KABEV

CASE STUDY MINISTRY OF AGRICULTURE AND FORESTRY

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REPUBLIC OF TURKEY
MINISTRY OF ENVIRONMENT,
URBANIZATION AND CLIMATE CHANGE

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KAMU BİNALARINDA
ENERJİ VERİMLİLİĞİ PROJESİ
YAPI İŞLERİ GENEL MÜDÜRLÜĞÜ

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ABOUT THE PROJECT – KABEV

The Energy Efficiency in Public Buildings (EEPB / KABEV) project is implemented by the Ministry of Environment, Urbanization and Climate Change (MoEUCC), **General Directorate of Construction Affairs (GDCA)** with funding from the World Bank.

Through the project, MoEUCC supports the renovation of central government and central-government affiliated buildings (i.e., schools, universities, court houses, administrative buildings and schools). It is expected that such subprojects will generate at least 20% energy cost savings and CO2 emissions reductions in addition to social co-benefits such as improving the comfort level within the buildings, which would form the basis for developing a national-level program for energy efficiency (EE) in public buildings.
Project investments primarily focus on public buildings with high energy consumption and shorter payback periods.

With the project, which aims to renew 500 public buildings in an energy efficient way, it is aimed to combat climate change by providing at least 20% energy and CO_2 savings, demonstrating deep renovations and nearly zero energy buildings (NZEB), energy performance contracts (EPCs), increasing comfort.

OVERVIEW

MINISTRY OF AGRICULTURE AND FORESTRY BUILDING

Ankara, Türkiye

Public Building

2 Administrative Buildings

49.166 m²

Ministry Building

Energy Efficiency Renovation

Picture 1. Ministry of Agriculture and Forestry (Main Building)

Turkish Ministry of Agriculture and Forestry is a headquarters building with two administrative blocks (Main building and a social facility block). The buildings are about 12 years old. They had excessive energy consumption leading to high energy bills for an office building, minor control over HVAC system due to lack of a qualified HVAC automation system, no heat recovery system and renewable energy system.

Building administration was enthusiastic to join KABEV program to resolve the technical and comfort problems orginating from high energy bills. What's more, building administration wanted to decrease the high energy bills by implementing an innovative and green solution which is solar PV energy system in this case. The implementation of energy efficiency works were done by an energy efficiency renovation contractor via conventional renovation construction contract.

Waste Heat Recovery and Outdoor Air Temperature Compensation Implementation to Hot Water Boilers

Heating system comprised of 3 pcs of floor mounted natural gas heating boilers (2 pcs of 3.500 kW and 1 pc of 100 kW for domestic hot water use) in the main building boiler room and constant speed heating water circulation pumps equipped with low efficiency electric motors.

Boilers were conventional boilers which do not have any sort of heat recovery feature. Now, the boilers are equipped with waste heat recovery units recovering heat from high temperature flue gas and transfering that waste heat to heating water. This causes the boilers consume less amount of natural gas and yer providing the same amount of heating energy.

On the other hand, hot water boilers' heating water supply temperature setpoint were either fixed during the heating season or manually controlled by the building technical operation staff during mild seasons. Now, heating water supply temperature reset control is integrated into the boiler automation system so that heating water supply temperature shall be reset based on outdoor dry-bulb temperature. For example, heating water temperature setpoint is 80°C in case the outdoor dry-bulb temperature is -5°C whereas, heating water temperature setpoint is reset as 65°C in case the outdoor dry-bulb temperature is 10°C. Heating water temperature setpoint is ramped linearly between 80°C and 65°C at outdoor air temperatures between -5°C and 10°C.

Picture 2. Waste Heat Recovery (Before vs After)

Boilers with waste heat recovery, capacity modulation and heating water supply temperature reset capability provide as much heating energy as demanded by the buildings leading to much less heating energy consumption.

Variable Speed Circulation Pumps

Constant speed heating and chilled water circulation pumps operate all the time and leading to excess energy consumption. Old and constant speed heating and chilled water circulation pumps including evaporator loop circulation pumps have been either replaced with brand new integrated variable speed circulation pumps or integrated with variable speed drive (frequency converters) in case pump replacement was not economically feasible.

Picture 3. Circulation Pumps Replacement (Before vs After)

Now, all the heating and cooling energy is distributed by more efficient circulation pumps avoiding overheating or overcooling and excess heating and cooling energy consumption. Circulation pumps now adjust their speed and operate only as much as the heating/cooling demand leading to savings both in heating/cooling and pump energy.

Electric Motors Upgrade from Standard Efficiency (IE1) to Premium Efficiency (IE3)

There were several standard efficieny (IE1 based on IEC terminology or EFF2 based on CEMEP terminology) electric motors coupled with predominantly air handling unit (AHU) fans. Electric motors having nominal power over 3 kW (over 30 pcs) have been replaced with premium efficiency (IE3) electric motors. Motors have capacity below 3 kW were not considered to be the focus of savings because they had insignificant power capacity.

Picture 4. Electric Motors (Before vs After)

Variable Speed Drive Integration to Social Facility Block's Air Handling Unit (AHU-5) Fan

Air handling unit serving to social facility block, AHU-5, did not have a variable speed drive, frequency converter. Constant speed air handling unit operated all the time leading to excess energy consumption. Installing air quality sensor (CO_2 ppm sensor) in AHU-5's return air duct, fan motors of air handling unit could be operated according to the data coming from the sensor which would mean providing fresh air based on the actual demand of the ventilated space. Embedding a simple automation system, variable speed drive (frequency converter) adjusts the fan speed according to the air quality data coming from sensor. When air handling unit adjusts the speed of fan motor depending on air quality, exhaust fans operating in same zone will also decrease its speed at the same rate. New frequency converters which are suitable operating with building automation system will be installed.

Now, the excess energy consumed by ventilation fans is avoided. AHU-5 ventilation fans now adjust their speed and operate only as much as the fresh air (outdoor air) demand leading to electricity savings.

Replacement of Conventional Air Handling Units with Heat Recovery Air Handling Units

The potential of replacement of current air handling units with air handling units equipped with "heat recovery module" were investigated and it was concluded that only AHU-18 and AHU-19 air handling units, which were located on the roof, had potential for replacement. Remaining air handling units were located in mechanical rooms and there was not enough space/floor height for heat recovery type AHUs in mechanical rooms.

As a result, AHU-18 and AHU-19, serving to office floors between floor 8 and 15, were replaced with brand new air handling units equipped with heat recovery modules. Heat recovery modules will transfer the waste heat of return air to supply air without mixing two air streams during heating season and eventually provide heating energy savings. The contrary will be realized during cooling seasons and eventually provide cooling energy savings.

Picture 5. Replacement of *AHU-18 and AHU-19 with heat recovery air handling units (Before vs After)*

Motorized Valve Implementation in Fan-Coil Units (FCUs)

Existing fan-coil unit (FCU) heating coil inlets were equipped with old fashioned manual control valves. Therefore, when room temperature reached the value set in FCU thermostat, only FCU fan stopped and water kept circulating through coils. As a result, FCU continued to function as a static heater or cooler and redundant energy consumption occured. Old fashioned manual control valves in FCU inlets have been replaced with motorized control valves. Now, the motorized valve closes when not needed, thus reducing energy consumption of heating water circulation pumps and boilers during heating season, and chilled water circulation pump and chillers during cooling season.

Now, all the spaces are heated/cooled by more efficient boilers (due to waste heat recovery modules and heating water temperature reset) / chillers distributing heating water/chilled water to fan-coil units equipped with motorized valves bringing the rooms to ideal heating/cooling temperature and avoiding overheating/overcooling and excess heating/cooling energy consumption. Circulation pumps now adjust their speed and operate only as much as the heating/cooling demand leading to savings both in heating/cooling and pump energy.

Renewable Energy

There was no renewable energy system within the facility before. After reducing the energy demand and consumption to the minimum level, on-site renewable energy measure has been adopted in order to further reduce carbon footprint of the facility. Solar photovoltaic system with a 400 kW_e rated power has been applied at open air carparks over canopies based on the effective canopy roof area and transformer capacity of the facility. Carports with steel framed canopies have been installed in parking area just infront of the main building. Parking area facing the south façade of the main building was deliberately selected in order to avoid any shading effect that might lead to respectively lower energy generation performance.

Picture 6. Parking lot carport solar photovoltaics (Before vs After)

Building Automation and Energy Monitoring System

There was a basic automation system in the building and there was no energy monitoring system. There was a potential in building automation system which can contribute to the overall energy efficiency. Within the scope of this energy efficiency renovation works, it has been proposed to upgrade building automation system for HVAC and auxiliary systems in addition to an energy monitoring system. It has been expected that energy would be saved as systems could be controlled automatically at an optimum operation scenario. Moreover, the energy savings within this project and possible future energy efficiency projects will be monitored and verified in compliance with the international performance measurement and verificaiton protocol (IPMVP) by means of this newly established established energy monitoring system.

On the other hand, considering the competencies and skills of operation and maintenance personnel in public buildings, such systems have been proposed to provide a basic level of control and monitoring in order to avoid difficulties in terms of user friendliness, operation complexity and an increase in the costs of maintenance. Thus, a qualified but not complex system has been installed that can be easily used by building staff who do not have a high level of competence in building automation systems. As a result, a system that can control and monitor the main HVAC equipments at a reasonable level, while monitoring energy consumption at the building level has been established.

Building System	Before Implementation of EEMs	After Implementation of EEMs
Building Envelope	Insulation as per local building insulation standard requirement.	Insulation as per local building insulation standard requirement.
Heating System	2 x 3.500 kW + 1 x 100 kW floor mounted natural gas heating boilers and constant speed circulation pumps.	2 x 3.500 kW + 1 x 100 kW floor mounted natural gas heating boilers and variable speed circulation pumps.
Cooling System	Air Cooled Chillers and constant speed circulation pumps.	Air Cooled Chillers and variable speed circulation pumps.
Ventilation System	Mechanical ventilation via constant speed air handling units.	Mechanical ventilation via air handling units with heat recovery modules and demand controlled ventilation in social facility block.
Domestic Hot Water System	Fed by a spcific DHW boiler	Fed by a spcific DHW boiler
Mechanical Installation/Plumbing	Insulated according to local plumbing insulation standard.	Insulated according to local plumbing insulation standard.
Interior Lighting System	Mostly LED bulbs	Mostly LED bulbs
Electrical System	2 x 2.500 kVA main transformers	2 x 2.500 kVA main transformers
Compensation System	Operational compensation system.	Operational compensation system.
Renewable Energy System	None.	Installed 400 kWe carport photovoltaic solar power system in parking lot.
Energy Monitoring System	None.	Energy monitoring system that allows building level monitoring for heating and electricity consumption.
Distributed Energy Source: Cogeneration/Trigeneration	None.	None.

Table 1. Building Systems Comparison (Before vs After EEMs)

ENERGY EFFICIENCY MEASURES AND EXPECTED SAVINGS

No	Energy Efficiency Measure	Energy Type	Energy Savings		Energy Cost Savings	Investment Cost	Payback Period
			kWh/y	%	TRY/y	TRY	Year
1	Waste Heat Recovery Impmenetation to Hot Water Boilers	N. Gas	178.917	1,6%	31.900	308.841	9,7
2	Two-Way Motorized Valve Implementation to Fan Coil Units	N.Gas	564.226	4,9%	388.653	1.304.210	3,4
		Electricity	355.888	3,1%			
3	Outside Air Compensation Application for Hot Water Boilers	N.Gas	62.387	0,5%	11.120	20.711	1,9
4	Variable Speed Drive (Frequency Converter) Implementation to AHU heating/cooling coil circulation pumps	N. Gas	874.740	7,6%	278.237	350.299	1,3
		Electricity	151.071	1,3%			
5	Variable Speed Drive Integration to Social Facility Block's Air Handling Unit Fan	Electricity	19.267	0,2%	15.598	21.473	1,4
6	Replacement of Conventional Air Handling Units with Heat Recovery Air Handling Units (AHU-18 and AHU-19)	N. Gas	221.191	1,9%	42.051	551.740	13,1
		Electricity	3.228	0,03%			
7	Variable Speed Drive Implementation to evaporator loop circulation pumps	Electricity	20.346	0,2%	16.471	142.110	8,6
8	Replacement of old twin pumps with high efficiency variable speed drive pumps and Electric Motors Upgrade from Standard Efficiency (IE1) to Premium Efficiency (IE3)	Electricity	94.870	0,8%	76.791	1.012.343	13,2
9	Solar Photovoltaic Panels (400 kWe)	Electricity	486.800	4,2%	394.019	3.898.639	9,9
10	Integration of Building Automation and Energy Monitoring System	N.Gas	300.351	2,6%	203.076	1.107.577	5,5
		Electricity	184.739	1,6%			
TOTAL SAVINGS		N. Gas (kWh)	2.201.812	19,1%	**1.457.915**	**8.717.944**	**6,0**
		Electricity (kWh)	1.316.209	11,4%			
		TOTAL	**3.518.021**	**30,5%**			

Table 2. List of Energy Efficiency Measures

Baseline Energy Use

Natural gas adjusted final energy use was 7.039.070 kWh/year and electricity final energy use was 4.484.059 kWh/year corresponding to 11.523.129 kWh/year overall adjusted baseline final energy use based on IPMVP.

Saving Targets

2.201.812 kWh/year ± 254.085 kWh/year natural gas energy was targeted to be saved corresponding to 19,1% ± 2,2% saving.

1.316.209 kWh/year ± 123.600 kWh/year electricity energy was targeted to be saved corresponding to 11,4% ± 1,1% saving with solar PV system.

3.518.021 kWh/year ± 377.685 kWh/year overall energy was targeted to be saved corresponding to 30,5% ± 3,3% saving with solar PV system.

SUMMARY OF RESULTS

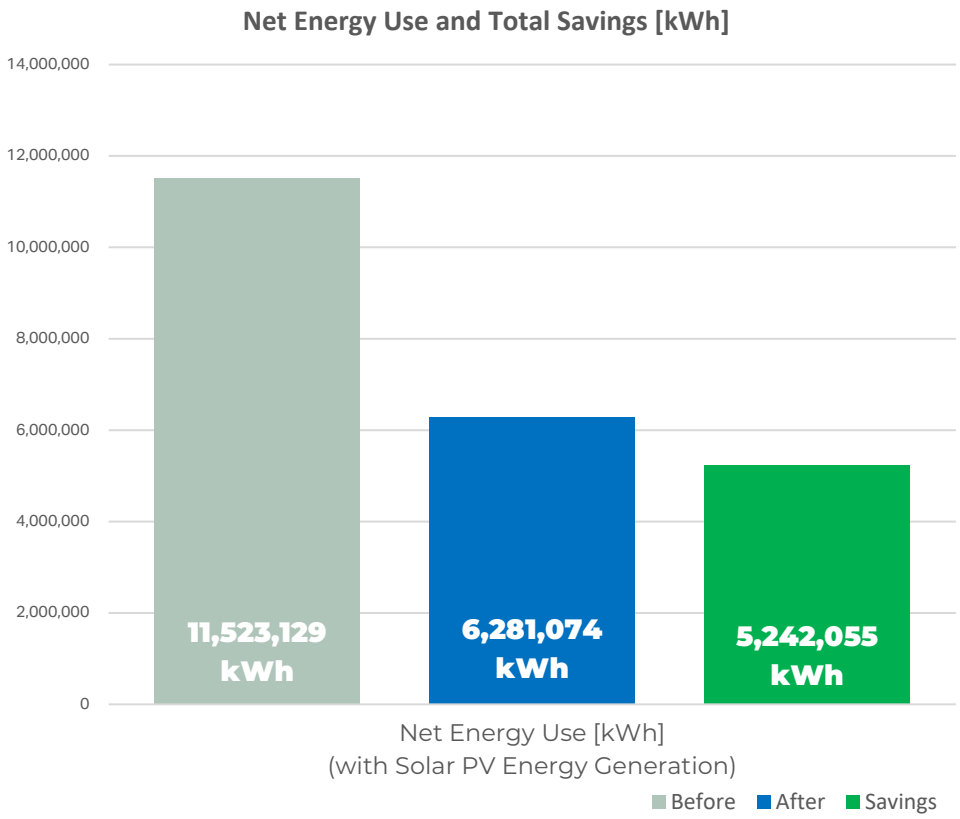
Energy Breakdown	Energy Before	Energy After	Energy Savings	Energy Saving %
Natural Gas Use [kWh]	7.039.070	3.552.850	3.486.220	49,5%
Electricity Use [kWh]	4.484.059	3.238.113	1.245.947	27,8%
Total Energy Use [kWh] (without Solar PV System)	11.523.129	6.790.963	4.732.166	41,1%
Renewable Energy Systems				
Solar PV Energy Generation [kWh]	0	-509.889	509.889	*4,4%*
Net Energy Use [kWh] (with Solar PV System)	**11.523.129**	**6.281.074**	**5.242.055**	**45,5%**
Annual Energy Cost [TRY]	**4.884.417**	**2.841.674**	**2.042.743**	**41,8%**
Green House Gas Emission [ton CO_{2e}]	**3.817,4**	**2.151,8**	**1.665,6**	**43,6%**
Corresponding No of Trees [pcs]			**76.510**	

Table 3. Summary of Energy and GHG Emission Results

Adjusted baseline overall energy use of the facility was 11.523.129 kWh/year. The energy use is reduced to 6.790.963 kWh/year corresponding to 41,1% savings without carport solar energy generation. When carport solar energy generation is included into the overall energy use calculations, overall energy use is reduced to 6.281.074 kWh/year corresponding to 5.242.055 kWh/year energy savings (45,5% saving) compared to 3.518.021 kWh/year ± 377.685 kWh/year [1]) expected energy savings (30,5% ± 3,3% saving).

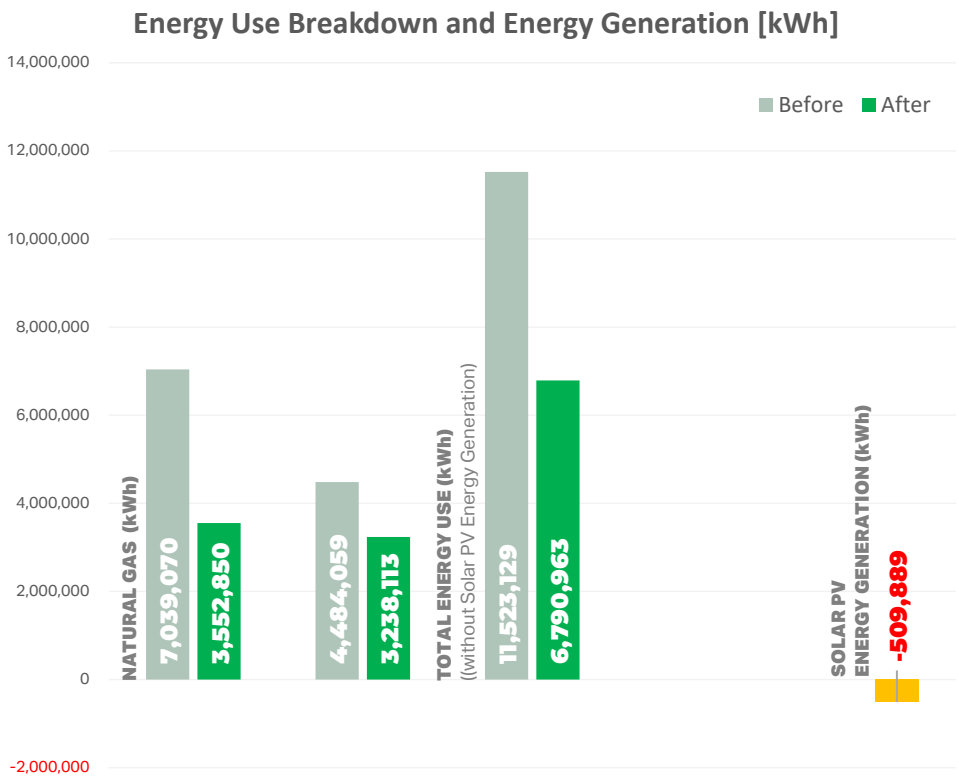
As a result, overall realized energy savings exceeded the expected savings by 1.214.146 kWh/year (34,5% higher than the expected savings).

[1] Based on baseline model uncertainty calculated at 90% confidence level as per IPMVP.



Graph 1. Net Energy Use (Before vs After) and Overall Energy Savings (with Solar PV Energy Generation)

Comparison of natural gas and electricity energy before and after EEMs are implemented are provided below along with onsite renewable energy.



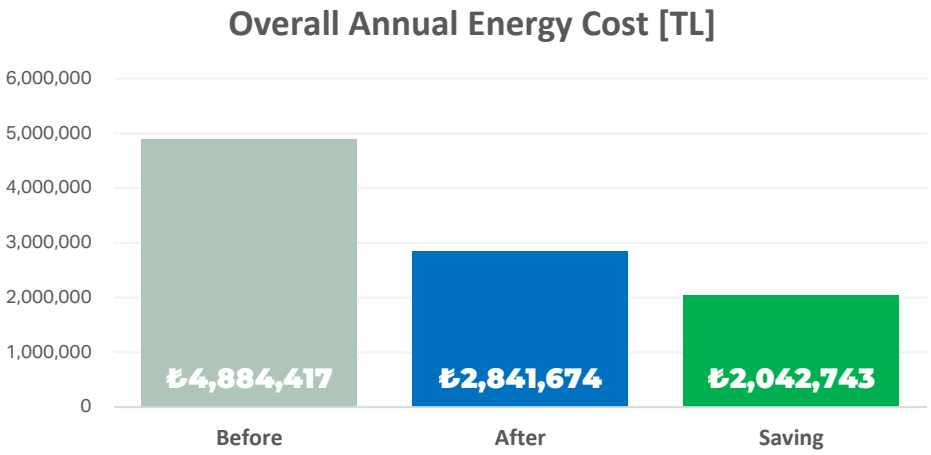
Graph 2. Energy Use Breakdown and Energy Generation Comparison (Before vs After)

Greenhouse gas emissions are calculated to be reduced from 3.817,4 tons of CO_{2e} to 2.151,8 ton CO_{2e} corresponding to 1.665,6 tons of CO_{2e} reduction. Overall green house gas emissions are reduced by 43,6% which would be a good example for other governmental office buildings in terms of decarbonization of buildings in the future.

Graph 3. Green House Gas Emissions Comparison and Corresponding No of Trees

Building occupants are all satisfied with the thermal comfort level after the energy efficiency measures were implemented.

Energy cost is reduced from 4.884.417 TL to 2.841.674 TL corresponding to 2.042.743 TL annual energy cost savings. It refers to 4,3 years of simple payback period.



Graph 4. Overall Annual Energy Cost (Before vs After)

PROJECT IMPLEMENTATION PROCESS

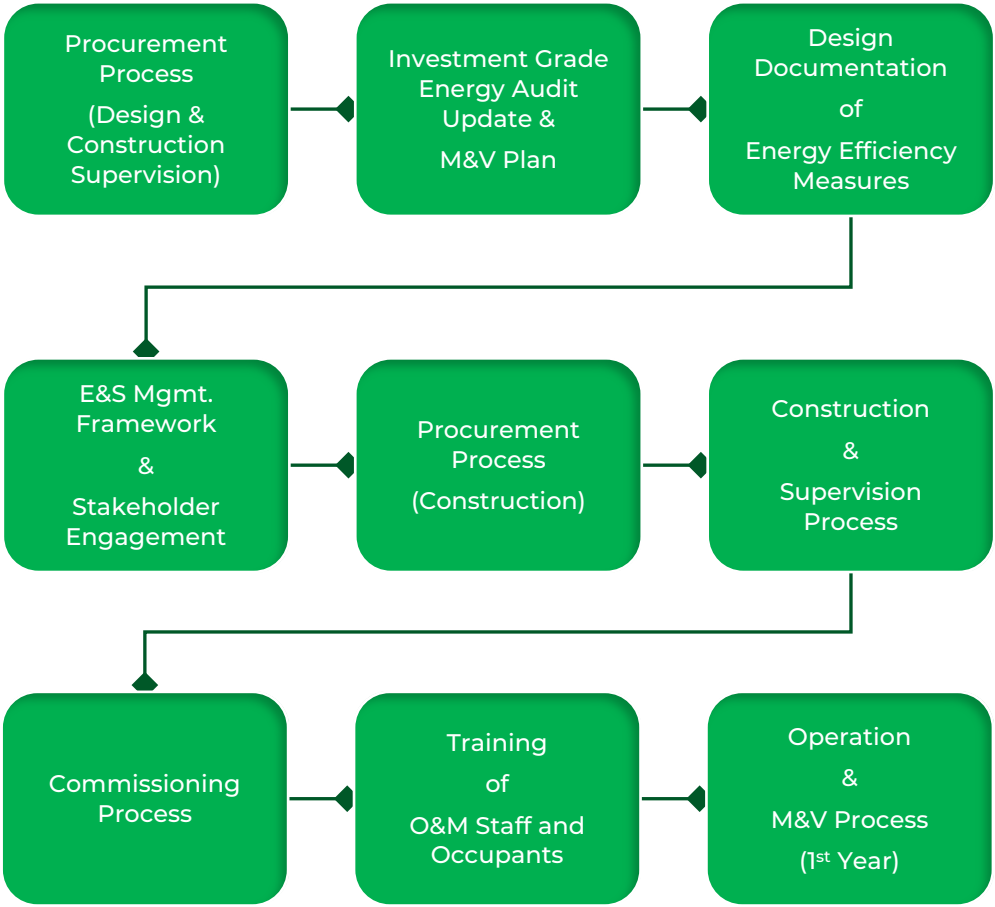


Figure 1. KABEV Project Implementation Process

Procurement Process (Design and Construction Supervision)

Ministry of Agriculture and Forestry had gone through an investment grade energy audit in 2019 in order to reveal the true energy efficiency potential and associated investment.

Based on that investment grade energy audit, it was decided by the GDCA to go for a quality and cost based selection tender for the consulting services for the update of energy efficiency measures (EEMs) of the energy audit from 2019, design documentation of EEMs and construction supervision of the implementation of EEMs. A design and construction supervision consultant was awarded the tender based on the highest combined score of technical and financial offers.

Energy Audit Update

Based on the contractual terms, the design and construction supervision consultant was required to update the EEMs of the final investment grade audit.

Since the last energy audit was done almost a year before the tender, following systems have been reaudited and evaluated by the consultant both from efficiency and comfort improvement points of view:

- Building envelope (exterior walls, roof, basement, windows, etc.)
- HVAC systems
- DHW system
- Pumps and fans
- Plumbing system and mechanical installation insulation
- Solar hot water system
- Lighting system
- Electrical infrastructure and compensation system
- Solar photovoltaic system
- Distributed energy generation systems (cogeneration, trigeneration, biomass, etc.)
- Heat pumps (air, water, ground sourced)
- Building energy monitoring and automation systems

As a result, previous EEMs were revisited and all of them were still found to be plausible. Only the energy and cost savings were updated based on the latest year energy consumption profile, energy unit prices and investment costs.

No	Energy Efficiency Measure (EEM)
1	Waste Heat Recovery Implementation to Hot Water Boilers
2	Two-Way Motorized Valve Application to Fan Coil Units
3	Outdoor Air Temperature Compensation Implementation to Hot Water Boilers
4	Variable Speed Drive (Frequency Converter) Implementation to AHU heating/cooling coil circulation pumps
5	Variable Speed Drive Integration to Social Facility Block's Air Handling Unit (AHU-5) Fan
6	Replacement of Conventional Air Handling Units with Heat Recovery Air Handling Units (AHU-18 and AHU-19)
7	Variable Speed Drive (Frequency Converter) Implementation to evaporator loop circulation pumps
8	Replacement of old twin pumps with high efficiency variable speed drive pumps and Electric Motors Upgrade from Standard Efficiency (IE1) to Premium Efficiency (IE3)
9	Solar Photovoltaic Panels (400 kW_e)
10	Integration of Building Automation and Energy Monitoring System

Table 4. Final EEMs

Especially, implementation plan was detailly reconsidered because, it was the in the middle of Covid-19 pandemics period in 2021 and public buildings were operating with utmost precaution and any wrong doing due to whatsoever reason would be untolerable by the building administration.

Measurement & Verification (M&V) Plan

Measurement and Verification (M&V) is the final assessment of the energy performance of an energy efficiency project and therefore, plays a key role while assessing the overall success of the project. International Performance Measurement and Verification Protocol (IPMVP) is at the epicenter of M&V process in KABEV project.

In order to ensure consistency throughout all KABEV subprojects and provide guidance to Turkish energy efficiency works implementation contractors that have relatively lower level of knowledge about M&V process, a M&V guide[2] in Turkish language was developed by GDCA and published in KABEV's website.

M&V Plan that explained how to verify savings for each EEM, how to adjust the reference energy consumption (or baseline) was prepared by design and supervision consultant. The plan included the verification method of savings, important measures to be taken, the timing of these activities, the duties and responsibilities of the parties and how to ensure quality assurance for this process.

Measurement and verification method per each EEM was selected among applicable options of IPMVP (Options A, B, C and D). GDCA reviewed the M&V plan and asked for revisions until it was satisfied with the baseline energy adjustment formulas, level of uncertainty and reliability. Finally, M&V plan was approved by GDCA and it was saved to be used for measurement & verification period of 12 months after the commissioning of energy efficiency renovation works.

Design Documentation

Energy efficiency renovation projects do not require a full fledged design development process as required in a new building design process. There are particular systems or components or spaces or sections of the building where an intervention is required to improve the energy efficiency and comfort rather than the whole building and all of its systems. Therefore, the design documentation should provide:

- an overview of the existing system which is to be renovated or retrofitted along with its surrounding auxilary components,
- the plans and schematics of the proposed design (improved situation),
- the notes and comments of the designer on the design plans and schematics detailly describing the EEM, what to be done in detail and emphasizing significant details about the scope of the implementation works.

[2]https://www.kabev.org/en/wp-content/uploads/2021/11/OLCME-VE-DOGRULAMA-KILAVUZU.pdf

To properly define the requirements and expectations of the design documentation in such a specific energy efficiency implementation works, a design handbook[3] was developed based on GDCA's minimum requirements and expectations. Designers followed this handbook while developing their design plans and documentation.

Design documentation was carried out by the design and supervision consultant and submitted to GDCA for the final approval. This design submittal and approval process was for the purpose of ensuring the common understanding of the scope of energy efficiency measures' implementation works for design and supervision consultant, GDCA (client) and the construction company to be awarded after a construction works tender. For example, the electric motors are to be changed as an EEM but, are the belt&pulley components going to be changed as well? In order to clear out such possible conflicts, the design documentation shall provide a clear picture about the scope of works and goal of the implementation works.

Finally, design and supervision consultant provided its design documentation including all plans, technical specifications, material definitions, etc. Based on the approval of the GDCA, the energy efficiency renovation construction works were tendered by GDCA.

Before the construction process, environmental and social management plan of Ministry of Agriculture and Forestry[4] project was developed based on the environmental and social framework[5] of the overall KABEV project. Stakeholder engagement meetings were carried out with all the relevant stakeholders such as school administration, educational personnel.

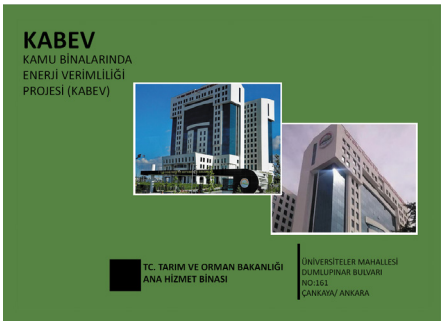
Picture 7. Stakeholder engagement meeting

In order to enhance the stakeholder engagement further and increase awareness among educational facility occupants, a project specific booklet was developed and distributed.

[3]https://www.kabev.org/en/wp-content/uploads/2022/03/TASARIM_EL_KITABI.pdf

[4]https://www.kabev.org/wp-content/uploads/2022/09/TARIM_CSYP_Nihai_r1.pdf

[5] Environmental and Social Framework of KABEV Project: https://www.kabev.org/cevresel-sosyal-yonetim/



Picture 8. Project specific booklet

In order to further increase awareness, a big billboard was hanged over the building façade indicating that "energy efficiency renovation works are being carried out in this building".

Procurement Process (Construction)

Based on the design documentation submitted by the design and supervision consultant, GDCA prepared the administrative specifications and completed the tender binder. Finally, the tender was announced in KABEV project website: https://www.kabev.org/ihale-ilanlari/

Tender type was cost based selection provided that the tenderers match the minimum technical, financial and administrative requirements of the tender. Similar work experience was required from the tenderers because, this assignment required specific knowledge and experience in terms of energy efficiency. The aim of this project was not to solely replace the old pumps but, to provide specific amount of energy savings and carbon emissions reduction. Therefore, it was required from the tenderer contractors to have at least the basic level of understanding of energy efficiency, carbon emission reduction, and aim this project.

Construction and Supervision Process

After the finalization of energy efficiency renovation construction tender, site implementation works and consequently the construction supervision works began. Supervision consultant company, which was selected before the energy efficiency renovation construction tender process and works as GDCA's consultant, carried out all the supervision works. Supervision consultant managed the site implementation works, revision requests of the construction contractor, monitored budget and construction progress both in terms of quality and quantity, coordinated and witnessed commissioning process and finally organized the provisional acceptance process.

Commissioning Process

Commissioning of systems plays a significant role especially in an energy efficiency focused project. Hence, commissioning and test of systems not only at the functional level but also from energy performance point of view is crucial. Since this was an energy efficiency renovation construction project, it was especially important to find out whether the expected energy savings were achieved and commissioning had a crucial role in doing so.

Therefore, a commissioning handbook[6] was developed by GDCA to provide guidance to implementation contractors and supervision consultants. Based on this guidance, commissioning process was supervised by the supervision consultant and executed by construction contractor.

Prefunctional checks and functional performance tests of implemented EEMs were carried out by defined test methodologies.

Once the tests were finalized and the final commissioning report was submitted, GDCA reviewed the submited report via its technical consultant.

Measurement & Verification (M&V) Process

Quarterly M&V reports and final M&V report at the end of the first year were prepared by design and supervision consultant based on M&V plan approved by GDCA before implementation works begin.

The measurement and verification methods table for Ministry of Agriculture and Forestry project is provided in below table.

No	Energy Efficiency Measure (EEM)	M&V Option
1	Waste Heat Recovery Implementation to Hot Water Boilers	Natural Gas Option C
2-1	Two-Way Motorized Valve Application to Fan Coil Units	
3	Outdoor Air Temperature Compensation Implementation to Hot Water Boilers	
4-1	Variable Speed Drive (Frequency Converter) Implementation to AHU heating/cooling coil circulation pumps	
6-1	Replacement of Conventional Air Handling Units with Heat Recovery Air Handling Units (AHU-18 and AHU-19)	
10-1	Integration of Building Automation and Energy Monitoring System	
5	Variable Speed Drive Integration to Social Facility Block's Air Handling Unit (AHU-5) Fan	Electricity Option A
7	Variable Speed Drive (Frequency Converter) Implementation to evaporator loop circulation pumps	Electricity Option A
8	Replacement of old twin pumps with high efficiency variable speed drive pumps and Electric Motors Upgrade from Standard Efficiency (IE1) to Premium Efficiency (IE3)	Electricity Option A
9	Solar Photovoltaic Panels (50 kW_e)	Electricity Option B

6https://www.kabev.org/en/wp-content/uploads/2022/03/D5.2_Commissioning-Handbook_ENG_Web_version_Final.pdf

No	Energy Efficiency Measure (EEM)	M&V Option
2-2	Two-Way Motorized Valve Application to Fan Coil Units	Electricity Option C
4-2	Variable Speed Drive (Frequency Converter) Implementation to AHU heating/cooling coil circulation pumps	
6-2	Replacement of Conventional Air Handling Units with Heat Recovery Air Handling Units (AHU-18 and AHU-19)	
10-2	Integration of Building Automation and Energy Monitoring System	

Table 5. IPMVP Option Table

Required measurements to prepare the M&V report were conducted quarterly. Supervision consultant compared the baseline and final energy bills, adjustments for degree days (HDD and CDD), changes in operating use, changes in energy prices, occupancy rates, etc. and finally submitted to GDCA.

Final M&V report was prepared one year after the renovation works were completed. GDCA reviewed and approved the M&V report after a few revision requests on the report. Revision requests originated from the fact that this sort of M&V process was conducted not conducted many time before in public sector in Türkiye. The M&V report demonstrated the amount of savings realized by comparing the actual energy consumption with the reference energy consumption in which the necessary adjustments were made according to IPMVP.

Energy monitoring system that was installed within the EE implementation works provided qualified and consistent data for M&V process. Hence, energy monitoring system and associated meters and sensors proved to be a useful tool to provide reliable data to M&V calculations.

LESSONS LEARNED

Ministry of Agriculture and Forestry energy efficiency improvement project was not a common renovation project and a lot of things were experienced for the first time for all parties including the project implementation unit (GDCA), supervision consultant, implementation contractor, beneficiary, etc. Therefore, several lessons were learned as an outcome of this specific project:

Energy Efficiency Renovation Contract Scope:

This project aimed for energy efficiency predominantly. Therefore, all of the site implementation measures were related with energy efficiency and carbon emission reduction. On the other hand, beneficiary administration had default expectations fom a renovation project such as renovation of interior architecture, furniture, flooring, bathrooms, façade, paints, etc. This lead to a mismatch between the contract scope and beneficiary expectations.

Expectations of beneficiary were aligned after stakeholder engagement meetings. The lesson learned from this issue is to manage expectations of beneficiary at the early stages of the project with more focused and clear communication about the exact scope and specific target of the project.

Design Documentation Process:

Design and supervision consultant was required to develop design documentation and submit to GDCA approval. The buildings did not have architectural plans of the existing situation. For this reason, design and construction consultant had to make architectural survey to come up with the up to date architectural plans. This process was the prerequisite to pass to stage of design documentation of energy efficiency measures. However, the level of detail of survey plans expected by GDCA were much higher than the required level of detail for an energy efficiency project because, GDCA was living up to the highest expectation for contruction projects as a general character of the organization. This caused a delay in approval of the survey plans leading to delay of the finalization of the the On the other hand, this was not a ground up construction project and did not need evey detail of the building and floors which were not relevant to energy efficiency measures. For example, frame or divider width of every single window should not be required in a project where there's window replacement. Interior door dimensions or baseboard height of an interior wall may not be relevant for an energy efficiency measure. Bathroom and restroom interior details are generally not relevant for an energy efficiency project.

Lesson learned from this project was to align the expectation of GDCA from a survey plan so that only relevant elements of a floor or a system will be required for an energy efficiency renovation project. In addition, survey plan approval was removed from the design documentation process. Instead, only energy efficiency renovation design

plans in each discpline are decided to approved by GDCA.

Formal Permits:

Formal permit procedures could have been planned or initiated before the tender for systems such as solar photovoltaic energy system which had to go through various authorities for the formal approval procedure. Consequently, the provisional acceptance and permit for grid connection could have been obtained renewable energy systems could have begun generating electricity several months before.

Tender Terms:

In a relatively infant building energy efficiency renovation market, the financial terms and conditions of the tender could have been more flexible and attractive in order to attract more interest from implementation contractors both locally and internationally.

The financial terms of this tender was with fixed prices in local currency which was under high pressure both from exchange rate risks aganist international currencies and high domestic inflation making all the overheads, general admin, material and labor costs difficult to predict during the implementation period. Therefore, the tender prices could have been done in internationally more stable currencies which would limit the price fluctuations at least in equipments and materials leading to less risk perception in interested tenderers. It would attract more international contractors making them not to think about local currency exchange rate and high domestic inflation risks. A price adjustment mechanism could also be embedded into tender financial terms for limiting the risks regarding domestic costs based on local currency. This would decrease the risk perception in financial terms of the tender and lead interested contractors turn their utmost attention into more technical aspects of the tender.

Measurement & Verification:

Lack of measurement and verification process experience lead to a delay in finalizing the measurement and verification plan. M&V plan went back and forth between design and supervision consultant and GDCA due to the fact that local M&V professional prepared such a compherensive M&V plan with too many EEMs for the first time. Hence, it was a learning process for both design and supervision consultant and GDCA.

More M&V professionals are necessary for a healthy operating energy efficiency market. Ministry of Energy and Natural Resources will consider to accept the accreditation of M&V professionals having certified from international M&V accreditation schemes.