MAtchUP

D2.2: Simulation models of the building stock, energy system, transportation, urban infrastructures in Valencia

WP 2, T 2.2

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Technical References

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Abbreviations and Acronyms

Acronym	Description
GHG	Greenhouse Gas
ICT	Information and Communications Technology
DHW	Domestic Hot Water
KPI	Key Performance Indicator
PV	Photovoltaic
EV	Electric Vehicle
BEST	Building Energy Specification Table
LFG	Landfill Gas
B(E)MS	Building (Energy) Management System
CHP	Combined Heat and Power
WP	Work Package
EPBD	Energy Performance in Buildings Directive
SCC	Smart Cities and Communication
SUMP	Sustainable Urban Mobility Plan
SEAP	Sustainable Energy Action Plan
TEST	Transport Energy Specifications Table
RES	Renewable Energy Sources
DH	District Heating
CPT	Clean Power for Transport
SCTP	Smart City Technology Packages
IPMVP	International Performance Measurement and Verification Protocol
M&V	Measurement and Verification

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0 Abstract

Within the scope of the MAtchUP, large scale demonstration projects integrating innovative technologies in the energy, mobility and ICT sectors will be deployed in Valencia (Spain), Dresden (Germany) and Antalya (Turkey), with the final aim of promote the transformation towards more efficient, sustainable and advanced urban models. To coordinate the complex activities within each demo-site three separate but parallel Work Packages (WP2, WP3 and WP4) have been established.

This report, “D2.2 Simulation models of the building stock, energy system, transportation, urban infrastructures in Valencia”, documents results of “Task 2.2 Baseline of interventions definition, Subtask 2.2.1 Simulation models (buildings, energy systems, and city infrastructures)” of the work package 2 dedicated to Valencia demonstrator.

The objective of the subtask 2.2.1 is the development of simulations and mathematical models needed to calculate and adjust baselines; since baselines are needed to have a reference period to compare the results gotten during the monitoring period and evaluate the improvement measures implemented in Valencia’s interventions.

This deliverable D2.2 includes the description of the methodology and tools used for develop the models, as well as the definition of those interventions that will require simulations and adjustments of its baseline. The report will be completed in the version D2.15 with the correspondent simulations and calculations.

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1 Introduction

1.1 Purpose an target group

This deliverable provides the methodological tools to be used in MAtchUP for determining through mathematical models any data necessary for the calculation of an indicator, when such data cannot be directly measured, obtained from historical records or through well-founded assumptions.

The data obtained through simulation may be used for the calculation of any kind of indicator (either technical, social or economic) defined in deliverables D5.1, D5.2 or D5.3, at action or intervention levels.

A typical use of simulation models is the determination of the baseline of energy consumption of new buildings. In such a case, the simulation must provide the consumption of a building of the same dimensions, use, occupancy, location… operating under the same weather conditions of the real one, but built with the minimum legal requirements for energy efficiency.

Although not really simulation models, this deliverable also provides information on the use of mathematical models for the calculation of some indicators. Typically, for the adjustment of a baseline of energy consumption, obtained from historical records, to the existing circumstances (ambient temperature, occupancy, activity…) during the reporting period, which are usually different from the ones existing during the baseline period.

Therefore, this deliverable provides:

- Identification of the couples indicator-action or indicator-intervention requiring simulated data for their calculation
- Description of the simulation methodology to be used in each case:
    - Tool used and characteristics
    - Model description and boundaries
    - Input data required
    - Output data obtained
    - Assumptions
    - Calibration/validation of the model
- Identification of the couples indicator-action or indicator-intervention requiring baseline adjustments for their calculation
- Description of the methodology to be used for baseline adjustments in each case:
    - Baseline period
    - Identification of factors requiring routine adjustments
    - Identification of factors requiring non-routine adjustments
    - Baseline data
    - Mathematical model obtained

The specific results obtained in each case will be specified and used in D2.3- “Baseline of Valencia demonstrator”.

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To provide the simulation models for the evaluation of the baseline of the areas of intervention in Valencia. These baselines will be the reference for the final technical assessment to be done in WP5.

These models will allow to evaluate at least the savings of the energy consumption and associated impacts (GHE and cost savings) obtained of the buildings, city infrastructure and, if necessary, in urban mobility actions

1.2 Contribution of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
ITE	Deliverable Leader. Leading definition of the actions and development of contents.
DRE	Energy expert of Dresde. participated in definition of ToC and chapter 2.1.3.
DEM	Energy expert of Antalya, participated in definition of ToC and chapter 2.1.1.

Table 1. Contribution of partners

1.3 Relation to other activities in the project

This deliverable is part of the Task 2.2 “Baseline of interventions definition”, more specifically of subtask 2.2.1 “Simulation models (buildings, energy systems, city infrastructures). The aim is to provide methodological tools to determine savings where it is computed through simulation or mathematical models. The outcome of Subtask 4.2.1 will be implemented in Subtask 4.2.2 “Baseline of interventions”. “Once developed the simulation models and established the design and evaluation framework in WP5, the reference baseline to evaluate the performance is outlined and implemented.” In WP5 in T.5.1 “Technical evaluation framework” it is highly recommended to design simulations for indicators selected for technical evaluation of the smart city solutions deployed in the demonstration actions to define expected performances of them.

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2 Approach for the Development and Implementation of Baseline Models

2.1 Models for baseline in energy interventions

The energy baseline (EnB) is a reference basis for comparison of energy performance and its adequate definition is essential to evaluate the real improvement derived from an energy intervention (ISO 50.006).

Sometimes, energy baselines can be directly stablished from consumption measures, without require any model. Nevertheless, in most cases, the effect of different variables needs to be taken into account, being necessary the use of mathematical tools to facilitate the adjustment of consumption data to environmental conditions of the evaluating periods. Moreover, other times, when critical information of the reference period does not exist (because of it is not available or the facility is new and there is no historical) it may be necessary to simulate, estimate or calculate the expected energy consumption.

At this regard, the energy baseline could be:

1 – Direct consumption records.
2 – Adjusted consumption from real energy records.
3 – Simulated/calculated consumption.

2.1.1 IPMVP protocol

MAtchUP project involves many actions and interventions under large scale demonstration projects of innovative technologies in energy, mobility and ICT sector. In line with the objectives of the MAtchUP, performance of each action and intervention needs to be analysed with a systematic approach and framework. The determination of the performance requires both accurate measurement and replicable methodology to reliably determine actual savings created within the project activities. IPMVP (International Performance Measurement & Verification Protocol) developed by the Efficiency Valuation Organization (EVO, 2012) has been identified as one of the suitable methodological tools to be followed for this project activity (MAtchUP D5.1 Technical Evaluation Protocol). This protocol defines the principles and procedures that an adequate measurement and verification plan should consider, being a prestigious address in this field.

Measure and verification process allows reliably and objectively verify the real savings that one or several energy conservation measures (ECM) produce, from the energetic, economic and environmental point of view.

Energy “Savings” or “Reductions” cannot be directly measured and requires comparing of two states: before and after implementation, being necessary to have two similar comparison periods (the reference period or baseline needs to have equivalent conditions to the reporting period).

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Baseline	Ξ	Reporting period
(Before ECM)		(After ECM)

To equate both periods, it is necessary to adjust the energy consumption of the baseline to the conditions of the reporting period, taking into account those variables that influence energy consumption and can change over time. There is also the option of obtaining standardized savings from fixed operating conditions, for which it is necessary to make adjustments over the two periods.

In an example, the KPI E2 of MAtchUP "Reduction in annual final energy consumption" cannot be directly measured since reduction represents absence of energy use or demand. Thus, the KPI is calculated by comparing the energy consumption before and after the implemented action. The implemented action might also have an impact on conditions (such as number of occupancies in the building, etc.), which must be also taken into account by making suitable adjustments for these changes.

Next graph shows an example of the energy consumption registered before and after the implementation of an energy conservation measure, and the adjustment of the baseline to the conditions of the reporting period in order to compare both periods and estimate savings.

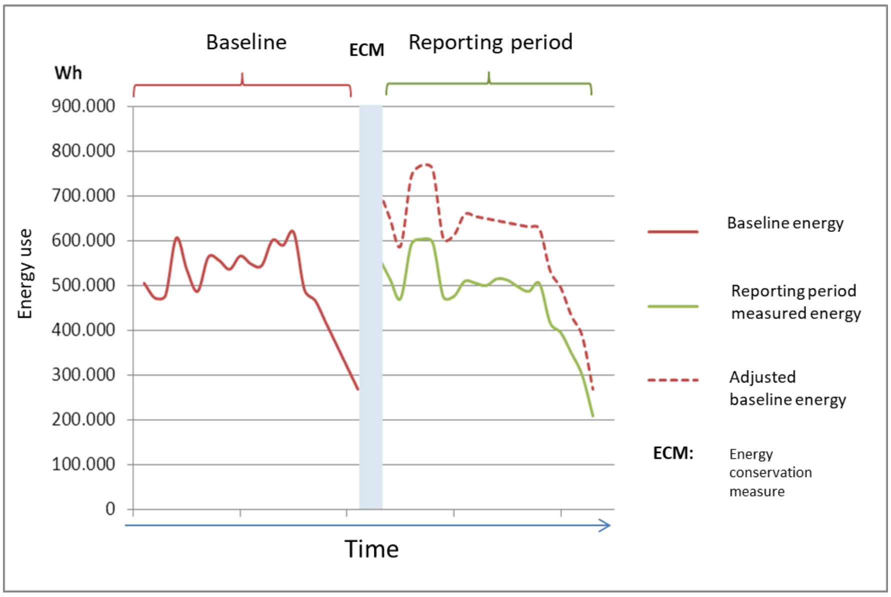

Figure 1 Example energy history

Accordingly, the IPMVP protocol proposes the next equation for calculating energy savings:

$$\boxed{Energy\ Savings = (Baseline\ Period\ Use\ or\ Demand - Reporting\ Period\ \ Use\ or\ Demand) \pm Adjustments}$$

Equation 1 IPMVP. Fuente: IPMVP Core Concept, EVO 10000 – 1:2016.

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The term baseline refers to the time period prior to the action[1] (modification or intervention such as insulating a building envelop, installation of a PV system, etc.), that provides a reference to which later performance of the action can be measured. How the baseline period use or demand is identified depends mainly on which approach is selected for Monitoring and Verification (M&V). The approach is mostly defined, inter alia, by the availability (and/or reliability) of the data itself.

The baseline in an existing facility, building, infrastructure, system etc. is usually the performance prior to modification. The baseline physically exists and the baseline use or demand could be either measured directly through monitoring or indirectly through documentation (such as energy bills) and assumptions where monitoring is not an option. A good example for this type of baseline approach could be the retrofitting of an old building. The use of better insulation materials (modification) is anticipated to decrease the heating demand resulting in reduction in energy use. Since the building is already physically there before the modification there is a high chance of monitoring the real energy use prior and after the modification to calculate the energy savings.

In new-built cases, the baseline is usually hypothetical and defined based on code, regulation, common practice or documented performance of similar facilities, buildings, systems etc. Use or demand data from a simulation can take place of the missing data for either part or all of the facility, building etc. An example would be the case where a building is completely demolished to achieve better performance including better energy ratings. In this case it might not be an option to monitor the prior performance. Thus, a simulation program could be used to model the performance of a similar building based on common practice techniques and materials.

Determination of savings is a necessary part of good design of the actions itself. Therefore, the basic approach in savings determination is closely linked with some elements of design. The basic approach common to all good savings determination involves several steps including;

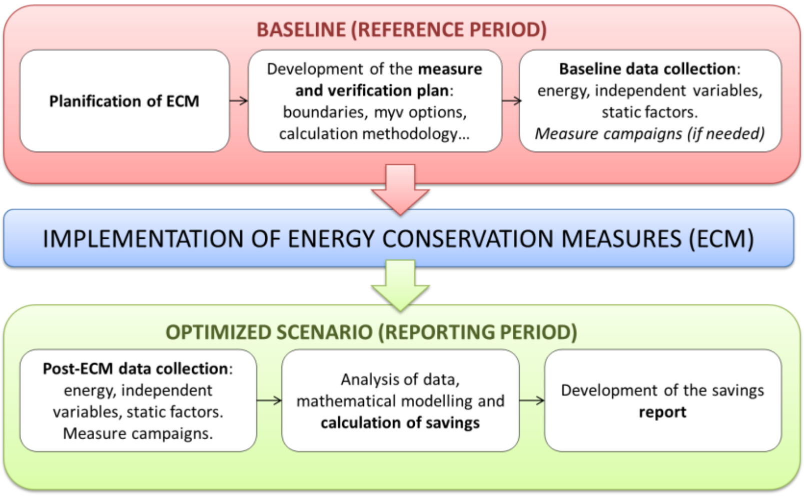

Figure 2 M&V Procedure

[1] Under the IPMVP document, the term ECM (Energy Conservation Measure) is used also used to define the action and is described as "*Action or set of actions designed to improve efficiency or conserve energy or water or energy demand*".

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2.1.1.1 Overview of IPMVP options

When facing the development of a measurement and verification plan, it is necessary to analyze which alternative is more convenient to address each study, depending on the scope, availability of information, budget, etc.

Therefore, the IPMVP protocol defines four options for carrying out a measurement and verification plan, which are structured as follows:

Retrofit isolation	Whole facility	Calibrated simulation
Only the effect of the ECM is measured. - Savings are not affected beyond the measurement boundaries. - Normally measuring equipment is needed (energy meters) - The adjustments can be simple (less independent variables and statistic factors are affected) **OPTION A**: Measurement of key parameter and estimation of the others. *Eg. Lighting: power measurement and estimation of operating hours.* **OPTION B**: Measurement of all parameters needed to compute energy. *Eg Replacement of equipment by a more efficient one, measuring energy consumption before and after the substitution.*	All the effects of the facility are measured. - Every positive or negative effect (intentional or unintended). - Usually use utility meters. - The adjustments can be more complex. **OPTION C**: Verification of the whole facility using real data from both periods: reference and reporting one. When several improvement measures want to be analyzed, when a single measure affects several equipment in an installation, when there are several cross effects, or when the savings on global consumption are needed. *Eg Improves efficiency buildings.*	**OPTION D**: Calibrated simulation is used when there is not data from some monitoring period or data are not of sufficient quality. Simulation tools like the open software Energy Plus could be used. Eg. New buildings.

Table 2 Overview of IPMVP options

As mentioned earlier, the selection of IPMVP options depends on several conditions. For example, option A is the only option suitable, where energy related parameter are already known with adequate accuracy and estimations may be made of some action

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parameters but others must be measured; on the other hand Option C or D might be opted where savings at facility level are required. If only action level performance is of concern then a retrofit-isolation technique may be more suitable pointing to Option A, B or D.

Taking into account the typology of the energy interventions developed in the project, where several energy conservation measures need to be evaluated at building/facility level, the more common IPMVP options used to define baselines and estimate energy savings are options C and D. Nevertheless, alternatives A and/or B could be also applied in cases when specific effects of isolated measures want to be studied.

Option C is oriented to assess energy performance of the total facility, analysing all the direct and indirect effects derived from the implementation of one or several improvements, being the most used for buildings when there is available data of both, reference and demonstrative period. As said before, when isolated effects of an improvement are analysed, options A and B are more suitable, and information of both periods need to be collected and/or measured. When the baseline information does not exist or has not got enough quality, simulation models need to be applied through option D, as the following diagram shows.

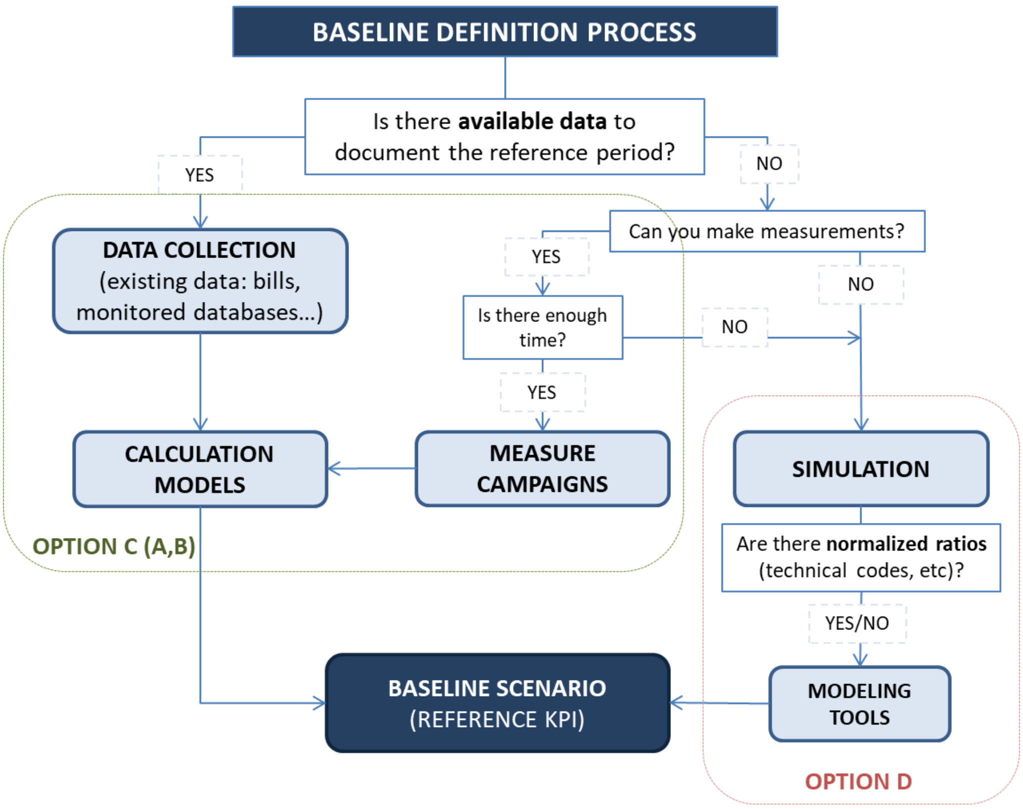

Figure 3. Baseline definition process.

Options A,B

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As mentioned above, retrofit isolation procedures are used when the verification of savings is delimited by the area in which one or several energy measures have been implemented, that is, only the area affected is analysed.

In this case, effects outside the limits of the intervention area are not measured, so utility meters and bills are not the most appropriate to be used, but rather measuring equipment will be placed in the analysis area.

Sometimes cross effects may occur that need to be quantified, and that may be outside the established measurement limits, so it may be convenient to extend these limits or estimate these collateral impacts. For example, an optimization of the lighting installation by reducing its power can be associated with a reduction in thermal load and therefore with an increase in heating needs or a reduction in air conditioning needs.

The main differences between A and B are that in the first option only the key parameter is measured and the rest are estimated while in the second option, every parameters of the energy equation need to be measured and more mathematical adjustments are usually needed.

Option C

According IPMVP protocol, alternative C is best applied when: (1) energy performance of the whole facility will be assessed analysing savings on global consumption, (2) several improvement measures want to be analysed in the same facility, (3) individual performance is difficult to separately measure, being several cross-effects to consider, (4) a single action affects some equipment of one facility, (5) savings are larger compared to the variance in the baseline and reporting period data (>10%) and/or (6) other options are more complex and expensive.

In this regard, the project interventions combine different kind of measures oriented to reduce energy demand of buildings, improve the energy efficiency and increase the use of renewable resources, being not easy to clearly identify the isolated contribution of each improvement to the global energy, socio-economic and environmental impact. Because of that, option C is expected to be the most utilized if there is available data.

To estimate energy savings through option C routine and non-routine adjustment are needed to consider the influence of environmental variables in the variation of energy consumption between the comparison periods. At this respect, to identify the correct independent variables is essential to develop valid mathematical models, as well as having controlled the facility changes that will require non-routine adjustments.

In this option, the energy data is usually obtained from utility meters, whole-facility meters, or sub-meters, and complete years are needed to determine a correct baseline.

Respect to MAtchUP's interventions, reference period values will be gotten when possible from historical monitored data and/or energy bills, while demonstrative data will be gotten from whole-facility meters and sub-meters installed in specific actions of the project. Influence factors will be either monitored (ambient temperature) or collected via questionnaires

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Option D: Calibrated Simulation

Option D involves the use of computer simulation software to predict one or both terms to calculate energy savings. The simulation is required to be calibrated in order to achieve an approximate match between the predicted energy characteristic with the actual metered data. Option D may be used for either the performance of actions for the whole facility or just the performance of individual systems within the facility. In case Option D is used for individual systems within the facility, energy consumption and demand of the system must be isolated from the rest of the facility by appropriate meters, which will be used for the calibration of the simulation model.

According to IPMVP protocol, alternative D is best applied in the following cases: (1) New construction project, where there no physical baseline facility exists; (2) Facility expansion needing to be assessed separately; (3) Centrally metered group of facilities without individual meters in the baseline, but with individual meters after the ECM, (4) Reporting-period energy data are unavailable or obscured by factors that are difficult to quantify; (5) It is desired to determine the savings associated with individual actions, but measurements with other options are too difficult or costly.

The accuracy of the simulation results depends on several factors such as user proficiency and model robustness however one of the most important factors is the level of calibration. Calibration is the process of comparing a result on one piece of equipment or system, to a reference standard. When calibrated, the simulation model should reasonably predict the load shape and energy use of the facility or system. In our case, the calibration is made by comparing model results to measured performance data (post-action monitoring), independent variables and static factors.

Calibration of building simulations is usually done with 12 consecutive months' monitored data over a stable operating period. These data might include operating characteristics, occupancy, weather, loads and equipment efficiency.

2.1.1.2 Selection guide

The selection of the IPMVP Option is based on several issues including the measurement boundary, project conditions, budget and expert judgement. The following template, based on the selection guide provided by the IPMVP Protocol, will facilitate the identification and definition of the best M&V procedures and could be used to summarize the results under Section 3 of this deliverable.

<Name of the intervention>: *Describe briefly the intervention. This might be a copy paste from DoA or action card.*			
Involved Action	Savings	Affected Equipment	Expected Savings
Provide a list of involved actions	*Describe in brief how the measure saves energy or*	*Provide a list of affected physical*	*A preliminary result on expected*

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	other resources (e.g., reduction of energy)	*equipment*	*savings*.
IPMVP Option Selection Guidance *Follow each question starting from 1. Highlight choice of selection with a colour.*			
Intervention Characteristics		YES	NO
[1] Need to assess Actions' performance individually?		Please go to [2]	Please go to [3]
[2] Able to isolate Actions(s) with meter(s)?		Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?		Please go to [5]	OPTION D
[4] Need full performance demonstration?		Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?		OPTION D	Please go to [6C]
[6A] Missing baseline period data?		OPTION D	OPTION B
[6B] Missing baseline period data?		OPTION D	OPTION A
[6C] Missing baseline period data?		OPTION D	OPTION C
Measurement Boundary *The selection of IPMVP Option needs to be complemented with defining the measurement boundary. A brief description or figure demonstrating the measurement boundary will be included under this section*			
Indicators		*Include indicators that are relevant to the simulation scope*	
Baseline Period		*This is the time period over which the facility or system baseline conditions are assessed and documented. This baseline*	

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	period is often a year but can be any period depending on the specific needs.

Table 3 IPMVP Option Template

2.1.2 Mathematical models for baseline adjustments

2.1.2.1 Routine and non-routine adjustments

As explained previously, IPMVP propose calculating energy savings comparing energy consumption before and after applying energy efficiency measures, following the general M&V equation. Nevertheless, baseline energy registered during the reference period cannot be directly compared to measured energy during the reporting period since energy consumption do not happen under the same conditions necessarily. In consequence, adjustments are needed in order to make metered energy directly comparable to baseline energy. In this regard, two types of adjustments are presented, following its nature:

- Routine adjustments, included in order to consider the impact of factors directly influencing energy consumptions, and which are expected to vary following a specified routine.
- Non-routine adjustments, that integrate in the equation the impact of factors also influencing energy consumption, but not expected to change routinely, thus related to occasional and sporadic changes, but never following an identifiable pattern.

An example of M&V process for evaluating energy savings would be a household where it is intended to reduce energy consumption through different energy efficiency measures. There are many possible non-routine adjustments in that case; change of appliances, birth of a new member in the family or absences for trips or during vacation periods are some of them. All this factors should be considered in the model if they are proved to really influence household energy consumption. Nevertheless, some of them like, for example, absences during holidays, could be included as routine adjustments if they are repeated every year during the same dates, thus creating a periodicity of the factor. On the other hand, the most typical routine adjustments for the presented case involve considering the impact of weather conditions, which usually follows some clear trends. In consequence, variables like temperature or even humidity, could be integrated in the model so that seasonality of the weather is considered, resulting in a variation in cooling and heating consumption.

2.1.2.2 Independent values

When a relationship between two or more variables is identified, the definition of a simple model involves traducing this relationship into a mathematical equation correlating these variables. In general, a representative example of correlation equation is the multiple linear regression, which can be described as follows:

$$y = \beta_0 + \beta_1 * x_1 + \cdots + \beta_n * x_n + e$$

In that equation y is known as dependent variable because it considers the measured variable whose values will be studied, and that is intended to be optimized in some cases either to their minimum or maximum possible value. On the other hand, the variables represented as x_n represent the impact of factors affecting the value of the dependent variable and, in consequence, are known as independent variables.

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Consequently, their value is measured in order to consider their impact on the dependent variable.

In general, some commonly used independent variables in energy consumption regression analysis are:

- Heating degree-days (HDD)
- Cooling degree-days (CDD)
- Number of occupants
- Units produced in a production process
- Ambient dry-bulb temperature

In the example of the household energy consumption model previously cited, the dependent variable would be the energy consumption calculated every period defined, for example every month. The independent variables (not all, but the most important ones) would be the exterior temperature and the number of inhabitants each month. Nevertheless, in that case the impact of the temperature only quantifies the correlation between energy consumption, mainly due to heating and/or cooling systems, and exterior conditions, without considering the impact of time of use of the equipment. In that sense, an alternative pair of variables such as the Cooling degree-days (CDD) and the Heating degree-days (HDD), which compare the difference between a reference temperature for cooling and heating equipment, can be introduced.

2.1.2.3 Regression techniques

As explained previously, regression techniques serve to verify if different variables have a consistent relationship between them thanks to the regression analysis. If this relationship is verified, then the regression model selected to make the analysis serve to define how the dependent variable will behave under the influence on the independent variables. The process to follow involves:

1) Identify all independent variables having real impact on energy consumption.

2) Collect and process data for all variables (dependent and independent) in order to get values for the same number of observations and periods of time, assuring its consistency. During this period, the existence of non-routine events affecting the dependent variable shall be also registered, in order to discard or adjust the corresponding values of the dependent variable accordingly.

3) Select the model and apply it to the collected data

When selecting the regression model, different regression techniques can be chosen, each one serving for different purposes, but the most important ones are those classified as *Linear regression models,* that assume a linear relationship between dependent and independent variables. It can be simple linear regression (a single independent variable) or multiple linear regression (more than one independent variable), and the linear regression equation has already been presented above.

Nevertheless, in some cases systems are dependent on a variable but only above and/or below a specific value. In that sense, simple regression change point models can be described in the same way than simple regression techniques but considering the impact of these changes. A representative example would be the case of certain

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cooling systems whose energy consumption present linear variations with outdoors temperature up to a certain value below which cooling is not needed.

Other cases may require using non-linear regression equations, whose general equation can be described as follows:

$$y = f(x, \theta) + \varepsilon$$

Where f is a non-linear function base on some unknown parameters θ. A typical example would be the polynomial regression;

$$y = a * x^2 + b * x + c$$

Where a, b and c represent the unknown parameters θ

4) Validate the model using adequate statistical indicators.

Finally, estimation models should be validated using statistical indicators in order to determine if baseline consumption equation is appropriate. Some of the most common ones are:

- R^2
- P-value
- T-statistic
- Net determination bias
- Coefficient of Variation (CV)

These indicators serve to validate the model and describe how its equation fits to real data, each of one providing different measures that must be properly understood. For example, the R-Square value (R^2) measure squares of the differences between estimated and real values, and the final ratio oscillates between 0 (no correlation) and 1 (excellent correlation). There is no general consensus on which should be the threshold to reach in order to validate the model, but commonly used value is 0.75. However, when there are two or more independent variables, the R-Square value must be corrected in order to consider the impact of adding more variables to the model.

The main advantages of using regression are its flexibility and the possibilities of extrapolating short-term measurements in order to calculate annual energy. Uncertainty can also be calculated, which allows to assess how accurate the model is, and if estimated savings are trustable or not.

Following the presented example of household consumption modelling, if a multiple linear regression model is selected, the corresponding equation would be the following:

$$y_m = \beta_0 + \beta_1 * x_{1,m} + \beta_2 * x_{2,m}$$

Where y_m represents the monthly energy total consumption, $x_{1,m}$ represents the heating degree-days for each month *m* considered, and $x_{2,m}$ represents the cooling degree-days, while the error term has not been considered. If the model is validated, this equation would serve to calculate adjusted energy consumption following external conditions and the set-points of cooling and heating equipment. In addition, it would be possible to predict energy consumption assuming future weather conditions. In any case, the linear multiple regression model is obtained from a sample of real data

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including pair of values of energy consumption, HDD and CDD. The results of this model taking fictitious energy consumption data for a household located in the south of Spain would be the following when represented on a graph:

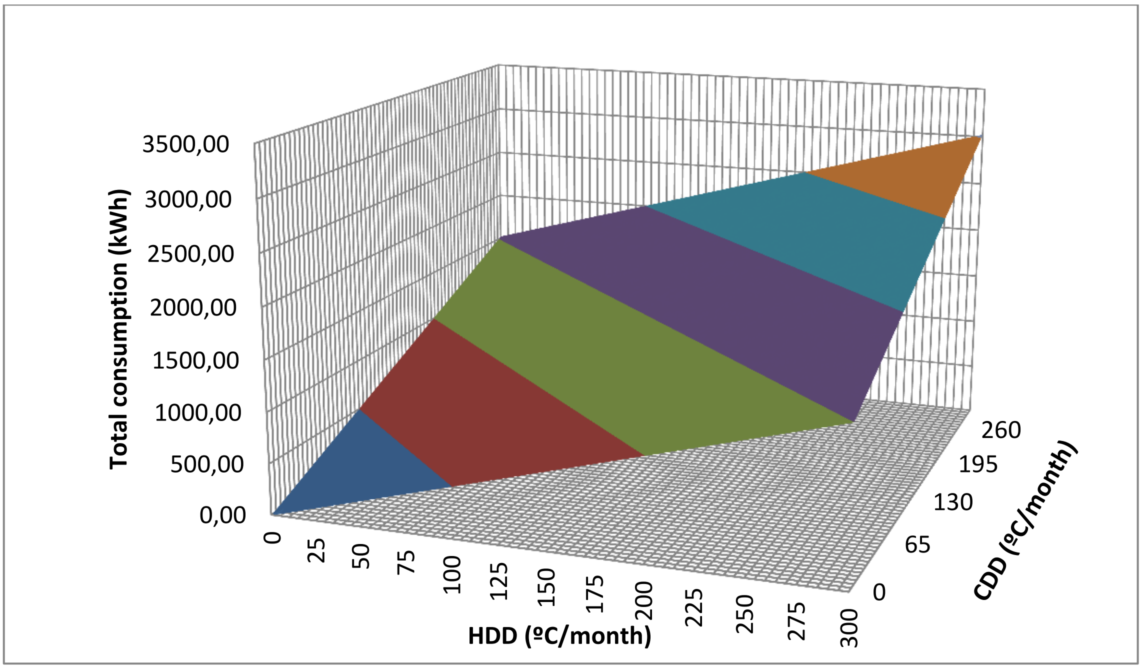

Figure 4. Linear model of monthly energy consumption (example)

2.1.3 Simulation models and tools

As already described in chapter 2.1.1 it is resulted that there need to be a simulated calibration, which has also been defined in Deliverable 5.1 "Technical evaluation procedure ". This subchapter aims to describe the simulation methodology to be used where models for baseline in energy interventions are necessary. It is necessary as it is the option D calibrated simulation, which has been defined previously.

For each case, a description of the simulation methodology needs to be done and can be implemented in the already given and introduced template of 2.1.1. The description involves following information:

- Simulation procedure
- Tool set and its characteristics
- Model description and boundaries
- Input data required
- Output data obtained
- Assumptions

Simulation procedure

Simulations in the Spanish case will be needed in reconstruction interventions, as well as in retrofitted buildings without baseline data. For that, methodologies and specific

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tools for building energy modelling will be used, as well as IPMVP indications will be taken into account for calibrate the models and get reliable results.

The procedure will have three main phases:

(1) Energy modelling

Different modelling tools, fed by building and environmental data will be used to get energy models. Specifically, as shows the diagram below, geolocation and structural parameters, building use, equipment and consumption patterns, joined with climate databases included in modelling tools are needed to obtain the building model, its demand and the expected energy consumption.

In the Spanish case is proposed the use of building energy simulation softwares complemented with a graphical interface, like Energy Plus and OpenStudio or Euclid (Sketchup pluggin) for building and thermal modelling. Moreover, additional spreadsheets will be developed for electrical modelling and to estimate final energy consumption.

(2) Validation

A calibration period is required for validate the obtained models using real consumption data of the buildings. If needed, adjustments of initial models will be made, in order to adjust predictions with the reality.

(3) Baseline calculation

Finally, initial conditions (inputs) of the validated models will be modified to simulate the reference period and to get the energy baseline for each building. Commonly, minimum requirements of technical building codes or other standardized/legal values will be used to feed the model (for example, minimum isolation conditions).

Valencia's models will take into account minimum legal requirements of the Building Technical Code approved by Royal Decree 314/2006, that is currently being updated, specifically the specifications included in the document DB-HE dedicated to energy saving.

The new Royal Decree, pending approval (Draft Royal Decree amending Royal Decree 314/206), will incorporate NZEB indicators in the document DBHE 2018, according to the requirements of Directive 2010/31/EU. This reference values will be taken into account in new buildings in order to reduce energy demand and increase the use of distributed and clean energy resources.

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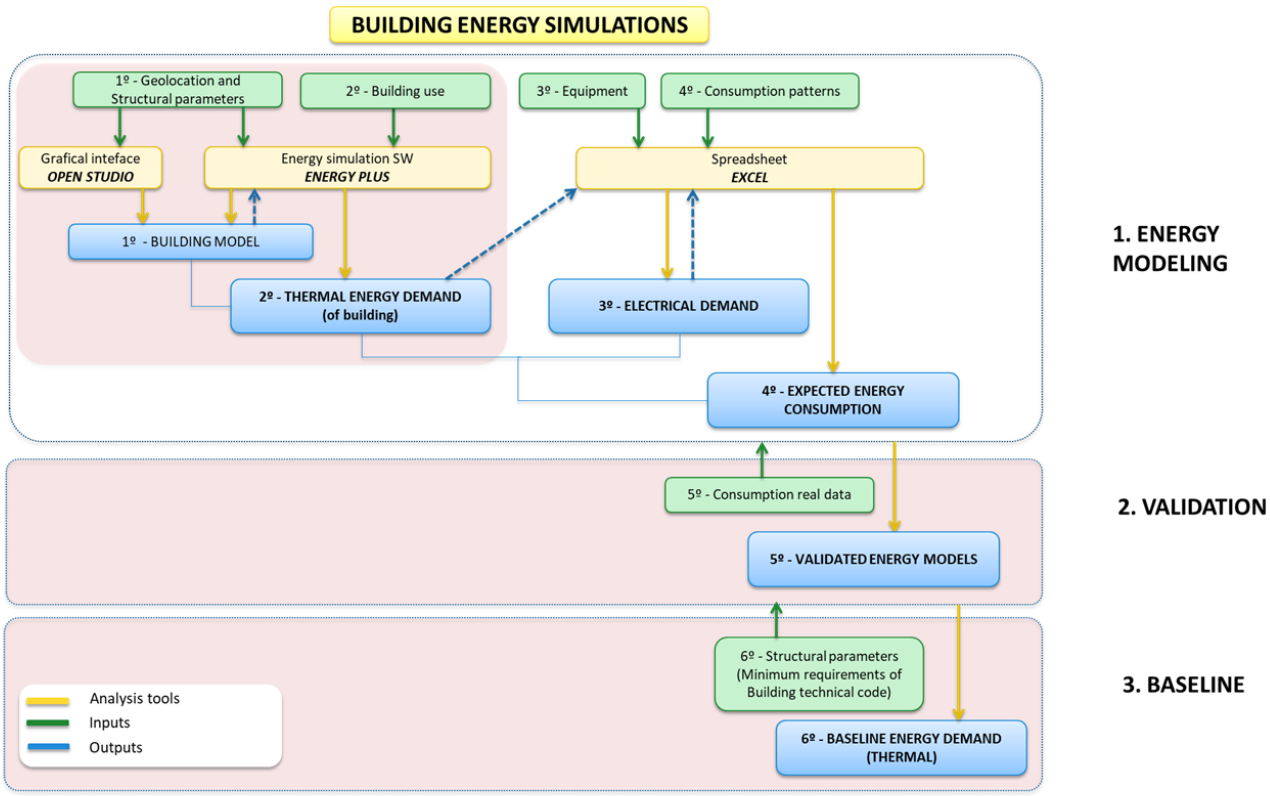

Figure 5. Energy simulations procedure

Tool set and characteristics

There are several tools that can be used to implement simulation methodologies. The MAtchUP lighthouse cities are free to decide which tool they prefer. Within the column "tool set and characteristics" the responsible partner needs to describe the tool and its characteristics.

These tools must be able to accurately simulate the building performance as well as energy supply system and corresponding energy management behaviour with an hourly or less temporal resolution.

Initially, for Valencia it is proposed the use of the internationally recognized tool Energy Plus (nevertheless, the use of any other similar software is not limited).

EnergyPlus^{TM} is a whole building energy simulation program use to model energy consumption and water use in buildings (*https://energyplus.net/*). This tool began to be developed in 1998 by the US Department of Energy. Since then it has been evolving, until the current version 9.1, increasing its capabilities with each new version.

It is a free and open source simulation engine, recognized worldwide and with various graphic interface for use, like Openstudio or Euclid. Some of the main features that integrate are: thermal loads, integrated simulation of loads and simulations, radiant exchange, thermal comfort, HVAC systems, natural ventilation, renewable energies, natural illumination, among others.

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Model description and boundaries

Most important for the deliverable D2.2 is the description of the implemented models and corresponding boundaries that occur with the use of the simulation.

As the level of calibration is the most important factor for us we need to ensure that the simulation model should reasonably predict the load shape and energy use of the facility or system.

Because of measurement boundaries of every model, there also need to be a description of the existing ones including their effects.

The interventions that will require simulations in Valencia will be detailed in section 3 of this report. As said before, simulations will be needed in new buildings and in retrofitted homes without baseline information. The models will be calibrated with real energy and environmental data monitored during the reporting period of the project.

Input data required

The calibration of the models shall be done by collecting the necessary data related to the building characteristics and occupancy. Most likely the data that will be required are operating characteristics, occupancy, weather, loads and equipment efficiency. For different interventions other different input data for the simulation model are required. Within the identification of the simulation models, there will be a listing and definition of input data identified to comprehend the outcome of the simulation.

The developed and required models for energy interventions in Valencia mainly refer to different types of buildings as well as occupancy. These different models require most likely the same set of input parameters, if available:

- Building construction plans; definition of refurbishment measures; building age, characteristic and occupancy type
- Available measurement data of at least one recent year (existing buildings) regarding heat, natural gas, electricity, cold, etc. consumption
- Description and design plans of power supply and HVAC system including brief overview of control schematic

Output data obtained

The obtained output data of the simulation are necessary to identify the baseline of interventions definition. A list of the data will be included for every intervention.

The collected data can include, for instance, the use of sub-metering by placement of monitoring equipment to collect data from the building automation system when available. These data can be useful, for instance for defining operational schedules (e.g. lighting, ventilation), and calibrating the model.[2]

[2] D5.1, p.50

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The energy intervention models in Valencia have been designed to provide feasible data and information about the implemented modernization measures for those aspects with missing or non-applicable or at least not available measurement data.

Building performance models will provide gains and consumption of different forms of energy (e.g. local renewables, heating, cooling and power supply, etc.)

Assumptions

With every identified intervention of option D that comes along with a simulation of the indicator bundle, several assumptions are related. A description of them can help to identify boundaries and predictions.

Option Template

With the description of the further information about the simulation tools the template given by IPMVP is now enlarged with five more columns:

Simulation models and tools *The following columns need to be filled with information about the simulation models and tools within the intervention*	
Tool set and characteristics	*Name simulation tool and describe its characteristics*
Model description and boundaries	*Describe model and boundaries that may occur*
Input data required	*List input data that is required for the simulation*
Output data obtained	*List output data that is obtained after the simulation*
Assumptions	*Identification and description of given assumptions of/for the simulation*

Table 4 Extended IPMVP Option Template

2.2 Models for baseline in mobility interventions

In the case of mobility interventions of the Valencian demonstrator, any simulation model is not needed.

2.3 Models for baseline in ICT interventions

In the case of ICT interventions of the Valencian demonstrator, any simulation model is not needed.

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2.4 Models for baseline in non-technical interventions

In the case of non-technical interventions of the Valencian demonstrator, any simulation model is not needed.

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3 Interventions / indicators requiring baseline simulation or adjustment

As explained previously, the IPMVP method proposes different options to obtain the energy baseline for energy efficiency verification and validation. In some cases, when previous data is not available and it is difficult to measure energy consumption, baseline is simulated in order to obtain values allowing verifying the effectiveness of efficiency actions carried out. Hereafter, a list of interventions requiring baseline simulation and/or adjustments is presented in order to identify and justify the selection of simulations tools or mathematical models:

3.1 Intervention 1: Reconstruction of private residential building (Comprises actions A1, A2, A3, A4, A5, A12 and A28)

In this intervention, 16 buildings are reconstructed so that they may be considered new buildings in terms of energy efficiency and performance. In general, simulations or a similar method will be required to calculate baseline values, considering that in some cases the buildings were not inhabited.

Intervention 1: Reconstruction of private residential buildings.			
This intervention is oriented to rebuild 16 private houses taking into account energy efficiency aspects and integrating distributed energy resources.			
Involved Action	Savings	Affected Equipment	Expected Savings
A.1 Reconstruction of 16 houses. *A.2 PV integration.* *A.3 Electrical storage for self consumption model integration.* *A.4 Smart meters for buildings.* *A.5 Next generation of smart controls at building level.* *A.28 Smart Home Energy Management System (SHEMS).*	*Energy conservation measures are proposed to reduce energy demand and consumption, based on: (1) the improvement of building architecture taking into account bioclimatic criteria (isolation level, natural lighting, ventilation…);(2) more informed and aware citizens able to improve their*	*Reconstruction actuations affect the building skin, climate equipment and lighting, while behavioural actions try to reduce the consumption of all the equipment of the building.*	*12.92 MWh/yr*

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	energy behaviour *Moreover, the generation, storage and use of renewable local energy is promoted, with the aim of reduce the use of fossil resources and GHG emissions.*		
IPMVP Option Selection Guidance			
Intervention Characteristics		YES	NO
[1] Need to assess Actions' performance individually?		Please go to [2]	**Please go to [3]**
[2] Able to isolate Actions(s) with meter(s)?		Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?		**Please go to [5]**	OPTION D
[4] Need full performance demonstration?		Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?		OPTION D	**Please go to [6C]**
[6A] Missing baseline period data?		OPTION D	OPTION B
[6B] Missing baseline period data?		OPTION D	OPTION A
[6C] Missing baseline period data?		**OPTION D**	OPTION C
Measurement Boundary - *Building/home level (boundaries are delimited by each reconstructed house)*			
Indicators		*E1) Reduction in primary energy demand and consumption*	
Baseline Period		*At least one year.*	
Simulation models and tools			

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The following columns need to be filled with information about the simulation models and tools within the intervention	
Tool set and characteristics	*Initially, for Valencia it is proposed the use of the internationally recognized tool Energy Plus (nevertheless, the use of any other similar software is not limited).* *EnergyPlus™ is a whole building energy simulation program use to model energy consumption and water use in buildings (https://energyplus.net/). This tool began to be developed in 1998 by the US Department of Energy. Since then it has been evolving, until de current version 9.1, increasing its capabilities with each new version.* *It is a free and open source simulation engine, recognized worldwide and with various graphic interface for use, like Openstudio or Euclid. Some of the main features that integrate are: thermal loads, integrated simulation of loads and simulations, radiant exchange, thermal comfort, HVAC systems, natural ventilation, renewable energies, natural illumination, among others.*
Model description and boundaries	*For this intervention simulations are needed because baseline data does not exist. The models will be calibrated with real energy and environmental data monitored during the reporting period of the project.*
Input data required	- *Building construction plans; definition of refurbishment measures; building age, characteristic and occupancy type* - *Description and design plans of power supply and HVAC system including brief overview of control schematic*
Output data obtained	*Building performance models will provide gains and consumption of different forms of energy (e.g. local renewables, heating, cooling and power supply, etc.)*

Table 5 Extended IPMVP Option table for intervention 1

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3.2 Intervention 2: Retrofitting of private residential building (Comprises actions A6, A2, A3, A4, A5, A12 and A28

Retrofitting efficiency actions are focused on previously habited households having access to previous data consumption, and in consequence simulation is, in general, not required.

Intervention 2: Retrofitting of private residential buildings			
The intervention aims to retrofit 548 private homes to improve their energy conditions, mainly increasing their isolation level.			
Involved Action	Savings	Affected Equipment	Expected Savings
A.6 Retrofitting of 548 private houses. *A.2 PV integration.* *A.3 Electrical storage for self consumption model integration.* *A.4 Smart meters for buildings.* *A.5 Next generation of smart controls at building level.* *A.28 Smart Home Energy Management System (SHEMS).*	*Energy conservation measures are proposed to reduce energy demand and consumption, based on: (1) the improvement of building skin and equipment taking into account bioclimatic architectural criteria (like the increase of isolation level, natural lighting and ventilation);(2) more informed and aware citizens able to improve their energy behaviour* *Moreover, the generation, storage and use of renewable local energy is promoted, with the aim of reduce the use of fossil resources and GHG emissions.*	*Retrofitting actuations will affect the building skin, climate equipment and lighting, while behavioural actions try to reduce the consumption of all the equipment of the building.*	*1,721.02 MWh/yr*
IPMVP Option Selection Guidance			

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<table>
<tr><td>Intervention Characteristics</td><td>YES</td><td>NO</td></tr>
<tr><td>[1] Need to assess Actions’ performance individually?</td><td>Please go to [2]</td><td>Please go to [3]</td></tr>
<tr><td>[2] Able to isolate Actions(s) with meter(s)?</td><td>Please go to [4]</td><td>Please go to [3]</td></tr>
<tr><td>[3] Are expected savings greater than 10%?</td><td>Please go to [5]</td><td>OPTION D</td></tr>
<tr><td>[4] Need full performance demonstration?</td><td>Please go to [6A]</td><td>Please go to [6B]</td></tr>
<tr><td>[5] Need to separately assess each Action?</td><td>OPTION D</td><td>Please go to [6C]</td></tr>
<tr><td>[6A] Missing baseline period data?</td><td>OPTION D</td><td>OPTION B</td></tr>
<tr><td>[6B] Missing baseline period data?</td><td>OPTION D</td><td>OPTION A</td></tr>
<tr><td>[6C] Missing baseline period data?</td><td>OPTION D*</td><td>OPTION C*</td></tr>
<tr><td colspan="3">(*) Option D or C depending on the availability and quality of baseline data.</td></tr>
<tr><td colspan="3">Measurement Boundary
There will be different levels according to the action:
- Private homes (for individual use of energy)
- Building (if common energy fluxes and equipment is affected)</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Indicators</td><td colspan="2">E1) Reduction in primary energy demand and consumption</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Baseline Period</td><td colspan="2">At least one year.</td></tr>
<tr><td colspan="3">Simulation models and tools
The following columns need to be filled with information about the simulation models and tools within the intervention</td></tr>
<tr><td>Tool set and characteristics</td><td colspan="2">Initially, for Valencia it is proposed the use of the internationally recognized tool Energy Plus (nevertheless, the use of any other similar software is not limited).
EnergyPlus™ is a whole building energy simulation program use to model energy</td></tr>
</table>

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	consumption and water use in buildings (https://energyplus.net/). This tool began to be developed in 1998 by the US Department of Energy. Since then it has been evolving, until de current version 9.1, increasing its capabilities with each new version. *It is a free and open source simulation engine, recognized worldwide and with various graphic interface for use, like Openstudio or Euclid. Some of the main features that integrate are: thermal loads, integrated simulation of loads and simulations, radiant exchange, thermal comfort, HVAC systems, natural ventilation, renewable energies, natural illumination, among others.*
Model description and boundaries	*For this intervention, simulations only will be needed in retrofitted homes without baseline information. The models will be calibrated with real energy and environmental data monitored during the reporting period of the project.*
Input data required	*- Building construction plans; definition of refurbishment measures; building age, characteristic and occupancy type.* *- Available measurement data of at least one recent year (existing buildings) regarding heat, natural gas, electricity, cold, etc. consumption* *- Description and design plans of power supply and HVAC system including brief overview of control schematic.*
Output data obtained	*Building performance models will provide gains and consumption of different forms of energy (e.g. local renewables, heating, cooling and power supply, etc.)*

Table 6 Extended IPMVP Option table for intervention 2

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3.3 Intervention 3: Reconstruction of public tertiary buildings (Centro Cívico: comprises A9, A2, A3, A4, A5 and A29)

As explained for Intervention 1, this intervention requires simulation for obtaining energy baseline values for the Civic Centre.

Intervention 3: Reconstruction of public tertiary buildings			
This intervention is oriented to rebuild public buildings (specifically the Civic centre) taking into account energy efficiency aspects and integrating distributed energy resources.			
Involved Action	Savings	Affected Equipment	Expected Savings
A.9 Civic centre. *A.2 PV integration.* *A.3 Electrical storage for self-consumption model integration.* *A.4 Smart meters for buildings.* *A.5 Next generation of smart controls at building level.* *A.29 Smart District Energy Management System (SDEMS).*	*Energy conservation measures are proposed to reduce energy demand and consumption, based on: (1) the improvement of building architecture taking into account bioclimatic criteria (isolation level, natural lighting, ventilation…);(2) more informed and aware citizens able to improve their energy behaviour* *Moreover, the generation, storage and use of renewable local energy is promoted, with the aim of reduce the use of fossil resources and GHG emissions.*	*Reconstruction actuations will affect the building skin, climate equipment and lighting, while behavioural actions try to reduce the consumption of all the equipment of the building.*	*28.45 MWh/yr*
IPMVP Option Selection Guidance			

Intervention Characteristics	YES	NO
[1] Need to assess Actions' performance individually?	Please go to [2]	**Please go to [3]**
[2] Able to isolate Actions(s) with meter(s)?	Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?	**Please go to [5]**	OPTION D
[4] Need full performance demonstration?	Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?	OPTION D	**Please go to [6C]**
[6A] Missing baseline period data?	OPTION D	OPTION B
[6B] Missing baseline period data?	OPTION D	OPTION A
[6C] Missing baseline period data?	**OPTION D**	OPTION C
Measurement Boundary - *Building level (boundaries are delimited by the Civic Centre installations)*		
Indicators	*E1) Reduction in primary energy demand and consumption* *E14) Compliance with Nearly Zero Energy Buildings (NZEBs) requirements*	
Baseline Period	*At least one year.*	
Simulation models and tools *The following columns need to be filled with information about the simulation models and tools within the intervention*		
Tool set and characteristics	*Initially, for Valencia it is proposed the use of the internationally recognized tool Energy Plus (nevertheless, the use of any other similar software is not limited).* *EnergyPlus™ is a whole building energy simulation program use to model energy consumption and water use in buildings*	

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	(https://energyplus.net/). This tool began to be developed in 1998 by the US Department of Energy. Since then it has been evolving, until de current version 9.1, increasing its capabilities with each new version. *It is a free and open source simulation engine, recognized worldwide and with various graphic interface for use, like Openstudio or Euclid. Some of the main features that integrate are: thermal loads, integrated simulation of loads and simulations, radiant exchange, thermal comfort, HVAC systems, natural ventilation, renewable energies, natural illumination, among others.*
Model description and boundaries	*For this intervention simulations are needed because baseline data does not exist. The models will be calibrated with real energy and environmental data monitored during the reporting period of the project.*
Input data required	- *Building construction plans; definition of refurbishment measures; building age, characteristic and occupancy type* - *Description and design plans of power supply and HVAC system including brief overview of control schematic*
Output data obtained	*Building performance models will provide gains and consumption of different forms of energy (e.g. local renewables, heating, cooling and power supply, etc.)*

Table 7 Extended IPMVP Option table for intervention 3

3.4 Intervention 4: Retrofitting of public tertiary buildings (Mercado del Cabanyal: comprises A10, A2, A3, A4, A5, and

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Agencia de Desarrollo Urbano: comprises A11, A2, A3, A4, A5, A12 and A29)

As explained for Intervention 2, this intervention does not require simulation for obtaining energy baseline values.

Intervention 4: Retrofitting of public tertiary buildings.			
The intervention aims to retrofit 548 private homes to improve their energy conditions, mainly increasing their isolation level.			
Involved Action	Savings	Affected Equipment	Expected Savings
A.10 Retrofitting of "Mercado del Cabanyal". *A.11 Retrofitting of Retrofitting of Urban development local agenc.* *A.2 PV integration. A.3 Electrical storage for self-consumption model integration.* *A.4 Smart meters for buildings.* *A.5 Next generation of smart controls at building level.* *A.29 Smart District Energy Management System (SDEMS).*	*Energy conservation measures are proposed to reduce energy demand and consumption, based on: (1) the improvement of building skin and equipment taking into account bioclimatic architectural criteria (like the increase of isolation level, natural lighting and ventilation);(2) more informed and aware citizens able to improve their energy behaviour* *Moreover, the generation, storage and use of renewable local energy is promoted, with the aim of reduce the use of fossil resources and GHG emissions.*	*Retrofitting actuations will affect the building skin, climate equipment and lighting, while behavioural actions try to reduce the consumption of all the equipment of the building.*	*A10: 49.35 MWh/yr* *A11: 19.73 MWh/yr*

IPMVP Option Selection Guidance		
Intervention Characteristics	YES	NO
[1] Need to assess Actions' performance individually?	Please go to [2]	**Please go to [3]**
[2] Able to isolate Actions(s) with meter(s)?	Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?	**Please go to [5]**	OPTION D
[4] Need full performance demonstration?	Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?	OPTION D	**Please go to [6C]**
[6A] Missing baseline period data?	OPTION D	OPTION B
[6B] Missing baseline period data?	OPTION D	OPTION A
[6C] Missing baseline period data?	**OPTION D***	**OPTION C***
(*) Option D or C depending on the availability and quality of baseline data.		
Measurement Boundary - *Retrofitted buildings*		
Indicators	*E1) Reduction in primary energy demand and consumption* *E14) Compliance with Nearly Zero Energy Buildings (NZEBs) requirements*	
Baseline Period	*At least one year.*	
Simulation models and tools		
Tool set and characteristics	*Initially, for Valencia it is proposed the use of the internationally recognized tool Energy Plus (nevertheless, the use of any other similar software is not limited).* *EnergyPlus™ is a whole building energy simulation program use to model energy consumption and water use in buildings*	

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	(https://energyplus.net/). This tool began to be developed in 1998 by the US Department of Energy. Since then it has been evolving, until de current version 9.1, increasing its capabilities with each new version. *It is a free and open source simulation engine, recognized worldwide and with various graphic interface for use, like Openstudio or Euclid. Some of the main features that integrate are: thermal loads, integrated simulation of loads and simulations, radiant exchange, thermal comfort, HVAC systems, natural ventilation, renewable energies, natural illumination, among others.*
Model description and boundaries	*For this intervention, simulations only will be needed in retrofitted homes without baseline information. The models will be calibrated with real energy and environmental data monitored during the reporting period of the project.*
Input data required	- *Building construction plans; definition of refurbishment measures; building age, characteristic and occupancy type* - *Available measurement data of at least one recent year (existing buildings) regarding heat, natural gas, electricity, cold, etc. consumption* - *Description and design plans of power supply and HVAC system including brief overview of control schematic.*
Output data obtained	*Building performance models will provide gains and consumption of different forms of energy (e.g. local renewables, heating, cooling and power supply, etc.)*

Table 8 Extended IPMVP Option table for intervention 4

3.5 Intervention 5: Smart controls (actions A4, A5 and A28 on buildings not included in previous interventions)

This intervention aims to include those cases where, depending on the evolution of the project, only involve deploying smart controls and the SHEMS tool. Consequently, simulation will only be necessary when users cannot provide previous energy data.

Intervention 5. Smart controls			
This intervention focuses on households having either smart meters or smart controllers with the SHEMS systems, which serves to analyse energy consumption and propose energy efficiency measures.			
Involved Action	Savings	Affected Equipment	Expected Savings
Actions involved are related to *A4 (Smart meters), A5 (Smart controllers)* *A28 (Smart Home Energy Management System, SHEMS)*	*This intervention saves energy mainly through the energy efficiency actions proposed by the systems to the participants*	*All the equipment in the house can potentially be affected by this measure depending on the progress of the participants and the particular characteristics of each one*	*Expected savings are expected to be greater than 10 %*
IPMVP Option Selection Guidance *Follow each question starting from 1. Highlight choice of selection with a colour.*			
Intervention Characteristics		YES	NO
[1] Need to assess Actions' performance individually?		Please go to [2]	Please go to [3]
[2] Able to isolate Actions(s) with meter(s)?		Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?		Please go to [5]	OPTION D
[4] Need full performance demonstration?		Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?		OPTION D	Please go to [6C]
[6A] Missing baseline period data?		OPTION D	OPTION B

[6B] Missing baseline period data?	OPTION D	OPTION A
[6C] Missing baseline period data?	OPTION D	**OPTION C**
Measurement Boundary *The boundaries in this case are restricted to the house itself, since every home will be analysed separately. In consequence, the entire house will be analysed using one single meter per type of energy consumed.*		
Indicators	*E2) Reduction in annual final energy consumption* *E4) CO2 emission reduction* *E5) Peak load reduction*	
Baseline Period	*Baseline period will be, at least, 12 months.*	
Simulation models and tools *The following columns need to be filled with information about the simulation models and tools within the intervention*		
Tool set and characteristics	*A specific software application (SHEMS itself) will be used to data collection and treatment.*	
Model description and boundaries	*Following the assumptions described previously, the model is limited to every home individually and all the related equipment.*	
Input data required	*Input data from users, mainly related to energy bills, characteristics of the analysed home affecting energy efficiency and feedback about the effective implementation of the measures will be needed by the systems to operate.*	
Output data obtained	*The users will get information about the energy savings and other interesting variables and indicators, like temperature or energy consumption.*	
Assumptions	*Some general assumptions will be taken for all the houses in order to develop a single analysis model. Nevertheless, each case may require particular assumptions.*	

Table 9 Extended IPMVP Option table for intervention 5

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3.6 Intervention 6: Building integrated RES and energy storage (actions A2, A3, A12))

In this case, simulation is not required as long as this intervention is transversal and is focused on evaluating the global impact of actions involving renewable energy generation and storage at district level.

<table>
<tr><td colspan="4">Intervention 6. Building integrated RES and energy storage.</td></tr>
<tr><td colspan="4">This intervention aims to the integration of distributed energy resources in buildings for self-consumption.</td></tr>
<tr><td>Involved Action</td><td>Savings</td><td>Affected Equipment</td><td>Expected Savings</td></tr>
<tr><td>Buildings of the interventions 1, 2, 3, 4:
A.2 PV integration. A.3 Electrical storage for self-consumption model integration. - Buildings
A.11 (Agencia de Desarrollo urbano), A.1 (16 private residential houses reconstructed) and A.6 (548 private houses retrofitted): A.12 Solar thermal integration.</td><td>The generation, storage and use of renewable local energy reduce the use of fossil resources and GHG emissions.</td><td>Distributed energy resources for generation and storage.</td><td>Contemplated in building actions.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">IPMVP Option Selection Guidance</td></tr>
<tr><td colspan="2">Intervention Characteristics</td><td>YES</td><td>NO</td></tr>
<tr><td colspan="2">[1] Need to assess Actions’ performance individually?</td><td>Please go to [2]</td><td>Please go to [3]</td></tr>
<tr><td colspan="2">[2] Able to isolate Actions(s) with meter(s)?</td><td>Please go to [4]</td><td>Please go to [3]</td></tr>
<tr><td colspan="2">[3] Are expected savings greater than 10%?</td><td>Please go to [5]</td><td>OPTION D</td></tr>
</table>

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[4] Need full performance demonstration?	Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?	OPTION D	Please go to [6C]
[6A] Missing baseline period data?	OPTION D	**OPTION B**
[6B] Missing baseline period data?	OPTION D	OPTION A
[6C] Missing baseline period data?	OPTION D	**OPTION C**
Options B are oriented to assess the performance indicators of the installations, while option C could be used to evaluate self-consumption indicators.		
Measurement Boundary		
The boundaries are delimited by the energy infrastructures and the location where the generated/storaged energy be used.		
Indicators	*E1) Reduction in primary energy demand and consumption* *E3) Increase in local renewable energy generation* *E5) Peak load reduction* *E6) Maximum hourly deficit* *E7) Monthly ratio of peak hourly demand to lowest hourly demand* *E8) Storage capacity factor* *E9) Functional storage capacity factor* *E10) Functional storage capacity factor*	
Baseline Period	*At least one year.*	
Simulation models and tools		
Tool set and characteristics	*Does not apply*	
Model description and boundaries	*Does not apply*	
Input data required	*Does not apply*	
Output data obtained	*Does not apply*	
Assumptions	*Does not apply*	

Table 10 Extended IPMVP Option table for intervention 6

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3.7 Intervention 7: Urban RES (Actions A8, A13 and A14)

Action A13 does not require simulation for evaluating its baseline data since it involves a renewable source of energy generation entirely implemented in this project. Actions A8 and A14 do not require baseline simulations because previous data involving energy consumption and other important data (temperature, occupation or similar important sources of deviation of energy consumption) is available. Nevertheless, a simple mathematical model may be suitable in order to make baseline adjustments.

<table>
<tr><td colspan="4">Intervention 7. Urban RES</td></tr>
<tr><td colspan="4">This intervention integrates wave energy converter to supply public lighting and advanced thermal sytems and sewerage energy recovery system for the “Nazaret Sports Center”.</td></tr>
<tr><td>Involved Action</td><td>Savings</td><td>Affected Equipment</td><td>Expected Savings</td></tr>
<tr><td>A8 Advanced thermal systems
A13 Pilot Wave Energy Converter to supply public lighting.
A14 Sewerage energy recovery system</td><td>The generation, storage and use of renewable local energy reduce the use of fossil resources and GHG emissions.</td><td>Distributed energy resources for generation and storage.</td><td>Savings are expected to be higher than 10%.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">IPMVP Option Selection Guidance</td></tr>
<tr><td colspan="2">Intervention Characteristics</td><td>YES</td><td>NO</td></tr>
<tr><td colspan="2">[1] Need to assess Actions’ performance individually?</td><td>Please go to [2]</td><td>Please go to [3]</td></tr>
<tr><td colspan="2">[2] Able to isolate Actions(s) with meter(s)?</td><td>Please go to [4]</td><td>Please go to [3]</td></tr>
<tr><td colspan="2">[3] Are expected savings greater than 10%?</td><td>Please go to [5]</td><td>OPTION D</td></tr>
<tr><td colspan="2">[4] Need full performance demonstration?</td><td>Please go to [6A]</td><td>Please go to [6B]</td></tr>
<tr><td colspan="2">[5] Need to separately assess each Action?</td><td>OPTION D</td><td>Please go to [6C]</td></tr>
</table>

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[6A] Missing baseline period data?	OPTION D	**OPTION B**
[6B] Missing baseline period data?	OPTION D	OPTION A
[6C] Missing baseline period data?	OPTION D	**OPTION C**
Options B are oriented to assess the performance indicators of the installations, while option C could be used to evaluate self-consumption indicators.		
Measurement Boundary		
The boundaries are delimited by the energy infrastructures and the location where the generated/storaged energy be used.		
Indicators	*E1) Reduction in primary energy demand and consumption* *E3) Increase in local renewable energy generation* *E4) CO2 emission reduction*	
Baseline Period	*At least 1 year.*	
Simulation models and tools		
Tool set and characteristics	*Does not apply*	
Model description and boundaries	*Does not apply*	
Input data required	*Does not apply*	
Output data obtained	*Does not apply*	
Assumptions	*Does not apply*	

Table 11 Extended IPMVP Option table for intervention 7

3.8 Intervention 8: Lighting actions (Actions A26 and A27)

Not required simulation or mathematical models to adjust consumption since lighting consumption and its variability are totally determined.

Intervention 8. Lightning actions
This intervention mainly involves the deployment of 10 Humble lampposts following the demand in the city and impact of these systems, and the replacement of 4.000 street

lamps in the Nazaret area of the Poblats Marimits district including more efficient light bulbs and innovative tele-management devices.			
Involved Action	Savings	Affected Equipment	Expected Savings
As described above, involved actions are: *A 26 – 10 Humble lumposts* *A27 – Smart lightning – 4000 street lamps*	*In these cases, savings come from using more efficient technologies, like for example those related to the light bulbs. In addition, both actions include in their actuation ITC technologies for a better and smarter way to manage energy in lightning.*	*In this case, affected equipment is referred to those luminaries of the city complemented or replaced by the described actions. For example, in the action A26, 4.000 street lamps are replaced.*	*Thanks to the humble lampposts, it is expected to save up to 34% of savings. On the other hand, regarding the replacement of old street lamps, savings are expected to be greater than 10 %*
IPMVP Option Selection Guidance			
Intervention Characteristics		YES	NO
[1] Need to assess Actions' performance individually?		Please go to [2]	Please go to [3]
[2] Able to isolate Actions(s) with meter(s)?		Please go to [4]	Please go to [3]
[3] Are expected savings greater than 10%?		Please go to [5]	OPTION D
[4] Need full performance demonstration?		Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?		OPTION D	Please go to [6C]
[6A] Missing baseline period data?		OPTION D	**OPTION B***
[6B] Missing baseline period data?		OPTION D	**OPTION A***
[6C] Missing baseline period data?		OPTION D	OPTION C
(*) The final choose of option A and B will depend on the availability and quality of the data.			

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Measurement Boundary *The measurement boundary in this case will be limited to the replaced and/or affected equipment. For example, action A27 will only be evaluated for the replaced street lamps.*	
Indicators	*E2) Reduction in annual final energy consumption*
Baseline Period	*The period considered initially will be around a week, always depending on the availability of data and quality of it. In case it is needed, this duration can be extended as long as necessary.*
Simulation models and tools *The following columns need to be filled with information about the simulation models and tools within the intervention*	
Tool set and characteristics	*No simulation tool is expected to be used for evaluating the performance of this intervention.*
Model description and boundaries	*The model and boundaries do not need to be defined since no evaluation will be carried out.*
Input data required	*Following the same logic, no input data is needed for simulation.*
Output data obtained	*No output data will be obtained through simulation.*
Assumptions	*Assumptions are not needed for the same reasons explained above.*

Table 12 Extended IPMVP Option table for intervention 8

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4 Conclusions

This report has been focused in analysing methodologies, models and tools to use to determine energy baselines when mathematical adjustments and/or simulations are needed. In the case of mobility, ICT and non-technical interventions of the Valencian demonstrator it has been concluded that any simulation model is not needed.

The international protocol IPMVP has being considered one of the most appropriate procedure to define baselines and to measure and verify energy savings, with the final aim of determine the performance and impact of the MAtchUP's interventions. In this regard the basis and alternatives (options A, B, C and D) that proposes this protocol and the use of mathematical models has being introduced analysing their application in the different interventions of Valencia. Moreover, simulation tools and procedures to be used, taking into account the specific conditions of those interventions, have being presented.

Finally, every energy intervention and actions of the Valencia demonstrator have being analysed detailing the most appropriate measure and verification option in each case, as well as the need to use simulations and models to calculate the final indicators. This table summarize these conclusions by intervention.

Intervention	IPMVP option	Simulations
Intervention 1	D	Yes
Intervention 2	C-D	When baseline is not available.
Intervention 3	D	Yes
Intervention 4	C/D	When baseline is not available.
Intervention 5	C	No. Only mathematical adjustments could be needed.
Intervention 6	B/C	No. Only mathematical adjustments could be needed.
Intervention 7	B/C	No. Only mathematical adjustments could be needed.
Intervention 8	A/B	No. Only mathematical adjustments could be needed.

Table 13 Summary of IPMVP option and simulation needs by each intervention of Valencia.

The report will be completed in the version D2.15 with the correspondent simulations and calculations of the identified cases.

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5 References

IPMVP Core Concepts, International Performance Measurement and Verification Protocol, EVO 10000 – 1:2016

Renewables application guide, International Performance Measurement and Verification Protocol, EVO 10200 – 1:2017

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