MAtchUP

D4.2: Simulation models of the building stock, energy system, transportation, urban infrastructures

WP 4, T 4.2

30.09.2019

September, 2019, (M24)

Authors: Ömer Akyürek

MAtchUP - SCC-1-2016-2017

Innovation Action – GRANT AGREEMENT No. 774477

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

Technical References

Project Acronym	**MAtchUP**
Project Title	MAximizing the UPscaling and replication potential of high-level urban transformation strategies - MAtchUP
Project Coordinator	Ernesto Faubel Ayuntamiento de Valencia efaubel@valencia.es
Project Duration	1 October 2017 – 30 September 2022 (60 Months)

Deliverable No.	D4.2
Dissemination Level	PU
Work Package	WP 4 – Demonstration in Antalya
Task	T 4.2 – Baseline of interventions definition of interventions definition Subtask 4.2.1 – Simulation models (buildings, energy systems, city infrastructures)
Lead beneficiary	16 (DEM)
Contributing beneficiary(ies)	14 (ANT), 15 (SAM), 17 (ANP), 18 (TAY), 19 (AKD)
Due date of deliverable	30.09.209
Actual submission date	25.09.2019
Estimated person-month for deliverable	16,5

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

Version	Person	Partner	Date
0.1	Ömer Akyürek	DEM	14 February 2019
0.2	Comments by Sophia Wolter	DRE	19 February 2019
0.3	Comments by Juan Pablo Gonzalez Gutierrez	ITE	24 April 2019
0.4	Ömer Akyürek, Juan Pablo Gonzalez Gutierrez, Linda Arnhold	DEM, DRE, ITE	30 July 2019
1	Ömer Akyürek	DEM	9 September 2019
2	Ömer Akyürek	DEM	23 September 2019

Disclaimer

The information reflects only the author's view and the Commission is not responsible for any use that may be made of the information it contains.

Table of Content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

List of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

List of Figures

This project has received funding from the European Union’s Horizon 2020
research and innovation programme under Grant Agreement N°774477

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
LFG	Landfill Gas
B(E)MS	Building (Energy) Management System
WP	Work Package
EPBD	Energy Performance in Buildings Directive
SCC	Smart Cities and Communication
SEAP	Sustainable Energy Action Plan
RES	Renewable Energy Sources
SCTP	Smart City Technology Packages
IPMVP	International Performance Measurement and Verification Protocol
M&V	Monitoring and Verification
HDD	Heating degree days
CDD	Cooling degree-days
BEP	Building Energy Performance

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

0 Abstract

This report constitutes Deliverable "*D4.2: Simulation Models of Building Stock, Energy System, Transportation, Urban Infrastructure in Antalya. First version*". The final version of this report will be delivered in September 2020 (project month M30). The purpose of this report is to provide methodological tools to determine savings where it is computed through simulation or mathematical models. There are 42 actions in total for Antalya Lighthouse, including actions under Energy, Mobility, ICT and Non-Technical. MAtchUP requires to monitor and to evaluate the impact of each smart city solution deployed in the demonstration actions. The analyses of the impact are based on defined indicators. The evaluation procedure consists of several steps including definition of the baseline situation before interventions. Determination of performance prior to intervention is required since impact could be quantified only with comparison of before and after. MAtchUP adopts specific procedures to deploy deep monitoring that will provide high quality data on performance of post action period. For pre-action period (baseline period), data based on monitoring or well documented historical data aren't always available. In this case this data could be determined through simulation or mathematical models and tools.

MAtchUP Antalya has two important interventions that will have an impact on energy savings as well as GHG reductions. Antalya will implement energy efficient, high performance buildings in KEPEZ District, which is an urban regeneration area. Energy demand will be lowered with high performance building constructions on both residential and commercial usage. Since these buildings are new constructions, it is not possible to have a baseline data based on real or historical data. To determine the performance of these interventions Antalya Team, require simulation tools to quantify performance prior to implementation.

A shared approach with other lighthouse cities (Dresden and Valencia) for the development and implementation of baseline models are explained under section 2. This section provides detailed explanation on IPMVP Protocol focusing on Option D of the protocol where simulation models are used. Also, mathematical models for baseline adjustments are detailed under section 2. Section 3 focuses on interventions and indicators requiring baseline simulation or adjustment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

1 Introduction

1.1 Purpose and 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.

The specific results obtained in each case will be specified and used in D4.3- “Baseline of Antalya Demonstration”.

1.2 Contribution of partners

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

Participant short name	Contributions
ANT	WP Leader. Leading definition of the actions.
SAM	Is the ICT expert for Antalya and will be involved in monitoring activities
DEM	Is the task leader for T4.2 and will coordinate the efforts in developing the deliverable D4.2. Will support the municipality in the definition of the intervention design. DEM will support all energy actions and involved in monitoring activities.
ANP	Will support the municipality in the definition of the intervention design. Will be involved in monitoring activities.
TAY	Is the mobility expert for Antalya and will be involved in monitoring activities.
AKD	Will support the municipality in the definition of the intervention design. Will support all energy actions and will involve in monitoring activities.
CAR	Will support the overall definition and the non-technical aspects of interventions in Antalya.

Table 1. Contribution of partners

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement N°774477

1.3 Relation to other activities in the project

This deliverable is linked with Task 4.2 “Baseline of interventions definition”, more specifically Subtask 4.2.1 “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.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement N°774477

2 Approach for the Development and Implementation of Baseline Models

2.1 Models for baseline in energy interventions

The energy baseline 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 (*EnB, ISO 50.006*).

Sometimes, energy baselines can be directly stablished from consumption measures, without requiring 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 data) 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 (energy savings) 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). s

Energy savings can be only determined by making comparison between the states before and after the implemented action. But this comparison is not enough to determine the savings and, in most cases, will require adjustments to take into account the impacts of the implementation on conditions (ex. Change in number of occupancies due to increased living space).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

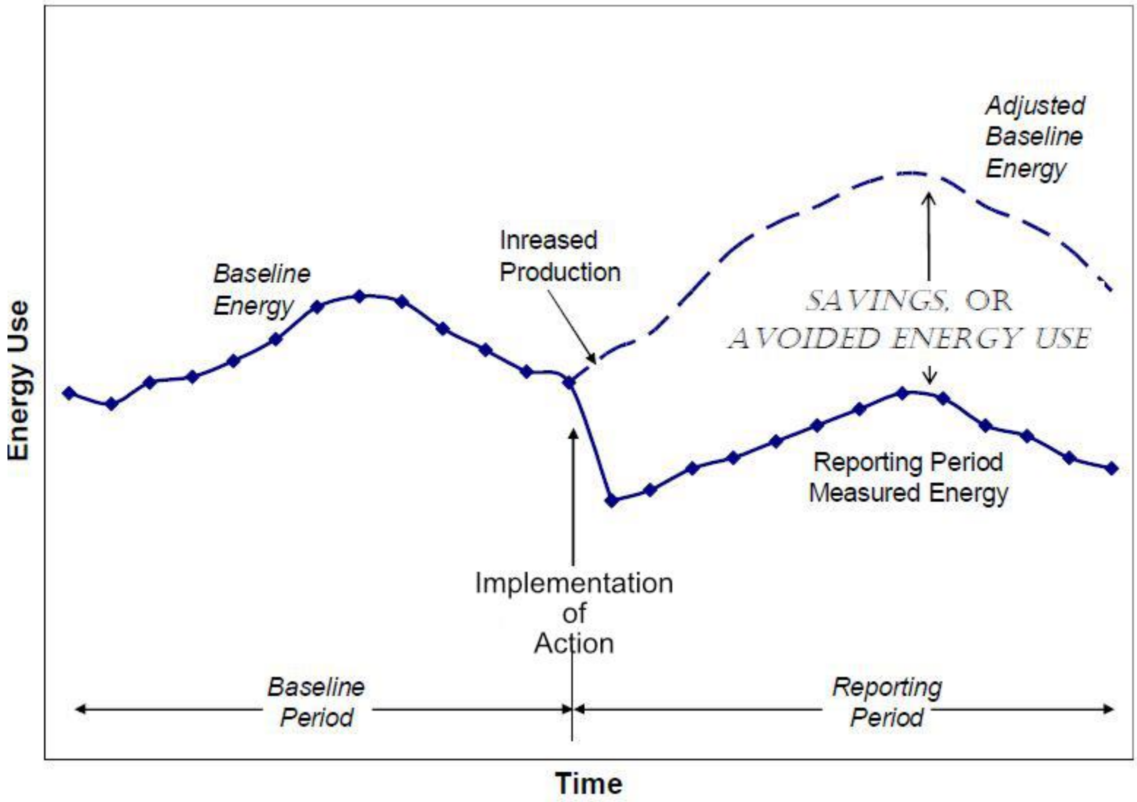


Figure 1 Example energy history (IPMVP 2012 Volume 1)

Under the IPMVP Volume 1, the equation for energy savings is generalized as follows:

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

[Equation 1]

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 energy use or demand is identified depends mainly on which approach is selected for Monitoring and Verification (M&V). This is defined, inter alia, by the availability or reliability of the data itself.

Determination of savings is a necessary part of good design of the actions itself. The basic approach common to all good savings determination involves several steps including;

[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*".

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

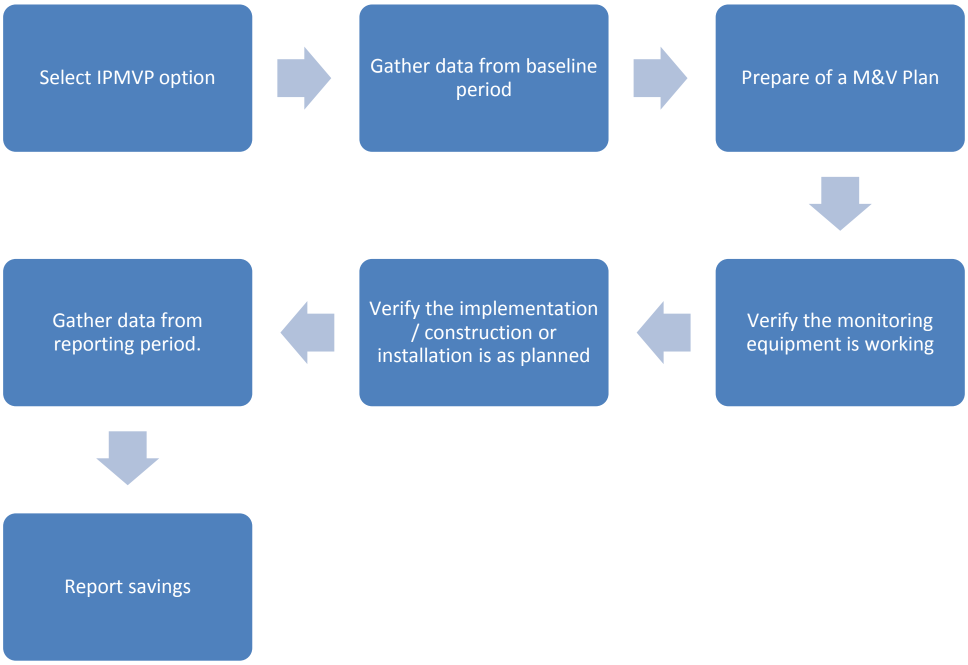


Figure 2 M&V Procedure

As already mentioned under 1.1, this deliverable (D4.2 Simulation models of the building stock, energy system, transportation and urban infrastructure) will focus on simulation models hence this document will mostly detail the first step; selection of IPMVP Options and its implications to the project activity.

Overview of IPMVP options

IPMVP provides four Options for determining savings; A, B, C and D. These options determine how to measure or quantify the parameters in [Equation 1]. Each requires data on energy consumption, demand and other parameters both for baseline period and monitoring period. These savings could be identified through different sources such as data from invoices, dedicated monitoring devices as well as computer simulations.

The following sections provide summaries of these four options and how to select them as indicated under the IPMVP Protocol Document.

IPMVP Option	Definition	How Savings are Calculated	Typical Applications
A. Retrofit-isolation: Key Parameter Measurement	- Savings are determined by field measurement of the key parameter(s), which define the energy consumption and demand of the ECM's affected system(s) or the success of the project. - Measurement frequency ranges from short term to	- Engineering calculation of baseline period energy and reporting period energy from: short-term or continuous measurement of key parameters and estimated values. - Routine and non-routine adjustments as required. Key parameters measured during both	A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on facility schedules and occupant behaviour.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

	continuous, depending on the expected variation in the measured parameter and the length of the reporting period. Parameters not selected for field measurements are estimated values. Estimates can be based on historical data, manufacturer specifications or engineering judgement. - Documentation of the source or justification of the estimated value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	baseline and reporting period.	
B. Retrofit-isolation: All Parameter Measurement	- Savings are determined by field measurement of the energy consumption and demand and/or related independent or proxy variables of the action affected system - Measurement frequency ranges from short-term to continuous, depending on the expected variations in savings and length of reporting period.	- Short term or continuous measurements of baseline and reporting period energy, or engineering computations using measurements of proxies of energy consumption and demand. - Routines and non-routine adjustments as required.	Application of a variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to measure power consumption and demand
C. Whole Facility	- Savings are determined by measuring energy consumption and demand at the whole facility utility meter level. - Continuous measurements of the entire facility's energy consumption and demand are taken throughout the reporting period.	- Analysis of the whole facility baseline and reporting period meter data. - Routine adjustments as required, using techniques such as simple comparison or regression analysis. - Non-routine adjustments as required.	Multifaceted energy management programs affecting many systems in a facility. Measure energy consumption and demand with the gas and electric utility meters for a twelve-month baseline period and throughout the reporting period.
D. Calibrated Simulation	- Savings are determined through simulation of the energy consumption and demand of the whole facility, or of a sub facility. - Simulation routines are demonstrated to adequately model actual energy performance in the facility. - This option requires considerable skill in calibrated simulation.	- Energy consumption and demand simulation, calibrated with hourly or monthly utility billing data. Energy end-use metering and metered performance data may be used in model refinement.	- Multifaceted energy management programs affecting many systems in a facility but where no meter existed in the baseline period. - Energy consumption and demand measurement, after installation of gas and electric meters, is used to calibrate simulation. - Baseline period energy, determined using the calibrated simulation, is compared to a simulation of reporting period energy consumption and demand.

Table 2. Overview of IPMVP options (2016 IPMVP Core Concept)

Antalya interventions involve construction of new residential and public buildings where energy savings will be achieved through several actions. Since it is not possible to provide a baseline data based on actual monitoring or historical records, MAtchUP team has to simulate the baseline data for these interventions. Since Option D is the only option involving simulation of energy consumption the following section provides further guidance on this option.

Option D: Calibrated Simulation

Option D is used to determine either one or both of baseline period and monitoring period energy use in [Equation 1]. This option is used when there is no available data from the baseline period (ex. In new constructions). This option could be used to determine both facility level or action level performance. In case Option D is used for

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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.

A simulation program that has been evaluated against ASHRAE Standard 140 should be preferred although other proprietary software may also be used. To ensure high accuracy the simulation results must be calibrated. 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. This is to assure that a full meteorological cycle is considered for calibration taking into account effects such as temperature and humidity. The simulation is then run again with the calibration period data to verify that energy results monitored is consistent with the simulated data.

Selection Guide

The selection of the IPMVP Option is based on several issues including the measurement boundary, project conditions, budget and expert judgement. Following the explanations of section 2.1.1 of this document including the selection guidance provided above, each LHC may identify which IPMVP Option to apply for each intervention / indicator bundle. The following template illustrated below 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 other resources (e.g., reduction of energy)*	*Provide a list of affected physical equipment*	*A preliminary result on expected 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	OPTION C
[6A] Missing baseline period data?	OPTION D	OPTION B
[6B] Missing baseline period data?	OPTION D	OPTION A

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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 period is often a year but can be any period depending on the specific needs.*
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 3 IPMVP Option Template

2.1.2 Mathematical models for baseline adjustments

2.1.2.1 Option C

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.

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. When this information does not exist, simulations models need to be applied through option D, as explained under section 2.1.1 as the following diagram shows.

<u>Application</u>

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.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

In this regard, the project interventions combine different kind of measures oriented to reduce energy demand of the building, 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.

Required data and calculations

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, 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.

In MAtchUP 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

2.1.2.2 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 in a typical household is presented in order to illustrate these concepts. 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

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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.

2.1.2.3 Independent variables

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. 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 described, 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 user's behaviour. 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.

2.1.2.4 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

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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 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

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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 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:

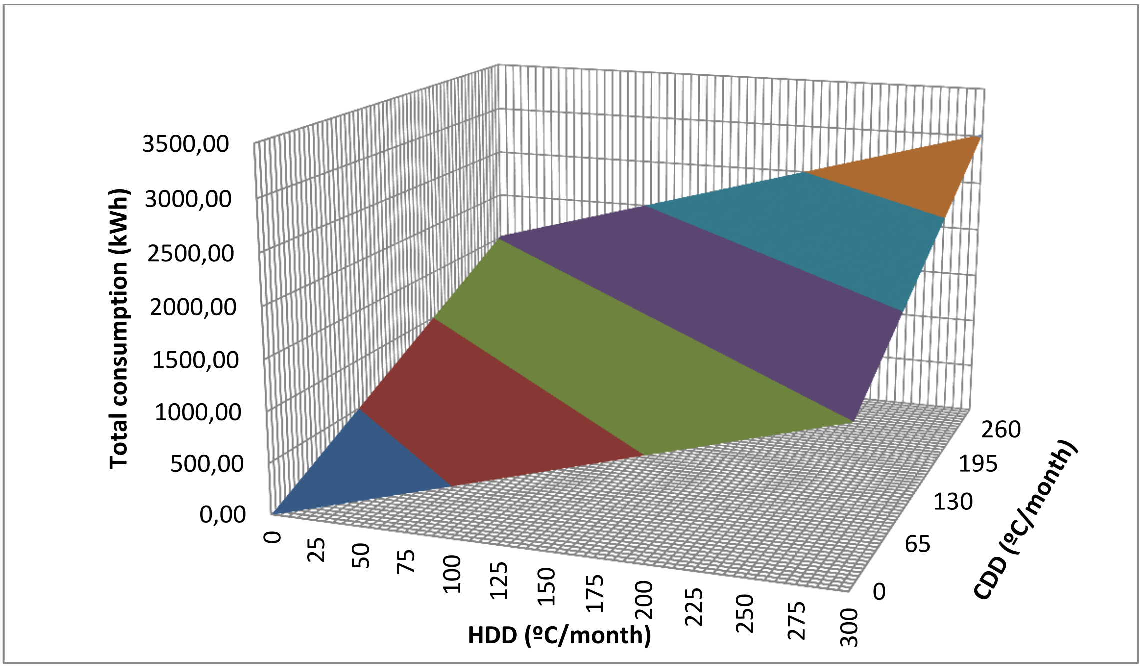


Figure 3 – Linear model of monthly energy consumption (example)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

2.1.3 Simulation models and tools

This subchapter aims to describe the tools and models to be used for baseline determination simulation methodology. The description involves following information:

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

Tool set and characteristics

There are several tools that can be used to implement simulation methodologies. Although lighthouse cities are free to decide which tool they prefer, the simulation program that has been evaluated against ASHRAE Standard 140 should be preferred.

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.

Simulation tool sets and characteristics in Antalya

Antalya, Kepez District simulation models are generated and calibrated by DEM. The simulations generate a wide range of outputs and reports guiding to compare the performance of design alternatives, optimising the building at any stage based on MAtchUP's objectives on action/interventions. DesignBuilder Software is adopted to utilize the simulated measures of Kepez District buildings (both residential and public). User behaviour data defines the number people in the space and the times of occupancy. This data is used in simulations and cooling design calculations together with the metabolic heat output of the occupants and holidays to calculate the heat input to the building. Schedules are applied for occupancy times, equipment, lighting HVAC operation, heating and cooling temperature setpoints and transparency of component blocks (usually seasonal).

Model description and boundaries

Under MAtchUP Antalya, energy related KPI's require simulation modelling for baseline to be determined for baseline scenarios as explained earlier. Both interventions -newly built residential and public building involve energy actions including building envelope insulation, high u value glazing, highly efficient HVAC systems and energy efficient lighting. These will have an impact on electricity demand as well as heating and cooling demand. The simulation boundaries should be defined in accordance.

Input data required

The simulation models in Antalya Kepez district indicate different building types, functions, occupancy and schedules. Nonetheless, both residential and public buildings require similar input data sets listed below:

- Architectural, mechanical, electrical and structural execution project of the buildings,

- Execution details on building envelope, mechanical, power systems definitions including brief overview of control schematic and insulation performance reports,
- Datasheets (Technical specifications) of technical systems (manufacturer data) including relevant performance data

Output data obtained

The energy simulation models of Antalya-Kepez District aims to provide energy demand analysis of the new constructions. Since there isn't any available data for the earlier low performance buildings (before urban regeneration project in Kepez), the new high-performance buildings energy demand analysis is obtained by the simulation models.

Building performance models comprising HVAC system, power supply and passive measures regarding envelope provide following general list of outputs:

- Gains and consumption of different forms of energy (e.g. local renewables, heating, cooling, air conditioning and power supply, surface heat transfer, internal gains including solar and latent loads.)
- Comfort and environmental outputs (e.g. fresh air supply, temperatures and humidity data for thermal comfort. Etc)
- Detailed Daylight outputs including daylight map and daylight at reference points.
- Evaluation and analyses of different performance optimization measures

Assumptions

The area that will be included in MAtchUP comprises a new construction area, located in Kepez Santral District. Since the buildings will be newly constructed, the baseline for energy demand corresponds to the minimum requirements of building codes applicable for heat and electricity. Following section provides a brief description of the building code TS 825.

<u>TS 825 Building Code</u>

Turkey's building energy regulation focuses on thermal resistance. The National Standard of Thermal Insulation Requirements for Buildings TS 825 was first issued in 1999 and became mandatory in June 2000. This standard has been revised several times subsequently, latest version of which was published in 2013. More recently, Turkey has begun to align with the European legislation on buildings, including the Energy Performance of Buildings Directive (EPBD). A part of this process is adoption of Building Energy Performance Regulation, which envisages the use of district heating and/or renewable energy for the buildings above a certain threshold. BEP is mandatory for all new buildings except for industrial buildings, temporary buildings used less than 2 years, buildings with a total useful floor area of less than 50 m², greenhouses, workshops as well as stand-alone buildings without heating or cooling requirements.

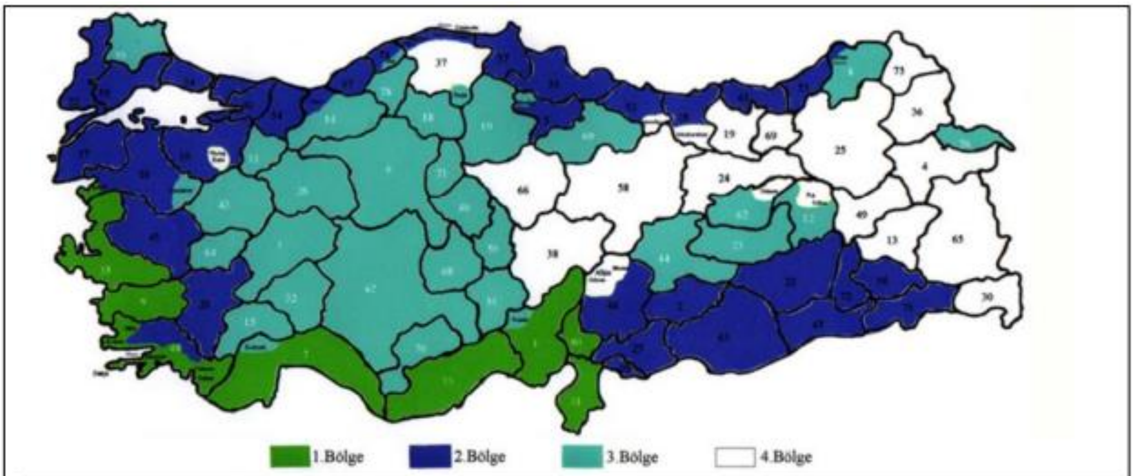
This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

Residential Buildings	Scale (National, Regional, Local, etc…)	Building size threshold
New Buildings	National (Building Energy Performance Regulation)	Buildings with more than 2,000 m^2 of usable space will be equipped with a central heating system; for buildings more than 20,000 m^2, various ways to use renewable energy and cogeneration facilities are defined.
Existing Buildings	National (thermal regulation only): TS 825	All new buildings except buildings containing passive solar energy systems

Table 4 Regulations for residential buildings

The TS 825 is related with the rules of calculation methods of the heating and cooling energy requirements of the new and old buildings. It divides Turkey into five climatic zones (depending on average degree days) and limits heat loss from the building envelope.

According to TS 825, five different degree-day regions have been defined for Turkey, which are shown in figure below. Antalya is considered within Zone 1.



01- ADANA	10- BALIKESİR	19- ÇORUM	28- GİRESUN	37- KASTAMONU	46- K.MARAŞ	55- SAMSUN	64- UŞAK	73- ŞIRNAK
02- ADIYAMAN	11- BİLECİK	20- DENİZLİ	29- GÜMÜŞHANE	38- KAYSERİ	47- MARDİN	56- SİİRT	65- VAN	74- BARTIN
03- AFYON	12- BİNGÖL	21- DİYARBAKIR	30- HAKKARİ	39- KIRKLARELİ	48- MUĞLA	57- SİNOP	66- YOZGAT	75- ARDAHAN
04- AĞRI	13- BİTLİS	22- EDİRNE	31- HATAY	40- KIRŞEHİR	49- MUŞ	58- SİVAS	67- ZONGULDAK	76- IĞDIR
05- AMASYA	14- BOLU	23- ELAZIĞ	32- ISPARTA	41- KOCAELİ	50- NEVSEHİR	59- TEKİRDAĞ	68- AKSARAY	77- YALOVA
06- ANKARA	15- BURDUR	24- ERZİNCAN	33- İÇEL	42- KONYA	51- NİĞDE	60- TOKAT	69- BAYBURT	78- KARABÜK
07- ANTALYA	16- BURSA	25- ERZURUM	34- İSTANBUL	43- KÜTAHYA	52- ORDU	61- TRABZON	70- KARAMAN	79- KİLİS
08- ARTVİN	17- ÇANAKKALE	26- ESKİŞEHİR	35- İZMİR	44- MALATYA	53- RİZE	62- TUNCELİ	71- KIRIKKALE	80- OSMANİYE
09- AYDIN	18- ÇANKIRI	27- GAZİANTEP	36- KARS	45- MANİSA	54- SAKARYA	63- ŞANLIURFA	72- BATMAN	81- DÜZCE

Figure 4 Turkey's provincial structure according to DD Zoning

Every new building constructed shall comply with at least C energy rating. In accordance with the minimum requirements of the code, the following table summarizes the minimum heat transfer coefficient values for buildings for Antalya

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

(Zone 1). These values are also considered as the baseline for buildings in Antalya Intervention Area (New Kepez Santral District).

	U_D	U_T	U_t	U_p
Zone 1	0,7	0,45	0,7	2,4

2.2 Models for baseline in mobility interventions

Within the finding process, we noticed that there are no simulation models for baseline in mobility interventions. Therefore, nor mathematical models for baseline adjustments neither simulation models and tools are needed.

2.3 Mathematical models for baseline adjustments

Within the finding process, we noticed that there are no simulation models for baseline in ICT interventions. Therefore, nor mathematical models for baseline adjustments neither simulation models and tools are needed.

2.4 Simulation models and tools

Within the finding process, we noticed that there are no simulation models for baseline in non-technical interventions. Therefore, nor mathematical models for baseline adjustments neither simulation models and tools are needed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

3 Interventions / Indicators requiring baseline simulation or adjustment

The interventions in Antalya cover the new construction of high-performance buildings in the district, which will reach, at least certificate B energy efficiency. Under District / Building level, Antalya has identified 2 interventions covering 7 Energy Actions.

The following table provides an overview of IPMVP selection guidance applied in accordance with the template under Section 2.1.1.

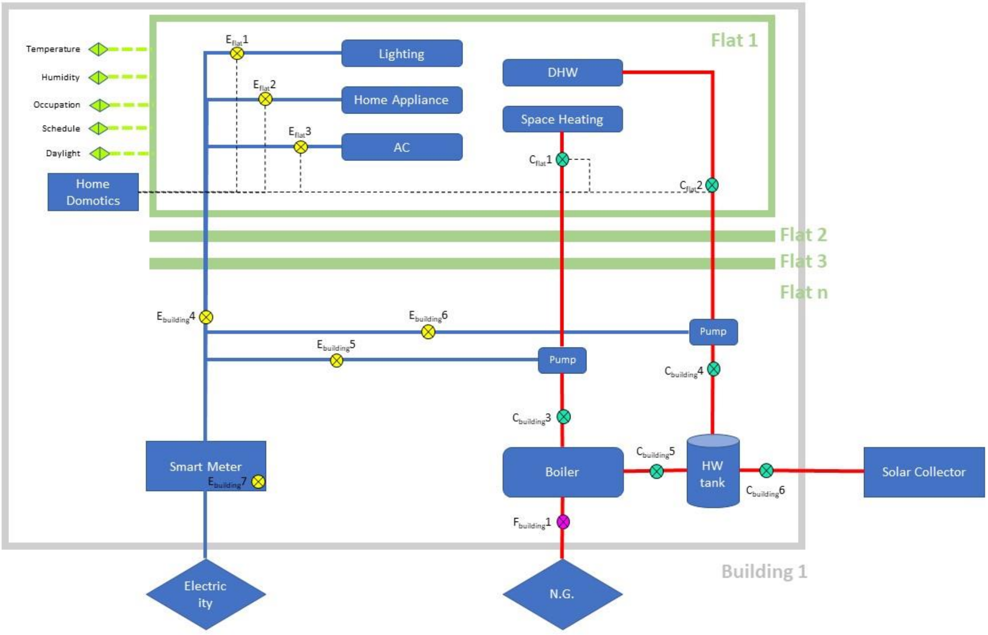
3.1 Intervention 1

<table>
<tr><td colspan="4"><u>Intervention 1: New Construction of Residential Buildings</u>
This intervention covers several actions. From a total area of 20,800 m2 (conditioned area) - 4 residential buildings - 264 flats that will be built beyond current standards for new construction will be the focus area. These buildings, whose constructive principles are high performance envelop through insulation, low u-value glazing, and energy efficient lighting [Action 1]. Demand for domestic hot water will be supplied mainly on renewables comprising Solar Thermal Collectors integrated in the buildings [Action 4]. This action also integrates other actions such as installation of home domotics and controls [Action 6] at apartment level as well as smart meters [Action 7].</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Involved Action</td><td>Savings</td><td>Affected Equipment</td><td>Expected Savings</td></tr>
<tr><td>A1: Residential Blocks (B Energy Rating District)
A4: Solar Thermal Collectors Installation for Residential Building
A6: Smart Control and Domotics
A7: Smart Meters</td><td>Insulation of building envelope together with low u-value glazing will decrease the heating and cooling demand of the buildings. This will lead to savings in both electricity and fuel consumption. Energy efficient lighting will further reduce the electricity consumption. Integration of Solar Collectors in the building will reduce the primary energy consumption for DHW, while smart controls and domotics will have a saving impact through energy management measures.</td><td>In order to achieve the anticipated savings; implementation of insulation material, low u-value glazing, centralized solar thermal collectors and integration of domotics to the BEMs is important.
The savings will be monitored through electricity meters and calorific meters installed after the implementation of the intervention (post action monitoring).</td><td>The energy consumption of the building is expected to reduce by 25-30% with actions under intervention1.</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>

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement N°774477

[4] Need full performance demonstration?	Please go to [6A]	Please go to [6B]
[5] Need to separately assess each Action?	OPTION D	OPTION C
[6A] Missing baseline period data?	OPTION D	OPTION B
[6B] Missing baseline period data?	OPTION D	OPTION A

Measurement Boundary



* Electricity consumption of “Home Appliances” are not within the boundary and the meters are used to isolate the home appliances from the rest of the intervention. The above monitoring boundary is similar for 4 other buildings.

Indicators	E1: Reduction in primary energy demand and consumption E2: Reduction in annual final energy consumption
Baseline Period	12 Month: The baseline period is defined as 12 consecutive months to include a full seasonal cycle to be able to identify all weather conditions cooling and heating demand.

Simulation models and tools

Tool set and characteristics	Design Builder ®
Model description and boundaries	*New construction of residential building involves actions to insulation and low u-value glazing aiming to decrease heating and cooling demand decreasing the energy consumption from the baseline fuel type. Also, energy efficient light will be used which will result in lowered electricity consumption for lighting. Therefore, the Baseline sources are described as* ** Electricity consumption for lighting* ** Electricity consumption for cooling* ** Fuel consumption for heating*

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement N°774477

Input data required	• *Architectural, mechanical, electrical and structural execution project of the buildings,* • *Execution details on building envelope, mechanical, power systems definitions including brief overview of control schematic and insulation performance reports* • *Datasheets (Technical specifications) of technical systems (manufacturer data) including relevant performance data*
Output data obtained	• *Gains and consumption of different forms of energy* • *Comfort and environmental outputs* • *Detailed Daylight outputs including daylight map and daylight at reference points.* • *Evaluation of dimensions and feasibility of technical system components* • *Evaluation and analyses of different performance optimization measures*
Assumptions	*The baseline building is assumed to have at least an energy performance in line with the minimum requirements of TS825*

3.2 Intervention 2

<u>Intervention 2: New Construction of Public Tertiary Buildings</u>

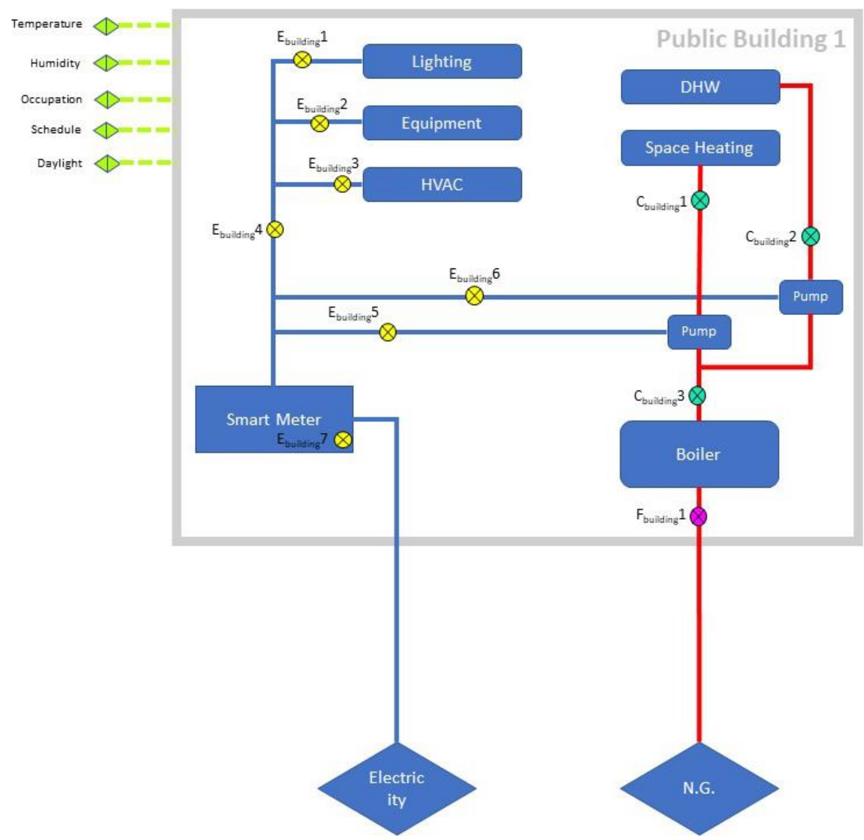
This intervention covers several actions. From a total area of 50,000 m^2 from public buildings in Kepez District will be built beyond current standards for new constructions. These buildings, will be built with high performance envelop (better insulation, glazing), advanced lighting and control systems, high performance HVAC systems, heat recovery ventilation system, occupancy controls. Through these measures the buildings will achieve an Energy Performance Rating of at least B [A2]. This action also integrates other actions such as installation of smart controls [Action 6] as well as smart meters [Action 7].

Involved Action	Savings	Affected Equipment	Expected Savings
A2: New construction of public tertiary buildings 50,000 m^2 (B Energy Rating District) A6: Smart Controls A7: Smart Meters	Insulation of building envelope together with low u-value glazing will decrease the heating and cooling demand of the buildings. Further, use of high-performance HVAC system and heat recovery ventilation system will lead to savings in both electricity and fuel consumption. Energy efficient lighting will further reduce the electricity consumption. Smart controls will have a saving impact through energy management measures.	*In order to achieve the anticipated savings; implementation of insulation material, low u-value glazing, High Performance HVAC, heat recovery ventilation and integration of smart controls to the BEMs is important.* *The savings will be monitored through electricity meters and calorific meters installed after the implementation of the intervention (post action monitoring).*	*The public building is not selected yet. Hence no expected savings could be calculated.*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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	OPTION C
[6A] Missing baseline period data?	OPTION D	OPTION B
[6B] Missing baseline period data?	OPTION D	OPTION A

Measurement Boundary



* Electricity consumption of "Equipment" is not within the boundary and the meters are used to isolate the home appliances from the rest of the intervention. The above monitoring boundary is similar for all other public buildings.

Indicators	E2: Reduction in annual final energy consumption
Baseline Period	12 Month: The baseline period is defined as 12 consecutive months to include a full seasonal cycle to be able to identify all weather conditions cooling and heating demand.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

Simulation models and tools	
Tool set and characteristics	Design Builder ®
Model description and boundaries	*New construction of public building involves actions to insulation and low u-value glazing aiming to decrease heating and cooling demand decreasing the energy consumption from the baseline fuel type. Also, energy efficient light will be used which will result in lowered electricity consumption for lighting. Therefore, the Baseline sources are described as* ** Electricity consumption for lighting* ** Electricity consumption for cooling* ** Fuel consumption for heating*
Input data required	• *Architectural, mechanical, electrical and structural execution project of the buildings,* • *Execution details on building envelope, mechanical, power systems definitions including brief overview of control schematic and insulation performance reports* • *Datasheets (Technical specifications) of technical systems (manufacturer data) including relevant performance data*
Output data obtained	• *Gains and consumption of different forms of energy* • *Comfort and environmental outputs* • *Detailed Daylight outputs including daylight map and daylight at reference points.* • *Evaluation of dimensions and feasibility of technical system components* • *Evaluation and analyses of different performance optimization measures*
Assumptions	*The baseline building is assumed to have at least an energy performance in line with the minimum requirements of TS825*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

4 Conclusions

MAtchUP in Antalya has two important interventions that will have an impact on energy savings as well as GHG reductions. Antalya will implement energy efficient, high performance buildings within KEPEZ District, which is an urban regeneration area. Energy demand will be lowered with high performance building constructions on both residential and commercial usage. Since these buildings are new constructions, it is not possible to have a baseline data based on real or historical data. To determine the performance of these interventions Antalya Team, require simulation tools to quantify performance prior to implementation. This deliverable has provided necessary methodological tools to determine savings in these buildings. Under section 3.2, it is demonstrated that only Option D is the valid option to determine the performance prior to implementation. A simulation tool will be used to determine two critical indicators:

E1: Reduction in primary energy demand and consumption

E2: Reduction in annual final energy consumption

These two indicators will be also used to calculate

E4: CO_2 emission reductions.

Also tool set and characteristics as well as baseline period, monitoring boundaries, input data, important assumptions and expected outcome from the simulation have been identified under section 3.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477

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

Regulation on Energy Performance at Buildings, #27075

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N°774477