.2 Key measurement parameters

Once defined the specifications, procedure and equipment for the monitoring phase of the project, the variables which should be collected are highlighted in this section. The list of key measurement parameters are reflected in Table 10 where the variable, resolution, meaning and when is usable are remarked. 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 loss of data. Finally, the temperature is not varying excessively in a period of 15 minutes, therefore, this resolutions 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, these requirements are those minimum for the M&V plan, but monitoring & visualization (see D4.2) defines the final resolution period.

Data-point name	Resolution	Description	Time period
Gas consumption	Monthly	Total gas consumption of actual heating power plant taken from bills according to the current gas consumption for heating	Baseline
Gas consumption	Monthly	Total gas consumption of new heating power plant taken from gas meter according to the new gas consumption for heating	Reporting
Actual boiler energy generation	Monthly	The energy generated by the actual boiler and provided to the buildings through the distribution system	Baseline
Condensing boiler energy generation	15 minutes	The energy generated by the condensing boiler and provided to the buildings through the distribution system	Reporting
Heating energy consumption	15 minutes	Individual energy for each dwelling used for heating purposes	Reporting
Electric energy consumption	15 minutes	Individual energy for each dwelling used for different purposes	Reporting
Outdoor	15 minutes	External temperature for calculation HDD	Baseline and

temperature	or CDD	Reporting

Table 10: Metering requirements for the M&V plan

For the construction of the baseline and reporting period curves has to be underlined that only energy generation data from the natural gas condensing boiler will be considered; this values will be compared to the energy generation data gathered from the monitored consumptions of the actual energy generation system.

A similar comparison could be carried out between natural gas consumption before and after ECMs implementations.

10.3 Estimated parameter(s) and justification for estimates

Further devices could be installed for the evaluation of comfort and discomfort. The building energy performance evaluation can become more precise, if the comfort analysis is taken into account. The salient features of "high-quality buildings" include indoor air quality, thermal comfort, visual and acoustic characteristics, as well as low impact on the environment.
The final goal of high-quality buildings is to be, at the same time, healthy, thus decreasing the energy use by buildings and consequently resulting in a reduction of CO_2 emissions from primary energy used for ventilation, heating, cooling and humidity control.
The outdoor environmental characteristics (temperature, solar radiation, wind, dust, pollution, noise, etc.) change with the location of the building so it is very important to compensate for environmental changes using active techniques also thanks to the building automation.
Here follows a list of some potential additional devices. They are some dedicated microclimate instrument to measure different parameters.

Additional parameters	**Description**
Indoor light sensor	It is a brightness sensor for closed rooms. The light sensor is mounted in a standard installation box in the ceiling
Outdoor Lux sensor	Lux sensor for illuminance measurement according to the response of human eye in outdoor applications
Radiant temperature sensor	A globe thermometric probe. Opaque copper is made to measure radiant temperature for thermal environment index calculation
Fan type anemometer	Fan type anemometer sensor for directional measurement of air speed inside pipes or environments. Cable with Mini-Din connector for data loggers with connector input type
Temperature probe	Independent probes: one for measuring floor temperature and the other one for measuring temperature at the height of the ankles. Used for measuring local discomfort due to vertical thermal gradient. Different couple of probes can be located in different points.
Thermohygrometer	It is an instrument to measure environmental temperature, relative humidity and dew point

Table 11: Possible additional devices

The above-listed devices do not belong to the KNX network but they are directly connected to the PLC thanks to the I/O modules. The parameters are stored and monitored in the same server.

11 Monitoring responsibilities

The specific equipment installed are detailed in the section below. In terms of monitoring responsibilities the main stakeholders involved in the Genova demo site are:

- 162 household tenants: they should not damage the equipment and take advantages from the measures provided to optimise their behaviour to obtain higher energy savings.
- Genova team:
    - The municipality of Genova as building owner will be responsible for the collection of info on devices malfunctioning or user requests.
    - ABB and DAPP will take care of the communication between the equipment and the server for data storage.
    - UNIGE: will check if the profiles monitored are in line with the project expectations.

11.1 Technical monitoring

After the ECM intervention, each dwelling will be equipped with a local heat counter that will give the consumption of each dwelling served by the same plant.

This consumption data will be collected for each dwelling and will be also associated with the internal air temperature registered in each dwelling (for the same period) by a local control station.

Moreover, each electric switchboard of each street number will be equipped with an electric energy meter. The meters store all energy registers and input counter values together with a date/time stamp upon change of day, week or month. This way, all total values regarding all dwellings of each street number are stored. In meters equipped with the tariff feature, all the tariff registers will also be stored. The electric and thermal consumptions data are stored and monitored from a central control system located in the common power station room.

All of the previous-mentioned energy meters and equipment for key measurement parameters can be interfaced to the PLC with, for example the Ethernet, Profinet, Profibus, Modbus TCP protocol or other ones.
The AC500 is the ABB PLC of choice when scalability, flexibility, performance, integration and communication are mandatory. Numerous I/O modules, carefully specified powerful CPUs and real-time communication couplers provide the basis. It is used for the experimental sensors acquisitions, central visualization and commands. All the thermal and electric energy consumptions data and system information are collected in a central server and can be visualised thanks to the computer located in the central power station room.

The communication between the operating system (for example Windows, etc.) and the PLC is made possible thanks to the OPC software standard interface. The OPC server is a software package that converts the hardware communication protocol used by a PLC into the OPC protocol and provides access to real-time process information in protection and control devices.

After the central acquisition in the Genoa demo site, the Web Application retrieves from the Server the processed data through the (Secure) File Transfer Protocol ((S)FTP) thanks to the available Internet connection. At the end, the processed data will be sent by the Web Application to Concerto's Server data collector.The data that will be exported by the Web Platform will be used by the CONCERTO platform for its indicators related to impact assessment and energy performance assessment.

12 Expected accuracy

The expected accuracy in this M&V process is:

1) Measurement and data capture:
   - m^3 of natural gas consumptions for heating: these data were directly provided by the centralised plant manager and are the same data through which he pays the natural gas supplier and through which he prepares bills for each dwelling.

   - °C of external air temperature to calculate the HDD: these data were taken from two sources. The weather underground source gives data from METAR service but it doesn't certify weather data. The A.R.P.A.L source gives data from a proper weather station which is controlled and recalibrated twice a year. Under payment it's possible to get the certification of the data.

2) Sampling:
   - Consider the HDD as the unique independent variable (in the construction of the energy baseline model) is not a real sampling because the only regulation system currently present is a climatic unit.

3) Data analysis:
   - As reported in D4.1 (chapter 5), the simple linear regression is a good method to construct a baseline models like this one. With the data listed above it was obtained an high value of the R^2 coefficient and, even that's already a good result, it's possible to reasonably imagine that it could be even higher if the independent variable "external air temperature" was provided in hourly mean value (instead of daily mean) so that could be possible calculate a mean monthly value only considering the actual hours of operation of the centralised boiler.

Uncertainties are related to the following aspects:

- Equipment uncertainties
- Communication problem
- Calculation protocols and adjustments on independent and static factors

13 Budget and resources

The interventions that have been planned in the framework of R2CITIES project are related to an overall area of 18.000 m2. According to the FP7 call requirements it is foreseen to have an availability of 100€ for each square meters that will be renovated. Due to the specific context in Genova, where there will not be any further contributions for the realization of the intervention (tenants and ESCOs for example will not be involved) the budget available for the implementation of the ECM is fixed to 1.8 Million Euro and it this amount is co-funded by the Municipality of Genova partner of R2CITIES project.

Resources are currently defined only in terms of numbers, since we know that the renovation process will be addressed to 162 dwellings belonging to the two high bars of the district covering 18000 m2. The features of the resources that will be deployed in the demo will be influenced by the tender procedures and by the competition that will be created among the stakeholders that will apply as suppliers for the tender itself.

14 Report format

The validation of the overall approached followed as M&V plan will be reported in project Deliverable “D4.8 Feedback of the M&V plan implementation and proposed improvements”. The main chapters will be the following:

- Baseline and reference period
- Metered data (sample)
- Computed Y and X data
- Regression Equations and adjustment
- Results from analysis
- Results from measures.

15 Quality assurance

To perform an adequate linear regression analysis it's necessary to synchronize data. The data synchronization has to be done after the verification of the quality of data themselves.

As reported di D4.1, to perform a data quality control procedure it's mostly recommended to check if dates and times are correct in the extract of measuring equipment, if the measurement frequency is correct and if calculated data has integrity against historical data.

In the framework of R2CITIES the quality and availability of data will be monitored initially biweekly. This will allow checking if the frequency is reasonable or if it will be necessary to re-calibrate the approach. In case of communication stop it will be necessary to detect those as soon as possible in order to avoid lack of data for the analyses needed.

The draft reports developed will be checked by all the partners involved in the demo site.

16 M&V Plan for Genoa demo-site

Taking into account all the information presented in the previous sections, the development of a specific M&V Plan for the Genoa demo-site will has been based on the M&V planning process shown in Figure 12, which was presented in Deliverable 4.1 “Report of the measurement and verification protocol analysis”. The specific M&V Plan for Genoa demo-site can be found in the spreadsheets that accompanies this document.

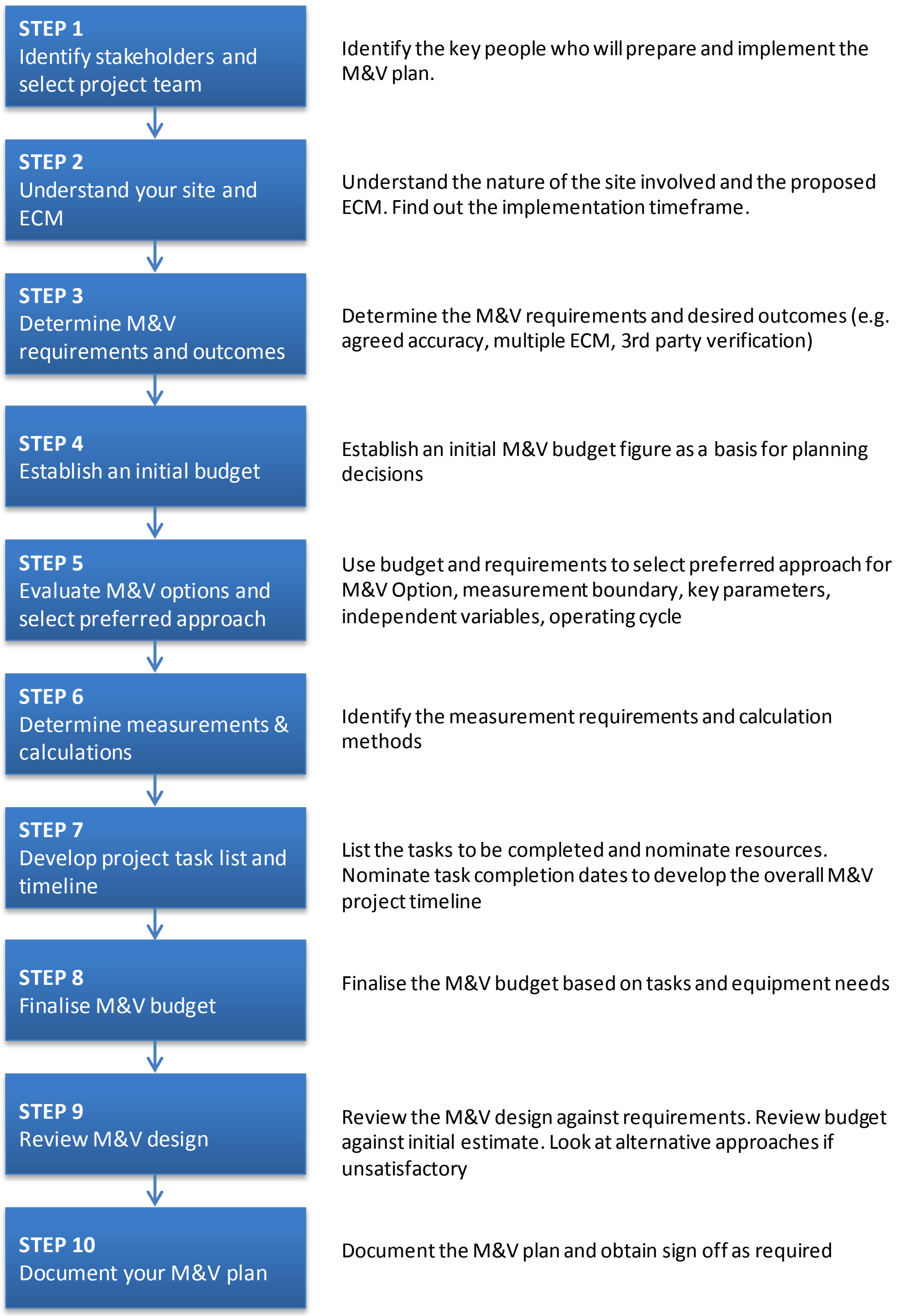

Figure 12: M&V planning process