KABEV

CASE STUDY BURSA YÜKSEK İHTİSAS HASTANESİ

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REPUBLIC OF TURKEY
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KAMU BİNALARINDA
ENERJİ VERİMLİLİĞİ PROJESİ
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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 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 YÜKSEK İHTİSAS EĞİTİM VE ARAŞTIRMA HASTANESİ

Bursa, Türkiye

Public Hospital

2 Healthcare Blocks

89.772 m^2

Main Hospital Building and Maternity Care Block

Energy Efficiency Renovation


Picture 1. Bursa Yuksek Ihtisas E.A.H. – Main Building

Bursa Yuksek Ihtisas Egitim ve Arastirma Hastanesi (E.A.H.) is a training and research healthcare facility with multi hospital blocks. The buildings are about 20 years old. They had major technical and comfort problems such as insufficient heating due to often malfunctioning boilers, insufficient cooling capacity during peak demand hours of cooling season, limited control over HVAC system due to lack of a capable HVAC automation system and very high energy bills.

Building administration was enthusiastic to join KABEV program to resolve the technical and comfort problems orginating from insufficient heating and cooling, frequently malfunctioning boilers, insufficient and inefficient chillers, and high energy bills. They also would like to avoid unplanned repair services due to malfunctioning boilers. What's more, building administration wanted to decrease the high energy bills of the buildings.
The implementation of energy efficiency works were done by an energy efficiency renovation contractor via conventional renovation construction contract.

Heating System

Heating system comprised of 4 pcs of 2.325 kW floor mounted natural gas heating boilers serving to main building and 2 pcs of 2.325 kW floor mounted natural gas heating boilers including stand-by units serving to maternity care block, fan-coil units and air handling units with old valves and constant speed low efficiency heating water 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 5 pcs x 2.325 kW floor mounted natural gas boilers, all of them equipped with economizers. Now, the boilers with higher thermal efficiency, capacity modulation and economizers provide as much heating energy as demanded by the buildings leading to much less heating energy consumption.

Picture 2. Boiler Room – Boilers, Economizers and Calorimeters

Motorized Valves in Fan-Coil Units (FCUs) and Variable Speed Drive in Circulation Pumps

The fan-coil units were equipped with old fashioned valves causing constant speed heating water and chilled water circulation pumps operate all the time and leading to excess energy consumption and low thermal comfort. These old fan-coil unit valves have been replaced with brand new motorized valves. Old and constant speed heating water and chilled water circulation pumps have been integrated with variable speed drive. Now, all the spaces are heated by more efficient boilers distributing heating water to fan-coil units equipped with motorized 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 3. Boiler Room

Belt and Pulley System of Air Handling Unit Fan Motors

If standard belts used in air handling unit fans are replaced with cogged belts, fan efficiency will increase. Cogged belts are more easily twisted, which means more efficient belt drive system. Notches in belt structure allow belt to be bended repeatedly around pulley with less effort. Power and energy consumption are reduced by 2-4% through higher efficiency levels.[1]

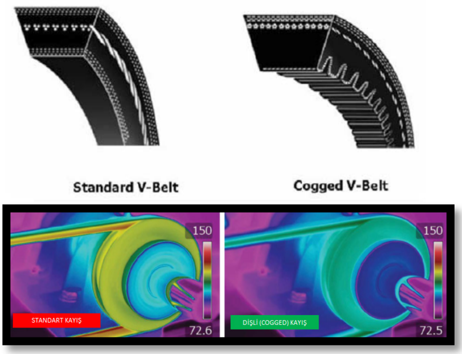


Figure 01. Standard V-Belt vs Cogged V-Belt

Air handling unit fan motors in Bursa Yuksek Ihtisas E.A.H. facility were equipped with standard V-belts and they have been replaced with cogged V-belts leading to less fan energy consumption.

Picture 4. Belt and Pulley (Cogged V-Belt)

[1] Doty, S., Commercial Energy Auditing Reference Handbook, The Fairmont Press, USA, S.294

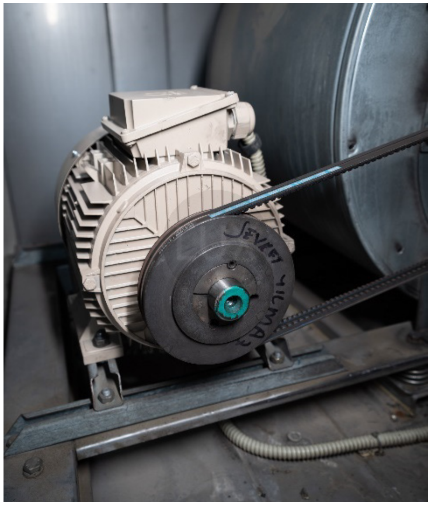
Chiller Replacement

There were several chillers in the healhcare campus. Four of them (700 kW cooling capacity each) served to main service building and another four (700 kW cooling capacity each) served to maternity and children service building. They were all air-cooled chillers with low coefficient of performance (COP), most of them over 15 years of age. All the chillers have been replaced with state of the art highly efficient chillers equipped with variable speed drive (inverter units) leading to even much higher performance levels during partial cooling load conditions.

Picture 5. New Variable Speed Air-Cooled Chillers

Electric Motors Replacement

There were dozens of old electric motors in the healtcare facility, mostly as a component of ventilation system fans. Therefore, a detailed list of electric motors within the facility were developed and analyzed so that the ones with respectively shorter payback period were selected to be replaced. As a result, 52 pieces of electric motors in the main hospital building and 36 pieces of electric motors in the maternity care building varying from 3 kW to 18,5 kW power have been replaced with IE4 super efficiency class electric motors.



Picture 6. New Efficient Electric Motor

Interior Lighting Retrofit

There were lighting fixtures of various types and powers within the healthcare facility. Although LED luminaires were partly used in interior lighting, luminaires generally used were surface mounted T8 fluorescents with magnetşic ballast. Inefficient luminaires have been replaced with more efficient LEDs.

In order to make an overall evaluation of lighting system, lighting fixtures inventory was prepared first. Types of lighting fixtures, their power, location, daily and annual operation hours were identified. Energy saving calculations were done based on these parameters. As a result, over 3.200 pieces in main hospital building and over 1.700 pieces in maternity care building summing up to 5.000 pieces of lighting bulbs have been replaced with LED type bulbs.

Picture 7. LED lighting fixtures

Illuminances and lighting levels were measured during energy audit and they were found to be sufficient. Site survey interviews with building staff and visual inspection of a lighting expert during audit confirmed that there was no significant issue in current lighting levels with the existing lighting fixtures. Luminous flux of the proposed LED luminaires have been better than the existing T8 luminaires. Hence, no issue has been experienced after interior lighting retrofit works.

Renewable Energy

There was no renewable energy system within the healthcare 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 kWe rated power has been applied at rooftops of main hospital building and maternity care block based on the effective roof area and transformer capacity of the facility.

Solar photovoltaic system's annual electricity generation corresponds to 2% of the buildings' electricity consumption annually. Due to the limited rooftop area, more on-site renewable energy installation cannot be made.

Picture 8. Rooftop solar photovoltaics (PV)

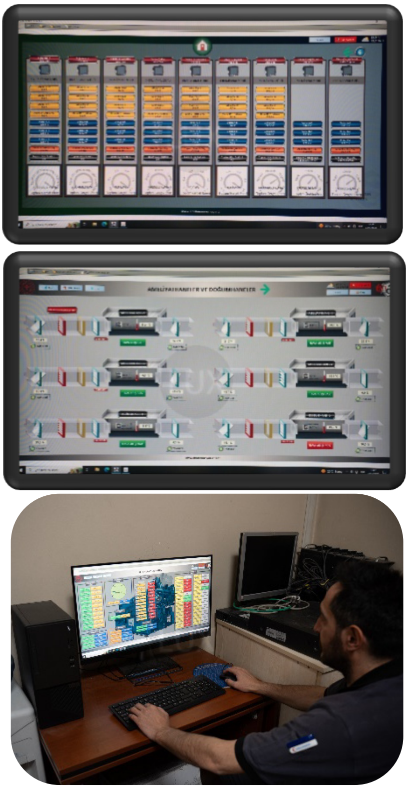
Picture 9. Rooftop solar photovoltaics (PV)

Building Automation and Energy Monitoring System

There was a very simple automation system in hospital building and there was no energy monitoring system. The only function of automation system was on-off control of HVAC equipments. Heating, cooling and ventilation demands from building spaces were not controlled. There was a potential in building automation system which can be further improved to contribute to the overall energy efficiency. Within the scope of this energy efficiency renovation works, it has been proposed to develop and expand 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 energy monitoring system.

Picture 10. Building Automation and 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 basic 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 the basic level, while monitoring energy consumption at the building level has been established.



Picture 11. Building Automation and Energy Monitoring System

Distributed Energy System

Existing facility did not have any distributed energy resource such as a cogeneration or a trigeneration system. Cogeneration or combined heat and power (CHP) is a system that produces heat and electricity simultaneously in a single plant, thereby guaranteeing a better energy yield than would be possible to achieve from two separate production sources. In this way, nearly all the thermal energy produced by combustion processes is not dissipated into the environment, as happens with traditional plants, but is recovered and reused. Trigeneration or combined cooling, heat and power (CCHP), is the process by which some of the heat produced by a cogeneration plant is used to generate chilled water for cooling. An absorption chiller is linked to the combined heat and power (CHP) to provide this functionality. Using the same fuel to generate both heating/cooling energy and electricity therefore improves energy efficiency, delivers environmental benefits such as greenhouse gas emissions reduction and ensures savings.

Based on general industry standard, optimum savings are accomplished in a cogeneration or a trigeneration system having over 5.000 operation hours per year. Healthcare facilities being open 7/24 throughout the year are optimum locations to benefit from the advantages of such systems.

On the other hand, thermal and electrical capacity of a cogeneration/trigeneration system should be sized based on the base demand of the facility in heating, cooling and electricity end-uses in order to ensure above mentioned industry average minimum operation hours (5.000 hours).

Here in Bursa Yuksek Ihtisas E.A.H. facility, the base demand in both heating, cooling and electricity were analyzed for a full year period and it was finally decided to establish a 1.200 kWe trigeneration plant which was calculated to operate no less than 5.840 hours annually (average of 16 hours/day). The system provides electricity energy along with heating energy and/or cooling energy depending on the demand side (building HVAC systems).

In a healthcare facility like Bursa Yuksek Ihtisas E.A.H., all three load types (electricity, heating and cooling) exist often simultaneously throughout the whole year. In summer period, electricity is demanded by lighting, cooling plants, building systems, plug loads; cooling energy is demanded by patient rooms, operating rooms, intensive care units, etc.; heating energy is demanded by domestic hot water system, medical laboratories, laundry and/or dry cleaning. In winter period, electricity is demanded by lighting, cooling plants, building systems, plug loads; cooling energy is demanded by operating rooms, specific medical laboratories, etc.; heating energy is demanded by patient rooms, common areas, domestic hot water system, medical laboratories, laundry and/or dry cleaning. As a result, healthcare facilities are ideal locations to maximize the benefits of a trigeneration system.

Picture 13. Trigeneration System

Picture 12. Trigeneration System and Automation Control

The automation and monitoring of the trigeneration system has been adopted into recently enhanced building automation and energy monitoring system. It provides the optimum operation of trigeneration plant based on the actual heating, cooling and electricity demand of the facility.

Picture 14. Trigeneration System and Automation Control

Building System	Before Implementation of EEMs	After Implementation of EEMs
Building Envelope	Insulation as per local building insulation standard.	Insulation as per local building insulation standard.
Fenestration	PVC framed double pane windows.	PVC framed double pane windows.
Heating System	6 x 2.325 kW floor mounted natural gas heating boilers, fan-coil units with old valves and constant speed circulation pumps. (two of the boilers often malfunctioning)	5 x 2.325 kW floor mounted cascade natural gas boilers with economizers, old valves replaced with motorized valves in fan-coil units, circulation pumps integrated with variable speed drive. (1.241 kW trigeneration heating capacity is in place additionally.)
Cooling System	8 x 700 kW old air cooled chillers with no variable speed drive and low COP.	Replaced with 8 x 700 kW variable speed and high COP & IPLV air cooled chillers.
Ventilation System	Air Handling Units with low efficiency fan motors along with pulleyand standard V-belt.	Air Handling Units with super premium efficiency fan motors along with pulley and cogged V-belt.
Domestic Hot Water System	Fed by main boilers via heat exchanger.	Fed by main boilers via heat exchanger. (1.241 kW trigeneration heating capacity is in place additionally.)
Mechanical Installation/Plumbing	Old insulation in the piping system.	Insulated according to local plumbing insulation standard.
Interior Lighting System	Mostly T8 flourescent bulbs	LED lighting bulbs
Electrical System	2 x 2.500 kVA and 2 x 1.600 kVA main distribution panels	2 x 2.500 kVA and 2 x 1.600 kVA main distribution panels
Compensation System	Operational compensation system.	Operational compensation system.
Renewable Energy System	None.	Installed 400 kWe rooftop photovoltaic solar power system.
Energy Monitoring System	None.	Energy monitoring system that allows building level monitoring for gas and electricity consumption.
Distributed Energy Source: Cogeneration/Trigeneration	None.	1.200 kW_e trigeneration plant (cogeneration + absorption chiller)

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

No	Energy Efficiency Measure	Energy Type	Energy Savings		Energy Cost Savings	Investment Cost (Tendered cost)	Payback Period
			Final	Primary			
			kWh/y	kWh/y	TRY/y	TRY	Year
1	Replacement of Existing Hot Water Boilers	N.gas	741.261	741.261	133.560	2.516.943	18,8
2	Motorized Two Way Valve App. to AHU & FCU Coil Inlets and Inverter App. to AHUs Heating and Cooling Circulation Pumps	N.Gas	717.332	717.332	845.219	4.572.317	5,4
		Electricity	911.437	1.888.497			
3	Replacement of Belt and Pulley System of Fan Motors of Air Handling Unit (Using Efficient Cogged V-Belt)	Electricity	33.393	69.190	26.232	72.356	2,8
4	Replacement of Existing Chillers with Efficient Inverter Chillers	Electricity	589.837	1.222.142	463.340	8.313.240	17,9
5	Replacement of Existing Motors with Super Premimum Class Efficient Motors	Electricity	75.217	155.850	59.086	389.861	6,6
6	Replacement of Inefficient Fluoresecent Luminaires with Efficient LED Luminaires	Electricity	505.141	1.046.652	396.809	1.380.940	3,5
7	Integration of Building Automation and Energy Monitoring System	N.Gas	520.079	520.079	650.116	859.101	1,3
		Electricity	708.313	1.467.625			
TOTAL (W/O SOLAR PV AND TRIGENERATION)		**N.gas (kWh)**	**1.978.672**	**1.978.672**	**2.574.362**	**18.104.758**	**7,0**
		Electricity (kWh)	**2.823.338**	**5.849.956**			
		TOTAL	**4.802.010**	**7.828.628**			
8	Solar Photovoltaic Panels (400 kW_e)	Electricity	454.444	941.608	356.984	4.104.416	11,5
9	Trigeneration Plant	N.Gas	-13.587.733	-13.587.733	3.018.373	12.110.826	4,0
		Electricity	7.730.383	16.017.354			
TOTAL (W/ SOLAR PV AND TRIGENERATION)		**N.gas (kWh)**	**-11.609.061**	**-11.609.061**	**5.949.719**	**34.320.000**	**5,8**
		Electricity (kWh)	**11.008.165**	**22.808.918**			
		TOTAL	**-600.896**	**11.199.857**			

Table 2. List of Energy Efficiency Measures

Baseline Energy Use

Natural gas primary energy use was 14.757.107 kWh/year and electricity primary energy use was 36.424.055 kWh/year corresponding to 51.181.162 kWh/year overall baseline primary energy use.

Saving Targets

1.978.672 kWh/year ± 345.027 kWh/year[2] natural gas primary energy was targeted to be saved corresponding to 13,4% ± 2,3% saving without solar PV and trigeneration system.

5.849.956 kWh/year ± 1.046.803 kWh/year[3] electricity primary energy was targeted to be saved corresponding to 16,1% ± 2,9% saving without solar PV and trigeneration system.

11.199.857 kWh/year ± 1.391.830 kWh/year[4] overall primary energy was targeted to be saved corresponding to 21,9% ± 2,7% saving with solar PV and trigeneration system.

SUMMARY OF RESULTS

Primary Energy Breakdown	Primary Energy Before	Primary Energy After	Primary Energy Savings	Primary Energy Saving %
Natural Gas Use [kWh]	14.757.107	12.968.441	1.788.666	12,1%
Electricity Use [kWh]	36.424.055	31.916.037	4.508.018	12,4%
Total Primary Energy Use [kWh] (without PV and Trigeneration)	51.181.162	44.884.478	6.296.684	12,3%
Renewables & Distributed Energy Systems				
Solar PV Primary Energy Generation [kWh]		-895.655	895.655	*(1,7%)*
Trigeneration Net Primary Energy Use [kWh] (Electricity, Heating & Cooling Energy Generated minus N.Gas Use)		-1.701.131	1.701.131	*(3,4%)*
Overall Primary Energy Generation [kWh]		-2.596.786	2.596.786	*(5,1%)*
Net Primary Energy Use [kWh] (with PV and Trigeneration)	**51.181.162**	**42.287.692**	**8.893.471**	**17,4%**
Annual Energy Cost [TRY]	**16.468.077**	**11.559.547**	**4.908.530**	**29,8%**
Green House Gas Emission [ton CO_{2e}]	**11.961**	**9.887**	**2.074**	**17,3%**
Corresponding No of Trees [pcs]			**95.281**	

Table 3. Summary of Energy and GHG Emission Results

[2] Based on baseline model uncertainty calculated at 90% confidence level as per IPMVP. (Relative uncertainty= ±17,4%)

[3] Based on baseline model uncertainty calculated at 90% confidence level as per IPMVP. (Relative uncertainty= ±17,9%)

[4] Based on baseline model uncertainty calculated at 90% confidence level as per IPMVP. (Relative uncertainty= ±17,4%)

Baseline overall primary energy use of the facility was 51.181.162 kWh/year. The energy use is reduced to 44.884.478 kWh/year corresponding to 12,3% savings without rooftop solar energy generation and trigeneration. When rooftop solar energy generation and trigeneration is included into the overall energy use calculations, overall primary energy use is reduced to 42.287.692 kWh/year corresponding to 8.893.471 kWh/year primary energy savings (17,4% saving) compared to 11.199.857 kWh/year ± 1.391.830 kWh/year[5]) expected energy savings (21,9% ± 2,7% saving).

As a result, overall realized primary energy savings fell 914.557 kWh/year short of the expected savings (9,3% less than the expected savings).

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

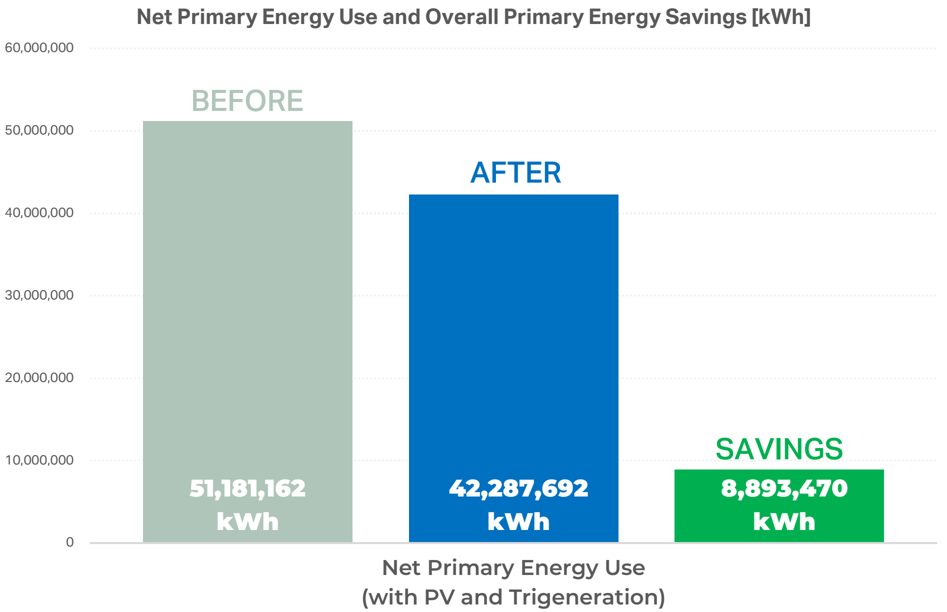
Due to measures imposed by government to reduce risk of contamination, extra ventilation was required that means over opening of windows leading to relatively higher natural ventilation through windows. That extra natural ventilation causes the cooling system to operate more hours with a higher cooling demand and eventually leading to higher electricity consumption than anticipated at the time of EEM saving calculations.

There seems to be a variation between expected and realized savings but, it is mainly due to the generated amount of heating&cooling energy and electricity by trigeneration energy system. Trigeneration system's net primary energy generation realized as 1.701.131 kWh/year corresponding to 3,4% of overall baseline primary energy consumption whereas, it was expected as 2.429.621 kWh/year corresponding to 4,7% of overall baseline energy consumption. It is mainly because it took approximately three months more than anticipated time to connect to the grid system due to a delay in administrative procedure of electricity utility company. That made the trigeneration system to be unoperational for those three months leading to reduced annual operation hours of trigeneration system although, it was ready to generate energy. Next year, it is certainly expected to produce the simulated amount of energy.

Greenhouse gas emissions are calculated to be reduced from 11.961 tons of CO_2e to 9.887 kg CO_2e corresponding to 2.074 tons of CO_2e reduction.

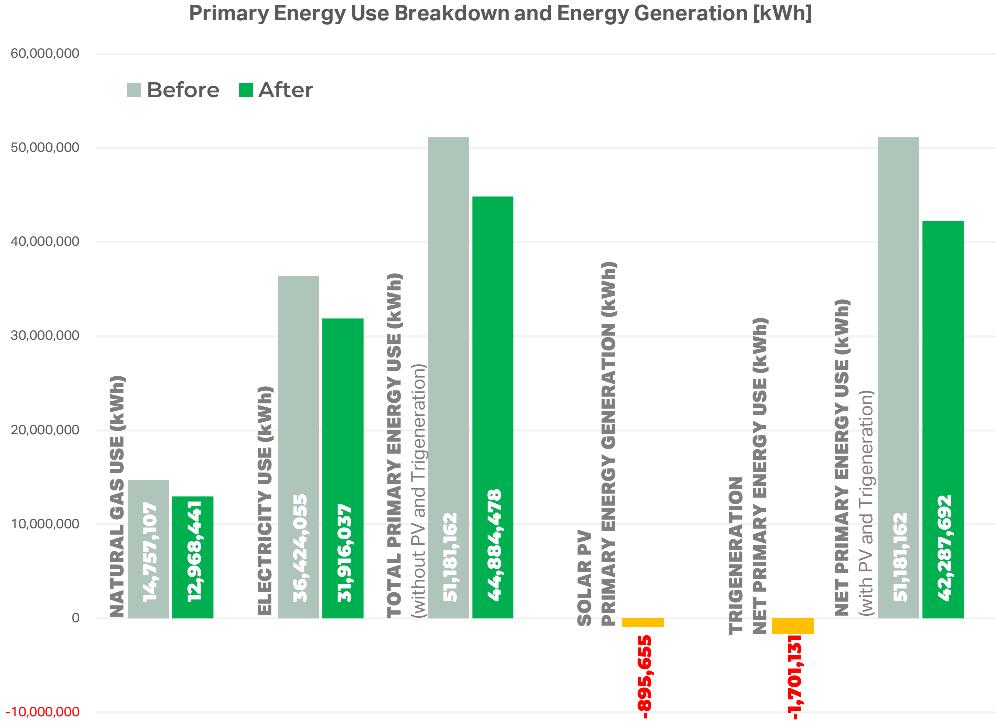
Building occupants are all satisfied with the thermal comfort level after the energy efficiency measures were implemented.

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



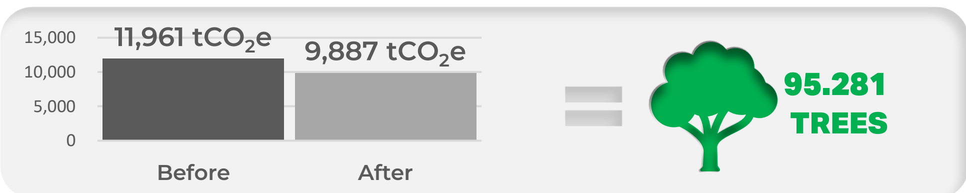
Graph 1. Net Primary Energy Use Comparison (Before vs After) and Overall Primary Energy Savings

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



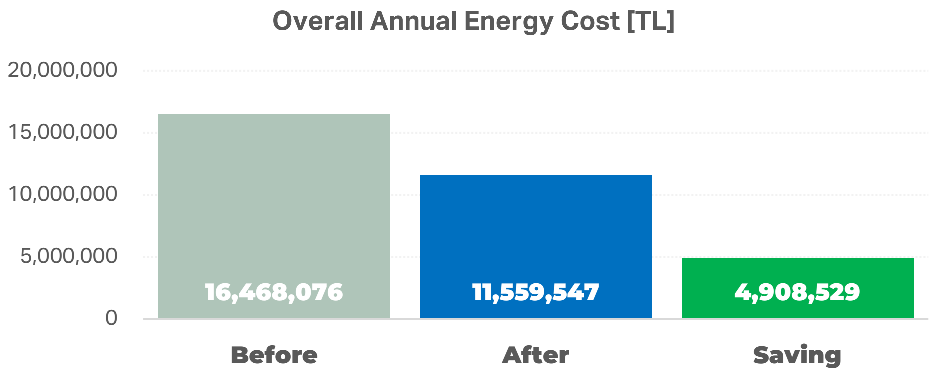
Graph 2. Energy Use Breakdown and Energy Generation Comparison (Before vs After)

Green house gas emissions before and after EEMs are implemented are represented in below graph. Overall green house gas emissions are reduced by 17,3% which would be a good example for other healthcare facilities in terms of decarbonization of buildings in the future.



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

Overall energy cost of healthcare facility before and after EEMs are implemented are represented in below graph. Energy cost is reduced from 16.468.076 TL to 11.559.547 TL corresponding to 4.908.529 TL annual energy cost savings. With an investment cost of 34.320.000 TL, it refers to 7 years of simple payback period.



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

PROJECT IMPLEMENTATION PROCESS

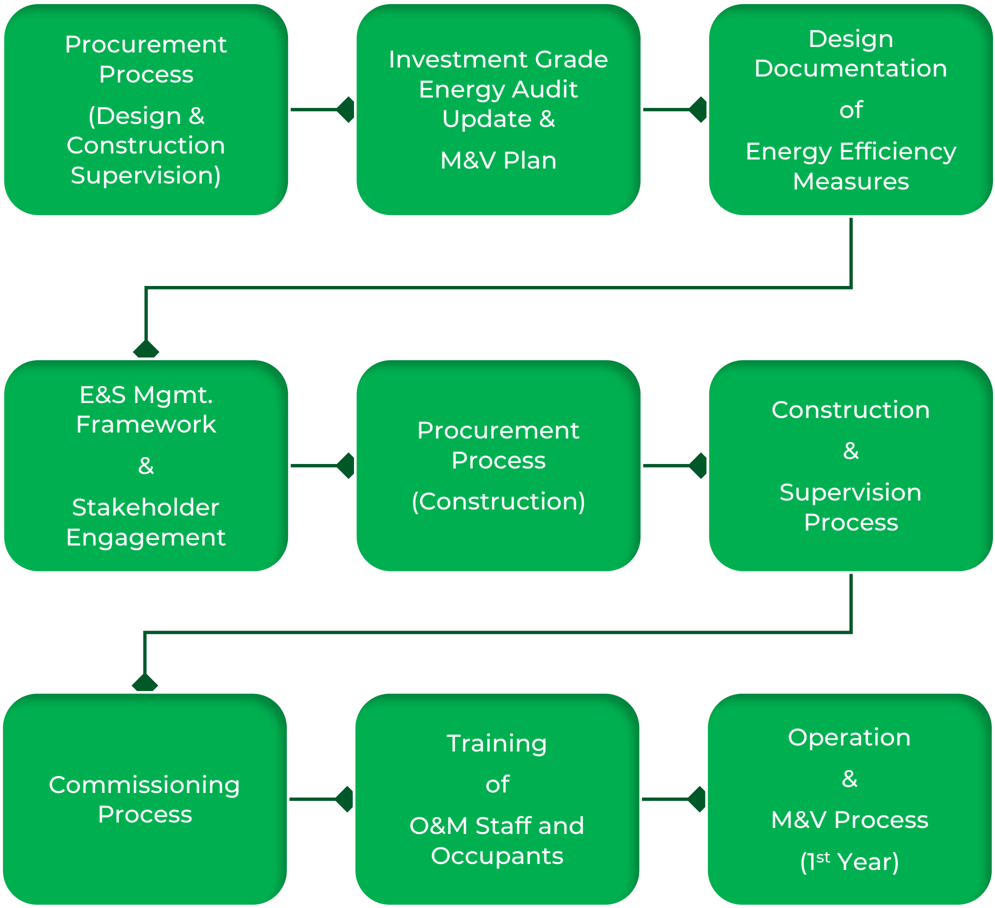


Figure 2. KABEV Project Implementation Process

Procurement Process (Design and Construction Supervision)

Bursa Yuksek Ihtisas E.A.H. 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	Replacement of Existing Hot Water Boilers
2	Motorized Two Way Valve App. to AHU & FCU Coil Inlets and Inverter App. to AHUs Heating and Cooling Circulation Pumps
3	Replacement of Belt and Pulley System of Fan Motors of Air Handling Unit (Using Efficient Cogged V-Belt)
4	Replacement of Existing Chillers with Efficient Inverter Chillers
5	Replacement of Existing Inefficient Motors with Super Premimum Class Efficient Motors
6	Replacement of Inefficient Fluoresecent Luminaires with Efficient LED Luminaires
7	Solar Photovoltaic Panels (400 kW_e)
8	Integration of Building Automation and Energy Monitoring System
9	Trigeneration Plant

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 healthcare facilities were operating over their capacity and any intervention due to whatsoever reason would be untolerable by the hospital administration.

Consequently, all the laboring costs were much higher than usual rates due to mentioned delicate and fragile construction working conditions and hours within a healthcare facility, leading to reckoning over the investment costs of EEMs.

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[6] 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

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

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[7] 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 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.

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 effisciency renovation construction works were tendered by GDCA.

Before the construction process, environmental and social management plan of Bursa Yuksek Ihtisas E.A.H.[8] project was developed based on the environmental and social framework[9] of the overall KABEV project. Stakeholder engagement meetings were carried out with all the relevant stakeholders such as hospital administration, doctors, medical personnel.

Picture 15. Stakeholder engagement meeting

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

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

[8]https://www.kabev.org/wp-content/uploads/2022/09/BURSA_SEVKET_YILMAZ_EGIITIM_VE_ARASTIRMA_HASTANESI_CSYP_REVIZYON01.pdf

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

Picture 16. Project specific booklet

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

Picture 17. Energy efficiency awareness

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 boilers and chillers 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[10] 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 previously 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 Bursa Yuksek Ihtisas E.A.H. project is provided in below table.

No	Energy Efficiency Measure (EEM)	M&V Option
1	Replacement of Existing Hot Water Boilers	Natural Gas Option C
2	Motorized Two Way Valve App. to AHU & FCU Coil Inlets and Inverter App. to AHUs Heating and Cooling Circulation Pumps	
3	Integration of Building Automation and Energy Monitoring System	
4	Motorized Two Way Valve App. to AHU & FCU Coil Inlets and Inverter App. to AHUs Heating and Cooling Circulation Pumps	Electricity Option C
5	Replacement of Belt and Pulley System of Fan Motors of Air Handling Unit (Using Efficient Cogged V-Belt)	
6	Replacement of Existing Chillers with Efficient Inverter Chillers	
7	Replacement of Existing Inefficient Motors with Super Premimum Class Efficient Motors	

10https://www.kabev.org/en/wp-content/uploads/2022/03/D5.2_Commissioning-Handbook_ENG_Web_version_Final.pdf

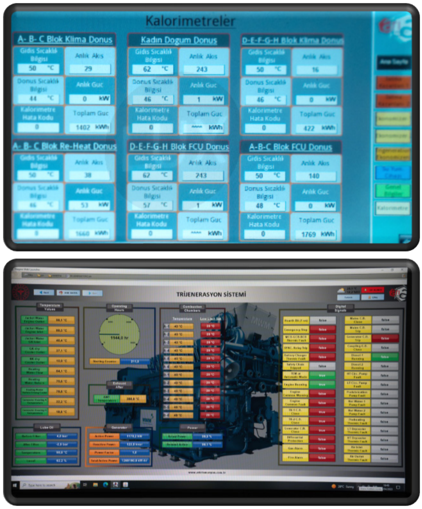
8	Integration of Building Automation and Energy Monitoring System	
9	Replacement of Inefficient Fluoresecent Luminaires with Efficient LED Luminaires	Electricity Option A
10	Solar Photovoltaic Panels (400 kW_e)	Electricity Option B
11	Trigeneration Plant	Electricity & Natural Gas Option B

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 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 18. Energy monitoring system

LESSONS LEARNED

Bursa Yuksek Ihtisas E.A.H. 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 (public hospital), local government, 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.

Another lesson is to include some non-energy efficiency measures such as renovating the whole boiler room and instrumentation even though only the boilers are replaced. This approach would improve the perception of the quality of the implementation of energy efficiency measures.

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 (architectural, mechanical, electrical, plumbing, etc.) are decided to approved by GDCA.

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Formal Permits:

Formal permit procedures could have been planned or initiated before the tender for systems such as trigeneration system and 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 and trigeneration and 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.