DÜZCE ÜNİVERSİTESİ | LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

BUILDING INFORMATION MODELLING INTEGRATED ENERGY SIMULATION TOOLS IN GREEN CAMPUS INITIATIVES: DUZCE UNIVERSITY CAMPUS

RUMEYSA ERYAMAN

MASTER THESIS
MASTER OF SCIENCE IN ARCHITECTURE

SUPERVISOR
ASST. PROF. NURAY BENLI YILDIZ

DUZCE, 2023

T.C.
DUZCE UNIVERSITY
GRADUATE EDUCATION INSTITUTE

BUILDING INFORMATION MODELLING INTEGRATED ENERGY SIMULATION TOOLS IN GREEN CAMPUS INITIATIVES: DUZCE UNIVERSITY CAMPUS

Submitted by RUMEYSA ERYAMAN in partial fulfillment of the requirements for the degree of Master of Science in Architecture Department, Duzce University by,

Thesis Supevisor

Asst. Prof. Nuray Benli Yıldız
Duzce University ______________________

Examining Committee Members

Asst. Prof. Nuray Benli Yıldız
Duzce University ______________________

Prof. Dr. ……….
Duzce University ______________________

Prof. Dr. ……….
Duzce University ______________________

Prof. Dr. ………
Duzce University ______________________

Prof. Dr. ……….
Duzce University ______________________

Date: 13/07/2023

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

13 July 2023
Name: Rumeysa
Last name: Eryaman
Signature:

To My Family

ACKNOWLEDGMENTS

I would like to thank my supervisor, Asst. Prof. Nuray Benli Yıldız, for her valuable support, encouragement, guidance and understanding throughout my master's thesis.

I would like to express my sincere thanks and love to my dear mother Rabia Eryaman, my dear father Metin Eryaman and my dear sisters and brother Firdevs Eryaman Utku, Feyza Eryaman Unlu and Yusuf Eryaman, who have always been by my side and supported me financially and morally, who trusted and believed and offered their love.

I would also like to thank my friends Ruveyda Nur Ocal and Hicran Birgul for their friendship, understanding, positive energy and valuable support throughout my work.

This study was supported by Duzce University Scientific Research Project (BAP) numbered BAP-2022.09.04.1324.

13 July 2023 **Rumeysa Eryaman**

TABLE OF CONTENTS

FIGURE LIST

Page No

TABLE LIST

Page No

ABBREVIATIONS

AASHE	Association for Advancement of Sustainability in Higher Education
AEC	Architecture, Engineering and Construction
AR	Augmented Reality
ARDEB	Research Funding Program Directorate
ATES	Aquifer Thermal Energy Storage
BAP	Scientific Research Projects
BHF	British Heart Foundation
BIM	Building Information Modelling
BREEAM	Building Research Establishment's Environmental Assessment Method
CAD	Computer-Aided Design
CEDBIK	Environmentally Friendly Green Building Monitoring and Evaluation System
CfE	Centre for the Environment
CIU	Cyprus International University
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
DAGEM	Beekeeping Research, Development and Application Center
DOE	Department of Energy
DUBAP	Duzce University Scientific Research Projects
EC	Energy and Climate Change
ECMs	Energy Conservation Measures
ED	Education
EEPBP	Energy Efficiency in Public Buildings Project
EPC	Energy Performance Certificate
ERU	Erciyes University
EU	European Union

GBC	Green Building Certifications
GIS	Geographic Information Systems
HFC	Hedgehog Friendly Campus
HVAC	Heating, Ventilating and Air Conditioning
IEQ	Indoor Environmental Quality
IES VE	Integrated Environmental Solutions Virtual Environment
ILO	Integrated Lights Out
IoT	Internet of Things
ISCN	The International Sustainable Campus Network
ISKI	Istanbul Water and Sewerage Administration
ITU	Istanbul Technical University
ITU CEC	Istanbul Technical University Continuing Education Center
LCA	Life Cycle Assessment
LEAF	Laboratory Efficiency Assessment Framework
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LTG	Lighting Systems
MSMB	Architect Sinan Engineers Association
NU	University of Nottingham
NTU	Nottingham Trent University
nZEB	Zero Carbon Emission Building Systems
PV	Photovoltaic
RE	Renewable Energy
RTF	Retrofit Analysis
SC	Sustainable and Smart Cities
SDGs	Sustainable Development Goals

SDSN	Sustainable Development Solutions Network
SEEB-TR	Sustainable Energy and Environmentally Friendly Buildings Turkey
SI	Structure and Infrastructure
TGBC	Turkey Green Building Council
TR	Transportation
TSWG	Technical Sustainability Working Group
TUBITAK	Scientific and Technical Research Council of Turkey
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UN SDSN	United Nations Sustainable Development Solutions Network
UN Women	United Nations Women
WEEE	Waste Electrical and Electronic Equipment
WP	Wind Power
WR	Water Systems
WS	Waste Management
WU	Wageningen University & Research
VR	Virtual Reality

ÖZET

YAPI BİLGİ MODELLEMESİ ENTEGRELİ ENERJİ SİMÜLASYON ARAÇLARININ YEŞİL KAMPÜS GİRİŞİMLERİNDE KULLANIMI: DÜZCE ÜNİVERSİTESİ KAMPÜSÜ

Rumeysa Eryaman

Düzce Üniversitesi

Lisansüstü Eğitim Enstitüsü, Mimarlık Anabilim Dalı

Yüksek Lisans Tezi

Danışman: Dr. Öğr. Üyesi Nuray Benli Yıldız

Temmuz 2023, 135 sayfa

Günümüzde giderek artan çevre sorunları, sürdürülebilirliğe ilişkin kaygıları artırmış ve ekonomik kalkınma tartışmaları için yeni bir gündem oluşturmuştur. Bu çerçevede ortaya koyulan çözüm, doğal kaynakların tamamen tüketilmeden, gelecek nesillere de aktarılmasının sağlanması olarak özetlenebilecek olan ‘’Sürdürülebilir Kalkınma’’ anlayışı olmuştur. Çevresel, ekonomik ve sosyal alanlarda olmak üzere çok geniş bir kapsamı olan sürdürülebilir kalkınmanın küçük kent ölçeğindeki üniversite kampüslerinde tanımlanışı ‘’Yeşil Kampüs’’ kavramı şeklinde olmuştur. Bu bağlamda, 2010 yılında Endonezya Üniversitesi tarafından yeşil kampüs uygulamaları için değerlendirme ölçüsünü belirleyen ‘’UI GreenMetric Endeksi’’ geliştirilmiştir. Bu çalışmanın temel amacı, UI GreenMetric çerçevesinde Düzce Üniversitesi Kampüsünün daha sürdürülebilir olması için öneriler oluşturmak ve YBMveri tabanlı enerji simülasyon araçlarının yeşil kampüs girişimlerinde kullanımını incelemektir. Çalışmada, Düzce Üniversitesi kampüsüne oluşturulacak öneriler için UIGreenMetric Endeksinde derece yapmış yeşil kampüsler her bir kategori doğrultusunda incelenmiştir. Ayrıca, UI GreenMetric Endeksinde belirlenen enerji ve iklim değişikliği kategorisi doğrultusunda akıllı bina olarak tasarlanan Düzce Üniversitesi Kampüs binası için YBM veri tabanlı Ecodesigner Star enerji simülasyon aracı kullanarak enerji tüketimi, sera gazı emisyonu, yenilenebilir enerji kaynakları, akıllı bina uygulamaları ve yeşil bina uygulamalarının temeli olan CO_2 emisyonuüzerine alan çalışması yapılmıştır. Alan çalışmasında, akıllı bina olarak tasarlanan kampüs binasındaki dış cephe kaplama malzemesinin CO_2 emisyonuna etkisi incelenmiştir.Çalışma sonucunda, incelenen örnek kampüsler doğrultusunda yapı ve altyapı, enerji ve iklim, atık yönetimi, su yönetimi, ulaşım ve eğitim kategorileri çerçevesinde öneriler oluşturulmuştur. Buna ek olarak enerji ve iklim kategorisi için yapılan alan çalışmasında mineral yün yalıtımlı dış cephe kaplaması ile binanın ısıtma ve soğutma enerjisinin düştüğü ve CO_2 emisyonunun 17.854 kg/yıl miktarı ile %3 oranında azaldığı bundan kaynaklı maliyet tasarrufunun2023 yılında yıllık yaklaşık 100.000 TRY/yıl'a ulaştığı gözlemlenmiştir. Bu nedenle çalışma Düzce Üniversitesi kampüsünün UI GreenMetric Endeksi kapsamında daha yeşil bir kampüs olması açısından önem taşımakla beraber kampüslerin daha sürdürülebilir olması sürecine de örnek teşkil etmektedir.

Anahtar Kelimeler: *Sürdürülebilir bina sistemleri, Enerji simülasyon araçları, Yapı bilgi modellemesi (YBM), Sera gazı emisyonu ve karbon ayak izi (CO_2) , Yeşil kampüs uygulamaları.*

ABSTRACT

BUILDING INFORMATION MODELLING INTEGRATED ENERGY SIMULATION TOOLS IN GREEN CAMPUS INITIATIVES: DUZCE UNIVERSITY CAMPUS

Rumeysa Eryaman

Duzce University

Graduate School, Department of Architecture

Master Thesis

Supervisor: Asst. Prof. Nuray Benli Yıldız

July 2023, 135 pages

Todays, increasing environmental problems have increased concerns about sustainability and created a new agenda for economic development discussions. The solution put forward in this framework has been the concept of "Sustainable Development", which can be summarized as ensuring the transfer of natural resources to future generations without being completely consumed. The definition of sustainable development, which has a wide scope in environmental, economic and social areas, in small city scale university campuses has been the concept of "Green Campus". In this context, the "UI GreenMetric Index", which determines the evaluation measure for green campus applications, was developed by the Universitas Indonesia (UI) in 2010.The main purpose of this study is to create suggestions for making the Duzce University Campus more sustainable within the framework of UI GreenMetric, and to examine the use of BIM data-based energy simulation tools in green campus initiatives. In the study, green campuses with degrees in the UI GreenMetric Index were examined in line with each category for suggestions to be made for Duzce University Campus. In addition, the Duzce University Campus building, which was designed as a smart building, in line with the energy and climate change category in the UI GreenMetric Index, fieldwork was conducted on CO_2 emissions, which form the basis of energy consumption, greenhouse gas emissions, renewable energy sources, smart building and green building applications by using BIM data-based Ecodesigner Star energy simulation tool. The field study investigated the effect of the exterior cladding material used in the campus building on CO_2 emission. As a result of the study, suggestions were made within the framework of the setting and infrastructure, energy and climate, waste management, water management, transportation and education categories in line with the sample campuses examined. In addition, in the field study conducted for the energy and climate category, it was observed that with the mineral wool insulation exterior cladding, the heating and cooling energy of the building has dropped, and CO_2 emissions decreased by 3% with the amount of 17,854 kg/a that's why cost savings of approximately 100,000 TRY/a was achieved as an annual in 2023.For this reason, the study is important in terms of making the Duzce University campus a greener campus within the scope of the UI GreenMetric Index, in addition sets an example for the process of making the campuses more sustainable.

Keywords: *Sustainable building systems, Energy simulation tools, Building information modelling (BIM), Greenhouse gas emission and carbon footprint (CO_2), Green campus applications.*

GENİŞLETİLMİŞ ÖZET

YAPI BİLGİ MODELLEMESİ ENTEGRELİ ENERJİ SİMÜLASYON ARAÇLARININ YEŞİL KAMPÜS GİRİŞİMLERİNDE KULLANIMI: DÜZCE ÜNİVERSİTESİ KAMPÜSÜ

Rumeysa Eryaman
Düzce Üniversitesi
Lisansüstü Eğitim Enstitüsü, Mimarlık Anabilim Dalı
Yüksek Lisans Tezi
Danışman: Dr. Öğr. Üyesi Nuray Benli Yıldız
Temmuz 2023, 135 sayfa

1. ÇALIŞMANIN AMACI

Günümüzde giderek artan çevre sorunları ve sürdürülebilirliğe ilişkin kaygıların artmasıekonomik kalkınma tartışmaları için yeni bir gündem oluşturmuştur. Bu çerçevede ortaya koyulan çözüm sürdürülebilir kalkınma anlayışı olmuştur. Sürdürülebilir kalkınmanın küçük kent ölçeğindeki üniversite kampüslerinde tanımlanışı ‘’yeşil kampüs’’ kavramı şeklinde olmuştur. Bu bağlamda, 2010 yılında Endonezya Üniversitesi tarafından yeşil kampüs uygulamaları için değerlendirme ölçüsünü belirleyen ‘’UI GreenMetric Endeksi’’ geliştirilmiştir. Bu çalışmanın temel amacı, Düzce Üniversitesi kampüsünün UI GreenMetric çerçevesinde daha sürdürülebilir olması için öneriler oluşturmaktır. Ayrıca, UI GreenMetric Endeksinde belirlenen enerji ve iklim değişikliği kategorisi doğrultusunda akıllı bina olarak tasarlanan Düzce Üniversitesi kampüs binası için YBM (Yapı Bilgi Modellemesi)veri tabanlı Ecodesigner Star enerji simülasyon aracı ile CO_2 emisyonu üzerine alan çalışmasıyapılarak, YBM entegreli enerji simülasyon araçlarının yeşil kampüs girişimlerinde kullanımını incelemektir.

2. LİTERATÜR ARAŞTIRMASI

Araştırma kapsamında, yeşil kampüslerin değerlendirildiği UI GreenMetric Endeksi ve bu endekste derece yapmış uluslararası sıralamada ve Türkiye’deki ulusal sıralamada ilk üçteki üniversiteler araştırılmıştır. Ayrıca UI GreenMetric Endeksinin enerji ve iklim kategorisi (EC) doğrultusunda akıllı bina olarak tasarlanan Düzce Üniversitesi Binası için alan çalışması yapılacağından akıllı binayıda içinde bulunduran sürdürülebilir bina sistemleri incelenmiştir. Alan çalışmasında kullanılacak ve tezin temel amacı arasında bulunan YBM entegreli enerji simülasyon araçlarının kullanımı için yaygın olarak kullanılan enerji simülasyon araçları ve YBM veri tabanı araştırılmıştır. Özellikle, çalışmada kullanılan YBM veri tabanlı Archicad programının EcoDesigner Star enerji simülasyon aracı incelenmiştir.

3. YÖNTEM

Çalışmada, Düzce Üniversitesi kampüsüne oluşturulacak öneriler için UIGreenMetric Endeksinde derece yapmış yeşil kampüsler her bir kategori doğrultusunda incelenmiş ve karşılaştırmalı tablo oluşturulmuştur. Ayrıca, UIGreenMetric Endeksinde belirlenen enerji ve iklim değişikliği kategorisi (EC) doğrultusunda akıllı bina olarak tasarlanan Düzce Üniversitesi kampüs binası için YBM veri tabanlı Archicad programının EcoDesigner Star enerji simülasyon aracı kullanarak enerji tüketimi, sera gazı emisyonu, yenilenebilir enerji kaynakları, akıllı bina uygulamaları ve yeşil bina uygulamalarının temeli olan CO_2 emisyonu üzerine alan çalışması yapılmıştır. Alan çalışmasında, kampüs binasında kullanılan dış cephe kaplama malzemesinin CO_2 emisyonuna etkisi incelenmiştir. İncelenen binada kullanılan mineral yünlükompozit dış cephe kaplama malzemesi Archicadprogramındaki goodies-aksesuar eklentisi ile binaya tanımlanmıştır. Malzemenin tanımlandığı ve tanımlanmadığı bina modeli EcoDesigner Star aracı ile simüle edilmiştir. Elde edilen simülasyon sonuçları ile CO_2 emisyonu, enerji tüketimi ve maliyet miktarları karşılaştırılmıştır. Böylece büyük ölçekli yapılarda dış cephe kaplama malzemesinin seçimi değerlendirilmiştir.

4. BULGULAR

Çalışma sonucunda, incelenen örnek kampüsler doğrultusunda Düzce Üniversitesi kampüsü için yapı ve altyapı (SI), enerji ve iklim (EC), atık yönetimi (WS), su yönetimi (WR), ulaşım (TR) ve eğitim (ED) kategorileri çerçevesinde öneriler oluşturulmuştur.Her bir kategori için, Düzce Üniversitesi kampüsünün mevcut durumunu ve oluşturulan önerileri içeren tablo oluşturulmuştur. Buna ek olarak, enerji ve iklim kategorisi için yapılan alan çalışmasında dış cephe kaplaması ile yıllık CO_2 emisyonunun 17,854 kg/a miktarında %3 oranında azaldığı ve 2023 yılında yıllık yaklaşık 100.000 TRY/a değerinde tasarruf sağlandığı gözlemlenmiştir.

5. SONUÇ VE DEĞERLENDİRME

Sonuç olarak, artan çevre sorunlarının çözümü için sürdürülebilirliğin temeli olan CO_2 emisyonlarının azaltılmasına yönelik çalışmalar yapılmalıdır. Bu bağlamda, Mimarlık, Mühendislik ve İnşaat sektöründe sürdürülebilir bina sistemlerinin yanı sıra, doğal, yeniden kullanılabilir malzeme seçimini artırmak, esnek, minimalist tasarımlar sağlamak ve büyük ölçekli tasarım alanlarında bina kullanımı için zaman yönetimi ile enerji tüketimini azaltmak için çaba gösterilmelidir. Sürdürülebilir çalışmalar arasında yer alan UI GreenMetric Endeksi, büyük ölçekli üniversitelerin sürdürülebilirliği için önemli bir çalışmadır. Düzce Üniversitesi bu bağlamda kendini geliştirmelidir. Ayrıca UI GreenMetric Endeksinin gelişmesi içinde düzenlemeler yapılmalıdır. Endekste sadece sonuç odaklı puanlama yerine tüm sürdürülebilir iş adımlarını puanlama gibi iyileştirmeler yapılarak daha kapsamlı bir teşvik sağlanılabilir. Örneğin, yeşil bina sertifikalarının varlığını puanlamak yerine, binadaki CO_2 emisyonlarını azaltmak için tüm adımları puanlayabilir. Ayrıca, değerlendirme sürecinde iklim tipi seçimi önemli olduğu için, UI GreenMetric Endeksindeki iklim tipi seçenekleri ile kısıtlayıcı olmak yerine, değerlendirilen üniversitelerin iklimini detaylandıran bir düzenleme yapılabilir. Buna ek olarak, Türkiye'deki yeşil bina sertifikaları ve bu alana odaklanan diğer çalışmalar yeşil kampüs değerlendirme sürecine teşvik edilebilir.

Gelecekteki çalışmalar, farklı sınır koşulları ile farklı alan çalışmaları yaparak bu çalışmaya katkı sağlayabilir. UI GreenMetric Endeksinde değerlendirilen diğer üniversiteler araştırılabilir ve üniversitelerin daha yeşil bir kampüse sahip olması için önerilerde bulunulabilir. Bu sayede, UI GreenMetic Endeksindeki eksiklikler tespit edilerek endeks de geliştirilebilir. Ayrıca, farklı alan çalışmaları ile farklı malzemelerin enerji tüketimini, CO_2 emisyonunu ve maliyeti nasıl etkilediği belirlenebilir. Böylece büyük ölçekli yapıların erken tasarım aşamasında malzeme seçimi için örnekler oluşturulabilir.

1. INTRODUCTION

Rapid population growth has become a significant concern globally over the past three decades (UNFPA, 2023). Population growth has increased the demand for limited natural energy resources. In line with this demand, environmental problems such as global warming, decrease in biodiversity, water scarcity, decrease in water quantity and quality, decrease in green areas, air pollution caused by automobile use and increase in health problems have emerged. According to the 2023 Sustainable Development Report, it is stated that climate change is still happening much faster than expected, and 2019 was the second warmest year on record. Meanwhile, ocean acidification is accelerating, land degradation continues, many species are threatened with extinction, and unsustainable consumption and production patterns remain prevalent (UNEP, 2022). In addition, the world's dependence on natural resources has continued to accelerate in the last two years (SDSN, 2023). The COVID-19 pandemic has created a setback for sustainable development everywhere. The pandemic has threatened decades of development gains and delayed the transition to greener, more inclusive economies. In addition to the pandemic, global challenges, including climate change and the biodiversity crisis, are causing the emergence of other zoonotic diseases and pathogens. Climate change is already on a sharp rise, leading to droughts, typhoons, rising sea levels and natural disasters such as heat waves(Sustainable Development Solutions Network, 2023). Along with all these environmental problems, the economic, social and environmental crises, the three dimensions of sustainable development, have made the Sustainable Development Goals (SDGs) more important.(UN Secretary-General António Guterres, 2023). According to the SDG index in the most recently published Sustainable Development Report, Turkey ranked 71st among 163 countries with 70.4 points (SDG-Turkey, 2022). In this context, studies must be carried out to increase sustainable development in Turkey. Higher Education Institutions, like small cities with their large population and many works and activities, are of great importance for sustainable studies (Deleye, 2023). The sustainability of universities ensures that the adverse effects of environmental, social and economic aspects are minimized while carrying out their activities and that they lead society in a sustainable way of life (The International Sustainable Campus Network - ISCN, 2023). This importance of Green Campuses for sustainable development necessitated studies on the sustainability of the campuses. One of these studies, The UI GreenMetric Index, implemented by the Indonesian University (UI) in 2010, evaluates campus sustainability studies (UNEP - UN Environment

Programme, 2023). UI GreenMetric Index evaluates campuses in categories consisting of six main headings. These categories are(UI GreenMetric World University Rankings, 2022):

1. Structure and Infrastructure (SI),
2. Energy and Climate Change (EC),
3. Waste Management (WS),
4. Water Systems (WR),
5. Transportation (TR),
6. Education (ED).

The *SI* includes green areas, initiatives for animals, healthy food, biodiversity, social equality, health and wellbeing programme, operation and maintenance activities, ecosystem services and stakeholder interaction topics. The *EC* includes using renewable energy, PV systems, wind turbines, HVAC systems, green building systems, CO_2 emissions, reduced water consumption, rainwater harvesting, green roof and LED lighting. The *WS* includes organic, paper, metal and plastics waste collection activities, recycling bins placement, waste reduction activities, sewage disposal, stakeholder interaction and education for waste management topics. The *WR* includes using superlab taps or aerators taps, purification of rainwater and grey water, reduction of water consumption, use of rainwater harvesting, drinking water service, drip irrigation, water extraction, water pollution control, and stakeholder interaction. The *TR* includes using bicycles, electric scooters, electric vehicles and public transport, a parking area plan, a pedestrian path, decrease private cars, a car-sharing network, a travel plan programme, and disabled access. The *ED* includes existing annual Sustainability Reports, sustainability organisational units, sustainability workshops, seminars, training, courses and events, green awards platforms, sustainability publications, sustainability offices, scholarships, sustainability websites, research centres and labs. In addition, while evaluating Universities according to these categories, since the climate data of each region will be different, the climate type is selected from the different options Köppen-Geiger climate classification in the UI GreenMetric Index.

The energy and climate change category, which has the highest impact percentage, consists of ten criteria. These criteria are (UI GreenMetric World University Rankings, 2022):

- Energy efficient appliances usage,
- Smart building implementation,
- Number of renewable energy sources on campus.
- Total electricity usage divided by total campus' population (kWh per person),
- The ratio of renewable energy production divided by total energy usage per year,
- Elements of green building implementation as reflected in all construction and renovation policies,
- Greenhouse gas emission reduction program,
- Total carbon footprint divided by total campus' population (metric tons per person),
- Number of innovative program(s) during covid-19 pandemic,
- Impactful university program(s) on climate change.

The Energy and Climate Change (EC) category,that includes sustainable building systems, focus on CO_2 emissions. The common goals of sustainable building systems and green campus practices include reducing CO_2 emissions. Among its applications, smart buildings are also designed to reduce CO_2 emissions. Smart building technology and materials are closely linked as they work together to improve the energy efficiency, sustainability and functionality of buildings. Smart building applications and material selection serve the common purpose of reducing CO_2 emissions and increasing the energy performance of the building. Therefore, they should be evaluated together.

It is inevitable to make energy simulations for these. Integrating energy simulations with Building Information Modelling (BIM), which can be actively used in all steps from the planning and design phase of the architectural project to the construction and finalization, creates an advantage for environmentalist designs as the construction teams keep in touch with each other and provide information flow between different levels. BIM can also provide cost control with its quantity calculation feature for the economy, which is one reason that prevents ecological designs. Integrating BIM and energy simulation software helps measure energy performance at the early design phase and realizes targeted design decisions. Significantly, this integration allows for combining energy simulation with the benefits of BIM.

In the study, by using BIM data-based energy simulation tool, in line with the energy and climate change category of the UI GreenMetric Index, a fieldwork was conducted on material selection for energy consumption, carbon footprint and cost analysis in the Duzce University campus building, which was designed as a smart building. In addition, in line with the campuses examined that top in the UI GreenMetric Index, suggestions were made within the framework of all categories.

2. LITERATURE REVIEW

2.1. SUSTAINABLE UNIVERSITIES

Sustainable development, according to the Brundtland Report, defines a type of development which is capable of providing for today's needs and in doing so does not jeopardize tomorrow's ability to meet their own needs (SDSN, 2023). Ensuring that the Earth's water, materials and other resources are sufficient for living systems is thus of paramount importance. It also means that the necessary balance of economic, social and environmental factors must be taken into account in any development. Sustainability has become one of the most important problems for governments, businesses and organisations since Brundtland's report was published (UNEP, 2022).Since 1990, universities have taken various initiatives related to sustainability, formed associations and societies, and signed declarations and conditions. These declarations and conditions are illustrated in **Figure 2.1.** Today, more than 1400 universities have signed these declarations. Considering that the number of universities in the world is 14000, although this number is low, it is seen that awareness about sustainability is increasing. Moreover, this awareness occurs not only in a region or country but also in all parts of the world, such as Europe, America, Canada, Australia, Asia and Africa (Grindsted, 2015)(Bilgili, 2021).

Year	Declaration
1990	*The Talloires Declaration (ULSF, 1990)*
1991	*The Halifax Declaration (See Lester Pearson institute for international development, 1992)*
1993	*The Kyoto Declarations (UNESCO, 1993)*
1993	*The Swansea Declaration (UNESCO, 1993)*
1994	*The CRE Copernicus Charter (CRE-Copernicus, 1994)*
1997	*Thessaloniki Declaration (UNESCO, 1997)*
2001	*Luneburg Declaration (UNESCO, 2001)*
2005	*The Graz Declaration (Oikos, Copernicus, TUG, 2005)*
2009	*The Bonn Declaration (UNESCO, 2009)*
2009	*The Turin Declaration (G8, 2009)*

Figure 2. 1. Declarations-conditions signed by universities (Sylvestre et al., 2013).

Today, sustainability is increasingly prioritized in higher education institutions (M. Report, 2023). Increasing scientific communities and institutions are actively involved in increasing the value of both students and higher education institutions to transcend the social, environmental and economic aspects (Y. Chen, Anthony, et al., 2023).

2.1.1. Green Campuses

Through its academic programmes, research, campus life and physical functioning, a green campus demonstrates its commitment to environmental sustainability. The concept of campus greening is an effort to create environmentally sustainable practices in educational establishments around the world. It applies sustainability principles at all corporate levels in order to reduce the impact of environmental footprints (Sahoo, 2016)(The Times of India, 2023).

By helping reduce carbon emissions contributing to global climate change, the Green Campus is an enduring commitment to enhance campus community and environment. To increase and broaden energy efficiency initiatives on campus, is the first action that will be taken in favour of a Green Campus. For this reason, it is crucial to make use of energy saving techniques for the conduct of campus activities. By creating a healthy environment, the campus can produce maximum learning and a supportive learning environment for students. Collaboration is required for the campus community, starting with students, faculty, non-teaching staff, local businesses, and visitors to create a healthy environment (Sadono et al., 2021)(Matana Júnior et al., 2023).

Green Campus Initiatives for Sustainability can be listed as follows (Novieto et al., 2023):

- Teaching-Learning applications,
- Designing the curriculum for greening management,
- Organizing seminars and workshops,
- Reducing the use of plastic materials on the campus,
- Effective use of technology,
- Reducing the use of vehicles,
- Training employees,
- Integration of different areas.

The Benefits of the Green Campus can be listed as 9 items (Sahoo, 2016)(Stein, 2023):

1. Reduced maintenance costs,
2. Efficiency gains for campus residents,
3. Carbon Neutral environment,
4. Uninterrupted clean power supply,
5. Serious pollution reduction,
6. Healthy, hygienic working environment,

7. Cooperation with Organizations,,
8. Attracts registered students,
9. Sustainable future.

2.1.2. UI GreenMetric Index

While the academic studies, research and teaching levels of universities are evaluated by various research institutions, the evaluation of their studies on environmental issues is quite new. “Green League, “Social Responsibility Index” and “Green Metric” evaluations are a few examples that can be given in this regard. Among these, Green Metric is the first to be a global measurement system and stands out (Günerhan 2016)(Trisakti, 2023). The Universitas Indonesia (UI) GreenMetric World University Rankings platform was created by Universitas Indonesia (UI) in 2010 to allow institutions worldwide to exchange their best practices and expertise for maintaining campus sustainability. Additionally, it gave each university the chance to assess its accomplishments and shortcomings in advancing green education and sustainable development. The ranking method is based on six main categories: setting and infrastructure (SI), energy and climate change (EC), waste management (WS), water management (WR), transportation (TR), education and research (ED). Since its launch, the UI GreenMetric World University Rankings have received continued attention from universities worldwide. The number of participating universities increased from 35 countries and 95 universities in 2010 to 62 countries and 360 universities in 2014, to 792 universities in 2020 and 1050 universities in 2022 (Universitas Indonesia, 2022).

Category and weight grades of GreenMetric are given in **Table 2.1.** Universities participate in the GreenMetric system online and answer the topics given in **Table 2.1** and **Table 2.2, Table 2.3, Table 2.4, Table 2.5, Table 2.6, Table 2.7.** in terms of their own universities. The scores they get as a result of the answers they provide also determine the place of the universities in the ranking. In addition, while evaluating Universities according to these categories, since the climate data of each region will be different, the climate type is selected from the different options in the UI GreenMetric Index (Contracting, 2017)(Universitas Indonesia, 2022)(UNEP - UN Environment Programme, 2023). The energy and climate change category has the highest weight with 21%.

Table 2. 1. UI GreenMetric percentages of category (Universitas Indonesia, 2022).

No	Category	Percentage of Total Points (%)
1	Setting and Infrastructure (SI)	15
2	Energy and Climate Change (EC)	21
3	Waste (WS)	18
4	Water (WR)	10
5	Transportation (TR)	18
6	Education and Research (ED)	18
	TOTAL	100

1. Setting and Infrastructure (SI): The SI weight is 15% and includes:
   - green areas,
   - initiatives for animals,
   - healthy food,
   - biodiversity,
   - social equality,
   - health and wellbeing programme,
   - operation and maintenance activities.
2. Energy and Climate Change (EC): The EC weight is 21% and includes:
   - using renewable energy,
   - PV systems,
   - wind turbines,
   - HVAC systems,
   - green building systems,
   - CO_2 emissions,
   - reduced water consumption, rainwater harvesting,
   - green roof and LED lighting.
3. Waste Management (WS): The WS weight is 18% and includes:
   - organic, paper, metal and plastics waste collection activities,
   - recycling bins placement,
   - waste reduction activities,
   - sewage disposal.
4. Water Management (WR): The WR weight is 10% and includes:

- using superlab taps or aerators taps,
- purification of rainwater and grey water,
- reduction of water consumption,
- use of rainwater harvesting,
- drinking water service,
- drip irrigation,
- water extraction,
- water pollution control.

5. Transportation (TR): The TR weight is 18% and includes:

- using bicycles, electric scooters, electric vehicles and public transport,
- a parking area plan,
- a pedestrian path,
- decrease private cars,
- a car-sharing network,
- a travel plan programme,
- disabled access.

6. Education and Research (ED): The ED weight is 18% and includes:

- existing annual Sustainability Reports,
- sustainability organisational units,
- sustainability workshops, seminars, training, courses and events,
- green awards platforms,
- sustainability publications,
- sustainability offices,
- scholarships,
- sustainability websites,
- research centres and labs.

Light green indicates new questions introduced in 2022 at **Table 2.2, Table 2.3, Table 2.4, Table 2.5, Table 2.6** and **Table 2.7.**

Table 2. 2. UI GreenMetric setting and infrastructure (SI) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
1	Setting and Infrastructure (SI)		15%
SI1	The ratio of open space area to the total area	200	
SI2	Total area on campus covered in forest vegetation	100	
SI3	Total area on campus covered in planted vegetation	200	
SI4	Total area on campus for water absorption besides the forest and planted vegetation	100	
SI5	The total open space area divided by the total campus population	200	
SI6	Percentage of university budget for sustainability efforts	200	
SI7	Percentage of operation and maintenance activities of building in one year period	100	
SI8	Campus facilities for disabled, special needs, and/or maternity care	100	
SI9	Security and safety facilities	100	
SI10	Health infrastructure facilities for students, academics, and administrative staff's wellbeing	100	
SI11	Conservation: plant (flora), animal (fauna), and wildlife, genetic resources for food and agriculture secured in either medium or long-term conservation facilities	100	
	TOTAL	1500	

Table 2. 3. UI GreenMetric energy and climate change (EC) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
2	Energy and Climate Change (EC)		21%
EC1	Energy-efficient appliances usage Smart building implementation	200	
EC2	Smart building implementation	300	
EC3	Number of renewable energy sources on campus	300	
EC4	Total electricity usage divided by total campus' population (kWh per person)	300	
EC5	The ratio of renewable energy production divided by total energy usage per year	200	

Table 2. 4. (continuation) UI GreenMetric energy and climate change (EC) category criteria (Universitas Indonesia, 2022).

EC6	Elements of green building implementation as reflected in all construction and renovation policies	200	
EC7	Greenhouse gas emission reduction program	200	
EC8	Total carbon footprint divided by total campus' population (metric tons per person)	200	
EC9	Number of the innovative program(s) in energy and climate change	100	
EC10	Impactful university program(s) on climate change	100	
	TOTAL	2100	

Table 2. 5. UI GreenMetric waste management (WS) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
3	Waste Management (WS)		18%
WS1	Recycling program for university's waste	300	
WS2	Program to reduce the use of paper and plastic on campus	300	
WS3	Organic waste treatment	300	
WS4	Inorganic waste treatment	300	
WS5	Toxic waste treatment	300	
WS6	Sewage disposal	300	
	TOTAL	1800	

Table 2. 6. UI GreenMetric water management (WR) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
4	Water Management (WR)		10%
WR1	Water conservation program & implementation	200	
WR2	Water recycling program implementation	200	
WR3	Water-efficient appliances usage	200	

Table 2. 7. (continuation) UI GreenMetric water management (WR) category criteria (Universitas Indonesia, 2022).

WR4	**Consumption of treated water**	**200**	
WR5	**Water pollution control in the campus area**	**200**	
	TOTAL	**1000**	

Table 2. 8. UI GreenMetric transportation (TR) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
5	**Transportation (TR)**		**18%**
TR1	**The total number of vehicles (cars and motorcycles) divided by the total campus' population**	**200**	
TR2	**Shuttle services**	**300**	
TR3	**Zero-Emission Vehicles (ZEV) policy on campus**	**200**	
TR4	**The total number of Zero-Emission Vehicles (ZEV) divided by the total campus population**	**200**	
TR5	**The ratio of the ground parking area to the total campus' area**	**200**	
TR6	**Program to limit or decrease the parking area on campus for the last 3 years (from 2019 to 2021)**	**200**	
TR7	**Number of initiatives to decrease private vehicles on campus**	**200**	
TR8	**The pedestrian path on campus**	**300**	
	TOTAL	**1800**	

Table 2. 9. UI GreenMetric education and research (ED) category criteria (Universitas Indonesia, 2022).

No	Criteria	Point	Weighting
6	**Education (ED)**		**18%**
ED1	**The ratio of sustainability courses to total courses/subjects**	**300**	
ED2	**The ratio of sustainability research funding to total research funding**	**200**	
ED3	**Number of scholarly publications on sustainability**	**200**	
ED4	**Number of events related to sustainability**	**200**	

Table 2. 10. UI GreenMetric education and research (ED) category criteria (Universitas Indonesia, 2022).

ED5	**Number of student organizations related to sustainability**	**200**	
ED6	**University-run sustainability website**	**200**	
ED7	**Sustainability report**	**100**	
ED8	**Number of cultural activities on campus**	**100**	
ED9	**Number of university program(s) to improve teaching and learning**	**100**	
ED10	**Number of sustainability community services projects organized and/or involving students**	**100**	
ED11	**Number of sustainability-related startups**	**100**	
	TOTAL	**1800**	

2.1.2.1. Green Campus Examples in the Framework of the UI GreenMetric Index

As seen in **Table 2.8**, the top three rankings of the UI GreenMetric Index Overall Ranking, in which 1050 universities participated, were ranked by Wageningen University & Research, Nottingham Trent University, and the University of Nottingham, respectively. WUR scored 9300 points, 125 points higher than NTU and 225 points higher than NU.

Table 2. 11. UI GreenMetric international overall rankings 2022 (Universitas Indonesia, 2022).

Rank 2022	University	Country	Total Score	SI	EC	WS	WR	TR	ED
1	Wageningen University and Research	Netherlands	9300	1325	1825	1800	1000	1600	1750
2	Nottingham Trent University	United Kingdom	9175	1300	1975	1800	850	1500	1750
3	University of Nottingham	United Kingdom	9175	1375	1700	1800	1000	1650	1650

2.1.2.1.1. Wageningen University & Research

Wageningen University is a research university located in the Netherlands. It specializes in agriculture, life sciences, and environmental sciences. Established in 1918, the university has gained a global reputation for its research and academic programs. It offers a wide range of bachelor's, master's, and doctoral programs in fields such as agriculture, food technology, biology, and economics. The university is known for its innovative research in areas like sustainable agriculture, food production, climate change, and biodiversity. The main campus in Wageningen provides modern facilities, laboratories, and experimental farms. The university promotes international collaboration and offers opportunities for students to engage in exchange programs and research projects abroad. Graduates from Wageningen University have successful careers in academia, industry, and government organizations. The university's focus on sustainability and its contribution to addressing global challenges make it a prominent institution in the field of agricultural and environmental sciences.

Wageningen University consists of several faculties, including the Faculty of Agrotechnology and Food Sciences, the Faculty of Animal Sciences, the Faculty of Environmental Sciences, the Faculty of Life Sciences, the Faculty of Social Sciences, the Wageningen School of Social Sciences, the Wageningen School of Economics, and the Wageningen Graduate Schools. The university had approximately 12,000 students and around 6,500 staff members, including academic faculty, researchers, and administrative personnel in the 2021academic year (WUR Website, 2023).

Figure 2. 2. Wageningen University & Research Campus (WUR Website, 2023).

Wageningen University & Research in the Wageningen, Netherlands has scored 9300 points in the UI GreenMetric rank. 1325 from the Setting & Infrastructure category at 15 percent, 1825 from the Energy & Climate Change category at 21 percent, 1800 from the Waste category at 18 percent, 1000 from the Water category at 10 per cent, 1600 from the Transportation category at 18 percent, 1750 from Education & Research category with 18 percent (UI GreenMetric World University Rankings, 2022).

Wageningen University & Research Setting & Infrastructure (WUR Sustainability Report, 2021)*;*

- The 60 hectares of the Wageningen campus, where more than 18,000 students study and work, are open to the public. It strives to create a public place that is adaptable, healthful, and climate resilient.
- The connection of the Wageningen Campus with nature areas has been improved.
- In order to conduct study on nesting tits, WUR installed 100 nest boxes in trees all over the campus. In the Netherlands, the big tit has come to represent the effective management of the oak processionary caterpillar by nature. This caterpillar is a favorite meal of the great tit, who consumes it at various stages of its life cycle. As a result, more and more businesses and municipalities are utilizing nesting boxes to combat the annoyance of oak processionary caterpillars. After they die, birds offer food for scavengers and decomposers, helping to maintain sustainable population levels of the species that serve as their prey and predators. Numerous birds are necessary for plant reproduction because they spread seeds or act as pollinators.
- Since there is a serious threat to biodiversity, Wageningen University & Research is actively engaged in this theme with experts from a variety of fields, including ecologists, soil specialists, plant and animal scientists, behavioural scientists, transition scientists, and other specialists who look into biodiversity issues that affect land, freshwater systems, and the seas.
- WUR has Biodiversity, ecosystem services and stakeholder interactions. This way, green design on campus differentiates between the tidy, intensely used parts for meeting and relaxation and more ‘rugged’ areas for biodiversity. Public spaces are designed to be nature inclusive like green roofs (e.g. Lumen) and nestle opportunities in buildings (e.g. bat and sparrow).

Wageningen University & Research Energy & Climate Change (WUR Sustainability Report, 2021)(Green Vision for Wageningen Campus, 2019)*;*

- WUR calculates its annual CO_2 footprint to assess its influence on the environment.
- WUR produces renewable energy at places in Lelystad, Bleiswijk, Goutum, Renkum, and Randwijk as well as on the rooftops of WUR structures. 2016 saw the initial installation of solar panels on the roof of a brand-new gym at Sports Centre De Bongerd. Currently, more than 10,000 solar panels on structures and grounds are producing sustainable energy. WUR uses the energy produced at the buildings and contributes around 3% of the nation's yearly energy needs (the remainder is met by wind energy). 109% of the energy used in 2019 was produced sustainably. That is, an extra 9 percent efficiency was obtained.
- WUR achieves zero gas consumption, lowers energy expenses, and limits CO_2 emissions. Aquifer Thermal Energy Storage (ATES) will soon be used to heat and cool nearly all of WUR's campus buildings and greenhouses. ATES is a type of renewable energy source that may be used to heat or cool buildings. Batteries are made up of underground, networked heat and cold storage wells. In the summer, cold water is pumped from the cold well and then transferred through a heat exchanger to the building's systems. The water is piped back to the hot well while the building warms the cold water. This process is reversed in the winter, when hot water is pumped up and utilized to warm the ventilation air before the water cools.The cold water is pushed back to the hot well while being heated by the structure. Therefore, a pump is used to alternately move groundwater between the cold and hot wells.
- As part of the energy transition, WUR has had 26 windmills in Lelystad since 2005. Through windmills, it distributes the energy to the city grid as much as it is consumed. It not only produces green wind energy, but also buys it for its daily use. 121% of the energy used by WUR overall in 2020 was produced sustainably. Due to good wind conditions, Lelystad's wind turbines have generated more renewable energy than in prior years more than 70 million kWh.
- Sustainability criteria are used for building construction, maintenance and renovation on the Wageningen Campus. In addition to the legal requirements, ambitions for energy and sustainability are set out in the General Technical

Programme of Requirements (ATPvE) for new construction and renovation projects. The aim is to include energy performance improvement in all construction projects. In 2021, the new greenhouse building on Wageningen Campus, Greenhouse Red, was commissioned, and construction was underway on the NPEC building. For new buildings, the BENG requirements are in force. The new buildings will also be connected to the ATES loop. Also, sustainability measures are being taken, such as applying double glazing and limiting light emissions. To comply with nature-related legislation and regulations, a quick scan of flora and fauna is carried out in case of planned demolition of buildings or major renovations. Furthermore, installation of heat recovery and fume hood ventilation with high-low control has been adjusted. For maintenance, a Sustainable Long-Term Maintenance Plan has been drawn up, incorporating the planned and additional investments for energy-saving measures at Wageningen Bioveterinary Research in Lelystad.

- Energy efficiency is crucial to lowering energy use, in addition to the creation of renewable energy. WUR has pledged to increase energy efficiency by 30% between 2005 and 2020. It has improved energy efficiency by 34% as of 2022.

Wageningen University & Research Waste Management (WUR Sustainability Report, 2021)*;*

- Approximately 4 million cardboard cups and 17 million paper towels are used annually at WUR. The recycled paper cups and towels are taken to WEPA Nederland B.V.'s manufacturing, where the shall be reprocessed into Paper Towels and Toilet Paper, which will subsequently be returned to WUR. This manufacturing procedure adheres to the cradle-to-cradle principles and is devoid of dangerous chemicals. For the project, the segregation of garbage such as cups, stir sticks, tea bags and food waste is encouraged. Or better yet, it is recommended to bring the mugs to campus or use €1 worth of recycled Billie Cup.
- To recycle the paper products, WUR has partnered with three organizations. Veolia Paper & Plastics Recycling B.V. will collect used paper products including cups and towels as well as outdated office supplies and private information and deliver them to WEPA Nederland B.V.'s manufacturing facility. towels and toilet paper will be made from recycled paper fibers. In the end, supplier Asito will provide these paper products back to WUR.

- For the best possible recycling, garbage is collected separately on campus for organic materials (vegetable, fruit, and food waste), paper, plastics, drink cartons (PD), coffee cups (cup2paper), and other materials at WUR.

Wageningen University & Research Water Management (WUR Sustainability Report, 2021)*;*

- In the KAS2030(name of an advanced experimental greenhouse project) in Bleiswijk, all drain and condensate water is recirculated. This means that, no nutrients are lost and no plant pesticide residues enter the wastewater.
- Water cooling is used in Vitae for some scientific apparatus. Recent advancements in cooling water reuse have reduced water usage by nearly half. The possibility of recycling cooling water is taken into account when purchasing new technology. Additionally, regular wastewater samples are taken for research.

Wageningen University & Research Transportation (WUR Sustainability Report, 2021)*;*

- WUR encourages employees to flexibly work remotely and cycle to work. There is a bike plan for staff to purchase bikes for videoconferencing on public transport in the Netherlands and Europe.
- The comprehensive system of bicycle lanes (some are biologically based) and bicycle parking near buildings, as well as the installation of electric charging stations for electric vehicles, e-bikes, and e-scooters, all help WUR promote sustainable mobility. They also favor suppliers that use electricity or green gas. More effective deliveries on campus may decrease the frequency of large delivery vehicles.
- Mobility as a Service (MaaS) was established by WUR to encourage more environmentally friendly mobility. Employees may plan, organize, and schedule their vacation using a pay-as-you-go app, which simplifies travel. MaaS offers several forms of mobility, including shared electric vehicles and bicycles available on campus, public transit that is connected with the travel advising app, and a fleet of minibuses and transport vans for bigger groups.
- WUR has a travel check in place for business travel that goes above and beyond the recommendation to use public transportation wherever possible. Short flights are explicitly discouraged, and rail reservations are made more straightforward. For destinations in Europe with less than 6 to 8 hours of travel time, train travel

should be normal. The goal is to reduce CO_2 emissions from all WUR transportation by at least 2% annually.

Wageningen University & Research Education & Research (WUR Sustainability Report, 2021)*;*

- The university uses the idea of a living laboratory. This strategy will present chances for research and educational experimentation. The creation and administration of the green space are decided in conjunction with WUR professionals from education, research, and operational management, using a living lab method.
- The Green Office Wageningen is a sustainability organization. GreenMatch, Shut the Hood, Reuse Revolution, Student Cooking Corner, and the Seriously Sustainable Week are a few of the initiatives. Students use GreenMatch to solve sustainability problems or create sustainability blogs. The Green Office serves as a liaison between students and customers to discuss potential subjects for theses, internships, and course assignments.
- WUR has a Green Impact Program where staff and students are committed to sustainability. With this program, it supports various programs, including the Plastics Pilot Project, which aims to reduce the significant plastic consumption in laboratories.
- The WUR has an annual sustainability report that was created in compliance with Global Reporting Initiative (GRI) standards. The yearly report provides general information on Corporate Social Responsibility (CSR)and sustainability.
- The 23 locations that make up WUR are home to numerous organizational units. Both Wageningen University (WUR) and Wageningen Research (WR) use a same operational management system. Therefore, the operational management for WUR as a whole is covered in the report. The major points of the health, safety, and environmental reports produced by WUR's several organizational divisions are included in this report.
- Several Green Impact workshops hold throughout the year on topics such as litter (with a special focus on plastic and cigarette butts), climate adaptation and modern slavery.

- The WUR has sustainability website (WUR Sustainability Website, 2023).

2.1.2.1.2. Nottingham Trent University

Nottingham Trent University (NTU) is a public research university located in Nottingham, England. It was founded in its current form in 1992 but has roots dating back to 1843. NTU is known for teaching and industry connections. It has multiple faculties, offering a wide range of undergraduate and postgraduate programs. NTU consists of several faculties, including the Nottingham Business School, School of Animal, Rural and Environmental Sciences, School of Architecture, Design and the Built Environment, School of Art & Design, School of Arts and Humanities, School of Science and Technology, School of Social Sciences, School of Social Sciences (NTU London), School of Education, School of Health Sciences, School of Law, School of Nottingham Institute of Education, and School of Social Work and Health Professions. NTU had over 35,000 students and employed over 3,000 staff members in the 2019/2020 academic year. The university focuses on applied research and has research centers and institutes in areas such as sustainability, health, business, and social sciences.

Figure 2. 3. Nottingham Trent University Campus (NTU Website, 2023).

Nottingham Trent University in the Nottingham, United Kingdom has scored 9175 points in the UI GreenMetric rank. 1300 from the Setting & Infrastructure category at 15 percent, 1975 from the Energy & Climate Change category at 21 percent, 1800 from the Waste category at 18 percent, 850 from the Water category at 10 per cent, 1500 from the Transportation category at 18 percent, 1750 from Education & Research category with 18 percent (UI GreenMetric World University Rankings, 2022).

Nottingham Trent University Setting & Infrastructure (NTU Sustainability Report, 2020)*;*

- The University has several campuses spread across 240 hectares of land. The campus at Brackenhurst includes a number of pond habitats, three unique woodland sections, a management strategy for hedgerows, and a total of 4.5 hectares of land. 8,000 m^2 of a wildflower meadow has been found on the Clifton campus, while the city campus has living walls, pocket parks, and green roofs.
- To supply essential nutrition, NTU constructed over 250 bird and bat boxes in trees across the estate, along with new bird feeders.

Nottingham Trent University Energy & Climate Change (NTU Sustainability Report, 2020)(NTU Net Zero Carbon Report, 2021)*;*

- NTU has buildings with PV solar energy that can produce a total capacity of 396 kW.
- The Pavilion building on the Clifton campus is one of 14 NTU buildings to gain a BREEAM "Excellent" grade. Using Passivhaus principles, which are a recognized worldwide design guideline for achieving optimum energy efficiency, the first Energy Performance Certificate (EPC) grade A+ building was built.
- At NTU three BREEAM 'Very Good' refurb projects have been completed and are in progress.
- Raw materials such as lumber and straw were used to construct the Lyth Building within the NTU.
- The Medical Technologies Innovation Facility (MTIF) building at the Clifton campus has BREEAM "Excellent" accreditation and was shortlisted for the "Sustainable Development of the Year" and "Commercial Development of the Year" categories in the East Midlands Brick Awards 2021.
- The NTU website now features images that are 55% less in file size, using 9% less energy to power our online pages as a consequence.
- NTU has Sustainability in Enterprise programme. The program's sustainability team has taken on positions as consultants, offering real-world assistance and

financial support to help qualified SMEs lower their carbon footprints. Consultants from the Sustainability Team assist with understanding and lowering carbon emissions, enhancing environmental performance, cutting expenses, and guaranteeing long-term corporate sustainability.

- NTU has carbon emission report. And total annual CO_2 measurement is carried out on campus.

Nottingham Trent University Waste Management (NTU Sustainability Report, 2020)(NTU Water Management Plan, 2022)*;*

- Recycling containers may be found throughout the NTU campus. The waste management provider at NTU provides a service that guarantees the majority of the University's garbage is reused or recycled and collected in a user-friendly manner under the strict supervision of the sustainability team. By engaging staff, students, and visitors in the waste hierarchy, NTU raises its recycling rate.
- NTU generated over 680 tonnes of garbage in 2020–2021, including confidential waste, industrial waste, mixed recyclables trade waste, Waste Electrical and Electronic Equipment (WEEE), clinical healthcare waste, food waste, glass, and hazardous waste. This production resulted in nearly 13 tCO2e. In addition to the garbage that is already separated on campus, the waste contractor separates waste materials even further. As a consequence, in 2020 and 2021, 99% of the waste generated by NTU will not end up in landfills.

Nottingham Trent University Water Management (NTU Sustainability Report, 2020)(NTU Water Management Plan, 2022)*;*

- In the Managed Estate, NTU utilized 52,518 m^3 of water in 2020 and 2021. Both provided water and processed water contribute to the water's carbon emissions.
- NTU has superlab tap. Standard hand wash basins use approximately 10 litres of water per minute. Superlab taps have a flow rate of 9.2 litres per minute, but a ‘magic’ eye restricts flow when hands are placed in front of the sensor.
- NTU has taps with aerators. The uses of other specialist nozzles have the ability to reduce water from the tap even further.
- NTU has Cooling technologies on autoclaves. Traditional autoclaves (steam under pressure sterilising machines) use the majority of the water to produce the vacuum

and to cool the waste water. A cycle can use more than 8000 litres of water. Cooling technologies on autoclaves reduce this substantially.

- NTU has reverse osmosis machines for purified water. Most large labs have moved away from water stills to produce purified water, and are investing in reverse osmosis machines. Traditional water still was found to waste approximately 470 litres of tap water in producing 25 litres of distilled water, with an energy consumption of 3kWh. It would take 7.5 hours to produce 25 litres of water. While reverse osmosis machines are relatively expensive, they use only 300W and only waste as much water as they produce.

Nottingham Trent University Transportation (NTU Sustainability Report, 2020)*;*

- The three completely electric and two hybrid electric cars on the campuses of NTU each replace a car that runs on fossil fuels.
- NTU publishes a cycle report. There are 150 bikes available for rent for students and coworkers. Additionally, there are 58 bicycle spots at Brackenhurst, 497 at Clifton, and 271 at the City Campus, which is intended to encourage the ownership and riding of bicycles. Near the substantial bike storage in Maudsley (City campus), further bike storage has been constructed. Additionally, the Clifton campus has a cycle parking area with a BREEAM "Excellent" rating that has space for up to 30 cycles.
- A new fleet of vehicles with Euro VI engines have been added to the Go2Uni4 bus service, which connects our City and Clifton campuses. In 2018 and 2019, 842,000 people used the program. Access to discounted bus travel is available to students on all campuses. Students can take advantage of unlimited NCT bus travel for $259 for the school years 2021 and 2022. NCT announced price freezes and travel reductions in 2021 and 2022, the same years that the tram users' NETGO App was made available. For only £1.50 roundtrip, students, coworkers, and guests to our Clifton campus can utilize the Clifton South Tram Park and Ride to go to the Rivergreen tram station.

Nottingham Trent University Education & Research (NTU Sustainability Report, 2020)*;*

- The Sustainable Development team is present at Nottingham Trent University (NTU). To promote a culture of sustainable development, improve the experience for students and employees, and support the university's goal of being the most environmentally responsible university in the UK by 2025, this team collaborates closely with departments throughout the institution.

- Representatives from academia, research, professional services, and the student population are included in each working group at NTU. The groups provide reports to the Carbon Programme Group, which is made up of specialists in the field from around the University. Ongoing progress updates are then presented to the Embracing Sustainability Strategy Board for onward reporting to the Board of Governors.
- NTU has a platform for "Green Awards." Through 58 events and activities, including Green Week, a Climate Action Summit, and Sustainability Action Week, it involved over 1000 coworkers and students. The app tallied 1,632 downloads (1,445 student and 187 staff), 83,608 sustainable activities, and 167,476.66kg CO_2 averted in 2020 and 2021.
- NTU earned the Bronze Hedgehog Friendly Campus (HFC) Award for 2020 and 2021.
- The Silver "Food for Life Served Here" Award by the Soil Association has been held by NTU Catering since November 2011. The Silver catering grade on a "Large Volume for Students" basis was first attained by NTU.
- The "Green Gown Awards 2021" were won by NTU Catering Services in 2021. The "Campus Health, Food and Drink" award was given in recognition of their all-encompassing commitment to sustainability, which includes a notable decrease in food miles, waste, and energy usage as well as a significant increase in Fairtrade, organic, Red Tractor, and plant-based products.
- For more than ten years, NTU has been an authorized user of the ISO 14001 Environmental Management System. NTU is a client partner of the Considerate Constructors Scheme in addition to these accomplishments.
- NTU has a policy on sustainable construction. The policy is to ensure that all new major developments comply with the BREEAM standard.
- NTU has 14 student organizations that have organized events, activities, and projects to promote environmental impact and sustainability conversations.
- NTU has a network of 20 workers' sustainability ambassadors and 25 ecoAmbassadors were appointed to share initiatives at universities with each other, propose improvements and help coordinate events. The Nottingham

Network has provided the Nottingham University Sustainability Action Group and workshop, where the University of Nottingham and the Nottingham City Council have shared guidance and led discussions with over 100 participants on climate change.

- 35 customized training sessions on environmental management and sustainability awareness were provided by NTU.
- The NTU has sustainability website (NTU Sustainability Website, 2023).

2.1.2.1.3. University of Nottingham

Nottingham University is a research-intensive university located in Nottingham, England. It was founded in 1881 as University College Nottingham and received its royal charter in 1948, becoming the University of Nottingham. The university has several faculties including the Faculty of Arts, Faculty of Engineering, Faculty of Medicine and Health Sciences, Faculty of Science, and Faculty of Social Sciences. It has over 34,000 students enrolled in undergraduate and postgraduate programs, and employs over 8,000 staff members. The University of Nottingham is known for its research profile and has research institutes and centers focused on various fields(NU Website, 2023).

Figure 2. 4. University of Nottingham Campus (NU Website, 2023).

University of Nottingham in the Nottingham, United Kingdom has scored 9175 points in the UI GreenMetric rank. 1375 from the Setting & Infrastructure category at 15 percent, 1700 from the Energy & Climate Change category at 21 percent, 1800 from the Waste category at 18 percent, 1000 from the Water category at 10 per cent, 1650 from the Transportation category at 18 percent, 1650 from Education & Research category with 18 percent (UI GreenMetric World University Rankings, 2022).

University of Nottingham Setting & Infrastructure (University of Nottingham Sustainability Report, 2021)(University of Nottingham Sustainable Food Policy, 2022)*;*

- The number of hedgehogs decreased by 50% in rural areas and 30% in urban gardens. That's why the university started the Hedgehog Friendly Campus Program. To bring attention to the condition of hedgehogs, a small number of university community members from Nottingham took part in the Hedgehog Friendly Campus Program.
- 420 new young trees were planted on the Sutton Bonington campus through work by the university, volunteer students, and members of the Sustainability Society.
- Students at the University of Nottingham run the veterinary clinic. In recognition of their efforts in Nottingham caring for the dogs of the homeless and vulnerable households, Vets in the Community (ViC) took home the prize in the Benefitting Society category. ViC offers veterinary treatment for these animals, which has a significant positive impact on their well-being and their owner's welfare. Veterinary students manage the free service, which offers immunizations, flea and worm treatment, microchipping, and general care, under the direction of competent experts. Because of the work of ViC, people have nothing to worry about how to feed their animals in times of need or go without meals to take care of them.
- The University uses a "Food Made Good" sustainable catering rating uses "Fairtrade" and provides milk alternatives in cafes free of charge.
- On the athletic fields at Highfields, Riverside, and University Park, new battery-powered mowers are in use. With battery-powered mowers, the grass is allowed to grow longer and blossom, increasing animal habits and food supplies. Additionally, fuel is conserved, CO_2 emissions are decreased, and staff health is benefited by a decrease in machine vibrations.
- For use in various academic research projects, the university maintains beehives at its King's Meadow Campus in Lenton and in Bunny Park, an agricultural area south of Nottingham. University honey is made available for purchase to faculty, staff, and students every fall and winter.

University of Nottingham Energy & Climate Change (University of Nottingham Sustainability Report, 2021)(University of Nottingham Sustainability Environmental Strategic Delivery Plan, 2020)(University of Nottingham Energy Report, 2020)(University of Nottingham Carbon Report, 2020)*;*

- Nottingham University took part in the student Switch Off competition. The National Union of Students (NUS) sponsors the energy-saving and recycling competition known as Student Switch Off. 33,000 kg of CO_2 were collectively saved through hall electricity reduction. This is the same as approximately 50 flights from Manchester to New York in reverse. More than 400 students participated in campaigns, adopting initiatives like conserving water, cutting back on waste, and recycling more. Over 800 people are actively using the program, and together they have taken more than 23,000 positive actions, saving more than 25,000 kg of CO_2.
- The University of Nottingham supports Laboratory Efficiency Assessment Framework (LEAF) green lab accreditation with the Technical Sustainability Working Group (TSWG) and operates -80°C freezers at -70°C (saving 25% in energy or £300 annually). Users of the lab can follow the steps in LEAF to conserve water, energy, plastics, and other resources. Participating laboratories will lower their carbon emissions and establish a setting that promotes high-quality research.
- The university has a project called "Creative Energy Homes." With regard to micro-smart grids, energy storage, demand-side management, tenants, and the adoption of novel technologies, it is a £1.9 million initiative that is an important resource.
- The University of Nottingham is introducing carbon labels on its food menus to support Nottingham carbon neutral targets and increase the university's sustainability. The name of this project is "Klimato".
- The University has sustainable building projects which name is University Park, GSK Carbon Neutral Laboratory for Chemistry, Research Acceleration and Demonstration building, Regeneration at Jubilee Campus and Creative Energy Homes. The projects minimise transportation during construction, use recycled and natural materials, apply low energy and reduce water consumption, enhance biodiversity, use rainwater harvesting, use living walls and green roofs, apply

passive design, use PV systems, smart building systems, and low carbon building systems.

- The university has constructed renewable energy projects that make use of biomass boilers, solar hot water, air source heat pumps, ground source heat pumps, and lake source heat pumps.

University of Nottingham Waste Management (University of Nottingham Sustainability Report, 2021)*;*

- • The British Heart Foundation (BHF) and Nottingham Trent University have partnered with the University of Nottingham since 2012 to provide donation stations in each residence hall on campus. 7,733 contribution bags were impressively collected, generating almost £108,262 for BHF research. This indicated that 61.86 tonnes of garbage, or the weight of 10.3 elephants, had been kept out of the landfill. This translates to a reduction of 629,590 kg of CO_2 emissions.
- Technical Sustainability Working Group (TSWG) is present at the university. To make the university greener and more sustainable, the dedicated members of the TSWG have worked to spearhead green initiatives and exchange sustainable practices and ideas. These programs have included automated recycling of "dirty" solvents.
- The University set up writing instrument recycling. Recycle points are located across University Park and Jubilee, with a local school benefiting from the scheme. The scheme has tip box recycling, lab plastics recycling, and chemical recycling IT equipment through our IT supplier.
- The University reduce food waste and using a campaign named "Too Good to Go" to sell surplus food, reducing disposables by moving towards crockery and encouraging reusable coffee cup usage through "Latte Levy". Latte Levy is a project that discounts when a customer uses their own cup to buy a drink.In addition, the university turns food waste from dormitories and cafeterias into compost every year.
- The university has waste projects that collaborate with contractors to minimize waste during construction projects, reuse extra furniture, host bookcrossing areas, promote the use of reusable water bottles and cups rather than disposable options,

provide a large number of recycling points on campus, and run battery recycling programs for portable batteries.

- University campuses have water fountains. In this way, the waste of disposable pet bottles is reduced.

University of Nottingham Water Management (University of Nottingham Sustainability Report, 2021)*;*

- The Technical Sustainability Working Group (TSWG) helped the university reduce energy usage and save around 1.2 million liters of water annually by implementing waterless condensers and chiller units throughout the laboratories in the Schools of Pharmacy and Chemistry.
- The university reduces its water consumption, uses rainwater harvesting, and uses living walls and green roofs.

University of Nottingham Transportation (University of Nottingham Sustainability Report, 2021)*;*

- The institution offers employees and students a semester-long bike rental program. Additionally, Dr. Bike offers complimentary bicycle maintenance inspections. There are about 5,000 bike parking places available on university campuses, including a number of covered and access-restricted cycle shops. Interactive maps provide information on access arrangements, nearby showers, and the location of cycling parking.
- There is a tram at the university. With stations at University Park, Queen's Medical Center, and King's Meadow Campus, the tram provides a direct connection between the city's campuses and the Nottingham railway station and city center.
- The university offers both employees and students a free intercampus transportation service.
- The University has partnered with a car-sharing network in the UK to offer a car-sharing program that is tailored to the needs of University of Nottingham workers. For personnel, there is a carsharing program available online. Staff members can use the web system to look for people who go in the same direction as them so they can travel together.

- The University is currently equipped with nine Renault Kangoo electric cars, which make up around 15 % of the vehicles that are used by Estates and catering staff on a daily basis. The vehicles are economical, costing about 3 pence per mile, and can go up to 80 miles between charges. The vans contribute to a calm environment on campus since they are quiet and minimize exhaust emissions, which leads to better air locally.

University of Nottingham Education & Research (University of Nottingham Sustainability Report, 2021)*;*

- The university conducts innovative studies in the domains of creative energy houses, energy technologies research institute, environment center, international center for corporate social responsibility, and modelling an unpredictable future, among other areas.
- The University of Nottingham has a program called Green Rewards. The web platform and mobile app illustrate the effects of activities that people may do, such as reducing carbon emissions, electricity usage, or the use of single-use cups and bottles. People receive Green Points in exchange, with the potential to win gift cards for themselves and charitable donations for their team.
- The Green Flag awards were won by the University of Nottingham. The university's dedication to providing a healthy, secure, and safe environment that is also sustainable is shown through the Green awards.
- The Center for the Environment (CfE) is a facility within the university. It serves as a portal to the University of Nottingham's environmental studies and the NERC British Isles continuous GNSS Facility.
- The university has mathematical modelling research. Services used every day include modeling techniques, from traffic mapping systems to weather reports. The university provides training on such services and products that can have an impact on sectors from entertainment to health.
- The NU has sustainability website (NU Sustainability Website, 2023).

As seen in **Table 2.9**, the top three rankings among the 83 Turkish universities participating in the UI GreenMetric Index were followed by Istanbul Technical University, Cyprus International University and Erciyes University, respectively. ITU scored 8585 points, 235 points higher than CIU and 325 points higher than ERU.

Table 2.9. UI GreenMetric Turkey overall rankings 2022 (Universitas Indonesia, 2022).

Rank 2022	University	Country	Total Score	SI	EC	WS	WR	TR	ED
47	Istanbul Technical University	Turkey	8585	1275	1535	1575	900	1575	1725
71	Cyprus International university	Turkey	8350	1250	1575	1425	1000	1450	1650
86	Erciyes University	Turkey	8260	1325	1535	1425	800	1600	1575

2.1.2.1.4. Istanbul Technical University

Istanbul Technical University (ITU) is a renowned technical university located in Istanbul, Turkey. It was established in 1773, making it one of the oldest technical universities in the world. ITU offers a wide range of programs in engineering, architecture, and natural sciences. The university is organized into faculties and schools covering various fields of study. ITU has had faculties including Architecture, Civil Engineering, Electrical and Electronics Engineering, Mechanical Engineering, Chemical and Metallurgical Engineering, Naval Architecture and Ocean Engineering, Aeronautics and Astronautics, Mining Engineering, Management, and Textile Technologies and Design. The university attracts both domestic and international students to its undergraduate and postgraduate programs. In terms of staff, ITU employs a dedicated team of academic and administrative personnel to support its educational and research activities. The university has a diverse faculty and committed support staff. ITU places a strong emphasis on research and innovation. It collaborates with industry partners and conducts cutting-edge research in various fields. The university has research centers and laboratories that contribute to advancements in engineering, technology, and applied sciences (ITU Website, 2023).

Figure 2. 5. Istanbul Technical University Campus (ITU Website, 2023).

Istanbul Technical University in the Istanbul, Turkey has scored 8585 points in the UI GreenMetric rank. 1275 from the Setting & Infrastructure category at 15 percent, 1535 from the Energy & Climate Change category at 21 percent, 1575 from the Waste category at 18 percent, 900 from the Water category at 10 per cent, 1575 from the Transportation category at 18 percent, 1725 from Education & Research category with 18 percent(UI GreenMetric World University Rankings, 2022).

Istanbul Technical University Setting & Infrastructure (Istanbul Technical University Sustainability Report, 2022)*;*

- The ITU, as an organization, supports landscaping projects using plant species that use less water and are suited to the local environment. Grassy regions have been created in some locations due to the high water demand. Most often, the land has been levelled and let to grow into a meadow without being planted.
- Academicians from the ITU Faculty of Architecture Landscape Department collaborated with the Istanbul Regional Directorate of Forestry, Istanbul Metropolitan Municipality, and ITU to conduct studies on sustainable landscaping. The objective of these studies is to protect the campus's green spaces at ITU Ayazaga.
- ITU collaborated with Bugday Association under the Nature-friendly Urban Gardens. The association seeds to the Campus Project where volunteers took courses regarding sustainable agriculture. Volunteers also planted heirloom seeds on the ITU Taskısla campus. No pesticides or any kind of chemicals were used in the process that would harm the ecosystem.

- There are two research projects at the ITU that collaborate with the Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies Fruit Research Institute, and the Food Engineering Department collaborated. Agricultural product quality criterion selection and supply chain-focused breeding goal determination are project issues.
- In order to encourage participation from interested local farmers and producers, the Safe and Sustainable Food Commission of the ITU has organized a unique event for World Food Day that is free and accessible to the public. All restaurants provide a variety of sustainable eating options. At all campuses of the Istanbul Technical University, dining halls connected to the Catering Branch Directorate have four kitchens and twenty-one cafeterias with varying capacities.
- The university has Adhoc (NetworkControl systems) project, which is involved in a number of regional and global programs aimed at enhancing or promoting health and wellbeing. Assistive audiology rehabilitation robot, or RoboRehab, is a TUBITAK 1001 project. We employ the humanoid robot Pepper, which has been upgraded with emotion, physiologically-based stress and attention recognition, face data, and gamification of traditional aural exams. Using affective computing technologies, the EMBOA ERASMUS+ project "Affective loop in Socially Assistive Robotics as an Intervention Tool for Children with Autism" intends to improve social robot intervention in children with autism. Under the EU Erasmus Plus Strategic Partnership for Higher Education Program, the project is carried out from 2019 to 2022.
- ITU, as a body, conducts and supports different works to promote the conservation of aquatic ecosystems. In 2021, ITU hosted an event called “Sustainable Environment, Sustainable Technologies”, collaborating with Environment Foundation and MSMB (Architect Sinan Engineers Association). Several presentations about sustainable development and the sustainable environment were made.
- The Istanbul Municipality hosted the Istanbul Ecosystems Workshop, which featured four academics from ITU organized into four workgroups. The new sustainable policies, the significance of wetland placements (like ITU Pond), and how they might enhance a region's biodiversity despite growing urbanization were all advocated by ITU academicians.

- ITU as a body provides educational programs on ecology and ecosystems for students and local communities. These educational practices may be conducted by student clubs or other centres by the authority of ITU. A celebration known as "Sustainable Ecosystem Days" is organized annually by the environmental engineering students club.
- Various bird species, including parrots, hawks, and magpies, may be found on campus. With the expansion of animal species on the Ayazaga Campus, such as the crow and magpie, it has been seen that sparrows are leaving the woodlands. The sparrow population grew when bird nests were installed all around the campus to allow the birds to get back to the wild.
- Other animal species that reside on campus include cats, dogs, hedgehogs, reptiles, and squirrels. Cabins have been built so that these creatures can feed and drink. Every dog and cat has had a vaccination, and a veterinarian has been appointed to oversee their well-being.

Istanbul Technical University Energy & Climate Change (Istanbul Technical University Sustainability Report, 2022)*;*

- ITU collaborates Sustainable Production and Consumption Association (SUT-D). The SUT-D, carries out social and technical practices to reduce greenhouse gas emissions and reduce their carbon footprint.
- The university hosted events like the electric vehicles summit, smart grids event, nuclear energy and future seminar, nuclear reactor technical tour, and national nuclear research university workshops in keeping with the incentives made by Istanbul Technical University in the 100% renewable energy field.
- ITU has a project for solar electric car speed and energy optimization. By making the most use of the energy available during both the track race and the long road, the project scope seeks to set up the infrastructure and develop the strategy for a program that will enable a solar vehicle to arrive at the specified location as quickly as possible.
- Under the guidance of novaTM, the "R&D Project of Multifunction Solar Panel in Nano, Micro, and Cube Satellites" is being carried out in accordance with the protocol inside the ITU Space Systems Design and Test Laboratory. As part of the project, multipurpose, inexpensive household solar panels are being created for Nano and Micro Satellites, which are incredibly common and inexpensive.

- Istanbul Technical University campuses all received Zero Waste Certificates. In this regard, the ITU Energy Institute National Nuclear Research University Workshops, the Development of Technological Infrastructure of Turkish Electricity Transmission Networks Project, and the Energy Efficiency Project in General Lighting Business Package known as HASAT were all carried out.
- The BMI Renewable Energy Technologies Certificate Program is offered by ITU. With the help of the ITU Energy Institute, the program aims to reduce the lack of knowledge among individuals who wish to work in the energy industry and the technical personnel already employed in the field by providing information on new legislation and cutting-edge techniques for renewable energy technology.
- The ITU as an organization has an Energy Management Directive that aims to establish policies for the effective use of energy by increasing energy efficiency in existing and newly planned buildings, conducting energy audits to identify areas where energy waste is high, and reducing investments in carbon-intensive energy industries, especially coal and oil, to protect the environment and increase efficiency in the use of energy resources within the responsibility and authority of the ITU.
- Two new buildings on the ITU campus applied for a LEED accreditation. Building for the Informatics Research Center has applied for LEED certification.
- ITU uses renewable energy sources for some of its electrical needs. The Graduate Education Institute and the ITU Abdulhakim Sancak Mosque on campus both have solar panels on their roofs. At Istanbul Technical University, renewable energy systems offer about 40 kw/h of electricity. The mosque's interior and exterior power, ventilation, heating, and cooling (apart from lighting) are all energy-efficient. The installations adhere to LEED standards.
- As part of the "Energy Efficiency in Public Buildings Project (EEPBP)" funded by the Ministry of Environment and Urbanization and Climate Change, investments will largely be made to renovate central public buildings that have high energy usage and quick payback periods.
- ITU has a Climate Action Plan and Strategic Plan which cover the energy consumption of each campus unit. The plan analyzes the transportation, energy, water, waste diversion and education situation of ITU and discusses how improvements can be made in the future.

Istanbul Technical University Waste Management (Istanbul Technical University Sustainability Report, 2022)*;*

- The National Waste Framework Directive and the ITU's waste management directive are compatible. The regulation outlines steps to cut down on and reuse packaging waste in addition to other types of waste. Glass is collected in green-white containers on the ITU Ayazaga Campus, while plastic, paper, and metals are placed in blue containers. In two separate places, green containers are used to collect used oil. Grey containers are used to gather all other waste.
- Studies on waste characterisation are conducted at the ITU Ayazaga Campus. This analysis categorizes the campus into four fundamental types. They include academic buildings, office buildings, dining halls, cafeterias, and residential sections (dormitories and houses). The research does not include facilities used for maintenance or laboratories. A building is selected from each category to characterize the waste. The wastes are gathered and classified during a week. There are 18 waste components that make up the wastes in the blue and grey containers.
- ITU holds lectures for faculty, staff, and students to raise awareness of recycling and waste reduction. Additionally, the institution undertakes public education by deciding on a waste collection program and collecting waste within that framework of the program.
- The Ministry of Environment, Urbanization, and Climate Change awarded ITU the Basic Level Zero Waste Certificate after confirming that ITU met all of the requirements.
- The University has placed storage equipment for glass waste and textile/clothing waste separately in locations that are easy to reach for separate collection of wastes.
- The university created waste collecting centers and start-up. Additionally, the university organizes, informs, and directs the collection of various wastes, including batteries, vegetable waste oil, electrical and electronic equipment trash, medication waste, and bulky wastes, to the Waste Collection Center.

Istanbul Technical University Water Management (Istanbul Technical University Sustainability Report, 2022)*;*

- The university has free drinking water service is provided in the cafeteria and dormitories. With the standards, Tap Water is available to drink directly.
- ITU hosts the spring of Kanlikavak water, one of Istanbul's oldest and most historical water resources. Istanbul Water and Sewerage Administration (ISKI) is responsible for protecting and maintaining water resources in Istanbul and has recently made a landscape design. ITU also supports ISKI in achieving this objective.
- The ITU Environmental Engineering Club is responsible for the Tears of Water project, which focuses on social responsibility. The Project seeks to raise elementary school students' awareness of water use by offering free seminars and workshops.
- ITU conducts initiatives to raise awareness for water conservation and water use projects in several locations. Such as research on the ocean, marine, arctic, and other sciences or green building initiatives.
- ITU National Research Center on Membrane Technologies (MEM-TEK) has conducted a long-term project with the collaboration of the Istanbul Water and Sewerage Administration and studied advanced water treatment by applying membrane technologies.
- ITU has a water pond, called as Golet, which is used as a source to rain water. Extracted water from Golet is used as irrigation water in campus.
- 4 Mucilage-related projects of ITU were granted support by TUBITAK Research Funding Program Directorate (ARDEB). The Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Water Management supports the Adaptation to Climate Change in Water Resources Project. 30 metropolitan municipalities in Turkey are included in the initiative.
- The DIGIWATER project is run by ITU. The project consolidates the knowledge gained from decades of experience in the field and ensures the digitalization of the water industry by bringing together six universities, six small and medium-sized enterprises (SMEs), and a European umbrella organization for water. A workshop on the Current Situation and Future of Water Resources in the Context of Climate Change is also organized by the organization.
- The "Marine Pollution Detection for the Northern Region of the Bosphorus Project" started by IC Ictas Insaat is supported by ITU as a body. The project's

remote monitoring system, which protects the marine environment, coastline, and public health and was put into action with the help of the Turkish Straits Maritime Application and Research Center at Istanbul Technical University, was installed on a bridge for the first time ever in Turkey and the rest of the world.

- The ITU Water Management Directive was published to set forth the guidelines for the sustainable management of water used for other purposes on ITU campuses, including the removal of wastewater in a way that does not endanger human and environmental health. This directive also covers alternative water sources, such as rainwater and grey water. In this situation, the campus's whole produced wastewater is collected from the buildings and sent outside. Balta Port Wastewater Treatment Plant, run by Istanbul Water and Sewerage Administration, receives the collected wastewater.

Istanbul Technical University Transportation (Istanbul Technical University Sustainability Report, 2022)*;*

- ITU offers and expands designated bike lanes and lanes for electric scooters across the campus. They are decorated with red, preventing access to motorised vehicles through specially constructed small obstacles resembling bees as the university mascot. In order to promote more environmentally friendly transportation on campus, ITU also converts routes for motorized cars into pedestrian zones. Festival Road, Agaclı Road, and Konukevi Road are a few examples.
- To reduce the usage of personal automobiles for a more environmentally friendly commute, the university provides staff and faculty members with access to the university's 61 shuttle buses.
- The ITU campus traffic rules is quite clear that bicycles and all other vehicles come last for pedestrians. Crosswalks have been set up at 32 various places across Ayazaga Campus to serve as a reminder of this. The main entrance, which is the area of the campus with the highest concentration of pedestrians, is further highlighted with patterned tiles as an added safety precaution for motorized vehicles. Only pedestrian and bicycle access is now allowed in some parts of the campus, which has been opened for motor vehicle use until now.

Istanbul Technical University Education & Research (Istanbul Technical University Sustainability Report, 2022)*;*

- ITU is an EELISA European University (https://eelisa.eu), which means that it has received funding for the Erasmus+ program of the European Union. In line with the 2030 Agenda for Sustainable Development and the SDGs, EELISA seeks to exchange higher education between Europe and Turkey while strengthening links between engineering and society.
- ITU has Sustainability Office. The Sustainability Office of ITU aims to integrate sustainability as a core principle throughout education, research, and management. ITU provides students with academicians who are skilled to teach SDGs. The collaborative seminar and workshops that are targeted to educate the students and staff are conducted to share advanced knowledge through various activities every academic year. Eventually, the students can take their knowledge into their careers in the future.
- ITU publishes its annual sustainability report which covers from January to December every year. Sustainability reporting and financial reporting dates align.
- ITU has education courses related to SDGs ensured by Istanbul Technical University Continuing Education Center (ITU CEC). There are currently 111 sustainability courses at all levels, for both undergraduate and graduate levels.
- ITU has workshops, club activities and joint events for sustainability. The activities, value chain and other business relationships of ITU are managed based on the directive on the protection and sustainable use of biodiversity and ecosystems.
- Istanbul Provincial Disaster Risk Reduction Plan was compiled under the coordination of AFAD, with the contribution of relevant public institutions, local administrations, private and civil sectors, and our citizens, and presented to the evaluation of experts in their fields. The main purpose of this plan, which was prepared in partnership with AFAD and ITU, is to reveal the current situation in Istanbul and to identify the dangers and risks. Finally, it is the follow- up of the targets set in order to reduce these dangers and risks.
- The support is provided to two initiatives created and carried out with the goal of "effective firefighting" in collaboration with Istanbul Technical University Scientific Research Projects (BAP) and STFA Investment Holding AS.
- ITU is working with the Tohum Institution, an NGO that describes itself as an association for education, culture, and environment. Tohum is a member of the

ITU Climate Change Research Center's advisory board as a result of this partnership.

- ITU has collaborations on a national and international for a sustainable world. Such as EELISA European Engineering Learning Innovation and Science Alliance, ATHENS Programme, which is aimed at carrying out intensive specialization courses, CESAER which is European Association of Specialised and Complete Universities in Science and Technology, United Nations Sustainable Development Solutions Network (UN SDSN), AASHE Association for Advancement of Sustainability in Higher Education.
- ITU's initiatives in the field of innovation are supported by ITU Arı Teknokent and ITU Cekirdek. ITU Cekirdek provides various programs, one of which is the Sustainability Program. The start-ups promote and aid in the development of low-carbon technologies and economies. Academics are encouraged by ITU Ar Teknokent to collaborate with ITU infrastructure and Technopark businesses for long-term academic and industrial collaboration.
- ITU has a Lunch Scholarship (free of charge lunch).
- The Environmental Engineering Students Club of ITU organizes an event called Sustainable Ecosystem Days.
- ITU participated Women's Studies Center in Science, Engineering and Technology, and The Levy Economics Institute of Board College in cooperation with Integrated Lights Out (ILO), United Nations Development Programme (UNDP), and United Nations Women (UN Women).
- The university offers several scholarships to students who cannot pay their tuition for the duration of their time at the university. Such as scholarships, food, housing, transportation, and legal services. The institution offers four types of scholarships: achievement, athlete, food (including free lunch), and necessity. Also, students receive computers donated by the graduates association. To assist underprivileged students from low- or middle-income countries, free education and funding programs are also made available.
- The ITU Psychological Counselling and Guidance Center is a free mental health assistance organization. The institution also offers joint sports facilities for the local municipality, neighborhood residents, community, and schools. The sports

activities include Capoeira, Pilates, Yoga and Zumba courses, swimming pool and give lessons for children and adults, sport school basketball and Football.

- ITU ranked in the top 100 in the world for five goals of the 2022 Times Higher Education Impact Rankings. According to the rating of THE, in the list where a total of more than 1,400 universities worldwide are evaluated, ITU was ranked 20th in the world under the 9th objective of "Industry, Innovation and Infrastructure" and was also the leader in Turkey. In "Qualified Education", the 4th goal, it ranked 18th in the world by taking 1st place in Turkey. Moreover, It has also made progress in the 7th Goal, "Accessible and Clean Energy," and the 17th Goal, "Partnerships for Goals".
- The ITU has sustainability website(ITU Sustainability Website, 2023).

2.1.2.1.5. Cyprus International University

Cyprus International University (CIU) is a private university located in Nicosia, the capital city of North Cyprus. It was founded in 1997 and offers a wide range of undergraduate and postgraduate programs. CIU has multiple faculties that provide education in various fields. CIU has had faculties including Economics and Administrative Sciences, Fine Arts, Design and Architecture, Arts and Sciences, Communication, Engineering, Health Sciences, Law, Education, and Applied Sciences. CIU attracts a diverse student body, both from Cyprus and internationally. CIU emphasizes research and innovation, fostering a culture of inquiry and collaboration. The university encourages research activities and partnerships with local and international institutions (CIU Website, 2023).

Figure 2. 6. Cyprus International University Campus (CIU Website, 2023).

Cyprus International University in the Nicosia, Cyprus has scored 8350 points in the UI GreenMetric rank. 1250 from the Setting & Infrastructure category at 15 percent, 1575 from the Energy & Climate Change category at 21 percent, 1425 from the Waste category at 18 percent, 1000 from the Water category at 10 per cent, 1450 from the Transportation category at 18 percent, 1650 from Education & Research category with 18 percent(UI GreenMetric World University Rankings, 2022).

Cyprus International University Setting & Infrastructure(Cyprus International University Sustainability Report, 2020)*;*

- The campus's plant vegetation, which includes lawns, gardens, green roofs, and interior planting, covers over 150,800 m^2, or around 24%, of its entire area.
- Earth, grass, concrete blocks, and other non-retentive surfaces, totaling 130,500 m^2, account for 21% of CIU's campus.
- Forest, tall green plants, and trees cover more than 102,000 m^2 of CIU, or 17% of the total area of CIU.

Cyprus International University Energy & Climate Change (Cyprus International University Sustainability Report, 2020)*;*

- To increase energy efficiency, 50% of the campus's buildings have automation systems, including HVAC, central vacuum, and central heating systems.
- There is a lighting project on campus. The project's goal is to use modern technologies and intelligent control systems to improve lighting quality while reducing energy use and emissions.
- 75% of the campus's buildings have energy monitoring and management systems, enabling us to track each structure's energy use and control the energy supply.
- Flow meters and other water management systems are installed in 63% of the campus buildings. Systems for collecting rainwater are also utilized for irrigation and flushing.
- Every building on campus has equipment that controls the indoor environment, including passive cooling systems, thermal comfort, and air quality.
- Every building on the campus has smart lighting systems, including sensors, solar shading, and incredibly efficient LED lighting.
- There is a PV project at the university. A flat roof, an inclined roof, a landscape, a facade, and carports are just a few of the mounting types that will be used in the

solar energy project. On the island, it is the biggest solar energy installation at a university. 470 tons of CO_2 are lowered annually by the PV plant.

- The University plans to reach 1,260 kW electricity capacity by producing 411 m^3/h biogas with the Biogas Power Plant Project. The project reduces about 70 tons of fresh waste each year. In addition, approximately 1000 kW of heat capacity has been realized. Biogas plant provides 2,500 tons of CO_2 reduction per year.

Cyprus International University Waste Management (Cyprus International University Sustainability Report, 2020)*;*

- On the CIU campus, specific paper bins are used to collect paper waste. Paper waste and newspapers weigh 60 kg each month on average. A program has been formed by the Sustainable Innovation Center to regularly recycle these papers and produce paper-recycled pencils. One pencil requires about 5 gr of recycled paper to be produced. More than 10,000 recycled pencils have been made since the initiative began. These products are distributed or sold for academic uses.

- The remainder of the wastepaper, or around 70%, is utilized in the university's effort to make recycled pencils and concrete pots. On campus, these pots are used in a variety of ways.

- Plastic-free areas include the Nature Cafe Area, University restaurants, and the CIU Rectorate building. Additionally, the institution intends to eliminate the use of plastic water bottles entirely by placing free drinking water fountains across the campus. The majority of used plastic bottles on campus are currently collected and segregated from other waste in five large bins close to the canteen area.

- CIU offers an eco-friendly bag initiative made using recycled materials through sustainability workshops. These are available in the campus market and reduce plastic usage.

- The two types of organic waste, food and yard trimming are separated and recycled on the CIU campus. More than 50 kg of organic waste from the university's restaurants is collected for the animals with the help of the Nicosia municipality. A government-owned firm collects and removes this waste from campuses every day.

- There is a Nature café at CIU. The designation "plastic-free zone" (PFZ) applies to this location. The café is utilized to teach the public and students about the negative environmental consequences of toxic items like single-use plastic and serve as an example of campus waste management.
- CIU manage toxic waste treatment and sewage disposal.

Cyprus International University Water Management (Cyprus International University Sustainability Report, 2020)*;*

- 21 fountains around the campus purify 70,000 litres of municipal water each day to give free drinking water. CIU also contains two underground water storage containers with a combined capacity of more than 600,000 litres (600 m^3).
- Drip irrigation is provided at CIU. A total of 150,000 square meters of flowers and grassy areas, over 100,000 square meters of forest land with tall trees, and other land are all covered with drip irrigation systems installed in modern underground irrigation piping.
- The monitoring issue is one of the crucial elements in sustaining the water management system. In 2019, the CIU Sustainable Campus Office successfully finished a project to deploy water flow meters to each campus building separately. To prevent water losses, the Campus Management monitors and records water use on campus in order to compile a comprehensive archive.

Cyprus International University Transportation (Cyprus International University Sustainability Report, 2020)*;*

- Six shuttles are served every day for the university. Additionally, both buses have areas that are accessible for individuals with disabilities. Every day, on average, around 11,000 students use campus buses. Additionally, Cyprus International University's Transportation Unit provides employees and students with complimentary shuttle services.
- The university campus has roughly 19,000 m^2 of open or horizontal type parking spaces, or about 3% of the overall campus area.
- Ramp roads and disability access are available at all campus buildings and facilities. The over 640 meters of tactile paving on the campus provide easy access to the numerous areas for people who are blind or visually impaired.

- There are 26 bicycles available at two major campus stations for biking around the university. Employees, campus administration, maintenance office, and security personnel use a total of 70 electrical bicycles.

Cyprus International University Education & Research (Cyprus International University Sustainability Report, 2020)*;*

- There are 430 courses pertaining to sustainability at the university, and more than 29 publications relevant to sustainability have been provided on Google Scholar. There are also 50 Master's and PhD theses on sustainability at CIU.
- The Sustainable Campus Project incorporates 40 staff members, 35 undergraduate and graduate students.
- The CIU Sustainable Campus team offers more than 100 hours of courses on topics like Simple Energy Management, Water Efficiency, and the Best Ways to Reduce Waste Production and the Recycling Process. The majority of the activities planned for summer school center on educating students about their environmental effect and getting them involved in the sustainable campus initiative.
- During the first week of August, which is Global Environment Day, the CIU conducts sustainable initiatives, including cleaning up the campus environment and planting trees. The campus was thoroughly cleaned throughout this week, and about 300 kilograms of environmental waste were collected.
- Outside activities, like yoga, are practiced on campus to be more environmentally conscious.
- The university has an energy laboratory project. In the project, hydrogen-powered cars were tried to be created using renewable energy forms and solar panels. A special certificate was created for the students with the recycled papers developed by the students during the workshops.
- The CIU has sustainability website (CIU Sustainability Website, 2023).

2.1.2.1.6. Erciyes University

Erciyes University is a state university located in Kayseri, Turkey. It was founded in 1978 and offers a wide range of undergraduate and postgraduate programs. Erciyes University is organized into several faculties covering various academic disciplines. Erciyes University has had faculties such as Medicine, Dentistry, Pharmacy, Engineering, Arts and Sciences, Veterinary Medicine, Economics and Administrative Sciences, Education, Fine Arts, Communication, Law, Architecture, Theology, and Health Sciences. Erciyes University has a significant student population, attracting students from Turkey and around the world. The university places on research and innovation, actively engaging in research projects and collaborations with national and international institutions (ERU Website, 2023).

Figure 2. 7. Erciyes University Campus (ERU Website, 2023).

Erciyes University in the Kayseri, Turkey has scored 8260 points in the UI GreenMetric rank. 1325 from the Setting & Infrastructure category at 15 percent, 1535 from the Energy & Climate Change category at 21 percent, 1425 from the Waste category at 18 percent, 800 from the Water category at 10 per cent, 1600 from the Transportation category at 18 percent, 1575 from Education & Research category with 18 percent(UI GreenMetric World University Rankings, 2022).

Erciyes University Setting & Infrastructure (Erciyes University Sustainability Report, 2021)*;*

- ERU campus has 95% open space and 24.38% cultivated green space. On the campus, the places for planting saplings are marked, a sapling pit is opened, the soil is distributed and planted. In addition, tree transplantation, grass planting, flower planting, ornamental plants planting, irrigation works, irrigation plant and repair, pruning works are carried out on the campus.

- In ERU, pesticides are applied in the pond area in the botanical garden to clean the water and prevent the formation of algae and odour. The reed beds in the pond are also pruned and maintained. In addition, environmental cleaning, fertilization, spraying and greenhouse activities are carried out within the campus.
- With the "Water Dispenser Project", one of the Social Responsibility Projects of Erciyes University, the water needs of birds, tides and other creatures are met thanks to the water dispensers installed all over the campus.

Erciyes University Energy & Climate Change (Erciyes University Sustainability Report, 2021)*;*

- During the transformation and restructuring of physical spaces throughout Erciyes University, the lighting systems in study offices, laboratories and classrooms were replaced with LED lamps instead of fluorescent lamps. In this way, both energy saving and an effective lighting system were created.
- Research is carried out at the university to ensure that all renovations and new construction comply with energy efficiency requirements. The university uses energy-efficient appliances, computers, and ventilation and heating systems.
- The 2500C waste heat generated in the heater used in the heating centre on the campus is concentrated with an economizer and used to heat the water. Groundwater in air conditioning systems has a heat recovery system for cooling and energy saving. The Genome and Stem Cell Centre uses inverter air conditioner technology with a heat recovery battery.
- Automation, security, energy, water, indoor environment and lighting criteria, which are among the smart building parameters, are applied in 81% of university buildings.
- On the campus and on the Technopark property, renewable energy sources like solar panels provide about 9384 KW of power each year.
- Erciyes University Energy Transformations Research and Application Center organized the International World Energy Conference.

Erciyes University Waste Management (Erciyes University Sustainability Report, 2021)*;*

- "Waste Management Training" was given by ERCEVREM and Environmental Engineering Department at Erciyes University. Information has been given about the environmental policies implemented at the university and on campus. In addition, a "Zero Waste Seminar for a Green and Blue World" has been held.

- Erciyes University Moon Child Education Center organized a "Zero Waste Costume Party" for our children to raise awareness about Zero Waste and recycling. The students, who performed the activity with their creative and cute costumes designed by re-evaluating waste materials, presented colourful images.
- Erciyes University Department of English Language and Literature initiated a social responsibility project to draw attention to waste batteries.

Erciyes University Water Management (Erciyes University Sustainability Report, 2021)*;*

- There are wastewater treatment processes in the university. And there is a grey water treatment system in one campus building, and the treated water can be reused. For example, wastewater from sinks and bathrooms is recycled using a grey water tank. Recycled water is used for siphoning garden sprinklers and toilets.
- The university has a pilot scale treatment system that purifies 10 m^3 of water daily and makes it reusable. This building was acquired through a project funded by the Scientific and Technical Research Council of Turkey (TUBITAK), and it serves as a research lab for students.
- Landscaping arrangements were made within the campus to minimize water use. Campus green areas are irrigated with timed drip or sprinkler systems according to needs.
- Sustainable water extraction on the lands of the university uses technologies. There are underground water wells on campus that are extracted according to need.
- In the university, the total water consumption is measured regularly through computer systems every year.
- "Smart City Management" and "Water Management in Cities" seminars were held online by ERU Environmental Problems and Cleaner Production Application and Research Center and Environmental Engineering Department.

Erciyes University Transportation (Erciyes University Sustainability Report, 2021)*;*

- Transportation to Kayseri, at a critical junction point of highways in Turkey, is provided by highway, airway and railway. The university, the city centre and the dormitories can be reached by company shuttles, buses and trams. There is a light rail system on campus.

- There are bicycle and electric scooter rental systems, which the Kayseri Metropolitan Municipality provides at many points in the central campus. In the procedure called KAYBIS, member students use bicycles for free for the first half hour. Secure bicycle storage areas have been created in the open car parks on the campus.
- Campus ring services are electrically operated and have low emissions. On-campus shuttle services are provided regularly and free of charge by the University.
- Disabled students are admitted to the university by Kayseri Metropolitan Municipality. A green bus has been allocated for our students, staff and other disabled individuals operating on campus.
- Ramps and directional blocks are designed for physically disabled pedestrians on the campus and have disabled-friendly applications.
- It is aimed to minimize the carbon level by reducing the vehicle traffic on the campus or making it carbon-neutral. Adequate lighting is provided on pedestrian paths and sidewalks. Necessary safety practices have been made to separate vehicle and pedestrian roads.

Erciyes University Education & Research (Erciyes University Sustainability Report, 2021)*;*

- Within the scope of undergraduate, graduate and doctorate courses at the university, ERU has had an average of 410 publications, 85 clubs and 459 events on sustainability and 85 courses on environment and ecology, 63 on water and wastewater, and 14 on waste directly. The budget allocated to research on sustainability has also increased by 10% in the last three years.
- ERU has ERCEVREM and Environmental Engineering Department, which organizes events and training related to sustainability.
- Erciyes University has a Sustainability Society. The group has an event called "From Plastic to Food, to Help Our Silent Friends" with the support of Melikgazi Municipality. Cat and dog foods are left at the points determined by this activity.
- The ERU has sustainability website (ERU Sustainability Website, 2023).

2.1.2.2. UI GreenMetric Index and Duzce University Campus

Duzce University is a state university located in Duzce, Turkey. It was founded in 2006 to meet the growing demand for higher education in the region. It has approximately 30,000 students and more than 1,500 academic staff. The faculties of the university are Engineering, Economics and Administrative Sciences, Arts, Design and Architecture, Education, Health Sciences, Technology, Communications, Medical School and Political Sciences. The campus of the university includes modern classrooms, libraries, laboratories, conference halls, sports facilities, dining halls and student clubs. In addition, social, cultural and sports activities are organized for students (DU Website, 2023).

Figure 2. 8. Duzce University Campus (DU Website, 2023).

Duzce University ranked 382nd in the index, which includes 1050 universities from various countries in 2022. It ranked 32nd among 83 Turkish universities in 1050 universities (Duzce University Computer Center, 2023).

Duzce University in the Duzce, Turkey has scored 6610points in the UI GreenMetric rank. 1125 from the Setting & Infrastructure category at 15 percent, 1235 from the Energy & Climate Change category at 21 percent, 1050 from the Waste category at 18 percent, 350 from the Water category at 10 per cent, 1275 from the Transportation category at 18 percent, 1575 from Education & Research category with 18 percent, as seen in **Table 2.9.**(UI GreenMetric World University Rankings, 2022).

Table 2. 12. UI GreenMetric Duzce University overall rankings 2022 (Universitas Indonesia, 2022).

Rank 2022	University	Country	Total Score	Setting & Infrastructure	Energy & Climate Change	Waste	Water	Transportation	Education & Research
382	Düzce University	Turkey	6610	1125	1235	1050	350	1275	1575

Duzce University Setting & Infrastructure (Duzce University Sustainability Report, 2022)*;*

- Duzce University has the geographical advantage of being closely located between metropolitan cities Istanbul and Ankara. The Genoese Castle, built in today's Akcakoca district (42 km from the university) in the early 13th century, is an important artefact that has survived the Roman period and has got its name written on the UNESCO World Heritage Tentative List. On the university campus is the Konuralp Museum, where valuable archaeological artefacts are also exhibited. Efteni Lake, where five streams pass through the city and meet, also appears as an important bird migration route point under the status of a wildlife protection and development area. The university is in a valuable geographical location with its rich history, natural and cultural structure.
- On the campus, there are three types of natural areas; natural oak forest, black pine forestation area and maquis vegetation, specific to the Mediterranean climate. The area covered by the natural oak forest is 298.770 m^2, the afforestation area is 294.525 m^2, and the area covered with maquis is 305.381 m2. 33.90% of the entire area is covered with forest vegetation.
- 1.661.123,50 m^2 of campus is open space. There is a botanical garden of 46,276 m^2 and a forest of 298,770 m^2 in the open areas. Other open areas consist of planted green areas, permeable and impermeable surfaces. 86% of the total area is comprised of open space.
- In addition to the forest and cultivated plants, there are other places on campus where water can be absorbed. The permeable areas on the campus are 173.481 m^2. The ratio of permeable areas to the total area is 10%.
- Various infrastructure opportunities and projects are available at Duzce University to protect plants, animals and wildlife. Conservation studies and works

are carried out on the central campus, within the University Greenhouse, Experimental Animals Application and Research Center, Herbarium, Biodiversity Application and Research Center and the botanical garden.

- Provincial development plans comprehend land sustainability, scientific management of soil wealth, space efficiency, environmentally friendly economic and urban development, etc. as main goals. In this context; the university has been declared as a “Specialization University in the Field of Environment and Health” by Turkish Higher Education Council.
- DU has DAGEM (Beekeeping Research, Development and Application Center). DAGEM's primary goal is to develop regional and country beekeeping and contribute to the solution of the problems in the sector, and to produce projects on both scientific and socio-economic issues. In the center, various TUBITAK, DUBAP and EU supported projects are carried out on bee biology, bee breeding, bee breeds, bee diseases, bee products, development of modern equipment used in beekeeping and beekeeper training.
- There is a security infrastructure on campus and there are fire extinguishers, fire cabinets, shelters, security units, etc. related to safety for accident, crime, fire and natural disaster.

Duzce University Energy & Climate Change (Duzce University Sustainability Report, 2022)*;*

- DU uses LED lighting.90% of the bulbs used in campus lighting are in the energy-saving bulb category.
- DU has two renewable energy sources, which are solar and wind energy.
- The campus has smart building implementation for the rectorate building. The building has automation systems for electricity and mechanical, such as control lighting, heating, cooling, and ventilation with a remote.
- Total annual CO_2 measurement is carried out on campus.

Duzce University Waste Management (Duzce University Sustainability Report, 2022)*;*

- Every unit has a recycling container placed by DU. Additionally, there are clothing donation points in each residence hall on campus.
- In line with the declaration of the University as "Specialization University in the Field of Environment and Health" by the Council of Higher Education,

"Agricultural Waste Recycling Application and Research Center for Industry" was established.

- The University is working on zero waste management applied throughout the Municipality.
- There is a program implemented for paper waste. Separately collected paper waste is sent for recycling periodically.
- EBYS (Electronic Document Management System) is used in order to save paper and speed up the processes during the work and transactions.
- Du manages the recycling of plastic, organic, inorganic and toxic waste.

Duzce University Water Management (Duzce University Sustainability Report, 2022)*;*

- In the DU campus, water is supplied from the wells drilled and delivered to the campus after the treatment process.
- Drip irrigation system is used in the campus.
- The campus has a water conservation program, and water pollution control is provided.

Duzce University Transportation (Duzce University Sustainability Report, 2022)*;*

- Various facilities are being provided for the disabled in the indoor and outdoor areas of the campus. There are elevators, ramps, WCs for disabled people, and notices written in Braille in all buildings. Pedestrian routes are suitable for the standards stated for disabled people. There is a tactile paving application on the pedestrian roads.
- There is a nursery on campus, although babysitting opportunities are limited.
- Du has projects for increasing pedestrian paths on campus.
- There are shuttles and public transport available on campus. There are staff service and a ring to the on campus cafeteria at lunch time.

Duzce University Education & Research (Duzce University Sustainability Report, 2022)*;*

- The campus has research centres and labs.
- DU prepare workshops, seminars, training, courses, activities and events for sustainability.
- DU has publications about sustainability on the postgraduate and undergraduate.

- DU provide sports facilities such as a fitness centre, swimming pool, basketball, football and volleyball court.

2.2. SUSTAINABLE BUILDING SYSTEMS

Sustainable buildings are designed and constructed using environmentally conscious practices to minimize negative environmental impacts and promote sustainable living. Such buildings aim to reduce energy consumption, minimize water usage, and utilize renewable resources.

There are several types of sustainable buildings:

- **Green Buildings:** These are buildings designed with environmentally friendly materials and technologies, including energy-efficient lighting and heating systems, green roofs, and natural ventilation(Al-Atesh et al., 2023)(Song et al., 2023)(Redlein, 2022)(Copiello & Coletto, 2023)(Jorge-Ortiz et al., 2023)(Manoj & Kumari, 2023).

  Green building certifications exist to evaluate green campuses. The most common certification systems are LEED, BREEAM, DGNB, EDGE, SBTool, GreenStar, WELL, Level(s), CASBEE(Boni, 2020)(Erbıyık et al., 2021)(Goubran et al., 2023)(Xhexhi, 2023)(Zhao et al., 2023).

  SEEB-TR and CEDBIK are green building certification systems in Turkey (TMMOB Mimarlar Odası, 2015)(Islam, 2022)(Kutlu & Bekar, 2023).
- **Passive Buildings:** These buildings utilize the building's orientation, insulation, and airtightness to maintain a comfortable indoor temperature without the need for active heating or cooling systems(Simpeh et al., 2023)(L. Zhang et al., 2023).
- **Energy-Efficient Buildings:** These buildings incorporate energy-efficient technologies and design features, such as efficient lighting systems, energy-efficient appliances, and high-performance insulation(ICE Publishing, 2023)(Raouf & Al-Ghamdi, 2023).
- **Low-Energy Buildings:** These buildings consume minimal energy, typically through a combination of energy-efficient design features and renewable energy sources(Nguyen & Macchion, 2023)(Nguyen et al., 2023).
- **Net Zero Energy Buildings (nZEB):** Net Zero Energy Building (nZEB) is a building that uses low primary energy and can make its annual energy balance zero with the renewable energy produced. These buildings use renewable energy

sources to generate all the energy they need to operate, typically through solar panels, wind turbines, and geothermal systems(Abrahamsen et al., 2023)(Backe et al., 2023)(Di Turi et al., 2023)(Masoud Sajjadian, 2023)(Plachinda et al., 2023)(Tirelli & Besana, 2023)(Wei et al., 2023)(J. T. Report, 2023).

- **Net Positive Energy Buildings:** Net Positive Energy Buildings are called structures that produce more energy than their own needs integrated into the building.These buildings often use renewable energy sources like solar cells, wind turbines, or geothermal systems to create more energy than they use(Alam & Masrafy, 2023)(Jung et al., 2023).
- **Smart Buildings:** These buildings use advanced technologies, such as sensors and automation systems, to optimize energy consumption, improve indoor air quality, and enhance occupant comfort(Ejidike & Mewomo, 2023)(Nižetić et al., 2023)(Qiu et al., 2023).

2.2.1. Smart Buildings

A smart building is a structure that uses advanced technology and automation to enhance the comfort, safety, and energy efficiency of its occupants. Smart buildings integrate different systems and devices, such as lighting, heating, ventilation, air conditioning, security, and communication systems, to provide a seamless and interconnected experience for the users(Tostado-Véliz et al., 2023)(Lam et al., 2023)(D. Li et al., 2023)(Haidar et al., 2023).

Some of the key features of a smart building are (Salsbury et al., 2023)(Amini Toosi et al., 2023)(H. Huang et al., 2023):

- Energy efficiency: Smart buildings use sensors and automation to optimize energy consumption and reduce waste, leading to lower operating costs and a smaller environmental footprint.
- Indoor air quality: Smart buildings monitor and regulate air quality by controlling ventilation and air filtration systems, ensuring a healthy and comfortable environment for occupants.
- Security: In order to provide a high degree of security and defend against threats, smart buildings utilize advanced monitoring and access control systems.

- Connectivity: Smart buildings offer seamless connectivity through wireless networks and internet-of-things (IoT) devices, enabling easy communication and collaboration between occupants and devices.
- Automation: Smart buildings automate many routine tasks, such as lighting and temperature control, freeing up time and resources for other activities.
- Data analytics: Smart buildings use data analytics to monitor and optimize their performance, identifying areas for improvement and predicting future needs.

While both smart buildings and other sustainable buildings share a focus on reducing environmental impact and increasing energy efficiency, there are some critical differences between those (Ghansah & Lu, 2023)(Caldera et al., 2023)(Blechmann et al., 2023)(Balakumar et al., 2023):

- Technology integration: Smart buildings use advanced technologies, such as automation, sensors, and artificial intelligence, to optimize energy use and improve occupant comfort. On the other hand, sustainable buildings focus on reducing energy use through passive design strategies, such as natural ventilation and daylighting.
- Occupant comfort: Smart buildings prioritize occupant comfort through personalized settings and real-time adjustments based on occupancy and environmental conditions. Sustainable buildings may prioritize energy efficiency over occupant comfort.
- Data analytics: Smart buildings use data analytics to monitor and optimize their performance, identifying areas for improvement and predicting future needs. Sustainable buildings may not have the same level of data analytics capabilities.
- Cost: Smart buildings may require a higher initial investment due to the advanced technology and systems needed. Sustainable buildings may have a lower initial cost but not the same advanced technology and automation level.
- Flexibility: Smart buildings are designed to adapt to changing occupant needs and preferences. Sustainable buildings may have a more fixed design based on passive strategies and may not be as easily adaptable to changing conditions.

In summary, smart and sustainable buildings aim to reduce environmental impact and increase energy efficiency. Smart buildings prioritize technology integration and occupant comfort through advanced systems and data analytics, while other sustainable buildings focus on passive design strategies and may have lower initial costs(Guillermo et al., 2023)(Khan et al., 2023)(Ilaria Salerno, 2023)(Khampuong et al., 2023)(Henrique et al., 2023).

2.3. ENERGY SIMULATION

Energy simulation is used to predict and analyze the energy performance of buildings, systems or processes. It helps optimize energy use, assess renewable energy potential, and estimate energy costs and savings. Input data is used to simulate energy performance, and outputs inform decision-making for energy efficiency measures, system design, and operational strategies.

The sustainability areas that can be evaluated and analyzed with energy simulation are listed as follows:

- Greenhouse Gas (GHG) and Carbon (CO_2) Emissions,
- Zero Carbon Emission Building Systems (nZEB),
- Life Cycle Assessment (LCA),
- HVAC Systems,
- Indoor Environmental Quality (IEQ),
- Lighting Systems (LTG),
- Water Management (WR),
- Photovoltaic (PV) and Wind Power (WP) Renewable Energy Assessments,
- Retrofit Analysis (RTF),
- Materials Analysis,
- Green Building Certifications (GBC),
- Sustainable and Smart Cities (SC),
- Cost Analysis,
- Climate Analysis.

2.3.1. Energy Simulation Tools

There are many simulation tools for AEC industry. The most common tools are *EcoDesigner Star*, *DesignBuilder*, *EnergyPlus*, *IES VE*, *Ladybug*, *Honeybee*, *Diva*, *Insight 360*, *Energy 3D*, *DOE-2*, and *eQUEST*. In addition, there are more software such as *Lightstanza*, *Dialux*, *PD Shading Box* and *3D Sun-Path*, which can analyze artificial and natural lighting and shadows of buildings, *Acoustic Calculator*, which can provide acoustic control in facilities, *Pathfinder*, which can calculate carbon footprint, *SimaPro* with the Ecoinvent database used for LCA, which can be used to calculate the environmental effects of a product from the cradle to the grave numerically(X. Li et al., 2023)(Chang & Hsieh, 2020).These tools and their features are given in the **Table 2.12.**

Table 2. 13. The commonly used energy simulation tool features.

Energy Simulation Tool	Price	Features
EcoDesigner Star	Free	Integrated with BIM-Archicad,building performance analysis,,passive design optimization, energy consumption estimation, carbon footprint calculations
DesignBuilder	Commercial	Building energy simulation, energy efficiency analysis, HVAC system optimization, renewable energy integration
EnergyPlus	Free	Climate simulation, energy consumption and building performance simulation, support for different HVAC systems
IES VE	Commercial	Building energy analysis, thermal comfort assessment, renewable energy integration, carbon footprint calculations
Ladybug	Commercial	Building performance analysis, energy simulation, microclimate analysis
Honeybee	Commercial	Building energy simulation, microclimate analysis, daylight analysis, parametric optimization
Diva	Commercial	Building energy simulation, thermal comfort analysis, visual comfort analysis, daylight analysis
Insight 360	Free	Integrated with BIM-Autodesk Revit, building energy analysis, thermal comfort assessment, renewable energy integration

Table 2. 14. (continuation) The commonly used energy simulation tool features.

Energy 3D	Free	Building energy simulation, solar energy analysis, renewable energy system design
DOE-2	Commercial	Building energy simulation, HVAC system analysis, indoor air quality assessment, thermal comfort analysis
eQUEST	Commercial	Building energy analysis, evaluation of energy-saving potential, renewable energy integration
Lightstanza	Commercial	Building energy simulation, daylight analysis, energy-saving analysis
Dialux	Free	Lighting simulation, interior lighting design, energy consumption estimation
PD Shading Box	Free	Shading analysis, solar irradiation simulation, energy-saving analysis
3D Sun-Path	Free	Sun path analysis, shading analysis,solar energy potential assessment
Acoustic Calculator	Commercial	Sound simulation, acoustic performance analysis, noise control, sound insulation optimization
SimaPro	Commercial	Life cycle assessment, environmental impact analysis, product sustainability assessment, carbon footprint calculations

DesignBuilder;

A software program used in energy modelling and simulation of building performance is called DesignBuilder. It is a thorough and user-friendly platform that enables building experts like architects, engineers, and others to examine and improve a building's energy performance during the design and operating stages (C. Chen et al., 2023)(Beyraghshamshir & Sarkardehei, 2023)(Anupong et al., 2023).

EnergyPlus;

The U.S. Department of Energy (DOE) created EnergyPlus, a program that is frequently used to simulate the energy usage of buildings. It is a tool for whole-building energy modelling that enables architects, engineers, and building specialists to simulate and assess the energy performance of buildings in order to enhance their conception, functionality, and energy efficiency(De León et al., 2023)(Ruan et al., 2023)(Eggimann et al., 2023).

EnergyPlus simulates the energy consumption of various building components, including heating, ventilation, and air conditioning (HVAC) systems, lighting systems, building envelope, and renewable energy systems. It uses detailed thermal, electrical, and airflow models to calculate energy use, thermal comfort, and indoor air quality in buildings(Zheng et al., 2023)(Cho et al., 2023)(H. X. Li et al., 2023).

EnergyPlus is capable of simulating a wide range of building types, from residential homes to complex commercial and industrial buildings. It includes a large library of building components, materials, and systems, allowing users to model different configurations and compare their energy performance. EnergyPlus also supports advanced features such as parametric analysis, weather data customization, and integration with other simulation tools and software platforms(X. Wang et al., 2023)(Arbulu et al., 2023)(Y. Chen, Gao, et al., 2023).

EnergyPlus is widely used by building professionals, researchers, and policymakers to evaluate the energy performance of buildings, assess the impact of different design and operational strategies, and guide decision-making related to building energy efficiency, renewable energy integration, and sustainability(Franco et al., 2023)(J. Huang & Kaewunruen, 2023)(W. Wu et al., 2023).

IES VE;

IES VE, short for Integrated Environmental Solutions Virtual Environment, is a building performance analysis software that is used for building energy modelling and simulation. It allows architects, engineers, and building professionals to simulate and analyze the energy performance, thermal comfort, daylighting, and other environmental factors of buildings in order to optimize their design and operation(Catto Lucchino & Goia, 2023)(Oleiwi & Mohamed, 2023)(Teo et al., 2023).

IES VE provides a wide range of capabilities, including building energy modelling, HVAC system simulation, lighting analysis, solar shading analysis, renewable energy analysis, indoor air quality analysis, and water use analysis. It can be used for various types of buildings, including residential, commercial, industrial, and institutional buildings(Morshed & Mourshed, 2023)(J. Li et al., 2023).

IES VE uses advanced simulation algorithms to predict the energy consumption and performance of a building, based on factors such as building geometry, construction materials, HVAC system design, lighting systems, and occupant behavior. It also provides options for incorporating renewable energy systems such as solar panels and wind turbines into the building design, and evaluating their impact on energy performance (Grygierek et al., 2023).

IES VE is commonly used in the architecture, engineering, and construction industries to inform design decisions, optimize building performance, and achieve sustainability and green building certifications such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method)(Garwood et al., 2018).

Ladybug;

Rhino Ladybug is a software plugin for Rhino, which is a popular 3D computer-aided design (CAD) software used in the architecture, industrial design, and product design fields. Rhino Ladybug is specifically designed for environmental analysis and simulation within the Rhino software environment. It provides tools for performing daylight analysis, energy modelling, and other environmental assessments to aid in sustainable design practices (Typologies, 2023).

The Rhino Ladybug plugin is based on the Ladybug Tools, which is an open-source set of environmental analysis tools for building performance simulation. It allows designers to analyze and visualize various environmental parameters such as daylight availability, solar radiation, thermal comfort, and energy consumption, among others. This information can be used to optimize building designs for energy efficiency, occupant comfort, and environmental sustainability (J. Huang et al., 2023).

Rhino Ladybug is often used by architects, engineers, and other design professionals who want to incorporate environmental analysis into their 3D modelling and design workflows. It provides a range of tools and visualizations to help users understand the environmental performance of their designs and make informed decisions to improve sustainability and performance (Sun et al., 2023).

Honeybee;

Honeybee is a plugin or extension for Rhino that is used for building energy modeling and environmental analysis, with a focus on sustainability (Ahmadi et al., 2023).

Honeybee is commonly used in the field of architecture, engineering, and sustainable design to simulate and analyze the performance of buildings in terms of energy efficiency, daylighting, thermal comfort, and other sustainability-related factors. It allows architects and designers to evaluate the environmental performance of their building designs, optimize energy consumption, and make informed decisions regarding building materials, orientation, and other design parameters (Rastegari et al., 2023).

The Honeybee tool in Rhino typically utilizes parametric modelling techniques, which allow designers to create and manipulate building geometries and environmental parameters within the Rhino interface. The tool then uses simulation engines, such as EnergyPlus or Radiance, to analyze the building's performance based on the defined parameters and provide feedback on energy consumption, lighting levels, and other sustainability-related metrics (Altitudes, 2023).

Using Honeybee in Rhino for sustainability analysis can help architects and designers make more informed decisions about building design and achieve more sustainable and energy-efficient buildings. It is worth noting that Honeybee is a specialized tool and requires expertise in building physics and environmental analysis to use effectively (Ulu, 2023).

Diva;

Diva Energy is a simulation tool used for evaluating and analyzing the energy performance of buildings. It is a software plugin that works with Rhino, a popular 3D modeling software used in architecture and design, and it is specifically designed for building performance analysis and daylighting simulation. Diva Energy allows architects, engineers, and designers to model and simulate the energy usage and daylighting performance of buildings during different times of the year, in order to optimize building design and make informed decisions for energy efficiency and sustainability (Navabi et al., 2023).

Diva Energy offers a wide range of features, including energy performance analysis, daylighting analysis, thermal comfort analysis, solar analysis, and shading analysis. It uses various simulation methods and algorithms to calculate energy consumption, daylighting levels, and other performance metrics based on the building's geometry, materials, and location. Diva Energy also provides visualizations and reports that help users interpret and analyze the simulation results, allowing them to identify potential areas for improvement in terms of energy efficiency and sustainability (Sorooshnia et al., 2023).

Insight 360;

Insight 360 for Revit is a software tool offered by Autodesk, a leading provider of design and engineering software, that integrates with Autodesk Revit, a widely used building information modelling (BIM) software. Insight 360 for Revit is specifically designed to provide energy analysis and simulation capabilities within the Revit environment, with the goal of helping architects, engineers, and building professionals optimize energy performance in building designs (Maglad et al., 2023)(Ferreira et al., 2023)(Mathews et al., 2023).

Insight 360 for Revit allows users to analyze and simulate various aspects of a building's energy performance, including heating, ventilation, and air conditioning (HVAC) systems, lighting systems, and building envelope performance. It provides insights and data-driven feedback on the energy performance of a building design, allowing users to assess the impact of different design options on energy consumption, thermal comfort, and environmental sustainability (Yusuf, 2023)(Altassan et al., 2023)(Gao et al., 2023).

Energy3D;

Energy3D is a software tool for designing and simulating renewable energy systems and sustainable buildings. It is a three-dimensional modelling tool that allows users to create virtual models of buildings, landscapes, and energy systems, and simulate their performance under various environmental conditions. Energy3D is often used in the field of sustainable architecture, urban planning, and renewable energy research to assess the energy efficiency of buildings, evaluate the performance of renewable energy technologies, and optimize the design of sustainable energy systems (Energy 3D, 2023).

Energy3D offers a wide range of features, including a comprehensive database of renewable energy technologies such as photovoltaic panels, wind turbines, and solar water heaters, as well as building components such as walls, roofs, windows, and shading devices. Users can design and customize their virtual models by placing and configuring these components in a 3D environment, and simulate their performance using various simulation tools (Energy 3D, 2023).

Energy3D also includes advanced simulation capabilities for solar energy, wind energy, and thermal energy, allowing users to analyse the performance of renewable energy systems under different weather conditions, geographic locations, and design parameters. The tool provides visualizations of energy production, consumption, and storage, as well as environmental impacts such as carbon emissions and shading analysis. Additionally, Energy3D supports integration with geographic information systems (GIS) data, allowing users to import real-world topographic and climate data for more accurate simulations (Energy 3D, 2023).

DOE-2;

DOE-2 (short for "Department of Energy-2") is widely used building energy simulation software developed by the United States Department of Energy (DOE). It is a whole-building energy analysis program that helps architects, engineers, and energy analysts evaluate the energy performance of buildings, including their energy consumption, heating, cooling, lighting, and other energy-related systems (Alhazzaa, 2023).

DOE-2 allows users to create virtual building models and simulate their energy performance under different weather conditions, occupancy schedules, and equipment configurations. It uses algorithms to calculate energy consumption and related performance metrics, such as HVAC system efficiency, lighting power density, and thermal comfort. Users can input various building parameters, such as building geometry, insulation levels, fenestration properties, and HVAC system details, to accurately model the building's energy performance (Tang et al., 2023).

DOE-2 is often used for building design and retrofit projects to evaluate the impact of different energy conservation measures (ECMs) and design alternatives on a building's energy performance. It can be used to optimize building design, assess compliance with energy codes and standards, estimate energy savings from retrofits, and support decision-making related to building energy efficiency (G. Li et al., 2023).

DOE-2 has been widely used in the field of building energy analysis and is recognized for its accuracy and flexibility. However, it has been largely superseded by more advanced building energy simulation tools such as EnergyPlus, which is also developed by the U.S. Department of Energy and offers improved capabilities and features for building energy analysis (T. Wu et al., 2023).

eQUEST;

eQUEST (short for Quick Energy Simulation Tool) is a widely used building energy modeling software program. It is used by architects, engineers, and other building professionals to simulate and analyze the energy performance of buildings, including their heating, cooling, lighting, and ventilation systems. eQUEST is known for its user-friendly interface and comprehensive capabilities for energy analysis, making it a popular choice for designing energy-efficient buildings and optimizing building performance (Kumar et al., 2023).

eQUEST allows users to input building design and operational parameters, such as building geometry, construction materials, HVAC (Heating, Ventilation, and Air Conditioning) systems, lighting, and occupancy schedules. It then uses simulation algorithms to calculate and analyze the building's energy use, energy consumption, and carbon emissions. eQUEST provides detailed reports and visualizations that help users understand and optimize a building's energy performance, compare different design alternatives, and make informed decisions about energy-saving strategies (Prabu & Rakesh, 2023).

eQUEST is widely used in the design and evaluation of various types of buildings, including commercial, residential, institutional, and industrial buildings. It is recognized by many green building certification programs, such as LEED (Leadership in Energy and Environmental Design), and is often used to demonstrate compliance with building energy codes and standards. eQUEST is also used in energy auditing, retrofit analysis, and performance monitoring of existing buildings to identify opportunities for energy savings and sustainability improvements (Rakesh et al., 2023).

EcoDesigner Star;

EcoDesigner Star is building energy analysis software developed by Graphisoft, a leading provider of BIM (Building Information Modelling) solutions for architects, engineers, and construction professionals. EcoDesigner Star is specifically designed for use with Graphisoft's Archicad, popular BIM software for architects and designers (Graphisoft, 2023)(Cascone, 2023).

EcoDesigner Star allows architects and designers to perform energy simulations and analysis directly within Archicad, helping them to optimize the energy performance of their building designs and make informed decisions about energy-efficient design strategies. The software provides a wide range of energy analysis on building energy consumption, amount of heating and cooling, solar radiation, shading and indoor comfort.It also allows users to evaluate the environmental impacts of their building designs, such as carbon emissions and life cycle assessment (LCA) (Shah et al., 2023)(Zahra Abdillahi, 2022).

EcoDesigner Star is a tool that can help architects and designers design more sustainable and energy-efficient buildings, comply with energy codes and standards, and achieve green building certifications. It can also assist in identifying potential energy-saving measures, comparing different design options, and improving overall building performance (Olanrewaju et al., 2022)(Bonomolo et al., 2021).

Greenhouse Gas Emissions (GHGE), Net Zero Emission Buildings (nZEB), Life Cycle Assessment (LCA), Heating, Ventilation, and Air Conditioning (HVAC), Indoor Air Quality (IAQ), Lighting (LTG), Water (WR), Renewable Energy (Photovoltaic Panel-Wind Power) (RE(PV-WP)), Retrofit (RTF), Material, Green Building Certification (GBC), Smart Cities (SC), Cost headings are examined in the **Table 2.13.**With this reviewtable, we can see which studies have been carried out on which subjects using Ecodesigner Star recently.

Table 2. 15. The EcoDesigner Star usage areas and the most recent studies.

	Citation	GHGE	nZEB	LCA	HVAC	IAQ	LTG	WR	RE (PV-WP)	RTF	Material	GBC	SC	Cost
ECODESIG	(Avduykova & Pridvizhkin, 2023)											✓		
	(Mohajer, 2022)	✓	✓											
	(Tagliabue & Yitmen, 2022)		✓											
	(Pierzchalski et al., 2021)	✓		✓										
	(S. Chen, 2021)												✓	

Table 2. 16. (continuation) The EcoDesigner Star usage areas and the most recent studies.

N E R S T A R	(Corticos, 2020)	✓									✓			
	(Gumbarevic et al., 2020)	✓	✓											
	(Pucko et al., 2020)			✓										✓
	(Triana et al., 2020)				✓	✓								
	(Edwards et al., 2019)	✓		✓										
	(Sylejmani & Milovanović, 2019)				✓									✓

2.3.2. Building Information Modelling (BIM) and Energy Simulation

Building Information Modelling (BIM) is the integration of data and information from many sources into a unified, coordinated, and interoperable digital model. It is a digital representation of the physical and functional attributes of a building or infrastructure. BIM is a collaborative process that involves architects, engineers, contractors, and other stakeholders working together to create, manage, and share information about a building project throughout its lifecycle, from design and construction to operation and maintenance (Graphisoft, 2023)(J. Zhang et al., 2023)(Sepasgozar et al., 2023).

BIM allows for the creation of a comprehensive, virtual 3D model that contains geometric, spatial, and non-geometric data, such as building components, materials, systems, performance characteristics, costs, and schedules. This data-rich model serves as a central repository of information that can be used for design analysis, clash detection, construction coordination, cost estimation, facility management, and other purposes (Onatayo, 2023)(Uvarova et al., 2023)(Montiel-Santiago et al., 2023).

The use of BIM can improve communication, coordination, and collaboration among project team members, reduce errors and rework, enhance decision-making, optimize construction schedules and costs, and improve the overall quality and sustainability of a building or infrastructure project. BIM has become increasingly prevalent in the architecture, engineering, and construction (AEC) industry, and is considered a powerful tool for enhancing project outcomes and delivering more efficient and sustainable built environments (Cheng et al., 2023)(Rashidian, Drogemuller, & Omrani, 2023)(Fauth et al., 2023).

Building Information Modelling (BIM) is used in various areas within the architecture, engineering, and construction (AEC) industry. Here are some examples of how BIM is utilized in different aspects of AEC (Shen & Pan, 2023)(Cao et al., 2023)(Youkhanna Zaia et al., 2023)(Shukri et al., 2023)(Rashidian, Drogemuller, Omrani, et al., 2023):

- Architecture,
- Structural Engineering,
- MEP Engineering,
- Construction Management,
- Clash Detection and Coordination,
- Construction Simulation and Visualization,
- Facility Operations and Maintenance,,
- Urban Planning and Infrastructure Design,
- Owner and Client Engagement,
- Historic Preservation and Restoration,
- Clash Resolution and Coordination in Large-Scale Projects,
- Code Compliance and Regulations,
- Construction Documentation,
- Virtual Reality (VR) and Augmented Reality (AR) Visualization,
- Collaborative Project Management,
- Facility Management and Operations,
- Facility Security and Safety,
- Construction Site Logistics,
- Construction Equipment and Resource Management,
- Construction Progress Monitoring and Reporting,
- Constructability Analysis,
- Transportation Infrastructure,
- Urban Planning and Development,
- Disaster Response and Recovery,
- Sustainability and Energy Analysis.

It is possible to make energy simulations with the EcoDesigner Star plug-in in Archicad software and the insight 360 plug-in in Revit software, which are BIM programs. BIM integrated energy simulation tools in the AEC industry provides numerous advantages, including enhanced design optimization, early detection of energy performance issues, improved energy efficiency, better collaboration and communication, compliance with energy codes and standards, cost savings, and promotion of sustainable design practices. Some of the advantages of using a BIM integrated simulation tool (Essam et al., 2023)(Ajayi et al., 2023)(Kamel & Kazemian, 2023)(Kresnanto et al., 2023)(Hosamo et al., 2023):

- Enhanced Design Optimization,
- Early Detection of Energy Performance Issues,
- Improved Energy Efficiency,
- Better Collaboration and Communication,
- Compliance with Energy Codes and Standards,
- Cost Control,
- Faster and More Accurate Analysis,
- Holistic Approach to Building Performance,
- Improved Communication with Clients and Stakeholders,
- Better Resource Management,
- Regulatory Compliance and Green Building Certifications,
- Operation and Maintenance Benefits,
- Future-proofing Design,
- Market Competitiveness.

In the study, the EcoDesigner Star tool was chosen due to the advantages provided by the BIM database and the opportunities provided by the EcoDesigner Star tool.

Greenhouse Gas Emissions (GHGE), Net Zero Emission Buildings (nZEB), Life Cycle Assessment (LCA), Heating, Ventilation, and Air Conditioning (HVAC), Indoor Air Quality (IAQ), Lighting (LTG), Water (WR), Renewable Energy (Photovoltaic Panel-Wind Power) (RE(PV-WP)), Retrofit (RTF), Material, Green Building Certification (GBC), Smart Cities (SC), Cost headings are examined in the **Table 2.14.**With this reviewtable, we can see which studies have been carried out on which subjects using

Building Information modelling (BIM) recently.Studies using the EcoDesigner Star tool are given in a separate table with more detailed research as it is the tool used in this study.

Table 2. 17. Studies carried out so far in 2023 for BIM usage areas in sustainability studies, except EcoDesigner Star (Works on EcoDesigner Star Table 2.13. are also given).

	Citation	**GHGE**	**nZEB**	**LCA**	**HVAC**	**IAQ**	**LTG**	**WR**	**RE (PV-WP)**	**RTF**	**Material**	**GBC**	**SC**	**Cost**
	(Q. Li et al., 2023)(Newberry et al., 2023)(Su et al., 2023)(Khalili Tari et al., 2023)(Y. Chen, Wang, et al., 2023)(Kineber et al., 2023)(Visartsakul & Damrianant, 2023)			✓										
BIM	(Ogutucu, 2023)(Pinto et al., 2023)(Seduikyte, 2023)(Ben Bachouch et al., 2023)(Haggag, 2023)(Ma, 2023)						✓							
	(Danial et al., 2023)(Guillermo et al., 2023)(Marzouk et al., 2023)(Musarat et al., 2023)(Yoon, 2023)(Case et al., 2023)(Azima & Seyis, 2023)									✓				

Table 2. 18. (continuation) Studies carried out so far in 2023 for BIM usage areas in sustainability studies, except EcoDesigner Star (Works on EcoDesigner Star Table 2.13. are also given).

	Citation	GHGE	nZEB	LCA	HVAC	IAQ	LTG	WR	RE (PV-WP)	RTF	Material	GBC	SC	Cost
BIM	(Francisco, 2023)(Fernández Bandera et al., 2023)(Bu et al., 2023)(Lu et al., 2023)(Khoja, 2023)(Kotarela et al., 2023)(Alsharif et al., 2023)(Famakin et al., 2023)(Ismail, 2023)(Chenjie, 2023)(D. Wang, 2023)											✓		
	(Drewniok et al., 2023)(Surveying, 2010)(Hu et al., 2023)(Zakeri et al., 2023)(Apostolopoulos et al., 2023)(Shibata et al., 2023)(Almeida et al., 2023)(Kresnanto et al., 2023)(J. Wang, 2023)(Salzano et al., 2023)(Pinto et al., 2023)(Waqar et al., 2023)(S. H. Chen & Xue, 2023)(Athari Nikooravan & Golabchi, 2023)													✓

Table 2. 19. (continuation) Studies carried out so far in 2023 for BIM usage areas in sustainability studies, except EcoDesigner Star (Works on EcoDesigner Star Table 2.13. are also given).

	Citation	**GHGE**	**nZEB**	**LCA**	**HVAC**	**IAQ**	**LTG**	**WR**	**RE (PV-WP)**	**RTF**	**Material**	**GBC**	**SC**	**Cost**
BIM	(Liu et al., 2023)(Tong et al., 2023)(Lee et al., 2023)(Z. Chen, 2023)(Ebuy et al., 2023)(Forth et al., 2023)(Bu et al., 2023)(Howell & Woodbury, 2023)	✓												
	(Khoja, 2023)(Kotarela et al., 2023)(Shree et al., 2023)		✓											
	(Gan et al., 2023)(Sadati et al., 2023)(Shah et al., 2023)(Paneru et al., 2023)(Honic et al., 2023)(F. Li et al., 2023)(Y. Wang et al., 2023)(Otero et al., 2023)										✓			

Table 2. 20. (continuation) Studies carried out so far in 2023 for BIM usage areas in sustainability studies, except EcoDesigner Star (Works on EcoDesigner Star Table 2.13. are also given).

	Citation	GHGE	nZEB	LCA	HVAC	IAQ	LTG	WR	RE (PV-WP)	RTF	Material	GBC	SC	Cost
BIM	(Fernández Bandera et al., 2023)(Lu et al., 2023)(Sedighi et al., 2023)								✓					
	(Alsharif et al., 2023)(G. Li & Tian, 2023)(Cai et al., 2023)(Mertens et al., 2023)(Truong et al., 2023)				✓									
	(Yakut & Esen, 2023)(La Guardia & Koeva, 2023)(Xiao et al., 2023)												✓	
	(Selicati & Cardinale, 2023)(Selicati & Cardinale, 2023)(Loo & Wong, 2023)(Informatics & Denmark, 2023)(Psillaki et al., 2023)					✓								
	(Redweik et al., 2023)(Singh et al., 2023)(Hammond et al., 2023)(Al-tamimi et al., 2023)(Mawra et al., 2023)							✓						

3. MATERIAL AND METHOD

The common goals of sustainable building systems and green campus practices include reducing CO_2 emissions. The Energy and Climate Change (EC) category, which has the highest weight with 21% in the UI GreenMetric index, where green campuses are evaluated, has smart buildings, green buildings, renewable energy, HVAC systems,green roof, green wall, LCA and LED lighting applications. All of these applications focus on CO_2 emissions. Among its applications, smart buildings are also designed to reduce CO_2 emissions. Smart building technology and materials are closely linked as they work together to improve the energy efficiency, sustainability and functionality of buildings.

Smart buildings use a network of sensors, devices, and systems to monitor and control various aspects of the building environment, such as lighting, temperature, and air quality. On the other hand, material selection can be used to improve the performance of building systems and components, such as insulation and exterior cladding. For example, high-performance insulating exterior cladding systems can help reduce energy consumption and improve indoor air quality by minimizing air leaks and preventing moisture build-up. It also reduces the CO_2 emissions of buildings by reducing heating and cooling energy.

In other words, it serves the common purpose of reducing CO_2 emissions and increasing the energy performance of the building in smart building applications and material selection. Therefore, they should be evaluated together.In this context, the CO_2 emission was evaluated with the facade material of the Rectorate Building, which is designed as a smart building on the Duzce University Campus. EcoDesigner Star energy simulation tool of BIM data-based Archicad program was used for evaluation.

Duzce University is a state university located in Duzce, Turkey. The campus area is located on Akcakoca Road, close to Duzce city center and 10 km away. The university has large green areas and sports facilities with a modern campus design.

The climate of Duzce is a transitional feature between the Black Sea and continental climate. Winters are cold and rainy, and summers are hot and humid. Rainfall is evenly distributed throughout the year. Generally, snowfall is seen in high-altitude regions, while snowfall is less in areas located at sea level. The temperature is usually between 25-30°C in the summer. In December, January and February, the temperature varies between 0-5°C on average. Spring and autumn seasons are generally warm and rainy. Since the climate type was chosen from the different options in the UI GreenMetric Index, Mediterranean was selected from among the options for Duzce University.

Duzce University was established in 2006 and consists of 11 faculties, five colleges, five vocational colleges, one institute and one conservatory. It has approximately 30,000 students and more than 1,500 academic staff.

The faculties of the university are Engineering, Economics and Administrative Sciences, Arts, Design and Architecture, Education, Health Sciences, Technology, Communications, Medical School and Political Sciences.

The campus of the university includes modern classrooms, libraries, laboratories, conference halls, sports facilities, dining halls and student clubs. In addition, social, cultural and sports activities are organized for students.

Duzce University Rectorate Building is the main building where the administrative affairs of the university are carried out. The building is located in the campus area of the university and draws attention with its modern architectural design as seen in the **Figure 3.1.**

Figure 3. 1. Duzce University Campus rectorate building (DU Website, 2023).

The Rectorate building was completed in 2012. It has seven floors, including a basement and a terraced roof, with a total closed area of approximately 18,000 m^2. The building has rectorate offices, administrative units, meeting rooms, a cafeteria and various event halls.

The building is designed as a smart building and has energy-saving features. Especially lighting and heating, ventilation and air conditioning (HVAC) automation. The rectorate building is one of the modern and innovative structures of Duzce University. It is an important centre with administrative units serving both students and staff.

For the field study, the work flow chart was applied step by step as seen in the **Table 3.1.**

Table 3. 1. Work flow chart.

1	The Rectorate Building, designed as a Smart Building on the Duzce University Campus, was chosen for the field study.
2	The Rectorate Building was modelled with Archicad by creating a composite, covering the exterior cladding, and defining the building zones.
3	Environmental data is processed in EcoDesigner Star for the energy simulation of the building.
4	The building zones were converted into thermal blocks with the EcoDesigner Star tool.
5	Building systems consisting of heating, cooling and ventilation are assigned for each thermal block created in the EcoDesigner Star tool.
6	As a result of the simulation, the energy evaluation report created by the EcoDesigner Star tool was created.
7	In order to evaluate the exterior cladding of the Rectorate building, the cladding of the modelled building was removed and simulated again.
8	In line with the results, suggestions were made on the exterior cladding of sustainable buildings for CO_2 emission.

Firstly, the Rectorate Building was modelled with Archicad by creating composites to the building elements as seen in the **Figure 3.2.** The used building materials were selected from the Archicad building materials catalogue resource to create composites for the exterior wall in the building as seen in the **Figure 3.3.** In order to completely define the properties of the materials used in the building, the material properties are arranged in the Archicad building materials catalogue from the ÖKOBAUDAT Sustainable Building Information Portal and Environmental Product Declaration (EPD), which is the source of the material catalogue.

In addition, in order to define the exterior cladding material of the rectorate building to the model, the properties of the exterior cladding material used in the building were examined from the ÖKOBAUDAT Sustainable Building Information Portal and Environmental Product Declaration (EPD).In line with the properties found, URSA Mineral Wool TERRA Vento P4252 ES material was found from bimobject and its properties were confirmed, as we can see in **Figure 3.4.** The material in bimobject has been downloaded for use in the Archicad model. The downloaded material is defined with accessories in the Archicad goodies plugin and covered on the modelled building as we can see in **Figure 3.5.**

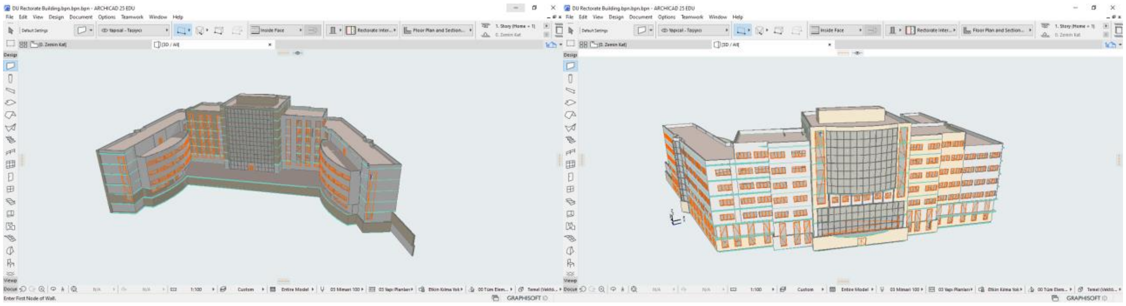


Figure 3. 2. Archicad model of the rectorate building in Duzce University Campus.

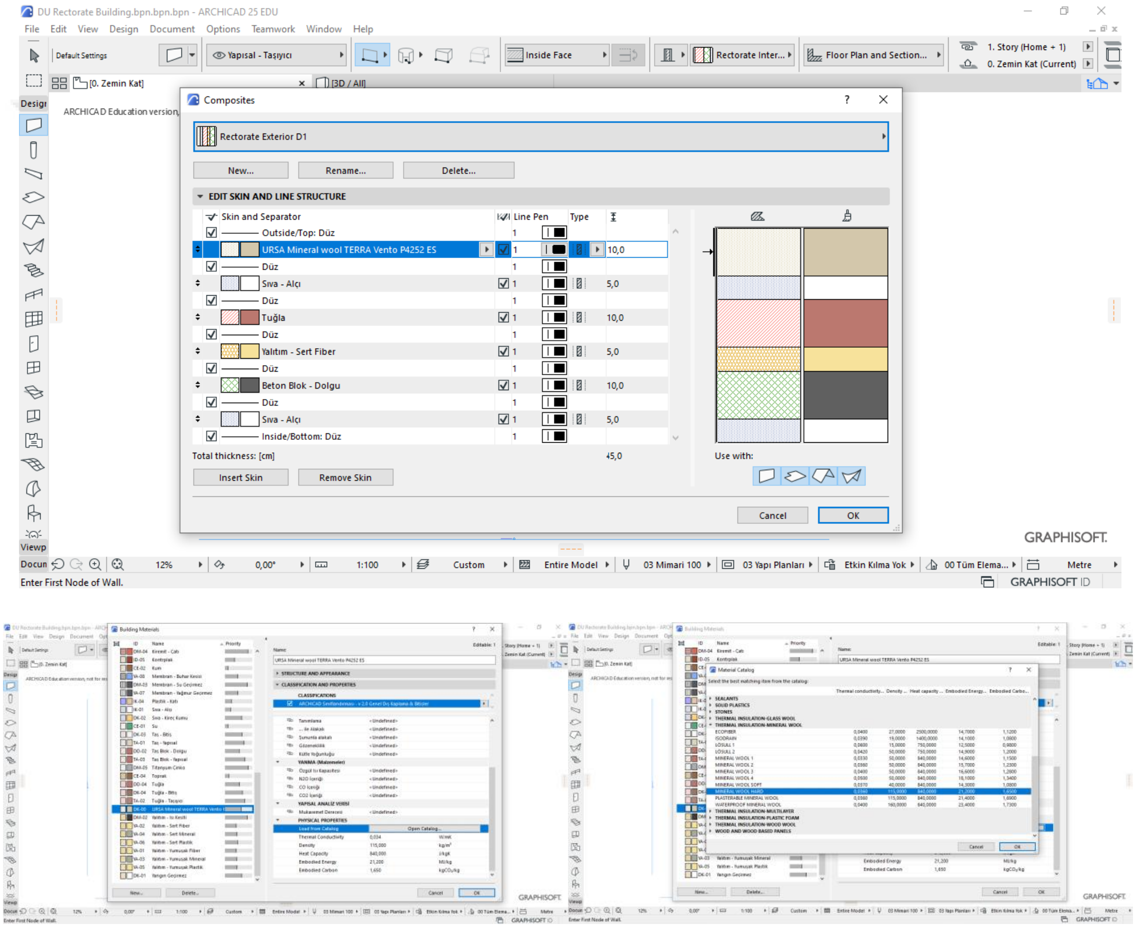


Figure 3. 3. Composites were created on the exterior wall of the building to define the building materials used in the model.

Parameters	Unit	Test method	Value										
Thickness	mm		25	40	50	60	80	100	120	140	160	180	200
R-value	m²·K/W		0.70	1.15	1.45	1.75	2.35	2.90	3.50	4.10	4.70	5.25	5.85
Thermal Conductivity	W/(m.K)	EN 12667 EN 12939	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Fire reaction	Euroclase	EN 13501-1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1
Air Flow resistivity		EN 29053	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5	AFr5
Sound absorption coefficient (Aw)			0.60	0.75	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Thickness tolerance		EN 823	T3	T3	T3	T3	T3	T3	T3	T3	T3	T3	T3
Dimensional stability (Δε) (70ºC 90% humidity)	%	EN 1604	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Water vapour transmission (μ)		EN 12086	MU1	MU1	MU1	MU1	MU1	MU1	MU1	MU1	MU1	MU1	MU1
Short term water absorption	kg/m²	EN 1609	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
Long term water absorption	kg/m²	EN 12087	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3
Reference standard to declare the efficacy of the product	EN 13162												
Designation code CE	MW-EN 13162-T3-MU1-WS-AFr5-WLp-DS(70,90)-AWi												
Certificate	(AENOR 020/003326)												
Application	Thermal insulation in Building / thermal Insulation of interior walls.												

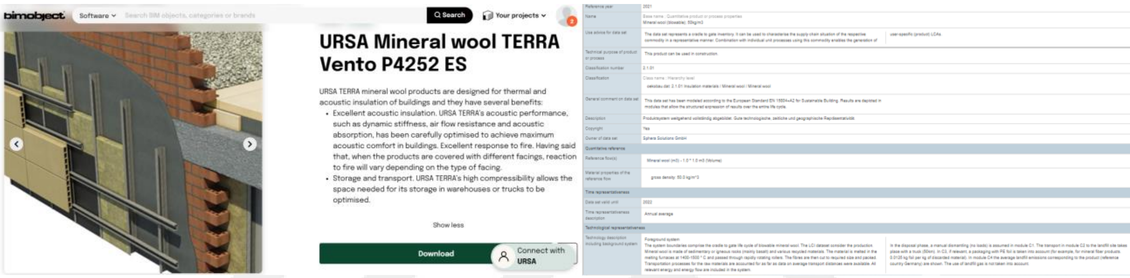


Figure 3. 4. Features of the exterior cladding of the Rectorate Building (EPD, 2022)(ÖKOBAUDAT, 2023)(BIMobject, 2023).

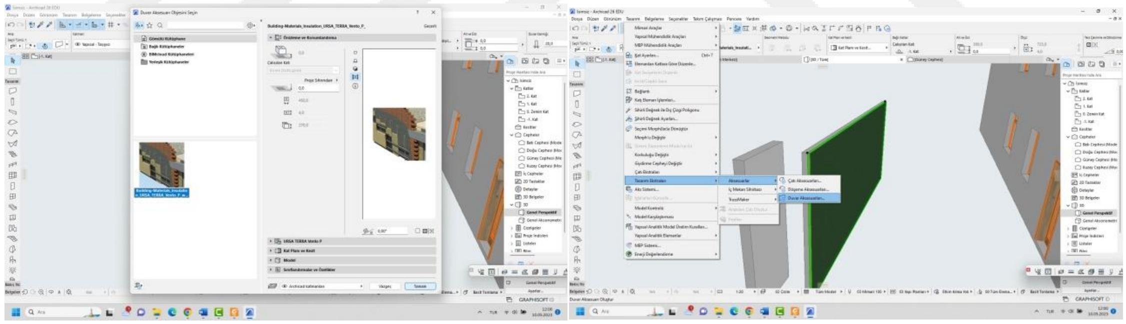


Figure 3. 5. Defining the exterior cladding of the Rectorate Building in the Archicad model with the accessories in the goodies add-on (BIMobject, 2023).

After the building is modelled in Archicad, environment settings are made on the EcoDesigner Star tool simulation screen, as seen in **Figure 3.6.** In the environment settings, kmz data as location information and epw data as climate information are imported. In addition, wind protection and horizontal shading can be adjusted from the same segment. After the environmental settings, in the operation profile section of the EcoDesigner Star tool, the purpose and usage days of the project are stated. It is also stated which type of lighting equipment is used, such as LED lighting, as seen in **Figure 3.7.** After entering the environmental data of the project, zones are defined for each area in the Archicad model and thermal blocks are created in EcoDesigner Star in order to perform the energy simulation. Zones are assigned to the created thermal blocks, as seen in **Figure 3.8.** After the update energy model review to the created heat blocks, structures where the building elements are seen and the opening where the door windows are seen are formed. And the exterior wall features along with the exterior cladding created in this project are shown in **Figure 3.9.** Finally, the heating, cooling and ventilation propertiesin the building systems are defined for each thermal block, as seen in **Figure 3.10.**

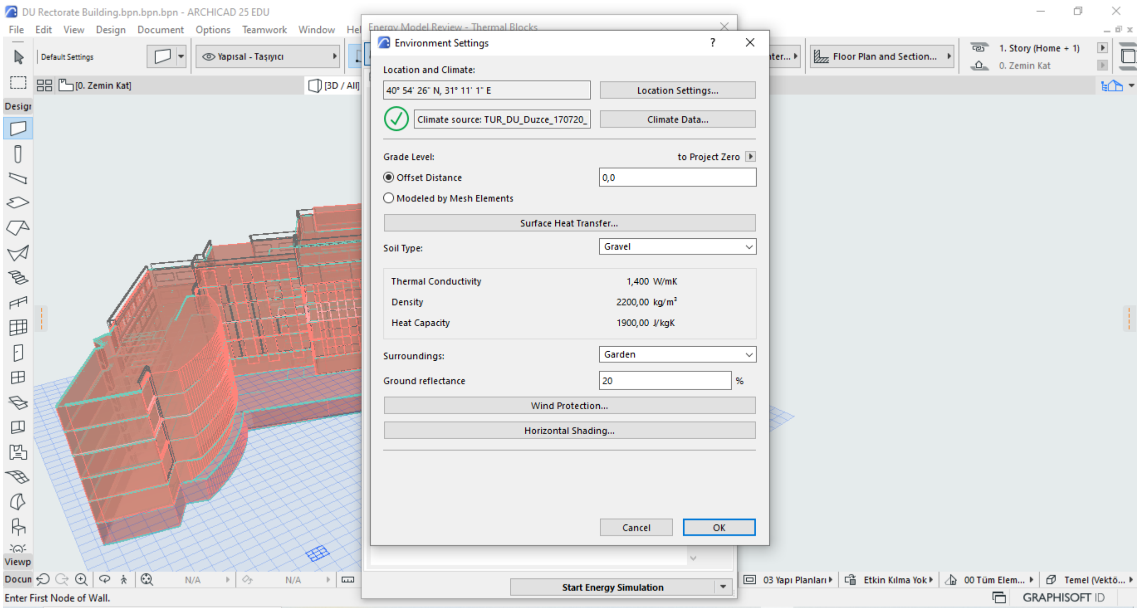


Figure 3. 6. Processing the environmental data of the project in the EcoDesigner Star tool.

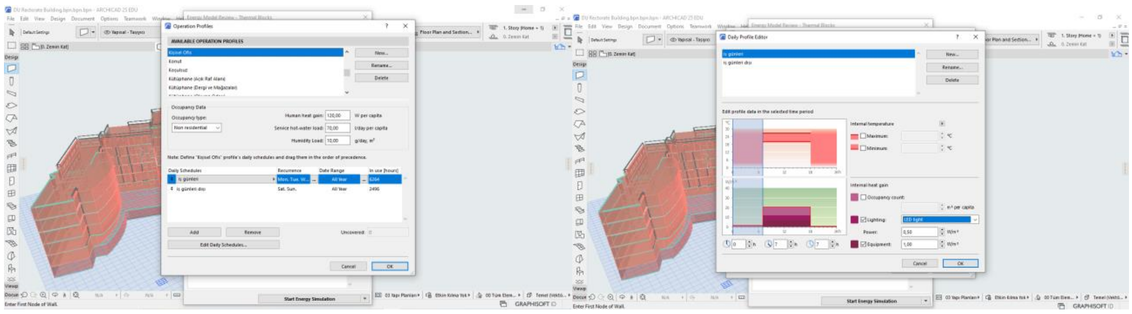


Figure 3. 7. Operation profile settings of the project in the EcoDesigner Star tool.

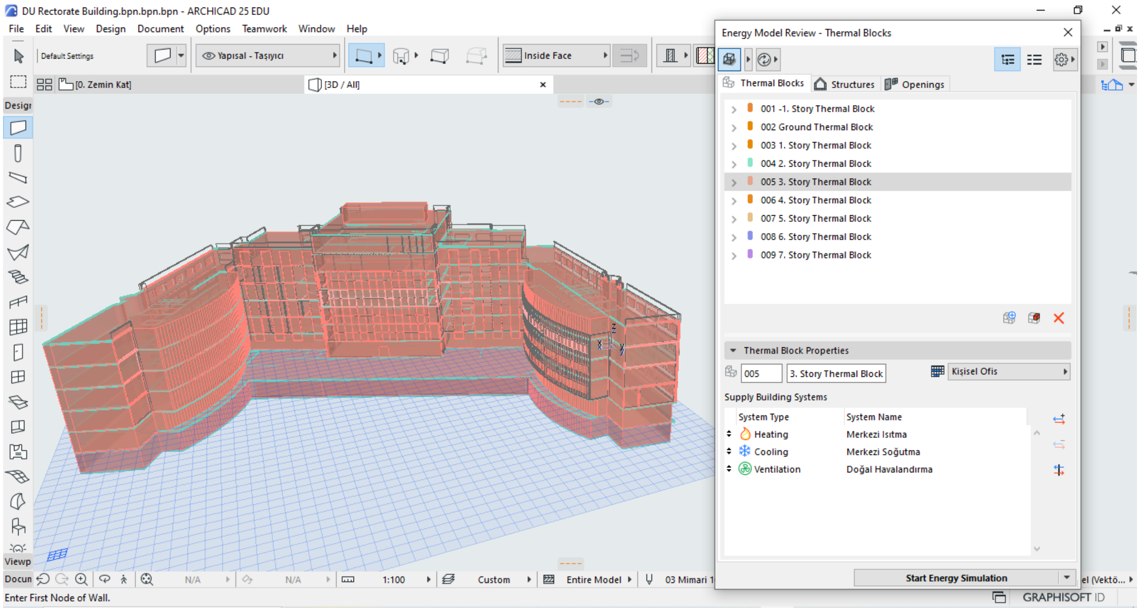


Figure 3. 8. Defining zones assigned in Archicad to thermal blocks created in EcoDesigner Star.

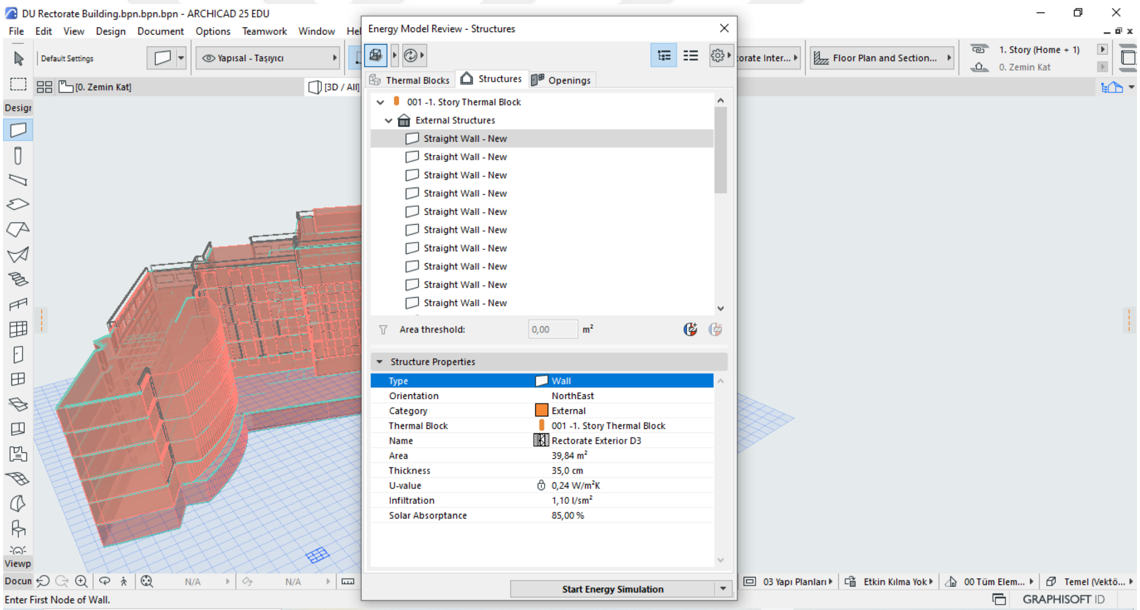


Figure 3. 9**.** The segment showing the exterior cladding material and other structures defined in the model in the thermal blocks created in EcoDesigner Star.

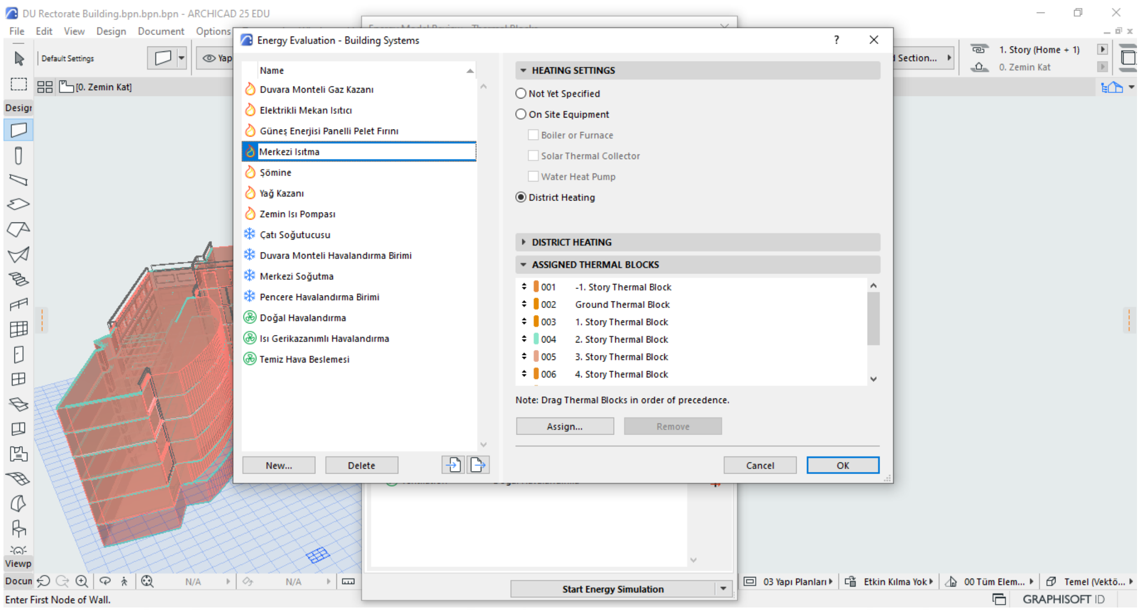


Figure 3. 10. Defining the heating, cooling and ventilation properties of the created heat blocks with building systems in the EcoDesigner Star tool.

After all project data has been entered, the energy simulation is started. As a result of the energy simulation, a report is obtained. The report includes the amounts of heating, cooling, ventilation energy, primary energy, lighting energy, electrical energy, service hot water, human heat gain, solar energy gain and CO_2 emission. It also calculates the energy cost. The environmental impact values found as a result of the energy simulation for the Rectorate Building when there is exterior cladding material were given in the **Figure 3.11.** In order to evaluate the exterior cladding, the URSA Mineral Wool TERRA Vento P4252 ES material in the rectorate building was removed and simulated again. The results found are given in the **Figure3.12.** When we focus on the CO_2 emission within the scope of the study, when there is exterior cladding, the CO_2 emission amount of electricity is 155199 kg/a, heating is 533458 kg/a, and cooling is 92249 kg/a. When there is no exterior cladding, the CO_2 emission of electricity is 155231 kg/a, heating is 549754 kg/a and cooling is 93776 kg/a. The total CO_2 emission amount is 780,908 kg/a with the exterior cladding, while the total CO_2 emission amount is 798,762 kg/a without the exterior cladding. As a result, the amount of CO_2 emissions decreased by 17,854 kg/a with the URSA Mineral Wool TERRA Vento P4252 ES exterior cladding. Because, CO_2 emission decreased by 16.296 kg/a for heating and by 1.527 kg/a for cooling. In line with this, 89.439 TRY/a total cost savings are achieved through the exterior cladding.

Energy Consumption by Sources

Source Type	Source Name	Energy Quantity MWh/a	Energy Primary MWh/a	Energy Cost TRY/a	CO_2 Emission kg/a
Secondary	Electricity	718	2155	1595106	155199
	District Heating	2667	13336	2667294	533458
	District Cooling	461	2306	461249	92249
Total:		3847	17798	4723650	780908

Figure 3. 11. Environmental impact values found as a result of energy simulation when there is exterior cladding material for the Rectorate Building.

Energy Consumption by Sources

Source Type	Source Name	Energy Quantity MWh/a	Energy Primary MWh/a	Energy Cost TRY/a	CO_2 Emission kg/a
Secondary	Electricity	718	2155	1595438	155231
	District Heating	2748	13743	2748770	549754
	District Cooling	468	2344	468880	93776
Total:		3936	18244	4813089	798762

Figure 3. 12. Environmental impact values found as a result of energy simulation when there is no exterior cladding material for the Rectorate Building.

4. RESULTS AND DISCUSSIONS

As a result of the study, Duzce University Campus was evaluated according to the UI GreenMetric Index, which is used to evaluate green campuses. The score distribution of the universities evaluated in the UI GreenMetric index was shown in the **Table 4.1.** to compare the universities within the categories. Also, with the information in the sustainability reports of the universities, criteria were created for all categories and a table was created with them. In the **Table 4.2.** all universities were evaluated according to the criteria determined for the categories. Only the data given in the sustainability reports of the relevant universities are included in the **Table 4.2.** If there is information that is not given in the report, it is not marked in the table because it is not included in the report. For example, ITU has a botanical garden, but it is not marked because it is not given in the sustainability report. Another example, universities have a scholarship program or sport facilities, but it is not marked because it is not mentioned in the sustainability report. Also, the markings in the table for Duzce University Campus are based on university data, experience and observations because Duzce University does not have a sustainability report.

Table 4. 1. UI GreenMetric score distribution for selected universities.

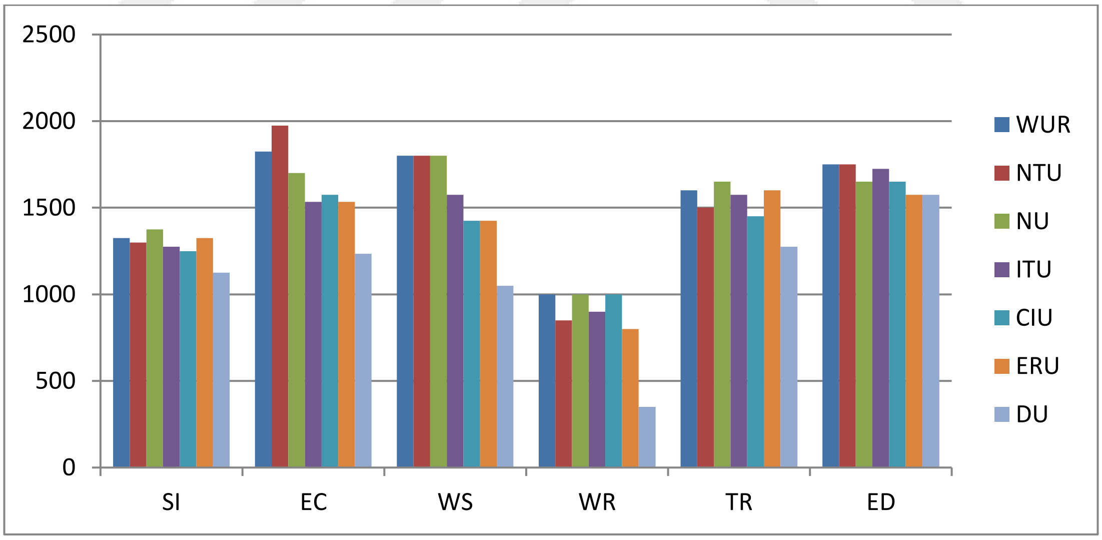


Table 4. 2. Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

SI	WUR	NTU	NU	ITU	CIU	ERU	DU
connection of the with nature areas	✓	✓	✓	✓	✓		✓
increase green areas such as planting tree	✓	✓	✓	✓	✓	✓	
maintain biodiversity such as using battery-powered mowers	✓	✓	✓	✓	✓	✓	✓
existence of botanical garden						✓	✓
existence of non-retentive surfaces (e.g. earth, grass, concrete block, etc.) for water absorption	✓	✓	✓	✓	✓	✓	✓
sufficient amount of public space	✓	✓	✓				
sustainable food service, such as agricultural production, honey production on campus			✓	✓			✓
nest boxes in trees across the campus for birds	✓	✓		✓		✓	
protection other animalssuch as reptiles, squirrels, hedgehogs, cats and dogs	✓		✓	✓		✓	✓
existence of ecosystem services and stakeholder interactions under the SI	✓	✓	✓	✓			
security infrastructure such as fire extinguishers, fire cabinets, shelters, security units, etc. related to safety for accident, crime, fire and natural disaster	✓	✓	✓	✓	✓	✓	✓

Table 4. 3. (continuation) Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

EC	WUR	NTU	NU	ITU	CIU	ERU	DU
measure CO_2 footprint	✓	✓	✓				✓
implementing carbon labelling with LCA			✓				
renewable energy with solar panels	✓	✓	✓	✓	✓	✓	✓
renewable energy with windmills	✓						✓
renewable energy withBiomass Boilers and Biogas Power Plants	✓		✓		✓		
use of heating-cooling-air conditioning automation systems such as HVAC Systems, Central Vacuum Systems, and Central Heating Systems and Heat Pumps	✓	✓		✓	✓	✓	
existence of green roofs	✓	✓	✓		✓		
existence of living walls		✓	✓				
implement technology and smart control systems for lighting such as sensors, shielding from the sun (solar shading) and highly efficient LED lighting				✓	✓	✓	✓
have a green building certificate		✓		✓			
smart building initiatives			✓			✓	✓
ensure sustainable criteria in the building construction, maintenance and renovation	✓	✓					
creating buildings using raw materials, including timber and straw, on the campus		✓					
innovation management and technology adaptation				✓		✓	

Table 4. 4. (continuation) Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

reduce the file size of images on the website to reduce the energy required to run web pages		✓					
WS	**WUR**	**NTU**	**NU**	**ITU**	**CIU**	**ERU**	**DU**
recycling bins placement	✓		✓	✓			✓
recycle management of organic waste such as vegetable, fruit and food	✓	✓	✓	✓	✓		✓
recycle management of papers such as paper towels, cardboard cups, stir sticks, tea bags and toilet paper	✓		✓	✓	✓		✓
recycle management for plastics	✓	✓	✓	✓	✓		✓
recycle management of glass	✓	✓	✓	✓			
recycle management of metals	✓			✓			
recyclemanagement other waste such as construction waste, industrial waste, mixed recyclables trade waste, WEEE, clinical healthcare waste, hazardous waste, confidential waste	✓	✓	✓	✓	✓		✓
providingreuse, such as reuse raw material, use of reusing spare furniture	✓	✓	✓	✓	✓	✓	
encouraging the use of reusable water bottles and cupsthan disposable options	✓	✓	✓				
water fountains for the waste of disposable pet bottles to reduce on the campus			✓		✓		
provide donation points in each hall of residence on campus for clothes			✓	✓			✓
hosting bookcrossing zones			✓				

Table 4. 5. (continuation) Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

prepare workshops, activities, seminars, training, courses and events for waste	✓	✓	✓	✓	✓	✓	✓
waste management servicesand stakeholder interactions	✓	✓	✓	✓	✓	✓	
WR	**WUR**	**NTU**	**NU**	**ITU**	**CIU**	**ERU**	**DU**
rainwater harvesting and use in processes such as irrigation, household and industrial	✓		✓	✓	✓		
use of drip irrigation				✓	✓	✓	✓
sewage disposal and use grey water	✓			✓	✓	✓	
water treatment and use of purified water	✓	✓	✓	✓	✓	✓	
use of osmosis machines for purified water		✓					
use of cooling technologies on autoclavesfor reduce water consumption		✓					
use of chiller units and waterless condensers			✓				
use of superlab tap		✓					
use of taps with aerators		✓					
initiatives to reduce water pollution				✓		✓	✓
carry out the monitoring and recording to create an archive about water consumption on the campus				✓	✓	✓	
water extraction process						✓	✓
prepare workshops, seminars, training, courses, activities and events for water management	✓	✓	✓	✓	✓	✓	

Table 4. 6. (continuation) Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

existence of water management services and stakeholder interactions	✓	✓	✓	✓		✓	
TR	**WUR**	**NTU**	**NU**	**ITU**	**CIU**	**ERU**	**DU**
bicycle presence on campus	✓	✓	✓	✓	✓	✓	
existence of bicycle paths and bicycle parking space	✓	✓	✓	✓	✓	✓	
increase pedestrian pathsinitiatives on campus				✓		✓	✓
ensure public transport such as tram, shuttle, bus, subway	✓	✓	✓	✓	✓	✓	✓
ensure electric vehicle such as cars, e-bikes, and e-scooters	✓	✓	✓	✓	✓	✓	
ensure shared electric cars	✓		✓				
existence of electric charging points	✓	✓	✓	✓	✓		
disabled-friendly applications				✓	✓	✓	✓
ED	**WUR**	**NTU**	**NU**	**ITU**	**CIU**	**ERU**	**DU**
existence of sustainability office	✓			✓	✓	✓	
prepare Annual Sustainability Report	✓	✓	✓	✓	✓	✓	
Prepare Annual Carbon Emission Report		✓	✓				
existence of sustainability website	✓	✓	✓	✓	✓	✓	
existence of research centres and labs	✓	✓	✓	✓	✓	✓	✓
prepare workshops, seminars, training, courses, activities and events for sustainability	✓	✓	✓	✓	✓	✓	✓

Table 4. 7. (continuation) Evaluation of selected universities with criteria created in line with UI GreenMetric Index categories.

existence of ecosystem services and stakeholder interactions	✓	✓	✓	✓	✓	✓	
existence of scholarships programmes such as achievement, athlete, food and necessity scholarships				✓			
publications about sustainability on the postgraduate and undergraduate	✓			✓	✓	✓	✓
Green Rewards Programme, which gives the award for sustainability initiatives		✓	✓				
provide sports facilities				✓			✓

At Duzce University, due diligence was made for each category of this index, which consists of six categories, and suggestions were made according to **Table 4.2.** and field study.

Structure and Infrastructure (SI);

The *SI* includes green areas, initiatives for animals, healthy food, biodiversity, social equality, health and wellbeing programme, operation and maintenance activities, ecosystem services and stakeholder interaction topics. In 2022, Duzce University received 1125 points from Setting & Infrastructure (SI), which has a weight of 15% and is evaluated over 1500 points. In line with the universities examined within the scope of the study for SI, increased green areas such as planting tree, sufficient amount of public space, adding nesting boxes to trees across campus for birds and nests in Turkish culture as in Ottoman architecture, existence of ecosystem services and stakeholder interactions, feeding cats and dogs regularly, planting tree species that squirrels and other animal's favourite were recommended to the Duzce University, as given in the **Table 4.3.**

Table 4.8. The current situation and the recommendations of Duzce University for SI.

analysis of current situation	recommendations
connection of the with nature areas	increase green areas such as planting tree
maintain biodiversity such as using battery-powered mowers	sufficient amount of public space
existence of botanical garden	adding nesting boxes to trees across campus for birds and nests in Turkish culture as in Ottoman architecture
existence of non-retentive surfaces (e.g. earth, grass, concrete block, etc.) for water absorption	existence of ecosystem services and stakeholder interactions under the SI
sustainable food service, such as agricultural production, honey production on campus	feeding cats and dogs regularly, planting tree species that squirrels and other animal's favourite
protection other animals such as reptiles, squirrels, hedgehogs, cats and dogs	
security infrastructure such as fire extinguishers, fire cabinets, shelters, security units, etc. related to safety for accident, crime, fire and natural disaster	

Energy and Climate Change (EC);

The *EC* includes using renewable energy, PV systems, wind turbines, HVAC systems, green building systems, CO_2 emissions, reduced water consumption, rainwater harvesting, green roof and LED lighting. In 2022, Duzce University received 1235points from Energy and Climate Change (EC), which has a weight of 21% and is evaluated over 2100 points. As can be seen, it received a low score, so suggestions were made for a more environmentally friendly campus. In line with the universities examined within the scope of the study for EC, implementing carbon labelling with LCA, increasing solar panels and windmills, production of renewable energy with Biomass Boilers and Biogas Power Plants, use of heating-cooling-air conditioning automation systems such as HVAC Systems, Central Vacuum Systems, and Central Heating Systems and Heat Pumps, existence of green roofs and inclusion in new project tenders, inclusion of living walls in new project tenders and conversion of retaining walls into green walls, increasing the number of buildings with green building certification and encourage Turkey's green building certification systems to develop a version on the evaluation of campus buildings, ensure sustainable criteria in the building construction, maintenance, renovation and adding sustainability-related clauses in construction tenders, creating buildings using raw materials, including timber and straw, innovation management and technology adaptation, reduce the file size of images on the website to reduce the energy required to run web pages were recommended to the Duzce University, as given in the **Table 4.4.**

Table 4.9. The current situation and the recommendations of Duzce University for EC.

analysis of current situation	recommendations
measure CO_2 footprint	implementing carbon labelling with LCA
renewable energy with solar panels	increasing solar panels and windmills
renewable energy with windmills	production of renewable energy with Biomass Boilers and Biogas Power Plants
implement technology and smart control systems for lighting such as sensors, shielding from the sun (solar shading) and highly efficient LED lighting	use of heating-cooling-air conditioning automation systems such as HVAC Systems, Central Vacuum Systems, and Central Heating Systems and Heat Pumps
smart building initiatives	existence of green roofs andinclusion in new project tenders
	inclusion of living walls in new project tenders and conversion of retaining walls into green walls
	increasing the number of buildings with green building certificationand encourage Turkey's green building certification systems to develop a version on the evaluation of campus buildings
	ensure sustainable criteria in the building construction, maintenance, renovation and adding sustainability-related clauses in construction tenders
	creating buildings using raw materials, including timber and straw, on the campus
	innovation management and technology adaptation
	reduce the file size of images on the website to reduce the energy required to run web pages

Like many sustainable studies, green campuses focus on indirectCO_2emissions. In particular, Energy and Climate Change (EC), which is the category of the UI GreenMetric Index, includes studies on reducing CO_2 emissions. The features of sustainable building systems, such as smart buildings and green buildings, which are among these studies, aim to reduce CO_2 emissions. In this context, the Rectorate Building, designed as a smart building at Duzce University, was chosen as a field study in this study. Energy simulation is inevitable for sustainable project designs such as sustainable building systems. For this reason, the EcoDesigner Star tool, which is a BIM-supported energy simulation tool, was used for the selected building. With the EcoDesigner Star, the energy simulation tool add-on of the BIM-based Archicad program, a study was conducted to reduce the CO_2 emission amount of the selected building. Facade design is essential for many large-scale corporate buildings. The exterior cladding used for the Duzce University Rectorate building was evaluated in order to create a prototype for more environmentally friendly designs. The URSA Mineral Wool TERRA Vento P4252 ES exterior cladding used in the building was evaluated with the EcoDesigner Star, focusing on CO_2 emissions. The material used in the building has been simulated with and without. And as a result, if an insulated exterior cladding material with natural materials is used in buildings, it has been observed that CO_2 emissions will decrease due to the reduction of heating and cooling energy in sustainable buildings and other buildings. In addition, since the energy consumption will decrease, the usage cost of the project will also decrease. Therefore, costly exterior cladding in construction will provide cost savings in the long run, as seen in the **Table 4.5.**

Table 4.10. Comparative table of CO_2 emission values found from energy simulation with and without the exterior cladding material defined for the Rectorate Building.

	CO_2 emission of theRectorate Building with exterior cladding (kg/a)	**CO_2 emission of theRectorate Building without exterior cladding (kg/a)**	**cost difference with and without exterior cladding (TRY/a)**
District Heating	53.3458	549.754	81.476
District Cooling	92.249	937.76	7.631
Total	780.908	798.762	89.439

Waste Management (WS);

The *WS* includes organic, paper, metal and plastics waste collection activities, recycling bins placement, waste reduction activities, sewage disposal, stakeholder interaction and education for waste management topics. In 2022, Duzce University received 1050 points from Waste Management (WS), which has a weight of 18% and is evaluated over 1800 points. As can be seen, it received a low score, so suggestions were made for a more environmentally friendly campus. In line with the universities examined within the scope of the study for WS, ensure recycle management of glass and metals, providing reuse, such as reuse raw material, use of reusing spare furniture, encouraging the use of reusable water bottles and cups than disposable options, existence of water fountains for the waste of disposable pet bottles to reduce on the campus, hosting bookcrossing zones, inclusion of a clause regarding the separation of organic wastes in the cafeteria tender, increase workshops, activities, seminars, training, courses and events, services and stakeholder interactions were recommended to the Duzce University, as given in the **Table 4.6.**

Table 4.11. The current situation and the recommendations of Duzce University for WS.

analysis of current situation	recommendations
recycling bins placement	ensure recycle management of glass
recycle management for plastics	ensure recycle management of metals
recycle management of organic waste such as vegetable, fruit and food	providingreuse, such as reuse raw material, use of reusing spare furniture
recycle management of papers such as paper towels, cardboard cups, stir sticks, tea bags and toilet paper	encouraging the use of reusable water bottles and cupsthan disposable options
recyclemanagement other waste such as construction waste, industrial waste, mixed recyclables trade waste, WEEE, clinical healthcare waste, hazardous waste, confidential waste	existence of water fountains for the waste of disposable pet bottles to reduce on the campus
provide donation points in each hall of residence on campus for clothes	hosting bookcrossing zones
prepare workshops, activities, seminars, training, courses and events for waste	inclusion of a clause regarding the separation of organic wastes in the cafeteria tender
	increase workshops, activities, seminars, training, courses and events
	existence of waste management servicesand stakeholder interactions

Water Systems (WR);

The *WR* includes using superlab taps or aerators taps, purification of rainwater and grey water, reduction of water consumption, use of rainwater harvesting, drinking water service, drip irrigation, water extraction, water pollution control, and stakeholder interaction. In 2022, Duzce University received 350 points from Water Systems (WR), which has a weight of 10% and is evaluated over 1000 points. As can be seen, it received a very low score, so suggestions were made for a more environmentally friendly campus. In line with the universities examined within the scope of the study for WR, rainwater harvesting and use in processes such as irrigation, household and industrial, use of drip irrigation, sewage disposal and use grey water, water treatment and use of purified water, use of osmosis machines for purified water, cooling technologies on autoclaves for reduce water consumption, chiller units and waterless condensers, superlab tap, taps with aerators, initiatives to reduce water pollution, carry out the monitoring and recording to create an archive about water consumption on the campus, prepare workshops, seminars, training, courses, activities and events for water management, the existence of water management services and stakeholder interactions were recommended to the Duzce University, as given in the **Table 4.7.**

Table 4.12. The current situation and the recommendations of Duzce University for WR.

analysis of current situation	recommendations
use of drip irrigation	rainwater harvesting and use in processes such as irrigation, household and industrial
initiatives to reduce water pollution	sewage disposal and use grey water
water extraction process	water treatment and use of purified water
	use of osmosis machines for purified water
	use of cooling technologies on autoclavesfor reduce water consumption
	use of chiller units and waterless condensers
	use of superlab tap
	use of taps with aerators
	initiatives to reduce water pollution

Table 4.13. (continuation) The current situation and the recommendations of Duzce University for WR.

	carry out the monitoring and recording to create an archive about water consumption on the campus
	prepare workshops, seminars, training, courses, activities and events for water management
	existence of water management services and stakeholder interactions

Transportation (TR);

The *TR* includes using bicycles, electric scooters, electric vehicles and public transport, a parking area plan, a pedestrian path, decrease private cars, a car-sharing network, a travel plan programme, and disabled access. In 2022, Duzce University received 1275 points from Transportation (TR), which has a weight of 18% and is evaluated over 1800 points. In line with the universities examined within the scope of the study for TR, increased bicycle presence on campus, ensure electric vehicles such as cars, e-bikes, and e-scooters, shared electric cars, existence of electric charging points were recommended to the Duzce University, as given in the **Table 4.8.**

Table 4.14. The current situation and the recommendations of Duzce University for TR.

analysis of current situation	recommendations
increase pedestrian pathsinitiatives on campus	bicycle presence on campus
ensure public transport such as tram, shuttle, bus, subway	ensure electric vehicle such as cars, e-bikes, and e-scooters
disabled-friendly applications	ensure shared electric cars
	existence of electric charging points

Education (ED);

The *ED* includes existing annual Sustainability Reports, sustainability organisational units, sustainability workshops, seminars, training, courses and events, green awards platforms, sustainability publications, sustainability offices, scholarships, sustainability websites, research centres and labs. In 2022, Duzce University received 1575 points from Education (ED), which has a weight of 18% and is evaluated over 1800 points. In line with the universities examined within the scope of the study for ED, prepare Annual Sustainability Report, prepare Annual Carbon Emission Report, the existence of a sustainability website, sustainability office, ecosystem services and stakeholder interactions, scholarships programmes such as achievement, athlete, food and necessity scholarships, Green Rewards Programme, which gives the award for sustainability initiatives were recommended to the Duzce University, as given in the **Table 4.9.**

Table 4.15. The current situation and the recommendations of Duzce University for ED.

analysis of current situation	recommendations
existence of research centres and labs	existence of sustainability office
prepare workshops, seminars, training, courses, activities and events for sustainability	prepare Annual Sustainability Report
publications about sustainability on the postgraduate and undergraduate	prepare Annual Carbon Emission Report
provide sports facilities	existence of sustainability website
	existence of ecosystem services and stakeholder interactions
	existence of scholarships programmes such as achievement, athlete, food and necessity scholarships
	Green Rewards Programme, which gives the award for sustainability initiatives

5. CONCLUSION

Nowadays, sustainability is essential against the rapidly increasing environmental problems. Sustainability, which is examined in three areas environmental, economic and social, aims to use resources efficiently, protect the environment, keep ecosystems in balance and increase the welfare of society in a world where natural resources are limited. With environmental sustainability, an effective approach is provided in seeking solutions to significant problems such as climate change, natural resource depletion, loss of biodiversity, and water scarcity. One of the environmental problems caused by the increase in greenhouse gas emissions is climate change.CO_2 emission means releasing an important greenhouse gas effect into the atmosphere. For this reason, sustainability studies should be carried out on reducing CO_2 emissions. This includes measures such as promoting the use of renewable energy sources, increasing energy efficiency, adopting sustainable transport models, protecting forests and reducing energy consumption.

The Architecture, Engineering and Construction (AEC) industry has a major impact on CO_2 emissions. Sustainable architecture encourages the use of energy efficient systems with sustainable building systems. For example, it reduces water consumption with water management measures, prevents waste generation with recycling systems, supports the sustainable use of resources with the selection of renewable materials, and offers healthy and energy efficient solutions to interiors with design strategies such as natural lighting and natural ventilation. In this way, sustainable architecture both reduces environmental impacts and increases the quality of life.

Among sustainable studies, there are green campus applications for campuses that appeal to a large scale. Green campuses are university campuses that adopt environmentally friendly practices and promote environmental sustainability. These campuses prioritise issues such as the protection of green areas, energy efficiency, waste management, water conservation, environmental education and transportation. Energy is saved, waste is managed, water is used effectively, and natural areas are protected. In addition, education and awareness on environmental issues are provided, and environmentally friendly transport options such as bicycles and public transport are encouraged. The UI GreenMetric Index was developed by Universitas Indonesia in 2010 to evaluate green campuses. The UI GreenMetric Index was developed by Universitas Indonesia in 2010 to evaluate green campuses. The UI GreenMetric Index, which analyzes green campuses in six areas on Structure and Infrastructure (SI), Energy and Climate Change (EC), Waste Management (WS), Water Systems (WR), Transportation (TR), and Education (ED), is a big step for sustainability.

The common goals of sustainable building systems and green campus practices include reducing CO_2 emissions. The Energy and Climate Change (EC) category focus on CO_2 emissions. Among its applications, smart buildings are also designed to reduce CO_2emissions. Smart building technology and materials are closely linked as they work together to improve the energy efficiency, sustainability and functionality of buildings. Smart building applications and material selection serve the common purpose of reducing CO_2 emissions and increasing the energy performance of the building. Therefore, they should be evaluated together.

In this context, it is inevitable to make energy simulations for sustainable studies. Integrating energy simulations with Building Information Modelling (BIM), which can be actively used in all steps from the planning and design phase of the architectural project to the construction and finalization, creates an advantage for environmentalist designs as the construction teams keep in touch with each other and provide information flow between different levels. BIM can also provide cost control with its quantity calculation feature for the economy, which is one reason that prevents ecological designs. Integrating BIM and energy simulation software helps measure energy performance at the early design phase and realizes targeted design decisions. Significantly, this integration allows for combining energy simulation with the benefits of BIM.

Within the scope of this study, in line with the energy and climate change category of the UI GreenMetric Index, a fieldwork was conducted on material selection for energy consumption, carbon footprint and cost analysis in the Duzce University campus building, which was designed as a smart building, by using BIM data-based EcoDesigner Star energy simulation tool. In this way, the use of BIM data-based energy simulation tool in green campus initiatives and the effect of exterior cladding material selection on the building were examined, and an example study was created for the process of reducing CO_2 emission. In addition, Wageningen University & Research, Nottingham Trent University and University of Nottingham, which are in the top three in the UI GreenMetric Index ranking, and Istanbul Technical University, Cyprus International University and Erciyes University, which are in the top three in Turkey, were examined and suggestions were made within the framework of all categories for the Duzce

University Campus. With the suggestions created, Duzce University was encouraged to have a greener campus within the framework of UI GreenMetric.

In conclusion, efforts should be made to reduce CO_2 emissions, which are essential for sustainability, in order to solve increasing environmental problems. Therefore, efforts should be made to increase building energy performance through material selection, the choice of natural, reusable materials, provide flexible, minimalist designs, and reduce energy consumption with time management for building use in large-scale design areas, as well as sustainable building systems in the AEC sector.

UI GreenMetric Index, which is among the sustainable studies, is an important study for the sustainability of large-scale universities. Duzce University should improve itself in this context in line with the recommendations made. While some recommendations were made in 2023, they should continue to be developed.

UI GreenMetric Index can also be improved. Since the climate type is essential in the evaluation process, instead of being restrictive with the options selected in the UI GreenMetric Index, an arrangement can be made that details the climate of the universities. UI GreenMetric Index can provide a more comprehensive incentive by making improvements such as scoring all sustainable business steps instead of just results-oriented scoring. For example, instead of scoring the existence of green building certifications, it can score all steps to reduce CO_2 emissions in the building.

In addition, green building certifications in Turkey and other studies focusing on this field can be encouraged to the green campus evaluation process.

Future studies can contribute to this study by conducting different field studies with different boundary conditions. Other universities evaluated in the UI GreenMetric Index can be researched, and suggestions can be made for universities to have greener campuses. In this way, the deficiencies in the UI GreenMetic Index can be detected, and the index can be improved. In addition, with different field studies, it can be determined how different materials affect energy consumption, CO_2 emission and cost. Thus, examples can be created for material selection in the early design phase of large-scale structures.

6. REFERENCES

Abrahamsen, F. E., Ruud, S. G., & Gebremedhin, A. (2023). Assessing Efficiency and Environmental Performance of a Nearly Zero-Energy University Building's Energy System in Norway. *Buildings*, *13*(1), 1–19. https://doi.org/10.3390/buildings13010169

Ahmadi, F., Wilkinson, S., Rezazadeh, H., Keawsawasvong, S., Najafi, Q., & Masoumi, A. (2023). Energy efficient glazing: A comparison of microalgae photobioreactor and Iranian Orosi window designs. *Building and Environment*, *233*(December 2022), 109942. https://doi.org/10.1016/j.buildenv.2022.109942

Ajayi, S. O., Oyebiyi, F., & Alaka, H. A. (2023). Facilitating compliance with BIM ISO 19650 naming convention through automation. *Journal of Engineering, Design and Technology*, *21*(1), 108–129. https://doi.org/10.1108/JEDT-03-2021-0138

Al-Atesh, E. A., Rahmawati, Y., Zawawi, N. A. W. A., & Utomo, C. (2023). A decision-making model for supporting selection of green building materials. *International Journal of Construction Management*, *23*(5), 922–933. https://doi.org/10.1080/15623599.2021.1944548

Al-tamimi, A. K., Alqamish, H. H., Khaldoune, A., & Alhaidary, H. (2023). *Framework of 3D Concrete Printing Potential and Challenges*.

Alam, Z., & Masrafy, S. E. (2023). *Net Zero Energy Buildings in Bangladesh : An Investigation of Solar Panel Feasibility and Potential*. *7*(2), 15–19.

Alhazzaa, K. (2023). Energy Efficient Rehabilitation of a Historic Building in Tucson, Arizona: Investigating the Potential for Energy Conservation While Preserving the Building'S Historical Integrity. *Journal of Architecture and Urbanism*, *47*(1), 12–19. https://doi.org/10.3846/jau.2023.16197

Almeida, R., Chaves, L., Silva, M., Carvalho, M., & Caldas, L. (2023). Integration between BIM and EPDs: Evaluation of the main difficulties and proposal of a framework based on ISO 19650:2018. *Journal of Building Engineering*, *68*(December 2022), 106091. https://doi.org/10.1016/j.jobe.2023.106091

Alsharif, R., Arashpour, M., Golafshani, E., Rashidi, A., & Li, H. (2023). Multi-objective optimization of shading devices using ensemble machine learning and orthogonal design of experiments. *Energy and Buildings*, *283*, 112840.

https://doi.org/10.1016/j.enbuild.2023.112840

Altassan, A., Othman, M., Elbeltagi, E., Abdelshakor, M., & Ehab, A. (2023). A Qualitative Investigation of the Obstacles Inherent in the Implementation of Building Information Modeling (BIM). *Buildings*, *13*(3), 700. https://doi.org/10.3390/buildings13030700

Altitudes, L. S. (2023). *Low Solar Altitudes*.

Amini Toosi, H., Del Pero, C., Leonforte, F., Lavagna, M., & Aste, N. (2023). Machine learning for performance prediction in smart buildings: Photovoltaic self-consumption and life cycle cost optimization. *Applied Energy*, *334*(January). https://doi.org/10.1016/j.apenergy.2023.120648

Anupong, W., Muda, I., AbdulAmeer, S. A., Al-Kharsan, I. H., Alviz-Meza, A., & Cárdenas-Escrocia, Y. (2023). Energy Consumption and Carbon Dioxide Production Optimization in an Educational Building Using the Supported Vector Machine and Ant Colony System. *Sustainability (Switzerland)*, *15*(4). https://doi.org/10.3390/su15043118

Apostolopoulos, V., Mamounakis, I., Seitaridis, A., Tagkoulis, N., Kourkoumpas, D. S., Iliadis, P., Angelakoglou, K., & Nikolopoulos, N. (2023). An Integrated Life Cycle Assessment and Life Cycle Costing Approach Towards Sustainable Building Renovation Via a Dynamic Online Tool. *Applied Energy*, *334*(December 2022), 120710. https://doi.org/10.1016/j.apenergy.2023.120710

Arbulu, M., Oregi, X., & Etxepare, L. (2023). Environmental and economic optimization and prioritization tool-kit for residential building renovation strategies with life cycle approach. *Building and Environment*, *228*(November 2022), 109813. https://doi.org/10.1016/j.buildenv.2022.109813

Athari Nikooravan, H., & Golabchi, M. (2023). Analysis of Barriers of Implementing BIM in Construction Industry: Iranian Private Projects. *Sharif Journal of Civil Engineering*. https://doi.org/10.24200/j30.2022.61059.3146

Avduykova, K. I., & Pridvizhkin, S. V. (2023). *Energy modeling is one of the main tasks of applying BIM*. 020005. https://doi.org/10.1063/5.0121041

Azima, M., & Seyis, S. (2023). Science mapping the knowledge domain of energy performance research in the AEC industry: A scientometric analysis. *Energy*, *264*(November 2022), 125938. https://doi.org/10.1016/j.energy.2022.125938

Backe, S., Pinel, D., Askeland, M., Lindberg, K. B., Korpås, M., & Tomasgard, A. (2023). Exploring the link between the EU emissions trading system and net-zero emission neighbourhoods. *Energy and Buildings*, *281*, 112731. https://doi.org/10.1016/j.enbuild.2022.112731

Balakumar, P., Vinopraba, T., & Chandrasekaran, K. (2023). Deep learning based real time Demand Side Management controller for smart building integrated with renewable energy and Energy Storage System. *Journal of Energy Storage*, *58*(February 2022), 106412. https://doi.org/10.1016/j.est.2022.106412

Ben Bachouch, R., Fousseret, Y., & Parmantier, Y. (2023). Optimal Sensor Placement in Smart Home Using Building Information Modeling: A Home Support Application. *Irbm*, *44*(3), 100745. https://doi.org/10.1016/j.irbm.2022.100745

Beyraghshamshir, M., & Sarkardehei, E. (2023). A comparison of the cooling and heating performance of two passive systems of central courtyards and atriums at an elementary school in Yazd City. *Solar Energy*, *252*(February), 156–162. https://doi.org/10.1016/j.solener.2023.01.034

Bilgili, M. Y. (2021). The Role and Importance of Talloires Declaration in Establishing Sustainable Higher Education Institutions. *Journal of Higher Education and Science*, *11*(2), 417–424. https://doi.org/10.5961/jhes.2021.461

BIMobject. (2023). *URSA Mineral wool TERRA Vento P4252 ES*. https://www.bimobject.com/en/ursa/product/terra_vento_p

Blechmann, S., Sowa, I., Schraven, M. H., Streblow, R., Müller, D., & Monti, A. (2023). Open source platform application for smart building and smart grid controls. *Automation in Construction*, *145*(September 2022), 104622. https://doi.org/10.1016/j.autcon.2022.104622

Boni, F. (2020). How to become a LEED Green Associate: Exam Preparation Guide. *Ugreen*, 173. www.ugreen.io

Bonomolo, M., Di Lisi, S., & Leone, G. (2021). Building information modelling and energy simulation for architecture design. *Applied Sciences (Switzerland)*, *11*(5), 1–32. https://doi.org/10.3390/app11052252

Bu, L., Chen, X., Gan, L., Yu, K., Zhou, Y., Cao, J., & Cao, Y. (2023). Low-carbon operation method of the building based on dynamic carbon emission factor of power system. *IET Smart Grid*, *6*(1), 67–85. https://doi.org/10.1049/stg2.12085

Cai, X., Schild, T., Kümpel, A., & Müller, D. (2023). MODI: A Structured Development Process of Mode-Based Control Algorithms in the Early Design Stage of Building Energy Systems. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020267

Caldera, M., Hussain, A., Romano, S., & Re, V. (2023). Energy-Consumption Pattern-Detecting Technique for Household Appliances for Smart Home Platform. *Energies*, *16*(2), 1–23. https://doi.org/10.3390/en16020824

Cao, Y., Xu, C., Aziz, N. M., & Kamaruzzaman, S. N. (2023). BIM–GIS Integrated Utilization in Urban Disaster Management: The Contributions, Challenges, and Future Directions. *Remote Sensing*, *15*(5), 1–35. https://doi.org/10.3390/rs15051331

Cascone, S. (2023). *Digital Technologies and Sustainability Assessment : A Critical Review on the Integration Methods between BIM and LEED*.

Case, L. A., Office, L., Kong, D., Yang, Y., Sa, X., Wei, X., Zheng, H., Shi, J., & Wu, H. (2023). *Evaluation of the Impact of Input-Data Resolution on Building-Energy Simulation Accuracy and Computational*.

Catto Lucchino, E., & Goia, F. (2023). Multi-domain model-based control of an adaptive facade based on a flexible double skin system. *Energy and Buildings*, *285*, 112881. https://doi.org/10.1016/j.enbuild.2023.112881

Chang, Y. T., & Hsieh, S. H. (2020). A review of building information modeling research for green building design through building performance analysis. *Journal of Information Technology in Construction*, *25*, 1–40. https://doi.org/10.36680/j.itcon.2020.001

Chen, C., Wang, M. Y., Shen, C., Huang, Y., Zhu, M., Wang, H., He, L., & Julien, D. B. (2023). Sensitivity Analysis of Factors Influencing Rural Housing Energy Consumption in Different Household Patterns in the Zhejiang Province. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020463

Chen, S. (2021). *Multi-Domain Multi-Objective Optimisation of Urban District Environmental Performance*. *December*.

Chen, S. H., & Xue, F. (2023). Automatic BIM detailing using deep features of 3D views. *Automation in Construction*, *148*(January), 104780.

https://doi.org/10.1016/j.autcon.2023.104780

Chen, Y., Anthony, M. T., & Ke, Y. (2023). *Proceedings of the 2022 2nd International Conference on Modern Educational Technology and Social Sciences (ICMETSS 2022)*. Atlantis Press SARL. https://books.google.com.tr/books?id=9XeiEAAAQBAJ

Chen, Y., Gao, J., Yang, J., Berardi, U., & Cui, G. (2023). An hour-ahead predictive control strategy for maximizing natural ventilation in passive buildings based on weather forecasting. *Applied Energy*, *333*(December 2022), 120613. https://doi.org/10.1016/j.apenergy.2022.120613

Chen, Y., Wang, X., Liu, Z., Cui, J., Osmani, M., & Demian, P. (2023). Exploring Building Information Modeling (BIM) and Internet of Things (IoT) Integration for Sustainable Building. *Buildings*, *13*(2), 0–27. https://doi.org/10.3390/buildings13020288

Chen, Z. (2023). *Project management mode under the concept of low carbon environmental protection and its value in intelligent construction*.

Cheng, J., Huang, L., Jiang, L., Chen, J., Chen, W., & He, Y. (2023). *Fostering Knowledge Collaboration in Construction Projects : The Role of BIM Application*. 1–14.

Chenjie, Z. (2023). Application of BIM Technology in New Assembly Type Green Building. *International Journal of Frontiers in Engineering Technology*, *5*(1), 8–14. https://doi.org/10.25236/ijfet.2023.050102

Cho, J., Heo, Y., & Moon, J. W. (2023). An intelligent HVAC control strategy for supplying comfortable and energy-efficient school environment. *Advanced Engineering Informatics*, *55*(December 2022), 101895. https://doi.org/10.1016/j.aei.2023.101895

CIU Sustainability Website. (2023). *CIU Sustainability Website*. https://www.ciu.edu.tr/en/about-us/impact/sustainability

CIU Website. (2023). *Cyprus International University Website*. https://www.ciu.edu.tr/en

Contracting, R. (2017). *Achieving Sustainable Campus Through Integrated Project Delivery In Northern Region Higher Education Institution*. *6*, 3–9.

Copiello, S., & Coletto, S. (2023). The Price Premium in Green Buildings: A Spatial Autoregressive Model and a Multi-Criteria Optimization Approach. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020276

Corticos, N. D. (2020). Improving residential building efficiency with membranes over facades: The Mediterranean context. *Journal of Building Engineering*, *32*(April 2020), 101421. https://doi.org/10.1016/j.jobe.2020.101421

Cyprus International University Sustainability Report. (2020). Cyprus International University Sustainability Report. *1st International Conference on Economics, Business, Entrepreneurship, and Finance (ICEBEF 2018)*, *65*(Icebef 2020), 27–35. https://www.tokyocentury.co.jp/download/pdf/en/network/id_sr2020.pdf

Danial, C. E., Mahmoud, A. H. A., & Tawfik, M. Y. (2023). Methodology for retrofitting energy in existing office buildings using building information modelling programs. *Ain Shams Engineering Journal*, *14*(6), 102175. https://doi.org/10.1016/j.asej.2023.102175

De León, L., Mora, D., Carpino, C., Arcuri, N., & Chen Austin, M. (2023). A Reference Framework for Zero Energy Districts in Panama Based on Energy Performance Simulations and Bioclimatic Design Methodology. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020315

Deleye, M. (2023). Which “sustainable university” are we actually talking about? A topic modelling-assisted discourse analysis of academic literature. *Environmental Education Research*, *0*(0), 1–22. https://doi.org/10.1080/13504622.2023.2167940

Di Turi, S., Ronchetti, L., & Sannino, R. (2023). Towards the objective of Net ZEB: Detailed energy analysis and cost assessment for new office buildings in Italy. *Energy and Buildings*, *279*, 112707. https://doi.org/10.1016/j.enbuild.2022.112707

Drewniok, M. P., Dunant, C. F., Allwood, J. M., Ibell, T., & Hawkins, W. (2023). Modelling the embodied carbon cost of UK domestic building construction: Today to 2050. *Ecological Economics*, *205*(December 2022), 107725. https://doi.org/10.1016/j.ecolecon.2022.107725

DU Website. (2023). *Duzce University Website*. https://duzce.edu.tr/

Duzce University Computer Center. (2023). *Duzce University Computer Center Department-GreenMetric*. Duzce University Green Campus Studies.

https://duzce.edu.tr/49f8/green-metric

Duzce University Sustainability Report. (2022). Duzce University Sustainability Report. *Duzce University*, *90*(380), 1–8.

Ebuy, H. T., Bril El Haouzi, H., Benelmir, R., & Pannequin, R. (2023). Occupant Behavior Impact on Building Sustainability Performance: A Literature Review. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032440

Edwards, R. E., Lou, E., Bataw, A., Kamaruzzaman, S. N., & Johnson, C. (2019). Sustainability-led design: Feasibility of incorporating whole-life cycle energy assessment into BIM for refurbishment projects. *Journal of Building Engineering*, *24*(February), 100697. https://doi.org/10.1016/j.jobe.2019.01.027

Eggimann, S., Mutschler, R., Orehounig, K., & Fiorentini, M. (2023). *Climate change shifts the trade-off between lower cooling and higher heating demand from daylight saving time in office buildings Climate change shifts the trade-off between lower cooling and higher heating demand from daylight saving time in office build*.

Ejidike, C. C., & Mewomo, M. C. (2023). Benefits of adopting smart building technologies in building construction of developing countries: review of literature. *SN Applied Sciences*, *5*(2). https://doi.org/10.1007/s42452-022-05262-y

Energy 3D. (2023). *Energy 3D the Concord Consortium*. https://energy.concord.org/energy3d/

EPD, I. (2022). *Environmental Product Declaration - URSA TERRA Vento P4252, URSA TERRA P4252 VN, TER34VV*. *Cem Iii*, 1–14. http://www.brick.org.uk/wp-content/uploads/2014/01/Please-click-here-to-download-the-EDP.pdf

Erbıyık, H., Çatal, T., Durukan, S., Topaloğlu, D. G., & Ünver, Ü. (2021). Assessment of Yalova University Campus according to LEED V.4 certification system. *Environmental Research and Technology*, *4*(1), 18–28. https://doi.org/10.35208/ert.812339

Erciyes University Sustainability Report. (2021). Erciyes University Sustainability Report. *Erciyes University*.

ERU Sustainability Website. (2023). *ERU Sustainability Website*. https://yesilkampus.erciyes.edu.tr/

ERU Website. (2023). *Erciyes University Website*. https://www.erciyes.edu.tr/

Essam, N., Khodeir, L., & Fathy, F. (2023). Approaches for BIM-based multi-objective optimization in construction scheduling. *Ain Shams Engineering Journal*, *14*(6), 102114. https://doi.org/10.1016/j.asej.2023.102114

Famakin, I. O., Othman, I., Kineber, A. F., Oke, A. E., Olanrewaju, O. I., Hamed, M. M., & Olayemi, T. M. (2023). Building Information Modeling Execution Drivers for Sustainable Building Developments. *Sustainability (Switzerland)*, *15*(4). https://doi.org/10.3390/su15043445

Fauth, J., Pasetti Monizza, G., & Malacarne, G. (2023). Understanding processes on digital building permits – a case study in South Tyrol. *Building Research & Information*, *0*(0), 1–15. https://doi.org/10.1080/09613218.2023.2178372

Fernández Bandera, C., Bastos Porsani, G., & Fernández-Vigil Iglesias, M. (2023). A demand side management approach to increase self-consumption in buildings. *Building Simulation*, *16*(2), 317–335. https://doi.org/10.1007/s12273-022-0933-9

Ferreira, A., Pinheiro, M. D., Brito, J. de, Mateus, R., & Mendonça, R. (2023). Wall and roof solutions for a retail building considering cost investment and life cycle approach: A case study in Portugal. *Journal of Cleaner Production*, *383*(November 2022), 135314. https://doi.org/10.1016/j.jclepro.2022.135314

Forth, K., Abualdenien, J., & Borrmann, A. (2023). Calculation of embodied GHG emissions in early building design stages using BIM and NLP-based semantic model healing. *Energy and Buildings*, *284*, 112837. https://doi.org/10.1016/j.enbuild.2023.112837

Francisco, J. (2023). *Sustainable Design Protocol in BIM Environments : Case Study of 3D Virtual Models of a Building in Seville (Spain) Based on BREEAM Method*.

Franco, A., Miserocchi, L., & Testi, D. (2023). Energy efficiency in shared buildings: Quantification of the potential at multiple scales. *Energy Reports*, *9*, 84–95. https://doi.org/10.1016/j.egyr.2022.11.142

Gan, J., Li, K., Li, X., Mok, E., Ho, P., Law, J., Lau, J., Kwok, R., & Yau, R. (2023). *Parametric BIM-Based Lifecycle Performance Prediction and Materials and Designs*.

Gao, Z., Liu, H., Xu, X., Xiahou, X., Cui, P., & Mao, P. (2023). Research Progress on

Carbon Emissions of Public Buildings: A Visual Analysis and Review. *Buildings, 13*(3), 677. https://doi.org/10.3390/buildings13030677

Garwood, T. L., Hughes, B. R., Oates, M. R., O'Connor, D., & Hughes, R. (2018). A review of energy simulation tools for the manufacturing sector. In *Renewable and Sustainable Energy Reviews* (Vol. 81, pp. 895–911). Elsevier Ltd. https://doi.org/10.1016/j.rser.2017.08.063

Ghansah, F. A., & Lu, W. (2023). Major opportunities of digital twins for smart buildings: a scientometric and content analysis. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-09-2022-0192

Goubran, S., Walker, T., Cucuzzella, C., & Schwartz, T. (2023). Green building standards and the United Nations' Sustainable Development Goals. *Journal of Environmental Management, 326*(PA), 116552. https://doi.org/10.1016/j.jenvman.2022.116552

Graphisoft, T. (2023). *graphisoft*. https://graphisoft.com/

Green Vision for Wageningen Campus. (2019). Green Vision for Wageningen Campus. *Wageningen University & Research, June*, 1–17.

Grindsted, T. S. (2015). Sustainable Universities From Declarations on Sustainability in Higher Education to National Law. *SSRN Electronic Journal, 2*(2), 29–36. https://doi.org/10.2139/ssrn.2697465

Grygierek, K., Nateghi, S., Ferdyn-Grygierek, J., & Kaczmarczyk, J. (2023). Controlling and Limiting Infection Risk, Thermal Discomfort, and Low Indoor Air Quality in a Classroom through Natural Ventilation Controlled by Smart Windows. *Energies, 16*(2). https://doi.org/10.3390/en16020592

Guillermo, B., Jan, V., Han, V., & Irena, K. (2023). Smart building and district retrofitting for intelligent urban environments. *Intelligent Environments*, 395–420. https://doi.org/10.1016/b978-0-12-820247-0.00011-4

Gumbarevic, S., Dunovic, I. B., Milovanovic, B., & Gaši, M. (2020). Method for building information modeling supported project control of nearly zero-energy building delivery. *Energies, 13*(20). https://doi.org/10.3390/en13205519

Gunerhan, S. A., & Gunerhan, H. (2016). Sustainable university model for Turkey. *Engineer and Machinery, 57*(682), 54.

Haggag, A. (2023). The Effect of Using Nanotechnology in Construction Processes Applied by BIM. *Journal of Engineering Research*, *0*(0), 0–0. https://doi.org/10.21608/erjeng.2023.185411.1140

Haidar, N., Tamani, N., Ghamri-Doudane, Y., & Boujou, A. (2023). Selective reinforcement graph mining approach for smart building energy and occupant comfort optimization. *Building and Environment*, *228*(November 2022), 109806. https://doi.org/10.1016/j.buildenv.2022.109806

Hammond, E. B., Coulon, F., Hallett, S. H., Thomas, R., Hardy, D., & Beriro, D. J. (2023). Digital tools for brownfield redevelopment: Stakeholder perspectives and opportunities. *Journal of Environmental Management*, *325*(PA), 116393. https://doi.org/10.1016/j.jenvman.2022.116393

Henrique, L. F., Silva, W. N., Silva, C. C. A., Dias, B. H., Oliveira, L. W., & de Almeida, M. C. (2023). Optimal siting and sizing of distributed energy resources in a Smart Campus. *Electric Power Systems Research*, *217*(December 2022), 109095. https://doi.org/10.1016/j.epsr.2022.109095

Honic, M., Ferschin, P., Breitfuss, D., Cencic, O., Gourlis, G., Kovacic, I., & De Wolf, C. (2023). Framework for the assessment of the existing building stock through BIM and GIS. *Developments in the Built Environment*, *13*(December 2022), 100110. https://doi.org/10.1016/j.dibe.2022.100110

Hosamo, H. H., Nielsen, H. K., Kraniotis, D., Svennevig, P. R., & Svidt, K. (2023). Digital Twin framework for automated fault source detection and prediction for comfort performance evaluation of existing non-residential Norwegian buildings. *Energy and Buildings*, *281*, 112732. https://doi.org/10.1016/j.enbuild.2022.112732

Howell, E., & Woodbury, M. (2023). *Centre for Building Performance Holistic Carbon Accounting : Extending the design life of the existing commercial scale building stock* . (Issue January).

Hu, Y. J., Huang, H., Wang, H., Li, C., & Deng, Y. (2023). Exploring cost-effective strategies for emission reduction of public buildings in a life-cycle. *Energy and Buildings*, *285*, 112927. https://doi.org/10.1016/j.enbuild.2023.112927

Huang, H., Tan, H., Xu, X., Zhang, J., & Zhao, Z. (2023). LACE: Low-Cost Access Control Based on Edge Computing for Smart Buildings. *Electronics (Switzerland)*, *12*(2). https://doi.org/10.3390/electronics12020412

Huang, J., & Kaewunruen, S. (2023). Forecasting Energy Consumption of a Public Building Using Transformer and Support Vector Regression. *Energies*, *16*(2). https://doi.org/10.3390/en16020966

Huang, J., Reitberger, R., Banihashemi, F., & Lang, W. (2023). A novel risk-based design framework for urban heat island: A case study of Kempten, Germany. *Building and Environment*, *228*(October 2022), 109671. https://doi.org/10.1016/j.buildenv.2022.109671

ICE Publishing. (2023). *ICE Manual of Blue-Green Infrastructure*.

Ilaria Salerno. (2023). Optimising Heating and Cooling of Smart Buildings by University of Edinburgh School of Mathematics. *PhD Thesis*.

Informatics, E., & Denmark, S. (2023). *An ontology-based innovative energy modeling framework for scalable and adaptable building digital twins*.

Islam, S. (2022). The Green Shadow: Paradox Of Increasing Green Practices And Stagnant Labour Conditions. *Braz Dent J.*, *33*(1), 1–12.

Ismail, Z. A. Bin. (2023). A BIM-based model checking in the green building maintenance: a review. *Construction Innovation*, *23*(2), 487–503. https://doi.org/10.1108/CI-10-2020-0161

Istanbul Technical University Sustainability Report. (2022). Istanbul Technical University Sustainability Report. *Istanbul Technical University*. https://sustainability.itu.edu.tr/sustainability-office/sustainability-report

ITU Sustainability Website. (2023). *ITU Sustainability Website*. https://sustainability.itu.edu.tr/

ITU Website. (2023). *Istanbul Tecnical University Website*. https://www.itu.edu.tr/

Jorge-Ortiz, A., Braulio-Gonzalo, M., & Bovea, M. D. (2023). Exploring how waste management is being approached in green building rating systems: A case study. *Waste Management and Research*. https://doi.org/10.1177/0734242X221143952

Jung, Y., Heo, Y., Cho, H., Kang, Y. T., Kim, Y., & Lee, H. (2023). A plan to build a net zero energy building in hydrogen and electricity-based energy scenario in South Korea. *Journal of Cleaner Production*, *397*(January), 136537.

https://doi.org/10.1016/j.jclepro.2023.136537

Kamel, E., & Kazemian, A. (2023). BIM-integrated thermal analysis and building energy modeling in 3D-printed residential buildings. *Energy and Buildings*, *279*, 112670. https://doi.org/10.1016/j.enbuild.2022.112670

Khalili Tari, M., Reza Faraji, A., Aslani, A., & Zahedi, R. (2023). Energy simulation and life cycle assessment of a 3D printable building. *Cleaner Materials*, *7*(December 2022), 100168. https://doi.org/10.1016/j.clema.2023.100168

Khampuong, P., Chairungruang, S., Rodcharoen, P., Leelittham, C., Eak-ieamvudtanakul, P., Kumpuang, C., & Chompoowong, P. (2023). Smart Campus Vocational College with Digital Twin for Sustainable Comfort Monitoring. *International Journal of Educational Communications and Technology*, *3*(1), 10–22. https://ph01.tci-thaijo.org/index.php/IJECT/article/view/248609

Khan, F. A., Ullah, K., ur Rahman, A., & Anwar, S. (2023). Energy optimization in smart urban buildings using bio-inspired ant colony optimization. *Soft Computing*, *27*(2), 973–989. https://doi.org/10.1007/s00500-022-07537-3

Khoja, A. (2023). Scale matters: exploiting cross-scale interactions for a smart and sustainable built environment. In *Intelligent Environments*. Elsevier B.V. https://doi.org/10.1016/b978-0-12-820247-0.00018-7

Kineber, A. F., Othman, I., Famakin, I. O., Oke, A. E., Hamed, M. M., & Olayemi, T. M. (2023). Challenges to the Implementation of Building Information Modeling (BIM) for Sustainable Construction Projects. *Applied Sciences*, *13*(6), 3426. https://doi.org/10.3390/app13063426

Kotarela, F., Kyritsis, A., Agathokleous, R., & Papanikolaou, N. (2023). On the exploitation of dynamic simulations for the design of buildings energy systems. *Energy*, *271*(January), 127002. https://doi.org/10.1016/j.energy.2023.127002

Kresnanto, N. C., Ramadhan, R. I., Willdan, M., & Putra, P. B. P. (2023). BIM's Contribution as A Sustainable Construction Accelerator. *Applied Research on Civil Engineering and Environment (ARCEE)*, *4*(01), 38–52. https://doi.org/10.32722/arcee.v4i01.5333

Kumar, Y., Thakur, T., & Saha, S. (2023). *Simulation Analysis Of Conventional Building To Convert It Into Net Zero Ebergy Building*.

Kutlu, İ., & Bekar, İ. (2023). Investigation of building certification systems in terms of sustainable preservation: the case of Mardin city in Turkey. *Mehran University Research Journal of Engineering and Technology*, *42*(1), 183. https://doi.org/10.22581/muet1982.2301.17

La Guardia, M., & Koeva, M. (2023). Towards Digital Twinning on the Web: Heterogeneous 3D Data Fusion Based on Open-Source Structure. *Remote Sensing*, *15*(3). https://doi.org/10.3390/rs15030721

Lam, K. H., To, W. M., & Lee, P. K. C. (2023). Smart Building Management System (SBMS) for Commercial Buildings—Key Attributes and Usage Intentions from Building Professionals' Perspective. *Sustainability (Switzerland)*, *15*(1). https://doi.org/10.3390/su15010080

Lee, J., Lee, M.-G., Shih, Y.-F., & Lee, L. (2023). Sustainable Development: Emerging Trends in Energy Efficiency, Carbon Reduction, and Green Building Materials. *Buildings*, *13*(3), 735. https://doi.org/10.3390/buildings13030735

Li, D., Li, J., Zeng, X., Stankovic, V., Stankovic, L., Xiao, C., & Shi, Q. (2023). Transfer learning for multi-objective non-intrusive load monitoring in smart building. *Applied Energy*, *329*(November 2022), 120223. https://doi.org/10.1016/j.apenergy.2022.120223

Li, F., Wang, Z., Pang, C., & Yang, H. (2023). 3D Modeling of Mine Protection Complex Steel Structure Based on BIM Technology. *Journal of Applied Mathematics*, *2023*, 1–9. https://doi.org/10.1155/2023/7193935

Li, G., & Tian, H. (2023). Mapping Knowledge Domain to Analyze the Building Information Modeling on Building Energy Saving Based on Visualized Analysis Method. *Advances in Civil Engineering*, *2023*. https://doi.org/10.1155/2023/5159067

Li, G., Tian, W., Zhang, H., & Fu, X. (2023). A novel method of creating machine learning-based time series meta-models for building energy analysis. *Energy and Buildings*, *281*, 112752. https://doi.org/10.1016/j.enbuild.2022.112752

Li, H. X., Okolo, D. E., Tabadkani, A., Arnel, T., & Zheng, D. (2023). An integrated framework of ground source heat pump utilisation for high - performance buildings. *Scientific Reports*, 1–16. https://doi.org/10.1038/s41598-023-27704-2

Li, J., Jimenez-Bescos, C., Calautit, J. K., & Yao, J. (2023). Evaluating the Energy-Saving Potential of Earth-Air Heat Exchanger (Eahx) for Passivhaus Standard Buildings in China. *SSRN Electronic Journal*, *288*, 113005. https://doi.org/10.2139/ssrn.4330896

Li, Q., Yang, W., Kohler, N., Yang, L., Li, J., Sun, Z., Yu, H., Liu, L., & Ren, J. (2023). A BIM–LCA Approach for the Whole Design Process of Green Buildings in the Chinese Context. *Sustainability (Switzerland)*, *15*(4). https://doi.org/10.3390/su15043629

Li, X., Han, Z., Sun, J., & Liu, G. (2023). Venis: A designer-centric support tool for building performance design at early design stages. *Journal of Building Engineering*, *63*(PA), 105429. https://doi.org/10.1016/j.jobe.2022.105429

Liu, S., Wang, Y., Liu, X., Yang, L., Zhang, Y., & He, J. (2023). How does future climatic uncertainty affect multi-objective building energy retrofit decisions? Evidence from residential buildings in subtropical Hong Kong. *Sustainable Cities and Society*, *92*(December 2022), 104482. https://doi.org/10.1016/j.scs.2023.104482

Loo, B. P. Y., & Wong, R. W. M. (2023). Towards a Conceptual Framework of Using Technology to Support Smart Construction: The Case of Modular Integrated Construction (MiC). *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020372

Lu, C., Li, S., Gu, J., Lu, W., Olofsson, T., & Ma, J. (2023). A hybrid ensemble learning framework for zero-energy potential prediction of photovoltaic direct-driven air conditioners. *Journal of Building Engineering*, *64*(November 2022), 105602. https://doi.org/10.1016/j.jobe.2022.105602

Ma, W. (2023). *Technical framework of energy-saving construction management of intelligent building based on computer vision algorithm*. 1–15.

Maglad, A. M., Houda, M., Alrowais, R., Khan, A. M., Jameel, M., Rehman, S. K. U., Khan, H., Javed, M. F., & Rehman, M. F. (2023). Bim-based energy analysis and optimization using insight 360 (case study). *Case Studies in Construction Materials*, *18*(December 2022), e01755. https://doi.org/10.1016/j.cscm.2022.e01755

Manoj, S., & Kumari, P. V. P. (2023). Green Banking Practices and Strategies for Sustainable. *Res Militaris*, *13*(1), 380–392.

Marzouk, M., El-Maraghy, M., & Metawie, M. (2023). Assessing retrofit strategies for mosque buildings using TOPSIS. *Energy Reports*, *9*, 1397–1414.

https://doi.org/10.1016/j.egyr.2022.12.073

Masoud Sajjadian, S. (2023). A critique on the UK's net zero strategy. *Sustainable Energy Technologies and Assessments*, *56*(January), 103003. https://doi.org/10.1016/j.seta.2022.103003

Matana Júnior, S., Antonio Leite Frandoloso, M., & Barbosa Brião, V. (2023). The role of HEIs to achieve SDG7 goals from Netzero campuses: case studies and possibilities in Brazil. *International Journal of Sustainability in Higher Education*, *24*(2), 462–480. https://doi.org/10.1108/IJSHE-07-2021-0282

Mathews, M. E., Shaji, A. E., Anand, N., Andrushia, A. D., Chin, S. C., & Lubloy, E. (2023). IoT-based BIM integrated model for energy and water management in smart homes. In *Intelligent Edge Computing for Cyber Physical Applications*. INC. https://doi.org/10.1016/b978-0-323-99412-5.00009-5

Mawra, K., Rashid, K., Ju, M., Alqahtani, F. K., & Zafar, I. (2023). Thermo-physical and energy performance of building envelope modified by natural fiber through building information modelling. *Journal of Building Engineering*, *68*(January), 106117. https://doi.org/10.1016/j.jobe.2023.106117

Mertens, N., Wohlfahrt, T., Hartmann, N., & Reddy, C. B. V. (2023). *Automatic Transformation of HVAC Diagrams into Machine-Readable Format BT - Product Lifecycle Management. PLM in Transition Times: The Place of Humans and Transformative Technologies* (F. Noël, F. Nyffenegger, L. Rivest, & A. Bouras (eds.); pp. 410–419). Springer Nature Switzerland.

Mohajer, M. F. (2022). *Building Information Modeling (BIM) And Building Energy Modeling (BEM): Assessment of BIM-BEM Workflows And Energy Simulation Tools*. *October*.

Montiel-Santiago, F. J., Hermoso-Orzáez, M. J., & Terrados-Cepeda, J. (2023). *A Systematic review of the BIM Methodology Applied to the Management and Sustainability of Hospital Centers. The Digital BIM Twin in the Management and Sustainability of Hospital Buildings. Case Study: University Hospital of Jaén BT - Proceedings of the* (P. S. Duque de Brito, J. R. da Costa Sanches Galvão, P. Monteiro, R. Panizio, L. Calado, A. C. Assis, F. dos Santos Neves, F. Craveiro, H. de Amorim Almeida, J. O. Correia Vasco, R. de Jesus Gomes, S. de Jesus Martins Mourato, & V. S. Santos Ribeiro (eds.); pp. 218–227). Springer International

Publishing.

Morshed, T., & Mourshed, M. (2023). Overheating and energy use in urban office buildings in a warming climate. *Japan Architectural Review*, *6*(1). https://doi.org/10.1002/2475-8876.12307

Musarat, M. A., Alaloul, W. S., Cher, L. S., Qureshi, A. H., Alawag, A. M., & Baarimah, A. O. (2023). Applications of Building Information Modelling in the Operation and Maintenance Phase of Construction Projects: A Framework for the Malaysian Construction Industry. *Sustainability*, *15*(6), 5044. https://doi.org/10.3390/su15065044

Navabi, D., Amini, Z., Rahmati, A., Tahbaz, M., Butt, T. E., Sharifi, S., & Mosavi, A. (2023). Developing light transmitting concrete for energy saving in buildings. *Case Studies in Construction Materials*, *18*(March), e01969. https://doi.org/10.1016/j.cscm.2023.e01969

Newberry, P., Harper, P., & Norman, J. (2023). Life cycle assessment of building shell options for eco self-build community housing through the integration of building energy modelling (BEM) and LCA tools. *Journal of Building Engineering*, *70*(September 2022), 106356. https://doi.org/10.1016/j.jobe.2023.106356

Nguyen, H. D., Do, Q. N. H., & Macchion, L. (2023). Influence of practitioners' characteristics on risk assessment in Green Building projects in emerging economies: a case of Vietnam. *Engineering, Construction and Architectural Management*, *30*(2), 833–852. https://doi.org/10.1108/ECAM-05-2021-0436

Nguyen, H. D., & Macchion, L. (2023). Risk management in green building: a review of the current state of research and future directions. *Environment, Development and Sustainability*, *25*(3), 2136–2172. https://doi.org/10.1007/s10668-022-02168-y

Nižetić, S., Arıcı, M., & Hoang, A. T. (2023). Smart and Sustainable Technologies in energy transition. *Journal of Cleaner Production*, *389*. https://doi.org/10.1016/j.jclepro.2023.135944

Novieto, D. T., Kulor, F., Apprey, M. W., & Ayeke, E. (2023). Appraisal of students' perceptions on green building concepts in a technical university. *Frontiers in Engineering and Built Environment*. https://doi.org/10.1108/febe-08-2022-0034

NTU Net Zero Carbon Report. (2021). Net Zero Carbon Report. *Nottingham Trent*

University. https://www.tokyocentury.co.jp/download/pdf/en/network/id_sr2020.pdf

NTU Sustainability Report. (2020). Sustainability Report. *1st International Conference on Economics, Business, Entrepreneurship, and Finance (ICEBEF 2018)*, *65*(Icebef 2018), 27–35. https://www.tokyocentury.co.jp/download/pdf/en/network/id_sr2020.pdf

NTU Sustainability Website. (2023). *NTU Sustainability Website*. https://www.ntu.ac.uk/about-us/strategy/sustainability

NTU Water Management Plan. (2022). NTU Water Management Plan. *Nottingham Trent University*, *June*, 1–5.

NTU Website. (2023). *Nottingham Trent University Website*. https://www.ntu.ac.uk/

NU Sustainability Website. (2023). *NU Sustainability Website*. https://www.nottingham.ac.uk/sustainability/#

NU Website. (2023). *Nottingham University Website*. https://www.nottingham.ac.uk/

Ogutucu, R. (2023). *The Impact of Bim Based Tools on Sustainable Building Design within the Framework of Integrated Building Design Approach: Daylight Analysis in A Mass Housing Project*.

ÖKOBAUDAT. (2023). *Sustainable Construction Information Portal*. https://www.oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?lang=en&uuid=b3abdd33-34fc-473a-a235-218cfd601c8e&version=20.21.060

Olanrewaju, O. I., Enegbuma, W. I., & Donn, M. (2022). Systematic Literature Review of Building Information Modelling and Green Building Certification Systems. *Proceedings of the International Symposium on Automation and Robotics in Construction*, *2022-July*(Isarc), 167–174. https://doi.org/10.22260/isarc2022/0025

Oleiwi, M. Q., & Mohamed, M. F. (2023). The Impacts of Passive Design Strategies on Building Indoor Temperature in Tropical Climate. *Pertanika Journal of Science and Technology*, *31*(1), 83–108. https://doi.org/10.47836/pjst.31.1.06

Onatayo, D. (2023). *A Scientometric Review of BIM in Facility Management Research*. *March*, 1–13. https://doi.org/10.20944/preprints202303.0095.v1

Otero, R., Lagüela, S., Cabaleiro, M., Sousa, H. S., & Arias, P. (2023). Semi-automatic

3D frame modelling of wooden trusses using indoor point clouds. *Structures*, *47*(December 2022), 1743–1753. https://doi.org/10.1016/j.istruc.2022.11.122

Paneru, S., Ghimire, P., Kandel, A., Thapa, S., Koirala, N., & Karki, M. (2023). An Exploratory Investigation of Implementation of Building Information Modeling in Nepalese Architecture–Engineering–Construction Industry. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020552

Pierzchalski, M., Ryńska, E. D., & Węglarz, A. (2021). Life cycle assessment as a major support tool within multi-criteria design process of single dwellings located in Poland. *Energies*, *14*(13). https://doi.org/10.3390/en14133748

Pinto, M. C., Crespi, G., Dell'Anna, F., & Becchio, C. (2023). Combining energy dynamic simulation and multi-criteria analysis for supporting investment decisions on smart shading devices in office buildings. *Applied Energy*, *332*(December 2022), 120470. https://doi.org/10.1016/j.apenergy.2022.120470

Plachinda, P., Morgan, J., & Coelho, M. (2023). Towards Net Zero: Modeling Approach to the Right-Sized Facilities. *Sustainability (Switzerland)*, *15*(1). https://doi.org/10.3390/su15010163

Prabu, E. M., & Rakesh, P. (2023). Influence of various parameters on lifecycle cost of buildings with active energy efficiency measures. *IOP Conference Series: Earth and Environmental Science*, *1130*(1). https://doi.org/10.1088/1755-1315/1130/1/012048

Psillaki, M., Apostolopoulos, N., Makris, I., Liargovas, P., Apostolopoulos, S., Dimitrakopoulos, P., & Sklias, G. (2023). Hospitals' Energy Efficiency in the Perspective of Saving Resources and Providing Quality Services through Technological Options: A Systematic Literature Review. *Energies*, *16*(2). https://doi.org/10.3390/en16020755

Pucko, Z., Maucec, D., & Šuman, N. (2020). Energy and Cost Analysis of Building Envelope. *Energies*, *13*(10), 1–24.

Qiu, D., Xue, J., Zhang, T., Wang, J., & Sun, M. (2023). Federated reinforcement learning for smart building joint peer-to-peer energy and carbon allowance trading. *Applied Energy*, *333*(December 2022), 120526. https://doi.org/10.1016/j.apenergy.2022.120526

Rakesh, P., Harisankar, R., & Das, B. B. (2023). Comparative Study of Energy Efficiency

Criteria for IGBC and GRIHA Systems Using Simulation. *Journal of The Institution of Engineers (India): Series A*, *104*(1), 39–50. https://doi.org/10.1007/s40030-022-00687-5

Raouf, A. M., & Al-Ghamdi, S. G. (2023). Framework to evaluate quality performance of green building delivery: construction and operational stage. *International Journal of Construction Management*, *23*(2), 253–267. https://doi.org/10.1080/15623599.2020.1858539

Rashidian, S., Drogemuller, R., & Omrani, S. (2023). Building Information Modelling, Integrated Project Delivery, and Lean Construction Maturity Attributes: A Delphi Study. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020281

Rashidian, S., Drogemuller, R., Omrani, S., & Banakar, F. (2023). A review of the interrelationships and characteristics of Building Information Modeling, Integrated Project Delivery and Lean Construction maturity models. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-10-2022-0236

Rastegari, M., Pournaseri, S., & Sanaieian, H. (2023). Analysis of daylight metrics based on the daylight autonomy (DLA) and lux illuminance in a real office building atrium in Tehran. *Energy*, *263*(PB), 125707. https://doi.org/10.1016/j.energy.2022.125707

Redlein, A. (2022). *The Impact of Building Certificates in regard to the implementation of relevant SDGs Master of Science Diplomarbeit*. *December*.

Redweik, P., Reis, S., & Duarte, M. C. (2023). a Digital Botanical Garden: Using Interactive 3D Models for Visitor Experience Enhancement and Collection Management. *Virtual Archaeology Review*, *14*(28), 65–80. https://doi.org/10.4995/var.2023.17629

Report, J. T. (2023). *Defining Zero-Emission Buildings*. https://doi.org/10.2760/107493

Report, M. (2023, January 21). *Campus Beautification And Garden Making For This College Under Plan Scheme Green Campus 2022-2023*. https://stanford.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&site=eds-live&db=edsgao&AN=edsgcl.734187553

Ruan, Y., Qian, F., Sun, K., & Meng, H. (2023). Optimization on building combined cooling, heating, and power system considering load uncertainty based on scenario generation method and two-stage stochastic programming. *Sustainable Cities and*

Society, *89*(December 2022), 104331. https://doi.org/10.1016/j.scs.2022.104331

Sadati, S. E., Rahbar, N., & Kargarsharifabad, H. (2023). Energy assessment, economic analysis, and environmental study of an Iranian building: The effect of wall materials and climatic conditions. *Sustainable Energy Technologies and Assessments*, *56*(January), 103093. https://doi.org/10.1016/j.seta.2023.103093

Sadono, S., Zen, A. P., Yuningsih, C. R., Trihanondo, D., & Wiguna, I. P. (2021). Green areas mapping of Telkom University as a support towards green campus. *IOP Conference Series: Materials Science and Engineering*, *1098*(5), 052012. https://doi.org/10.1088/1757-899x/1098/5/052012

Sahoo, M. K. (2016). "Green Campus" -a Competitive Advantage and Sustainability for Management Institutions. *DRIEMS Business Review*, *1*(74), 74–80.

Salsbury, T. I., Devaprasad, K., Lutes, R., & Rogers, A. P. (2023). Smarter building start – A distributed solution. *Energy and Buildings*, *282*, 112776. https://doi.org/10.1016/j.enbuild.2023.112776

Salzano, A., Parisi, C. M., Acampa, G., & Nicolella, M. (2023). Existing assets maintenance management: Optimizing maintenance procedures and costs through BIM tools. *Automation in Construction*, *149*(January), 104788. https://doi.org/10.1016/j.autcon.2023.104788

SDG-Turkey. (2022). *Sustainable Development Report 2022-Turkey*. https://www.tr.undp.org/content/turkey/en/home.html

SDSN. (2023). Sustainable Development Report 2023. In *Cambridge University*. https://doi.org/10.1017/9781009106559

Sedighi, M., Qhazvini, P. P., & Amidpour, M. (2023). Algae Powered Buildings_A Review of an Innovative. *Sustainability*.

Seduikyte, L. (2023). *Evaluation of the Smart Readiness Indicator for Educational Buildings*.

Selicati, V., & Cardinale, N. (2023). *Beneficial Impacts on Environment and Society Through Smart Sustainable Maintenance of Public Real Estate*. *41*(1), 46–54.

Sepasgozar, S. M. E., Khan, A. A., Smith, K., Romero, J. G., Shen, X., Shirowzhan, S., Li, H., & Tahmasebinia, F. (2023). BIM and Digital Twin for Developing

Convergence Technologies as Future of Digital Construction. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020441

Shah, D., Kathiriya, H., Suthar, H., Pandya, P., & Soni, J. (2023). *Enhancing the Building's Energy Performance through Building Information Modelling—A Review BT - Recent Trends in Construction Technology and Management* (M. S. Ranadive, B. B. Das, Y. A. Mehta, & R. Gupta (eds.); pp. 247–253). Springer Nature Singapore.

Shen, Y., & Pan, Y. (2023). BIM-supported automatic energy performance analysis for green building design using explainable machine learning and multi-objective optimization. *Applied Energy*, *333*(December 2022), 120575. https://doi.org/10.1016/j.apenergy.2022.120575

Shibata, N., Sierra, F., & Hagras, A. (2023). Energy & Buildings Integration of LCA and LCCA through BIM for optimized decision-making when switching from gas to electricity services in dwellings. *Energy & Buildings*, *288*, 113000. https://doi.org/10.1016/j.enbuild.2023.113000

Shree, V., Goyal, N., Saxena, A., Bhattacharyya, S., Dwivedi, A., & Goel, V. (2023). Assessment of thermal loading in energy-efficient buildings: parametric review on the window design aspects. *Journal of Thermal Analysis and Calorimetry*, *148*(7), 2703–2718. https://doi.org/10.1007/s10973-022-11815-5

Shukri, N. S. M., Aminudin, E., Yap, L. S., Zakaria, R., Hamid, A. R. A., & Kiong, M. T. (2023). Application of BIM in construction site safety: Systematic review. *IOP Conference Series: Earth and Environmental Science*, *1140*(1). https://doi.org/10.1088/1755-1315/1140/1/012014

Simpeh, E. K., Smallwood, J. J., Ahadzie, D. K., & Mensah, H. (2023). Analytical taxonomy of challenges to the implementation of green building projects in South Africa. *International Journal of Construction Management*, *23*(2), 286–296. https://doi.org/10.1080/15623599.2020.1863172

Singh, A. K., Sathvik, S. C., Krishnaraj, L., Irfan, M., Kumar, V. R. P., & Işik, C. (2023). Assessing thermo-physical products' efficiency in the building and construction industry: a bibliometric analysis approach. *Environmental Science and Pollution Research*, *30*(7), 16867–16877. https://doi.org/10.1007/s11356-022-25103-0

Song, Y., Lau, S. K., Lau, S. S. Y., & Song, D. (2023). A Comparative Study on Architectural Design-Related Requirements of Green Building Rating Systems for New Buildings. *Buildings*, *13*(1). https://doi.org/10.3390/buildings13010124

Sorooshnia, E., Rashidi, M., Rahnamayiezekavat, P., Rezaei, F., & Samali, B. (2023). Optimum external shading system for counterbalancing glare probability and daylight illuminance in Sydney's residential buildings. *Engineering, Construction and Architectural Management*, *30*(1), 296–320. https://doi.org/10.1108/ECAM-03-2021-0191

Stein, S. (2023). Universities confronting climate change: beyond sustainable development and solutionism. *Higher Education*, *0123456789*. https://doi.org/10.1007/s10734-023-00999-w

Su, S., Ju, J., Guo, Q., Li, X., & Zhu, Y. (2023). A temporally dynamic model for regional carbon impact assessment based on city information modeling. *Renewable and Sustainable Energy Reviews*, *173*(November 2022), 113076. https://doi.org/10.1016/j.rser.2022.113076

Sun, R., Liu, J., Lai, D., & Liu, W. (2023). Building form and outdoor thermal comfort: Inverse design the microclimate of outdoor space for a kindergarten. *Energy and Buildings*, *284*, 112824. https://doi.org/10.1016/j.enbuild.2023.112824

Surveying, L. (2010). *Developing a BIM-Based LCA Approach for Cost-Effective Lifecycle Optimization of Building Energy and Carbon Emissions*. 2010.

Sylejmani, A., & Milovanović, B. (2019). *Cost-optimal thermal transmittance and energy performance of residential buildings in various cities in Kosovo*. *September 2019*, 209–220. https://doi.org/10.5592/co/phdsym.2020.17

Sylvestre, P., McNeil, R., & Wright, T. (2013). From talloires to turin: A critical discourse analysis of declarations for sustainability in higher education. *Sustainability (Switzerland)*, *5*(4), 1356–1371. https://doi.org/10.3390/su5041356

Tagliabue, L. C., & Yitmen, I. (2022). Special Issue Cognitive Buildings. *Applied Sciences (Switzerland)*, *12*(5), 1–5. https://doi.org/10.3390/app12052460

Tang, H., Yu, J., Geng, Y., Liu, X., & Lin, B. (2023). Optimization of operational strategy for ice thermal energy storage in a district cooling system based on model predictive control. *Journal of Energy Storage*, *62*(November 2022), 106872.

https://doi.org/10.1016/j.est.2023.106872

Teo, Y. H., Yap, J. H., An, H., Xie, N., Chang, J., Yu, S. C. M., Poon, W. C., Zhang, L., & Cheong, K. H. (2023). A simulation-aided approach in examining the viability of passive daylighting techniques on inclined windows. *Energy and Buildings*, *282*, 112739. https://doi.org/10.1016/j.enbuild.2022.112739

The International Sustainable Campus Network - ISCN. (2023). *Sustaınable Development: Educatıng Wıth Purpose*. https://international-sustainable-campus-network.org/

The Times of India. (2023, January 26). *NIFT to create green campus*. https://stanford.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&site=eds-live&db=edsinc&AN=edsinc.A734578293

Tirelli, D., & Besana, D. (2023). Moving toward Net Zero Carbon Buildings to Face Global Warming: A Narrative Review. *Buildings*, *13*(3), 684. https://doi.org/10.3390/buildings13030684

TMMOB Mimarlar Odası. (2015). *Sustainable Building Design Guide*.

Tong, X., Yu, H., Han, L., Liu, T., Dong, L., Zisopoulos, F., Steuer, B., & de Jong, M. (2023). Exploring business models for carbon emission reduction via post-consumer recycling infrastructures in Beijing: An agent-based modelling approach. *Resources, Conservation and Recycling*, *188*(August 2022), 106666. https://doi.org/10.1016/j.resconrec.2022.106666

Tostado-Véliz, M., Hasanien, H. M., Kamel, S., Turky, R. A., Jurado, F., & Elkadeem, M. R. (2023). Multiobjective home energy management systems in nearly-zero energy buildings under uncertainties considering vehicle-to-home: A novel lexicographic-based stochastic-information gap decision theory approach. *Electric Power Systems Research*, *214*(January 2022). https://doi.org/10.1016/j.epsr.2022.108946

Triana, M. A., De Vecchi, R., & Lamberts, R. (2020). *Building Design for Hot and Humid Climate in a Changing World BT - Building in Hot and Humid Regions: Historical Perspective and Technological Advances* (N. Enteria, H. Awbi, & M. Santamouris (eds.); pp. 59–73). Springer Singapore. https://doi.org/10.1007/978-981-13-7519-4_3

Trisakti, U. (2023). *Human Resources Management In The Green Campus Project Of Universitas Trisakti*. 37–46.

Truong, N. S., Luong, D. L., Ngo, N. T., Nguyen, Q.-T., & Dang, N. T. L. (2023). *Enhancing Building with Adaptive Design Objects Using Building Information Modelling Towards Consuming Energy Efficacy in Building BT - ICSCEA 2021* (J. N. Reddy, C. M. Wang, V. H. Luong, & A. T. Le (eds.); pp. 241–252). Springer Nature Singapore.

Typologies, U. (2023). *Generative Sustainable Performance Design Exploration Applied to Greek Generative Sustainable Performance Design Exploration Applied to Greek Urban Typologies*. *March*.

UI GreenMetric World University Rankings. (2022). *UI GreenMetric Guide*.

Ulu, Ü. N. (2023). Analyzing Thermal Comfort Of Transitional Spaces Through Climate Responsive Design Solutions. *METU Master Thesis*, *13*(1), 104–116.

UN Secretary-General António Guterres. (2023). *Sustainable Development Goals Report – Sustainable Development*. United Nations. https://www.un.org/sustainabledevelopment/progress-report/

UNEP. (2022). *SDG Academy 2022 Annual Report*. https://resources.unsdsn.org/sdg-academy-2021-annual-report?_ga=2.153980027.270451635.1633292828-36469729.1633077373

UNEP - UN Environment Programme. (2023). *UI GreenMetric*. https://www.unep.org/

UNFPA. (2023). *SWOP Report 2023|United Nations Population Fund*. https://www.unfpa.org/swop

Universitas Indonesia. (2022). *UI GreenMetric World University Rankings 2022*. vii–viii. https://doi.org/10.31826/9781463236984-toc

University of Nottingham Carbon Report. (2020). University of Nottingham Carbon Report. *University of Nottingham*.

University of Nottingham Energy Report. (2020). University of Nottingham Energy Report. *University of Nottingham*.

University of Nottingham Sustainability Environmental Strategic Delivery Plan. (2020). University of Nottingham Sustainability Environmental Strategic Delivery Plan.

University of Nottingham, February.

University of Nottingham Sustainability Report. (2021). Sustainability Report. *UK*, 1–11.

University of Nottingham Sustainable Food Policy. (2022). University of Nottingham Sustainable Food Policy. *University of Nottingham*, 21–22.

Uvarova, S. S., Orlov, A. K., & Kankhva, V. S. (2023). Ensuring Efficient Implementation of Lean Construction Projects Using Building Information Modeling. *Buildings*, *13*(3), 770. https://doi.org/10.3390/buildings13030770

Visartsakul, B., & Damrianant, J. (2023). A review of building information modeling and simulation as virtual representations under the digital twin concept. *Engineering Journal*, *27*(1), 11–27. https://doi.org/10.4186/ej.2023.27.1.11

Wang, D. (2023). *Application of machine learning based BIM in green public building design*. 1–11.

Wang, J. (2023). *Cost Optimization Control System of Prefabricated Building Based on BIM Technology BT - Tenth International Conference on Applications and Techniques in Cyber Intelligence (ICATCI 2022)* (J. H. Abawajy, Z. Xu, M. Atiquzzaman, & X. Zhang (eds.); pp. 193–201). Springer International Publishing.

Wang, X., Zhang, X., Zhu, S., Ren, J., Causone, F., Ye, Y., Jin, X., Zhou, X., & Shi, X. (2023). A novel and efficient method for calculating beam shadows on exterior surfaces of buildings in dense urban contexts. *Building and Environment*, *229*(1239). https://doi.org/10.1016/j.buildenv.2022.109937

Wang, Y., Aslani, F., Dyskin, A., & Pasternak, E. (2023). Digital Twin Applications in 3D Concrete Printing. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032124

Waqar, A., Qureshi, A. H., & Alaloul, W. S. (2023). Barriers to Building Information Modeling (BIM) Deployment in Small Construction Projects: Malaysian Construction Industry. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032477

Wei, J., Li, J., Zhao, J., & Wang, X. (2023). Hot Topics and Trends in Zero-Energy Building Research—A Bibliometrical Analysis Based on CiteSpace. *Buildings*, *13*(2). https://doi.org/10.3390/buildings13020479

Wu, T., Wang, B., Zhang, D., Zhao, Z., & Zhu, H. (2023). Benchmarking Evaluation of Building Energy Consumption Based on Data Mining. *Sustainability*, *15*(6), 5211. https://doi.org/10.3390/su15065211

Wu, W., Benner, J., & Luo, Z. (2023). Developing analytical model for nighttime cooling of internal thermal mass. *Applied Thermal Engineering*, *220*(December 2022), 119798. https://doi.org/10.1016/j.applthermaleng.2022.119798

WUR Sustainability Report. (2021). Wageningen University & Research (WUR) Sustainability Report. In *Sustainability Report* (Vol. 2, Issue 1).

WUR Sustainability Website. (2023). *WUR Sustainability Website*. https://www.wur.nl/en/about-wur/our-values/sustainable-business-operations.htm

WUR Website. (2023). *Wageningen University & Research Website*. https://www.wur.nl/en.htm

Xhexhi, K. (2023). *LEED and BREEAM Building Standards and Albanian Law Related to Building Thermal Performance BT - Ecovillages and Ecocities: Bioclimatic Applications from Tirana, Albania* (K. Xhexhi (ed.); pp. 83–95). Springer International Publishing. https://doi.org/10.1007/978-3-031-20959-8_3

Xiao, J., Zeng, L., Ding, T., Xu, H., & Tang, H. (2023). Deconstruction evaluation method of building structures based on digital technology. *Journal of Building Engineering*, *66*(January), 105901. https://doi.org/10.1016/j.jobe.2023.105901

Yakut, M. Z., & Esen, S. (2023). A comprehensive survey of the urban building energy modeling (UBEM) process and approaches. *International Journal of Energy Studies*, *7513*(1), 87–116. https://doi.org/10.58559/ijes.1228599

Yoon, S. (2023). In situ modeling methodologies in building operation: A review. *Building and Environment*, *230*(December 2022), 109982. https://doi.org/10.1016/j.buildenv.2023.109982

Youkhanna Zaia, Y., Mustafa Adam, S., & Heeto Abdulrahman, F. (2023). Investigating BIM level in Iraqi construction industry. *Ain Shams Engineering Journal*, *14*(3), 101881. https://doi.org/10.1016/j.asej.2022.101881

Yusuf, P. I. (2023). *Evaluation of Energy use Intensity and Cost of Institutional Buildings using Building Information Modelling*. *January*. https://doi.org/10.5281/zenodo.7619641

Zahra Abdillahi. (2022). International Journal of Medicine International Journal of Medicine. *Building Information Modelling for Sustainable Construction*, *7*(1), 12–17.

Zakeri, S. M. H., Tabatabaee, S., Ismail, S., Mahdiyar, A., & Wahab, M. H. (2023). Developing an MCDM Model for the Benefits, Opportunities, Costs and Risks of BIM Adoption. *Sustainability (Switzerland)*, *15*(5), 1–19. https://doi.org/10.3390/su15054035

Zhang, J., Zhu, X., Khan, A. M., Houda, M., Kashif Ur Rehman, S., Jameel, M., Javed, M. F., & Alrowais, R. (2023). BIM-based architectural analysis and optimization for construction 4.0 concept (a comparison). *Ain Shams Engineering Journal*, *14*(6), 102110. https://doi.org/10.1016/j.asej.2022.102110

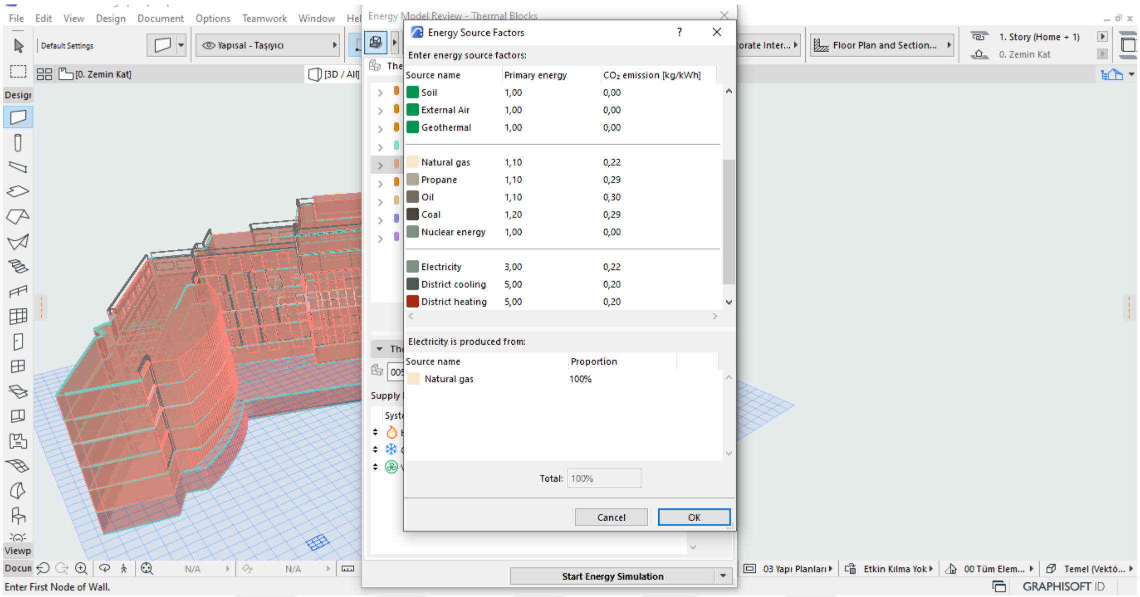
Zhang, L., Liu, D., Cai, G., Lyu, L., Koh, L. H., & Wang, T. (2023). An optimal dispatch model for virtual power plant that incorporates carbon trading and green certificate trading. *International Journal of Electrical Power and Energy Systems*, *144*(June 2022), 108558. https://doi.org/10.1016/j.ijepes.2022.108558

Zhao, W., Peng, P., Guo, B., Deng, X., & Wu, W. (2023). Comprehensive Social Cultural and Economic Benefits of Green Buildings Based on Improved AHP–FCE Method. *Buildings*, *13*(2), 1–19. https://doi.org/10.3390/buildings13020311

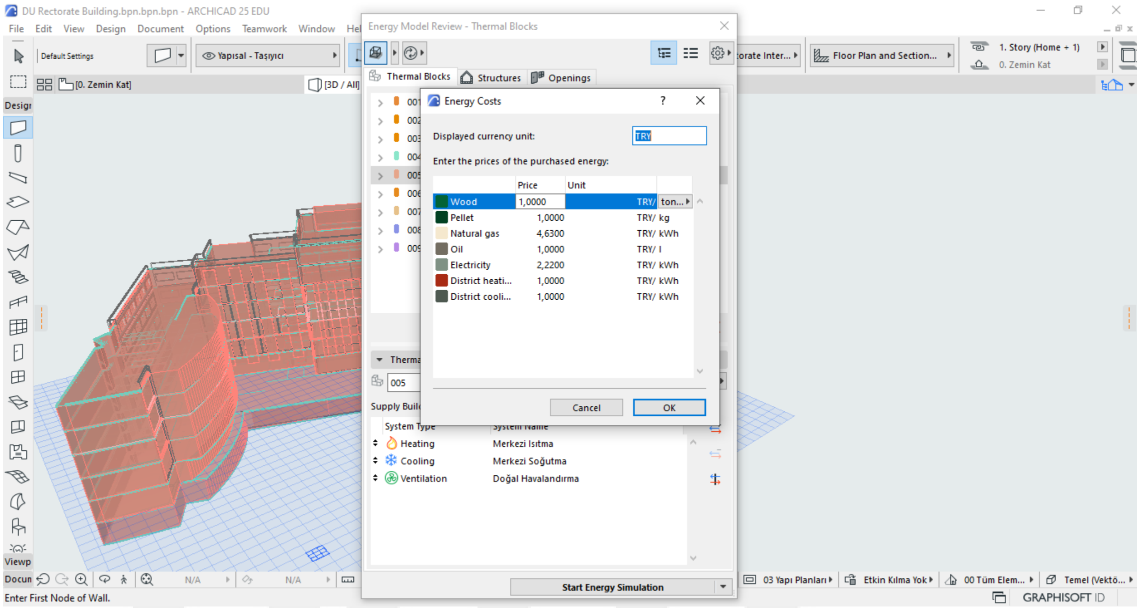
Zheng, X., Chen, L., & Yang, J. (2023). Simulation framework for early design guidance of urban streets to improve outdoor thermal comfort and building energy efficiency in summer. *Building and Environment*, *228*(November 2022), 109815. https://doi.org/10.1016/j.buildenv.2022.109815

7. APPENDICES

7.1. APPENDIX 1 THE SEGMENT IN THE ECODESIGNER STAR TOOL WHERE THE VALUES OF CO_2 EMISSIONS AND PRIMARY ENERGIES ARE ADJUSTED BY ENERGY SOURCE FACTORS.



7.2. APPENDIX 2 THE SEGMENT IN THE ECODESIGNER STAR TOOL WHERE THE ENERGY COST IS SET.



7.3. APPENDIX 3ENERGY PERFORMANCE EVALUATION REPORT OF RECTORATE BUILDING ON THE CAMPUS OF DUZCE UNIVERSITY AS A RESULT OF ECODESIGNER STAR SIMULATION WHEN THERE IS EXTERIOR CLADDING.

Key Values

General Project Data		
Project Name:	DU Rectorate Building.bp...	
City Location:		
Latitude:	40° 54' 26" N	
Longitude:	31° 11' 1" E	
Altitude:	0,00	m
Climate Data Source:	TUR_DU_Du...urTMY.epw	
Evaluation Date:	12.05.2023 19:45	

Building Geometry Data		
Gross Floor Area:	**17880,69**	m²
Treated Floor Area:	**17586,87**	m²
External Envelope Area:	**19707,95**	m²
Ventilated Volume:	**62433,87**	m³
Glazing Ratio:	**6**	%

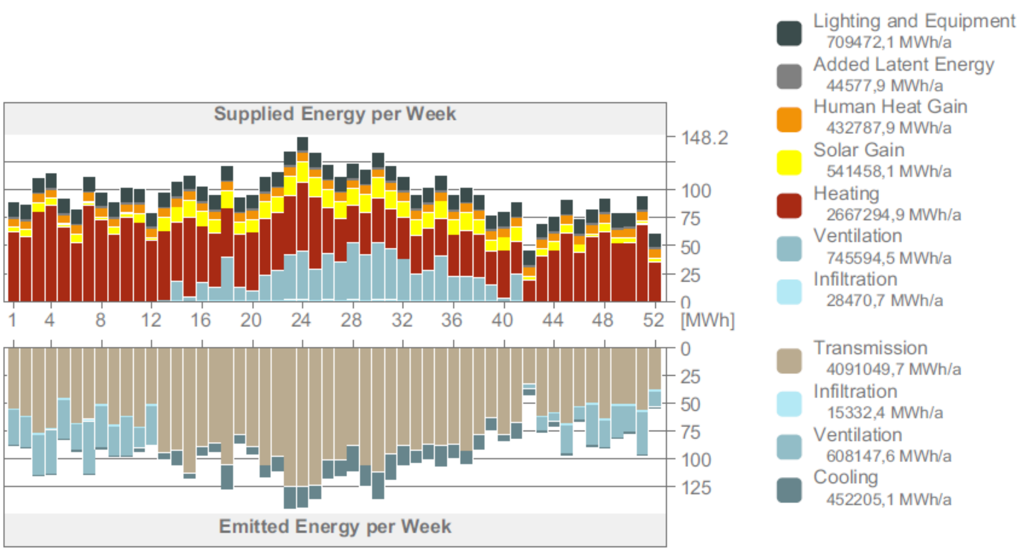
Building Shell Performance Data		
Infiltration at 50Pa:	**1,43**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**2,78**	
Floors:	**2,04 - 2,04**	
External:	**0,23 - 6,44**	
Underground:	**0,24 - 1,44**	
Openings:	**2,11 - 3,51**	

Specific Annual Values		
Net Heating Energy:	**151,66**	kWh/m²a
Net Cooling Energy:	**25,71**	kWh/m²a
Total Net Energy:	**177,38**	kWh/m²a
Energy Consumption:	**217,72**	kWh/m²a
Fuel Consumption:	**218,75**	kWh/m²a
Primary Energy:	**1012,02**	kWh/m²a
Fuel Cost:	**268,59**	TRY/m²a
CO_2 Emission:	**44,40**	kg/m²a

Degree Days	
Heating (HDD):	**3608,06**
Cooling (CDD):	**1477,03**

Project Energy Balance



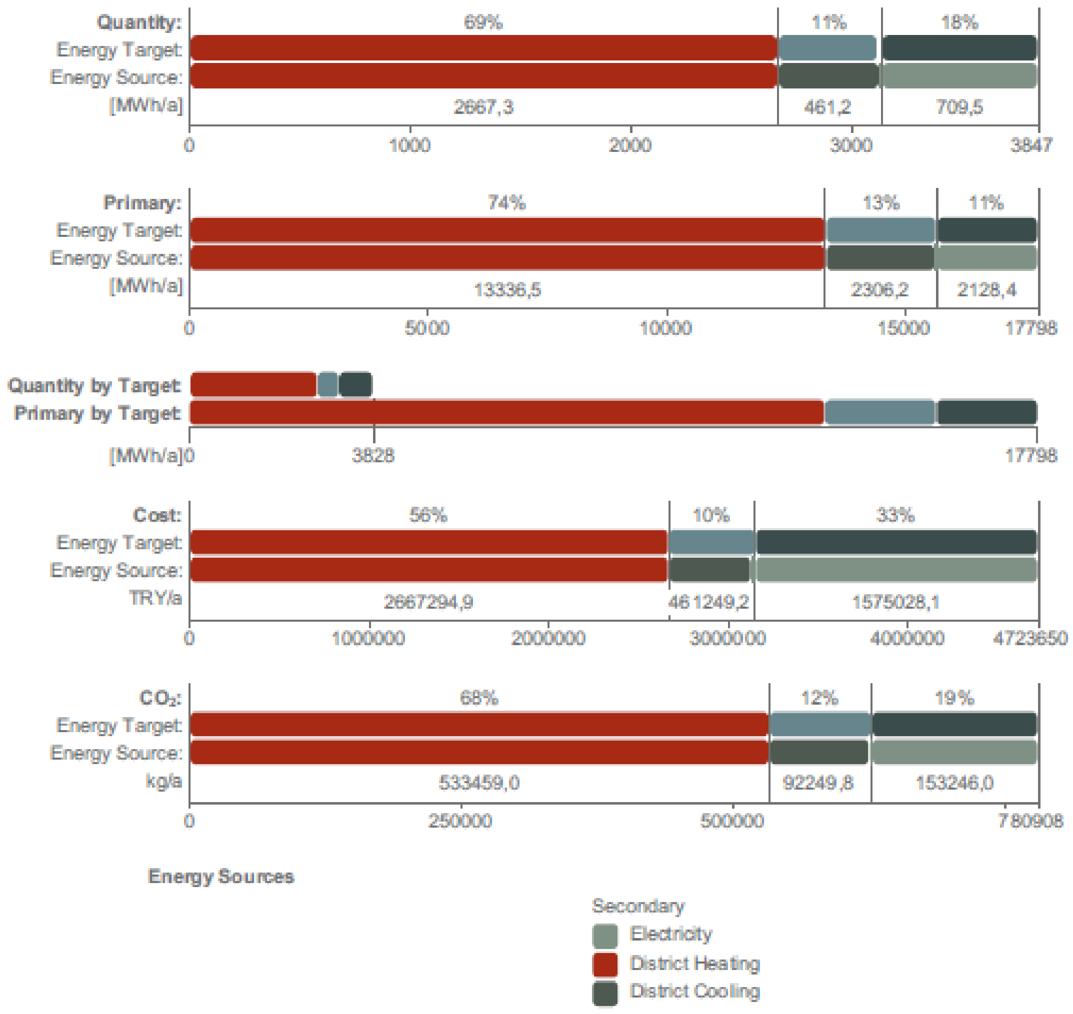
Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 -1. Story Thermal Block	1	Kişisel Ofis	3273,51	11538,91
002 Ground Thermal Block	1	Kişisel Ofis	2395,55	8443,80
003 1. Story Thermal Block	1	Kişisel Ofis	2612,24	9045,81
004 2. Story Thermal Block	1	Kişisel Ofis	2598,46	9042,27
005 3. Story Thermal Block	1	Kişisel Ofis	2614,08	9105,70
006 4. Story Thermal Block	1	Kişisel Ofis	2604,22	9105,70

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
007 5. Story Thermal Block	1	Kişisel Ofis	1098,21	3876,55
008 6. Story Thermal Block	1	Kişisel Ofis	561,94	1991,62
009 7. Story Thermal Block	1	Kişisel Ofis	79,86	283,51
Total:	**9**		**17838,08**	**62433,87**

Energy Consumption by Targets

Target Name	Energy Quantity MWh/a	Energy Primary MWh/a	Energy Cost TRY/a	CO_2 Emission kg/a
Heating	2667	13336	2667294	533458
Cooling	452	2333	481327	94203
Service Hot-Water	0	0	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	709	2128	1575028	153245
Total:	**3828**	**17798**	**4723650**	**780908**



Energy Consumption by Sources

Source Type	Energy Source Name	Quantity MWh/a	Primary MWh/a	Cost TRY/a	CO_2 Emission kg/a
Secondary	Electricity	718	2155	1595106	155199
	District Heating	2667	13336	2667294	533458
	District Cooling	461	2306	461249	92249
	Total:	**3847**	**17798**	**4723650**	**780908**

Environmental Impact

Source Type	Source Name	Primary Energy MWh/a	CO_2 emission kg/a
Secondary	Electricity	2155	155199
	District Heating	13336	533458
	District Cooling	2306	92249
	Total:	**17797**	**780906**

7.4. APPENDIX 4 ENERGY PERFORMANCE EVALUATION REPORT OF RECTORATE BUILDING ON THE CAMPUS OF DUZCE UNIVERSITY AS A RESULT OF ECODESIGNER STAR SIMULATION WHEN THERE IS NO EXTERIOR CLADDING.

Energy Performance Evaluation

[Project Number] [Project Name]

Key Values

General Project Data

Project Name:	DU Rectorate Building.bp...	
City Location:		
Latitude:	40° 54' 26" N	
Longitude:	31° 11' 1" E	
Altitude:	0,00	m
Climate Data Source:	TUR_DU_Du...urTMY.epw	
Evaluation Date:	12.05.2023 17:56	

Building Geometry Data

Gross Floor Area:	**17838,08**	m²
Treated Floor Area:	**17586,87**	m²
External Envelope Area:	**19675,45**	m²
Ventilated Volume:	**62433,87**	m³
Glazing Ratio:	**6**	%

Building Shell Performance Data

Infiltration at 50Pa:	**1,43**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**2,81**	
Floors:	**2,04 - 2,04**	
External:	**0,41 - 6,44**	
Underground:	**0,77 - 1,44**	
Openings:	**2,11 - 3,51**	

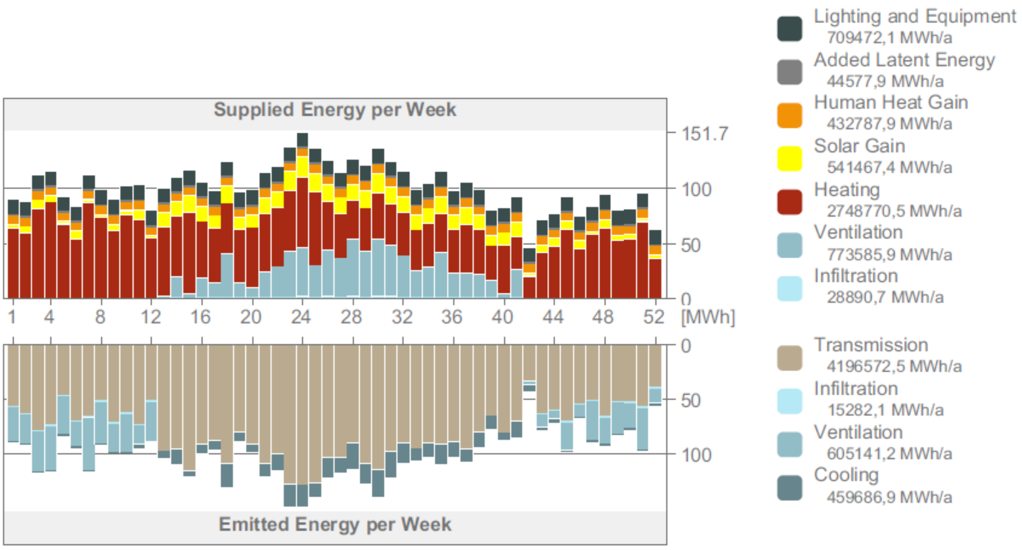
Specific Annual Values

Net Heating Energy:	**156,30**	kWh/m²a
Net Cooling Energy:	**26,14**	kWh/m²a
Total Net Energy:	**182,43**	kWh/m²a
Energy Consumption:	**222,78**	kWh/m²a
Fuel Consumption:	**223,82**	kWh/m²a
Primary Energy:	**1037,38**	kWh/m²a
Fuel Cost:	**273,68**	TRY/m²a
CO_2 Emission:	**45,42**	kg/m²a

Degree Days

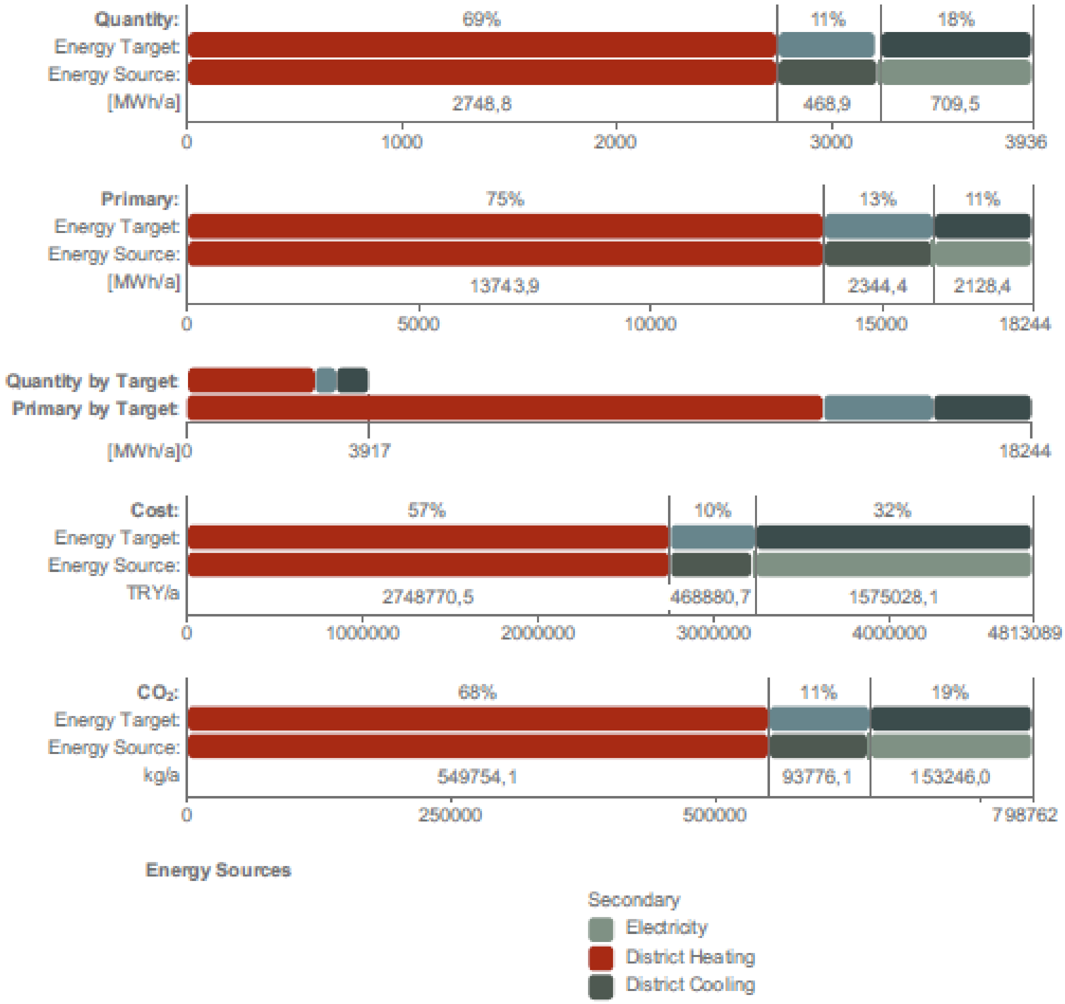
Heating (HDD):	**3608,06**
Cooling (CDD):	**1477,03**

Project Energy Balance



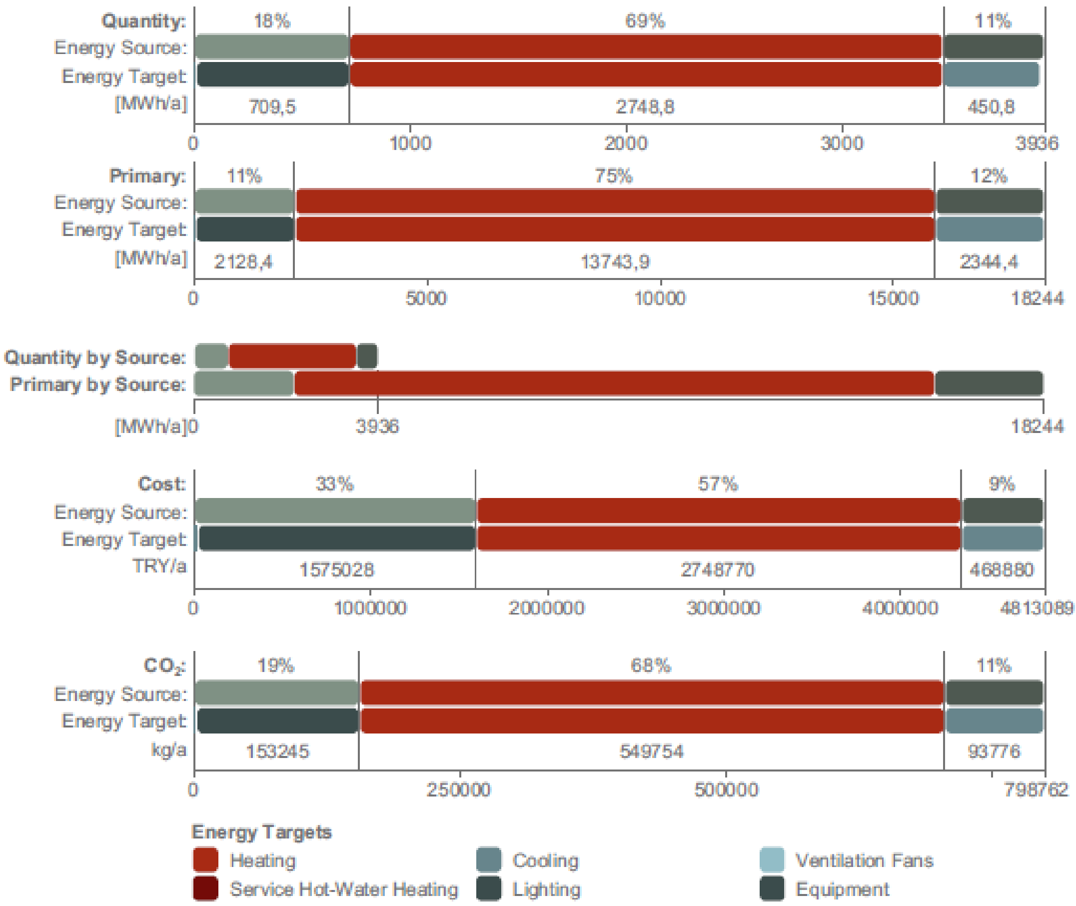
Energy Consumption by Targets

Target Name	Energy Quantity MWh/a	Primary MWh/a	Cost TRY/a	CO_2 Emission kg/a
Heating	2748	13743	2748770	549754
Cooling	459	2371	489290	95761
Service Hot-Water	0	0	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	709	2128	1575028	153245
Total:	**3917**	**18244**	**4813089**	**798762**



Energy Consumption by Sources

Source Type	Energy Source Name	Quantity MWh/a	Primary MWh/a	Cost TRY/a	CO_2 Emission kg/a
Secondary	Electricity	718	2155	1595438	155231
	District Heating	2748	13743	2748770	549754
	District Cooling	468	2344	468880	93776
	Total:	**3936**	**18244**	**4813089**	**798762**



Environmental Impact

Source Type	Source Name	Primary Energy MWh/a	CO_2 emission kg/a
Secondary	Electricity	2155	155231
	District Heating	13743	549754
	District Cooling	2344	93776
	Total:	**18242**	**798761**

CV

PERSONAL INFORMATION

Name Surname : Rumeysa Eryaman

Foreign language : Advanced English

EDUCATIONS

Degree	Field	University	Year
Master of Science	Architecture	Duzce University	2020-2023
Bachelor of Science	Architecture	Duzce University	2016-2020

EXPERIENCES

Volunteer Intern Architect/ International Construction Company in Serbia 2022

AISEC International Intership Project / Pyramid ing Construction Company Novi Sad

Architect/ Owner at ADA Company in Turkey 2020-2022

Architect/ International Website 2020-2021

http://www.onlinecaddrawing.com/

PROFESSIONALS

Autocad, Sketchup (Energy Plus), Lumion, Lightstanza, Dialux, PD Shading Box, 3D Sun-Path, Energy3D, Acustic Calculator, Space Syntax, DesignBuilder, IES, Archicad (EcoDesign Star), Photoshop, Rhinoceros 3D (Diva, Honeybee, LadyBug), Revit (Insight360), Simapro, 3D Studio Max.