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Energy Consumption Analysis, Efficiency Measures and Renewable Energy Investments Towards a Nearly Net-Zero Campus: The Case Study of Cyprus International University

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Abstract. According to the International Energy Agency, energy and process emissions from buildings are responsible for nearly 33 % of global CO_2 emissions in 2021; with two other leading sectors; transportation and industry with emissions of 22 % and 30 %, respectively. As a result, parallel with global signs of progress, the topic of energy efficiency and energy management in buildings has come to be a rule of energy policy in Cyprus International University (CIU) buildings. In Cyprus, similar to the reference of IEA, nearly 30% of the energy consumption is from the buildings, which is the most open to energy-saving measures. Since 2017, Sustainable Energy Research Centre in CIU has been working on the energy measures of CIU on both supply and demand sides. To increase the university's sustainability further in the Energy and Climate section of both UI GreenMetrics and contribution to UN Sustainable Development Goals, conscious energy steps are taken both in energy saving and alternative renewable energy sources in the whole campus which resulted in making CIU a leading example of a sustainable university campus in the Middle-East as it holds the 3rd place for the most sustainable university campus in the region according to UI GreenMetrics World Sustainable University Ranking in 2022. In this paper, an energy audit study will be presented which evaluates the total energy load and energy-saving potential on campus and propose measures that should be taken. In order to conduct this study, Education and Humanities (EH) Building is taken as the pilot study which considers a detailed audit and actions to minimize energy consumption. Then the findings obtained from this energy efficiency study are generalized to all existing buildings on the campus and the expected effect of energy efficiency attempts is projected. These results are joined with the future alternative energy projects planned on the campus and the roadmap to nearly net-zero campus is discussed at the end of the study.

Keyword: Energy Efficiency, Energy Management, Buildings, CO_2 Emissions, Sustainable Energy.

1. Introduction

Energy use in buildings is responsible for 34% of worldwide energy consumption including energy use for production of cement and steel. In addition, buildings accounted for 35% of electricity consumption in 2021 [1]. Educational Buildings such as universities are included in this category. The average Energy Use Intensity (EUI) for educational buildings, schools, and universities buildings ranges between 50 – 250 kWh/m^2 of EUI, however, Mediterranean countries such as Cyprus and Greece are between 50 – 100 kWh/m^2 [2]

The goal of net zero carbon campuses is to achieve zero greenhouse gas emissions in order to lessen their environmental effect and prevent greenhouse gas emissions. Renewable energy plays a big role in becoming net-zero carbon. As there is always an energy consumption, it results in CO_2 emissions. Therefore, it is important to adapt energy production in situ [3]. This situation plays directly to sustainability as well as Sustainable Development Goals (SDGs) provided by United Nations (UN). This paper is contributing to affordable and clean energy as well as climate action of SDG 7 and 13 respectively as well as UI GreenMetric's Energy and Climate section.

Sustainability in CIU has been a rising concern and development since 2009, as Centre of Excellence under this topic was established to work on these rising issues. Further down in 2017, Students for a Sustainable Campus (SCC) organization and Sustainable Workshop were established to allow students to be involved in the common mission of being sustainable. In 2018, CIU has started to be evaluated by a respected external body (UI GreenMetric's) on the campus' sustainability actions. Overall, it is evident from the timeline seen in Figure 1 that CIU is committed to being a sustainable university.

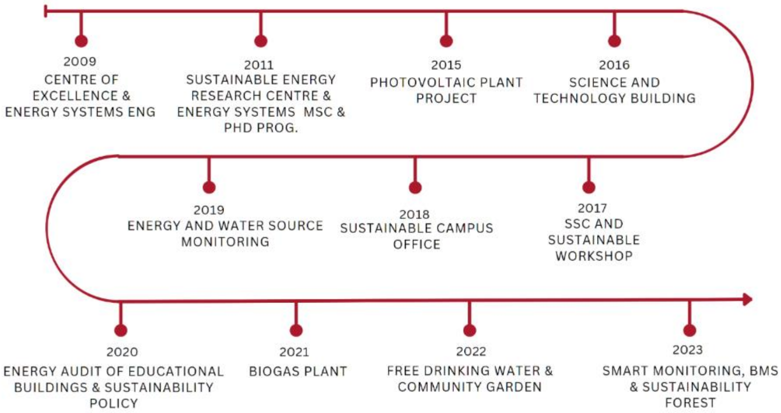

Figure 1. Sustainability Timeline of Cyprus International University

The main objective of this paper is to consider the energy conservation measures taken in the buildings throughout the campus and find out the energy mitigation potential in consumption. Also, viable renewable energy investments are mapped out to supply this mitigated energy need on the road to becoming a greener campus.

2. Methodology

This study is carried out as follows;

(1) An ordinary building, where energy efficiency measures were implemented is chosen

as a sample building.

(2) Energy Efficiency measures taken in this building were technically and economically evaluated and their results are presented.

(3) The findings in the sample building are extracted to all the campus buildings and the total energy conservation amount is predicted.

(4) Renewable Energy investment, which will be commissioned in 2025, is discussed.

(5) Energy Status of CIU in 2025 after energy efficiency actions and renewable energy investments is projected.

2.1. Selecting an Ordinary Faculty Building as a Case Study

Based on observation, survey and discussion with the management, it was concluded that there is a "must" for implementing an energy efficiency program on buildings due to high consumption of utilities, especially electricity, and lack of comfort for occupancies. Nearly half of the faculty buildings on the campus were audited and selected measures are being implemented in these buildings. This process will continue throughout the campus until energy efficiency measures are implemented in all the faculty buildings. However, to see the influence of energy efficiency actions throughout the campus, one of the faculty buildings that have gone through this process, Education and Humanities Building (EHB) is chosen as a sample building which could represent all the buildings and the facilities available inside the campus as it includes well-equipped laboratories, IT rooms, smart classrooms, etc.

The building was constructed in 2008 and since that time, no mature maintenance has been done. EHB is a 2-story building with an 8286 m^2 floor area built and located on the middle of the CIU campus. With a capacity of almost 2500 students and staff, EHB is the second-largest educational building on the CIU campus.

2.2. Energy Efficiency

In this section, the energy efficiency process will be presented from the energy audit step till the implementation of energy efficiency measures.

2.2.1 Energy Audit Through the Building

A walk-through audit was done as an initial step in EHB and possible energy conservation measures were determined by observation. Then, the baseline data (Drawings, Interviews, Site visits, equipment inventory… etc.) was obtained and energy consumption trends for previous years were calculated. After the calculations, the building was modeled with Hourly Analysis Program (HAP) of Carrier, and SketchUp software was used to model the building which then translated for energy consumption, illumination, and natural daylight. Also, a thermal camera was used to find out the temperature variations in determining energy-saving potentials. Last but not least, all the internal comfort variables (air quality, temperature, illumination) were measured by indoor air quality prob, LUX meter, and flue gas analysis instrument. All data from different evaluations were analyzed to present the findings. Finally, the results from the case study were analyzed, and the financial aspect was conducted and shared with the energy management department for future saving costs.

2.2.2 Techno-economic Analysis

After the energy audit process, the following tasks were selected as potential energy conservation measures owing to the results, and the techno-economical analysis was carried out;

A) Thermal Insulation

The building envelope (roof, walls, and windows) was modeled in a simulator to minimize heat loss/gain. In addition, to identify the crucial points that increase the loss of energy through the building envelope a thermal camera is used. In Figures 2 and 3 the thermal imaging and the sample simulation table of the building can be seen.

	DESIGN COOLING COOLING DATA AT Jul 1500 COOLING OA DB / WB 37.2 °C / 20.6 °C			DESIGN HEATING HEATING DATA AT DES HTG HEATING OA DB / WB 1.7 °C / -1.4 °C		
ZONE LOADS	Details	Sensible (W)	Latent (W)	Details	Sensible (W)	Latent (W)
Window & Skylight Solar Loads	1292 m²	94054	-	1292 m²	-	-
Wall Transmission	1357 m²	17847	-	1357 m²	38868	-
Roof Transmission	2762 m²	123334	-	2762 m²	104838	-
Window Transmission	1292 m²	46257	-	1292 m²	87718	-

	DESIGN COOLING COOLING DATA AT Jul 1500 COOLING OA DB / WB 37.2 °C / 20.6 °C			DESIGN HEATING HEATING DATA AT DES HTG HEATING OA DB / WB 1.7 °C / -1.4 °C		
ZONE LOADS	Details	Sensible (W)	Latent (W)	Details	Sensible (W)	Latent (W)
Window & Skylight Solar Loads	1292 m²	94054	-	1292 m²	-	-
Wall Transmission	1357 m²	18865	-	1357 m²	38868	-
Roof Transmission	2762 m²	21301	-	2762 m²	18835	-
Window Transmission	1292 m²	43239	-	1292 m²	87718	-

Figure 2. The comparison between heat gain during peak load before and after applying the Envelope insolation

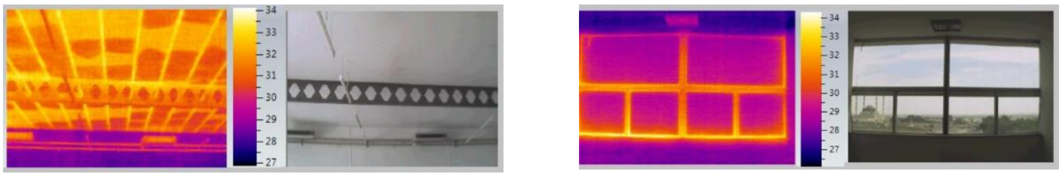

Figure 3. Heat gain/loss through the building envelope

B) Cooling & Heating

Heat gain and loss evaluation was carried out by site analysis and also calculations paired with simulations to find out the correct capacity and a more efficient HVAC system. The sun path analysis was done by Curic Sun Plugin and also, and boiler efficiencies obtained by the exhaust gas analyzer are presented as a sample of evaluation results, presented in Figure 4.

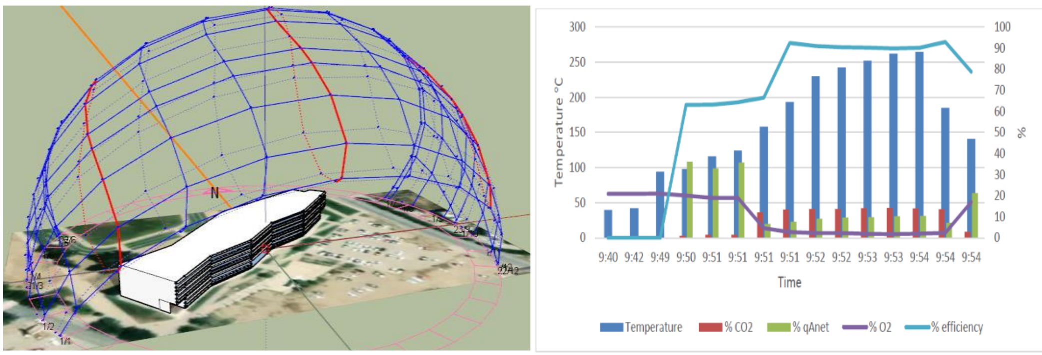

Figure 4. 12-Month Sun Pathway Over the Case Study & Boiler's Exhaust

C) Illumination

All classrooms and offices were measured several times (with and without daylighting) with LUX meter prob in at least 4 locations in each room to create a reliable average and the data gathered was compared with standard values for educational rooms. Also, working hours of illumination in vacant rooms were recorded to prepare a study for applying motion sensors to prevent energy loss.

D) Energy Efficiency Appliances for EHB Equipment

As indicated above, the information collected from all electrical devices in EHB, such as computers, printers, projectors, etc., are not verified by energy star and no standby mode is available to decrease energy consumption while not in use. By using thermal cameras, in Figure 5, it is seen that many electrical devices are consuming energy while they are not in operation

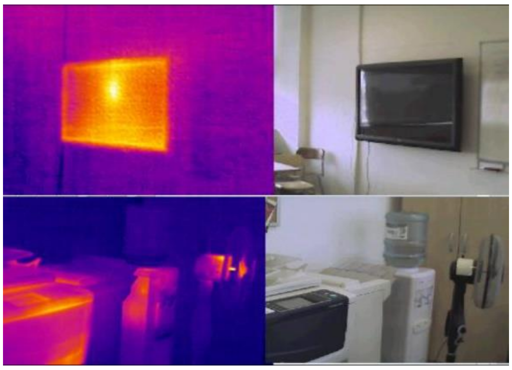

Figure 5. Energy lost in Standby mode

2.2.3 Implementing the Selected Energy Measures & Principles

After the energy modeling and thermal camera imaging, it was clear that a huge energy gain/loss has occurred due to the lack of and/or worn thermal insulation on pipelines, on the walls, and on the roof of the building. Therefore, an appropriate insulation material was selected to apply to the piping and building envelope. In Table 1, the thermal values of the roof can be seen.

Table 1. Thermal Values of EHB Roof

Recommended Thermal Insulation	Current Roof U-Value (W/m^2K)	Recommended Roof U-Value (W/m^2K)
RSI 2.6	1.867	0.335

In terms of lighting, it was determined that all the appliances are Compact Florescent Lamps (CFLs) with lower efficiencies and lifetime. In addition, no automation was present for the control of these appliances. Initially, an illumination analysis was done by modeling the building with SketchUp and additionally, site measurements were taken. As a result of the measurements, it was decided to switch 1148 CFLs to LED.

The previous air conditioning system worked with a 500kW water-cooled chiller system that had a COP of 2, which then was replaced by a highly efficient 600kW gas-operated VRF system with a COP of more than 4.

Additionally, it was seen that there are around 200 electrical appliances in EHB alone, and an energy star rating or similar could not be seen in some of the appliances. As a result, the procurement policy was adjusted for future purchases of appliances to have higher efficiency.

2.3. Extracting the Results of EHB Through the Campus & Total Energy Efficiency Analysis

As EHB is the sample building that can reflect nearly all the facilities that are found in other faculty buildings, the influence of energy efficiency and mitigation in energy consumption could be used as a sample figure for all the other buildings. Therefore, whenever similar energy efficiency implementations as EHB are completed in other faculty buildings, it is expected that the same energy-saving ratio will be achieved.

2.4. Considering Future Renewable Energy Investment & Steps Towards a Green Campus

In addition to the Solar PV Plant located on the campus with a size of 1.3 MWp, an investment of 600 kWp biogas plant is planned. With the implementation of energy efficiency actions and investment of the biogas plant, the aim of CIU is to be a greener campus in terms of energy and climate.

3. Results and Discussions

3.1. Energy Consumption Analysis in EHB

Through the energy audit that was done in EHB, it is seen that 65% of the energy load is directed towards air conditioning, 8% for lighting and the remaining 27% is towards appliances and others which is further visualized in Figure 6. These figures are theoretically applied to the whole of the campus.

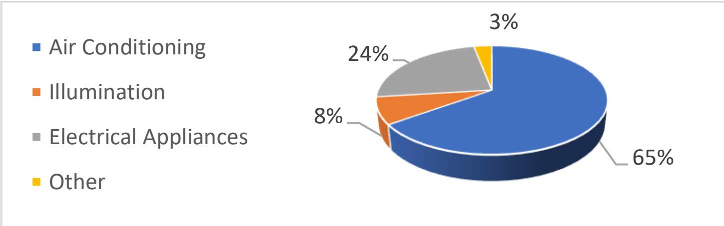

Figure 6. End Use Energy Consumption in EHB

After the energy audit, an energy conservation table similar to Table 2 is prepared. Then technically and economically feasible energy conservation measures (ECMs) were selected to be implemented. Table 2 shows the ECMs that were implemented in EHB.

Table 2. Techno-Economical Analysis of Energy Efficiency Implementations

Measure	Annual Source Saving		Installation Cost ($)	NPV ($)	PP (year)
	Energy (kWh)	Money ($)			
Envelope & Pipe Insulation	60,000	12,000	15,000	43,435	1.3
EE Appliances	26,600	5,350	7,000	19,052	1.3
LED Replacement	33,000	6,600	3,000	19,389	1.9
VRF Installation	385,440	77,088	300,000	75,386	3.9

3.2. Energy Consumption Trends in CIU

The campus is run off by 2 types of energy: LPG and Electricity, where LPG is used mainly for heating and cooking where electricity is used for everything else. The share of LPG and Electricity over the past 10 years is 24% and 76%, respectively which is visualized in

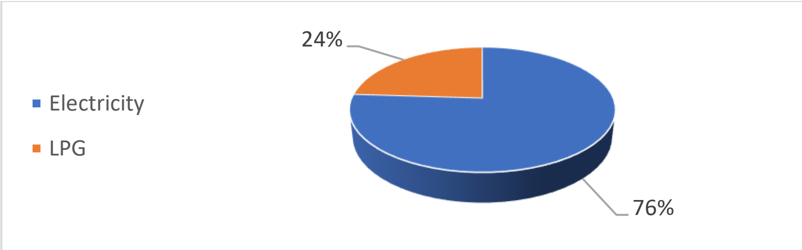

Figure 7. Energy Consumption Sources in CIU over 10 Years

3.3. Energy Efficiency Projection in CIU

The results of energy efficiency implementations in EHB are extracted throughout the campus buildings and energy conservation amounts are projected. The energy conservation measures were assumed to be taken for the energy consumption tasks; Heating and cooling, illumination, automation, and electrical appliances. These amount to 96% of the total energy consumption.

3.3.1. Energy Efficiency: Insulation and Automation Implementations

CIU has around 120,000 m2 of closed building area where 24,200 m2 is equipped fully with insulation (roof thermal insulation) and automation (IR sensors, CO2 sensors…etc.). The trend of EE is increasing throughout the years which is visualized in Figure 8. The trendline indicates that the more area we have in buildings the more energy efficiency is applied. In 2025, it is planned to cover 50% of the closed building area with these measures, resulting in more than 1,000,000 kWh/year savings in electricity.

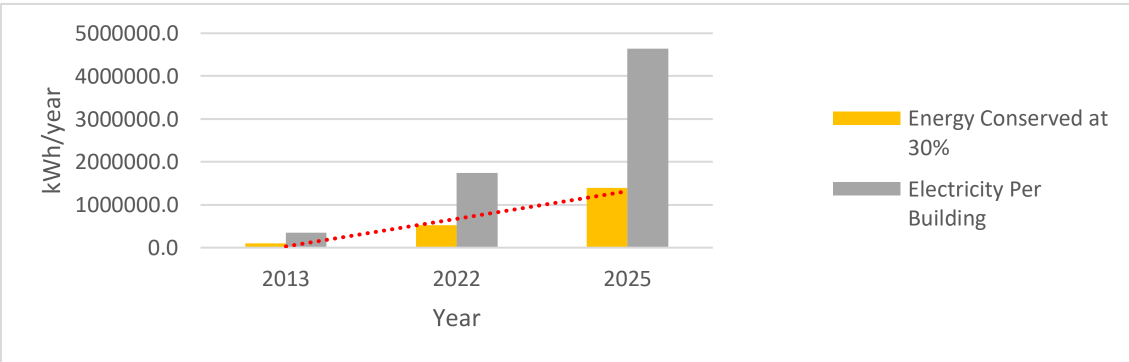

Figure 8. Energy Conservation with implemented EE measures and Automation

3.3.2. VRF Applications

The previous AC systems for the conditioned area were changed to VRF which has a COP (Coefficient of Performance) of 4 whereas the previous system's COP value was around 2. Though throughout the years, the building area covered by VRF reached around 35% in 2022 which allowed for 1,000,000 kWh savings in that year only. As 50% of the area is planned to be covered in 2025, this will result in 1,500,000 kWh of further savings in that year which is visualized in Figure 9.

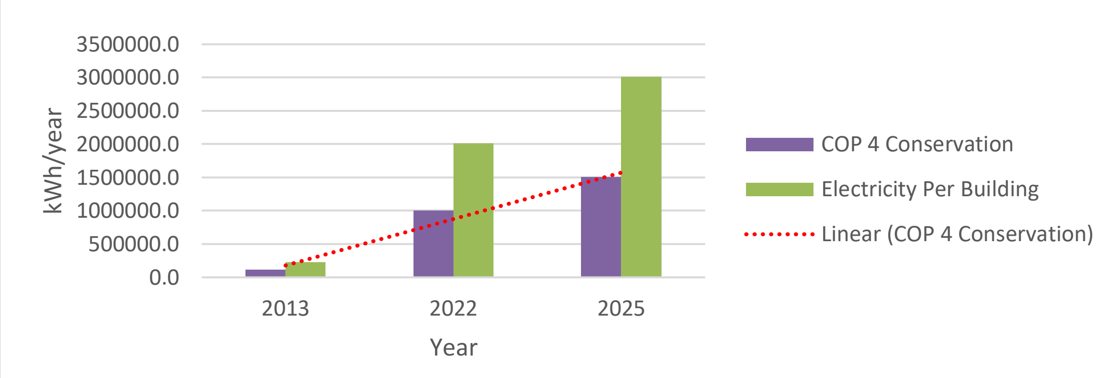

Figure 9. Energy Conservation after VRF replacement

3.3.3. LED Applications

The application of LED has reached almost 45% across the whole campus in 2022 which is seen in Figure 10. This implementation saved 150,000 kWh in 2022 and the adaptation is planned to cover 75% of the area, therefore a saving of around 250,000 kWh in 2025 is expected.

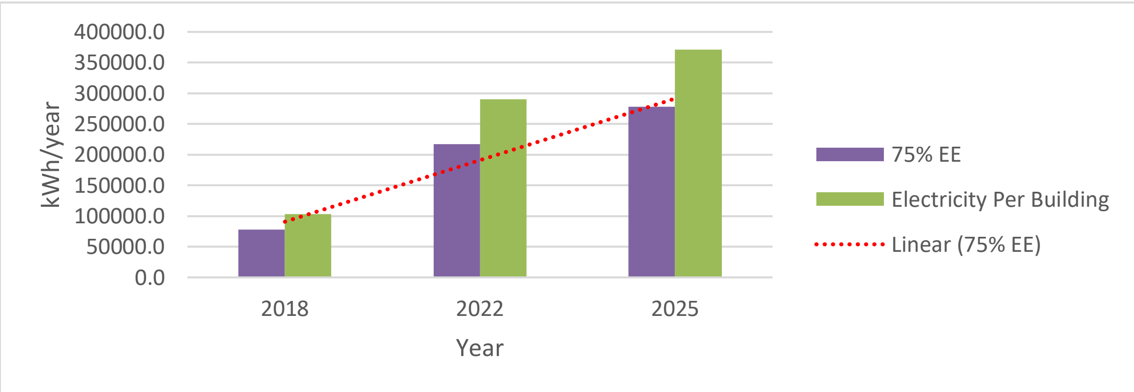

Figure 10. LED Energy Savings

3.4. Greener CIU; Combining Energy Efficiency with Future Renewable Energy Investment

The future plan is to cover 100% of the campus with renewables with the commissioning of the Biogas Plant. As can be seen in Figure 11, currently around 30% of the electricity consumption in CIU is from the PV plant. For 2025 the energy-saving measures are expected to reach at least 50% of the whole of the building area. With the help of energy-saving measures, the campus will be able to run purely on renewable energy with the commissioning of the 600-kWp biogas plant.

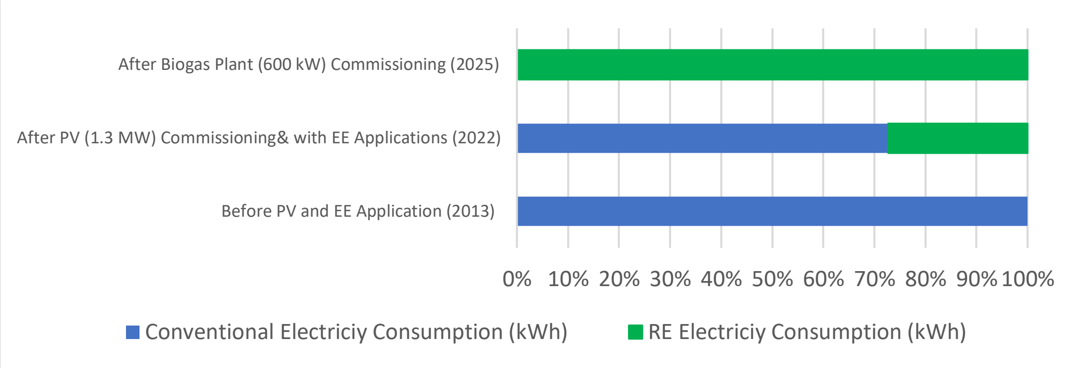

Figure 11. Electricity Transition from Conv. Sources to RE in CIU

With the implementation of the plant as well as the energy efficiency measures, CO2 emissions per capita will reduce from 0.44 to 0.03 tons per year which is seen in Figure 12. Also, the EUI value of CIU will decrease by around 30% to 53.53 kWh/m2.

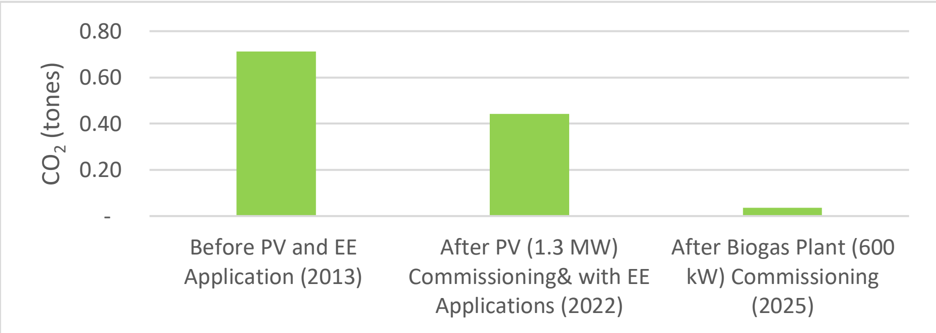

Figure 12. Net CO2 Emission Per Capita

4. Concluding Remarks

This study aims to present the current energy status of CIU and to discuss existing and also future energy demand and supply towards being a greener campus. An energy efficiency projection, which is based on the realized application, was carried out. Also, energy production, by two sustainable sources; a biogas plant that is planned to be commissioned in 2025 and the existing PV plant, are considered.

After extracting the data from EHB throughout the campus, in 2025, it is foreseen that the total energy saved will reach 2,750,000 kWh which leads to a reduction of 700,000 kg of CO2 in 2025 alone. With the implementation of the Biogas Plant, it is seen that the CIU campus will nearly be a net-zero carbon campus. As a result, further implementations of EE will definitely result in the goal of a carbon-neutral campus.

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