Electricity Savings and Carbon Mitigation Potential of a University Campus in Ho Chi Minh City, Vietnam

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Abstract
This study estimates the electricity consumption and related carbon dioxide (CO_2) emissions for the buildings and facilities the main campus of the International University – Vietnam National University in Ho Chi Minh City, Vietnam. The AIM/Enduse model is used to calculate the CO_2 emissions in 2019 based on the recorded electricity consumption and project the electricity consumption as well as the CO_2 emissions for the two scenarios, namely 2030baseline and 2030mitigation, in 2030 based on the future strategic plan to evaluate the energy savings and CO_2 mitigation potential for the university. We found that space cooling accounts for 67.9% of total electricity use, followed by laboratory equipment with 19.1%, official equipment with 9.4%, lifting with 1.7%, lighting with 0.4% and remaining services with 1.4%. If electricity efficiency technologies are applied, especially in space cooling service, then the electricity consumption and CO_2 emissions in 2030 could be 13% less than baseline scenario. Consumer behavior, particularly students, is also important in increasing the potential of electricity savings for the university. These findings for A1-A2 buildings are necessary for IU-VNU in implementing energy savings and mitigation measures for the new building A3 to achieve sustainable investment and higher CO_2 mitigation potential.

Keywords: Electricity Consumption, Co2 Emissions, Aim/Enduse Model, Bottom-up Approach, International University - Vietnam National University

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Introduction

International University – Vietnam National University Ho Chi Minh City (IU-VNU[1]), established in 2003, is the first public English-speaking university of Vietnam. The university has many twinning programs and exchange programs with other universities in United State (US), United Kingdom (UK), Europe (EU), Australia, Japan, etc. Therefore, it's important for IU-VNU to learn and apply the energy savings practices from these countries. In which, improve energy efficiency, investing in innovative energy production technologies, increase young student's energy and environmental awareness and reduce energy waste are considered as mitigation measures towards zero energy or even zero carbon communities by many university campuses all over the world.

At service-specific level, Stefano (2000) evaluated the potential for energy efficient lighting to save energy and reduce CO_2 emissions at Melbourne University, Australia; Abolarin et al. (2013) presented the energy efficiency improvement for lighting service at University of Lagos, Nigeria; and Gorgulu and Kocabey (2020) investigated the energy savings potential of lighting retrofit scenarios in outdoor lighting systems in Burdur Mehmet Akif Ersoy University, Turkey. Besides, Vásquez et al. (2015) conducted the evaluation of greenhouse gas (GHG) emissions and proposals for their reduction in travelling by different means of transport at Universidad de Talca, Chile. On the other hand, Park et al. (2016) proposed the optimal photovoltaic (PV) system implementation strategy to achieve the national CO_2 emissions reduction target in 2030 with a focus on educational facilities in South Korea. Moreover, Semprini et al. (2016) showed the importance of energy audit and management in heating system for University of Bologna, Italy; while Shea et al. (2019) provided the results of reducing air handling unit energy usage through controls-based energy efficiency measures for University of Dayton, US.

At whole-building level, Chung and Rhee (2014) analyzed the potential opportunities for energy conservation in existing buildings on university campus in South Korea based on field survey of energy consumption patterns; Emeakaroha et al. (2014) performed the role of a novel integrated system combining human psychology with technology feedbacks to assist real time energy conservation for University of Kent, UK. Moreover, Escobeto et al. (2014) estimated energy consumption and related GHG emissions for the buildings and facilities of the main university campus at the National Autonomous University of Mexico; Yeo et al. (2019) estimated the energy efficiency of educational buildings with the case study of buildings in City University of Hong Kong, China; while Liu and Ren (2020) conducted the research on the building energy efficiency design strategy of Chinese universities based on green performance analysis; Mohammadalizadehkorde and Weaver (2020) quantified potential savings from sustainable energy projects by an energy efficiency assessment for Texas State University, US. Besides, Olivieri et al. (2020) studied the potential of installing PV distributed generation towards an emission-free supply at Universidad Politécnica de Madrid, Spain. Moreover, Mytafides et al. (2017) discussed about the transformation of a university building into a zero energy building in Mediterranean climate under the context of EU energy efficiency initiatives. Kolokotsa et al. (2018) summarized the energy technologies and performance in different university campuses, with detail study for Technical University of Crete, Greece.

[1] International University – Vietnam National University Ho Chi Minh City

It's worth noticing that educational buildings have high potential in energy savings and GHG emissions reduction. Following these studies, this research aims to conduct a GHG inventory and projection for existing buildings (A1 and A2) in the main campus of IU-VNU. Different scenarios are developed with various assumptions on using conventional technology and applying advanced technology that are needed to comparison between the level of energy consumption and GHG emissions in base year 2019 as well as in target year 2030. These assumptions are not simply concerned with energy-efficient devices for less GHG emissions, but also include selection of economic efficient technologies to ensure a profitable operation for the university.

Overview of Energy Consumption in IU-VNU

Ho Chi Minh City (HCMC[2]) has a tropical weather with the warmest months are April-May and the coldest months are December-January. Figure 1 shows the monthly average temperature measured at Tan Son Hoa station in HCMC for the past fifteen years (the thermometer is located at two meters above the ground), in which the average temperature varies typically between minimum 25.9 degrees Celsius in January and maximum 31.3 degrees Celsius in May. In the base year 2019, (red line-with-markers in Figure 1), the temperature increased to be hotter than previous years in most of the months. The record shows that the weather in HCMC is getting hotter, that might lead to the increasing demand in electricity for cooling service.

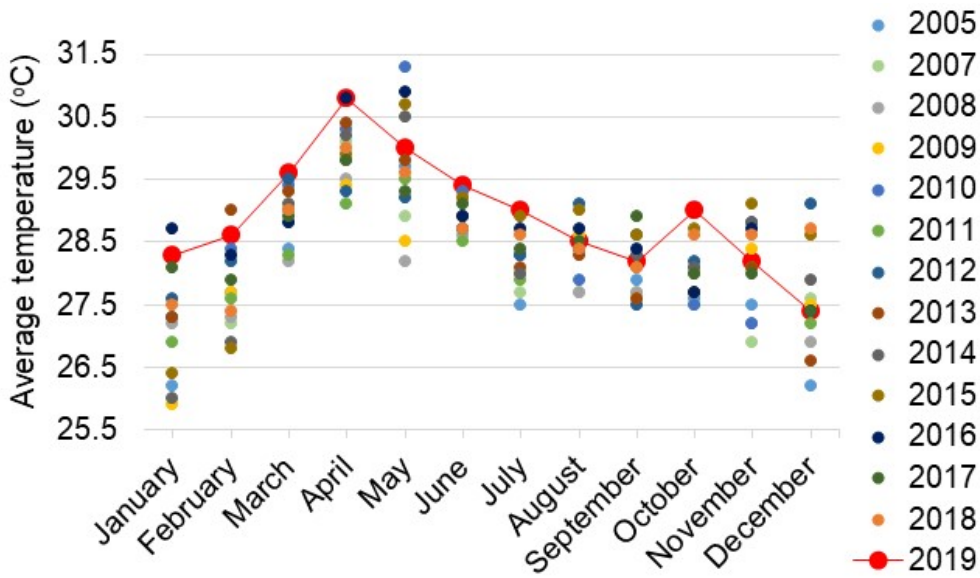

Figure 1. Monthly Average Temperature over 15 Years in Ho Chi Minh City, Vietnam

IU-VNU is paying energy bills for activities in buildings and facilities as well as transporting faculties and staffs by shuttle buses, in which more than 80% of energy bills is for electricity. Figure 2 shows the record of total electricity consumption in IU-VNU in five-year period (2016-2020) based on electricity bills. There is an increasing trend in electricity consumption with 1.9% - 6.2% increasing rate annually; from 2.23 GW in 2016 to 2.28 GW in 2017, 2.42 GW in 2018 and 2.52 GW in 2019. However, in 2020 when Covid-19 pandemic happened, the university had to switch to online study for several months, leading to 11.3% reduction of

[2] Ho Chi Minh City

electricity consumption compared to 2019. This is the reason why we chose 2019 as the base year for this study to reflect the actual image of electricity consumption of the university without the pandemic. Moreover, we can observe that April and October are the two months that have highest electricity consumption since these are the examination months where more students gather at the campus; and August has the lowest electricity consumption since this is the summertime where only several summer classes are held.

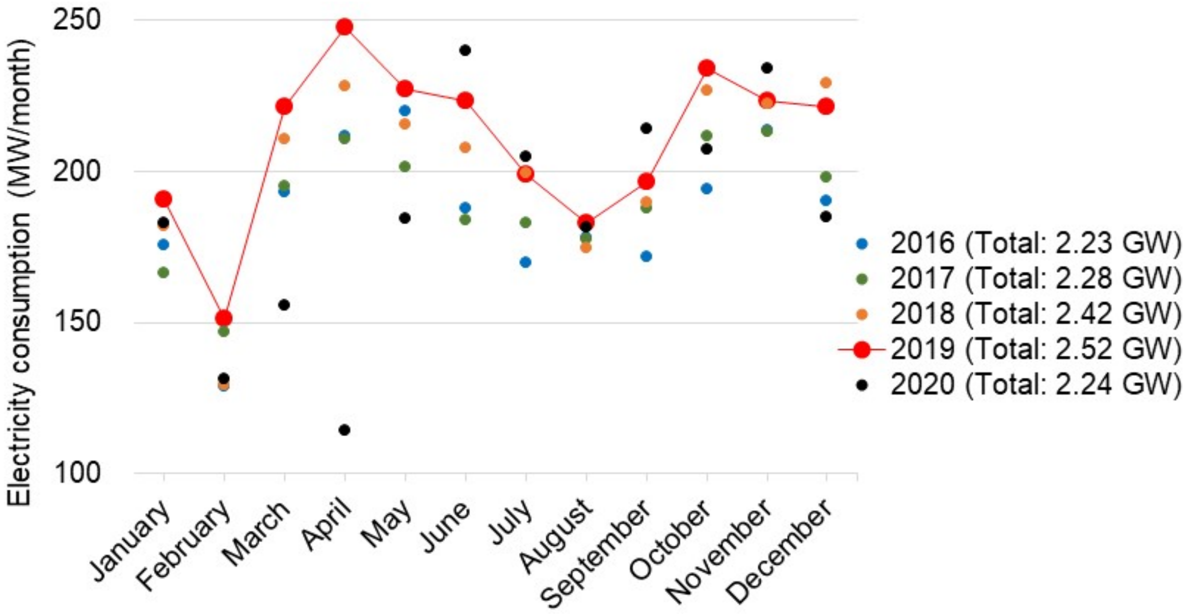

Figure 2. Total Electricity Consumption in IU-VNU

Body

Several methods for analyzing energy consumption in educational campuses are reviewed and compared. A framework is conducted by Koo et al. (2014) to analyze the effect of energy-saving techniques at the current point as well as in different scenarios at the future point for selected educational facilities. However, this study only focuses on three energy-saving techniques for three services: space heating and cooling, lighting, and room electricity. Besides, the optimization process using a genetic algorithm only considers the financial aspects (initial investment cost, net present value, and saving-to-investment ratio). On the other hand, Ascione et al. (2017) study the role of cost-effective refurbishment through a multi-step and multi-objective optimization in calibrated numerical models. This study expands the consideration to not only costs, incentives, indoor comfort, but also energy demands for heating and cooling. However, the proposed methodology is not user-friendly since it requires expertise in building energy modelling as well as in the implementation of the employed optimization algorithms.

In term of GHG mitigation, a more general framework for the assessment of carbon footprints along with overall sustainability in educational campuses is developed by Jain et al. (2017). A broader view is considered based on experts' opinion and literature review in weighting and scoring twenty-four indicators that cover four components of sustainability. The framework is applied for TERI University (New Delhi, India) and show the result on annual emissions per capita. This is important for the comparison with other universities to encourage the emission reduction within the campuses. Nevertheless, the role of technology aspect is not described in detail. In contrast, Ocampo Batlle et al. (2020) developed a method to estimate baseline energy use and quantify savings in electrical energy consumption by taken into account types of activities carried out in the building, weather conditions, building materials, air conditioning system and occupancy. The results on energy savings potential, GHG emission reduction and economic benefit are extensive for a university towards sustainable existence.

AIM/Enduse Model

In this study, we try to bridge the methodological gaps of previous studies and obtain aforementioned results for IU-VNU. AIM/Enduse model (Hanaoka et al. 2015) is used to calculate the level of electricity consumption as well as CO_2 emissions in A1 and A2 buildings if IU-VNU main campus with distinct scenarios: base year 2019, 2030baseline and 2030mitigation scenarios. The difference of two scenarios for 2030 is the share of using technologies, which means that the transfers from conventional to advanced technologies are assumed in IU-VNU buildings in the near future so as to reduce the energy consumption and mitigate the CO_2 emissions.

The AIM/Enduse model, developed by National Institute for Environmental Studies (NIES) in Japan, is an optimization linear programing approach with detailed technology selection framework within an energy-economy-environment system. This is a bottom-up approach considering not only the financial aspects (costs of technologies, energy price, taxes and subsidies) but also technical aspects (service demands, lifetime, share of technology diffusion) as well as market availability of the technology (stock quantity). There are excel files for data input and output as a user-friendly platform instead of running the AIM/Enduse model via General Algebraic Modeling System (GAMS) program.

The main function for cost optimization is shown in Eq.1, followed by various constraints such as service demand (Eq.2), stock dynamics (Eq.3), emission quantity (Eq.4 and Eq.5), energy supply (Eq.6 and Eq.7), and service share (Eq.8 and Eq.9).

Total cost = Initial investment cost ($) + Operating and maintenance cost ($/year) + Energy cost ($/year) + Payment for energy tax ($/year) + Payment for emission tax ($/year) *(Eq.1)*

$$\boldsymbol{D(j) \leq \sum_l A(j,l) * X(l)} \qquad (Eq.2)$$

where:
$D(j)$: Service demand quantity of service type j
$A(j,l)$: Output of service j per unit operation of device l
$X(l)$: Operating quantity of device l

$$\boldsymbol{S(l) = \bar{S}(l) * \left(1 - \frac{1}{T(l)}\right) + r(l) - w(l)} \qquad (Eq.3)$$

where:
$S(l)$: Stock of device l
$\bar{S}(l)$: Stock of device l in the previous year
$T(l)$: Lifetime of device l
$r(l)$: Recruited quantity of device l
$w(l)$: Retired quantity of device l

$$\boldsymbol{Q(m) = \sum_l X(l) * e(l,m)} \qquad (Eq.4)$$

$$\boldsymbol{Q^m(m) \leq \hat{Q}(m)} \quad \textit{(Eq.5)}$$

where:

$Q(m)$: Emission of gas *m*

$e(l, m)$: Emission of gas *m* per unit operation of device *l*

$\hat{Q}(m)$: Maximum limit on emission of gas *m*

$$\boldsymbol{E(k, l) * X(l) \leq \hat{E}^{max(k)}} \quad \textit{(Eq.6)}$$

$$\boldsymbol{E(k, l) * X(l) \geq \hat{E}^{min(k)}} \quad \textit{(Eq.7)}$$

where:

$E(k, l)$: Energy use of energy *k* per operating unit of device *l*

$\hat{E}^{max(k)}$: Maximum supply quantity of energy *k*

$\hat{E}^{min(k)}$: Minimum supply quantity of energy *k*

$$\boldsymbol{\theta^{max}(j, l) * \sum_{l'} A(j, l') * X(l') \geq \sum_{l} A(j, l) * X(l)} \quad \textit{(Eq.8)}$$

$$\boldsymbol{\theta^{min}(j, l) * \sum_{l'} A(j, l') * X(l') \leq \sum_{l} A(j, l) * X(l)} \quad \textit{(Eq.9)}$$

where:

$\theta^{max}(j, l)$: Maximum share of device *l* in service *j*

$\theta^{min}(j, l)$: Minimum share of device *l* in service *j*

Data Collection and Assumptions

Due to the data availability, this study only focuses on electricity audit and electricity related CO_2 inventory and projection. The end-use electricity consumption is necessary to discover the energy savings potential when technological change is implemented. In buildings and facilities, the main electricity consumption services are elevation, lighting, water heating, space cooling, refrigeration, office equipment, laboratory equipment, miscellaneous.

In the current seven-floors A1 and A2 buildings, there are forty-four classrooms, sixty-two administrative offices, sixty laboratories, two libraries, four food courts and one separated canteen that provides services for nearly five hundred staffs and faculties as well as more than nine thousand students. Table 1 shows the current status of facilities and devices in IU-VNU with total electricity consumption capacity.

Facility	Device/Area	Quantity	Unit	Unit capacity (kW)	Total capacity (kW)
Elevation	Elevator	8	elevator	7.5	60.0
Laboratory	Equipment	60	lab.	20.0	1,200.0
Classroom	50-seats	24	room	2.0	48.0
	90-seats	12	room	2.2	26.4
	150-seats	4	room	2.8	11.2
	170-seats	4	room	3.0	12.0
Office room	$30m^2$	30	room	2.5	75.0
	$60m^2$	22	room	4.0	88.0
	$93m^2$	10	room	6.0	60.0
Library	$1,160m^2$	2	room	5.0	10.0
Lobby	Light	1,500	light	0.009	13.5
	Water heater	28	heater	1.0	28.0
Streetlights	Lights	35	light	0.1	3.5

Space cooling	Air conditioner	319	air conditioner	2.4	780.0
Others	Pumps	-	pump	20.0	20.0
Total					2,425.6

Table 1. Number of Facilities and Devices in A1 and A2 Buildings of IU-VNU in 2019.

Based on the total electricity consumption in 2019 (as shown in Figure 2) and the list of electricity service demand (as summarized in Table 1), a breakdown of electricity consumption by service is conducted for IU-VNU and is compared with other university's electricity consumption structure (as shown in Table 2). For universities located in tropical regions, the largest electricity consumer is air conditioning. Therefore, it's necessary to discover the energy savings potential in this service, especially under the context of warming climate that leads to increasing cooling demand.

Service	**Electricity consumption structure (%)**			
	IU-VNU (2019)	**National Autonomous University of Mexico** (Escobedo et al. 2014)	**City University of Hong Kong** (Yeo et al. 2019)	**Universiti Malaya** (Birkha Mohd Ali et al. 2021)
Lighting	0.4	33.6	34.5	18.0
Air conditioning	67.9	4.4	32.3	34.0
Computer equipment	9.4	4.9	-	10.0
Lifting	1.7	-	-	7.0
Refrigeration	-	16.9	-	6.0
Laboratory equipment	19.1	15.2	14.5	18.0
Miscellaneous	1.4	4.1	18.7	7.0
Motors	-	2.3	-	-
Space heating	-	0.4	-	-

Table 2. Electricity Consumption Structure by Services in Educational Buildings

To discover the potential of energy savings and GHG emission mitigation in IU-VNU, three scenarios are developed with different assumptions, especially for the future projections. The 2030baseline scenario measures the level of consumed energy and GHG emissions with the existing technologies and the 2030mitigation scenario with the replacement to advanced technologies in target year 2030. In 2030baseline scenario, there is assumption that the share of electricity-intensive equipment will decrease in 1% -20% of usage, and the electricity-saving devices are assumed to be increased at the same rate. In addition, in 2030mitigation scenario additional replacement of conventional technology will be added with 3-35% more than 2030baseline's level, even with the elimination of some conventional devices. Table 3 summarizes the value of main parameters to be inputted in the AIM/Enduse model for the calculation.

Parameter	Unit	Value			Explanation
		2019	2030 baseline	2030 mitigation	
Emission tax	USD	0	0	50	Only applied for mitigation scenario to consider measures towards emission reduction, for the cost optimization in Eq.1
Energy tax	USD	0	0	50	
Technology discount rate	%	33	33	33	For the annualization of investment cost in Eq.1 (assume average 3-year payback period for technology investment) (high discount rate)
Emission factor	tCO_2eq /toe	5.5	5.2	5.2	Emission factor of electricity generation in 2019 is declared by the Climate change department of Vietnam. In 2030, Vietnam increases the contribution of renewable energies in power generation structure, thus we assume the emission factor will be lower.
Electricity price	1,000 USD/toe	0.51	0.77	0.77	Electricity price in 2019 is based on the actual price (0.08 USD/kWh). In 2030, the price is estimated to increase 1.5 times compared to 2019.
Total electricity service demand	toe	2,571	3,857	3,857	Service demand in 2019 is based on the actual demand. In 2030, the service demand is estimated to increase 1.5 times compared to 2019 to follow the increasing trend.
Device share	%	Based on actual calculation	Reduction of conventional technologies		Total share of devices for each service is 100%. There is increasing share

	of advanced (high-efficient) technologies for the replacement of conventional technologies.

Table 3. Assumptions of Main Parameters in AIM/Enduse Model for IU-VNU

Electricity Consumption

Under the increasing service demand in space cooling, laboratory equipment, office equipment, lighting and others, the electricity demand for these services also increases relatively (as shown in Figure 3). The main electricity consumption services are space cooling, laboratory equipment and office equipment, with the increasing level in 2030 is 1.5 times compared to 2019.

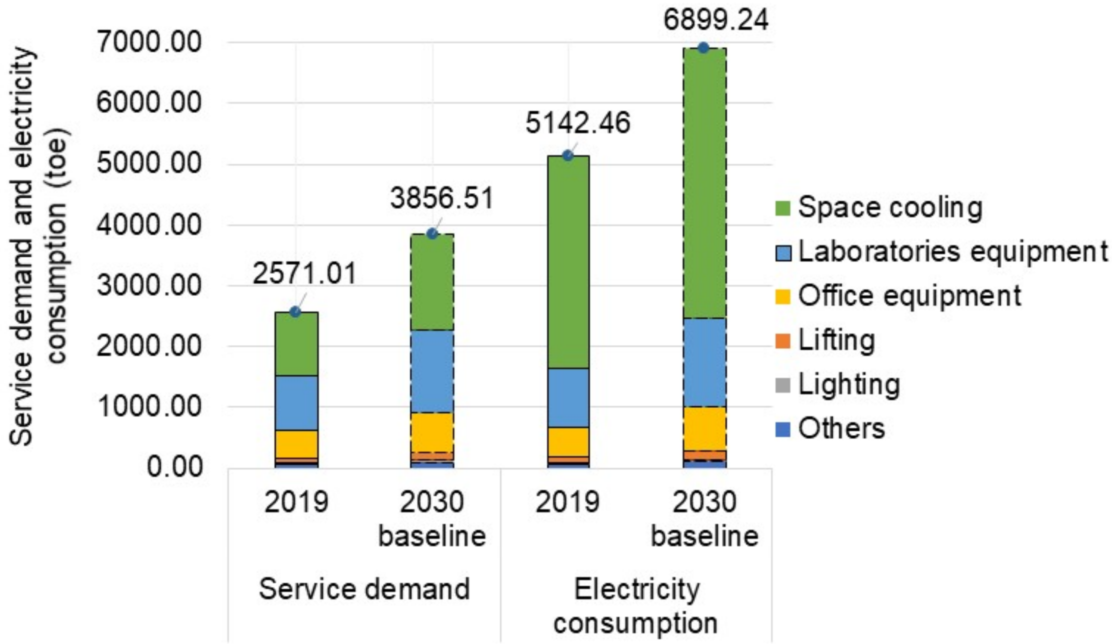

Figure 3. Service Demand and Electricity Consumption

The total electricity consumption in 2019 is 5,142.46 toe with the highest consumption comes from space cooling with 3,493.87 toe (67.9%) and the smallest consumed amount is lighting with 19.83 toe (0.4%). The second and the third highest electricity consumption are laboratory equipment and office equipment with the figures of 984.37 toe and 485.72 toe, respectively. In 2030baseline, the main electricity consumers are still space cooling, laboratory equipment and office equipment with 1.2 – 1.5 times higher than 2019. Under the assumption of device replacement from conventional to advanced technologies, the electricity consumption in 2030mitigation is reduced 13.0% compared to 2030baseline. Detail of electricity consumption by services in different scenarios are described in Table 4.

Service	2019	2030 baseline	2030 mitigation	2030baseline/ 2019	2030mitigation/ 2030baseline
Space cooling	3,493.87	4,426.35	3,523.89	1.27	0.80
Laboratory equipment	984.37	1,476.55	1,476.55	1.50	1.00

Office equipment	485.72	728.58	728.58	1.50	1.00
Lifting	88.15	132.23	132.23	1.50	1.00
Lighting	19.83	29.75	29.75	1.50	1.00
Others	70.52	105.78	105.78	1.50	1.00
Total	**5,142.46**	**6,899.24**	**5,996.78**	**1.34**	**0.87**

Table 4. Electricity Consumption by Service in Three Scenarios (toe)

CO_2 Emissions

Among the services, space cooling is the largest electricity consumer, and thus the biggest emitter compared to other services. Besides, this is the only service that has the potential of electricity savings as well as emission mitigation that contribute to the reduction potential of IU-VNU. With 20% reduction of electricity consumption in space cooling service, it helps to reduce 13% of total electricity consumption in IU-VNU and leads to 13% reduction of CO_2 emissions. Detail of CO_2 emissions by services in different scenarios are presented in Table 5. In which, space cooling is the biggest emitter with 67.94% of total emissions, followed by laboratory equipment and office equipment with 19.14% and 9.45% contribution, respectively. The remaining services (including lifting, lighting and others) contribute 3.47% of total emissions in IU-VNU.

Service	**2019**	**2030 baseline**	**2030 mitigation**	**2030baseline/ 2019**	**2030mitigation/ 2030baseline**
Space cooling	19,151.76	23,017.00	18,324.21	1.20	0.80
Laboratory equipment	5,395.84	7,678.06	7,678.06	1.42	1.00
Office equipment	2,662.48	3,788.61	3,788.61	1.42	1.00
Lifting	483.21	687.59	687.59	1.42	1.00
Lighting	108.72	154.71	154.71	1.42	1.00
Others	386.57	550.07	550.07	1.42	1.00
Total	**28,188.57**	**35,876.03**	**31,183.25**	**1.27**	**0.87**

Table 5. CO_2 Emissions by Service in Three Scenarios (tCO_2eq)

Contribution of Technology Change in the Reduction of Electricity Consumption and Co_2 Emissions

In each service, we assumed that there are conventional and advanced devices available in the stock for the AIM/Enduse model to select. The selection is based on the actual specification of the devices including their lifetime, costs, electricity intensity as well as the assumption of their shares for the contribution to meet the service demand. Generally, in 2030baseline scenario we assumed that the share of electricity-intensive devices will be reduced 1%-20% compared to 2019 as the tendency of replacing end-of-lifetime devices by the new devices that are available on market, in which the new devices will be more energy-efficient than the old ones. Moreover, in 2030mitigation scenario this reduction will be 3%-35% added, assuming that IU-VNU will actively replace old devices that highly consuming electricity with electricity-saving devices even though those old devices are still workable. Under this assumption, there will be some old devices that will be completely eliminated and replaced by newly advanced technology.

Particularly, for space cooling, which is the service that has the highest potential of energy savings as well as CO_2 mitigation, the centralized electricity-intensive 2-piece air conditioners will be replaced by decentralized electricity-saving air conditioners and steam fans with lower electricity consumption. The switch from centralized to decentralized operation will promote the role of end-users in controlling the devices.

Besides, in office equipment, 2030mitigation scenario assumes that IU-VNU uses electricity-saving printers and photocopies whereas continue using several types of electricity-intensive devices. However, the university is planning to establish a central printing and copying room where most of the printing works will be done in this room to increase the effectiveness of this service for the whole university, instead of the current status where administrative and faculty offices have their own devices. Another service where technology change can be implemented is lighting. Currently, the fluorescent lamp consumes more than 50% compared to LED lamps; therefore, the replacement of the fluorescent lamp by LED lamps is necessary to increase the electricity savings potential in this service. In contrast, lifting service may not have technology change since the elevators were installed permanently.

The Role of End-Users in Electricity Saving

From the analysis of technology contribution, we could realize the importance of end-users in reducing the electricity consumption, especially in the services where technology change is difficult to be implemented. Therefore, an online survey was conducted with the targeted group is students at IU-VNU since this is the largest group of electricity users. Nearly five hundred students from different batches answered the questions related to the frequency of using electricity, type of devices, duration and purpose of usage as well as their opinion on the electricity saving actions within the campus.

In student's evaluation on the usage frequency of electrical equipment, air conditioners are the most used equipment with 94.46%, followed by lighting equipment with 87.30% in an average time of using from 2 up to 5 hours per day. Public electricity networks (electrical sockets along the corridor) with 69.28%, laboratory equipment with 23.56%, office and auditorium with 21.71%, which are rarely used in an average usage less than 2 hours. There is difference in the percentage of consumption between student's evaluation and electricity audit. For instance, the laboratories equipment is continuously operated day by day, so in the technology aspect the energy consumption of those equipment is a large amount. However, as the students use the equipment only in their lecture time, the frequency for using laboratory equipment is low in their evaluation.

In general, the use of electrical equipment mainly serves the learning purposes, so the energy consumption of the students' activities are considered to be a reasonable amount. The consumption of laboratories equipment is uncontrollable as the frequency of usage not only in office hours but also during nighttime.

Conclusions

The electricity consumption structure of IU-VNU is analyzed to discover the electricity savings and CO_2 mitigation potential in 2030, especially in space cooling service that consumes electricity the most. The technology transfer from conventional to advanced devices will bring energy efficiency as well as environmental and economic benefits. Under the assumptions in this study, IU-VNU can achieve 13% reduction of electricity consumption as well as CO_2 emissions, that lead to nearly 1.5 billion Vietnam Dong (nearly 70,000 USD) savings annually. This saving money can be used for replacement of conventional to advanced energy-saving devices. Moreover, consumer behavior change, particularly in students, will greatly contribute to the success of electricity saving actions within the campus. Since IU-VNU is constructing a new building (namely A3), the findings in this study will be useful for the selection and installation of devices, especially for air-conditioners and office equipment when A3 building will become administrative building and A1-A2 buildings will be for classrooms and laboratories.

This study remains several limitations due to the lack of information for all electrical devices used in IU-VNU campus (such as at canteen and parking lots). Moreover, the availability of devices in the stock market for 2030 and the share of devices is subjectively assumed. Therefore, In terms of data uncertainty associated to CO_2 emissions, we can refer to the method and reference from IPCC (International Panel on Climate Change 2019), in which the average uncertainty for electricity consumption and related emission factor is 18%.

This study suggests that university should have annual energy audits for all activities within the campus, with the installation of smart meters at various points. Moreover, a record of all electrical devices with detail specification should be kept and updated frequently. In addition, a participatory planning process (integrating end-users such as faculty, staff, and students) should also be implemented to increase consumer's awareness and engagement in reducing energy waste towards sustainable energy-use campus. Since the solar energy is having incentives from the Vietnamese government, it's worth noticing that IU-VNU may install the roof-top solar panels to reduce the electricity dependence on grid power.

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References

Abolarin, S. M., A. O. Gbadegesin, M. B. Shitta, A. Yussuff, C. A. Eguma, L. Ehwerhemuepha, and O. Adegbenro. 2013. "A Collective Approach to Reducing Carbon Dioxide Emission: A Case Study of Four University of Lagos Halls of Residence." *Energy and Buildings* 61:318–22. doi: 10.1016/j.enbuild.2013.02.041.

Ascione, Fabrizio, Nicola Bianco, Rosa Francesca De Masi, Gerardo Maria Mauro, and Giuseppe Peter Vanoli. 2017. "Energy Retrofit of Educational Buildings: Transient Energy Simulations, Model Calibration and Multi-Objective Optimization towards Nearly Zero-Energy Performance." *Energy and Buildings* 144:303–19. doi: 10.1016/j.enbuild.2017.03.056.

Birkha Mohd Ali, Siti, M. Hasanuzzaman, N. A. Rahim, M. A. A. Mamun, and U. H. Obaidellah. 2021. "Analysis of Energy Consumption and Potential Energy Savings of an Institutional Building in Malaysia." *Alexandria Engineering Journal* 60(1):805–20. doi: 10.1016/j.aej.2020.10.010.

Chung, Min Hee, and Eon Ku Rhee. 2014. "Potential Opportunities for Energy Conservation in Existing Buildings on University Campus: A Field Survey in Korea." *Energy and Buildings* 78:176–82. doi: 10.1016/j.enbuild.2014.04.018.

Emeakaroha, Anthony, Chee Siang Ang, Yong Yan, and Tim Hopthrow. 2014. "Integrating Persuasive Technology with Energy Delegates for Energy Conservation and Carbon Emission Reduction in a University Campus." *Energy* 76:357–74. doi: 10.1016/j.energy.2014.08.027.

Escobedo, Azucena, Sonia Briceño, Héctor Juárez, Daniel Castillo, Mireya Imaz, and Claudia Sheinbaum. 2014. "Energy Consumption and GHG Emission Scenarios of a University Campus in Mexico." *Energy for Sustainable Development* 18:49–57. doi: 10.1016/j.esd.2013.10.005.

Gorgulu, Sertac, and Sureyya Kocabey. 2020. "An Energy Saving Potential Analysis of Lighting Retrofit Scenarios in Outdoor Lighting Systems: A Case Study for a University Campus." *Journal of Cleaner Production* 260:121060. doi: 10.1016/j.jclepro.2020.121060.

Hanaoka, Tatsuya, Toshihiko Masui, Yuzuru Matsuoka, Go Hibino, Kazuya Fujiwara, Yuko Motoki, and Ken Oshiro. 2015. *AIM Enduse Model Manual*. National Institute for Environmental Studies.

International Panel on Climate Change. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Chapter 3: Uncertainties*. IPCC.

Jain, Suresh, Archit Agarwal, Viveka Jani, Shaleen Singhal, Prateek Sharma, and Ramesh Jalan. 2017. "Assessment of Carbon Neutrality and Sustainability in Educational Campuses (CaNSEC): A General Framework." *Ecological Indicators* 76:131–43. doi: 10.1016/j.ecolind.2017.01.012.

Kolokotsa, Dionysia, Junjing Yang, and Lee Siew Eang. 2018. “5.20 Energy Management in University Campuses.” Pp. 808–26 in *Comprehensive Energy Systems*. Elsevier.

Koo, Choongwan, Hyunjoong Kim, and Taehoon Hong. 2014. “Framework for the Analysis of the Low-Carbon Scenario 2020 to Achieve the National Carbon Emissions Reduction Target: Focused on Educational Facilities.” *Energy Policy* 73:356–67. doi: 10.1016/j.enpol.2014.05.009.

Liu, Qibo, and Juan Ren. 2020. “Research on the Building Energy Efficiency Design Strategy of Chinese Universities Based on Green Performance Analysis.” *Energy and Buildings* 224:110242. doi: 10.1016/j.enbuild.2020.110242.

Mohammadalizadehkorde, Milad, and Russell Weaver. 2020. “Quantifying Potential Savings from Sustainable Energy Projects at a Large Public University: An Energy Efficiency Assessment for Texas State University.” *Sustainable Energy Technologies and Assessments* 37:100570. doi: 10.1016/j.seta.2019.100570.

Mytafides, Christos K., Argiro Dimoudi, and Stamatis Zoras. 2017. “Transformation of a University Building into a Zero Energy Building in Mediterranean Climate.” *Energy and Buildings* 155:98–114. doi: 10.1016/j.enbuild.2017.07.083.

Ocampo Batlle, Eric Alberto, José Carlos Escobar Palacio, Electo Eduardo Silva Lora, Arnaldo Martín Martínez Reyes, Maurish Melian Moreno, and Milen Balbis Morejón. 2020. “A Methodology to Estimate Baseline Energy Use and Quantify Savings in Electrical Energy Consumption in Higher Education Institution Buildings: Case Study, Federal University of Itajubá (UNIFEI).” *Journal of Cleaner Production* 244:118551. doi: 10.1016/j.jclepro.2019.118551.

Olivieri, Lorenzo, Estefanía Caamaño-Martín, Louise-Nour Sassenou, and Francesca Olivieri. 2020. “Contribution of Photovoltaic Distributed Generation to the Transition towards an Emission-Free Supply to University Campus: Technical, Economic Feasibility and Carbon Emission Reduction at the Universidad Politécnica de Madrid.” *Renewable Energy* 162:1703–14. doi: 10.1016/j.renene.2020.09.120.

Park, Hyo Seon, Kwangbok Jeong, Taehoon Hong, Cheolwoo Ban, Choongwan Koo, and Jimin Kim. 2016. “The Optimal Photovoltaic System Implementation Strategy to Achieve the National Carbon Emissions Reduction Target in 2030: Focused on Educational Facilities.” *Energy and Buildings* 119:101–10. doi: 10.1016/j.enbuild.2016.03.029.

Semprini, Giovanni, Cosimo Marinosci, Annarita Ferrante, Giorgia Predari, Giovanni Mochi, Massimo Garai, and Riccardo Gulli. 2016. “Energy Management in Public Institutional and Educational Buildings: The Case of the School of Engineering and Architecture in Bologna.” *Energy and Buildings* 126:365–74. doi: 10.1016/j.enbuild.2016.05.009.

Shea, Ryan P., Kelly Kissock, and Abinesh Selvacanabady. 2019. “Reducing University Air Handling Unit Energy Usage through Controls-Based Energy Efficiency Measures.” *Energy and Buildings* 194:105–12. doi: 10.1016/j.enbuild.2019.04.020.

Stefano, Julian Di. 2000. “Energy Efficiency and the Environment: The Potential for Energy Efficient Lighting to Save Energy and Reduce Carbon Dioxide Emissions at Melbourne University, Australia.” *Energy* 25:823–39. doi: 0360-5442/00/$.

Vásquez, Leonardo, Alfredo Iriarte, María Almeida, and Pablo Villalobos. 2015. “Evaluation of Greenhouse Gas Emissions and Proposals for Their Reduction at a University Campus in Chile.” *Journal of Cleaner Production* 108:924–30. doi: 10.1016/j.jclepro.2015.06.073.

Yeo, Joonho, Ye Wang, Alicia Kyoungjin An, and Lin Zhang. 2019. “Estimation of Energy Efficiency for Educational Buildings in Hong Kong.” *Journal of Cleaner Production* 235:453–60. doi: 10.1016/j.jclepro.2019.06.339.

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