Residential Renovation
towards nearly zero energy CITIES

R2CITIES

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

D4.6 M&V Plan for Kartal (Istanbul) demo site

WP 4, Task 4.3

July, 2014 (M12)

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

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Project Coordinator	Rubén García (rubgar@cartif.es) Fundación CARTIF		
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03/03/2014	0.1	CARav	First draft (scheme)
28/08/2012	0.2	REE	Format reviewed, technical description of ECMs explained, missed references completed
12/09/2014	0.3	REE	Baseline model and reporting period of M&V were explained in more detail
19/09/2014	0.4	REE	Offical logo of EU flag is added, document history updated, some technical informations of interventions were summarized
30/09/2014	0.5	CAR	Review of the content
10/10/2014	0.6	REE	Minor updates

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Executive Summary

This report is a side document to the deliverable 4.6 M&V Plan for Turkish demo site, Kartal Elderly House. It describes the on-site measurements and verification processes under the topics below:

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

1 M&V project plan preparation

A well-defined and implemented M&V plan provides the basis for documenting performance in a transparent manner that can be subject to independent, third party verification. A good M&V plan balances the savings uncertainty associated with energy improvement projects against the cost to execute the plan [1].

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

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

Table 1: Recommended M&V plan table of contents

A full description of these topics for the Kartal (Istanbul) demos-site is provided in the following sections.

2 Project Intent

The ultimate goal of R2CITIES project is to develop and demonstrate an open and easily replicable strategy for designing, constructing and managing large scale district renovation projects for achieving nearly zero energy cities. Therefore, a robust performance monitoring and evaluation system will be implemented to reduce energy consumption, peak electric demand, and water use in Kartal Building by providing actionable information to facility managers and building operators. A simple energy monitoring and targeting platform itself can provide approximately 5 % energy cost savings. Carbon Trust has conducted a study over 1000 small businesses and has concluded that on average an organization could save 5%. [2] When this monitored energy data is combined with the sophisticated data evaluation process through advanced monitoring and evaluation system, it is expected to identify corrective actions that would reduce energy consumption approximately 60%. To achive this, a well-defined M&V plan is necessary for documenting performance in a transparent manner that can be subject to independent, third party verification.

2.1 Project description

2.1.1 General description of the site

The project area is located between the Sea of Marmara to the South and the TEM motorway to the North (Figure 1). Motorways, ferries, suburban railways, the Kartal Metro extension and the completion of the Marmaray rail make the location as one of the most accessible sides in Istanbul. The presence of the International Sabiha Gökçen Airport, Formula 1 tract and Sabancı University contributes to the economic structure of the area together with small scale commerce and manufacturing.

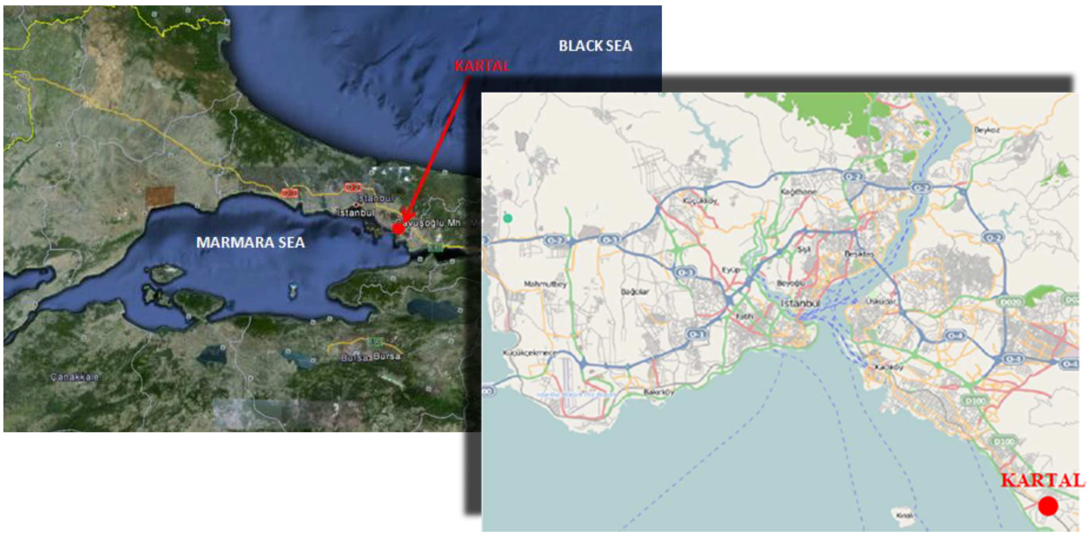


Figure 1: Location of Kartal Demo Site

Within R2CITIES project concept the demo building will be renovated in an open and easily replicable strategy for achieving nearly zero energy cities. Kartal municipality goes a step forward with an urban plan which aims at improving the quality of life of the city by developing a strong social, environmental and economic sustainable city based on public participation, respect of the natural and cultural heritage.

The selected pilot site is located at **Yakacik district of Kartal**. Table 2 summarizes the buildings within the scope of R2CITIS which are part of the demo site (see Figure 2).

City	Istanbul
Address	Kartal/Yakacık
Year of Construction	1987 (Building 2) 2005 (Building 1) 2006 (Building 3)
Number of Buildings	3
Uses classification	Residential

Table 2: Demo Site Identification

Three of the demo buildings are constructed as concrete blocks. Building 1 has 8 stories which was constructed in 2005, Building 2 has 5 stories which was constructed in 1987, Building 3 has 4 stories which was constructed in 2006.

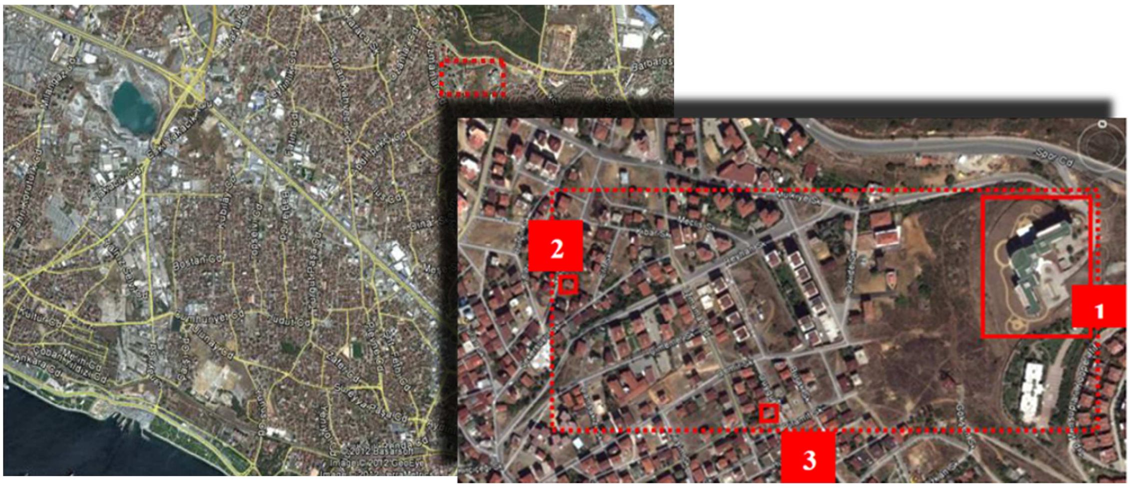


Figure 2: Location of Yakacık District

All three demo buildings are equipped with poor quality building systems especially in lighting applications and are characterized by considerable energy consumption for domestic hot water production. Therefore, energy efficiency strategies were set.

Building 1 has the largest total building floor area and a poor quality envelope. It also shows very good possibilities to integrate a PV plant on the façade and solar thermal systems on the roof. **Building 2 & 3** have similar structural characteristics so their consumptions are evaluated together. Both buildings are equipped with low efficient lighting systems and are characterized by considerable energy consumption for domestic hot water production.

The project aims to **develop a methodology to retrofit a residential district through energy efficient strategies**. Passive design strategies, interventions on heating & cooling systems and integration of renewable energy sources are examined.

The Kartal Municipality has also set its strategy to use 40% of the area for roads, green area, sport areas, cultural facilities and similar amenities. Building 1 has different management policy as it is owned by municipality, while other two are owned by a private owner with multi properties. For the scope of this project, retrofitting plan covers 3 building blocks with 18,813 m^2 floor area and total 580 inhabitants.

2.1.2 Constructive Features of Buildings

Even though external wall insulation represents the main problem related to energy losses in buildings in Turkey, the demo buildings were built after the building energy performance regulation in 2000 and therefore have a certain level of insulation in compliance with law.

Figure 3: Building Type of Yakacık District

Building type 1

Number of stories	8
Total conditioned floor area (m2)	18,108
External wall insulation	5 cm low density expanded polystyrene (EPS)
Roof insulation	Asphalt based water insulated EPS
Glazing	Double glazed windows with aluminum frames in residential rooms and double glazed windows with vinyl frames in common areas

Table 3: Constructive features of Building 1

Building type 2

Number of stories	5
Total conditioned floor area (m2)	396
External wall insulation	5 cm low density expanded polystyrene (EPS)
Roof insulation	Asphalt based water insulated EPS
Glazing	Double glazed windows with aluminum frames

Table 4: Constructive features of Building 2

Building type 3

Number of stories	4
Total conditioned floor area (m2)	309
External wall insulation	5 cm low density expanded polystyrene (EPS)
Roof insulation	Asphalt based water insulated EPS

Glazing	Double glazed windows with aluminum frames

Table 5: Constructive features of Building 3

2.1.3 Envelope elements and thermal characteristics

Soil-Contact External wall	U-value	[W/m^{2}K]	0,959

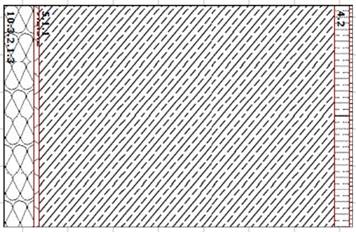
Description	Details: section's sketch from inner face to outer face	Picture
1. External Coating 2. Cement mortar 3. Reinforced Concrete 4. PVC 5. Extrude Polistrene		

Figure 4: External wall constructive features of Building 1

Roof	U-value	[W/m^{2}K]	0,633

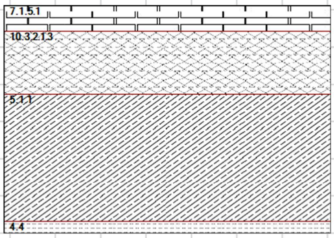
Description	Details: section's sketch from inner face to outer face	Picture
1. External Coating 2. Concrete 3. Extrude Polistrene 4. Brick Wall 5. Internal Coating		

Figure 5: Roof constructive features of Building 1

Ground floor	U-value	[W/m²K]	0,7138

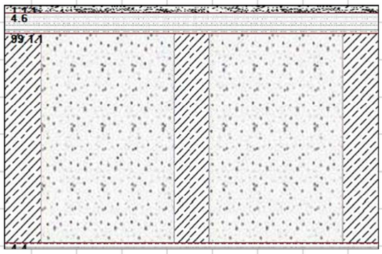
Description	Details: section's sketch from inner face to outer face	Picture
1. External Coating 2.Filler-joist Floor 3. Cement Finish 4. Hardwood Finish		

Figure 6: Ground floor constructive features of Building 1

Internal floor	U-value	[W/m²K]	0,6316

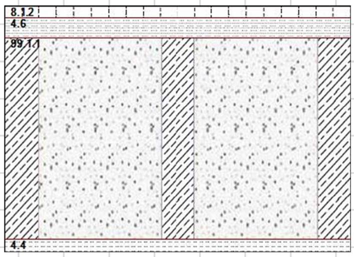
Description	Details: section's sketch from inner face to outer face	Picture
1. External Coating 2. Filler-joist Floor 3. Cement Finish 4. Hardwood Finish		

Figure 7: Internal floor constructive features of Building 1

Internal partition	U-value	[W/m²K]	0,537

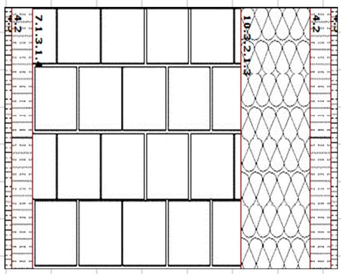
Description	Details: section's sketch from inner face to outer face	Picture
1. External Plaster 2. Cement Coating 3. Extrude Polistrene 4. Brick Wall 5. Cement Coating 6. Internal Plaster		

Figure 8: Internal partition constructive features of Building 1

Pitched roof	U-value	[W/m²K]	2,10

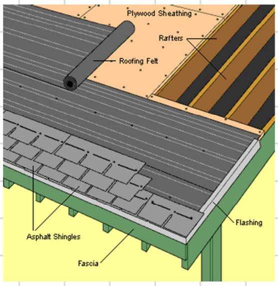
Description	Details: section's sketch from inner face to outer face	Picture
1. Shingles 2. Roofing Felt 3. Wooden Strips		

Figure 9: Pitched roof constructive features of Building 1

Window (type 1)	U-value (glazing)	[W/m²K]	3,4
	g-value (glazing)		0,74
	U-value (frame	[W/m²K]	

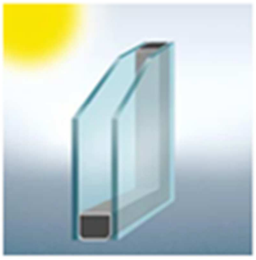
Description	Details: section's sketch from inner face to outer face	Picture
Double Glazed and PVC Frame		

Figure 10: Windows technical features of Building 1

2.1.4 HVAC and lighting systems

Heating	2-pipe fan coil units
Cooling	2-pipe fan coil units
Ventilation	Fan-coil units with air handling unit
Lighting	Fluorescence lamps in common areas and incandescent lamps in bedrooms

Table 6: HVAC and Lighting system of Building 1

Heating	Natural gas supplied radiator heaters
Cooling	N/A
Ventilation	Natural Ventilation
Lighting	Incandescent lamps

Table 7: HVAC and Lighting system of Building 2

Heating	Natıral gas supplied radiator heaters
Cooling	N/A
Ventilation	Natural Ventilation
Lighting	Incandescent lamps

Table 8: HVAC and Lighting system of Building 3

2.1.5 Description of Interventions

Several alternatives and combinations of technologies have been compared and analyzed, based on their effect on whole building energy performance, CO_2 emissions and costs.

Thermal insulation increase and thermal bridges elimination or reduction

A retrofit action concerning thermal insulation increase and thermal bridges elimination or reduction will be performed. This solution includes the single use of innovative or standard low cost techniques or a combination of them. In particular, the use of standard thermo-hygrometric materials, innovative high-performance products (thermal insulating paint or/and panel, or/and waterproofing membrane) and colours to optimize the solar absorption and reflection of the external envelope will be considered.

ECM Analysis table			
Thermal insulation increase and thermal bridges elimination or reduction	Investment	700,00 €	
	Exact location	Envelope of all the buildings	
	Size of the intervention	All the covered area of the buildings	
		Existing Condition U-Value (W/m2-K)	**Final U-Value (W/m2-K)**
	Exterior Wall with insulation	0,6	0,223
	Windows	3,4	1,6
	Roof	0,4	0,4
	Floor	2,839	2,839
	Interior Wall	0,453	0,453
	Underground Wall	0,959	0,482

	Exterior Wall color			light	light
	Shading			0,649	0,649
	ECM CLASSIFICATION	Obligatory nature		Not obligatory (according to current regulation)	
		Urgency		Low	
		Durability		50 years	
		Reliability		High	
		Replicability		Replicable in situations with poor external insulation	
	SAVINGS	Energy savings	Heating + DHW (gas)	724,970 kWh/year	
			Electricity	13,803.6 kWh/year	
		Costs savings		23,326.4 €/year	
		CO_2 savings		140,669 $kgCO_2$/year	

Table 9: Analysis of features for the thermal insulation EMC

Installation of radiant heating and cooling systems

Low temperature heating systems or high temperature cooling systems that is suitable for residential buildings can use a variety of fuels and renewable energy sources. These systems use energy efficiently while providing a comfortable indoor climate. For making use of environmental energy in an efficient way, it is beneficial to use heat or cooling energy with moderate temperature levels. For example, heat pumps work more efficiently when the heating output temperature is lower. The expected savings from this intervention are around 82.500 kWh/m^2a in the heating and cooling system.

ECM Analysis table			
Installation of radiant heating and cooling systems	Investment		66,56 €
	Exact location		1.Basement Floor
	Size of the intervention		512 m^2
	ECM CLASSIFICATION	Obligatory nature	Not obligatory (according to current regulation)
		Urgency	Low
		Durability	30 years
		Reliability	High

		Replicability		Replicable in the whole district
	SAVINGS	Energy savings	Heating + DHW (gas)	82,500 kWh/year
			Electricity	1,570.8 kWh/year
		Costs savings		2,742 €/year
		CO_2 savings		25,742 $kgCO_2$/year

Table 10: Analysis of features for the heating and cooling ECM

Installation of solar thermal systems

Solar thermal technology uses the sun energy as the primary energy source to generate thermal energy that can be used for the domestic hot water production. By utilizing solar energy instead of fossil fuels, solar thermal systems reduce the amount of greenhouse gases emissions and fuel consumptions. The system includes solar thermal collectors mounted on the roof and faced to the South with a tilt angle to optimize solar energy gain. Another basic component of the solar thermal system is the hot water storage tank: monovalent or bivalent tanks in the heating room will be connected to the solar thermal collectors with their heat exchanger coils inside. Between tanks and solar thermal collectors there will be circulators and solar controllers.

For residential buildings, thermosyphon solar water heaters are planned to be installed to cover the hot water demand. Their passive design allows heat transfer using natural convection in a closed fluid loop. The advantage is that they do not require pump, this keeps the complexity and costs of a termosyphon system low. In addition, being a compact solution, tanks, solar thermal collectors and other equipment will be installed on the roof and will not require an additional room inside the building.

ECM Analysis table			
Installation of solar thermal systems	Investment		80,00 €
	Exact location		Roof
	Size of the intervention		Total 456m^2 gross surface area
	CHARACTERISTICS	System efficiency (%)	30,6
		DHW Solar fraction (%)	39,6
		Solar contribution to DHW (MWh)	209,46
		Installed collector power (kW)	319,2

		Installed collector gross area (m2)		456	
		Energy delivered by collectors (MWh)		257,26	
	ECM CLASSIFICATION	Obligatory nature		Not obligatory (according to current regulation)	
		Urgency		Low	
		Durability		30 years	
		Reliability		High	
		Replicability		Replicable only in buildings with free south oriented area	
	COMPARISON			Existing Condition (kWh/year)	Final Condition (kWh/year)
			Heating + DHW (gas)	4297917	4018917
			Electricity	3462899	3462899
	SAVINGS	Energy savings	Heating + DHW (gas)	279,000 kWh/year	
			Electricity	0 kWh/year	
		Costs savings		8,450 €/year	
		CO_2 savings		50,500 $kgCO_2$/year	

Table 11: Analysis of features for the solar thermal ECM

Replacement of the existing building appliances and lighting systems

Electricity appliances account for a significant portion of utility bill, in particular lighting is a major source of electricity consumption in buildings. Because of prevalent use of inefficient lighting technologies especially in the residential sector, they are a very good target for demand-side energy efficiency initiatives.

In this context, a complete replacement of the lighting systems in the demo buildings is planned as a part of the retrofitting project. The existing fixtures will be replaced with more efficient LED systems. The number and the specific locations of the replaced lighting systems will be determined after the project implementation. The benefits of energy efficient lighting's installation include energy saving and reduced electricity bills.

In addition, a replacement of the existing residential appliances (refrigerators, washing machines, etc.) with A or A+ energy class products is also planned. Appliances number and locations will be specified by the Municipality.

ECM Analysis table				
Replacement of the existing building appliances and lighting systems	Investment			151,000 €
	Exact location			Almost all living spaces, rooms, commonly used areas
	Size of the intervention			- Almost all spaces existing lighting system - living rooms, commonly used areas - Appliances in Elderly Buildings
	ECM CLASSIFICATION	Obligatory nature		Not obligatory (according to current regulation)
		Urgency		Low
		Durability		5 years
		Reliability		High
		Replicability		Replicable in situations with poor lighting system
	SAVINGS	Energy savings	Heating + DHW (gas)	0
			Electricity	1,049,000 kWh/year
		Costs savings		129,000 €/year
		CO_2 savings		723,271 $kgCO_2$/year

Table 12: Analysis of the appliances substitution ECM

Energy consumption monitoring and control (automation) systems

Similar to Genoa's pilot site, an energy consumption monitoring and control system will be deployed to improve building energy management. Such a system creates an understanding of energy usage patterns and may reveal issues that are often neglected by users, identifying opportunities to improve building energy efficiency and reduce energy costs. The energy monitoring system is composed of several devices for monitoring and data acquisition that are listed below:

- energy meter;
- calorimeter;
- gas meter;
- flow meter;
- temperature sensors;
- humidity sensors;
- light sensors;
- solar radiation sensors;
- pressure sensors;
- heat flow sensors;
- reliable occupancy sensors;
- actuators;

These sensors provide measurements of some physical parameters like temperature and light that can be used by the system to perform some automatic adjustments within the energy management system. As stated before, this management system will be defined in Deliverable 2.12 "District Monitoring Platform" [3] and Deliverable 2.13 "District Energy Management Platform" [4], in correspondence to Task 2.2 of WP2.

<table>
<tr><th colspan="5">ECM Analysis table</th></tr>
<tr><td rowspan="13">Energy consumption monitoring and control system</td><td colspan="3">Investment</td><td>322,000 €</td></tr>
<tr><td colspan="3">Exact location</td><td>• Elderly House for Lighting, Mechanical and Electricity Automation
• Residential Buildings for Electricity and Gas metering</td></tr>
<tr><td colspan="3">Size of the intervention</td><td>• Whole building system based application (lighting, electricity and mechanical automation for Elderly house;
• electricity and gas usage measurement for Residential)</td></tr>
<tr><td rowspan="5">ECM CLASSIFICATION</td><td colspan="2">Obligatory nature</td><td>Not obligatory (according to current regulation)</td></tr>
<tr><td colspan="2">Urgency</td><td>High (It is important to make the planning of the automation system at the beginning of the ECM installations for Elderly House)
Low (residential metering units can be implemented independent from the time)</td></tr>
<tr><td colspan="2">Durability</td><td>10 years for automation systems
more than 30 years for monitoring</td></tr>
<tr><td colspan="2">Reliability</td><td>High</td></tr>
<tr><td colspan="2">Replicability</td><td>Replicable in any building type having controllable lighting and HVAC systems or measurement units</td></tr>
<tr><td rowspan="4">SAVINGS</td><td rowspan="2">Energy savings</td><td>Heating + DHW (gas)</td><td>29% (1,250 MWh/year) for space heating</td></tr>
<tr><td>Electricity</td><td>35% (1,220 MWh/year) for electricity</td></tr>
<tr><td colspan="2">Costs savings</td><td>159,500 €/year</td></tr>
<tr><td colspan="2">CO_2 savings</td><td>959,750 $kgCO_2$/year</td></tr>
</table>

Table 13: Analysis of the energy management ECM

<u>Windows Replacement</u>

The window replacement makes a major contribution on energy and cost saving in demo site. The source of major heat losses are windows. The purpose of this intervention, reduced heat losses and increase energy efficiency on heating and cooling system.

The intervention consist two sections in building which are rooms and common area windows. With this intervention, existing windows are changed with double glazing windows which have a U-value of 1.2 W/m2-K and a shading coefficient of 0.29.

<table>
<tr><th colspan="5">ECM Analysis table</th></tr>
<tr><td rowspan="18">Window Replacement</td><td colspan="2">Investment</td><td colspan="2">115,00 €</td></tr>
<tr><td colspan="2">Exact location</td><td colspan="2">Rooms and common areas window</td></tr>
<tr><td colspan="2">Size of the intervention</td><td colspan="2">2,900m2</td></tr>
<tr><td rowspan="5">ECM CLASSIFICATION</td><td>Obligatory nature</td><td colspan="2">Not obligatory (according to current regulation)</td></tr>
<tr><td>Urgency</td><td colspan="2">Medium (conditions vary window by window)</td></tr>
<tr><td>Durability</td><td colspan="2">30 years</td></tr>
<tr><td>Reliability</td><td colspan="2">High</td></tr>
<tr><td>Replicability</td><td colspan="2">Replicable in the whole district</td></tr>
<tr><td rowspan="5">CHARACTERISTICS</td><td></td><td>Existing Condition</td><td>Final Condition</td></tr>
<tr><td>Shading Coefficient</td><td>0.86</td><td>0.29</td></tr>
<tr><td>Solar Transmittance</td><td>0.8</td><td>0.58</td></tr>
<tr><td>Glazing U-value (W/m2-K)</td><td>3.4</td><td>1.2</td></tr>
<tr><td>Infiltration (ac/h)</td><td>1.1</td><td>0.2</td></tr>
<tr><td rowspan="4">SAVINGS</td><td>Energy savings – Heating + DHW (gas)</td><td colspan="2">474,247.7 kwh/year</td></tr>
<tr><td>Energy savings – Electricity</td><td colspan="2">356,315.9 kwh/year</td></tr>
<tr><td>Costs savings</td><td colspan="2">49,859 €/year</td></tr>
<tr><td>CO2 savings</td><td colspan="2">331,495 kgCO2/ year</td></tr>
</table>

Table 14: Analysis of the window replacement ECM

<u>Application of Water Savings Installation of thermostatic valves and an individual metering system</u>

Showering is one of the leading uses of water inside the residential building. Thermostatic valves and low flow showerheads are used to provide water and energy saving in retrofitted buildings. A thermostatic temperature control shower valve allows providing optimal temperature and avoiding scalding problem. Water routed through to the valve is automatically dispensed at desired temperature. In this intervention, thermostatic valves are used.

One of the simple ways to create water and energy saving in bathrooms is to use the low flow showerheads which are inexpensive and easy to install. In this project, the proposed equipment is planned to provide 80% less flow.

ECM Analysis table				
Application of Water Savings Installation of thermostatic valves and an individual metering system	Investment			173,000 €
	Exact location			Rooms Bathroom
	Size of the intervention			228 room showerhead
	ECM CLASSIFICATION	Obligatory nature		Not obligatory (according to current regulation)
		Urgency		Low
		Durability		20 years
		Reliability		High
		Replicability		Replicable in situations with poor water appliance systems
	SAVINGS	Energy savings	Heating + DHW (gas)	281,984.4 kwh/year
			Electricity	0 kwh/year
		Costs savings		8,459.5 €/year
		CO2 savings		51,014 kgCO2/ year

Table 15: Analysis of the water savings ECM

<u>**Air-Source Heat Pump Installation**</u>

Heating and cooling system consume the major part of the building energy use. High efficient systems can be an alternative to provide low energy use.

Aim of this intervention is to replace part of the existing heating and cooling system with an air-source heat pump which can provide efficient heating and cooling in buildings. Air source heat pump system is basically located at outdoor around the building, and takes the air then boosts it to a higher temperature by operating heat pump.

The system was planned to be integrated only at Elderly building. The capacity of the air-source heat pump was defined according to the heating and cooling peak load of existing building condition.

ECM Analysis table				
Air-Source Heat Pump Installation	Investment			660,000 €
	Exact location			System installation area was located around the building
	Size of the intervention			Heating capacity is 310kW Cooling capacity is 297kW
	ECM CLASSIFICATION	Obligatory nature		No obligation
		Urgency		Not urgent
		Durability		20 years
		Reliability		High
		Replicability		Replicable
	SAVINGS	Energy savings	Heating + DHW (gas)	1,278,786 kwh/year

			Electricity	393,422 kwh/year
		Costs savings		77,705.7 €/year
		CO2 savings		502,706 kgCO2/ year

Table 16: Analysis of the heat pump ECM

As a result of energy audit technical indicators have been calculated to determine the energy diagnosis and evaluate the effectiveness of R2CITIES interventions shown in Table 17 below; The technical indicators were obtained from D1.1 "District Level audit and Diagnosis Methodology" [5]

TECHNICAL INDICATOR		DISTRICT AREA	BUILDING 1	BUILDING 2	BUILDING 3
Density of final energy demand [D1]	$kWh/m^2/yr$	484.66	484.66	234,96	151,54
Peak load of electricity demand [D4]	kW	287,901	287,901	18,03	12,87
Peak load of thermal energy demand [D5]	kW	5288,17	5288,17	118,44	63,17

Table 17: Energy Demand on Demo Site

2.1.6 Estimated Investment Costs

The estimated costs for the envisaged systems are hereby summarized:

- Envelope retreatment including thermal insulation increase and thermal bridges elimination or reduction: 700,000 €
- Installation of radiant heating and cooling systems 66,560 €
- Windows Replacement : 115,000 €
- Installation of solar thermal systems: 80,000 €
- Replacement of the existing building appliances and lighting systems: 151,000 €
- Energy consumption monitoring and control system and Automation: 322,000€
- Application of Water Savings Installation of thermostatic valves and of an individual metering system: 173,000 €
- Mechanical Installation: Air-Source Heat Pump: 660,000 €

2.2 Expected project benefits

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

- Energy savings: it is the amount of energy saved (i.e.: not consumed) if compared to the previous scenario and/or the amount of energy produced by means of the innovative/renewable systems installed within the Project;
- Costs savings: it is the quantification of the economic benefits directly related to the energy savings/self-production;
- CO_2 savings: it is the environmental benefit originated by the energy saving/self-production; each kWh of energy, litre of fuel, or whatever the energy carrier considered, corresponds through an emission factor to greenhouse gas emissions; so, GHG emissions are saved whenever those units of energy are saved and/or self-produced.

On the basis of information provided by the companies which will apply the interventions on the site and the building simulation results which show the before and after situations, estimated cost savings are calculated for each intervantions. Table 18 summarizes the benefits of interventions in terms of cost and environmental affect. Table 19 gives the summary of total energy demand of demo site and estimated percentage of savings.

KARTAL INTERVENTION COSTS	Savings
Envelope insulation and retreatment	Energy Saving: 738,774 kWh/year
Insulation and recovering of basement **Electro-osmosis Dewatering System**	Costs Saving: 23,326.4 €/year
External Wall Insulation **Roof Insulation**	CO_2 Saving: 140,669 kgCO2/year
Installation of radiant heating and cooling systems	Energy Saving: 84,071 kWh/year
	Costs Saving: 2,742 €/year
	CO_2 Saving: 25,742 kgCO2/year
Installation of solar thermal systems	Energy Saving: 279,204.9 kWh/year
	Costs Saving: 8,451.69 €/year
	CO_2 Saving: 50,509 kgCO2/year
Replacement of the existing building appliances and lighting systems	Energy Saving: 1,048,901.5 kWh/year
	Costs Saving: 128,805.1€/year

	CO_2 Saving: 723,271 kg CO2/year
Energy consumption monitoring and control system	Energy Saving: 472,936.5 kWh/year
	Costs Saving: 31,860 €/year
	CO2 Saving: 18,606 kgCO2/year
Windows Replacement	Energy Saving: 830,563.6 kWh/year
	Costs Saving: 49,859 €/year
	CO2 Saving: 331,495 kgCO2/year
Application of Water Savings Installation of thermostatic valves and of an individual metering system	Energy Saving: 281,984.4 kwh/year
	Costs Saving: 8,459.5 €/year
	CO2 Saving: 51,014 kgCO2/ year
Mechanical Installation: Air-Source Heat Pump	Energy Saving: 1,672,208 kWh/year
	Costs Saving: 77,705.7 €/year
	CO2 Saving: 502,706 kgCO2/year

Table 18: Summary of the quoted benefits

TECHNICAL INDICATOR	BUILDING 1	BUILDING 2	BUILDING 3	TOTAL DEMAND	TOTAL SAVINGS	% SAVINGS
Density of final energy demand [D1] kWh/m^2yr	484.66	151.54	234.96	871.16	344.619	60.4

Table 19: Summary of Energy Demand and Estimated Savings

2.3 M&V project team and manager

For the Kartal demo site the project team will be composed by **the municipality of Kartal [KAR], Istanbul Technical University [ITU] and Reengen [REE]**

The municipality of Kartal with different responsibilities:

- Owner of the demo site;
- Input on the selection of the most suitable interventions;
- Finalization of preliminary and definitive implementation project (technical and administrative aspects);
- Tender publication and assessment of the demands that will be applied;
- Overall overview during the work implementation;

Istanbul Technical University with different responsibilities:

- Input on the selection of the most suitable interventions in particular in term of envelope performances and internal comfort conditions;
- Diagnosis and energy/sustainable audit of the demo;
- Input for the preliminary and definitive project (technical aspects,Drawings, numerical simulation with standard and innovative instruments;
- Co-coordination (together with the other Turkish partners) and analysis of the results related to the ECMs (Energy Conservation Measures) deployed and to the research activities in the "in situ laboratories".

REENGEN with different responsibilities:

- Input on the selection of the most suitable interventions in particular in term of sensors for the monitoring phase
- Input to the preliminary and definitive project (technical aspects)
- ICT platform development for data storage
- Monitoring system data analytics platform development
- Determining technical aspects of building automation systems
- Combining all BEMS systems into one monitoring platform

In particular with the monitoring project Reengen will be responsible for Kartal Demo Site in R2Cities project.

3 Selected IPMVP option and measurement boundary

Protocols for M&V have been agreed upon and documented by the evaluation industry through the International Performance Measurement and Verification Protocol, or IPMVP. The IPMVP provides an overview of current, best-practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It is also be used by facility operators to assess and improve facility performance. IPMVP procedures should be adopted into the district requirements considering the building types, their operations etc.

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

3.1 M&V Option

There are four options in IPMVP, identified as Option A, B, C and D for determining savings. These options depend on the project's specifications and availability of data. The options range from isolating the specific energy conservation measure (ECM) — such as a lighting retrofit — to measure energy use at whole facility level – such as measuring gas and electric utility meters for a twelve month base year period and throughout the post-retrofit period.

The details of M&V options and supported option by Kartal demo site are briefly described in the table below.

	How Savings Are Calculated	Supported by Kartal Demo Site
A. Partially Measured Retrofit Isolation **Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous.**	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.	No

B. Retrofit Isolation **Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.**	Engineering calculations using short term or continuous measurements	No
C. Whole Facility **Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.**	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.	No
D. Calibrated Simulation **Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.**	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end- use metering.	Yes

Table 20: M&V Option Details

The reason why Kartal Demo site supports option D is that for Building 1, baseline data is not available and for Building 2 and Building 3 utility bill data for baseline period is unreliable. Therefore, savings will be determined through simulation of the energy use of components at whole district and real-data (during reportin period) to collect the energy consumption after intervention. Istanbul Technical University researchers will perform the simulations for each building by taking pre-retrofit and post-retrofit period into account, so that the impact of each intervention on the buildings can be shown. The site will be modelled in detail, usually via specialised energy modelling software. The model will built from the ‘bottom up’, including a full asset list and equipment ratings, operating schedules, control strategies, and data for site-based independent variables.

Modelling will incorporate 12 months of data, usually in hourly or half-hourly increments. Base year energy use determined by whole building energy simulation will be calibrated by the post-retrofit period real-time data. Since there will be a real-time monitoring system in buildings, ongoing M&V will be considered.

3.2 Measurement boundary

According to the ECM applications, saving calculations and their verification methodologies can differ depending on the application area such as, entire building, equipment based, etc.

If the energy saving strategy targets management of the equipments or systems, then all the system saving should be calculated aroun that involved equipment. This approach means Retrofit Analysis, Option A and B. If the main aim is to report entire building energy savings, then the boundary should be entire building and the methodology used is Option C. If there is not enough and reliable historical data or baseline model, then calibrated energy simulation data can be used in order to support the unreliability. This boundary shows the Option D.

Besides these calculation methodologies, there are indirect effects of ECMs, which are called interactive effect. The indirect effect of the LED lighting can be considered as reducing heating loads and decreasing cooling need in summer, increasing heating load in winter.

In Kartal Demo site, each of the buildings will be considered separately with same methodoly by using historical data and simulation data since there is no reliable pre-retrofit energy data for demo site. So the boundary is split into each single building.

As in Kartal demo site, the main ECMs will be implemented for the Building 1, which will be an Elderly House and has the bigger gross floor area in the demo site. These ECMs have been summarized in

ECM Analysis table			
Thermal insulation increase and thermal bridges elimination or reduction	Investment	700,00 €	
	Exact location	Envelope of all the buildings	
	Size of the intervention	All the covered area of the buildings	
		Existing Condition U-Value (W/m2-K)	**Final U-Value (W/m2-K)**
	Exterior Wall with insulation	0,6	0,223
	Windows	3,4	1,6
	Roof	0,4	0,4
	Floor	2,839	2,839

	Interior Wall			0,453	0,453
	Underground Wall			0,959	0,482
	Exterior Wall color			light	light
	Shading			0,649	0,649
	ECM CLASSIFICATION	Obligatory nature		Not obligatory (according to current regulation)	
		Urgency		Low	
		Durability		50 years	
		Reliability		High	
		Replicability		Replicable in situations with poor external insulation	
	SAVINGS	Energy savings	Heating + DHW (gas)	724,970 kWh/year	
			Electricity	13,803.6 kWh/year	
		Costs savings		23,326.4 €/year	
		CO_2 savings		140,669 $kgCO_2$/year	

Table 9-Table 16 above and for Building 1 will include the envelope retreatments, radiant heating and cooling system application, automation, monitoring and control for HVAC and lighting sytem, window replacements, implementation of solar thermal sytem and air-pump system. For Building 2 and Building 3 ECMs will include envelope and window replacements as stated in Building 1, however, automation and control system implementation is not included for these residential type of buildings. Therefore each single building will be taken into account separately in measurement boundary. Figure 11 gives an overlook into the district area and each building involved in measurement boundary.

Figure 11: Kartal district boundary

3.3 Key Performance Indicators

Key performance indicators can give the energy characteristics of the buildings and should be determined in details and calculated according to the type of site. For energy assesment and energy saving, the key performance indicators are;

1. **Energy consumption:** This is the amount of energy used within the measurement boundary, before and after. It gives energy consumption calculated by calibrated simulation in pre-retrofit period and energy consumption by the whole building and internal systems such as lighting, HVAC and electrical systems measured during the post-retrofit period.

   To enable the comparability between all three buildings, the total energy consumption is related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered time interval (e.g. year).

   The benchmarks are expressed in terms of energy density (kWh/m2 per year) and separated into electrical and non-electrical components;

$$Electrical\ energy\ density = \frac{Electrical\ consumption\ per\ year}{Gross\ floor\ area}\left[\frac{kWh}{m2 - year}\right]$$

$$Thermal\ energy\ density = \frac{Natural\ gas\ consumption\ per\ year}{Gross\ floor\ area}\left[\frac{kWh}{m2 - year}\right]$$

During the baseline period, the KPI will be obtained from the building energy simulations performed for every building. Moreover, the measured data will be used for the calibration of simulation.

2. **End-use energy consumption:** It is expressed by kWh/m2 and indicates the energy consumptions of each major service (e.g. lighting, pumps, fan) used in the building divided by the building area.

3. **Independent variables**: These are the variables that cause routine changes in energy use, which must be incorporated as routine adjustments in an M&V savings calculation. The analysis on saving calculations will be done considering the temperature effect. Environmental and structural conditions of buildings give a clear picture for the benchmarking consumption values. The independent variables considered in calculations for Kartal site are:
   1. Weather: including ambient temperature and humidity
   2. Operating hours: daily/weekly/seasonal operating schedules.
   3. Occupancy: staff, students, patients, shoppers, tenants, visitors, etc.
   4. System loads/ activity levels: heating/cooling requirements, temperature set points, work required from equipment, etc.

There are some details about the KPIs for each building type below:

Kartal Elderly House	Residential - 1 and 2
•Electrical energy density •Thermal energy density •End-use energy consumption •Wheather •Operating hours •Occupancy number	•Electrical energy density •Thermal energy density •Wheather •Occupancy number

Table 21: Key Performance Indicators by Building Type

3.4 Interactive effects

IPMVP defines the interactive effects as energy effect generated by ECM, but it does not consider the measurements within the boundary. Interactive effects mean the indirect effect of ECMs on building operational cost. For the Kartal Elderly House, the source of different kind of interactive effects is mainly dependent on systems and their retrofit type. For example, in Kartal, there will be solar termal application on the rooftop and the main effect will be on the hot water, heating and cooling. Beside, it also has interactive effects based on the shadow effect on roof, which reduces the heating load and decrease the cooling cost. Then, the indirect effect of the LED lighting can be considered as reducing heating loads and decreasing cooling need in summer, increasing heating load in winter.

3.5 Additionality

In this project, three energy automation systems will be implemented in Kartal Elderly House.

Building Automation and Control System (BACS) has an impact on building energy performance from many aspects. BACS provides effective automation and control of heating, ventilation, cooling, hot water and lighting appliances etc., that increase operational and energy efficiencies. A study based on EN 15232-Effects of Building Automation on Building Efficiency standard indicates that 20% can be saved by building automation and control. [6] When we integrate energy data analytics platform, it creates dynamic adjustments on these systems according to the weather conditions, dynamic energy pricing, consumption forecast and increase saving levels. This control & optimization part of the project would be the innovative part of the implementation.

In addition, using white and black box benchmarking method, monitoring system can calculate the energy saving effect of the ECMs. There will be at least three ECM applications on the project site: insulation on the walls, solar thermal system and LED lighting. Comparing with the baselines calculated by the dynamic simulation method will give accurate saving effect of such applications.

4 Baseline: period, energy and conditions

4.1 Baseline and post-retrofit measurement periods

Baseline model will be created by building energy simulation models for each building since there is no historical metered data belonging to the buildings. These simulation models will be prepared by Istanbul Technical University (ITU) researchers. Simulations will be performed on eQuest building energy simulation software. A simulation will be performed for each building, which is for showing the pre-retrofit condition without ECMs on each building. During the post-retrofit period real-time data will be measured for Building 1 through building automation system. For Building 2 and Building 3, real-time data will be collected via smart meters for 12-month period after each ECMs are completed. Simulations will be calibrated by taking real measurements and independent variables like whether and occupancy into account and an accurate baseline models will be created for each building.

Lack of historical consumption data increases the importance of baseline to verify the retrofits. Every structural data (orientation, internal systems planned to use, area, etc) and operational data (schedule, occupancy rate gathered from the whole-day energy audits in buildings.

Structural data: It consists of building area, ventilated volume, orientation, type of walls and insulation.

System data: It consists of energy infrastructure (equipments) and estimated loads under different conditions and hours. Each system from fans, pumps, to lightings is taking into account zone by zone.

Dynamic data: Weather is a very important parameter affecting the energy usage after human factor. There is also another data from the occupancy rate via occupancy measurement sensors that we install them on each entrance. These dynamic data will upgrade the baseline model from static results to dynamic continuous baseline.

4.2 Operating cycle

Operating cycle of the monitoring of savings should cover the whole months after ECMs completed for each building on the site. This is because, there will be a baseline simulation output for 12 months and it is necessary to show the impacts of ECMs for whole building during each month of the year to be able to compare the calibrated baseline simulation model and post-retrofit real-time measurement in each month. Therefore the seasonal changes and its impacts on ECMs within a year will have considered.

4.3 Baseline conditions

Baseline conditions include physical, operational, and energy use data on the facility and systems. Baseline conditions will be determined through surveys and inspections in Kartal dmeo site. Since pre-installation metering is not available for the site, baseline conditions will be predicted through simulation by inputting all key characteristics of the buildings, including

– Physical properties of building materials (walls, floors, roof, windows, partitions, doors, insulation).

– Site specific information, including location, reflectivity of external surfaces, wind conditions, shading from external objects.

– Infiltration rates (how well the building is sealed) − Internal loads, including occupancy density, metabolic rate (activity levels and clothing).

– Occupancy patterns (occupation levels at various times).

– Equipment details (energy using equipment including size, power draw, equipment usage patterns and control strategies, heat output).

– Lighting details (types, numbers, locations of lights and/or lighting density, heat output, operating schedules).

All these characteristics will then be calibrated according to the data measured from reporting period.

5 Reporting period

The reporting period should encompass at least one normal operating cycle of the equipment or facility, in order to fully characterize the savings effectiveness in all normal operating modes. Therefore, for the Kartal M&V plan, the reporting period will set up twelve months after all ECMs implemented and monitoring of site completed. This period will not include the installation of the required meters for the data collection during post-retrofit period. After the 12-month of reporting period savings will be calculated, however ongoing reporting will continue through web enabled monitoring platform.

The activities during reporting period can be divided into measurement and calibration of baseline model. The time interval of the measurements from each system will be adjusted to 15 minute periods. It gives us chance to analyse the effect of the systems in details.

In addition, weekly, monthly and seasonal reports give a better view of energy saving applications. Monthly and seasonal system based reporting will be used to detect each building's performance and saving effect within specific time period.

In the the calibration period the data will be compared with the theoretical results. The model will be calibrated and validated when the next conditions are accomplished.

* Monthly error = ±15%

* Net mean bias error annual = ±5%

6 Basis for Adjustment

First of all, all energy measurement devices with special certifications will be calibrated in order to read correct data. The units of the data from electricity consumption (kWh) to natural gas usage (m^3) and their conversion methods for proper comparison will be defined.

Also, simulation models of the buildings will be revised according to the as built projects with all details. In dynamic environmental conditions in order to make proper performance benchmark, we will create an adjusted baseline model according to the static and dynamic variable in Kartal Demo Site. The saving, or "avoided energy use" is the difference between the adjusted-baseline energy and the energy actually metered during the reporting period.

6.1 Independent variables and the basis for adjustments

Independent variables affecting the baseline energy use are commonly weather conditions, occupancy rate and production rate of the facility.

In the case of Kartal Elderly House and other Residentials, Production rate is not an available variable for measurement and not applicable. Main independent variables for the demo sites are outdoor temperature, which is called dry-bulb temperature, humidity and occupancy.

Dry-bulb temperature and humidity level will be taken into account by the 15min measurements from the on-site weather sensors. If this is not available then the monitoring system gathers the real-time data via web services, which is collecting the data from the nearest weather station. Although humidity level is directly used as a basis for adjustments, temperature value converted to the degree-days. Degree-days value gives the cooling and heating need on the site according to the daily average temperature and calculated as follows [7]:

Heating Degree Days (HDD):

If Temperature (T) < 15, HDD = (18 – (T))* day, if not, HDD = 0

Cooling Degree Days (CDD)

If Temperature (T) > 22, CDD = ((T) – 22) * day, if not, CDD = 0

7 Analysis procedure for calculating results

This section describes the data analytics models, algorithms and assumptions to be used in each saving report. Energy analysis on the Kartal Demo Site will be calculated as a combination of dependent and independent variables.

The mathematical model for the energy saving calculations before and after ECM applied on the site will be replicable model for any other site. The multiple linear regression (MLR) and the support vector machine (SVM) are the high-tech models for energy performance calculations. In these models, one dependent variable mostly energy data is defined in terms of other independent variables. MLR method is the first level for such application and we will use this method with several independent variables related with energy usage. Common model expression is as follow:

$$Y = a*x_1 + b*x_2 + c*x_3 + \ldots + d \text{ (constant)}$$

where:

- y is the dependent variable, mostly energy consumption of a desired period (daily, weekly, monthly etc). y can be a system based and a zone based consumption value as well. For each different definition of y, we should determine different independent variable. The list of this is given below.
- x's shows the independent variables related with the energy consumption. This could be weather conditions like temperature, humidity, HDD, CDD and simulation or baseline results of the building

Variables	HDD	CDD
Whole Building Energy Consumption	X	X

Table 14: Dependent and Independent Variables related with energy measurements

In the case of Kartal demo site, the dependent variables will be HDD and CDD since baseline simulation model and post-retrofit measurement period will cover the whole year (both cooling season and heating season) as mentioned before. Therefore a multiple linear regression model will be created.

8 Energy prices for cost savings calculations

In Turkey conditions, there are two type of pricing model for buildings electricity usage; one is fixed price and second is three-time price.

In fixed price method, your electricity usage is read by the supplier and multiplied by fixed unit price and added taxes on it. This model is same for natural gas and water usage. Average electricity price is around 0.25 TL/kWh + %50 VAT. However, in three-time price, the supplier gives three different prices for fixed time intervals. Table 22 summarizes the three-time price model in Turkey.

Time of Use	Pricing
06:00 - 17:00	0.18 TL/kWh + 50% VAT (approximately)
17:00 - 22:00	0.34 TL/kWh + 50% VAT (approximately)
22:00 - 06:00	0.07 TL/kWh + 50% VAT (approximately)

Table 22: Time of use periods and pricing

The defined time intervals are 06:00 – 17:00, 17:00 – 22:00, 22:00 – 06:00. If the facility uses more energy between 22:00 – 06:00, this model is almost half price of the fixed pricing.

In Kartal Demo site, considering the increase in energy prices in almost every 6 months, we get the dynamic energy pricing from the common database and compare it with the other energy suppliers pricing in order to analyse if there is chance to get cheaper energy.

9 Meter specifications

Main metering points are separated into four systems, HVAC, lighting, electricity and IAQ (Indoor Air Quality) sensors. All these data sources run on the separate automation systems with different communication protocols and databases. With monitoring platform we gather all these information in one platform and provide data connection to the Concerto database.

All the meters and their values will be calibrated and checked before commissioning. Main structure of the metering system is given below.

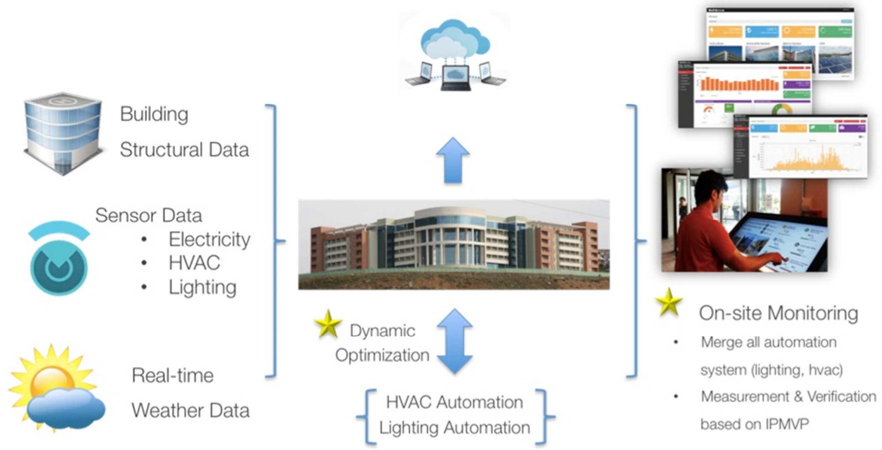


Figure 12 General Structure of Metering and Data Transfer

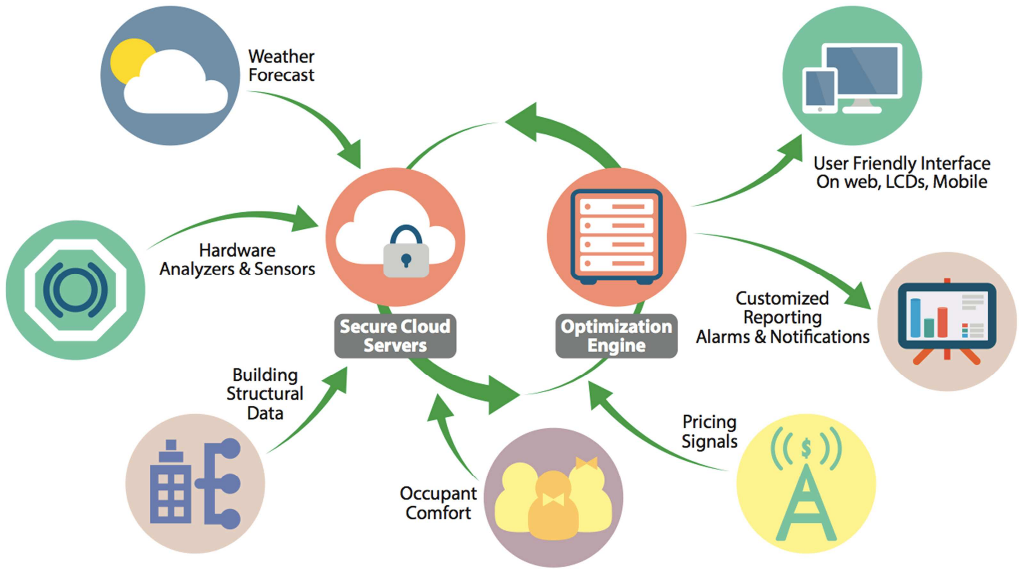


Figure 13: Conceptual Design of Data Analytics Algorithms

9.1 Collecting data, equipment requirements and metering specifications

The electrical automation will be controlled through the central computer placed in the Energy Center of the Kartal Building and Schneider Vijeo Citect software will be used. The Vijeo Citect software includes monitoring of basic parameters of electricity for each floor including line currents, line voltages, harmonics, frequency, active power and reactive power. The measurement units and the technical units used in long term monitoring of electrical consumption of the Kartal Building are as follows:

- V = Voltage, A = Current in amperes, kW = Real power in kilowatts, kWh = Energy in kilowatt hours, kVA = Apparent Power in kilovolt-amperes, kVAR = Reactive Power in kilovolt-amperes reactive
- Meter: Measurement device that includes the following components: Calculation (meter), communication, and power supply.
- Metering system: Cabled network of meters and other networked devices that transmit to and store discreet energy analyzer data at a central location.
- Circuit: The closed path conductor or wire through which electric current flows. There are two types of circuits: feeder and branch.
- Feeder Circuit: A circuit that carries a large block of power from service equipment to a point where the power is broken down (i.e. a panelboard).
- Branch Circuit: A smaller circuits that distribute power from the service panel to point of use. In other words, a feeder supplies power to the panel or main breaker and branch circuits leave the panel to power devices.
- Panelboard: Component of an electrical distribution system which divides the current and provides a fuse or breaker for protection.
- Feeder Meters: Used to measure the electrical consumption at the whole building level.
- Shorting block: Switch that shorts 5 amp CT conductors to ground to reduce shock hazards to electricians.
- Voltage Tap: Connection from meter to electrical distribution system that allows the meter to measure voltage and may power the meter.
- Fuse block: Equipment designed to house fuse overcurrent protection between the voltage tap and the meter.
- Server: The computer which houses Automation system software and is connected to the metering system network located in energy distribution center.
- Real Power: the amount of power that is used by an electrical device or system.
- Apparent Power: the amount of power that the utility must commit to a building. It includes both the real power and the reactive power.
- Reactive Power: Power that is required by inductive loads such as motors.
- Power Metering System Architecture: In Kartal Building power metering system, data is collected at individual energy analyzers in each floor and then transmitted over a Modbus communications network to a server, where it becomes accessible to applications software, Schneider Vijeo Citect.
- Meters and Metering Hardware: Hardware includes meters, current transformers, voltage taps, and shorting blocks.
- Communications Network: The communications network includes data loggers, servers, gateways, cabling between meters, Ethernet cards, switches, routers, and other similar components that communicate via standard protocols. Common

protocols include RS-485, RS-232, and TCP/IP.

Figure 14: Energy Analyzer for Electricity Parameters Measurement

Software: Kartal Energy management and visualization software includes software modules that gather, store, analyze, normalize, and present data collected by meters within the metering system.

Lighting system will be controlled by DALI KNX automation, where the dim level, on/off level of the individual armatures can be controlled from the central programming software.

The lighting consumption of each floor can be monitored by Vijeo Citect Software from the main electricity panels. There are lighting sensors connected to the lighting automation system which arrange the automation status regarding the natural lighting level. The armatures can be groupped and programmed according to custom user wishes. The parameters that will be measured in the concept of lighting quality are lux, lighting intensity, lighting quality, day light factor.

Figure 15: DALI KNX Gateway and Lighting Level Sensor for Lighting Automation

The mechanical systems including heating, ventilation, air conditioning, Air ground heat exchanger, air quality sensors are all controlled and monitored by web based BACnet automation tool Total Control Software. (The software that would be planned to install) Air quality sensors will measure temperature, humidity level and CO2 level.

Figure 16: Indoor Air Quality Sensor for Mechanical Automation System

The Kartal Building mechanical systems are all defined in Total Control software with a reference icon. The on/off, differential controls are arranged to be done automatically by the sensor feedbacks, however, manual operation and intervention is still possible.

All single units including rooms and common áreas should have CO2 and temperature sensors, which are operated as part of the BACnet mechanical automation. The following particular units are selected according to their orientation, function and dimensions. Additional sensors have been selected to these single units

As an Option D requirement, we use e-Quest modeling results. The Inputs of the modeling is mostly from the electricity, mechanical and lighting plans of the building and other data to be used as a input were gather from site visits and staff working in building. The output of the modelling gives us a system and zone based hourly energy consumption estimations.

9.2 Key measurement parameter(s)

Key parameters to be measured in order to calculate the most precise energy performance analysis are given on Table 23. They provide the minimmun requirements for analyzing M&V details based on the Options given in previous sections.

	Measuring parameter	Time Period
1	Total Electricity Consumption (kWh)	15 min. / monthly bill
2	Lighting consumption by zones (kWh)	15 min.
3	HVAC (pumps, fans) consumption by zones (kWh)	15 min.
4	Plug Loads consumption by zones (kWh)	15 min.
5	Outdoor weather conditions (Temp, Hum)	15 min.
6	Indoor air quality (Temp, CO2,	15 min.
7	Natural Gas Consumption (m3)	15 min. / monthly bill
8	Dynamic pricing signals (TL/kWh)	15 min.

9	Solar Thermal RES Production (kWh)	15 min.
10	Water Usage (m3)	15 min. / monthly bill

Table 23: Measurement Parameters (Data-points)

9.3 Estimated parameter(s) and justification for estimates

As depicted before, the unique data-point to be estimated is the energy consumption for the as-it-is status of the buildings because only a set of representative buildings will be monitored and not all the invoices are available for completing the baseline period. This estimation will be used for future energy demand forecast, filling the missing data, and calibrating the baseline results.

Approach used to assess energy performance of Kartal building utilizing data mining technologies in sophisticated monitoring software which includes regression analysis and web based service oriented architectures. The method uses a statistical procedure known as linear regression to generate a model of building energy performance. This model can be used to predict energy use, to estimate savings, and to assess building energy performance trends. The energy consumption of each electrical and mechanical system is also measured and recorded by this online monitoring system. By comparing the results of the analysis with building energy modeling software output, the method can identify building parts and systems with the greatest energy saving opportunities and recommend the types of energy efficiency measures. Moreover, it derives all of this actionable information from readily available real time energy flow and real-time wheather data.

The energy performance modeling software static output data is enriched with the real time energy flowing and indoor air quality data in order to calibrate the simulation results with actual values. In the software, there exist some web services that get the hourly meteorological data from location based weather services.

The steps of estimation methodology can be summarized as below:

1. The first step is to create regression models of each type of energy use versus weather and occupancy rate for buildings. The model parameters represent weather independent energy use (base load), weather dependent energy use (building heating and cooling sensitivity) and the building balance-point temperature.
2. The second step involves building a baseline model from Simple Hourly Building Energy Simulation which shows us simulated hourly energy consumption data. This data is cross-checked with older hourly data captured from the metering points and calibrated to analyze historical performance trends.
3. The third step involves benchmarking the building performance with the baseline model created by simulation engine. The resolution of the benchmark will enable us to see how whole building and stand alone systems such as lighting, heating, cooling, air conditioning systems perform.
4. The final step is to estimate the size of the energy savings for each building.

10 Monitoring responsibilities

Main issue is the design of the monitoring concept and compatibility between automation system and monitoring system. After proper designing period, next step is the selecting products and installer company with very low cost because of the governmental installation. This lowest price procedure is a bit risky for the infrastructure of the monitoring platform however we define all technical details in technical specification guide for the installer companies.

With regard to the responsibilities in the demonstrator, Table 24 points them out.

Task Description	Partner	Responsibility
Energy Modelling	ITU	Generating proper energy simulation of the buildings for both baseline and ideal modelling.
Technical Specifications about Automation Systems	REENGEN	HVAC, Lighting and Electricity System Concept and Technical Design
Automation System Installation	KARTAL	Make the bidding competition and find the winner as a installer
Monitoring Platform Development	REENGEN	Developing the customized monitoring platform
Data gathering and commissioning	REENGEN/Installer	Integration of the automation systems with monitoring platform
Data Analytics	REENGEN	Generate building specific analytics and visualising
ECMs	MIR/KARTAL/ITU	Energy efficient applications and innovative technologies

Table 24: Responsibility Table

10.1 Technical monitoring

To start up, a summary of the Concerto technical monitoring guide [8] is highlighted in order to establish the common framework to be applied. First of all, Concerto specifies those minimum parameters to enable the energy analysis. Thus, the overall generated, delivered and consumed energy have to be measured. This M&V plan obeys these minimum requirements through the selected data-points in Table 23. Moreover, it ideally sets up a common period for metering for all the data-points, which is applied in R2CITIES with energy flow measurements each 15 minutes. Furthermore, the energy should be expressed per unit of gross/heated/cooled area, such as R2CITIES is doing for the definition of the measurements, as well as the ECM(s) performance.

Nevertheless, the energy data comparison among different years has a different impact depending on the climate conditions. Therefore, the energy information should be normalized with the HDD and/or CDD. In the M&V plan these values are considered for the adjustment in the overall equation for energy savings. Furthermore, Concerto defines a timeframe to be applied, as shown in Figure 17. Three stages are described: definition of the monitoring concept, implementation of the monitoring measures and monitoring of the energy supply and consumption. At this moment, the project is running in the stage 1 where the monitoring concept and the integration of the meters will be rendered, whereas the next two stages will be carried out in advance. However, R2CITIES span is of 4 years, reducing the first stage in one year for applying with the guidance of Concerto.

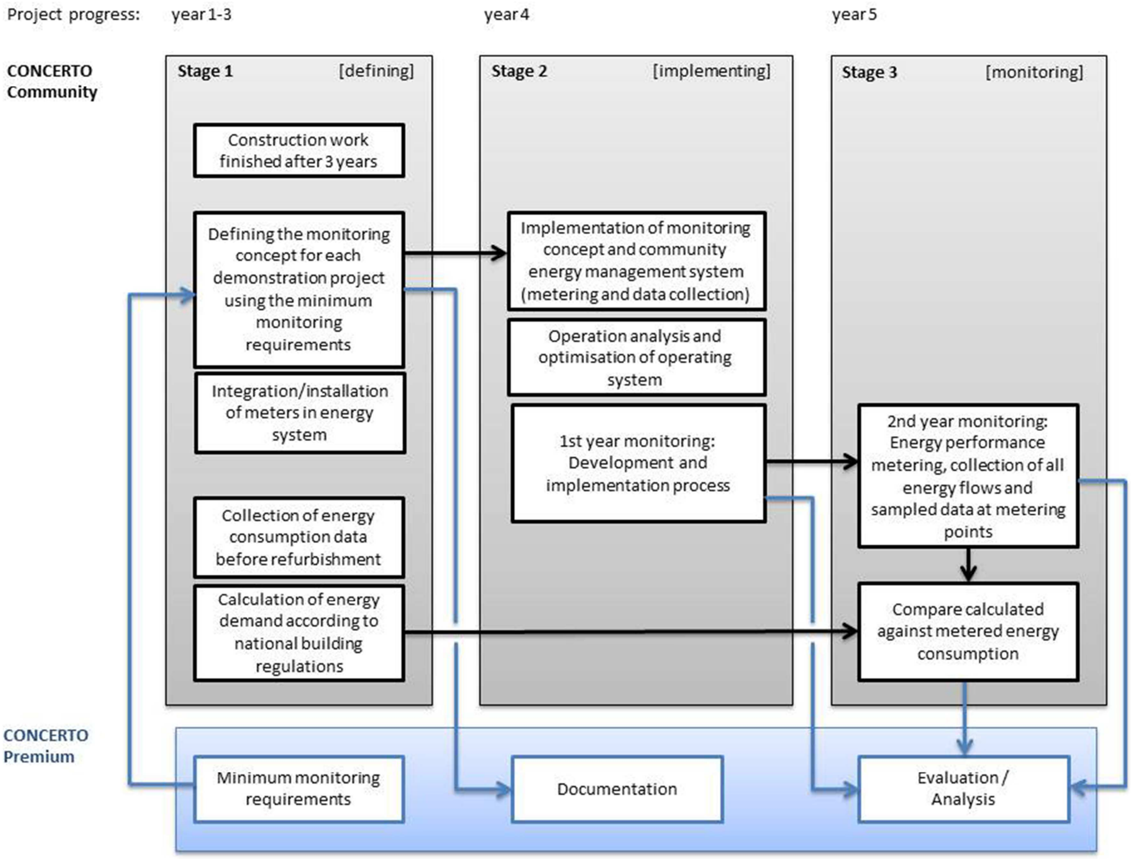


Figure 17: Timeframe according to Concerto

On the other hand, Concerto establishes where to meter, being the main point the Renewable Energy Sources (RES), as well as the energy uses (i.e. DHW, heating, electricity consumption…) separately. That guideline includes the zones if the building has multiple areas with different requirements of energy.

Finally, so as to contribute with Concerto premium database, R2CITIES will compile the information of the monitoring system, before and after refurbishment, as well as energy analysis in order to feed the Excel sheets provided by Concerto.

11 Expected accuracy

In every measurement devices, calculations based on convergency, using unreliable data and so on can affect the accuracy of the results. None of the meters can measure with 100% accuracy on the market and the accuracy of them changes according to the quality, calibration, and the environmental properties of the site where it is applied.

On the demo site there could be different parameters that can affect the reportings and calculations:

- Errors based on devices: This is generally refers to negligible deviation from the expected results. The error rates of such metering devices are changes btw +- 1% and +-1 ^{o}C for temperature measurement.
- Modeling errors: This refers to the assumptions and methodologies, which the simulation programs are using. Also, the reliability of the input data affects this error rate.
- Sampling error rate: This means the rough values for the non-metered parameters, not precise measurement such as occupancy rate.
- Interactive effects: These are the effects which can not be calculated easily and can be negligible depending on the requirements.

As overall maximum acceptable error range can change between 3% and 5% for the M&V plan.

12 Report format

M&V Plan reports will include the measurement period, measured energy data and measured independent variables like weather data, occupancy number and indoor temperatures.

In addition to the measured data, M&V reports will also include description and justification for any corrections made to observed data. Energy price used in the calculations and any other computed savings and monertary units will be included. The results of M&V plan for Kartal demo site will be expressed on D4.8.

For ongoing M&V period, there will be a customizable monitoring interface, which can be categorized according to the user level such as admin, technical person, financial managers, general usage etc. This gives a real-time reporting based on the calculations mentioned previous sections.

In addition, there will be template report formats for weekly and monthly energy performance benchmarks. This report includes the total energy consumptions in desired time interval, building energy performance according to the historical data, energy breakdowns and regression results, heat maps, forecasts and heat map for energy usage. Sample version for the reporting format is given below.

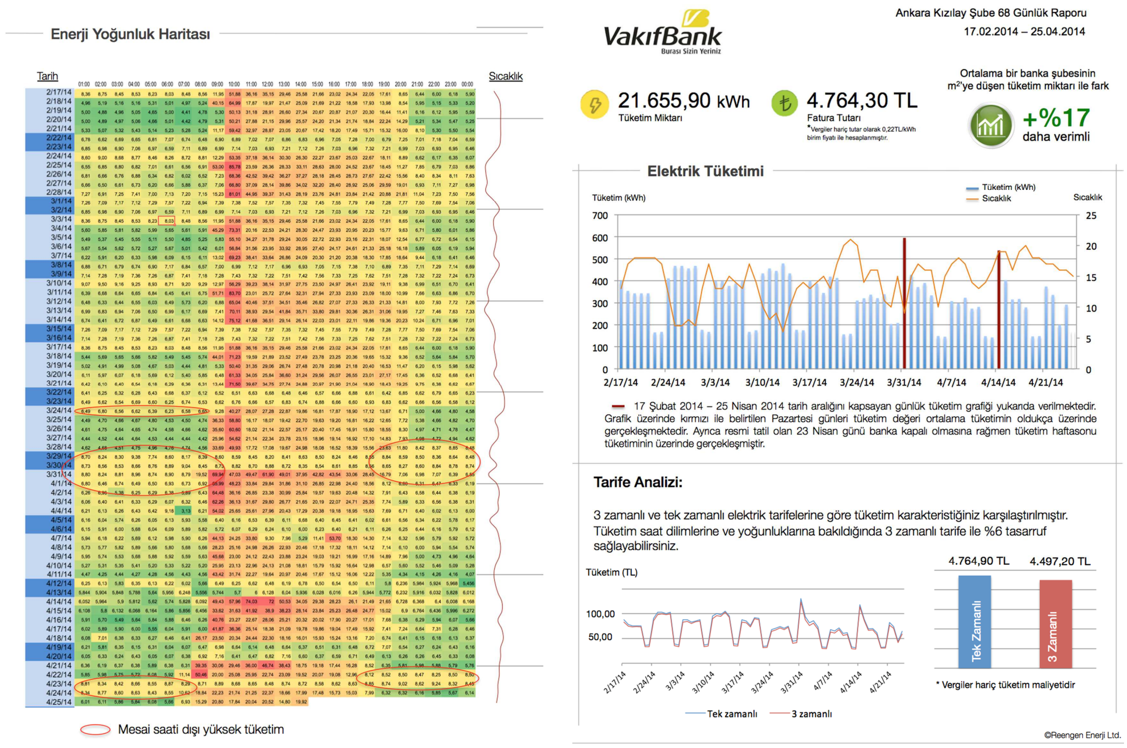


Figure 18: Sample Report Formats

13 Quality assurance

Quaility of the data measured by meters on site is the most important part for the correct data analytics results. This importance covers all the parameters from gas volume to electricity consumptions, therefore each parameter will be checked automatically according to the defined alarm range whether they measured correct or not. If there is something wrong then the technical guy gets alarms about the missing part. Definition and detail of the alarm management system is mentioned in D4.3. If there is no data gathered from the field then missing data algorithms fill these gaps by analysing general historical trends of these parameters.

Avoiding from the future failures, all these measured data are backed up in every week and the system works without any missing part.

14 References

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