KABEV

CASE STUDY BURSA KIZ LİSESİ

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REPUBLIC OF TURKEY
MINISTRY OF ENVIRONMENT, URBANIZATION AND CLIMATE CHANGE

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KABEV
KAMU BİNALARINDA
ENERJİ VERİMLİLİĞİ PROJESİ
YAPI İŞLERİ GENEL MÜDÜRLÜĞÜ

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 hospitals). 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

BURSA KIZ LİSESİ

Bursa, Türkiye

Public School

2 School Blocks + 1 Dormitory Block

10.285 m²

High School and Dormitory

Energy Performance Contract (EPC)

Picture 1. Bursa Kız Lisesi – A Block Pictures – old at the left, new at the right side

Bursa Kız Lisesi is a high school with two educational blocks and one dormitory block. The buildings are over 40 years old and had an old appearence due to lack of sufficient maintenance. They had major technical and comfort problems such as insufficient heating due to lack of façade insulation and often malfunctioning boilers, excessive infiltration through old single pane windows.

Building administration was enthusiastic to join KABEV program to resolve the comfort problems orginating from insufficient heating, frequently malfunctioning boilers, draft through the old frames of single pane windows during winter. They also would like to avoid too frequent repair services due to malfunctioning boilers and burners. What's more, building administration wanted to renovate the appearance of the buildings which were too old and perceived as outdated by the students and their families.

The implementation of energy efficiency works were done by an energy service company (ESCO) via energy performance contract (EPC). This method was deliberately selected by GDCA in order to demonstrate that deep renovations can be carried out by EPC method and set an example for the rest of public authorities and private sector.

Building Envelope

Buildings were not insulated and had single pane windows and therefore was cold in the winter and hot in the summer. By installing 10 cm rock wool insulation on the façade and attic of the building and replacement of the windows to triple pane windows with highly insulating frames, it is now able to maintain a better indoor temperature as the heat losses are reduced in the winter and the heat gain is reduced in the summer. At the same time, the façade insulation and brand new windows improved the exterior of the building, and it now appears as a new building from the outside.

Picture 2. Building façades and roofs – Before (Left) vs After (Right)

Heating System

Heating system comprised of 700 kW floor mounted natural gas heating boiler, radiators with old valves and constant speed low efficiency circulation pumps. Boilers had frequent faults causing too much interruption in heating system. Additionally, thermal efficiency of the boilers were found out to be low when flue gas measurements were carried out. Boilers have been replaced with brand new and efficient 4 x 90 kW wall mounted cascade natural gas condensing boiler. Now, the boilers with higher thermal efficiency and capacity modulation provides as much heating energy as demanded by the buildings leading to much less heating energy consumption.

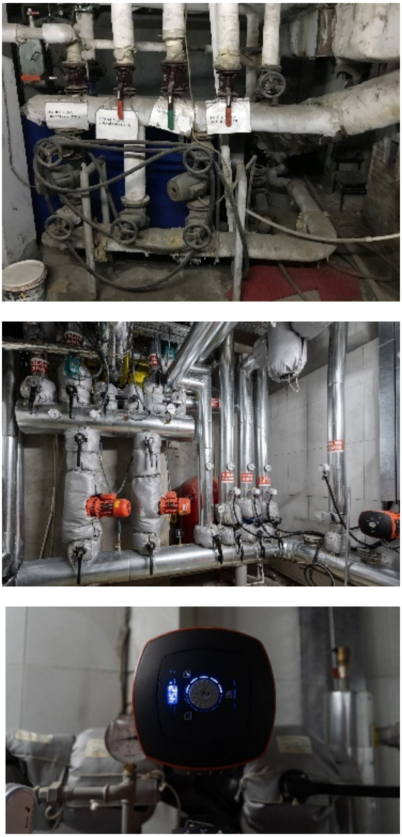
Picture 3. Boiler Room - Before vs After

The radiators were old and rusty inside along with old fashioned valves causing constant speed heating water circulation pumps operate all the time and leading to excess energy consumption and low thermal comfort. Radiators have been replaced with brand new panel radiators. Old valves have been replaced with thermostatic valves in radiators. Old and constant speed heating water circulation pumps have been replaced with brand new variable speed circulation pumps. Now, all the spaces are heated by more efficient radiators controlled by thermostatic valves bringing the rooms to ideal heating temperature and avoiding overheating and excess heating energy consumption. Circulation pumps now adjust their speed and operate only as much as the heating demand leading to savings both in heating and pump energy.

Picture 4. Radiator and Thermostatic Valves – Before vs After

Boiler Room Retrofit

Mechanical installation and plumbing instruments including piping, valves, etc. had no insulation. The piping and instrumentation in the boiler room have been replaced with new systems having proper insulation based on local plumbing insulation standard.



Picture 5. Boiler Room Pumps- Before vs After

Domestic Hot Water

Domestic hot water was provided by an old 175 kW floor mounted natural gas heating boiler and 2 pcs of old 500 litre hot water tanks. It's now provided by central cascade boiler system with 1.000 litre hot water tank. The central boiler system has higher efficiency compared to old boiler system leading to energy savings in domestic hot water heating.

Picture 6. Boiler Room (*Domestic Hot Water Tank) – Before vs After*

Exterior Lighting

Old exterior lighting bulbs which are metal halide and sodium vapor type have been replaced with LED bulbs providing higher efficiency and lighting quality.

Picture 7. LED exterior lighting bulb

Electrical Panels Retrofit

Very old main distribution control panel was replaced with brand new main distribution control panel with enhanced electrical safety systems. Poorly working old compensation system experiencing penalty fees due to exceeding the reactive power limits of the electricity grid was replaced with brand new compensation system with higher capacity due to additionally installed frequency inverters, LED bulbs, etc.

Picture 8. Replacement of compensation, main distribution control panels

Renewable Energy

After reducing the energy demand and consumption to the minimum level, remaining energy was targeted to be generated on site by a rooftop solar photovoltaic system. Based on the transformer capacity of the buildings, solar photovoltaic system has been installed. Solar photovoltaic system's annual electricity generation is more than the buildings' electricity consumption annually. This leads to exporting excess amount of electricity back to the grid to other educational facilities in the area especially in summer months when school's electricity consumption is low because it's closed and solar energy generation is at its peak due to respectively higher summer solar radiation level.

Picture 9. Rooftop solar photovoltaics (PV)

Since the electricity consumption would be fully sourced from the solar photovoltaic system, it was considered to adopt a heat pump application to both support heating system and domestic hot water system.

Picture 10. Heat pump application supported by solar PV system

It would decrease the fossil fuel use in natural gas boilers leading to mitigation of green house gas emissions originating from heating end use and its electricity consumption would be both free and zero emission because its electricity would be produced by onsite rooftop solar photovoltaic panels. As a result, 16 kW air sourced heat pump has been adopted into newly replaced heating system as an complimentary capacity during transition seasons and its power is generated by rooftop PV system.

Picture 11. Heating automation system and associated equipment, sensors and valves

Energy Monitoring System

Energy monitoring system has been installed within the EE implementation works which would provide qualified and consistent data for M&V process.

Energy monitoring system and associated meters and sensors proved to be a useful tool to provide reliable data to M&V calculations.

Building System	Before Implementation of EEMs	After Implementation of EEMs
Building Envelope	No insulation.	10 cm rock wool insulation on external walls + 10 cm glass wool insulation on roof.
Fenestration	Single pane windows.	Triple pane windows with brand new highly insulated frames.
Heating System	700 kW floor mounted natural gas heating boiler, radiators with old valves and constant speed circulation pumps.	4 x 90 kW wall mounted cascade natural gas condensing boilers, old valves replaced with thermostatic valves in radiators, old circulation pumps replaced with variable speed circulation pumps.
Cooling System	None (no cooling season operation).	None.
Ventilation System	Natural ventilation.	Natural ventilation.
Domestic Hot Water System	175 kW floor mounted natural gas heating boiler and 2 pcs of 500 litre hot water tanks.	1 pc of 1.000 litre hot water tank supplied by central heating system.
Mechanical Installation/Plumbing	No insulation in the piping system.	Insulated according to local plumbing insulation standard.
Interior Lighting System	LED lighting bulbs	LED lighting bulbs
Exterior Lighting System	Metal halide bulb, sodium vapor bulbs and LED bulbs.	Metal halide and sodium vapor bulbs replaced with LED bulbs.
Electrical System	Very old main distribution control panel and interior with overheating.	Replaced with brand new main distribution control panel with enhanced electrical safety systems.
Compensation System	Poorly working old compensation system experiencing penalty fees due to exceeding the reactive power limits of the electricity grid.	Replaced with brand new compensation system with higher capacity due to additionally installed frequency inverters, LED bulbs, etc.
Renewable Energy System	None.	Installed rooftop photovoltaic solar power system.
Energy Monitoring System	None.	Energy monitoring system that allows building level monitoring for gas and electricity consumption.
Fuel Conversion and Electrification: Heat Pump Adoption	None.	16 kW air sourced heat pump adopted into newly replaced heating system as an complimentary capacity during transition seasons and its power is generated by rooftop PV system.

Table 1. Building Systems Comparison (Before vs After EEMs

No	Energy Efficiency Measure	Energy Type	Energy Savings		Energy Cost Savings	Investment	Payback Period
			kWh/y	%	TRY/y	TRY	Year
1	Building insulation application and window/door replacement	N.gas	758.962	66,9	140.408	2.050.928	14,6
2	Boiler replacement	N.gas	23.676	2,3	4.380	65.389	14,9
3	Thermostatic valve in radiators and VSD circulation pumps	N.gas	16.470	1,5	3.407	31.780	9,3
4	Boiler room mechanical installation insulation	N.gas	10.520	0,9	1.946	13.611	7,0
5	Heating system automation	N.gas	22.892	2,0	4.235	61.111	14,4
6	Heat pump application supported by solar PV system	N.gas	10.513	0,9	1.945	22.000	11,3
7	LED bulbs replacement for exterior lighting	Electricity	3.504	0,3	3.119	12.000	3,8
8	Rooftop solar photovoltaic system application (generated for self use)	Electricity	122.443	10,8	108.989	2.968.210	10,7
	Rooftop solar photovoltaic system application (to be exported to other educational facilities in the area)	Electricity	190.438	16,8	169.467		
9	Energy monitoring system and electrical compensation system renewal	Electricity	-	-	-	35.000	-
TOTAL		N.gas (kWh)	843.033	74,3	156.321	2.244.819	
		Electricity (kWh)	316.386	27,9	281.575	3.015.210	
		TOTAL	**1.159.420**		**437.896**	**5.260.029**	**12,0**

Table 2. List of Energy Efficiency Measures

1.159.420 kWh/year ± 226.675 kWh/year [1] energy was targeted to be saved based on above list of energy efficiency measures (EEMs).

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

SUMMARY OF RESULTS

Item / Subject	Before	After	Savings	Saving %
Natural Gas Consumption [kWh]	1.027.649	370.462	657.187	64,0%
Electricity Consumption [kWh]	107.158	103.594	3.564	3,3 %
Total Energy Consumption [kWh]	1.134.807	474.056	660.751	58,2%
Renewable Energy Generation [kWh]	0	-282.708		*(-24,9%)*
Net Energy Use [kWh]	**1.134.807**	**191.348**	**943.459**	**83,1%**
Energy Cost [TRY]	**1.295.623**	**56.402**	**1.239.221**	**95,6%**
Green House Gas Emission [ton CO_{2e}]	**292,3**	**0,0**	**292,3**	**100,0%**
Corresponding No of Trees [pcs]			**13.428**	

Table 3. Summary of Energy and GHG Emission Results

Baseline energy consumption of the building was 1.134.807 kWh/year even with insufficient heating. The energy use is reduced to 474.056 kWh/year corresponding to 58.2% savings without rooftop solar energy generation. When rooftop solar energy generation is included into the overall energy use calculations, 943.459 kWh/year energy is saved (corresponding to 83.1% savings) compared to 1.159.420 kWh/year ± 226.675 kWh/year[2] expected energy savings, meeting the expected level of savings.

The variation in savings is mainly due to uncontrolled opening of windows between classes due to extra outdoor air ventilation demand by students as a post pandemic habit.

Due to measures imposed by government to reduce risk of contamination in highly occupied rooms such as classrooms in schools, extra ventilation was required that means over opening of classroom windows leading to relatively higher natural ventilation through windows. That extra natural ventilation causes the heating system to operate more hours with a higher heating demand and eventually leading to higher natural gas consumption than anticipated at the time of EEM saving calculations.

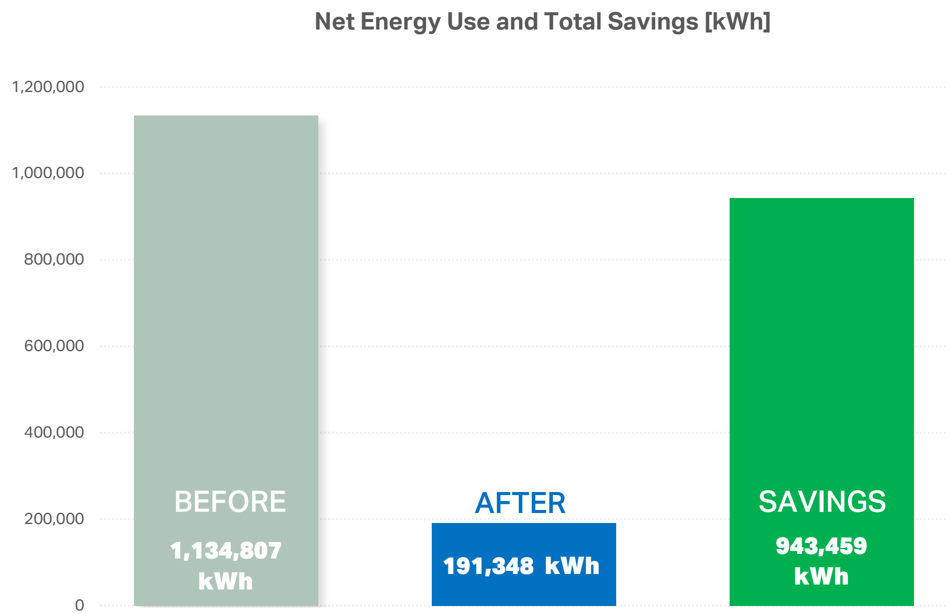
There seems to be a variation between expected and realized electricity savings but, it is mainly due to the generated amount of electricity by solar photovoltaic (PV) renewable energy system. Solar PV system's realized energy generation corresponds to 24,9% (at table 3 above) of overall baseline energy consumption whereas, it was expected as 27,6% (at table 2) of overall baseline energy consumption. It is mainly because it took a few weeks more than anticipated to connect to the grid system due to a delay in administrative procedure of electricity utility company. That made the solar PV system to be unoperational for a few weeks although it was ready to generate energy. Next year, it is certainly expected to produce the simulated amount of energy. On the other hand, realized electricity savings without solar PV system

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

is 3,3% (at table 3 above) whereas, expected electricity savings was 0,3% (at table 2) meaning that the realized electricity savings went beyond expected electricity savings.

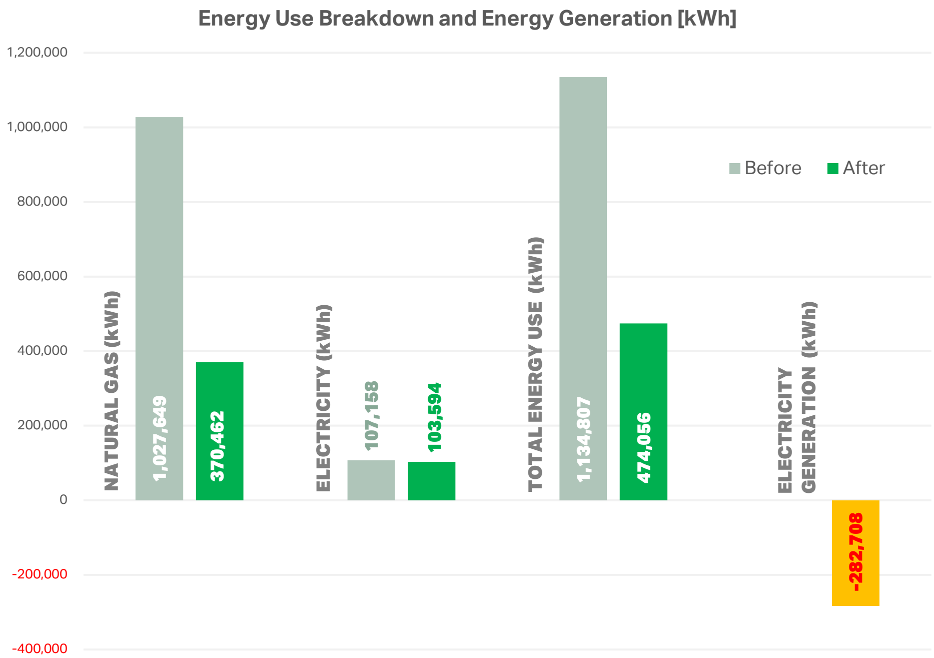
There is still on-site emissions from the natural gas use but, the greenhouse gas emissions are calculated to be zero due to offset effect of exported electricity to the grid by the rooftop renewables.

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



Graph 1. Net Energy Use Comparison (Before vs After) and Total Savings

Comparison of natural gas and electricity energy before and after EEMs are implemented are provided below along with onsite renewable energy generation. Part of the generated energy is for self consumption of the school buildings. Excess part of the generated energy are exported the educational facilities nearby by sending back to the grid.



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

Green house gas emissions before and after EEMs are implemented are represented in below graph. Due to very high amount of energy savings and on-site renewable energy generation, overall green house gas emissions are reduced to net zero carbon level which would be a good example for other educational facilities and public buildings in terms of reaching to net zero carbon target in the future.

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

PROJECT IMPLEMENTATION PROCESS

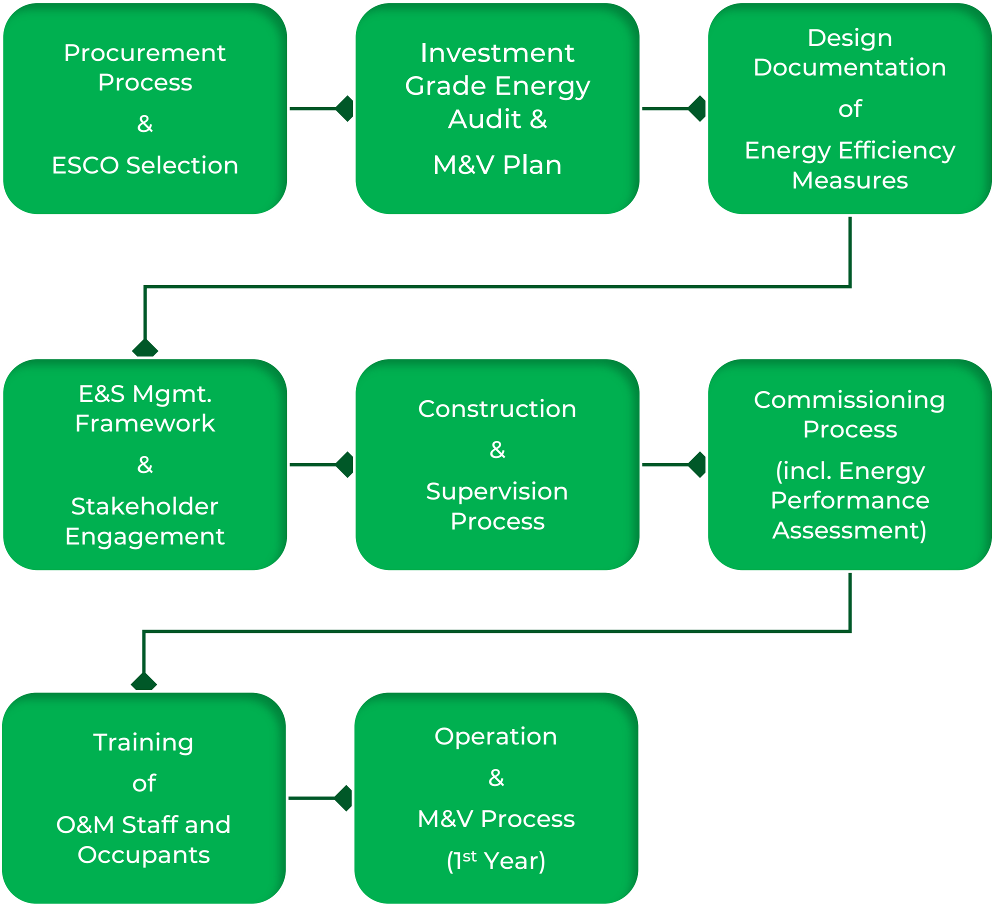


Figure 1. KABEV Project Implementation Process

Procurement Process

Bursa Kız Lisesi 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 the energy perfromance contract (EPC) type tender to make a pilot study and develop know-how and experience in Turkey.

The tenderer ESCOs[3] were free to suggest any EEM they thought fit provided that their proposal meets the minimum requirements. Hence, ESCOs made site visits, carried out their own preliminary audits and developed additional energy efficiency measures (EEMs) in addition to the EEMs addressed in the energy audit carried out in 2019. Tenderers proposed a set of EEMs along with their annual energy and cost savings, simple payback period, IRR and 20-year net present value (NPV). Net present value of an investment is highly dependent on the parameters such as inflation, energy unit cost, discount rate. Hence, all of these variables were provided as part of the tender documents so that all tenderers use the same parameters while submitting their proposals.

The proposal with the highest NPV was supposed to win the tender provided that below minimum requirements were met:

- the EEMs and associated calculations were plausible,
- 50% energy savings to be realized as a minimum,
- max. 15 years of simple payback period.

What is an ESCO?[4]

An ESCO is a company that offers energy services which may include implementing energy-efficiency projects (and also renewable energy projects) and in many case on a turn-key basis. The three main characteristics of an ESCO are:

- *ESCOs guarantee energy savings and/or provision of the same level of energy service at lower cost. A performance guarantee can take several forms. It can revolve around the actual flow of energy savings from a project, can stipulate that the energy savings will be sufficient to repay monthly debt service costs, or that the same level of energy service is provided for less money.*
- *The remuneration of ESCOs is directly tied to the energy savings achieved;*
- *ESCOs can finance, or assist in arranging financing for the operation of an energy system by providing a savings guarantee.*

Therefore, ESCOs accept some degree of risk for the achievement of improved energy efficiency in a user's facility and have their payment for the services delivered based (either in whole or at least in part) on the achievement of those energy efficiency improvements.

Since this was the first energy performance contract (EPC) to be carried out by an ESCO in Türkiye public sector, payments were just partly based on the achieved savings in order to encourage the potential tenderers and prospect ESCOs. Hence, rather than ESCO sharing the energy cost savings with beneficiary public school, investment amount would be paid to ESCO based on certain milestones. Payment milestones of the full investment amount was as follows:

- 5% upon the finalization of updated investment grade energy audit report by ESCO,
- 10% upon the finalization of design documentation of EEMs,

[3] ESCO: Energy Service Company

[4] https://e3p.jrc.ec.europa.eu/node/190

- 50% upon the finalization of implementation of EEMS,
- 15% upon the quick energy performance assessment of implemented EEMs within two weeks of finalization of commissioning,
- 20% of the overall contract amount based on achieved energy savings.

As a result, 65% of the payments were input-based and 35% were linked to energy performance/savings. Overall, 80% of payments were done upon successful commissioning and remaining 20% of payments at the end of the 12-month M&V period.

The proposal with the highest NPV was reviewed by both the GDCA experts and external technical consultant. Finally, the proposal was found to be eligible and the tenderer was awarded the contract.

The proposal with the highest NPV comprised the following EEMs:

No	Energy Efficiency Measure (EEM)
1	Building insulation application and window/door replacement
2	Boiler replacement
3	Thermostatic valve in radiators and VSD circulation pumps
4	Boiler room mechanical installation insulation
5	Heating system automation
6	Solar hot water panel application for DHW
7	LED bulbs and lighting system automation
8	Rooftop solar photovoltaic system
9	Energy monitoring system

Table 4. Proposed EEMs

Energy Audit

Based on the contractual terms, the contractor (ESCO) was required to carry out a final investment grade audit based on ISO 50002 and submit an energy audit report.

Following systems have been audited and evaluated by ESCO 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 of the energy audit, previous EEMs were revisited and below highlighted EEMs replaced old measures:

No	Energy Efficiency Measure (EEM)
1	Building insulation application and window/door replacement
2	Boiler replacement
3	Thermostatic valve in radiators and VSD circulation pumps
4	Boiler room mechanical installation insulation
5	Heating system automation

No	Energy Efficiency Measure (EEM)
6	*Heat pump application supported by solar PV system (previously solar hot water panel application for DHW)*
7	*LED bulbs replacement for exterior lighting (previously LED bulbs and lighting system automation)*
8	Rooftop solar photovoltaic system application
9	*Energy monitoring system and electrical compensation system renewal (not proposed previously)*

Table 5. Final EEMs

Since the last energy audit was done almost a year before the tender, a few energy efficiency measures were found to be not valid anymore because, the school management already either fully or partly implemented that measure. For example, interior lighting fixtures were replaced with LED bulbs until the EPC tender was finalized. Hence, the ESCO company which won the tender had to revise the interior lighting system energy efficiency measure as exterior lighting bulbs replacement.

Another revision was replacing solar hot water panel application with heat pump application supported by solar photovoltaic system. The school rooftop was going to be covered by photovoltaic panels leading to free renewable energy generation that will correspond to the full electricity consumption of the school campus. Since the electricity consumption would be fully sourced from the solar photovoltaic system, it was considered to adopt a heat pump application to both support heating system and domestic hot water system. It would decrease the fossil fuel use in natural gas boilers leading to mitigation of green house gas emissions originating from heating end use and its electricity consumption would be both free and zero emission because its electricity would be produced by onsite rooftop solar photovoltaic panels.

Picture 12. Building Facade – Before vs After

Picture 13. Building roofs - Before vs After

A measure previously not considered was added to the set of EEMs as the electrical compensation system because, the school recently began to experience penalty fees from the electricity grid operator due to exceeding reactive power threshold. Compensation system is a requisite for the safe and reliable operation of electrical devices so, this measure was added to the project although it was not providing energy efficiency directly.

Picture 14. Building windows - Before vs After

An important remark is about the cross effect of EEMs where there's a set of several energy efficiency measures having consequential effects on each other. For example, if an insulation on building envelope is proposed as an EEM, it would have an effect on the energy saving calculation of a boiler replacement EEM because an insulation measure on building envelope would reduce the overall heating demand of a building which consequently would reduce the heating energy consumption of that building regardless of a boiler renovation measure. Hence, while proposing the energy efficiency measures together as a set of actions or a package, the cross effects of EEMs among each other shall be considered and energy savings calculations shall be done based on cross effect phenomenon.

Picture 15. Rooftop solar photovoltaics (PV)

In Bursa Kız Lisesi energy efficiency project, cross effects of building envelope insulation and windows replacement measure on other measures related with heating energy end use are considered and taken into account during energy saving calculations.

Picture 16. Heat pump application supported by solar PV system

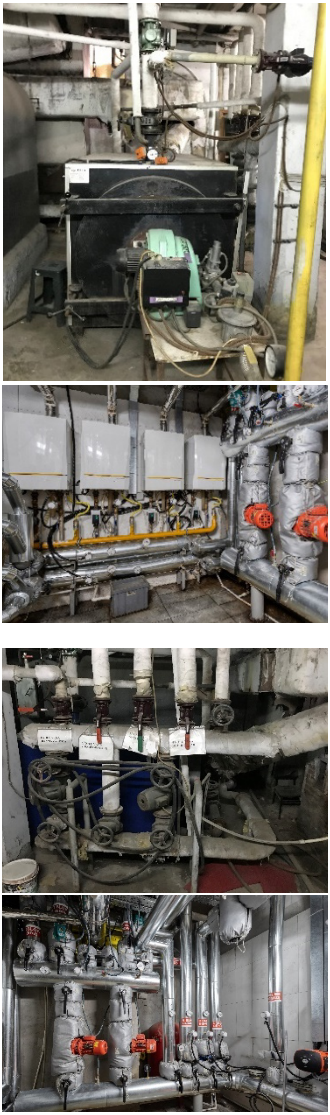
Design Documentation

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.

To properly define the requirements and expectations of the design documentation in such a specific energy efficiency implementation works, a design handbook[5] was developed based on GDCA's minimum requirements and expectations. Designers followed this handbook while developing their design plans and documentation.

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



Picture 17. Boiler Room (Boilers, Pumps, Insulation) - Before vs After

Picture 18. Boiler Room (Boilers, Pumps, Insulation) - Before vs After

Since Bursa Kız Lisesi energy efficiency works was implemented in the form of an EPC, the design documentation was done by the ESCO and submitted to GDCA for the final approval. This design submittal and approval process was for the purpose of ensuring the mutual understanding of the scope of energy efficiency measures' implementation works for ESCO (contractor) and GDCA (client). For example, the lighting bulbs are to be changed as an EEM but, are the lighting fixtures going to be changed as well or is the ceiling which the lighting fixtures are mounted on going to be painted? 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.

Therefore, ESCO provided its design documentation before the initiation of site implementation works. Based on the approval of the GDCA, the site works commenced.

Picture 19. Thermostatic Valves – Before vs After

Construction and Supervision Process

After the finalization of the design documentation, construction and supervision works began. Since it's an energy peformance contract (EPC), energy service company (ESCO) carried out all the contruction works. Supervision consultant company, which was selected before the ESCO tender process and works as GDCA's consultant, carried out all the supervision works.

Before the construction process, environmental and social management plan of Bursa Kız Lisesi[6] project was developed based on the environmental and social framework[7] of the overall KABEV project. Stakeholder engagement meetings were carried out with all the relevant stakeholders such as school management, teachers, student council, neighbourhood society.

In order to enhance the stakeholder engagement further and increase awareness among school students, the façade paint colours have been polled to students and students voted for among the several alternative façade paint colours.

[6] https://www.kabev.org/wp-content/uploads/2021/09/kabev-1b-epc-works-01-csyp-bursa-kiz-lisesi-20210304092259-1.pdf

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

Picture 20. Stakeholder meeting and facade paint color voting

Picture 21. Building insulation application

Picture 22. Old boiler disassembly and new boiler room installations

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 performance contract, 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[8] which emphasizes the quick energy assessment of renovated systems was

8https://www.kabev.org/en/wp-content/uploads/2022/03/D5.2_Commissioning-Handbook_ENG_Web_version_Final.pdf 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 ESCO.

Quick energy assessment was used for the first performance evaluation of the project implementation. The objective was to have a first indication of the system behaviour regarding energy performance and compliance with the energy audit objectives.

Prefunctional checks and functional performance tests were carried out and finally quick energy assessment of implemented EEMs were executed by previously defined test methodologies. Some tests were in the form of spot measurements and additional calculations based on those spot measurements and assumptions as per technical data sheets depending on the complexity of system or outdoor temperature or season of the test date. Spot measurements included flue gas analysis and consequently thermal efficiency of new boilers, power consumption of new circulation pumps, COP of heat pump, efficacy of LED bulbs, etc.

Quick energy assessment methods are provided in below table.

No	Energy Efficiency Measure (EEM)	Performance Test Method
1	Building insulation application and window/door replacement	Thermal inspection by thermal camera and calculation of U-value by U-value measurement device.
2	Boiler replacement	Flue gas analyzer measurement and thermal inspection of boiler's surfaces by thermal camera leading to calculation of system thermal efficiency
3	Thermostatic valve in radiators and VSD circulation pumps	Flow measurement with ultrasonic flow meter and power measurement of circulation pumps in various load conditions. (%25, %50, %75, %100)
4	Boiler room mechanical installation insulation	Calculation of losses with the results of thermal inspection by thermal camera.
5	Heating system automation	Test of all points of automation system (Analog Input, Analog Output, Digital Input, Digital Output points)
6	Heat pump application supported by solar PV system	COP&EER calculation via ultrasonic flow meter and power analyzer
7	LED bulbs replacement for exterior lighting	Adjacent measurement with power analyzer (before & after power measurement of lighting bulbs)
8	Rooftop solar photovoltaic system application	Determining of photovoltaic panel efficiency vith pyronometer and power analyzer

Once the tests were finalized and the final commissioning report including quick energy assessment results was submitted, GDCA reviewed the submited report via its technical consultant. The quick energy assessment results were reviewed and compared with the assumptions or parameters of energy saving calculations of proposed EEMs. The results were generally consistent with the assumptions or expected output parameters of EEMs and therefore, the submitted commissioning report was approved by GDCA.

Picture 23. Heating automation system and associated equipment, sensors and valves

Measurement & Verification (M&V) Process

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[9] in Turkish language was developed by GDCA and published in KABEV's website. M&V plan, quarterly M&V reports and final M&V report at the end of the first year were prepared by ESCO based on this M&V guide.

M&V Plan that explained how to verify savings for each EEM, how to adjust the reference energy consumption (or baseline) was prepared by ESCO and submitted to GDCA for approval. 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. The measurement and verification method table for Bursa Kız Lisesi ESCO project was as in Table 7.

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

No	Energy Efficiency Measure (EEM)	M&V Option
1	Building insulation application and window/door replacement	Natural Gas Option C
2	Boiler replacement	
3	Thermostatic valve in radiators and VSD circulation pumps	
4	Boiler room mechanical installation insulation	
5	Heating system automation	
6	Heat pump application supported by solar PV system	
7	LED bulbs replacement for exterior lighting	Electricity – Option A
8	Rooftop solar photovoltaic system application	Electricity – Option B

Table 6. 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 approved the report to be 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 for this first time in public sector in Turkiye. 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.

Picture 24. LED exterior lighting bulb and Replacement of compensation, main distribution control panels

PERFORMANCE RESULTS

Item / Subject	Before	After	Savings	Saving %
Natural Gas Consumption [kWh]	1.027.649	370.462	657.187	64,0%
Electricity Consumption [kWh]	107.158	103.594	3.564	3,3 %
Total Energy Consumption [kWh]	1.134.807	474.056	660.751	58,2%
Renewable Energy Generation [kWh]	0	-282.708		*(-24,9%)*
Net Energy Use [kWh]	**1.134.807**	**191.348**	**943.459**	**83,1%**
Energy Cost [TRY]	**1.295.623**	**56.402**	**1.239.221**	**95,6%**
Green House Gas Emission [ton CO_{2e}]	**292,3**	**0,0**	**292,3**	**100,0%**
Corresponding No of Trees [pcs]			**13.428**	

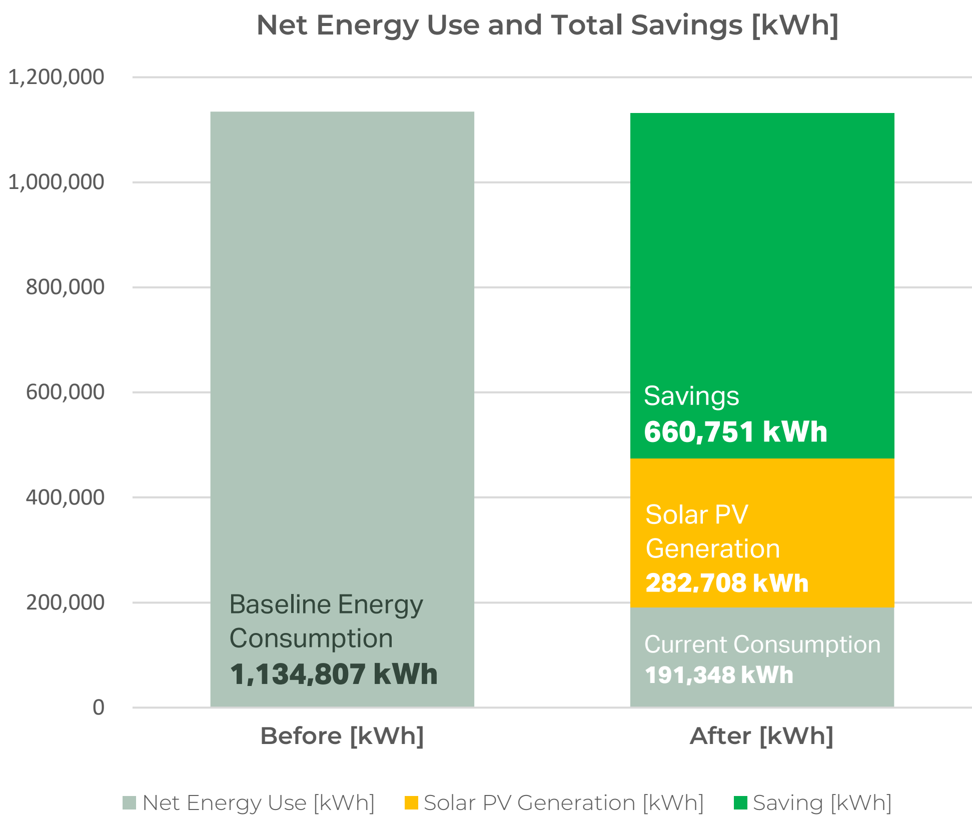
Final M&V report concluded with the following energy performance graphs. Baseline energy consumption of the building was 1.134.807 kWh/year even with insufficient heating. The energy use is reduced to 474.056 kWh/year corresponding to 58.2% savings without rooftop solar energy generation. When rooftop solar energy generation is included into the overall energy use calculations, 943.459 kWh/year energy is saved (corresponding to 83.1% savings) compared to 1.159.420 kWh/year ± 226.675 kWh/year expected energy savings, meeting the expected level of savings.

The variation in savings is mainly due to uncontrolled opening of windows between classes due to extra outdoor air ventilation demand by students as a post pandemic habit.

Due to measures imposed by government to reduce risk of contamination in highly occupied rooms such as classrooms in schools, extra ventilation was required that means over opening of classroom windows leading to relatively higher natural ventilation through windows. That extra natural ventilation causes the heating system to operate more hours with a higher heating demand and eventually leading to higher natural gas consumption than anticipated at the time of EEM saving calculations.

There seems to be a variation between expected and realized electricity savings but, it is mainly due to the generated amount of electricity by solar photovoltaic (PV) renewable energy system. Solar PV system's realized energy generation corresponds to 24,9% (at table 3 above) of overall baseline energy consumption whereas, it was expected as 27,6% (at table 2) of overall baseline energy consumption. It is mainly because it took a few weeks more than anticipated to connect to the grid system due to a delay in administrative procedure of electricity utility company. That made the solar PV system to be unoperational for a few weeks although it was ready to generate energy. Next year, it is certainly expected to produce the simulated amount of energy. On the other hand, realized electricity savings without solar PV system is 3,3% (at table 3 above) whereas, expected electricity savings was 0,3% (at table 2) meaning that the realized electricity savings went beyond expected electricity savings.

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

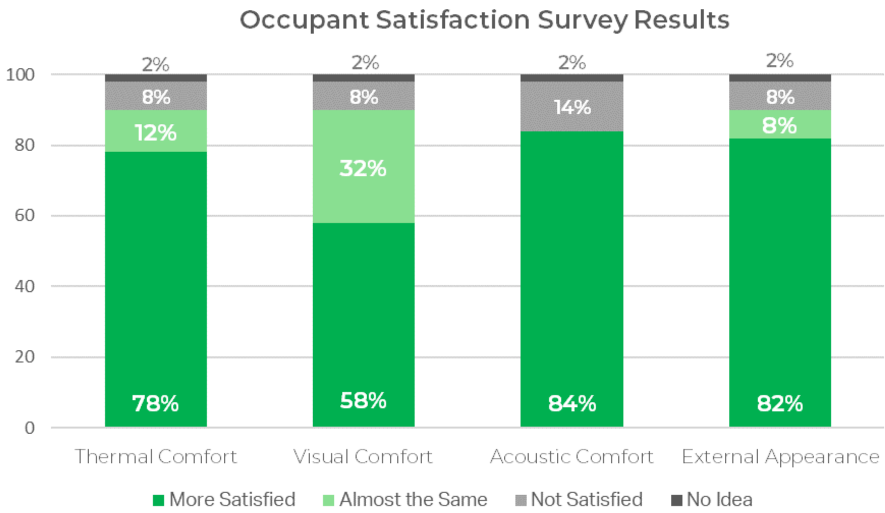


Graph 4. Energy Overview: Baseline Energy Use - Energy Savings - Solar PV Generation = Current Net Energy Use

BUILDING OCCUPANT EXPERIENCE

During the renovation process, two methods were implemented to gather user suggestions, satisfaction, or complaint cases. Pre and post-renovation surveys were conducted among 450 randomly selected individuals out of 822 building users with a sampling error of 0.03 to assess their feedback.

Satisfaction surveys were selected as the method for elaborating on recommendations and feedback. Occupant satisfaction rates were measured for four comfort criteria (thermal, visual, acoustic, and external appearance) and the results are provided at below Graph 5.



Graph 5. User Satisfaction Survey Results

LESSONS LEARNED

Bursa Kız Lisesi energy efficiency improvement project was the first of its kind as an EPC project and a lot of things were experienced for the first time for all parties including the project implementation unit (GDCA), supervision consultant, contractor (ESCO), beneficiary (public school), local government, school council, etc. Therefore, several lessons were learned as an outcome of this specific project:

Energy Performance Contract Method:

Selecting energy performance contract (EPC) method in Bursa Kız Lisesi energy efficiency renovation project provided the following advantages:

- Saved time compared to conventional energy efficiency renovation works process in which there's an additional procurement process for audit, design and supervision services. In the conventional process, a consultant company has to be selected first to do energy audit, design and supervision works. After the design process is finalized, another procurement process takes place for selection of implementing contractor. As a result, EPC method saved time for reaching to the realized energy savings by an ESCO motivated for achieving minimum energy savings.
- Simplified the process flow starting from energy audit to design and to implementation eventually. One responsible party for all the process and the performance results. No other party left to blame or no execuse to disclaim responsibility. Otherwise, energy audit and design would be carried out by a different party and implementation contractor could force to shift the responsibility to the designer in case of a low performance or not achieving the energy savings.
- Reduce the overall cost due to savings in energy audit and design works being carried out by a single party (contractor) as a package, namely ESCO.
- ESCO being motivated to achieve savings because a significant portion of the payment is tied to energy performance. This phenomenon leads to qualified implementation works and higher performance equipment without the enforcement of a detailed, hundred pager technical specification document.

Selecting energy performance contract (EPC) method in Bursa Kız Lisesi energy efficiency renovation project provided the following disadvantages:

- ESCO market is at early stages in Türkiye and therefore, there's lack of sufficient number of qualified and experienced ESCOs leading to relatively less competition in procurement process. Therefore, more energy performance contracts need to be done in order to make local ESCOs become more familiar with the process and make it less unknown for them. As a result, more companies will become ESCOs and more companies will be willing to enter into EPC tenders.
- Lack of experience and know-how about EPC leads to difficulty in calculating risks and eventually reluctance at contractors in engaging an EPC. More energy performance contract tenders will

make insurance and financial institutions be aware of a new market and encourage them to provide products and services that will limit the risks of an ESCO. That will in turn decrease the reluctance at contractors in engaging an EPC.

- Lack of measurement and verification process knowledge leads to higher perceived risks than actual risks in terms of achieving minimum energy savings discouraging prospect ESCOs to engage and decreasing competition in the procurement process. More M&V professionals are necessary for a healthy operating ESCO 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.
- Lack of sufficient qualified and experienced technical staff specialized especially in EPC of buildings leads the contractors to perceive technical risks and complexity of the works more than its true risks.
- Buildings have too many systems interacting with each other (building façade with heating and cooling system, lighting system with cooling system, etc.). This phenomenon creates relatively more complexity especially in implementing the energy efficiency measures in a building which is already in operation and also in calculating the energy savings with more accuracy. (Unlike an equipment or system change in a single process in an industrial facility.) Therefore, ESCO projects may be selected among building energy efficiency renovation projects with less complex measures which for instance would not include façade insulation and window replacement or include relatively low number of measures.

Energy Audit Process:

Tender awarded ESCO was required to do its own investment grade audit and submit to GDCA approval after the tender as a part of their tasks. This task could have been done by ESCOs before the tender and they could have done it much faster and efficiently before the tender stage and submit their EEMs proposal as part of their bid. As a result, a significant time could be saved for the implementation period.

Design Documentation Process:

ESCO was required to develop design documentation and submit to GDCA approval. Since ESCO implements the design itself on site, it could have saved time and energy for all teams if ESCO was not required to prepare and submit a detailed design documentation to start the site implementation works. A clear and detailed set of technical specifications defining the quality, efficieny, performance and features of equipments, materials and systems that represents the expectations and requirements of GDCA would be sufficient for ESCO while developing its design documentation of EEMs.

Formal Permits:

Formal permit procedures could have been planned or initiated before the tender for systems such as rooftop solar PV system which has to go through electricity grid operator's formal approval procedure. Consequently, the provisional acceptance and permit for grid connection could have been obtained and renewable energy generation could have begun a few months before.

Energy Capacity:

ESCO designed rooftop solar PV plant capacity in a way that its annual electricity generation was more than the annual electricity consumption of the public school so that NPV of the energy efficiency project was maximized by selling the excess electricity energy generation back to the grid. However, the essence of unlicenced rooftop solar PV plants is to produce energy for self consumption of buildings. Exceeding the limit does not fully represent the main aim of the unlicenced energy generation directive. Therefore, it was decided by GDCA to limit the rooftop or carpark canopy solar PV plant capacities with the annual self consumption level for future projects as an outcome of learned lessons from this project.

Tender Terms:

In a relatively infant ESCO market, the financial terms and conditions of the tender could have been more flexible and attractive in order to attract more interest from ESCOs 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 ESCOs 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 ESCOs turn their utmost attention into more technical aspects of the tender.