GREEN CAMPUS APPLICATION: BOĞAZİÇİ UNIVERSITY

by

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ABSTRACT

GREEN CAMPUS APPLICATION: BOĞAZİÇİ UNIVERSITY

The aim of this thesis is to investigate smart city, smart campus and green campus applications all around the world and Turkey while introducing green campus initiatives and applications to Boğaziçi University. Increase in population depletes natural resources by increasing energy use and water use. In order to preserve and maintain limited natural resources, green and smart initiatives must be taken. Current use of resources is investigated by conducting water footprint analysis and solid waste characterization of students of Boğaziçi University. Zero-waste campus applications with the least consumption preferences, energy and water efficient appliances are preferred while introducing smoke-free campus initiatives to decrease greenhouse gas emissions and water footprint. Solar panels and rainwater harvesting studies are performed to benefit from the sun and rain available in nature. Disability-friendly and pet-friendly campus applications are also studied to create an adaptive, connected campus for the benefit of every member in the campus. Lastly, attendance system with face recognition technique is introduced and studied to save time and decrease fraudulent actions. Furthermore, green campus initiatives are studied in terms of their economic and environmental benefits, system implementation and installation. Campuses are small representations of the cities, and young minds have the power of shaping the future. This is why green initiatives at campus level allow testing applicability and adaptability in city level.

ÖZET

YEŞİL KAMPÜS UYGULAMASI: BOĞAZİÇİ ÜNİVERSİTESİ

Bu tezin amacı, tüm dünyada ve Türkiye'deki akıllı şehir, akıllı kampüs ve yeşil kampüs uygulamalarını araştırmak ve Boğaziçi Üniversitesi'ne yeşil kampüs girişimleri ve uygulamalarını tanıtmaktır. Nüfustaki artış, enerji ve su kullanımını artırarak doğal kaynakları tüketmektedir. Sınırlı doğal kaynakları korumak ve sürdürmek için yeşil ve akıllı girişimler başlatılmalıdır. Boğaziçi Üniversitesi öğrencilerinin su ayak izi analizleri ve katı atık karakterizasyonları yapılarak mevcut kaynak kullanımı araştırılmıştır. Sera gazı emisyonlarını ve su ayak izini azaltmak için dumansız kampüs girişimleri, en az tüketim tercihine sahip sıfır atık kampüs uygulamaları, enerji ve su tasarruflu cihazlar tercih edilmelidir. Doğada bulunan güneş ve yağmurdan yararlanmak için güneş panelleri ve yağmur suyu toplama çalışmaları yapılmıştır. Engelli dostu ve hayvan dostu kampüs uygulamaları da kampüsteki her üyenin yararı göz önünde bulundurularak bağlı bir kampüs oluşturmak için incelenmiştir. Son olarak, zaman kazandıran yüz tanıma tekniği ile yoklama sistemi tanıtılmıştır. Yeşil kampüs girişimleri ekonomik ve çevresel faydaları, sistem uygulamaları ve kurulumları açısından incelenmiştir. Kampüsler şehirlerin küçük temsilleridir ve genç beyinler geleceği şekillendirme gücüne sahiptir. Bu nedenle kampüs seviyesindeki yeşil girişimler, şehir düzeyinde uygulanabilirliği ve uyarlanabilirliği test etmeyi sağlar.

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A_A	Collecting area in square meters
e	Yield coefficient in %
d	Tolerated margin of error
E_R	Rainwater yield in liters per year
h_N	Quantity of precipitation in liters per square meter or millimeters (mm)
J	Joule
kg	Kilogram
L	Liter
L/A	Liter per area
m^2	Square meters
m^3	Cubic meters
m^3/c.d.	Cubic meters per capita per day
M_u	Number of months pool is not covered
N_b	Number of times bath taken per time
N_c	Number of times of car washing
N_d	Number of times dish washing per time
N_f	Number of flushes
N_g	Number of times gardening per time
N_{ist}	Population of Istanbul
N_{km}	Number of kilometers per week
N_m	Number of minutes running water
N_p	Number of people living in the house
N_{pr}	Population in the year of available recycle data
N_r	Amount of recycle per year
N_w	Number of times washing per time
p	Estimated proportion of the population that represents the characteristic
p_e	Percentage of electricity supplied by utility

p_s	Percentage of electricity supplied by solar panels
q	Estimated proportion of the population that does not represent the characteristic
Q_f	Flow rate based on faucet type
Q_l	Liters per load
Q_s	Flow rate based on shower type
Q_t	Flow rate based on toilet type
t	Time multiplier
t_f	Number of minutes for chosen sink use interval
t_s	Number of minutes for chosen shower interval
TJ	Terajoule
WF(b)	Average water use in bath per capita per day
W_p	Water use for gardening per time
W_r	Water saved in liters per kg of recycled material type
$WF_{(s,c,o)}$	Water footprint for supply, construction and operation
WF(c)	Water use for car wash
WF(d)	Water use in driving
WF(e)	Water use for electricity in Boğaziçi University
WF(e)	Water use for electricity in Istanbul
WF(f)	Water use in bathroom faucets per capita per day
WF(g)	Water use in gardening
WF(k)	Water use in kitchen sink
WF(s)	Water use per capita per day in shower
WF(t)	Water use in toilet per capita per day
WF(w)	Water use in washing dishes
WF(wa)	Water use in washing
WS(p)	Water use for pool
WS(r)	Water saved by recycling
WS(rb)	Water saved by rain barrel
WS(x)	Water saved by xeriscaping
Z	Level of confidence according to the standard normal distribution

η	Hydraulic filter efficiency

LIST OF ACRONYMS/ABBREVIATIONS

ACS	American Chemical Society
AUB	American University of Beirut
BU	Boğaziçi University
BUHAY	Boğaziçi University Animal Rights Society
BÜREM	Boğaziçi University Guidance and Psychological Counseling Center
CE	Civil Engineering
ChE	Chemical Engineering
CIMI	Cities in Motion Index
CMPE	Computer Engineering
DM	Dry mass
DTU	Technical University of Denmark
EE	Electrical and Electronic Engineering
HVAC	Heating, Ventilating and Air Conditioning
IBB	Istanbul Municipality
ICA	Independent Component Analysis
ICT	Information and Communication Technologies
IE	Industrial Engineering
ISKI	Istanbul Water and Sewage Administration
IT	Information Technologies
ITU	Istanbul Technical University
GETEM	Visually Impaired Technology and Education Laboratory
GIS	Geographic Information System
ME	Mechanical Engineering
METU	Middle East Technical University
PCA	Principal Component Analysis
PDA	Personal Digital Assistant
PV	Photo Voltaic
RB	Recycle Bin

RCA	Relevant Component Analysis
RFID	Radio Frequency Identification
UCPH	University of Copenhagen
USTDA	United States Trade and Development Agency
WB	Waste Bin
WF	Water Footprint

1. INTRODUCTION

1.1. Research Overview

Increasing population in the world, pressures the natural resources by increasing the demand in energy and water. Increased population will create environmental issues such as diminishing fresh water supplies, lack of sewage capacity, increasing pollution, incapability of existing services for citizens such as transportation, and health. In order to balance these issues, smart and green solutions should be adopted.

"Smart City" has been put on agenda to create a network of solutions to the capacity and inefficiency related problems. Smart economy, smart people, smart governance, smart mobility, smart living and smart environment are characteristics of smart cities (Giffinger, 2007). By collecting data generated by citizens in a main center and analyzing them in order to find the energy efficient, and water efficient solutions seem to be an efficient way of creating a solution path to these problems. In this way, sustaining natural resources will be possible while putting human in the center of all actions and being supported by government and its agencies. For these purposes, smart city initiatives have been taken in all around the world such as New York, Copenhagen, Seoul, Singapore, Amsterdam, Izmir, Istanbul, Karaman, and Çanakkale.

In today's digital and fast world, smart initiatives in the campus environment should also be taken. Therefore, smart campuses are created to connect information of students, their behavior in the campus, buildings and building related information to create a link between the user behavior and energy and water sources. This way, energy and water use in the campus should be minimized, also other resources should be maintained while creating a ubiquitous learning environment for the students. New technologies have changed the way people learn and adopt the changes, by making campuses "smart", efficiency in teaching and learning can be supplied. Campuses are small representation of cities with its governor, citizens and facilities, if smart applications are adopted and experienced at campus level, it will be easier to adopt in city level. University of Glasgow, Yonsei University, Technical University of Denmark, Izmir Ekonomi University, Middle East Technical University, Hacettepe University and Boğaziçi University are some examples of smart campuses in the world. Smart energy, smart waste management, smart service, smart learning, smart management, smart security are components of smart campus. In this thesis, these smart applications are analyzed and their applicability to Boğaziçi University are investigated.

Higher education in Turkey is still in development phase. Every year more and more students attend to college. Therefore, energy and water used by universities increase while generating a huge amount of solid waste. Since universities have bright minds that will affect the future and act like a small representation of cities, green initiatives should be started at campus level. Energy, waste, water, security, management of campuses should go green. University of Saint Petersburg, UC Berkeley, University of Copenhagen, Middle East Technical University, Istanbul Technical University, Piri Reis University and Boğaziçi University are examples of green campuses. In this study, rainwater harvesting, water footprint, solar energy, solid waste analysis and composting, attendance with face recognition, zero waste, smoke free and disability friendly Boğaziçi University are investigated in terms of applicability and economic and environmental benefits.

In order to sustain the resources, current use of resources should be investigated. Therefore, water footprint analysis of students of Boğaziçi University is performed. After learning water footprints of the students, it is seen that current level is above the Turkey's average and world's average. Since there is no water footprint study that includes direct and indirect water footprint at university level, nations and worlds water footprint study results are used to compare. Going zero-waste with the least consumption preferences, energy and water efficient appliances should be preferred to decrease current water footprint. Also, solar panels and rainwater harvesting system should be installed in order to benefit from sun and rain available in the environment. To decrease greenhouse gas emissions, smoke-free campus initiatives should be taken. Also, to create an adaptive and connected campus that guards benefit of every member in the campus disability friendly and pet friendly campus applications should be taken.

Last but not least, people should be in the center of all the applications because if human do not adopt the initiatives, it will not be efficient whichever green solution is performed.

1.2. Outline of the Thesis

Thesis is focused on green campus applications in Boğaziçi university while introducing smart city, smart campus and green campus applications around the world and Turkey. An introduction is presented in Chapter 1. Chapter 2 covers smart cities are presented with a brief introduction and definition continued with the smart cities and their applications in the world and in Turkey; smart campuses are presented following a brief introduction and components of smart campuses and smart campus examples and applications around the world and in Turkey; green campuses are presented with a brief explanation and examples and applications from the world and Turkey. Furthermore, theory of water footprint is presented in Chapter 3. Chapter 4 consists of studies conducted in Boğaziçi University such as water footprint study with a brief introduction, methodology, calculations of direct, indirect and virtual water use, results and advises on how to reduce water footprint; rainwater harvest study with a brief introduction, quality and treatment assessments of rainwater; solid waste study in Boğaziçi University with solid waste characterization of Perkins Hall and engineering students, economic value analysis and two recycling incentives: BuCard implementation and Precious Plastic, while introducing composting barrel turning system; solar energy study with examples of around the world and applicability in Boğaziçi University; attendance system using face recognition technology; and other studies such as zero-waste campus, smoke-free campus and disability-friendly campus applicability. Chapter 5 summarizes and discusses green applications studied throughout the thesis. Chapter 6 presents conclusion and further studies.

2. LITERATURE REVIEW

2.1. Smart Cities

According to United Nations Population Division (2017), world population was 7.6 billion in 2017, and is expected to be 8.6 billion by 2030, 9.8 billion by 2050 and 11.2 billion in 2100. Also, as can be seen from Figure 2.1, life expectancy at birth has increased by 3.6 years from 67.2 to 70.8 years. Globally, life expectancy at birth is expected to rise from 71 years to 77 years in near future.

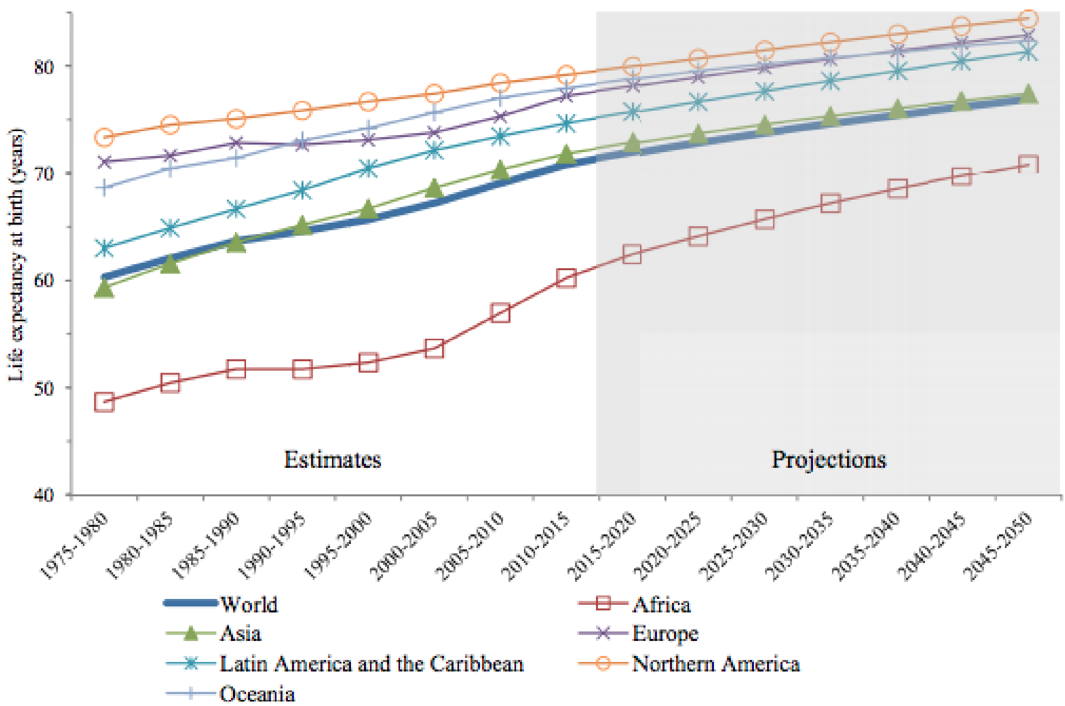

Figure 2.1. Life expectancy at birth (years) by region: estimates 1975-2015 and projections 2015-2050 (United Nations,2017)

Projections of United Nations (2017) show that there is a gradual shift from rural to urban areas together with an increase in the population generated from birth. Population living in cities that is 55 % in 2018, is expected to reach 68 % by 2050 with an increase in urban population by 2.5 billion. According to IBM (2009), population that lives in cities is forecast to be increased in both developed and developing countries (Figure 2.2). In developed countries, it will only increase by 15% from 1990 to 2050 whereas in developing countries, increase in population that lives in cities will be approximately twice of that of 1990 in 2050. What is more, people migrate in order to reach a more comfortable life style, quality in education, access to health and job options. Migrations from other countries result in an increase in the population while depleting the limited resources.

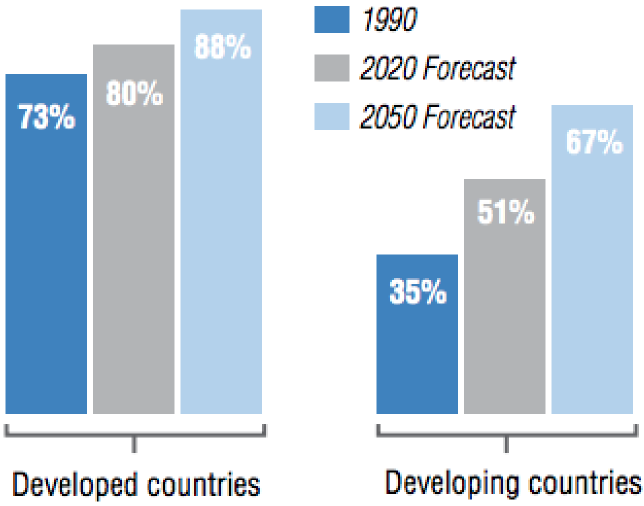

Figure 2.2. Percentage of total population that lives in cities 1990-2050 (forecast) (IBM, 2009)

According to United Nations (2015), cities in the world cover up 3 % of land, yet are responsible for 60-80 % energy consumption, and 75 % of carbon emissions. Increased population in cities and rapid urbanization open up some challenges and opportunities such as diminishing fresh water supplies, lack of sewage capacity, disturbances in living environment and public health, rising pollution level, increased crime rates, lack of housing, lack of transportation, incapability of energy systems, high cost of living due to limited resources.

Inefficiencies raised from increasing population and rapid urbanization can be prevented by investing smart solutions namely efficient use of limited resources with the help of technology. Investing in smart cities that consist of smart buildings, living, transportation, energy, communication, network, and environment will ensure populations survival.

2.1.1. Definition of Smart Cities

The concept of smart city has been frequently covered in many areas in recent years. Scholars argue that there is no general and accepted definition of a smart city concept. The need for finding smart solutions to the problems of the cities has created the smart city concept. Smart solutions will ease the problems in the cities and create long term remedies. By involving human into every step of the solution process will ease the acceptance of human and create long-term efficient solutions.

The purpose of smart cities is to combine sustainable use of resources, sustainable development and improvement, increase in life quality, increase in competition, increase in participation and increase in communication devices together in an efficient way in a city.

Since there is no uniquely determined and accepted definition of smart cities, definition of smart cities according to different and multiple resources as follows:

- A city that is not only a static outcome but rather a process of outcomes with its high citizen engagement rate, connected infrastructure, social capital and technology. A city that is more livable, sustainable and adaptive (UK Department for Business, Innovation and Skills, 2013).
- A city that benefits from the solutions that uses data and digital areas of business development, citizen participation, culture, health-care and social services (The Danish Ministry of Transport, Building, and Housing and Danish Business Authority, 2015).
- A city that is the "one makes optimal use of all the interconnected information available today to better understand and control its operations and optimize the use of limited resources." (IBM, 2011).

- A city that adopts "scalable solutions that take advantage of information and communications technology to increase efficiencies, reduce costs, and enhance quality of life." (Cisco, 2012).

Harrison *et al.* (2010) holds that smart cities have the privilege of connection through data gathering with the use of technological devices such as health equipment, smart phones, human networks and social networks. Besides, Chourabi *et al.* (2012), components of smart cities are management and organization, technology, governance, policy, people and communities, economy, built infrastructure, natural environment.

Giffinger (2007) states that there are only six characteristics of smart cities:

- Smart Economy (Competitiveness) considers innovative spirit and entrepreneurship.
- Smart People (Social and Human Capital) covers that the level of knowledge is the combination of level of education and qualification as well as level of qualification, fondness in lifelong learning, social and ethnic multiplicity, flexibility, creativity, participation in public life.
- Smart Governance (Participation) encompasses participation in making decisions, public and social services, transparency in governance, political strategies and perspectives.
- Smart Mobility (Transport and ICT) includes the importance of local and international accessibility, availability of ICT infrastructure, sustainable, innovative and safe transport systems.
- Smart Environment (Natural Resources) including appeal of natural conditions, pollution, environmental protection, sustainable resource management.
- Smart Living (Quality of Life) including cultural facilities, health, housing, education conditions and individual safety.

The concept and term of smart city call for innovative social, technological and economic growth (Atkinson and Castro, 2008; Belisent, 2010; Shapiro, 2003). These innovative actions that are initiated under the smart city action led to green solutions in order to prevent environmental pollution and reduce emission of CO_2 (Atkinson and Castro, 2008; Belisent, 2010). Cities are now able to connect the technology with current applications and able to find some smart solutions for green environment and well-being of the citizens while putting citizen-participation in the center.

2.1.2. Smart Cities in the World

According to the IESE Cities in Motion Index 2018 (CIMI), New York is selected as the smartest city in the world while Istanbul is ranked as 114th (Figure 2.3). CIMI analyzed the developments level of 165 cities from 80 countries in terms of human capital, economy, environment, governance, urban planning, technology, mobility and transportation. Istanbul is ranked as 114th overall, while 87th in economy, 118th in human capital, 155th in social cohesion, 124th in environment, 139th in governance, 106th in urban planning, 18th in international outreach, 26th in technology, and lastly 124th in mobility and transport.

Cities are ranked according to their developments and efforts in terms of sustainability in innovation, growth. Some cities have adopted the "Smart City" strategy in order to better off with their limited resources to increasing populations.

<u>2.1.2.1. New York City - USA.</u> According to CIMI (2018), New York is the most important economic center in the world, therefore it ranked as 1st in the economy dimension of CIMI ranking. Since New York City has a variety of office and residential buildings with a high concentration per square meter, it ranked as 1st in urban planning dimension of CIMI ranking. Also, it placed in top places in human capital, transportation, international outreach and mobility.

The most known smart city application in New York City is LinkNYC. According to LinkNYC (2018), it allows citizens to make video calls, international calls and free calls 50 states. Also, it gives access to city maps, directions and free and fast Wi-Fi.

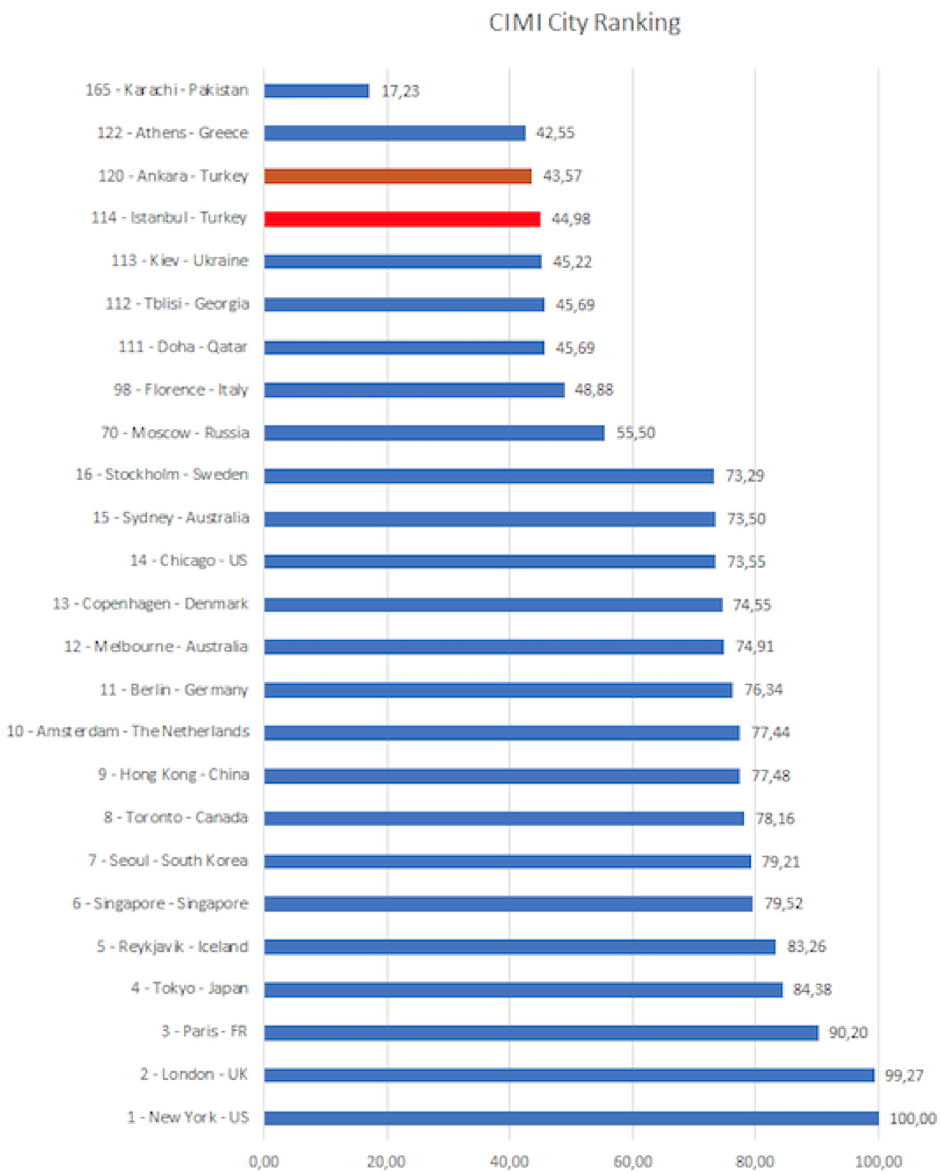

Figure 2.3. Smart city ranking (CIMI, 2018).

2.1.2.2. Barcelona - Spain. According to Bakıcı *et al.* (2013), Barcelona is ambitious about being a smart city and this can be understood from the city having more than 400 research centers. Barcelona tries to connect the government, people and businesses. The most effective component is competitiveness of the people. Main areas of the Barcelona smart city initiatives are “Smart Governance” with many municipal kiosk, e-government and open data platform, “Smart Economy”, “Smart Living” and “Smart People”. The smart governance and economy create the infrastructure for the smart city. On the other hand, for smart living, human capital is reformed under personal digital assistants (PDAs) used by the municipal police, new incidents and communication tool in vehicles and intelligent environment solutions. Also, information reforms for smart people is carried by Cibernarium and Citilab Cornelia.

2.1.2.3. Amsterdam - the Netherlands. Amsterdam is one of the most serious smart city applicators in the world. The Amsterdam Smart City Initiative has a plenty of projects currently in order to make the world better and sustainable place. According to the Amsterdam Smart City Initiative (2018), some projects conducted by the Amsterdam Smart City Initiative are:

- City-zen: Electricity is produced at homes via solar panels and stored at homes in reused batteries. If the amount of electricity produced exceeds the storage capacity, electricity is given to the grid.
- City Data: Project aims to collect all the data generated in Amsterdam and give an open access to every citizen in the world.
- Amsterdam Smart Citizens Lab: In order to turn into all smart, people should be educated first. The transformation of smartness starts from people in the center. The project aims to educate people about smart applications.
- Green Living Lab: Green living labs are constructed to all over the city in order to increase the green in the city and familiarize citizens with sustainable and healthier living style.

2.1.2.4. Seoul - South Korea. South Korea also promises its citizens smart living solutions. According to Lee (2018), some of the smart city projects in Seoul are “Seoul Open Data Plaza” that aims to provide public data culture, administration, health and environment to citizens to improve services in Seoul; “Late Night Bus” aims to decrease carbon emissions from taxi use by providing bus service at night via optimizing taxi routes.

2.1.2.5. Singapore - Singapore. Singapore has awarded as “Smart City of 2018” in the Smart City Expo World Congress. According to Smart Nation Singapore (2018), some smart applications are “HealthHub” where people can access medical reports and health information; “myENV” that collects all weather related information and send notifications to citizens about daily weather.

2.1.2.6. Copenhagen - Denmark. City of Copenhagen applies smart city initiatives in order to increase and maintain smart and green living. They are mostly interested in investing health, mobility, energy and climate, learning and citizens. According to Copenhagen Smart City (2018), some smart initiatives are free and fast Wi-Fi, “Smart Parking” that shows occupied and free parking lots, “Smart Lightning” that increases the intensity of illumination at the road intersections when bicycle approaches, “Living Lab” where citizens come together and create smart solutions in favor of the city.

2.1.3. Smart Cities in Turkey

Turkey is currently a developing country with an increasing urban population. There should be some smart solutions in order to increase and maintain the quality of life of the citizens and tourists visiting Turkey. Smart city projects are at the beginning phases, in 5 years it is expected to gain smart habits and smart applications in Turkey.

2.1.3.1. Istanbul. United States Trade and Development Agency has granted Istanbul Municipality (IBB) in order to initiate smart solutions for the city of Istanbul. The grant aims to improve disaster management, city operations and provide proper public services for Istanbul (TBB, 2016).

Currently IBB is working with IBM and Vodafone to make the public transportation “smart”. Vodafone provides communication technologies while IBM analyzes transportation data. Also, IBM has launched Turkish Smart Cities Technology Center.

Some smart applications are:

- Geographic Information System (GIS): It is expected to improve existing GIS technology to a better and improved technology that will improve services for citizens, disaster management and mitigation.
- Citizen 360: It is aimed to create a citizen IT service to improve systems for citizens and understanding the citizen’s needs.
- Talking Roads and Talking Vehicles: Project aims to decrease carbon emission, delay rates of public transportation with an improved signalization system.
- ISPARK: Renting bicycle for citizens and paying parking fees with automated kiosks.
- MobIETT: Platform that people create routes for their travel destinations and see the time left for the transportation vehicle to arrive to the station.
- SCADA: Online monitoring of dams and water reservoirs are held by SCADA systems from satellite for Istanbul Water and Sewage Administration (ISKI).
- Recycling: Municipality initiated a recycling program for citizens. Citizens can earn money for each recycle and after 50 recycle they are gifted to free theatre ticket.

2.1.3.2. Izmir. Izmir one of the most developed cities in Turkey. In order to provide smart activities to the residents, city undertook some smart applications (IzmirBel, 2017):

- SCADA: System that water distribution system can be managed centrally.
- WizmirNET: Open access free Wi-Fi system.

- Smart Traffic: Sensors are placed to sense the type of vehicles and the system priorities public transportation devices, ambulances and fire trucks. Also, it will sense violations in the traffic and will sent automatic fine to plate number of vehicles.

2.1.3.3. Karaman. "Akilli KenTT" was launched by Turk Telekom Group in Karaman with Innova Group. Innova Group was the manager of the project and it provided sensors, infrastructure, kiosks, technological equipments and data and operations centers to the city of Karaman (Innova, 2018).

2.1.3.4. Çanakkale. According to Novusens (2018), "Aklım Fikrim Çanakkale" project has initiated by Kale Group with Turkish Informatics Foundation and NOVUSENS. Project aims to increase the life standards of the city of Çanakkale by increasing sustainability level of Çanakkale.

2.2. Smart Campus

Increasing population in the world, and in urban areas has led an increase in number of students go to college. Also, digitalization has led everything become faster than it usually is. Therefore, being smart in a campus environment became the most important thing in today's world. Not only increasing population and number of students but also the way that students learn and adapt are in a constant changing process. New technologies allow students to think and learn in a different way from their teachers or their parents. This rapid change needs an adaptive, connected and self-learner system that will enable new ways of teaching and processing data.

Campuses are representations of cities, with its students, management, and faculty. Using smart solutions in the campus to monitor and control every facility will create more efficient use of resources while minimizing the excess consumption, result in being a "smart campus". Also, using smart solutions in the campus is a benchmark to reach ultimate goal of creating a smart city that monitors and controls every facility.

Strategies specially developed for campuses connect the information of students, every move and behavior in the campus, the buildings and building related information. These strategies will eventually create cost benefit balance while giving an importance in time and efficiency aspects.

Universities are the places that young minds and academicians develop ideas freely and conduct research about them. Therefore, a smart campus is the learning and living environment that allows people and university to be more sustainable, economic, interactive and adaptive while enhancing the potential. As mentioned before, smart solutions should be centered around people to be more effective. First, people adapt the solution then they will spread the information to their surroundings.

Main smart campus applications are for increasing safety and security, maintaining energy savings and sustainability, regulating management and utilization of campus, providing network use and connectivity, transportation, collaboration and learning shown in Figure 2.4 (Accenture, 2016). All applications and factors in smart campus strategy will increase the willingness of learning and capability in learning of students and this will result in a more dynamic and adaptive learning environment.

The smart campus applications exist but they are not connected, yet. Library has its own barcode system for checking in and out, dining hall has a system that students can pay with student ID cards, there is a separate system for lecture materials. However, these systems do not talk to each other, they are not connected and do not act like one main system. Connection of smart applications will accelerate becoming smart a campus and ultimately becoming smart a city. This connection will occur step by step. Adaption of smart applications in the areas such as security, safety, infrastructure, teaching, learning, marketing, communication, and research will complete the aim of digital strategy. It will increase flexibility and efficiency of the applications. With the help of cloud strategy, these applications will be available from everywhere and it will increase speed, cost and computing power. Lastly, by including internet of things strategy to the strategies above, connection, personalization and prediction will be possible. This connection will create safer campus environment, reduce cost of energy while detecting over-consumption and increase sustainability.

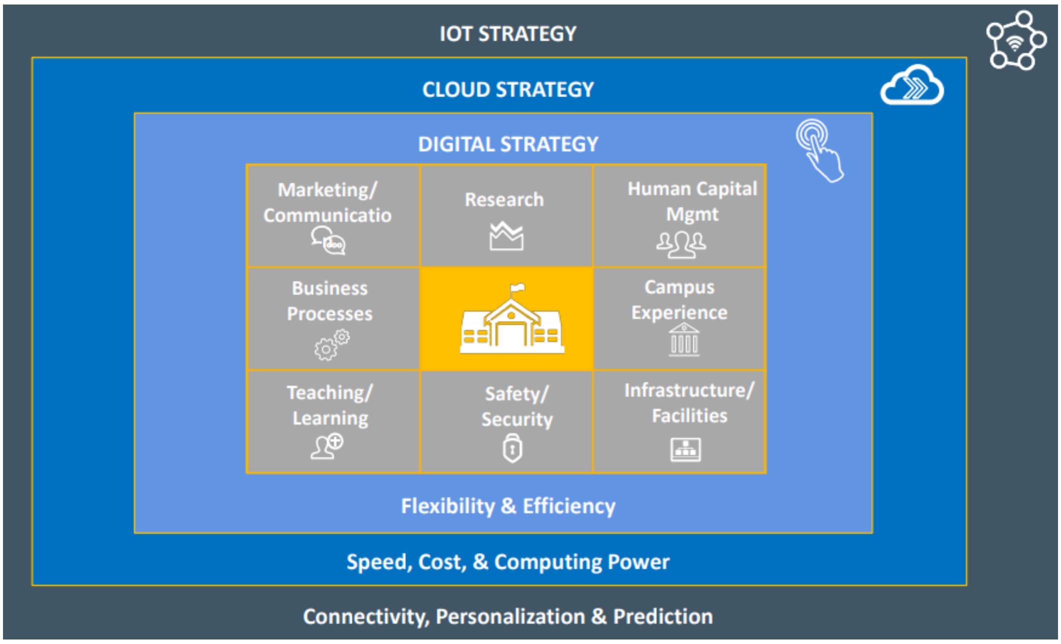

Figure 2.4. Smart campus strategies (Accenture, 2016).

2.2.1. Components of Smart Campus

According to Özüpak *et al.* (2017), components of smart campus are:

- Smart Management: Management of all components of smart campus.
- Smart Learning: Aims to increase all learning and teaching activities in the campus.
- Smart Energy: Electric, water and HVAC systems of campus are controlled and managed in a center.
- Smart Transportation: Connecting IT solutions with already existing transportation devices will enable controlling of transportation scheme, road and vehicles.
- Smart Service: Automation of libraries and all electronic documents.
- Smart Security: Improved security system with smart applications.
- Smart Health: Aims to provide smart health services to students, for example online appointment, automated appointment notifications, data analysis for effective diagnosis.

- Smart Communication: Connection of all of the smart applications with each other.
- Smart Waste Management: Waste and carbon footprint minimization and maintenance of sustainable environment.

2.2.2. Smart Campuses in the World

2.2.2.1. University of Glasgow - Scotland. University of Glasgow has adopted the smart campus strategy to become more resilient, sustainable, adaptive and initiative for campus environment and the users of the campus (University of Glasgow, 2018). Some smart applications in University of Glasgow are:

- Library of Glasgow University has a system that shows the empty and occupied spaces in the library.
- Optimized timetable which allows students to see the other courses that a student can add to their schedule while choosing a course on their schedules.
- Smart Parking system allows students to see the occupied and empty places in the parking lots.
- Football sensors are put in order to track students and the ball itself.
- 5G is used in the campus.

2.2.2.2. Yonsei University - South Korea. Yonsei University is one of the leaders of smart campus movement. According to Yonsei University (2018), some smart applications in Yonsei University are:

- Students can see the shuttle bus location and book a seat.
- Students can learn and share the campus activities via Yonsei Gong-Gam application. The application sends a message when the activity approaches.
- Electronic attendance via student ID cards or online application in the lectures.
- Dining halls have a smart system that allows students to see the empty and occupied seats in the dining hall, and get information about daily menu.

- Students can reach their ID cards via a platform that stores a mobile barcode and student's information.
- Library of Yonsei also has a system that allows students to check the empty and occupied spaces in the library and checkout book via kiosk and mobile alert about late return of the materials taken from library.

2.2.2.3. Technical University of Denmark - Denmark. Technical University of Denmark has a platform called "DTU Smart Campus" that connects and conducts all of the smart activities happening in campuses and prospect projects for campuses. Also, the partners of the platform try to increase familiarity of the platform by promoting some incentives via seminars and posters. DTU has environmental sensors that records environmental data for all over its campuses. These data are open to all of the students that want to create an impact on the environment for a better future.

According to DTU (2018), some smart applications in Technical University of Denmark are:

- In order to save energy in the libraries, 620 smart light bulbs are replaced with the old LED bulbs. Smart light allows user to adjust the intensity and color of the light. The sensors on the light bulbs can collect information about indoor air quality parameters such as temperature, humidity, and CO_2 level.
- Smart street lights are installed to the streets of DTU. Free power and Wi-Fi access is available with the help of smart street lights.
- DTU created a work space where students and members of DTU can league together and share innovative ideas with each other.

2.2.3. Smart Campuses in Turkey

2.2.3.1. Izmir Ekonomi University - Izmir. Izmir Ekonomi University adopted some smart strategies such as Blackboard Learning Management, and Panopto.

According to Izmir Ekonomi University (2018), some of the smart strategies adopted are:

- Blackboard Learning Management: It is a platform that professor can add course materials, exams, quizzes and students can see and download their results and course materials.
- Blackboard Collaborate: It is a platform that students and professors can share audio, video and text.
- Panopto: It is a platform that enables to record videos on instructor's computer screen or projection device. Students can watch or listen these videos at the comfort of their homes.

2.2.3.2. Middle East Technical University (METU) - Ankara. METU currently concentrated on the smart campus applications in their campuses. They received grant of $830000 from United States Trade and Development Agency (USTDA) for the subject of smart campus in METU in 2018. The project is about efficiency and smart applications in energy, transportation, construction and water management (US Embassy, 2018).

2.2.3.3. Hacettepe University - Ankara. According to Hacettepe Teknokent (2016), Hacettepe University also support smart campus projects. University decided to create energy storage places in their green areas and fast charging of electric cars will be possible. Moreover,the stored energy will channel into the building illumination systems. Heating, Ventilating and Air Conditioning (HVAC), illumination, storage and charging places will be managed in one control center.

2.2.3.4. Boğaziçi University - Istanbul. Boğaziçi University hosts smart campus applications such as the platform "Moodle", course management system, "BuCard" system, library system, smart lightning and two innovation centers. These smart campus initiatives are:

- Moodle: Instructors can add course materials, exams and quizzes to Moodle and platform allows students to access course materials and exam grades.
- Library: Self check in and check out desks are available in the library. Also, smart booking of books and barrels, late alert is also available.
- Technology Center: There are two active technology centers in Boğaziçi University. One of them acts like a business incubator while the other acts like a research center. They allow researcher or businessperson to conduct research or businesses. Also, Boğaziçi University and Dudullu Organizational Industrial Zone collaborated in order to create "Budotek" in Dudullu, which is also an incubation and technological center.
- Bizero: Bicycle platform that students or members of Boğaziçi University can book and rent electric bicycle online.
- Smart Lightning: In the South Campus there are smart lightning bulbs which collect and store the energy of sun and use it in the night.
- BuCard: Smart Card that allows students to enter the campus, using in library to book a book and using in dining halls to eat meals. Also, the logs can be seen in smart platform of registration.
- Waste Management: Electronic, dangerous and recyclable wastes are collected separately. Zero-waste initiative are adopted and transformation occurs stepwise.

2.3. Green Campus

Higher education in Turkey is experiencing a fast development. Currently, there are 206 universities with 7.5 million students. Each year as can be seen from Figure 2.5 approximately 1.3 million students enroll to universities. Increase in demand for higher education that is compensated by opening new universities or departments or just increasing the number of students in the universities create a demand in energy, water and other resources. If attractivity of higher education continues, sources will not be adequate to new population. Therefore, green campus initiatives that are in favor of efficiency in energy consumption and water consumption, sustainability should be placed in the campuses.

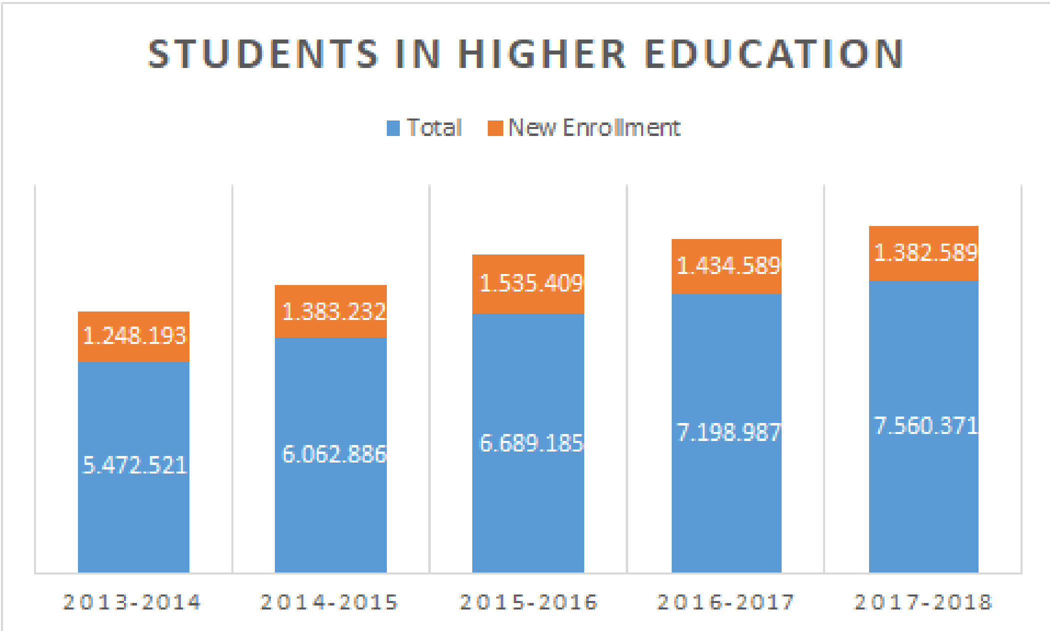

Figure 2.5. Number of students in higher education in Turkey between 2013-2018 (YÖK, 2018).

Smart adaptations in campuses such as smart waste management, smart transportation, smart security, smart management that includes controlling and monitoring every facility in the campus will eventually lead becoming more efficient while minimizing the energy use. By reducing excess use and maintaining the natural resources "green campus" is constructed. Universities have the intellectual power to connect and control all facilities while maintaining new technologies to create "smart campus" and "green campus".

A green campus can be defined simply as being an eco-friendly sustainable campus program. Being a "green campus" is not only about adopting eco-friendly sustainable campus program but making it a life style. If students, faculty and visitors do not apply sustainable solutions to their routine when they are at home or at university, going green will not be effective for example using energy efficient air conditioner is useless if user forgets to turn it off. In order to adopt green campus and its applications, university-level leadership and coordination should be performed (Tan *et al.*, 2014). This campus program can be carried out by different projects, such as making campaigns to raise awareness about water usage, recycling waste and importance of renewable resources, not only using rainwater and solar panels to save water and energy is the meaning of green campus but also the most important part of the green campus project is participation and competitiveness of people. Main aims are to create awareness for the unnecessarily used energy and water, use of natural resources such as rainwater, to raise awareness regarding the environmental pollution, to create a platform for sharing information about activities, transportation, and initiatives such as these (METU, 2018; University of Copenhagen, 2016).

2.3.1. Difference between Smart Campus and Green Campus

Smart campus is an integrated campus with all of its facilities. Applications for smart campus are smart waste management, smart management, smart transportation, smart learning, smart energy, smart environment, smart security, smart health, smart communication. Integrating all the facilities to each other, inefficiencies in the system can be seen and precautions can be taken. As a result of going smart, conservation of natural resources can be provided. It can help to reduce time waste for waiting for the service. However, green campus can be a part of smart campus that mostly focused on sustainability and environmentally friendly issues such as energy and water save, minimizing and reclamation of waste, minimizing carbon emission. If all the activities are integrated, a green campus can also be a smart campus while sustaining and maintaining resources.

2.3.2. Green Campuses in the World

2.3.2.1. UC Berkeley. UC Berkeley has a project called "The Green Initiative Fund" which collects $8 per student per semester as an increase in their fee. One third of the fee goes to financial aid services, and the rest is collected under "The Green Initiative Fund" which is a program that gives necessary funding to those who have a project about sustainability. Also, university has solar panels installed in various buildings to generate 1 MW power from the sun. University decided to decrease carbon emission levels below the levels in 1990s. University currently is getting to zero waste, and their goal is to give zero waste to landfill areas by 2020. Compactors for recycling and composting are spread all over the campus to compost and recycle the wastes (UC Berkeley, 2018).

2.3.2.2. University of Copenhagen. University of Copenhagen (UCPH), started a green campus project in 2008, with the purpose of making a sustainable, environmentalist campus. Their first aim was to decrease the energy consumption and carbon-dioxide emissions. They accomplished their aim in 5 years and created a strategy until 2020. The targets of the project "Green Campus 2020" are as follows:

- Decreasing the carbon-dioxide emissions.
- Decreasing the amount of used energy.
- Decreasing the amount of material and resources use (efficiency in material and resources usage).
- Controlling the pollution of environment (chemical pollutants).
- Management of the energy and resources of the university.
- Creating an environment for students to practice and put the knowledge into action regarding sustainability and green campus.

Decreasing carbon-dioxide emissions was the first goal of the UCPH, with this purpose they first calculated the source of the emissions and take action to decrease it. The most emission was from the energy usage. The creation of energy was the factor for the carbon-dioxide emissions, to decrease this they find the solution to change to the renewable energy sources. The other effective factor was the transportation, for that they made arrangements to reduce the increase in transportation on yearly basis. UCPH reduced their energy consumption by 20 % in 5 years and they plan to raise it to 50 % by 2020. They have 24 % return from the recycle process (University of Copenhagen, 2016).

2.3.3. Green Campuses in Turkey

2.3.3.1. Boğaziçi University. Boğaziçi has initiated "Zero-Waste Project" which has received an award as "Sıfır Atık-İyi Gelecek" in November 2018. According to Yeşil Kampüs BOUN (2018), 15 buildings are selected out of 65 due to the applicability and variety and recycle trash bins are placed. Recycle trash bins are placed in Hisar Campus, Rectorate Building, New Hall, Perkins Hall and Faculty of Science.

For Dining Halls, the necessary equipment for separation of food waste are determined and designs are made for North Campus Dining Hall. Food waste will be sent to animal shelters and organic wastes will be composted in "Boğaziçi University Compost Center" in South Campus parking lot (Figure 2.6). Other non-recyclable materials will be sent to Municipalities of Beşiktaş and Sarıyer.

Figure 2.6. Boğaziçi University Compost Center.

Metal, paper, bottle and plastic recyclable waste, toner, batteries and hazardous waste, waste oils will be sent to authorities recognized by Ministry of Environment and Urbanization General Directorate of Environmental Management. Recyclable wastes are collected weekly by Sarıyer and Beşiktaş Municipalities. Electronic wastes are collected in every 5 months by MHK Hurda A.Ş. and toner waste are collected by secretaries in each department and collected yearly by Anel Doğa Entegre Geri Dönüşüm End. A.Ş.. Hazardous wastes are collected yearly by Ekolojik Enerji A.Ş..

Boğaziçi University has two buildings that have the Leed Gold Certificate: Boğaziçi University Kandilli Observatory and Earthquake Research Institute National Earthquake Monitoring Institute (UDIM) and Hamlin Hall (Dormitory). Both buildings have grey water system and energy and water efficient appliances. 900 kW wind turbine system is placed in Kilyos Campus which can save 900-ton carbon dioxide. Furthermore, Kilyos Campus has "Istanbul Microalgae Biotechnologies Research and Development Center" and "Rainwater Cistern".

2.3.3.2. Middle East Technical University. An example of the green campus project is carried out by METU. Students of METU started an initiative for creating a green campus in 2011. Project started for saving water and energy resources but later with the participation of more people it developed. METU is operating "Green Office Activities", "Energy Activities" and "Environmental Activities" for green campus project. With these three activities students try to decrease the energy consumption, create a more eco-friendly campus, and find new solutions to save resources and to be more eco-friendly. They prepared a presentation in 2017 to give information about their path to create a green campus. They touched the topics of; "Indoor Air Quality", "Energy", "Carbon-dioxide Emissions", "Water", "Solid Waste", "Noise" and "Awareness". For this purposes they have 4 projects named as "Bike First Campus", "Campus Bike", "Solid Waste Recycling" and "METU NCC Community Gardens Project". "Bike First Campus" projects aim is to mainly reduce the carbon-dioxide emissions. Also, by using the bicycle the students will lose weight, get strong and much healthier. As in "Bike First Campus", the project "Campus Bike" is about decreasing the carbon-dioxide emissions. This project will rent bicycle for using in the campus and the rents will be donated to the Scholarship Fund Office. "Solid Waste Recycling" project is about decreasing the pollution by creating recycling systems and awareness (METU, 2018).

2.3.3.3. Piri Reis University. Piri Reis University set its sustainability goals when construction of the university was completed in 2014 (Erten, 2014). University tries to minimize water and energy use in the campus. Solar panels provide hot water to the buildings. Besides, all systems in the buildings and consumption parameters are controlled by Building Management Systems. Lightning is designed in order to benefit from natural daylight.

2.3.3.4. Istanbul Technical University. Istanbul Technical University (ITU) placed as 77th among 619 university in GreenMetric evaluation. Evaluation is done according to infrastructure, recycling, climate change, water resources, transportation and education potentials of campus (Yeşil Kampüs İTÜ, 2018). They constructed Biogas Facility that produces electricity from solid waste starting from tea waste to toilet waste and "Accessible Green Office" (Figure 2.7). The aim of this project is to be in harmony with

Figure 2.7. Accessible Green Office (on the left), Office constructed from mud (in the middle), Biogas Facility Container (on the right).

nature and protect it by creating an eco-friendly environment and awareness. Some green projects developed by ITU are "The Sustainable Landscape Understanding" is about making roads for bicycles and pedestrians more compatible for them and creating the area perception; "Unimpeded ITU" is about making the campus more suitable and easy to move around for disabled people; "Ensuring the Life Cycle" is to protect the environment. Also, the artificial lake in the campus is used for gathering rainwater and use it in the irrigation.

(i) Accessible Green Office: Previously used, recently idle containers are used in the construction process of the office. In this way, any cement or other raw materials that will increase water and carbon footprint are not used. Other materials used in construction process are selected as low energy consuming and recyclable. Urine-separating toilets are used in the building to decrease the amount of water required by faeces waste to move easily into waste water disposal system. However, they use the urine and faeces waste in the facility. For urine part, they installed micro-algae tank onto the façade of the Accessible Green Office (Figure 2.8). Produced biomass is transferred into the biogas facility to produce electricity (Altınbaş M., ITU, Personal Communication, November 2018).

Figure 2.8. Micro algae tank and urine storage system.

(ii) Biogas Facility: The effective volume of Biogas Facility is 50 m^3 in order to be a mobile unit. It consists of two containers, in the first container (on the left), the solid waste is fed to the system. After initial grinding, the second grinding process is applied in order to decrease the size of solid waste particles. Dry matter should be below 10 %, so they need to add waste water in to the system. Waste is taken into a storage that is kept under 70°C for several hours to sterilize the solid waste according to European Standards. Later, sterilized the product goes to the second container (on the right).

The hydraulic retention time is kept as 30 days. Capacity is 1.67 m^3/day as dry mass (DM). Only 75 % of DM can be used which is 1.25 m^3/day. 1 ton DM produces 350 m^3/day of CH_4, and 1 m^3 CH_4 can produce 10 kWh, theoretically. The facility runs with 35 % efficiency because the system needs initial energy to start and sterilize the waste at 70°C. As a result, 61 kWh energy is produced per hour through biogas facility (Altınbaş M., ITU, Personal Communication, November 2018). Electricity produced can now only be used for charging the electric car stations which will be implemented to ITU Ayazağa Campus.

3. THEORY OF WATER FOOTPRINT

Water footprint (WF) is the volume of water used directly or indirectly. Direct water footprint is the volume of water used in the form of taking shower, drinking, washing dishes, laundry, and washing cars. However, indirect water footprint is the volume of water used in the production, and supply chain of the product.

Water is vital for humans. One of the important matters in order to stay alive and function properly as a human-being is the need to access to water besides air and food. However, of all the water available in the world only 2.5 % is fresh water. Of all the fresh water available in the world, 68.7 % is in the ice and snow form; 29.9 % is in groundwater and 0.26 % is found in the lakes, rivers and reservoirs (Shiklomanov, 2000). Problems with water efficiency and water quality are critical. Increased population generates problems related to the water and its sustainability. Since, sea water has a limited access for those who live on land, one can and should be able to sustain fresh water for drinking, washing, cooking or irrigation. There are numerous studies and ways to make use of sea water such as desalination. However, desalination of sea water is not only expensive and costly but also demands too much energy.

According to World Economic Forum Water Initiative (2008), cities consume 60% of all water allocated for human use. In 2009, 44% of the world's population, which is 2.8 billion people, lived in areas where the supply of water is insufficient. People who will have an insufficient water reach is expected to be around 4 billion by 2030 as can be seen in Figure 3.1 (World Economic Forum Water Initiative, 2008).

Inefficient supply of water creates many problems in human health and accordingly in economic growth by increasing food prices for those who even have not enough money to have water. One, first, needs to calculate water footprint (WF) in order to understand how much fresh water is consumed and how much fresh water is available and how they can preserve the water supply.

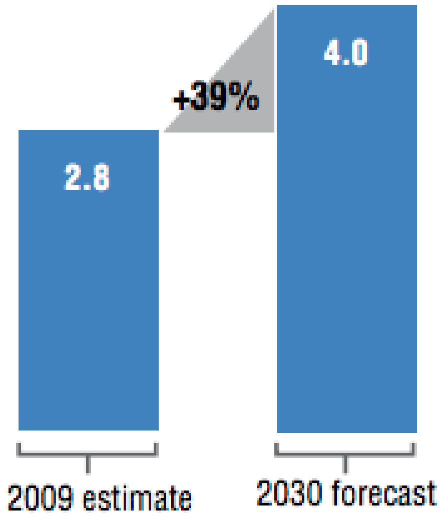

Figure 3.1. Global population (billions) in high water stress areas (World Economic Forum, 2009).

Water footprint term and its calculation are first introduced by Hoekstra (2002). Hoekstra (2002) states that water footprint is necessary in order to measure and calculate the freshwater use through supply chain of the processes and products. Basically, water footprint is the calculation of water use in terms of volume. Water footprint can be calculated in terms of water used in the production process of a product, shipment and supply chain of the product. After Hoekstra's (2002) introduction of water footprint, water footprint has been used as an indicator of freshwater use of "processes, products, consumers, a group of consumers, a business, a business sector, and humanity" as a whole (Water Footprint Assessment Manual, 2011).

There are different types of water footprint:

- Direct Water Footprint: Volume of water consumed directly by consumers in the form of taking shower, drinking, cooking, cleaning.
- Indirect Water Footprint: Volume of water consumed in the production phase of the products that consumers use in their lives. Generally, the largest part of the water consumption. For example eating habits, and shopping habits affect indirect water footprint since water is used in production and supply-chain of products.

- Blue Water Footprint: Volume of fresh surface water or groundwater use of consumers.
- Green Water Footprint: Volume of rainwater consumed during the production process.
- Grey Water Footprint: Volume of fresh water used to distort pollutant.

Blue, Green and Grey water footprint are used in the calculations of both direct and indirect water footprints.

$$TotalWaterFootprint = BlueWF + GreenWF + GreyWF \tag{3.1}$$

$$GreyWaterFootprint = DirectWF + IndirectWF \tag{3.2}$$

$$TotalWaterFootprint = DirectWF + IndirectWF \tag{3.3}$$

Falkenmark and Rockström (2004) state that the distinction between green and blue water footprint is crucial not only because the hydrological and environmental impacts but also the economic benefits of the use of surface and groundwater for production. Also, virtual water is water consumed by production phase of everyday materials depending on where they are produced and used, and the production method. Virtual water allows nations to trade from “water-rich” nations to “water-poor” nations.

3.1. Direct Water Footprint

Direct water footprint is increased by volume of water use in shower, bathtub, bathroom sink, toilets, kitchen, washing dishes, laundry, lawn and garden watering, swimming pool and car washing. Besides, using grey water and rain barrel systems, xeriscaping are methods of water saving that decreases direct water footprint.

3.1.1. Showers

Water use in shower is directly related to shower head type. Low-flow shower heads do not allow water to flow as much and fast as conventional shower heads. Flow rate of low-flow shower head is 0.1577 l/min and that of conventional shower head is 0.31545 l/min (Alliance for Water Efficiency, 2018). For these reasons, shower head types are asked and each preferences are assigned to a flow rate. In order to determine average water use in home, average shower time of students are collected as a time interval. Each time interval is assigned to an average amount of time (Table 3.1). Water use per capita per day in shower is calculated according to Eq. 3.4 where t_s is the number of minutes for chosen shower interval and Q_s is flow rate based on shower type.

Table 3.1. Shower and bathroom faucet running duration per usage.

Interval	**Value Used**
Under 5 min	4 minutes
5-10 min	8 minutes
11-15 min	13 minutes
Over 15 min	15 minutes

Table 3.2. Water use of low-flow shower head (Alliance for Water Efficiency, 2018).

Shower Head Type	**Flow Rate (l/min)**
Yes	0.1577
Some	0.2397
No	0.31545

$$WF(s) = t_s \times Q_s \tag{3.4}$$

3.1.2. Bathtub

The average bath uses 133 liters of water (Alliance for Water Efficiency, 2018). Finding the frequency of taking bath will give the amount of water use per capita per day when it is multiplied with average water use per bath and time multiplier for converting the number of baths taken per time to number of baths taken per day (Table 3.3). Water use in bath per capita per day is calculated according to Eq. 3.5 where N_b is the number of times bath taken per time, t is time multiplier, N_p is the number of people living in the house, and 133 is the average water use per bath in liters.

Table 3.3. Time period time multiplier (WFC, 2018).

Time Period	**Multiplier**
per day	1/1
2-3 times per week	3/7
per week	1/7
per month	1/30
per year	1/365
I don't	0

$$WF(b) = \frac{133 \times N_b \times t}{N_p} \tag{3.5}$$

3.1.3. Bathroom Sink

In order to find the water use in bathroom sink, how long students leave the faucets running include brushing teeth or shaving is asked and for choosing the best interval representing the running time of bathroom sinks the values in the Table 3.1 is used. Faucet type affects the water use directly. Low-flow faucets allow to save water since they do not flow as much and fast as old shower heads. Flow rate of low-flow faucet is 5.68 l/min and that of conventional faucet is 18.97 l/min (Residential End Uses of Water, 2018) (Table 3.4). Water use in bathroom faucets per capita per day is calculated according to Eq. 3.6 where t_f is the number of minutes for chosen sink use interval and Q_f is flow rate based on faucet type.

Table 3.4. Water use of low-flow bathroom, kitchen faucet and toilet (Residential End Uses of Water, 2018).

Faucet Type	**Flow Rate (l/min)**
Yes	5.68
Some	12.50
No	18.97

$$WF(f) = t_f \times Q_f \tag{3.6}$$

3.1.4. Toilets

People use toilet from 3 times per day to 3 times per week, which results in 1.7 faeces waste per day on average (Mayoclinic, 2018). Also, people flush 5 times per day on average (WFC, 2018). Not flushing every time can save water rather than flushing every time. An average person who do not flush every time when they use toilet, flushes 1.7 times per day, whereas flushing every time is 5 flushes per day, on average (WFC, 2018). Non-flushing behaviors of students are asked and responses are assigned to average flush per day (Table 3.5). Also, students are asked if they have low-flow toilets at home (Table 3.4). Low-flow toilets use 5.68 liter per flush, and conventional toilets use 18.97 liters per flush. Water use for toilet is shown with WF(t) and calculated by Eq. 3.7, number of flushes is shown with N_f, flow rate based on toilet type is shown with Q_t.

Table 3.5. Number of flushes per day according to letting it mellow (WFC, 2018).

Letting it Mellow	**Flushes per Day**
Of Course!	1.7
Sometimes	3.4
Gross. No!	5

$$WF(t) = N_f \times Q_t \tag{3.7}$$

3.1.5. Kitchen

Time interval that students leave the kitchen faucet open for rinsing food, cleaning but not washing dishes, are asked and the intervals are assigned to average time duration (Table 3.6). Kitchen and bathroom faucets are generally the same type of faucets, so the flow rate is take the same with bathroom faucets (Table 3.4). Water use in kitchen sink is shown with WF(k) and calculated by Eq. 3.8, number of minutes running water is shown with N_m, flow rate based on faucet type is shown with Q_f.

$$WF(k) = N_m \times Q_f \tag{3.8}$$

3.1.6. Washing Dishes

The type of dish washing method affects the water. Hand-wash consumes more water comparing to conventional and energy efficient dishwashers. Eating out or using disposable dishes are directly related with number of people living in the house since

Table 3.6. Kitchen faucet running duration.

Interval	**Value Used**
Under 5 min	4 minutes
5-20 min	13 minutes
21-45 min	33 minutes
Over 45 min	45 minutes

one disposable dish requires 19 liters of water to be produced. Students are asked how many times they wash their dishes (Table 3.3), the answers are converted to day with time multiplier. Also, the method they use for washing dishes is asked (Table 3.7). Water use in washing dishes is shown with WF(w) and calculated by Eq. 3.9, N_d is the number of times dish washing per time, number of people living in the house is shown with N_p, liters per load is shown with Q_l, time multiplier is shown with t.

Table 3.7. Liter of water use according to dish washing method (Residential End Uses of Water, 2018).

Dishwashing Method	**Liters per Load**
Conventional dishwasher	57
Energy/water-efficient dishwasher	16
Hand wash	76
Disposable dishes or eat out	19 x N_p

$$WF(w) = \frac{N_d \times t \times Q_l}{N_p} \tag{3.9}$$

3.1.7. Laundry

Number of times that students do their laundry affect their water footprint. Conventional washing machines consume more water per load when comparing to energy efficient washing machines or laundromats. Students are asked how many times they do laundry and the answers are converted in to number of times per day with time multiplier (Table 3.3). Moreover, the type of laundry method that students prefer is asked (Table 3.8). Water use in washing is shown with WF(wa) and is calculated by Eq. 3.10, number of times washing per time is N_w, t is the time multiplier, liters per load is shown with Q_l, number of people living in the house is shown with N_p.

Table 3.8. Liter of water use according to washing method (Allience for Water Efficiency, 2018).

Washing Method	**Liters per Load**
Conventional washer	155
Energy/water-efficient washer	102
Laundromat, wash and fold or shared laundry rooms	144

$$WF(wa) = \frac{N_w \times t \times Q_l}{N_p} \tag{3.10}$$

3.1.8. Grey Water

Grey water systems that are installed at houses allows household to collect and reuse water from kitchen, laundry, shower and bath to water their garden. A typical household holds 56 m^3 reusable water per year from grey water system (James, 2010). Students are asked whether they have grey water system installed at their home.

WS(gr) is water saved by grey water system and calculated by Eq. 3.11 where 56,000 liters of water per year per house can be collected, number of people living in the house is shown with N_p.

$$WS(gr) = \frac{56000}{N_p \times 365} \tag{3.11}$$

3.1.9. Lawn and Garden Watering

Number of times that students water their garden and the size of the garden are asked and the answers are converted per day with time multiplier (Table 3.3). Watering garden or lawn affects water footprint. The size of the place that is being watered is directly proportional to water use as can be seen from Table 3.9. WF(g) is water use in gardening and calculated by Eq. 3.12, N_g is number of times gardening per time, t is time multiplier, W_p is water use for gardening per time, number of people living in the house is shown with N_p.

Table 3.9. Water use for gardening (Residential End Uses of Water, 2018).

Interval (m^2)	**Water use (liter)**
1-10	64
11-50	375
51-100	940
101-500	3747
501-1000	9350
1001-4000	31230
4000+	54415
I don't	0

$$WF(g) = \frac{N_g \times t \times W_g}{N_p} \tag{3.12}$$

3.1.10. Xeriscaping

Xeriscaping is the activity of planting in the garden that will decrease evapotranspiration by 33 % (WFC, 2018). WS(x) is water saved by xeriscaping and calculated by Eq. 3.13, WF(g) is water use in gardening.

$$WS(x) = 0.33 \times WF(g) \tag{3.13}$$

3.1.11. Rain Barrel

A rain barrel system is just a barrel that is connected to the outlet of the roof and collects rainwater in it. A rain barrel system can collect 5000 liters of rainwater per year which is approximately 15 liters per day (EPA, 2016). WS(rb) is water saved by rain barrel and calculated by Eq. 3.14.

$$WS(rb) = 15/N_p \tag{3.14}$$

3.1.12. Swimming Pool

An average pool requires 70 m^3 to fill completely. If user do not cover it while using, the pool loses approximately 4 m^3 per month by evaporation (WFC, 2018). WS(p) is water use for pool and calculated by Eq. 3.15 where M_u is number of months pool is not covered, number of people living in the house is shown with N_p.

$$WF(p) = \frac{70000 + 4000 \times M_u}{365 \times N_p} \tag{3.15}$$

3.1.13. Car Washing

Car washing affects the water footprint, too. Type of washing method and the frequency of washing affect water footprint. The frequency that students wash their cars are asked and the results are converted as per time with time multiplier. Type of car wash determines the amount of water use per wash. Washing the car on your own with a garden hose consumes 380 liters per wash while full-service car wash and self-service car wash consumes 220 and 57 liters per wash, respectively. WF(c) is water use for car wash and calculated by Eq. 3.16, N_c is number of times of car washing, Q_l is liters per wash and number of people living in the house is shown with N_p.

Table 3.10. Water use according to car washing method (Water Conservation, 2000).

Car Washing Method	**Liters per Wash**
Garden Hose	380
Full-Service Car Wash	220
Self-Service Car Wash	57
I don't have a car	0

$$WF(c) = \frac{N_c \times t \times Q_l}{N_p} \tag{3.16}$$

3.2. Indirect Water Footprint

Indirect water footprint is increased by using gasoline, electricity, shopping preferences, diet, and buying cat and dog foot. Also, it is decreased by recycling and using renewable resources as an energy source.

Virtual water content of a product is the volume of freshwater used to produce the product, measured at the place where the product was actually produced. It is the sum of water use in every step of the production chain. Also, the other definition of virtual water is that volume of water that would have been required to produce the product at the place where the product is consumed. The real-water content of products is negligible if compared to virtual-water content. Furthermore, the water footprint is a multidimensional indicator, not only referring to a water volume used, but also making explicit where the water footprint is located, what source of water is used, and when the water is used. The additional information is crucial in order to assess the impacts of the water footprint of a product.

A pullover will require cotton to be grown, ginning and spinning of the fibres, weaving, sewing and wet processing of the fabric to ultimately have the finished product. Each step has a direct water footprint and an indirect water footprint. The direct water footprint of one process becomes the indirect water footprint of the next process. In this way, the full amount of water consumed or polluted is taken into account in the product water footprint.

3.2.1. Gasoline

Producing and refining transportation fuels like oil, natural gas and biofuels requires a lot of water. Researchers at the Lawrence Berkeley National Laboratory estimate that the United States withdraws one to two billion gallons of water to refine nearly 800 million gallons of petroleum products like gasoline every day. To complete all the steps required to produce a liter of gasoline takes, on average, three to six liters of water (WFC, 2018).

Producing gasoline and transporting it to the sink consume water. Therefore, on an average car, driving 1 km consumes 1.72 liters of water (King *et al.*, 2008). The kilometers that students drive per week are asked and the results are converted to days by dividing it with 7. Also, the distance they travel is asked, and the results are assigned to specific distance measures as can be seen in Table 3.11. WF(d) is water use in driving and calculated by Eq. 3.17, N_{km} is number of kilometers per week, number of people living in the house is shown with N_p.

Table 3.11. Water use for driving (King *et al.*, 2008).

Interval (km)	**Value Used (km)**
1-40	40
51-100	80
101-150	125
150-300	250
300+	300
I don't	0

$$WF(d) = \frac{1.72 \times N_{km}}{7 \times N_p} \tag{3.17}$$

3.2.2. Electricity WF of Istanbul

The WF of electricity (m^3/TJ) refers to volume of water consumed and polluted in the different stages of the supply chain of electricity. Mekonnen *et al.* (2015), studied WF of electricity in terms of fuel supply, construction and operation. The first stage is relevant only for fuel-based electricity (when electricity is based on coal, lignite, oil, gas, uranium or biomass). In the other cases (hydro, solar, wind and geo-electricity), they only considered construction and operation stages.

In this thesis, electricity WF of Istanbul is calculated. Electricity is supplied from various sources in Istanbul such as solar, wind, bio gas and mostly from natural gas (IBB, 2018). Constructing the facility that electricity will be supplied, operating the facility and supplying the electricity from that facility consume some amount of water as can be seen in Table 3.12. The values are determined as water footprint as m^3 per terajoule (TJ) of electricity supplied to the city of Istanbul.

Table 3.12. Water footprint for supply, construction and production of electricity for Turkey (Mekonnen *et al.*, 2015).

Type	**Supply** (m^3/TJ)	**Construction** (m^3/TJ)	**Operation** (m^3/TJ)	**Total** (m^3/TJ)
Natural Gas	2.2	1	267	270.2
Solar	0	86	19	105
Wind	0	1	0.2	1.2
Biogas	19000	1	61	19062

89.9 % of electricity of Istanbul is supplied from natural gas and 1.9 % is supplied from biogas. However, water footprint of natural gas is zero while that of biogas is 28666 m^3/d. Water footprint generated from supplying electricity to Istanbul is WF(ei), calculated by Eq. 3.18 where S is type of supply, $WF_{(s,c,o)}$ is water footprint for supply, construction and operation, N_{ist} is population of Istanbul. WF(ei) is 1.91 liters of water per capita per day.

$$WF(ei) = \sum \frac{S \times WF_{(s,c,o)}}{N_{ist}} \tag{3.18}$$

The capacities of electricity suppliers are given in the Table 3.13. Population of Istanbul is 15 million (TUIK, 2018). By multiplying the water footprint per TJ with capacity of supply will give the total water footprint of Istanbul, which is 28682 m^3/day as can be seen in Table 3.14 and Table 3.15.

Table 3.13. Electricity capacity of different sources for Istanbul (IBB, 2018).

Type	**Capacity (MW)**
Natural Gas	2447.17 (89.80%)
Wind	222.95 (8.20%)
Biogas	52.96 (1.90%)
Solar	2.94 (0.10%)
Hydro-power	0.00 (0.00%)
Geothermal	0.00 (0.00%)
Coal	0.00 (0.00%)
Others	0.00 (0.00%)

3.2.3. Electricity WF of Boğaziçi University

In the survey, the source of electricity is asked. If it is supplied from renewable resources such as solar panels, and wind the water footprint accepted as zero, otherwise it is accepted as 1.91 liter per capita per day. WF(e) is the water use for electricity and calculated by Eq. 3.19, p_e percentage of electricity supplied by utility, p_s is percentage of electricity supplied by solar panels.

$$\begin{aligned} WF(e) = 1.91 \times p_e \\ +0 \times p_s \end{aligned} \tag{3.19}$$

Table 3.14. WF of supply, construction and operation of electricity of Istanbul.

Type	**$\sum$ Electricity Prod. (MWh/d.)**	**$\sum$ Prod. (TJ/d.)**	**WF Fuel Supply (m^3/d.)**	**WF Const. (m^3/d.)**	**WF Oprt. (m^3/d.)**
Solar	21.99	0.08	0.00	6.81	1.50
Wind	1802.88	6.49	0.00	6.49	1.30
Geothermal	0.00	0.00	0.00	0.00	0.00
Biogas	417.74	1.50	28573.40	1.50	91.74
Hydropower	0.00	0.00	0.00	0.00	0.00
Natural Gas	19743.70	71.08	0.00	0.00	0.00
Coal	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00
Total	21986.30	79.15	28573.40	14.80	94.54

Table 3.15. WF of Istanbul according to the source of electricity.

Type	**WF (m^3/d)**	**WF (m^3/c.d.)**
Solar	8.31082192	0.00000055
Wind	7.7884274	0.00000052
Geothermal	0	0.00000000
Biogas	28666.6368	0.00191111
Hydropower	0	0.00000000
Natural Gas	0	0.00000000
Coal	0	0.00000000
Others	0	0.00000000
Total	28682.736	0.00191218

3.2.4. Shopping

Since products consume water in their production and supply processes, water footprint related to shopping preferences of the students occurs. Water is required to make all the things people buy and use in their daily life, including plastics such as toys and food packaging, electronics, furniture, textile and packaging and shipping for all daily life products.

There are three types of shopping:

- Shop for basics: Only shopping when it is necessary.
- Like to shop: Shopping often even it is not necessary. For example going to shopping malls to see if there is a discount.
- Shop until you drop: Shopping as a hobby.

Table 3.16. WF according to shopping behavior (Hoekstra *et al.*, 2004).

Shopping Frequency	**Water use (l/p.d.)**
Shop for basics	1100
Like to shop	2210
Shop until you drop	4415

According to Hoekstra *et al.* (2004), shopping for only basics consumes 1100 liters of water per person per day, wheres shopping too much consumes approximately 4 times of shopping for basics, 4415 liter per capita per day. Average water use for shopping is given in Table 3.16. Students are asked about their shopping preferences and water footprint generated from shopping is calculated.

3.2.5. WF of recycling Paper, Plastic, Cans and Bottles, Textile for Turkey

Recycling materials reduces water footprint since recycled materials need less energy and water in the production process rather than raw materials. Amounts of recycled paper, can, bottle, plastic are found in the Bulletin of Ministry of Environment and Urban for recycled materials in 2016, the amounts recycled are given in the Table 3.17 (CSB, 2018). The amount of textile recycled is 10000 tons in 2010 (ÜÇGÜL, 2015).

For calculating the amount of recycled material per day, the amount of recycled matter per year is found and converted to daily amount by simply dividing it by 365. Then, for finding water footprint per person, it is divided by population when the recycle process was completed. Population in 2010 is 73,722,988 (TUIK, 2011) and population in 2016 is 79,814,871 (TUIK, 2017). WS(r) is water saved by recycling and calculated by Eq. 3.20, N_r is amount of recycle per year, W_r is water saved in liters per kg of recycled material type, N_{pr} is population in the year of available recycle data.

$$WS(r) = \frac{N_r \times W_r}{365 \times N_{pr}} \tag{3.20}$$

3.2.6. Diet

According to Hoekstra (2011), in an industrial beef production system, it takes on average three years before the animal is slaughtered to produce about 200 kg of boneless beef. The animal consumes nearly 1300 kg of grains (wheat, oats, barley, corn, dry peas, soybean meal and other small grains), 7200 kg of roughages (pasture, dry hay, silage and other roughages), 24 cubic meters of water for drinking and 7 cubic meters of water for servicing. This means that to produce one kilogram of boneless beef, 6.5 kg of grain, 36 kg of roughages, and 155 liters of water (only for drinking

Table 3.17. Water Footprint (l/c.d.) of recycling and donation.

Recycling	**Amount Recycled (ton/year)**	**Amount Recycled (kg/c.d.)**	**Water Saved (m^3/kg)**	**WS (l/c.d.)**
Paper	1,199,606	0.041178	26	1.070620
Plastic	498,887	0.017125	185	3.168088
Bottle	231,306	0.007940	90	0.714583
Can	169,798	0.005828	7	0.040799
Textile	10,000	0.000372	170	0.063176

and servicing) are used. Producing the volume of feed requires about 15300 liters of water on average. The water footprint of 1 kg of beef thus adds up to 15500 liters of water. This still excludes the volume of polluted water that may result from leaching of fertilizers in the feed crop field or from surplus manure reaching the water system. The numbers provided are estimated global averages. Therefore, the water footprint of beef will strongly vary depending on the production region, feed composition and origin of the feed ingredients.

Table 3.18. Water use according to diet (Hoekstra, 2002; WFC, 2018).

Diet	**Water use (l/day)**
Vegan	2415
Vegetarian	2990
Meat not every day	3157
Meat once a day	4090
Meat twice a day	5466
Meat every meal	8218

It can be seen that direct water footprint of a previous step is an indirect water footprint of the next step (Figure 3.2). That is why, direct water footprint is negligible compared to indirect water footprint. Furthermore, virtual water footprints of different types of food can be seen in Table 3.19. Eating habits can affect water footprint of each individual for example preferences of vegan do not consume as much water as preferences of meat eaters. To determine the dietary consumption patterns of vegans and vegetarians, it is assumed that vegans eat no meat or dairy while vegetarians eat dairy but no meat. In all cases except for vegans, egg consumption holds constant (WFC, 2018).

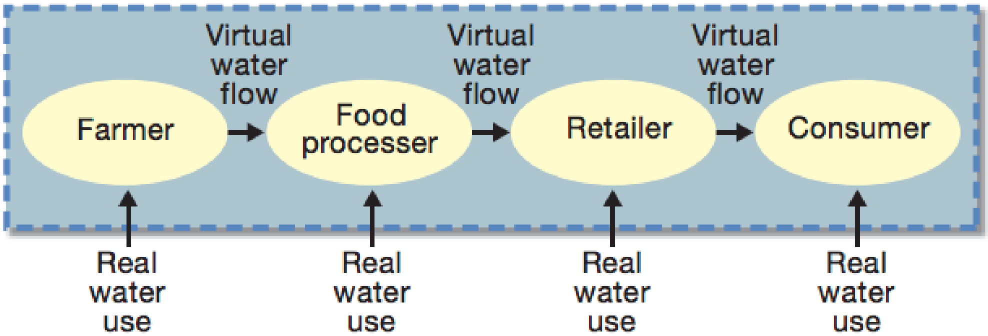

Figure 3.2. Virtual water chain (Hoekstra, 2011).

3.2.7. Dog or Cat Food

Boğaziçi University is also known for its cats and dogs. Buying cat and dog food also increases water footprint. For every $1 spend on cat or dog food, 760 liters of water is required to produce and transport it (WFC, 2018). By asking the animal dog shopping behaviors of the students, water use is calculated.

Table 3.19. Global average WF (l/kg) of food items (Hoekstra, 2011; Mekonnen *et al.*, 2015).

Food Item	**Unit**	**Global average WF(l/kg)**
Apple or Pear	1 kg	700
Banana	1 kg	860
Beef	1 kg	15500
Sheep and Goat meat	1 kg	8763
Bread (from wheat)	1 kg	1300
Cabbage	1 kg	200
Cereals	1 kg	1644
Cheese	1 kg	5000
Butter	1 kg	5553
Chicken	1 kg	3900
Chocolate	1 kg	24000
Cucumber	1 kg	240
Fruits	1 kg	962
Groundnuts (in shell)	1 kg	3100
Lettuce	1 kg	130
Maize	1 kg	900
Olives	1 kg	4400
Orange	1 kg	460
Peach or Nectarine	1 kg	1200
Potato	1 kg	250
Rice	1 kg	3400
Tomato	1 kg	180
Vegetables	1 kg	322
Beer (from barley)	1 glass of 250 ml	75
Milk	1 glass of 250 ml	250
Coffee	1 glass of 125 ml	140
Tea	1 cup of 250 ml	30
Wine	1 glass of 125 ml	120

4. STUDIES CARRIED OUT IN BOĞAZİÇİ UNIVERSITY

Sustaining and maintaining natural resources should start at university level due to their intellectual power and easy access to industries. Application of green campus initiatives in Boğaziçi University will make it a unique example for other universities, corporations, municipalities and ultimately cities. For this purpose, water footprint, rainwater harvesting, solid waste characterization, composting, solar energy, attendance system, zero-waste campus, disability-friendly campus and pet-friendly campus studies are carried out in Boğaziçi University. Adapting green campus initiatives and raising awareness of people in the campus will decrease carbon emission, energy and water use while conserving limited natural resources.

In addition to reducing carbon emission and water footprint, green campus initiatives create an economic benefit (Table 4.1). Rainwater harvesting will create an economic benefit of 195,995 TRY/year; recycling will create an economic benefit of 280,211 TRY/year; composting will create an economic benefit of 181,250 TRY/year; electricity generation from solar panels will create an economic benefit of 4.7 m TRY/year. Ultimately, 5.4 m TRY/year will be saved for the electricity, water and compost prices in year of 2018.

Table 4.1. Economic benefit of green campus initiatives in Boğaziçi University (2018).

Implementation	**Economic Benefit (TRY/year)**
Rainwater Harvesting	195,995.00
Recyclable Material	280,211.36
Compost	181,250.00
Solar Panel	4,732,800.00
Total	5,390,256.36

4.1. Water Footprint Study

Water Footprint Network developed a methodology in the name of the Water Footprint Assessment to quantify the water use. According to Hoekstra (2011), water footprint of world average is 3794 liter per capita per day (l/c.d.) whereas, water footprint of Boğaziçi University is 6082 liter per capita per day and water footprint of engineering students of Boğaziçi University is 6287 liter per capita per day; water footprint (WF) of Turkey is 4498 liter per capita per day (Figure 4.1). Figure 4.1 represents water footprints of nations in terms of liter per capita per day, and it is average water footprint between 1996 and 2005 (Hoekstra, 2011). However, WF of Boğaziçi University (BU) is calculated only in 2018. Numbers in parenthesis represent population.

4.1.1. Water Footprint of Students of Boğaziçi University

The Water Footprint Assessment Manual prepared by Hoekstra *et al.* (2011) is used for the calculation and measurement of water footprint of the students of Boğaziçi University. For the measurement part of the task, questions of the survey prepared by Hoekstra *et al.* (2011) are used in order to determine and pin point the water use behaviours of the students of Boğaziçi University.

The questionnaire consists of four parts:

(i) Education and Accommodation: 6 questions (Table 4.2)
(ii) Indoor Water Use: 14 questions (Table 4.3)
(iii) Outdoor Water Use: 9 questions (Table 4.4)
(iv) Virtual Water Use: 10 questions (Table 4.5)

The sampling method was random, survey is put into an online platform and students responded accordingly. According to Eq. 4.1 where Z is level of confidence according to the standard normal distribution, p is estimated proportion of the population that represents the characteristic, q is (1-p), and d is tolerated margin of error.

384 samples should be taken in order to be significant at a 95 % confidence interval.

$$n = \frac{Z^2 pq}{d^2} = \frac{1.96^2 \times 0.5 \times 0.5}{(0.05)^2} = 384 \quad (4.1)$$

The water footprint survey was answered by 394 students of Boğaziçi University in 2018/2019 academic year. In part (i) of the survey, there are questions about education level and accommodation preferences of the student (Table 4.2). Bachelor's, Master's and PhD students are 77 %, 17 %, and 6 % of total respondents, respectively. Also, 73 % of the students are staying off campus while 27 % of the students accommodate in dormitories. 35 % of the respondents are Civil Engineering students and 48 % of respondents is engineering students, in total.

In part (ii) of the survey, questions are about learning and measuring the indoor water footprint (Table 4.3). Average shower time, type of faucets in the house, cleaning behaviors of the respondents are asked.

In part (iii) of the survey, questions are related with the outside activities such as gardening, having a pool and a car and washing the car (Table 4.4).

In the last part (iv), questions are for measuring indirect water use. The distance that people drive every day increases their water footprint since the gasoline used by car consumes water when it was produced. Shopping, recycling and eating habits are also asked (Table 4.5).

29 % of total respondents are between 18-20 years old, 43 % of total respondents are between 21-23 years old, 19 % of total respondents are between 24-26 years old, and lastly 9 % of total respondents are 27 years old and above (Figure 4.2). Water footprints for those age periods are 6112 liter per capita per day, 5859 liter per capita per day, 6215 liter per capita per day and 6729 liter per capita per day, respectively.

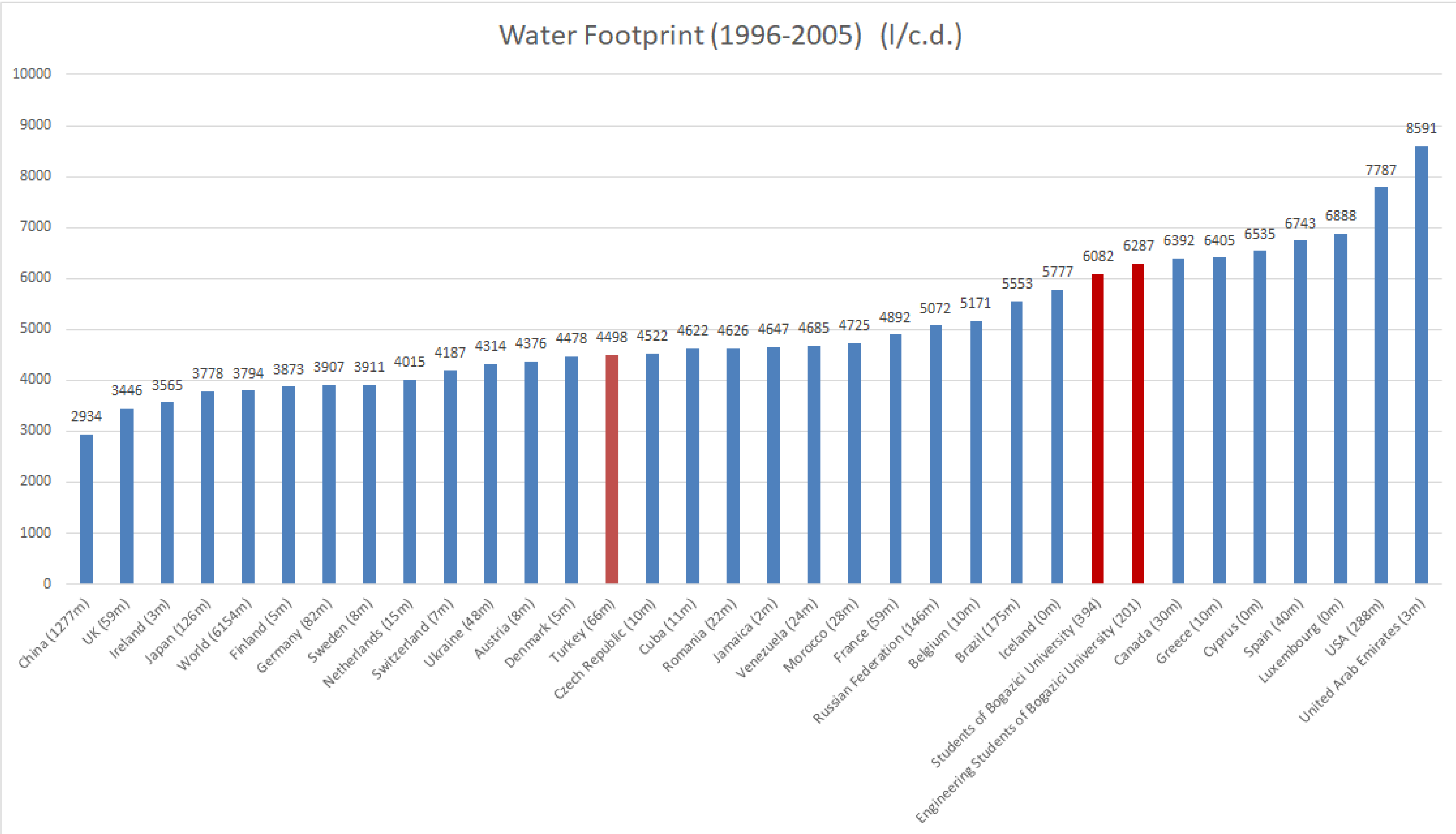

Figure 4.1. Comparison of WF of BU with global figures.

Table 4.2. The survey for measuring the water footprint - Education and accommodation part (WFC, 2018).

Education
Your Department
Your degree
Your grade
Age
Your Accommodation
How many people are in your household?

Table 4.3. The survey for measuring the water footprint - Indoor water use part (WFC, 2018).

Indoor Water Use
How long is the average shower in your household?
Do you have low-flow shower heads?
Do you take baths? If so, how often?
How long do you leave your bathroom faucets running each day?
(include brushing your teeth or shaving.)
Do your bathroom sinks have low-flow faucets?
Do you “let it mellow?”(not flushing every time you use toilet)
Do you have low-flow toilets?
How long do you leave the kitchen faucet running each day?
(include rinsing food and cleaning but not washing dishes)
Does your kitchen sink have a low-flow faucet?
How often do you wash your dishes?
How do you wash your dishes?
How often do you do laundry?
How do you laundry?
Do you have a grey-water system installed in your home?

Table 4.4. The survey for measuring the water footprint - Outdoor water use part (WFC, 2018).

Outdoor Water Use
Do you water a lawn or garden?
How much do you water lawn or garden? (area-wise)
Do you landscape with plants that require little or no water?
Do you have a rain barrel?
Do you have a swimming pool?
If yes, How many month out of the year do you keep it covered?
Do you have a car?
How often do you wash your car?
How do you wash your car?

Table 4.5. The survey for measuring the water footprint - Virtual water use part (WFC, 2018).

Virtual Water Use
How many kilometers do you drive per week?
Where does your electricity come from?
How much do you shop?
Do you recycle PAPER?
Do you recycle PLASTIC?
Do you recycle BOTTLES and CANS?
Do you donate or re-use old clothing, sheets, blankets and towels?
What is your diet?
How often do you eat meat?
How much money do you spend on dog and cat food each month? (TRY)

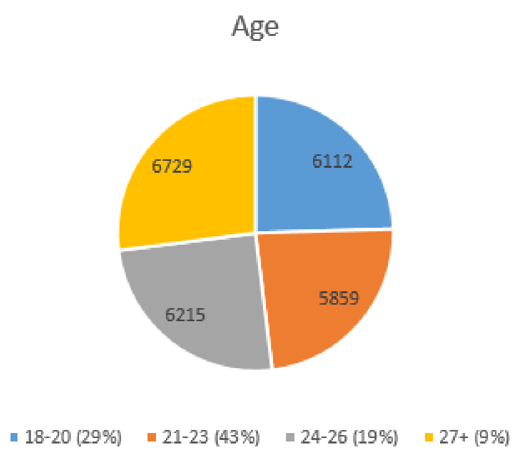

Figure 4.2. Water footprint (l/c.d.) according to age.

Water footprint of Bachelor's is 6023 liter per capita per day while PhD and Master's students are 6390 and 6247 liter per capita per day, respectively. Also, the respond rates of those students are 77 %, 6 % and 17 % as given in Figure 4.3, respectively where respond rate is equal to number of respondents divided by total number of students.

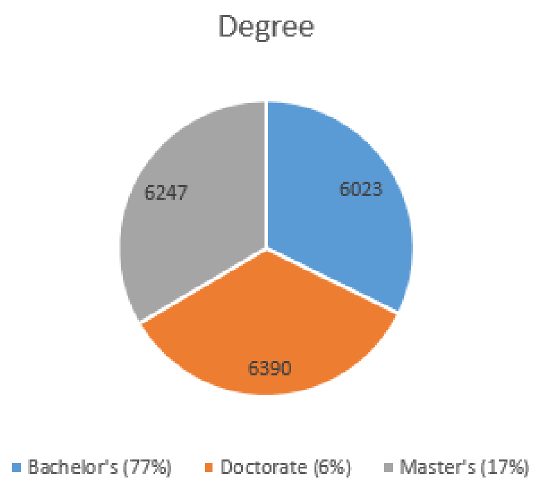

Figure 4.3. Water footprint (l/c.d.) according to degree.

Water footprint of those who stay at dormitory is 6100 liter per capita per day and those who stay at home is 6035 liter per capita per day. Students who stay at the dormitory are 27 % of total respondents, and students who stay at home are 73 % of total respondents as can be seen in Figure 4.4. As can be seen from Table 4.6, there are 3070 engineering students currently enrolled to Boğaziçi University for 2018/2019 academic year. 201 of those students responded the water footprint survey as can be seen from Table 4.7. The highest respond rate is among civil engineering students due to the personal access to those students.

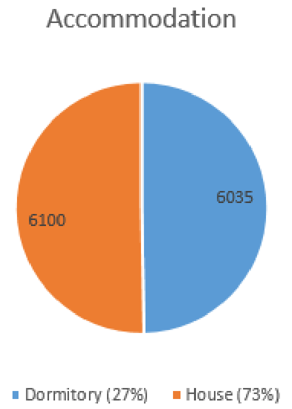

Figure 4.4. Water footprint (l/c.d.) according to accommodation.

Table 4.6. Number of engineering students in 2018/2019 academic year (Registrar Office, Personal Communication, November 2018).

Department	**Bachelor's**	**Master's**	**PhD**	**Total**
Computer Engineering	488	160	86	734
Electrical and Electronic Engineering	406	98	64	568
Industrial Engineering	376	87	38	501
Civil Engineering	309	106	57	472
Chemical Engineering	280	38	39	357
Mechanical Engineering	335	66	37	438
Total	2194	555	321	3070

From Figure 4.5, it can be seen that 7 Computer Engineering students, 8 Chemical Engineering students, 10 Electrical and Electronic Engineering students, 15 Mechanical Engineering students, 22 Industrial Engineering students and 139 Civil Engineering students responded to the water footprint survey. The water footprint of engineering students are 5795 liter per capita per day, 5247 liter per capita per day, 6118 liter per capita per day, 6357 liter per capita per day, 5535 liter per capita per day, and 6495 liter per capita per day, respectively.

Direct and indirect water footprint of students of Boğaziçi University are 446 liter per capita per day, 5636 liter per capita per day, respectively. Direct and indirect water footprint of Engineering students of Boğaziçi University are 438 liter per capita per day, 5850 liter per capita per day, respectively. Consequently, water footprint of students and Engineering students of Boğaziçi University is 6082 liter per capita per day and 6287 liter per capita per day, respectively.

Minimum total WF is 3494 liter per capita per day, minimum indirect WF is 3526 liter per capita per day and -32 liter per capita per day for direct WF. Direct WF is negative because that student has a grey-water system in home which can save 155 liters of water per capita per day since student lives alone. Maximum total WF is 21874 liter per capita per day since the student eats meat in all their meal and does not recycle. Maximum indirect WF is 17708 liter per capita per person, and maximum direct WF is 4166 liter per capita per day due to that student has a garden to water. Median levels of total, indirect and direct WF are 5566, 5199, and 379 liter per capita per day, respectively.

There are 33 students that have a water footprint of less than 4498 liter per capita per day which is the water footprint of Turkey. These students, generally, have regular recycling behavior, using energy and water efficient devices at home. The minimum water footprint is related to have grey water system installed at home, have rain barrel system, not to have swimming pool. However, there are 15 students that have a water footprint of more than 10000 liter per capita per day, which exceeds the world average of 3794 liter per capita per day. These students, in general, are eating meat in every meal, spending more than 200 TRY/month on cat or dog food, having an irregular recycling behavior, using conventional machines that do not help water and energy efficiency, taking bath every day, not having grey water or rain barrel system.

Water footprints are sorted from lowest to highest and plotted (Figure 4.6, Figure 4.7, Figure 4.8). Orange line represents data from which outliers are removed. For direct, indirect and total WF, R^2 values are greater than 95 % which is an indicator of the data is valid and accurate.

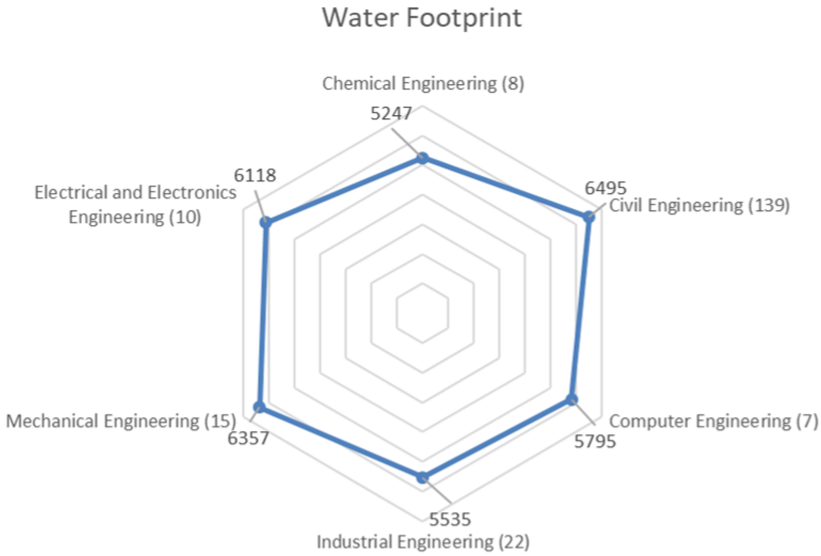

Figure 4.5. Radar graph representation of water footprint (l/c.d.) of engineering students.

4.1.2. Results

Average water footprints of each activity are shown in the Table 4.9 and Figure 4.11. In Figure 4.11, "WS" is the water saved due to xeriscaping, rain barrel, recycling, and donation. Also, "WF others" is the WF of activities that have WF of less than 50 l/c.d. such as washing dishes, laundry, swimming pool, car washing, gasoline, and electricity. Comparison of total WF can be seen from Figure 4.1, Boğaziçi University is compared with the countries and world average since there is no total water footprint analysis in the literature that covers both direct and indirect water use of students. Direct water footprint comparison is shown in Figure 4.9 where direct water footprint of universities marked with (*) are not as accurate as direct WF of Boğaziçi University. This is because of those universities only used domestic consumption in the buildings and irrigation in the universities with bottled water use (AUB, 2015).

Table 4.7. Number of engineering students who responded the survey.

Department	Bachelor's	Master's	PhD	Total
Chemical Engineering	8	0	0	8
Civil Engineering	86	37	16	139
Computer Engineering	4	3	0	7
Electrical and Electronic Engineering	9	0	1	10
Industrial Engineering	21	1	0	22
Mechanical Engineering	14	1	0	15
Total	142	42	17	201

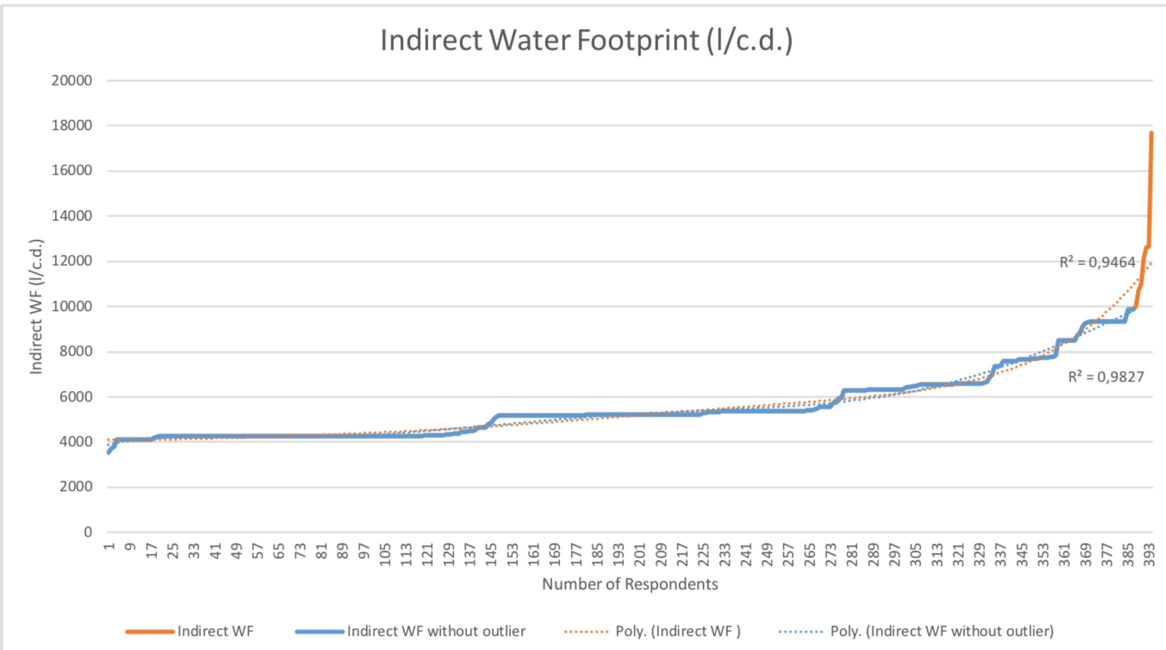

Figure 4.6. Indirect water footprint (l/c.d.) of students of Boğaziçi University.

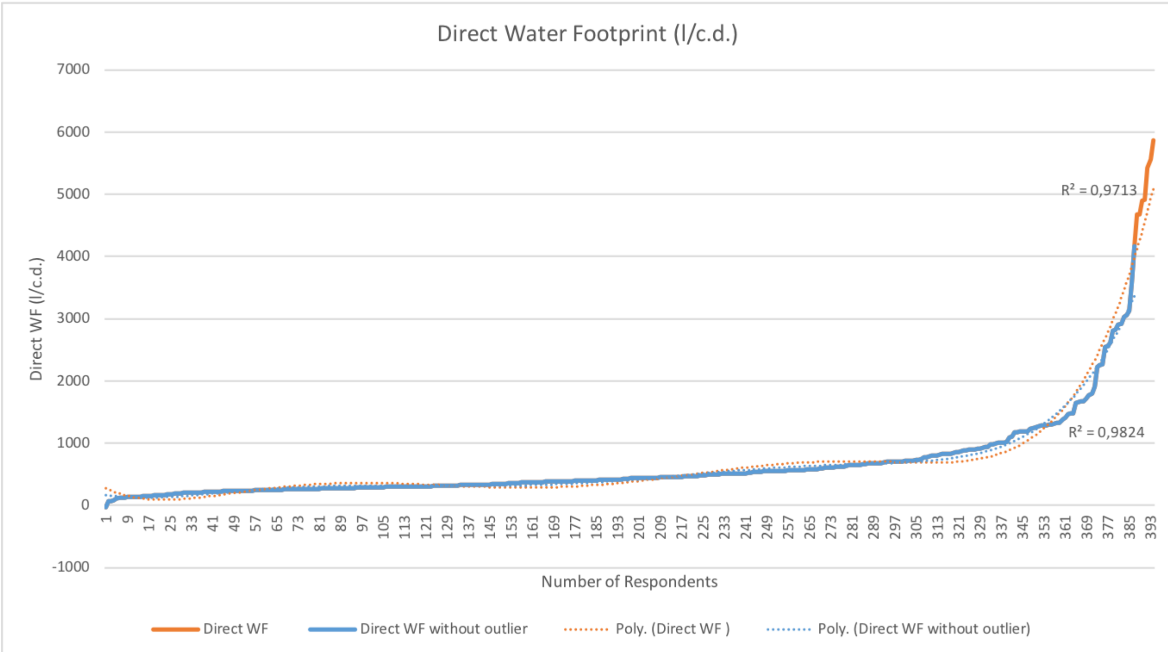

Figure 4.7. Direct water footprint (l/c.d.) of students of Boğaziçi University.

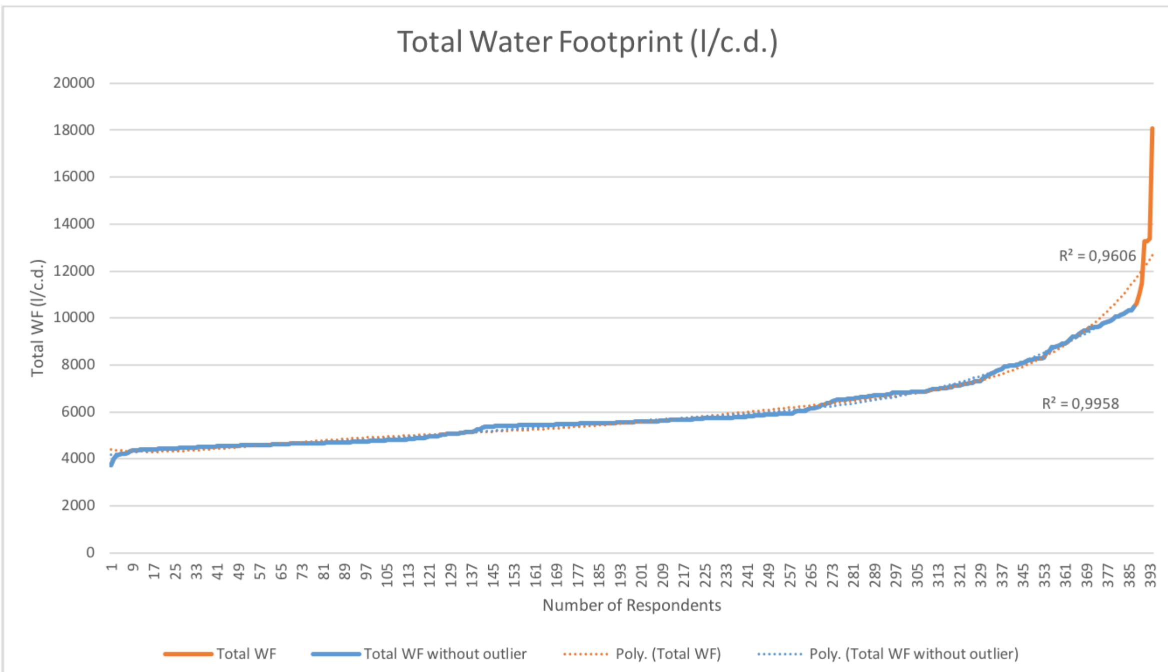

Figure 4.8. Water footprint (l/c.d.) of students of Boğaziçi University.

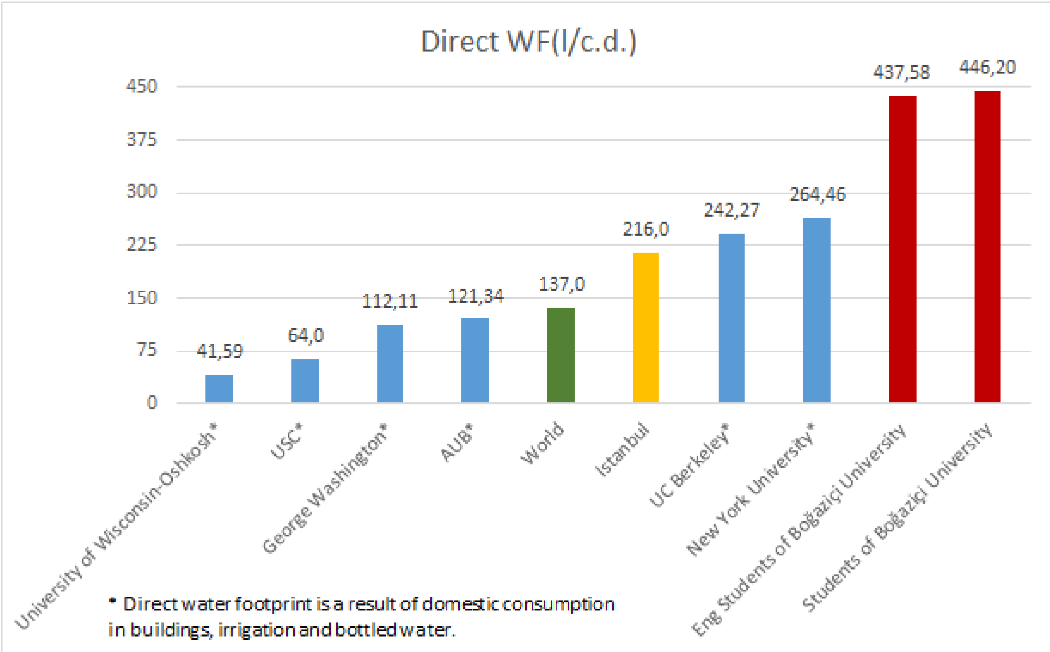

Figure 4.9. Direct water footprint comparison.

Linear regression is performed in IBM SPSS Statistics Data Editor 25. According to importance predictor, meat consumption nearly determines total WF since it has a importance of 56 % on total WF. Also, shopping and cat or dog food spending have importance of 26 % and 14 % on the total WF, respectively (Figure 4.10). Predictor importance test basically shows how much each content affects total water footprint in percentages. Moreover, t-test is performed in order to determine the significance of the model. Model is significant (Sig.= 0) with a 95 % confidence interval and 393 degrees of freedom (df). Also, lower confidence interval is 5907.89 liter per capita per day while upper is 6257.

Table 4.8. t-test for water footprint of students of Boğaziçi University.

				95% Confidence Interval of the Difference		
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Total	68.285	393	0.000	6082.00	5906.89	6257.11

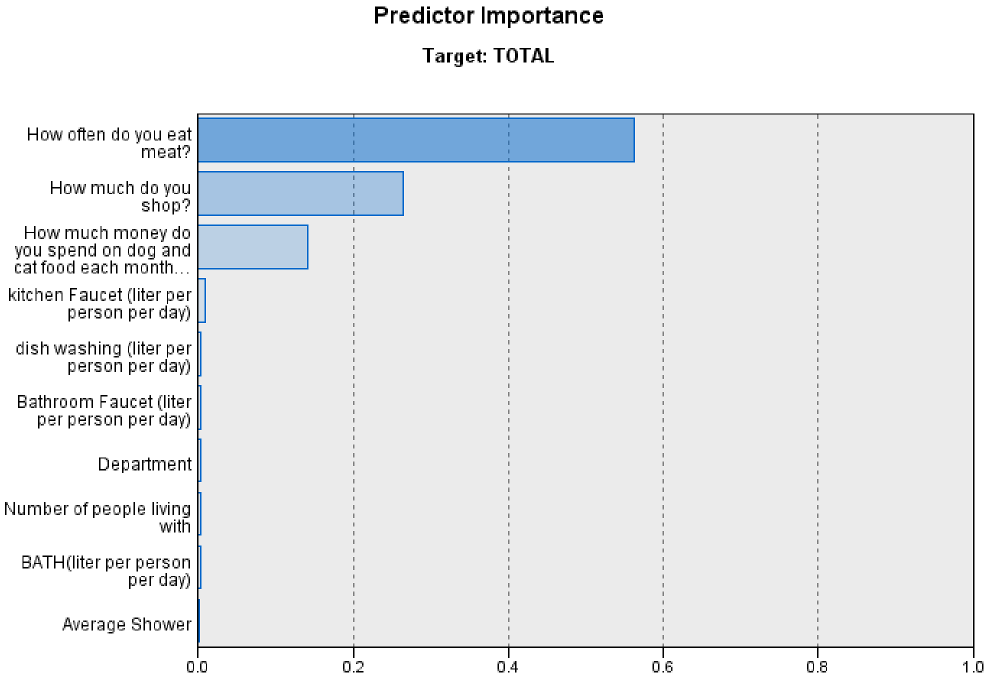

Figure 4.10. Predictors of total water footprint.

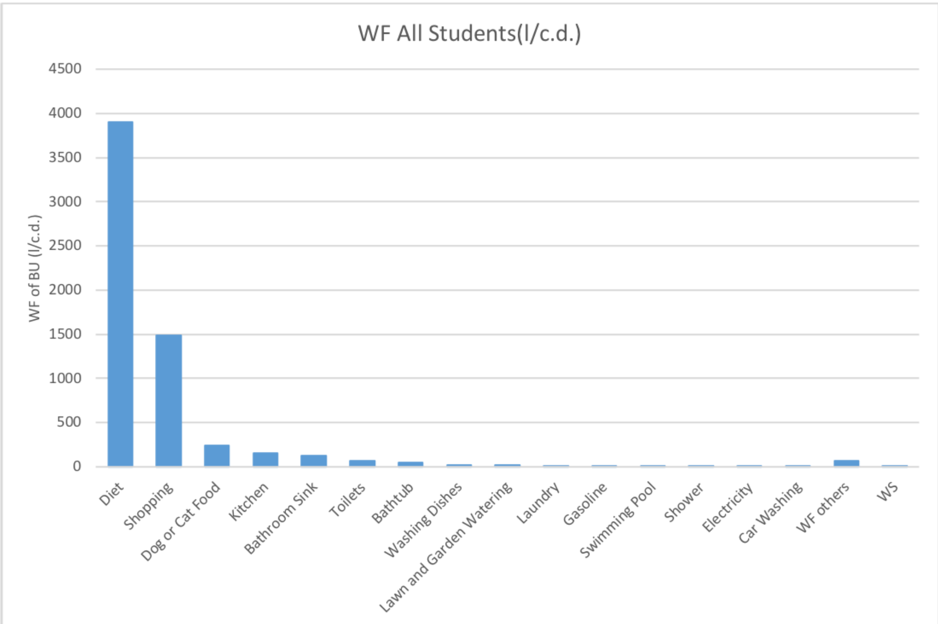

Figure 4.11. WF (l/c.d.) results of students of Boğaziçi University.

Table 4.9. WF results for students of Boğaziçi University and engineering students.

Type	**WF All Students (l/c.d.)**	**WF Engineering Students (l/c.d.)**
Indoor Direct Use		
Shower	2.92	2.69
Bathtub	50.7	53.45
Bathroom Sink	125.26	118.75
Toilets	64.84	65.77
Kitchen	154.38	156.6
Washing Dishes	21.5	20.07
Laundry	11.51	10.73
Grey Water*	6.20	6.04
Outdoor Direct Use		
Lawn and Garden Watering	14.81	7.83
Xeriscaping*	0.99	1.63
Rain Barrel*	0.45	0.35
Swimming Pool	6.46	7.82
Car Washing	1.44	1.93
Virtual Water Use		
Gasoline	6.94	8.13
Electricity	1.8	1.82
Shopping	1489	1448
Recycling Paper*	0.52	0.52
Recycling Plastic*	1.33	1.35
Recycling Cans and Bottles*	0.33	0.32
Donating Textile*	0.056	0.05
Diet	3901	4168
Dog or Cat Food	240	226
Total	6082	6287
(*) represents saved water because of the activity.		

The highest proportion of WF of students of Boğaziçi University is due to their eating preferences. As can be seen in Figure 4.12, 394 students responded to survey of which 3 students are vegan; 32 students are vegetarian; 180 students eat meat not every day, 120 students eat meat once a day; 40 students eat meat twice a day, and 19 students eat meat in every meal of day. WF of diet of Boğaziçi University is 3901 liter per capita per day while that of United States is 5280 liter per capita per day.

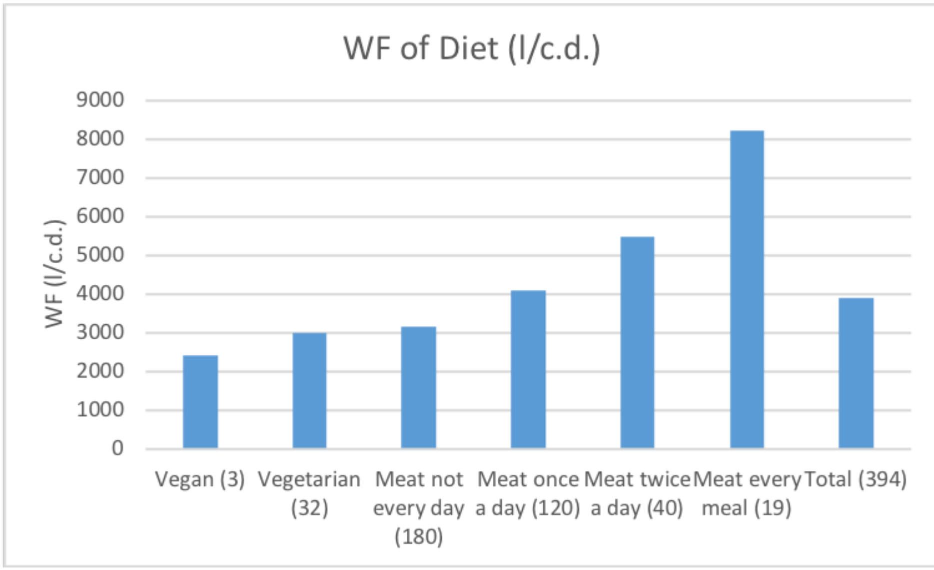

Figure 4.12. WF (l/c.d.) of diet of students of Boğaziçi University.

The second highest proportion of WF of students of Boğaziçi University is due to their shopping preferences. As can be seen in Figure 4.13, 394 students responded to survey of which 292 students shops for basics meaning that they only shop when they need something; 84 students like to shop; 18 students shop whenever they are ready to shop. WF of shopping of Boğaziçi University is 1489 liter per capita per day while WF of shopping in United States is 2206 liter per capita per day.

The third highest proportion of WF of students of Boğaziçi University is due to cat and dog food consumption. WF of cat and dog food of Boğaziçi University is 240 liter per capita per day while that of United States is 140 liters per capita per person.

Figure 4.13. WF (l/c.d.) of shopping of students of Boğaziçi University.

4.1.3. Reducing Water Footprint

Not only students of Boğaziçi University but most of the people seem to not understand and underestimate the importance of water. Unnecessary and extreme use of water will cause water shortage in near future. Water is the source of most of the things that people consume and use every day such as food, clothing, gasoline for car, construction for homes. In order to reduce water footprint:

- While conducting the survey, it was seen that most of the students does not know the meaning of water footprint. Personal water footprints and meaning of it should be taught and self-awareness environment should be constructed.
- On average, respondents leave water running for 9.5 minutes in the bathroom sink, and for 11.6 minutes in the kitchen sink. Water should be turned off while shampooing, shaving, brushing teeth and cleansing dishes. In this way, wasting of water will be minimized.
- Use of less water while gardening, and cover their pools when not using should be tried.
- On average, only 10 % of respondents recycle every recyclable material. Habit of recycling and not wasting, going zero-waste should be gained.

- 30 % of the respondents use energy and water efficient devices. Use of energy and water efficient (low-flow) devices should be increased.
- 3 % of respondents have plant at their homes. Plants decrease evapotranspiration, less water consuming plants should be planted.
- Water footprint of eating habits of students of Boğaziçi University is 3901 liter per capita per day; 4 % of respondents eat meat in every meal and 46 % of respondents eat meat in more than one meal. Changing eating habits into less water consuming options such as eating less meat, and drinking less coffee or switching coffee with tea will decrease water footprint.
- 6 % of respondents have grey water system installed at home. Grey water systems should be installed and used in order to reduce water footprint.
- Toilet is not a waste bin; waste should be thrown away in waste bins.
- 5 % of respondents have rain barrel system installed. In order to save water and decrease water footprint rain barrel use should be increased.
- 25 % of respondents have a car. Car sharing will allow students who use the same route to travel together.
- Bicycle use should be increased.
- 74 % of respondents shop for basics. If possible, buying unnecessary products should be minimized, in this way wasting can be minimized.

4.1.3.1. Drinking Fountain Installation. It is crucial to decrease plastic use in order to decrease water footprint and save water for the next generations. According to Hoekstra (2011), in order to produce one plastic bottle, 5.3 liters of water is used. Considering human needs to drink 2 to 2.5 liters of water per day, it will create a 21.2 liters per capita of water footprint, and 2 liters per capita of direct water footprint. Since, there are 18,664 people in Boğaziçi University in 2017, this number will add up to 395,677 liters of water per day. Also, 0.5 liter-plastic-bottle has a total carbon footprint of 82.8 grams (Gleick, 2009), for Boğaziçi University 6182 tons of carbon footprint occurs per day.

University of Central California, University of Edinburgh, Glasgow Caledoian University, University of London, University of Technology Sydney, Czech Technical University are some examples of the universities that use drinking fountains and water stations. Currently, only in dining halls and Washburn Hall in Boğaziçi University have this system. Implementing “drinking fountain” or/and “water stations” in the buildings and common places of Boğaziçi University rather than plastic water will create environmental benefits in terms of water footprint by 395 m^3 per day, and carbon footprint by 6,182 tons per day (Figure 4.14).

Figure 4.14. Water station (on the left) and drinking fountain (on the right) in University of Central California (UCF, 2012).

4.2. Rainwater Harvesting Study

Water is used for everything starting from food production to industry. Increasing population requires water supply and food supply, industrialization, may be luxurious products. This increasing demand for water will create water shortages, soon. The water supply in the world is constant and limited. Since water may not be created from nothing, the resources available should be preserved. Water use should be efficient and water resources should be sustained for a better and sufficient future for us and for next generations.

In order to provide sufficient water to those are in need of water, rainwater harvesting method can be used. Maintaining efficient water use in the sustainable environments is crucial, besides rainwater harvesting is one of the basic requirements of US Green Building Council. By providing a sufficient use and supply of water, waste of water can be minimized. Karahan (2009) states that rainwater can be the source of water used in gardening, toilet reservoirs and cleaning at 50 %. According to Meteorology General Directorate of Meteorology, average yearly rainfall in Istanbul is 817.4 mm (Table 4.10), using these rainfall as a resource of water. Therefore, using rainwater harvesting system will help to save and preserve water.

Kilyos Campus has "Rainwater Cistern" that catches rainwater on the surface. Pebbles on the surface acts like a treatment system and collected water is carried to groundwater collection system that has its own treatment system by drainage pipes. In winter seasons, on average, 30 m^3/day of water is collected through the system and used as drinking water in the buildings of Kilyos Campus. However, system is not used temporarily due to need of special treatment (Emre Otay, Personal Communication, December 2018).

Table 4.10. Monthly average rainy days and monthly average amount of rain (mm) in Istanbul between 1929 and 2017 (MGM, 2018).

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Yearly**
Avg # of Rainy Days	17.3	15.2	13.8	10.3	8	6.2	4.3	5	7.6	11.2	13	17.1	129
Monthly Avg. Rain(mm)	106	77.7	71.4	45.9	34.4	36	33.3	39.9	61.7	88	100.9	122.2	817.4

Rainwater harvesting is simply collected rainfall that flows on to the slope of the roof. Collected rainwater is stored in storage tanks in the building or under the ground (Figure 4.15). Hydraulic losses of the system is generally too low not to be neglected (Kantaroğlu, 2009).

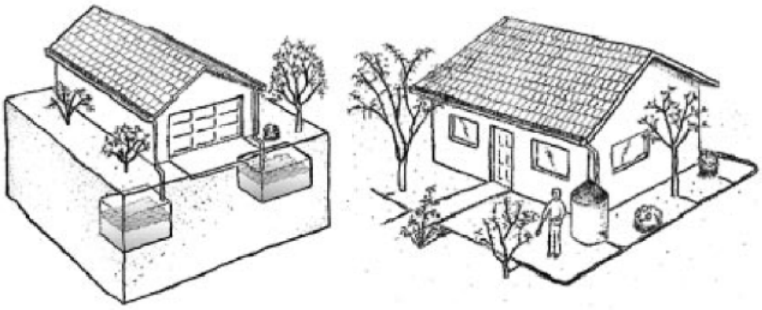

Figure 4.15. Rainwater harvesting systems (Kantaroğlu, 2009).

According to Karakaya and Gönenç (2005), advantages of rainwater harvesting system as follows:

- Rainwater harvesting system can be integrated to water distribution system.
- Supply of water is free.
- System decreases flood risks and pollution load in the sewer system.
- Water can be used without treatment since the supply of water is relatively less polluted than the other water supply methods.

Figure 4.16. Rainwater harvesting systems in Albert Long Hall.

According to Karakaya and Gönenç (2005), main disadvantages of rainwater harvesting system are uncertainty in rainfall decreases the reliability of the system and storage tanks consume too much place. Figure 4.16 shows a proposed rainwater harvesting system at Albert Long Hall, where red lines represent pipes that collect water and carry to main storage, and yellow lines represent pipes that distributes collected and filtered rainwater into the building.

4.2.1. Quality of Rainwater Harvested

Rainwater is generally low polluted. However, in a city like Istanbul where there is a high traffic rate, several industries and use of coal while heating, the rainwater is highly prone to be polluted by particles, and organic pollutants. Furthermore, rainwater catchment areas may be source of pollutants such as heavy metals and organic substances. Aluminum sheets, tiles and slates are examples of catchment surfaces where rainwater may prone to be low polluted whereas zinc, copper and bamboo roofs are prone to be highly polluted (Gould, 1992; Yaziz *et al.*, 1989; Helmreich, 2009). However, according to Tanık (2017), rainwater can be used in laundry since it was not seen any bacteriological difference between laundry washed by rainwater and drinking water.

4.2.2. Treatment of Rainwater Harvested

According to Helmreich (2009), harvested rainwater quality is appropriate according to WHO standards for drinking water. Since chlorine may react with the organic matter and create unwanted by-products in the collection tank, chlorination should be performed after the tank. Chlorine should be around 0.4-0.5 mg/L and can be applied by chlorine tablets or chlorine gas (Helmreich, 2009). Moreover, sand filtration and pasteurization by solar technology are also among the cheapest disinfection technologies (Khaengraeng, 2005).

4.2.3. Rainwater Harvesting in Boğaziçi University

Boğaziçi University has 6 campuses around Istanbul including South, North, Hisar, Kandilli, Uçaksavar and Kilyos Campus (Figure 4.17, Figure 4.18, Figure 4.19, Figure 4.20, Figure 4.21, Figure 4.22). In order not to allow miscounting, building lists are obtained from Construction Works Department of Boğaziçi University (Yapı İşleri). Buildings with proper and enough roof areas are spotted and by using Google Earth Pro version 7.3.2, roof areas are measured and calculated. There are 53, 18, 7, 32, 11, 7 proper roof that will allow rainwater harvesting installation in South, North, Hisar, Kandilli, Uçaksavar and Kilyos Campus, respectively (Table 4.11).

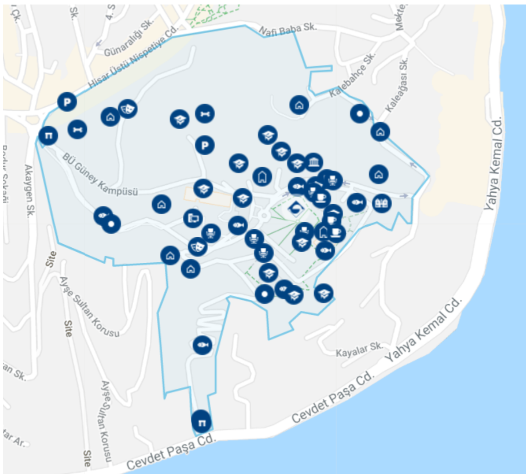

Figure 4.17. Buildings in South Campus.

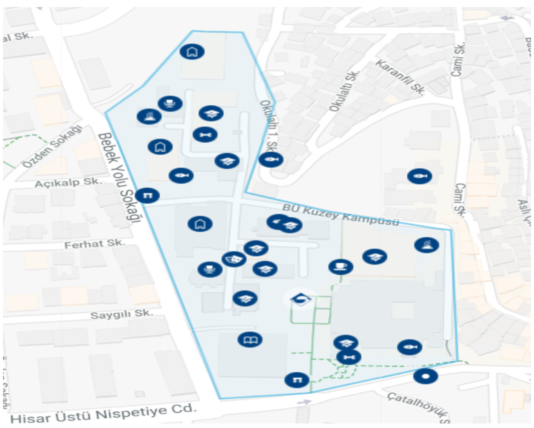

Figure 4.18. Buildings in North Campus.

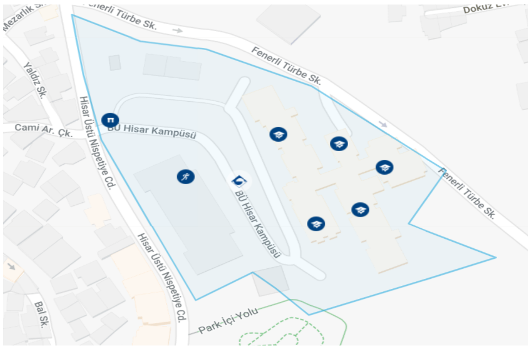

Figure 4.19. Buildings in Hisar Campus.

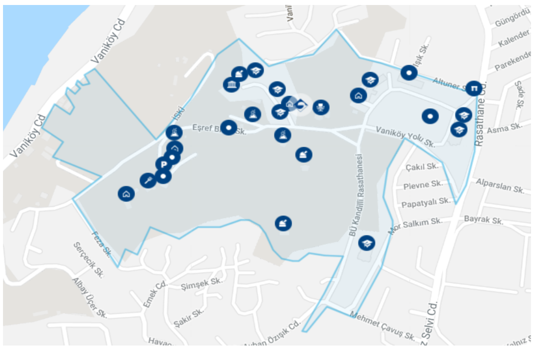

Figure 4.20. Buildings in Kandilli Campus.

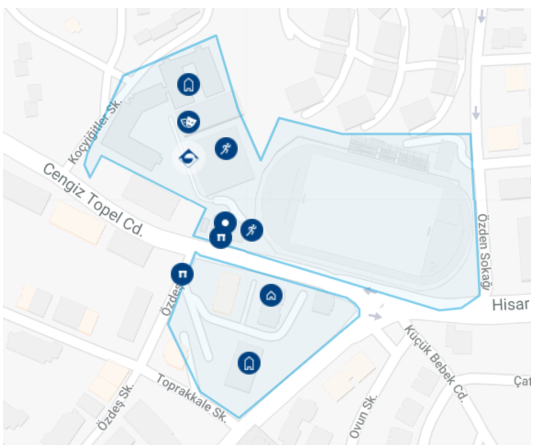

Figure 4.21. Buildings in Uçaksavar Campus.

Figure 4.22. Buildings in Kilyos Campus.

Table 4.11. Number of buildings and total area of roofs, Boğaziçi University.

Campus	**# of roofs**	**Area of roofs (m^2)**
South	53	18511.5
North	18	18399.29
Hisar	7	5269.66
Kandilli	32	11561.82
Uçaksavar	11	8361.93
Kilyos	7	9606.82
Total	128	71711.02

$$E_R = A_A \times e \times h_N \times \eta \tag{4.2}$$

$$Saving(TRY) = 4.30(TRY/m^3) \times 1.08 \times Rainwaterharvested(m^3) \tag{4.3}$$

According to German Institute for Standardization - DIN 1989 for Rainwater harvesting systems, for calculating the rainwater harvesting capacity of Boğaziçi University, the annual rainwater amount that can theoretically be stored is to be calculated according to Equation 4.2 where: E_R is the rainwater yield in liters per year (l/a), A_A is the collecting area in square meters (m^2), e is the yield coefficient in %, h_N is the quantity of precipitation in liters per square meter (l/m^2) or millimeters (mm), η is the hydraulic filter efficiency. Since all of the roofs in Boğaziçi University either slanted hard roof or flat roof without gravel, the yield coefficient (% e) is taken as 0.8 for both cases (DIN 1989) and η is taken as 0.9.

Table 4.12. Rainwater harvesting capacity of Boğaziçi University.

Campus	**Rainwater Harvested per year (m^3)**	**Rainwater Harvested per day (m^3)**	**Rainwater Harvested per rainy day (m^3)**
South	10894.54	29.85	84.45
North	10828.50	29.67	83.94
Hisar	3101.34	8.50	24.04
Kandilli	6804.45	18.64	52.75
Uçaksavar	4921.23	13.48	38.15
Kilyos	5653.88	15.49	43.83
Total	42203.94	115.63	327.16

There are 128 buildings in total that can be used for rainwater harvesting. The total roof area of those buildings is 71711 m^2 (Table 4.11). Also, there are 129 rainy days on average from 1929 to 2017 in Istanbul, and average yearly rain in total is 817.4 (mm). By using Equation 4.2, rainwater harvested theoretically in Boğaziçi University is calculated as 42204 m^3 per year, and 116 m^3 per day. If only rainy days are taken in to account, rainwater harvested theoretically on rainy days in Boğaziçi University is 327 m^3 per rainy day.

Water price is 4.30 TRY/m^3 before tax, and tax is 8% (ISKI, 2018). If rainwater system is installed to all the roofs specified, the savings will be 195995 TRY per year, and 537 TRY per month. Water bills paid by Boğaziçi University is on average 100,000 TRY for South and Hisar, 100,000 TRY for North and Uçaksavar, 40,000 TRY for Kilyos and 10000 TRY for Kandilli per month (Accounting and Realization Department, Personal Communication, November 2018). Total water bill is 250,000 TRY per month, which is 3 million TRY per year. If the system is implemented, 8 % of savings per year from water bills will be possible.

Initial cost of the system can be seen in Table 4.13. Underground tanks with 10000 gallons capacity are placed in South and North Campuses, with 5000 gallons capacity are placed in Kandilli, Uçaksavar, and Kilyos Campuses, and 2000 gallons capacity is placed in Hisar Campus. Initial cost consisting of installation and maintenance of pumping systems, water tanks, pipe installation, excavation for installing water tanks, first flush filters and valves cost 116520 USD (Hicks, 2008). Payback period is 4 years (1 USD = 5 TRY).

4.3. Solid Waste Study

Increased population also causes the increasing amount of waste generation. Among all waste types, plastic waste has an importance since plastic is lightweight, easy and cheap to produce, producers use it everywhere and every year produced plastic amount increases. Plastic wastes mostly end up in oceans besides resiliency of plastic does not allow easy breakdown. Plastic decomposes in 10-1000 years whereas plastic

Table 4.13. Cost of Rainwater Harvesting System.

Item	**Quantity**	**Unit Cost ($)**	**Total Cost ($)**
First Flush Filter	6	120.00	720.00
Underground Tank (10000 gallons)	2	24000.00	48000.00
Underground Tank (5000 gallons)	3	12000.00	36000.00
Underground Tank (2000 gallons)	1	5000.00	5000.00
Pump	6	3500.00	21000.00
Floating Intake	6	300.00	1800.00
Excavation			4000.00
Total			116520.00

bottles decompose in 500 years. Plastic was invented in 1907 (ACS, 1993), during World War II mass production of plastic has started (Thompson *et al.*, 2009). After mass production of plastic started, it has just produced, sometimes recycled but mostly sent to landfill areas.

In order to leave a better world with sufficient resources to next generations, one must know and care for sustainable development of the resources. The hardest part in sustainable development is waste management systems and integrating it well with to the existing waste management systems. In order to integrate waste management systems, one must know the characterization of the waste. After characterization of the waste, possible scenarios for management can be produced. According to waste management hierarchy (EPA, 2018):

(i) Source reduction and reuse of the waste: It is the most important and most preferred part of the waste management. Since waste prevention do not take time and money, it is namely educating people about not spending resources available without thinking the consequences. Instead of consuming too many plastic, paper, organic materials, people should learn to be more careful about environment and use less. The less here means to consume just enough for covering their needs without restraining their life. Example of this are reusing and donating, using packaged products less.

(ii) Recycling and Composting: Recycling is easy to apply but expensive due to transportation, grinding, and worker costs. In the long run, it will grant great benefits. It is simply making reuse of recyclable materials. In order to recycle, first a work force should sort the recyclable materials, educating people about sorting at home will ease the work load. After sorting process, materials are shredded and turn into raw materials ready to be re-manufactured. Benefits of recycling are energy saving, decreasing carbon and greenhouse gas emissions, reducing water pollutants, reducing the waste thrown away in landfill.

(iii) Energy Recovery: It is conversion of non-recyclable waste materials into usable heat, electricity or fuel through a variety of processes.

(iv) Treatment and Disposal: Treatment is the process of decreasing the amount of pollutants in the waste. Treated waste is sent to water resources if the pollution rate is within the requirements. Waste also is disposed to landfill areas. After storing in the landfill, methane gas accumulates and later electricity is produced from accumulated methane gas.

Figure 4.23. Waste management hierarchy (EPA, 2018).

In this research, characteristics of waste in Boğaziçi University Engineering Building (Perkins Hall) are studied. Also, wastes in Dining Halls in the form of raw material, and in the form of leftover food from students who do not finish their meals, are studied. Furthermore, hazardous wastes from Chemistry and Chemical Engineering, Physics, Molecular Biology and Genetics, Biomedical, and Environmental Sciences departments are studied. Also, economic benefits of recyclable materials, and composting from raw materials from canteens, restaurants and dining halls are determined.

4.3.1. Solid Waste Characterization in Boğaziçi University

Waste characterization is conducted in Engineering Faculty of Boğaziçi University. The characterization process lasted for 4 weeks. For each week, for one day, selected waste bins are observed, composition and their amounts are noted for one day. 90, 92, 82 and 92 kg of waste are generated on those 4 weeks, respectively. Generally, paper waste is 50 %, toilet paper is 15 %, plastic bottle is 20 %, bottle is 10 % and organic waste (package and fruit skin) is 5 % of total waste generated.

Civil, Mechanical and Industrial Engineering Departments are placed in Perkins Hall. Whereas, Chemical, Computer and Electrical and Electronic Engineering Departments are placed in North Campus. As it was seen in the water footprint survey, recycling behavior of these students are approximately the same. So, in order to find the waste characterization of engineering students, the results are adjusted to total number of engineering students. There are 1659 students in Chemical, Computer and Electrical and Electronic Engineering Departments and 1411 students in Civil, Mechanical and Industrial Engineering Departments; 3070 students in total.

Total waste generated in waste bins per day is 196.07 kg for 3070 engineering students. Total waste generated (Dining hall, recyclable and waste bin) per day per engineering student is 0.12 kg, 0.013 kg, 0.077 kg respectively and in total, 0.21 kg per day per student. In Turkey, average waste per person per day is 1.17 kg (Kor *et al.*, 2006).

In the Perkins Hall, there are also recycling waste bins in every floor. Every week, 5 garbage bags of paper are sent to recycling center, which is approximately 90 kg per week. Assuming other 3 engineering departments have the same recycling behavior as seen in water footprint survey, total amount of paper that is sent to recycling center is calculated as 196 kg per week, namely 39.2 kg per day. Most of the engineering students recycle everything or some as can be seen in Table 4.16, only approximately 11 % of engineering students recycle nothing.

Table 4.14. Perkins Hall waste measurement (kg/day) results.

Waste Type (kg/day)	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Average**
Paper (tea, coffee cup and paper)	45.00	47.00	43.00	49.00	46.00
Toilet Paper	15.00	18.00	17.00	14.00	16.00
Plastic bottle	16.00	14.00	13.00	15.00	14.50
Bottle	10.00	9.00	11.00	9.00	9.75
Package and Fruit skin	4.00	4.00	3.00	5.00	4.00
Total	90.00	92.00	87.00	92.00	90.25

Table 4.15. Waste characterization of waste bins used by engineering students per day.

Waste Type (kg/day)	**CE+ME+IE**	**ChE+EE+CMPE**	**Total**
Paper (tea, coffee cup and paper)	46.00	54.09	100.09
Toilet Paper	16.00	18.81	34.81
Plastic bottle	14.50	17.05	31.55
Bottle	9.75	11.46	21.21
Organic	4.00	4.70	8.70
Total	90.25	106.11	196.36

Waste characterization of waste bins used by engineering students is shown in Table 4.15, engineering students generate approximately 196 kg of waste per day. Also, they are not used to use recycle bins (RB) for recyclable materials. So, 81 % of recyclable materials such as paper, bottle, and plastic bottle are thrown away in waste bins (WB) which is 161 kg per day. Furthermore, 46091 kg of recyclable material are thrown away in waste bins per year by engineering students.

Table 4.16. Recycling behavior of engineering students.

Recycling	Paper	Plastic	Bottle and Can
Yes	15%	26%	27%
Some	73%	63%	58%
No	11%	11%	14%

4.3.2. Economic Value of Recyclable Materials

There is an economic value of recyclable materials which is if university does not give away its recyclable wastes, and sells it to recycle collectors. Normally, in Boğaziçi University, recyclable materials are collected by Beşiktaş and Sarıyer Municipality once a week, without paying.

There are five weekdays and two days on weekend. The capacity in weekdays are approximately full, but on weekends it is usually the half. So, one week is calculated as six days and one year is calculated as 40 weeks due to the breaks throughout year.

Paper thrown away to RB is 39.2 kg per day, whereas paper thrown away to WB is 100.09 kg per day, bottle 21 kg per day and plastic bottle is 31.55 kg per day. Besides, 9408 kg/year, 24020 kg per year, 5091 kg per year, 7571 kg per year of waste is generated by engineering students, respectively (Table 4.17). Price of paper is 0.6 TRY/kg on average, since separation at the source are not performed, it is an average value. Price of plastic is 1.3 TRY/kg and price of bottle is 0.2 TRY/kg (Hurda, 2018). Multiplying amount of recyclable waste with price of recyclable waste will result in the economic benefit of recyclable waste. If Boğaziçi University sells its recyclable materials to recycling centers, the economic benefit will be 30918 TRY per year for only engineering students.

Table 4.17. Amount of recyclable material of engineering students.

Recyclable Material	**Amount (kg/day)**	**Amount (kg/year)**
Paper (Recycle bin)	39.20	9408.00
Bottle	21.21	5091.28
Paper(Waste bin)	100.09	24020.41
Plastic Bottle	31.55	7571.65
Total	192.05	46091.35

According to Sayılarla Boğaziçi (2018), there are 17337 students both graduate and undergraduate and 1327 personnel, 18664 members in total. If the economic benefit of recycling for 3070 students is 30,918 TRY, the economic benefit for whole Boğaziçi University with its personnel and students will be 280,211 TRY per year.

Table 4.18. Price of recyclable materials and economic benefit analysis.

Recyclable Material	**Price (TRY/kg)**	**Amount (kg/year)**	**Economic Benefit Eng Students (TRY/year)**	**Economic Benefit Boğaziçi Member (TRY/year)**
Plastic	1.3	7571.65	9843.15	46,031.69
Paper	0.6	33,428.41	20,057.05	203,227.32
Bottle	0.2	5091.28	1,018.26	30,952.35
Total		46,091.35	30,918.45	280,211.36

4.3.3. Recycling - BuCard Implementation in Boğaziçi University

As can be seen in Table 4.16, the recycle habits of students of Boğaziçi University are quite primitive. On average, only 22 % of students recycle everything, 66 % recycle some and 12 % of students recycle nothing. According to Struck (2017) and Maki *et al.* (2016), when given incentives to recycle, people tend to collect and bring their recyclable waste to the recyclable waste container (reverse vending machine) (Figure

4.24). These incentives may be just a praise such as announcing who recycled the most for a specific time interval, or loading small amount of money on BuCard.

Columbia University, University of California, Harvard University, Purdue University, Brown University, Georgia Institute of Technology, and University of Barcelona, University of Glasgow have incentive programs for recycling. They mostly pay 10 cents per bottle. Also, Istanbul Municipality (IBB) initiated recycling incentives under the Zero-Waste movement. supplying smart card money that can be used in public transportation when recycling some amount of recyclable material. 1 plastic bottle is equal to 10 grams when it is recycled in automates, 0.02 TRY can be earned. Furthermore, recycling 50 or more plastic bottles will result in earning theatre tickets from Municipality Theatres (IBB, 2018).

Figure 4.24. Representation of reverse vending machines (Tomra, 2018).

In this research, it is proposed to give incentives to students and members of Boğaziçi University who collect recyclable materials, store and bring university recycling machines (Figure 4.25). These incentives may be in the form of money per 1 kg recyclable material recycled. Also, there should be posters and educative materials about recycling, where to recycle what and how. The person who recycles the most should be announced publicly.

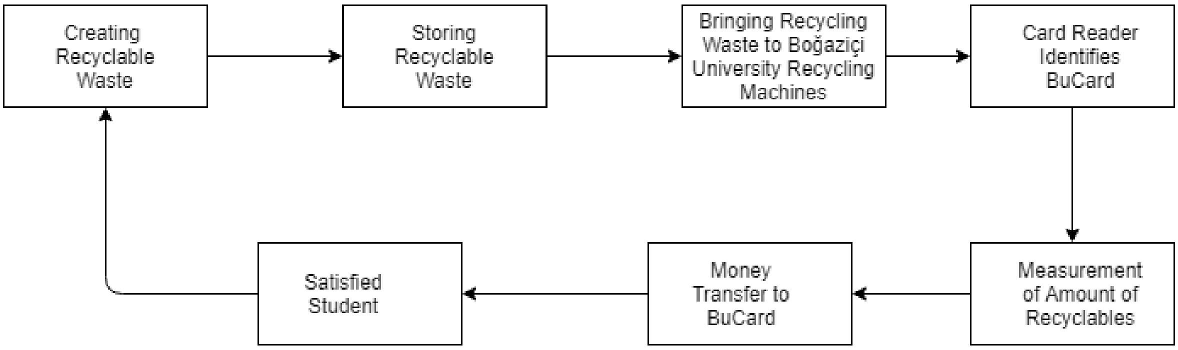

Figure 4.25. BuCard and recycling flow diagram.

4.3.4. Recycling - Precious Plastic in Boğaziçi University

A global community that connects people who want to reduce the plastic waste in the world together. What it does is simply connect hand-workers, technicians, craftsperson together and create meaningful objects or shred the plastic into pieces and then sell. They first collect the plastic wastes, then simply sort plastic according to their color. The sorted plastic waste goes to shredder and shredded plastic materials are sorted according to their color or size. If they want to make an art piece or everyday objects with it, they first melt it and then pour it into specimens. Art pieces or everyday objects are created by craftsperson.

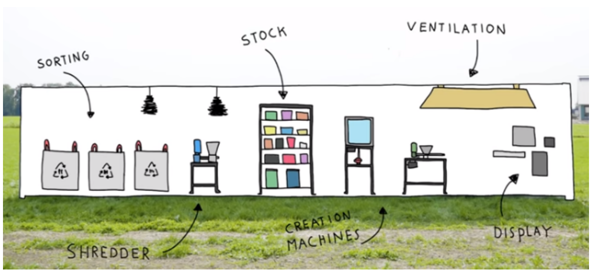

Figure 4.26. Precious Plastic work space example (Precious Plastic, 2018).

Boğaziçi University has a Fine Arts Department that mostly gives elective art courses such as painting, ceramics, and sculpture. Collaboration between Fine Arts department for creating art pieces by shredded plastic materials will be helpful in terms increasing raw material inventory for sculpture and selling those art pieces or everyday objects.

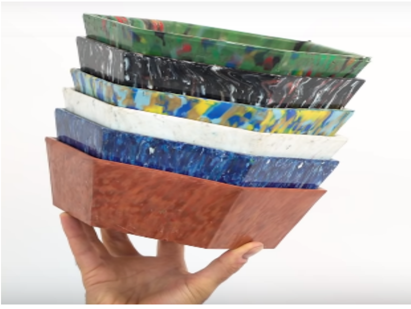

Figure 4.27. Precious Plastic everyday object example (Precious Plastic, 2018).

4.3.5. Dining Hall Waste Analysis

There are five dining halls in Boğaziçi University: South, North, Hisar, Kandilli and Kilyos. Students and personnel use these dining halls for daily lunch and dinner activities. However, students and personnel do not have the habit of completing their food or not taking food that they will not eat. Consequently, a high amount of food is thrown away to waste bins every day. Dining hall personnel do not separate the plastic, tissue and food waste when they are collecting the waste. This is all to say, if the food waste, plastic waste and tissue waste are separated from each other while they are collecting, the excess amount of half-eaten food can feed animals in the campus. Plastic waste can recycle and vegetable and fruit skins can be composted. The amount of food waste in dining halls per day is shown in Table 4.19, and per year is shown in Table 4.21.

To gather information about dining halls, each dining hall is visited several times and waste amount is noted as maximum, minimum whereas average is calculated later. Every meal served in Boğaziçi University is cooked in North Campus only. In order to have an understanding of the capacity and limitations of dining halls, North Campus Dining Hall visited separately and vegetable waste before cooking, the uneaten food by students, and leftovers are noted. Average food waste is 845 kg per day in total which is the highest in North Campus (570 kg/day) and lowest in Kandilli Campus (17.5 kg/day).

Table 4.19. Amount of food waste in dining halls per day.

Dining Hall (per day)	**Waste min (kg)**	**Waste max (kg)**	**Waste avg (kg)**
North	540	600	570
South	100	200	150
Hisar	35	40	37.5
Kandilli	15	20	17.5
Kilyos	60	80	70
Total	750	940	845

The food is cooked in big cookers and then, taken into containers. A container can carry minimum of 6 kg of food and maximum of 10 kg of food that depends on the type of food, and on average 8 kg of food. The amount of food that is cooked per day is shown in Table 4.20 and the amount of food that is cooked per week and per year are shown in Table 4.21.

Table 4.20. Amount of food that is cooked in dining hall per day.

Meal Cooked	**Meal Cooked min (# container)**	**Meal Cooked max (# container)**	**Meal Cooked avg (# container)**
Lunch (Weekday)	120	130	125
Dinner (Weekday)	80	100	90
Lunch (Weekend)	40	50	45
Dinner (Weekend)	40	50	45
Total	280	330	305

In Boğaziçi University, for serving 7000 people per meal per day, the amount of food that is cooked is minimum of 9280 kg per week and maximum of 10800 kg per week. The waste that is generated after eating the food, and throwing away what is uneaten is minimum of 4500 kg per week (750 kg/day $\times$ 6 days) , and maximum of 5640 kg per week (940 kg/day $\times$ 6 days). The percentage of food that is thrown away is minimum 42 % (minimum waste/maximum food cooked), maximum 61 % (maximum waste/minimum food cooked), and on average 50 % per day, per week and per year.

Table 4.21. Amount of food waste and cook in dining halls per week and per year.

Dining Hall	**min (kg)**	**max (kg)**	**avg (kg)**
Total waste (kg per week)	4500	5640	5070
Cooked (kg per week)	9280	10800	10040
Total waste (kg per year)	180,000	225,600	202,800
Cooked (kg per year)	371,200	432,000	401,600
Percentage (Waste/Cooked)	42 %	61 %	50 %

4.3.6. Composting

Composting is process of creating compost that will feed the depleted soil with nutrients. Waste of unprocessed vegetables and fruits can act as a carbon source, and coffee and tea waste can supply nitrogen to the compost. Simply, composting is the way of recycling the organic materials into fertilizer that will help soil to inhale and to be fed. Egg shells, vegetable wastes, fruit wastes, coffee and tea wastes, dry leaves, grass are examples of compostable organic materials.

Composting decreases the amount of waste that goes to landfill areas, and amount of fertilizer that has to be bought from supplier. Also, composting reduces the carbon-dioxide and water use by 30-60 %. For these reasons, it can be said that composting has some economic and environmental benefits.

There are two types of composting conditions: anaerobic and aerobic. In this research, aerobic composting condition is considered since it needs no initial cost and effort. According to Öztürk *et al.* (2010), the most important factor in composting is CO_2 and humidity ratio, and limiting factors are nutrients and pH. Carbon and nitrogen are crucial for microbial growth and activity while carbon acts like an energy source, and nitrogen helps production of cells.

According to First Law of Thermodynamics energy can neither produced or destroyed, it can only be transformed from one form to another form. Therefore, the amount of energy in the organic molecules is converted into reaction energy and biomass of microorganism. The amount of energy that is released after chemical reaction is converted into heat that will increase the temperature of surroundings and decrease the concentration of humidity in the compost. Composting are completed at least in 10 days and at most in 5-6 months. Factors that affect composting (Öztürk *et al.*, 2010):

(i) Size of Particles: Most of the organic matters that are used in composting have different, non-homogeneous shapes. The small particles can enter the pores and channels while blocking the movement of air in the composting system which in turn result in slowing down the reaction rate while limiting the diffusion rate.

(ii) Carbon/Nitrogen (C/N) Ratio: C/N ratio is the most important factor that affects the composting. Generally, phosphorus, potassium, magnesium, cobalt, zinc and iron exist enough to maintain the reaction. However, nitrogen is the limiting factor for biodegredation. Optimum C/N ratio is 20-25, and maximum C/N ratio is 50. C/N ratios of the organic materials are shown in Table 4.22. Furthermore, there is a relationship between C/N ratio and time of composting process. If C/N is 20 time that compost needs in order to be completed is 12 days, and C/N between 20 and 50 takes 14 days to compost (Öztürk *et al.*, 2010).

Table 4.22. C/N ratio and % of N of compostable organic waste (Tchobanoglous, 1993).

Organic Waste	**N percentage**	**C/N (Dry)**
Fruit	1.52	34.8
Vegetable	1.5	25
Paper	0.25	173
Lawn	2.15	20.1
Leave	0.5-1.0	40.0-80.0

(iii) Humidity: Humidity controls microbial activity due to the water needs of microorganisms. Minimum humidity should be around 30 %, and optimum humidity is around 50-60 %.

(iv) Temperature: Temperature affects microbial activity and reaction rate. Since composting reaction is exothermic, the temperature of the surroundings will increase to maximum of 65°C at which pathogens are destroyed. Also, there is an inverse correlation between humidity and temperature. The higher the temperature gets, the lower the humidity gets.

(v) Aeration: Microorganisms need O_2 to maintain the reaction. The optimum O_2 should be around 5-15 % in the first stages of composting, later it can be decreased to 1-5 %.

(vi) Mixing: Compost should be mixed every day in order to make it homogeneous and aired.

(vii) pH: pH level is related with the acidity which is also an important factor defining the composting process. pH level should be around 7-9 in order to maintain the compost reactions.

4.3.7. Compostable Waste Analysis

4.3.7.1. Dining Hall Waste. To gather information about dining hall and their procedures, the North Campus Dining Hall is visited since the meals are cooked there and distributed to other campuses. In order to cook the meals, the personnel that is responsible for cooking in the dining hall, peels the skins of vegetables and eliminate the bad part of the vegetables. Every day in Boğaziçi University to cook for 7000 people for 2 meals, 40 kg of vegetable skin is thrown away into the waste bins. The amount is decreased to 30 kg on weekends since some students are away from the campus (North Campus Dining Hall, 2018, Personal Communication, November 2018). In total 260 kg of vegetable waste are thrown into waste bins per week, and 10400 kg per year. Also, in every breakfast, approximately 500 boiled eggs are served. Egg shell has weight 10 % of the whole egg, which is 6 grams on average. 3000 eggs per week and 120000 eggs per year are used which will add up 18 kg egg shell per week and 720 kg egg shell per year, if they are stored separately from the other waste of that meal.

4.3.7.2. Lawn Mowing. According to Hennessy *et al.* (2012), growth rate of grass is 18 kgDMm^2/year. There are 7230 m^2 lawn area in both South and North campuses, which creates 130 tonDM/year of lawn each year.

4.3.7.3. Tea and Coffee Waste. There are several canteens and restaurants in the campuses of Boğaziçi University such as in the Perkins Hall, Natuk Birkan (NB), Orta Canteen, BİT, Wonderland, Börek, Yeni Derslik (YD), Moruq, Çatı Restaurant, Yadyok, North Canteen, Ağaç Ev Restaurant. Each canteen and restaurant are visited and the amount of waste as tea and coffee are noted in the Table 4.24. Total tea and coffee waste generated by these canteens and restaurants are 2080 kg and 1980 kg per year, respectively and given in Table 4.25.

Tea and coffee wastes, vegetable wastes and lawn residues can be used in composting. Total amount of organic compostable waste is 2942 kg per week, 117,692 kg per year in Boğaziçi University for the year 2018. Generally, efficiency of compost is around 77 % (Vázquez and Soto, 2017). Therefore, 90,625 kg of compost can be composed. According to Directorate of Waste Management of Istanbul Municipality, the average price of high quality compost is 2 TRY per kg. If initial needed barrels are supplied from old used barrels in the university, 181,250 TRY per year economic benefit is possible.

"Boğaziçi University Composting Center" is constructed in October 2018 in the South Campus Parking Lots. System energy to process the organic wastes. Energy is supplied from the grid which will increase electricity bill, while increasing carbon emission and water footprint related to electricity production. Besides, when there is a power shortage system can not be used. Therefore, "Composting Barrel Turning System" and "Aerated Windrow Composting in Kilyos Campus" are introduced in the scope of the thesis.

Table 4.23. Grass areas in Boğaziçi University Campuses.

Place	**Lawn area** (m^2)	**Lawn Mowed** (kgDMm^2/year)
South Campus		
Square	5266	94788
Scenery Place	449	8082
Perkins Hall	315	5670
North Campus		
Library	274	4932
KB (Kare Bina)	336	6048
ETA	224	4032
Dormitories	220	3960
Yadyok	146	2628
Total	7230	130,140

Table 4.24. Tea and coffee waste in canteens and restaurants in Boğaziçi University (kg/week).

Waste Type	**Eng Building (kg)**	**NB (kg)**	**Orta (kg)**	**BİT (kg)**	**Moruq (kg)**	**Çatı (kg)**	**Yadyok (kg)**	**Kuzey (kg)**	**Wonderland (kg)**	**Börek (kg)**	**Ağaç Ev (kg)**	**YD (kg)**
Tea waste	2.5	2.5	6	0	0	12	2	14	3	3	4	3
Coffee waste	2.5	1	2	20	21	0	0	2	0	0	0	1

Table 4.25. Compostable wastes in Boğaziçi University.

Compostable Waste	**Amount (kg/week)**	**Amount (kg/year)**
Vegetable	260	10400
Egg Shell	18	720
Grass	2500	130,000
Tea	52	2080
Coffee	49.5	1980
Organic Waste (buildings)	62.8	2512
Total	2942.3	117,692

4.3.8. Composting Barrel Turning System in Boğaziçi University

Barrel Turning System is the cheapest way of composting if barrels are readily on hand. The system basically needs a barrel and small holes around the barrel to start composting. Turning the barrel on its side is easier than the manual mixing, it allows compost to complete earlier. It has to be turned around daily in order to ventilate, and humidity should be preserved. This method may not be sufficient during winter because of lacking of insulation of barrels, if insulated properly the chemical reaction can heat up properly, and composting develop easily. Barrel turning system can be used when decomposition at the source is needed.

Figure 4.28. Composting barrel system (Green Energy, 2018).

Figure 4.29. Getting compost out of barrel (Green Energy, 2018).

4.3.9. Aerated Windrow Composting in Boğaziçi University

According to Öztürk *et al.* (2010), composting can be performed via traditional methods such as windrow composting (Figure 4.31). There is no barrel or container is used. Composting materials are piled together and require turning and watering. However, this method needs a place, and labor to ventilate and water the compost besides, composting process last at least 3 months to at most 6 months. For this method, the maximum cost will be initial experiments in the laboratories, and equipment purchase. Since, Boğaziçi University is famous for its green areas, therefore gardening equipment is available to use. Kilyos Campus is available to use for such a system (Figure 4.30).

In order to prevent water from evaporating, shelters should be provided. Liquid (leachate) that is occurred during composting should be collected and treated because it can leak to groundwater or surface water and acts like a contaminant.

Figure 4.30. Proposed Aerated Windrow Composting Center in Kilyos Campus.

Figure 4.31. Aerated Windrow Composting (Green Energy, 2018).

4.3.10. Hazardous Waste

Hazardous wastes are mostly generated in the laboratories of Boğaziçi University such as Chemistry and Chemical Engineering, Physics, Molecular Biology and Genetics, Biomedical, and Environmental Sciences departments. Microalgae Laboratory in Kilyos generates 88 liters of hazardous waste per year and Environmental Laboratory in Hisar Campus generates 145 liters of hazardous waste per year (Buse Yetişti, Personal Communication, November 2018). Hazardous wastes are collected and taken by Ekolojik A.Ş.. Hazardous waste stored and ultimate disposal is done by considering environmental aspects of the waste (Ekolojik Enerji, 2018).

4.4. Solar Energy Study

Electricity generation from renewable sources is important in terms of reducing greenhouse gas emissions, carbon footprint and water footprint. It also helps reducing the electricity bill and preserve nonrenewable natural resources. Using renewable resources as a supply of electricity generation will help becoming green and sustainable.

Figure 4.32. Amount of hazardous waste generated in Boğaziçi University between 2011-2015 (Yeşil Kampüs BOUN, 2018).

There are some universities that uses solar panels to produce electricity such as:

- Northwestern University with 20000 kWh per year, they collected USD 117000 with fund-raising.
- Drexel University and Butte College provide 100 % of their electricity from solar panels.
- University of Arizona generates 28000 kW per year.
- Princeton University provides energy for 7800 laptops with their solar energy installations.
- Özyeğin University provides 506 MWh per year electricity from solar panels.
- Harran University is installing 5 MW per year electricity farm.
- Hasan Kalyoncu University provides 257 MWh electricity per year with solar panel farm and solar panels installed on the roofs.

Solar panels will be connected to grid. If electricity produced is more than electricity needed, there will be surplus and excess energy will transfer into grid. Also, if electricity produced is lower than electricity needed, the deficit will be supplied from the grid. Solar radiation potential in Istanbul is 1400-1450 kWh/m^{2}year (Figure 4.33).

Also, hours of sunshine in Istanbul is at maximum with 10 hours in the summer, and 3-8 hours during the winter and springs (Figure 4.34). Global radiation value in Istanbul is around 6 kWh/m^{2}year during summer and between 1-4 kWh/m^{2}year during winter and springs (Figure 4.35).

From Figure 4.36, it can be seen that the most efficient Photo-Voltaic (PV) panel (Figure 4.37) is mono PV module with 220 kWh/m^{2}year. Total price of 1 Watt is 7 TRY (panel, regulator, cables, connectors, circuit breaker).

Figure 4.33. Solar radiation potential of Istanbul (kWh/m^{2}day) between 1985-2006 (YEGM, 2018).

4.4.1. Electricity Generation from Solar Panels in Boğaziçi University

As can be seen in Table 4.11, total roof area of Boğaziçi University is 71711 m^2. Using mono PV module with 220 kWh/m^{2}year, will create a capacity of 15776 MWh/year. On average there are 8 hours of sunshine during the year (Figure 4.34). So, dividing by 365 and 8 will give capacity in terms of MW/day which is 5.4 MW/day. Since a solar panel can supply 240 W at maximum, 22512 solar panels can supply total amount of 5.4 MW/day. According to WholeSolar (2018), 240 W solar panel costs 1680 TRY and total price of solar panel installation will cost 37 million TRY (If Solar panels are imported it can be cheaper.)(Figure 4.37).

According to Boğaziçi University electricity bills average electricity bill is equal to 410,000 TRY(Electricity price is 0.30 TRY/kWh.) (Accounting and Realization Department (Tahakkuk), Personal Communication, November 2018). A capacity of 15776 MWh/year of providing electricity will create an economic benefit of 4.7 million TRY per year. Payback period is 8 years. Since solar panels which emits 99 g carbon per kWh generated will provide the electricity rather than natural gas which emits 504 g carbon per kWh generated, (Wind 10.2 g CO_2/kWh, Hydro 10 g CO_2/kWh, Biogas 11 g CO_2/kWh) (Martin, 2006). Solar panel use will reduce carbon footprint by 405 g carbon per kWh and in total 6389 ton carbon emission per year will be decreased.

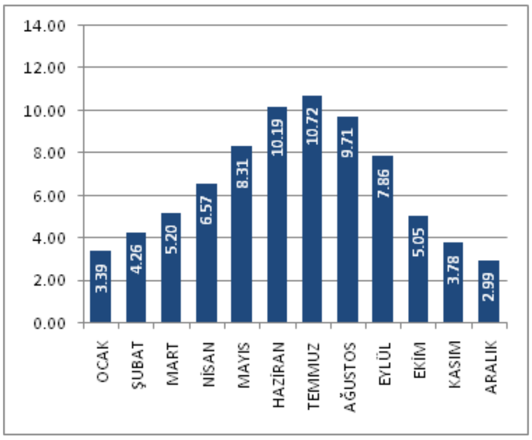

Figure 4.34. Hours of sunshine in Istanbul (hour) between 1985-2006 (YEGM, 2018).

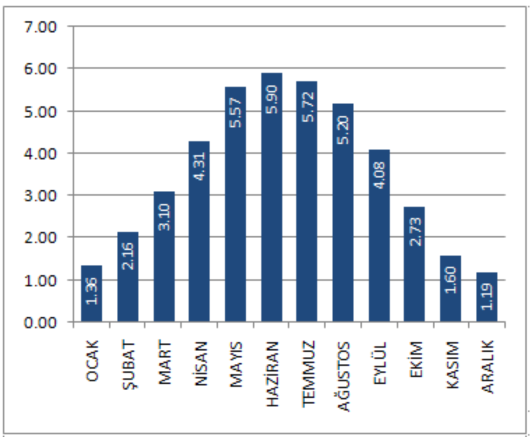

Figure 4.35. Global radiation values of Istanbul (kWh/m^{2}day) between 1985-2006 (YEGM, 2018).

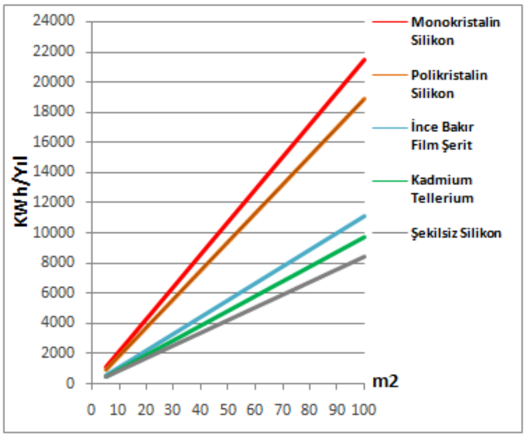

Figure 4.36. Electricity generation potential from solar panels (kWh/year) (YEGM, 2018).

Figure 4.37. Mono-crystalline PV panels (Solar, 2018).

4.5. Attendance System

For some lectures, attendance is necessary not only punishing students but also encouraging them to understand and take good grades. High rate of attendance in the class improve their motivation and success rates by simply creating a interactive learning environment (Stanca, 2006; Pani, 2016). Attendance that is taken in the classroom are for the incentive for the lecture. Mostly, instructors assign a percentage of total lecture points to attendance system or assign a threshold limit in order to take the exams and pass the lecture. Generally, attendance is taken either in the way that instructor reads the name of each student in the class one-by-one or in the way that instructor prepares an attendance sheet that students can sign on it. The former method is mostly time consuming. Taking into consideration that most of the lectures in Boğaziçi University is 50 minutes, 5 minutes for attendance is 10 % of the lecture. Students may ask questions about the lecture rather than signing or approving for attendance. The latter is misleading because students can sign for their friends who do not want to attend the lecture. What is more, after taking the attendance in the classroom with traditional attendance techniques, instructors have to type them down on an electronic platform that keeps the total number of lectures attended by student.

Nowadays, instructors want to try new methods such as taking attendance with QR code, random number generation, RFID, finger print, iris and face recognition.

- QR code: They simply open the QR code in the projector, students attend the lecture by reading the QR code with their smart phones. This method can also be misleading due to sharing QR codes with the students who do not attend the lecture.
- Random number generation in the class with a time limit: Students read the number in the projector and type it into the attendance system. This method shares the same drawbacks with the previous method, students may send the number to their friends who do not attend the lectures.

- RFID: Students receive a RFID tag and when attending the lecture RFID reader reads their tags. Therefore, automatic attendance is taken. Drawback of this method is that students can give their RFID tags or cards to their friends without attending the lecture.
- Finger Print: Only one student can be identified, slow and long process. Also, finger print systems are usually placed at the entrances of the classrooms, students may come and be identified by the system, and leave the classroom.
- Iris Recognition: This method is the same with previous one but differs in the type of body part. It is slow, and misleading. Also, invades privacy of students.
- Face recognition: This method is the most efficient attendance method since it does not take a lot of time and effort, and it is placed inside of the classroom.

Attendance taking systems with a technology placed outside of the classroom may be used in fraudulent actions. In order to prevent those actions, instructor should control the attendance taking while it is happening. Besides, these methods take too much time both students and instructor.

4.5.1. Attendance System Using Face Recognition

After registration period, photos of each student should be taken and stored until the end of note-giving-period. These images will be used in the training phase of the face recognition software. According to Turkish Privacy Act - 6698 (Kişisel Veri Koruma Kanunu), in order to store the images for one semester, permission of students should be taken in order not to invade their privacy.

At the beginning of each lecture after everyone is seated, instructor should take a photo of the classroom making sure that every face in the system is visible. Then, uploads it to the system to take attendance. After uploading, face recognition and verification algorithm runs, if the face of the student matches with the image, attendance is approved and noted, otherwise attendance is not taken. Also, all the face logs are kept in a separate system (Figure 4.38).

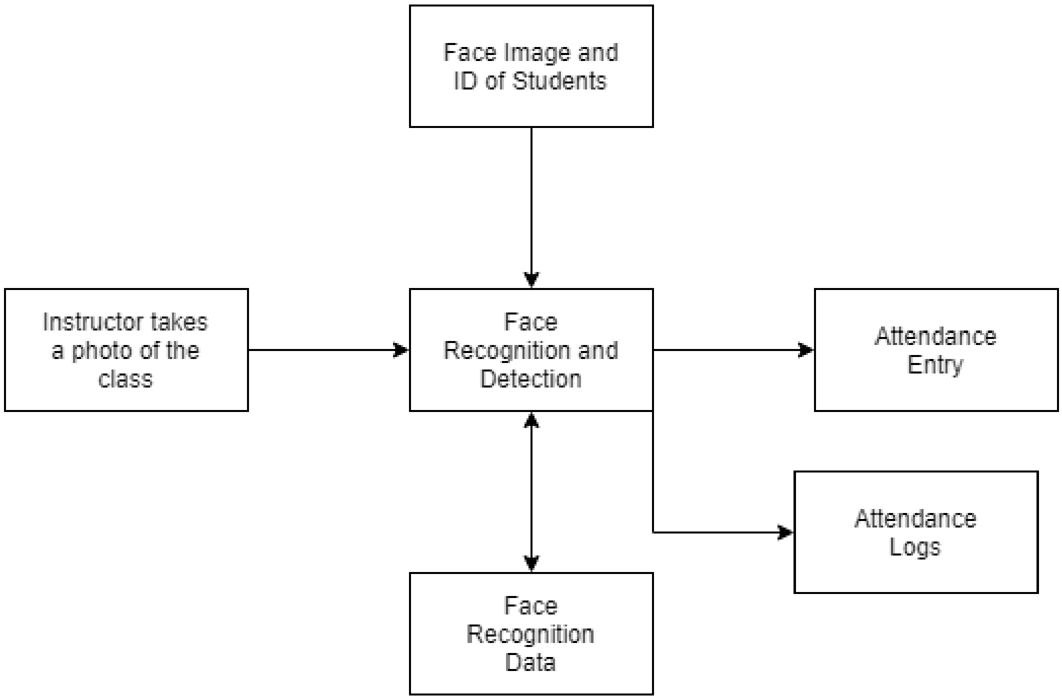

Figure 4.38. Attendance with face recognition technology.

4.6. Other Studies

4.6.1. Zero-Waste Campus

As of January 2018, China banned plastic imports that are contaminated more than 1 % which is below the average contamination percentage of recyclable plastic. Because of lacking of proper recycling habits, use of plastic should also be minimized. The minimized waste, later, can be recycled.

Zero-waste is a movement that reducing the waste of what people consume in order to create a sustainable world. For example, using cloth bags instead of using plastic bags, reducing the package food consumption, using bottles instead of plastic one-time-use bottles. Boğaziçi University is awarded as “Sıfır Atık- İyi Gelecek” in 2018 due to zero-waste initiatives in Boğaziçi University.

By looking at the recycling behaviors of students (Table 4.16), it can be seen that students have not adopted a habit of recycling, yet. In order to go zero-waste, students and personnel should be educated on the advantages of recycling and not to waste resources. Also, all appliances should be changed into water, and energy efficient ones.

4.6.1.1. Air Conditioning Use . There is one air conditioning device in every room of Perkins Hall in Boğaziçi University. Most of the time these air conditioning systems are taken into granted in such a way that:

- Leaving air conditioning on when leaving the room permanently, most of the time people forget to turn off and it stays on until the next morning or next time.
- Opening doors or windows while air conditioning is on.
- Using around 18 - 20 °C in the summer in a way that will consume more energy.

Air conditioning use should be reviewed in a way that does not consume too much energy and emit carbon-dioxide. There should be an autonomous system that sets the temperature of air conditioning to a reasonable level.

4.6.1.2. Dining Hall Waste. Every day approximately 1 ton of food are thrown away to the waste bins in Boğaziçi University. According to a survey conducted with 500 students in Berkeley UC by Lam (2010), poor food quality and being served too much in dining halls are the top reasons why students throw away their excess meals.

In order to solve food wasting problem, students should be educated about where food waste are sent if they do not eat and not taking the food if they do not want to eat. Also, food quality in dining halls should be revised. Personnel of dining hall knows which kind of foods are not preferred by students and go to waste, which kind of the foods that students love the most. According to preferences of students, meal plan should be reviewed.

4.6.1.3. Bicycle Use. Boğaziçi University has a start up called "BiZero" for renting electric bicycles and getting charged by per minute use. System has stations in Kandilli Campus, Kilyos Campus, Hisar Campus, Uçaksavar, South Gate and South Square, North Kpark and North Square. From an application in mobile phone, renting is possible. System is now used in Yıldız Technical University and Istanbul Technical University.

In order to increase bicycle use there should be bicycle stations at the entrances of every building, because when it rains or students are tired, they do not want to take and drop the bicycle from the specific stations. Also, it applies for their own bicycles, there is not enough place to secure the bicycle when they are at the lecture. The secure parking and available station should be increased.

4.6.2. Smoke-Free Campus

According to Turkish Statistical Institute (2017), 425,000 people died in 2017, and 120,000 people die from smoking related diseases. In US approximately 500,000 people die from smoking related diseases, and 41,000 people die from being exposed to smoke (USDHHS, 2014). Changing the smoking habits will affect smoking related diseases and decrease the death ratio.

Not only smoking itself but also being exposed to smoke carries health risks. Besides, cigarette waste is considered to be a toxic waste, because it contains non-biodegradable cellulose acetate in its filter and nicotine in tobacco part (Novotny *et al.*, 2009). In order to minimize the health issues related with smoking and being exposed, smoking should be allowed only in specific smoking areas, if necessary.

Turkish Republic Ministry of Health initiated a project called "Havanı Koru - Dumansız Hava Sahası" which is about protecting the air quality that is free of smoking. They created a website and line 171 for quitting smoking. Website gives information about health issues related with smoking and how to quit smoking.

Also, indoor places, public transportation vehicles, bus stops are places that smoking is not allowed.

Being smoke-free is one of the standards of LEED by US Green Building Council. According to LEED BD+C Healthcare: Environmental Tobacco Smoke Control (USGBC, 2018):

- Smoking-free indoors.
- Smoking-free outdoors. Smoking areas should be 7.5 m away from all entries, outdoor air intakes and windows.
- Announce with signs 3 m away from all building entrances.

Figure 4.39. Cigarette butts collected from Kilyos Campus in 2018.

Figure 4.39 is an example of pollution of cigarette waste in Kilyos Campus of Boğaziçi University. Furthermore, students of Boğaziçi University suffer from being exposed to smoke. Students try to educate their peers in order to live peacefully and smoke-free. They share the places where smokers should not smoke in order not to danger their friends' health. The places that are highly exposed to smoke:

- In front of Library.
- In front of South Study and North Study.
- In front of Kare Building (KB).

- In front of Perkins Hall.
- In front of dormitories.
- Common places such as the one in South Campus main road, and scenery place in South Campus.
- Shuttle, dining hall queues.

4.6.2.1. Smoke-Free Campuses.

- Canada: 16 universities are smoke-free including Marine Institute, and College of North Atlantic.
- United States: 2082 campuses are smoke-free including Harvard, California State University, University of California, Tufts University, University of Massachusetts, New York University.
- Finland: University of Helsinki, Eastern Finland and Turku are smoke-free.
- Ireland: National University of Ireland, Limerick and University College Dublin.
- United Kingdom: 6 universities are smoke free including University of Warwick, Imperial College London, King's College London, Northumbria University.
- Australia: All universities are smoke-free including RMIT, University of Melbourne and Monash University.
- New Zealand: All universities are smoke-free including University of Waikato and University of Canterbury.
- China: 4 universities are smoke-free such as Peking University, Tsinghua University, China University of Political Science and Law, University of Science and Technology Beijing.
- Hong Kong: According to Hong Kong Law it is not allowed to smoke in the places where education and teaching activities take place.
- Indonesia: University of Macau.
- Philippines: University of Santo Tomas.
- Turkey: Bilkent University aims to be a smoke-free campus starting from 1 September 2022. Karadeniz Technical University - Vocational School is also smoke-free.

Most of the smoke-free campuses are also tobacco free which means all tobacco products are prohibited in campus area. In some campuses there are designated smoking areas, however most of them do not have such areas. All universities have a domain under their official university website where authorities share information why not to smoke, how to quit smoking, how to reach help from supervisors. Since, smoking is a personal activity, quitting is also a personal activity that needs help from peers, and supervisors. Students who quit smoking after attending their programs receive an incentive such as money and free of medicine and therapy sessions.

Boğaziçi University may create smoke-free areas as a starting point and announce a smoke-free campus policy by supporting it with posters and a team of delegate students with a supervisor. These delegates will support and encourage their peers to decrease and eventually quit smoking. Also, BÜREM (Boğaziçi University Guidance and Psychological Counseling Center) can assist and guide students who are in need. As a result of quit-smoking program, students who accomplished quitting smoking can be given incentives in the form of book-scholarship, and BuCard-Scholarship.

4.6.3. Disability-Friendly Campus

Boğaziçi University has awarded as being a disability-friendly campus in 2018. Boğaziçi University has a department for blind people under the name of Visually Impaired Technology and Education Laboratory (GETEM). Their main duty is to help blind people in terms of converting books into audibles. Blind people can access to those books online or via phone.

There are yellow ribbons for blind people in the campuses of Boğaziçi University. However, the other people are not educated enough to know the meanings of those ribbons. Most of the time cars park on those ribbons by blocking the road for blind people. Moreover, yellow ribbons are not installed to the way that goes to GETEM.

Also, for student council elections, they have to go to GETEM to vote in person. In rainy or snowy days, blind people can not go to GETEM to vote, so the participation rate becomes low. There is no online platform for voting such as transferring "registration.boun.edu.tr" into online voting center.

The campuses are not suitable for walking disabled people. There are sharp stairs and hills all over the campus which makes it impossible or hard to reach.

The lectures are not suitable for deaf people. If the lectures are recorded and loaded to an online platform that will have a sign language explanation of the lectures.

4.6.4. Pet-Friendly Campus

Boğaziçi University is an icon with its numerous of cats and dogs. Currently, there is no veterinary in the school. Boğaziçi University Animal Rights Society (BUHAY) takes care of the hurt animals when they need. Currently, BUHAY does not have any sponsors, students cook meal and sell it in favor of animals in order to pay the veterinary bill and meals. Also, university provides cat and dog food in some specific areas throughout the campus. However, on weekends when less people are in the campuses, animals are mostly hungry and seek attention.

Leftover foods can be supplied to animals especially on the weekends when less people are around. In this way, waste will be minimized and animal friends will be fed.

Stephens College initiated foster program for cats and dogs in the campus. This program allows students to take care of the adoptable animals in their dormitory rooms. Boğaziçi University can also adopt a foster program for kittens, and puppies especially when it is cold. There should be a website that shows the pictures of baby animals to the students who want to adopt an animal, through a system animal can be adopted. In this way, it will be guaranteed that animal will not be a stray animal anymore. Also, shelters should be provided to animals in the winter.

5. SUMMARY AND DISCUSSION

5.1. Water Footprint Study

Water footprint study is conducted using the methodology Water Footprint Network. Survey prepared by Water Footprint Network is used and 394 students responded.

Water footprint (WF) of Boğaziçi University (BU) is 6082 liter per capita per day while WF of engineering students is 6287 liter per capita per day. 56 % of total water footprint is due to dietary preferences of students. WF of diet is 3901 liter per capita per day due to meat consumption considering there are only 3 vegans and 32 vegetarian student who responded the survey; WF of diet of United States is 5280 liter per capita per day. The second biggest effect in total WF of BU is due to shopping habits of BU students, WF of shopping is 1489 liter per capita per day while that of United States is 2206 liter per capita per day. The third biggest effect in total WF of BU is cat and dog food consumption. WF of cat and dog food in BU is 240 liter per capita per day while that of United States is 140 liter per capita per day.

While conducting the survey, it was seen that most of the students do not know the meaning of water footprint and how their shopping and dietary preferences may affect their water footprint. What is more, students do not know where to recycle and what to recycle. They prefer to throw recyclable wastes into waste bins. Amount of recyclable materials in the waste bins were three times of amount of recyclable materials in recycle bins. Students prefer to recycle paper in BU rather than plastic and bottle. When they do recycle, they mostly throw away in the wrong section of recycle bins. Students recycle regularly are 10 % of total respondents.

Only 30 % of students have energy and water efficient devices at their homes. Use of these appliances are not common. Only 5 % of students have grey water and rain barrel systems that help to save water. Students should be educated about importance of water and water use. Furthermore, by installing “drinking fountains” WF of 396,000 liter per day and carbon footprint of 6.1 ton carbon per day can be eliminated.

5.2. Rainwater Harvesting Study

There are 128 buildings in Boğaziçi University where rainwater harvesting can be done. Total roof area is 71,711 m^2 which can harvest 42,204 m^3/year and generates economic benefit of 195,995 TRY/year and payback period is 4 years. Rainwater harvest capacity of BU is calculated according to German Institute for Standardization - DIN 1989 for Rainwater harvesting systems.

5.3. Solid Waste Study

Solid waste characterization is studied in Perkins Hall and lasted 4 weeks. On average, waste of 90.25 kg/day is generated in waste bins of Perkins Hall. Paper waste is 50 %, toilet paper is 15 %, plastic bottle is 20 %, bottle is 10 % and organic waste (package and fruit skin) is 5 % of total waste generated. Behavior of engineering students are almost the same according to results of WF survey. Hence, by interpolation waste of 196.36 kg/day is generated in waste bins by all of the engineering students which are 3070 students in 2018. Also, 39.2 kg/day of paper is thrown away in recycle bins.

There are 17337 students both graduate and undergraduate and 1327 personnel, 18664 members in total. Economic benefit of recycling for 3070 students is 30918 TRY/year, the economic benefit for whole Boğaziçi University with its personnel and students will be 280,211 TRY/year.

On average, food is thrown away in dining halls is 845 kg/day that includes the form of raw material, and in the form of leftover food from students who do not finish their meals. Meals are served for 7000 students and weigh 1434 kg/day. Almost, 50 % of food cooked is thrown away. Studies show that poor food quality and being served too much increases the amount of food waste. Also, while conducting the waste analysis study it was seen that personnel knows exactly which meals are not preferred and which meals are preferred the most. If menu is prepared according to students' eating habits while considering the calorie intake and proportions of protein, fat and carbon-hydrate, food waste can be minimized.

Total waste generated (Dining hall, recyclable and waste bin) per day per engineering student is 0.12 kg, 0.013 kg, 0.077 kg respectively and in total, 0.21 kg per day per student. In Turkey, average waste per person per day is 1.17 kg (Kor *et al.*, 2006).

The most efficient and preferable method in waste management hierarchy is source reduction and reuse. Students and personnel should be educated about the importance and easiness of separation at source and self-awareness environment should be created. Studies show that when given incentives people tend to collect and bring their recyclable waste to recycling centers. If students and personnel are given incentives in the form of cinema ticket in SineBU or free meal in dining halls, or small money load to BuCard, recycling rate will increase. Furthermore, BU can be a member "Precious Plastic" movement and created art pieces can be sold.

Composting can be performed with compost barrels and aerated windrow composting method which will be placed in Kilyos Campus. Composting can be performed for raw vegetable waste in dining halls, egg shells, lawn, tea and coffee waste. BU generates 117,692 kg organic waste per year. Studies show that composting is efficient only 77 %, therefore composting capacity is 90,625 kg/year which will result in an economic benefit of 181,250 TRY/year.

5.4. Solar Energy Study

Boğaziçi University has a 71,711 m^2 roof area and has a capacity of 15,776 MWh/year which will create an economic benefit of 4.7 million TRY/year. Calculations and methodology of General Directorate of Renewable Energy is used. Payback period is 8 years. Also, Carbon footprint will be reduced by 4389 ton carbon/year (Solar panel emits 99 g carbon/kWh, nat-gas emits 504 g carbon/kWh).

5.5. Other Studies

Attendance can be taken with face recognition technology. It is a cheap and the most convenient method that will eliminate fraudulent actions taken by students and minimize time and energy waste of attendance for instructors and students.

Boğaziçi University is located on hills that is dangerous and inaccessible for walking disabled members of BU. More reachable university environment can be created in favor of members. Also, lectures are hard to follow for deaf students, in time lectures can be uploaded to an online platform with a sign language option. For visually impaired members, Boğaziçi University has yellow ribbons. However, yellow ribbons do not reach all of the buildings even GETEM. It is seen that car owners in the campus do not pay attention to yellow ribbons and they park on them. Educative materials should be provided while engineering designs of disability-friendly campus environment can be provided.

Smoking affects not only smokers but also people around smokers. Also, cigarette butts are considered to be toxic waste and they are non-recyclable. Applications of smoke-free campus environment can be constructing peer support groups for quitting smoking, psychological help, incentives for people who quit smoking via quitting programs provided by BU. Smoke-free campus will decrease water and carbon footprint of BU.

6. CONCLUSION AND FURTHER STUDIES

Maintenance and sustainability of natural resources are the challenge of today and tomorrow. Increased population demands more water use, and energy use and eventually will deplete natural resources. For these reasons, smart city, smart campus and green campus applications are performed all around the world. Smart solutions will ease the adaptation and application process of the solution.

Universities are the places that young and leader minds study. Initiating smart and green applications at campus level will accelerate the adaptation and spreadablity of the applications. While initiating projects actors, namely, students and members of the universities should be educated. Therefore, adoption and applicability of the solutions to the cities can be studied.

In this thesis water footprint analysis of students Boğaziçi University, rainwater harvesting in Boğaziçi University, solar energy study, solid waste study in Perkins Hall and Dining Halls are performed. Also, rain barrel composting system, and attendance with face recognition are introduced to Boğaziçi University. Zero waste, smoke free, disability friendly and pet friendly campus are introduced. Current green campus applications in Boğaziçi University are evaluated and improved.

It is seen that recycling behaviors of students of university are not adequate, and students are prone to consume carelessly. In order to save water, water efficient appliances should be placed in all of the buildings, dining hall and other wastes should be minimized. Drinking fountains should be implemented throughout the campus in order to minimize plastic bottle use. Before everything else, students and personnel should be educated about the consequences of their behaviors and encouraged to calculate their water footprint and carbon footprints. For a fresh start, these footprints must be known and act accordingly.

In order to save water and energy, solar panels and rainwater harvesting system should be implemented to the roof of the buildings. Since, sunlight and rainwater are common resources, university can also benefit from their presence and availability. Installing rainwater harvesting system will create an economic benefit of 195,995 TRY/year, composting will create an economic benefit of 181,250 TRY/year, solar panel installation will create an economic benefit of 4,732,800 TRY/year and economic benefit of recyclable materials will be 280,211 TRY/year, in total 5.4 million TRY/year.

Campus should be a secure place with no fraudulent actions. In order to minimize the time and effort in taking and saving attendance, technological solutions should be adopted. Attendance with face recognition system will save from the class time and effort of instructors for taking attendance.

Universities should be a common ground for all beings namely people with disabilities and animals. University should provide a suitable environment for people with disabilities such as for those who are blind, deaf and have walking disabilities as being disability friendly campus. Current campus applications are mostly focused on blind people, but one must remember there are other people also. Boğaziçi is famous for its unique cat and dog population. Currently, there is no sufficient system for taking care of those beings. Taking pet-friendly campus initiatives like foster program for kittens, or providing sufficient food for animals, will help the pet population of the campus.

Smoking is not also harmful for those who are smoking but also harmful for those who are exposed to smoke. Adopting smoke-free campus initiatives such as restricting smoking areas, giving seminars, preparing posters, psychological help for quitting will help turning into a smoke-free campus.

Going green and smart will decrease carbon emission, water and energy use, waste while creating an economic benefit as well as social behaviors. It must be remembered that going green is not a one time application. Besides, pursuing green applications will help next generations to benefit from the environment and natural resources.

In this thesis, solar energy and attendance studies are given in preliminary design. For further studies, solar energy panels and efficiency of Boğaziçi University can be modeled and face recognition and face detection algorithms for Boğaziçi University can be developed. Also, solid waste study is only conducted in Perkins Hall, it can be done in all of the buildings of Boğaziçi University. Rainwater harvesting study is also given in preliminary design, final detailed design of rainwater harvesting capacity of Boğaziçi University can be studied. Engineering designs of roads, buildings and implementations to classrooms can be provided for a disability-friendly campus environment. Furthermore, for recycling and going zero-waste, posters, educative materials and a web domain can be prepared while forming pioneer groups.

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