CARBON FOOTPRINT ASSESSMENT AND EMISSIONS REDUCTION STRATEGIES FOR THE UNIVERSITY OF TEXAS AT ARLINGTON

By

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Abstract

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The University of Texas at Arlington, 2021

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In the past decade, many universities have started to ascertain their emissions and benchmark their progress towards sustainability and climate control. The University of Texas at Arlington (UTA) is no exception in working toward the goal of carbon neutrality. While UTA continues to grow and transform, its goal is to simultaneously reduce energy intensity and greenhouse gas (GHG) emissions. To this end, the Office of Sustainability is maintaining a carbon inventory for each year to track GHG emissions and provide information to guide reduction strategies.

The primary objectives of this research were:

1. To update UTA's greenhouse gas emissions inventory to include 2017-2019,

2. To suggest short-term and long-term greenhouse gas emission reduction strategies,

The inventory was conducted using SIMAP (Sustainability Indicator Management and Analysis Platform), offered by The Sustainability Institute at the University of New Hampshire.

Data on the University's major carbon-emitting activities were gathered, and total carbon dioxide (CO_2) emissions were calculated from three sources: building energy use, transportation fuel consumption, waste (including food waste). For the first time, GHG emissions due to water usage at UTA were estimated. Also for the first time, Scope 3 emissions (emissions due to student, staff and faculty commuting) were estimated for UTA.

The University's total 2018-2019 emissions were estimated at 101,319 metric tons of carbon dioxide equivalent ("$MTCO_2e$"). This is equivalent to 0.01384 $MTCO_2e$ per gross square foot Gross Square Foot (GSF) and 2.03 $MTCO_2e$ per fullt-time equivalent (FTE) student. UTA emissions decreased from 2017 to 2019, despite increased student enrollment and a 7% increase in building area. Although UTA electricity consumption increased during this period, emissions from electricity decreased due to reduced coal generation and increased wind power. In addition, emissions from commuting decreased due to a 9% increase in online enrollment, coupled with a 6% decrease in on-campus enrollment.

The study also examined several potential methods of reducing the carbon footprint of the university.

- Solar power output for UTA's rooftops were assessed with the help of Helioscope a solar panel design tool. It was found that solar panel placements at 14 major UTA building rooftops will yield a power output of 4659 MWh, which will offset UTA's Scope 2 (purchased electricity) emissions by 6.37%.
- GHG emission reduction due to afforestation at UTA was estimated with the help of I-canopy (a software to determine the reductions in GHG emissions due to afforestation). It was found that about 23.9% of UTA's campus is covered with trees, which absorb 467

tons of CO_2 emissions annually. Traditional air pollutants are also removed, providing an estimated $10,000 benefits. UTA's trees also provide benefits of almost $9000 per year in terms of avoided runoff.

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Chapter 1: Introduction

1.1 Background

1.1.1 Greenhouse effect

The greenhouse effect is a naturally occurring phenomenon. The Earth’s atmosphere is transparent to incoming short-wavelength radiation from the sun but partially opaque to outgoing long-wavelength radiation re-radiated by the Earth back to space. Some of the outgoing radiation absorbed by greenhouse gases in the atmosphere is re-radiated back to the Earth’s surface, making it 60°F warmer than it would otherwise be without the greenhouse effect, allowing life to be sustained.

The problem arises when the concentration of greenhouse gases in the atmosphere is increased beyond natural levels, resulting in excess outgoing radiation being absorbed and trapped inside the earth's atmosphere. It is estimated that about 80% of U.S energy source is based on fossil fuels, which generate greenhouse gases (U.S. Energy Information Administration, 2021).

1.1.2 What are Greenhouse Gases?

“Greenhouse gases from human activities are the most significant driver of observed climate change since the mid-20th century”. (IPCC, 2013) Greenhouse gases have the property of absorbing infrared radiation; these gases in the earth’s atmosphere will lead to trapping and holding of solar radiation or heat in the atmosphere. (IPCC, 2013). Specific gases like carbon dioxide, water vapor, and methane are transparent to incoming short-wave radiation from the sun but absorb the long-wavelength infrared radiation re-radiated from the earth into outer space (Florida Atlantic University's Center for Environmental Studies, 2021). These gases do not have a rotating chemical bond that vibrates in a manner of a dipole moment, whereas gases like oxygen and nitrogen have this property. The missing dipole moment makes these gases vibrate in specific infrared frequencies, thus absorbing heat in the atmosphere. The most significant contributor to climate change is carbon dioxide (CO_2), accounting for about three-fourths of global emissions. (US EPA, 2021).

As of the year 2019, the concentrations of carbon dioxide, methane and nitrous oxide are approximately 412 ppm, 1883 ppb, and 332 ppb, respectively (EPA, 2019). The concentrations were only about 283 ppm, 710 ppb, and 266 ppb before the Industrial Revolution in the 1800s. This increase was primarily due to the combustion of fossil fuels and secondarily due to agricultural fertilizers, waste and biomass burning. Other greenhouse gases like water vapor also influence global warming; however, it has a shorter lifetime in the atmosphere than other greenhouse gases like carbon dioxide and nitrogen dioxide.

1.1.3 Climate change impacts

Since the early Industrial Revolution, the earth's surface temperature has increased approximately by 2 to 4 °C (Dutton et al., 2015a; Haywood et al., 2016), which is more than the projected global ground surface temperature increase of 0.5 ℃s Celsius in 25 years (1975 to 2000) (Mann et al., 1999; Hughes and Diaz, 1994; Jones and Bradley, 1992). The drastic changes in the global surface temperature have led to the melting of ice caps in the Antarctic region (EPA/Climate Indicators, 2021). The global melting of ice caps has simultaneously increased the sea level, causing damage to coast lines and increasing the risk of flooding and storm intensities (Ghanbari, 2021). It is estimated that there will be an increase in global mean sea level of 4 feet by 2100 (Church et al., 2013). For example, Harris County, which contains the city of Houston, Texas, USA, is likely to have storm surge flooding by 2100 due to human activities that cause climate changes. (Prykhodko, 2020).

1.1.4 GHG emissions in the USA and on a global scale:

The United States of America has an annual GHG emission of about 6,558 million metric tons of carbon dioxide equivalents. There has been a 13% decrease in the production of GHG emissions when comparing 2005 and 2019 carbon dioxide (EPA, 2021). On a global scale, there was a 1.1% growth rate in GHG gas emissions for the year 2019, and this change was mainly due to an increase in transportation and industrial activities of developing nations. China alone contributes 28% of the global GHG emissions. On the other hand, developed nations like the United States of America (15%), Germany (2%), France (1%) have higher per capita GHG emissions when compared to developing countries (Center for Climate and Energy Solutions, 2021). Although the per capita GHG emissions are more significant in developed nations, initiatives to reduce emissions include carbon credits, solar panel installation, and promoting public transport.

The Paris climate change agreement is a legally binding international treaty on climate change; some countries like the U.S came out of the agreement in the year 2020 and reentered in 2021. The agreement proposed an enhanced transparency framework (ETF), which will help stakeholders, government and other institutions track GHG emissions and implement new programs or remedial measures to fight climate change.

1.2 Overview of GHG inventories in Higher Educational Institutions (HEI):

The college student population in the US increased from 2 million to 18.4 million from 2007 to 2017. About 6.1% of the overall population is currently college students in the United States. About 23% of the global population is currently a student pursuing any education.

(Education.org, 2021; UNESCO, 2017) College student activities, including going to classes, performing research duties, and attending conferences, can affect national and global GHG emissions. Thus, calculating the inventory for higher educational institutions will play a vital part in determining US GHG emissions. According to the Association for the Advancement of Sustainability in Higher Education (AASHE), 519 US universities have received a gold, silver or bronze medal for GHG emissions reporting. Conducting an annual GHG emissions inventory will improve the HEI community's environmental awareness and improve the efficacy of future policies and measures to reduce GHG emissions (Valls-Val, 2021).

Additionally, a number of cities and towns developed largely based on the higher education institute present. For example, the city of Arlington was majorly developed based on the University of Texas at Arlington (UTA) (Wikipedia, 2021). The overall city of Arlington has a population of about 400,000 (United States Census Bureau, 2019). UTA has a student enrolment of about 48,000 and a faculty and staff population of about 5,700. 13.5% of Arlington's population has ties to the university as either student, staff members, or faculty.

UTA has inspired administration, faculty, staff, and students on campus to embrace environmental responsibility and help UTA become a leader in sustainability among academic institutions. Following the Office of Sustainability establishment in 2010, UTA has developed programs and principles that foster sustainability practices across the university.

While UTA continues to grow and transform, its goal is to simultaneously reduce energy intensity and greenhouse gas (GHG) emissions. To this end, the Office of Sustainability is maintaining a carbon inventory for each year to track GHG emissions and provide information to guide reduction strategies.

1.3 Thesis objectives

The primary objectives of this project were:

1. To assess UTA's greenhouse gas emissions inventory to include 2017-2019,
2. To suggest short-term and long-term greenhouse gas emission reduction strategies.

The inventory was conducted using SIMAP (Sustainability Indicator Management and Analysis Platform), offered by The Sustainability Institute at the University of New Hampshire. SIMAP was used in this study for the following reasons:

- Ease of use: the tool has several options to input data and has a convenient user interface, including an online data account for every user, which can be used for the import and export of data,
- Complete coverage of emissions calculations in three areas or scopes,
- Graphical output,
- Free for the first two months,
- Calculation of emissions based on carbon dioxide, methane, nitrogen dioxide, along with carbon dioxide equivalent,
- They were used by several universities for AASHE STARS reporting.

1.4 Thesis outline

The rest of the thesis is outlined as follows:

2. Chapter 2 reviews the literature on GHG assessment and reduction strategy studies conducted at various higher educational institutions worldwide.

3. Chapter 3 describes the detailed methodologies and procedures for data collection, analysis of data, and input into the SIMAP tool to accomplish the study's objectives.

4. Chapter 4 discusses the analysis of data and the findings of this research study.

5. Chapter 5 explains the suggested short-term and long-term greenhouse gas emission reduction strategies.

6. Chapter 6 summarizes the findings and conclusions of this study and provides future recommendations.

Chapter 2: Literature Review

2.1 Causes of climate change

The global and regional climate change process due to anthropogenic use of fossil fuels started at the last of the 20th century, due to a steep increase in atmospheric carbon dioxide, methane, and nitrous oxide.

Climate change is majorly due to an increase in the global human population, and an increase in the people leads to severe energy demand in all the sectors. For example, underdeveloped countries have a higher growth rate of population than developed nations. The energy demand is often met with improper or conventional energy sources in the undeveloped countries; on the other hand, some parts of developed nations are switching to renewable sources rather than conventional fossil fuel sources.

Fossil fuel use as an energy source has been increasing since the Industrial Revolution in the 1700s. The primary fossil fuels used are natural gas (34% source of energy in USA) and coal (10% source of energy in USA) (EIA, 2020). **Figure 1** show the energy consumption by source in the U.S for 2020.

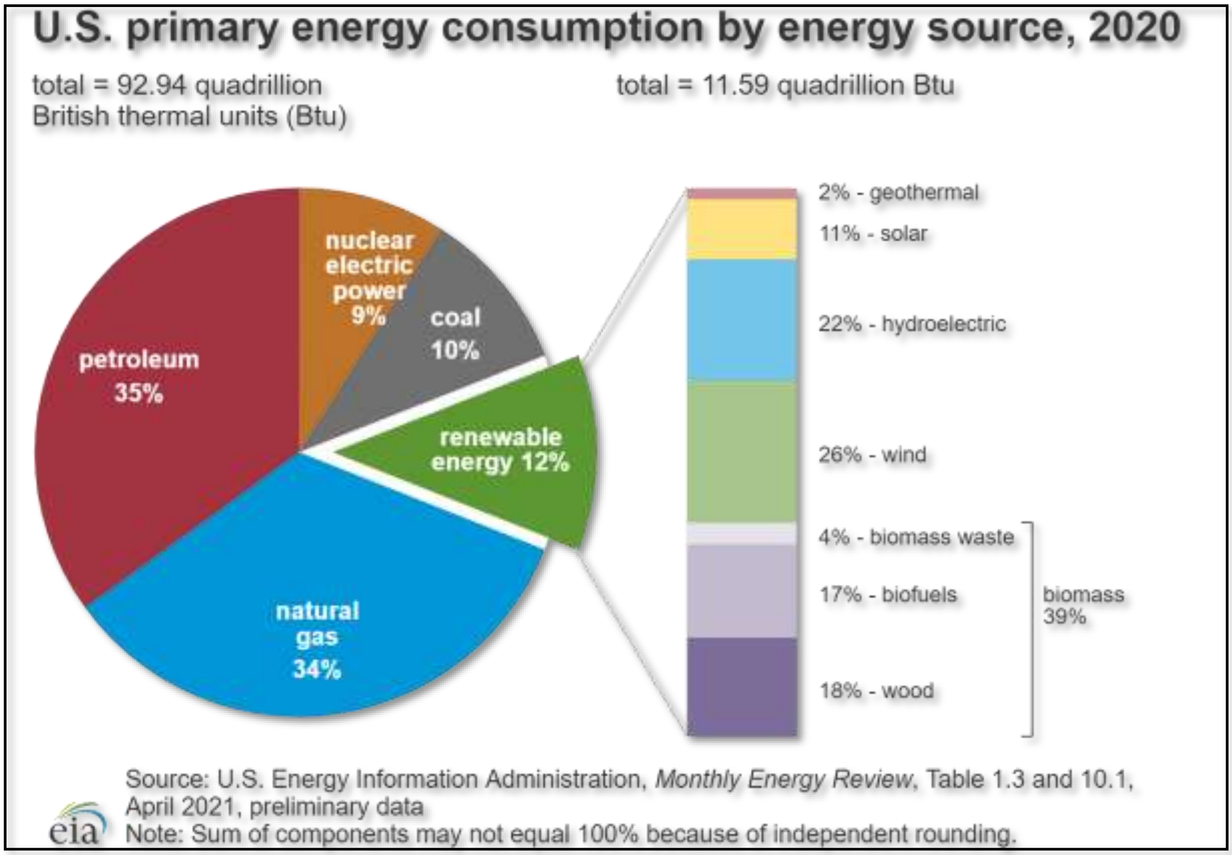

Figure 1. Monthly energy source distribution in the U.S for April 2021

When used as energy sources, fossil fuels are usually burned in furnaces to produce thermal energy, which is used to heat the water into steam. The steam at a high temperature and pressure will lead to the mechanical motion of turbines, and this mechanical movement is converted into electrical energy with the help of an electro-motive generator. This process requires a large initial amount of fossil fuel to produce the heat, resulting in large amounts of carbon dioxide emissions. The type of coal also determines the amount of carbon emissions produced in the process; for example, one pound of anthracite type coal will have 1300 to 1500 BTU of energy and GHG emissions of 228.6 MTCDE per million BTU (EIA, 2021). Good quality coal like anthracite will produce fewer emissions more energy output; a good quality coal will also occupy a smaller space, which will lessen the supply chain emissions for the energy production. Even though anthracite has a good efficiency in energy production and produces less emissions, there is less than 1% of the mined coal of this type. Bituminous coal is accounted for about 44% of the U.S coal production and is the best available coal for reduced emissions with a higher energy output; other types of coal widely used are sub-bituminous and lignite (EIA, 2020).

The GHG emissions produced from commercial, residential, industrial and transportation sectors build up in the Earth's atmosphere. According to **Figure 2,** industrial activities are the greatest contributor to the GHG emissions in the U.S, with 33%, followed by transportation (EIA, 2020). **Figure 2** represents the distribution of energy consumption by end-use sectors in the U.S.

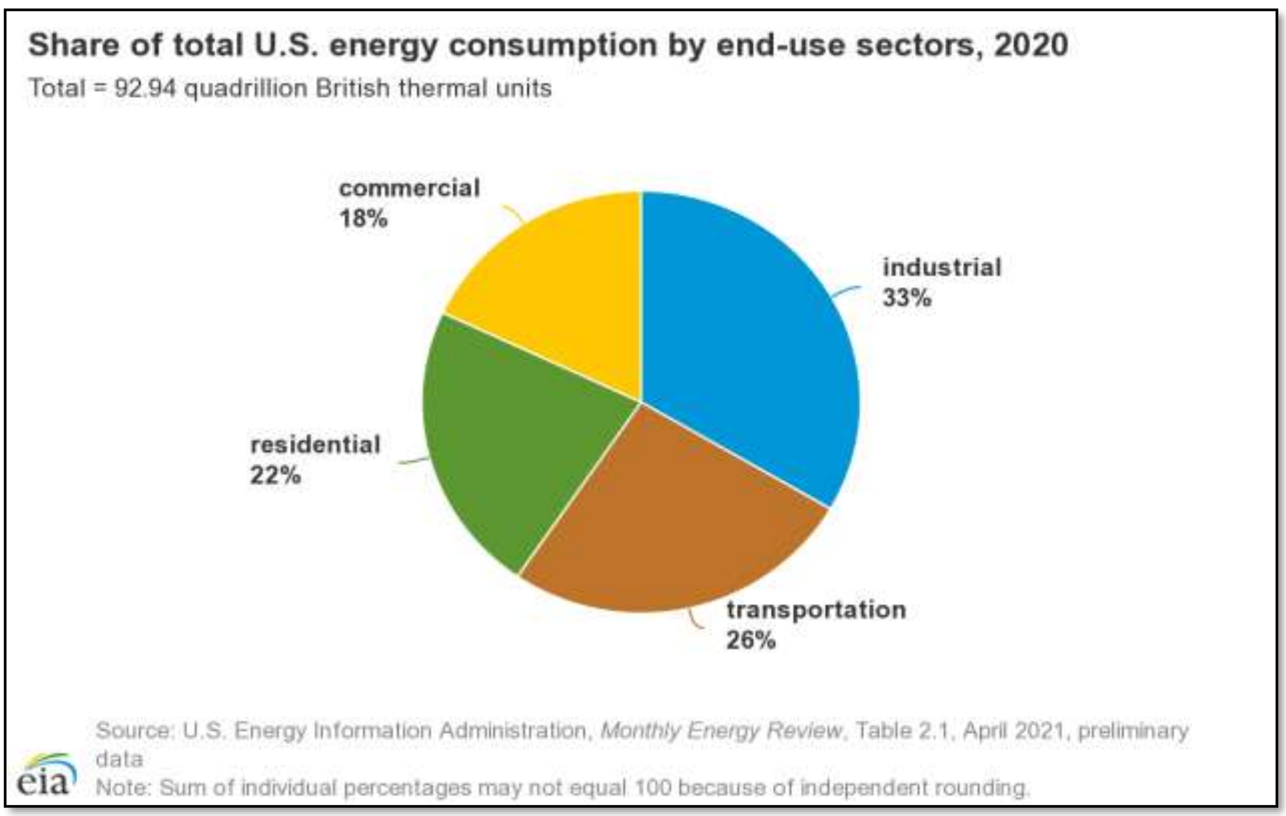

Figure 2. Distribution of energy consumption by end-use sectors in the U.S

2.2 Effects of climate change

Trapped heat causes a global increase in temperature. The global average temperature since the Industrial Revolution has increased by 1.5 °C. An increase of 1.1–6.4°C above the average global 1990 temperature is forecast by the year 2100 (IPCC, 2021).

An increase in global temperature has been found in both the earth's atmosphere and water bodies. According to a study conducted by Illinois State University, lakes globally have experienced an average temperature increase of 0.61 ℃s Fahrenheit. The average ocean temperature is predicted to increase by 1 to 4℃ by the year 2100 (IPCC, 2013). Temperature increases in water bodies melt the ice caps in the polar region and pose a severe threat to the aquatic habitats in the region. For example, due to the increase in lake temperature of 13℃, there has been a decline in the population of *Salvelinus fontinalis* and *Salvelinus alpinus* type of species in the lake with a mortality of approximately 30%. (Prokešová, et al., 2020)

The earth has two major ice masses, namely the Antarctic and Arctic regions. Both the regions are in the process of melting, and it is predicted that the 2030s will completely melt the Arctic region if the current trend of temperature change occurs, according to a report by the Arctic Council's Monitoring and Assessment Program (AMAP, 2021). There is a rapid freezing and thawing process for Antarctica, and studies show that the region is currently developing a crack that will soon form the enormous icebergs recorded in human history. It is also rereported that the ice cap loss for each annual cycle in Antarctica is increasing, but this is not the case for the Arctic region. The Arctic region has ice enclosed by landmasses on all sides; the formation of this sea ice decreases every year (National Snow and Ice Data Center, 2021)

As discussed above, the increase in global mean temperature and water body temperature has caused a melting of glaciers and ice caps and thermal expansion of seawater. This has led to an increase in the mean sea level, which will cause coastal regions like Japan to be permanently under water. It is forecast that about 63-72 km^2 of Japan will be flooded by the year 2090 due to climate change (Suzuki, 2009). The increase in global temperature will also change the regional climate (Risser, 2017); for example, the region of the panhandle in Texas is projected to have longer winters with higher intensity rainfalls, while the spring and fall will have fewer intensity rainfalls. (Jiang, 2012) Conditions like this will make disaster more prone and lead to the large displacement of people in coastal regions or riverbanks. High abnormal rainfalls lead to excessive flooding due to storm drains and catchment basin overflows (Wasko, 2017; Wasko et al., 2019).

A tide gauge or satellite image usually measures the slow but steady increase in global sea level. The rise of the worldwide sea level started in the late 1880s and has been in an increasing pattern ever since, and it is studied that the global mean sea level has increased approximately 8 inches since 1900. Although the average global mean sea level increase is 8 inches, some places are noted to have more than 8 inches of sea-level rise. The primary issue with an alarming rise in sea level is the increased frequency of floods and flooding of coastal and riverine areas (U.S Global Change Research Program, 2021). A pictorial depiction of the global average sea level increase is shown in **Figure 3.**

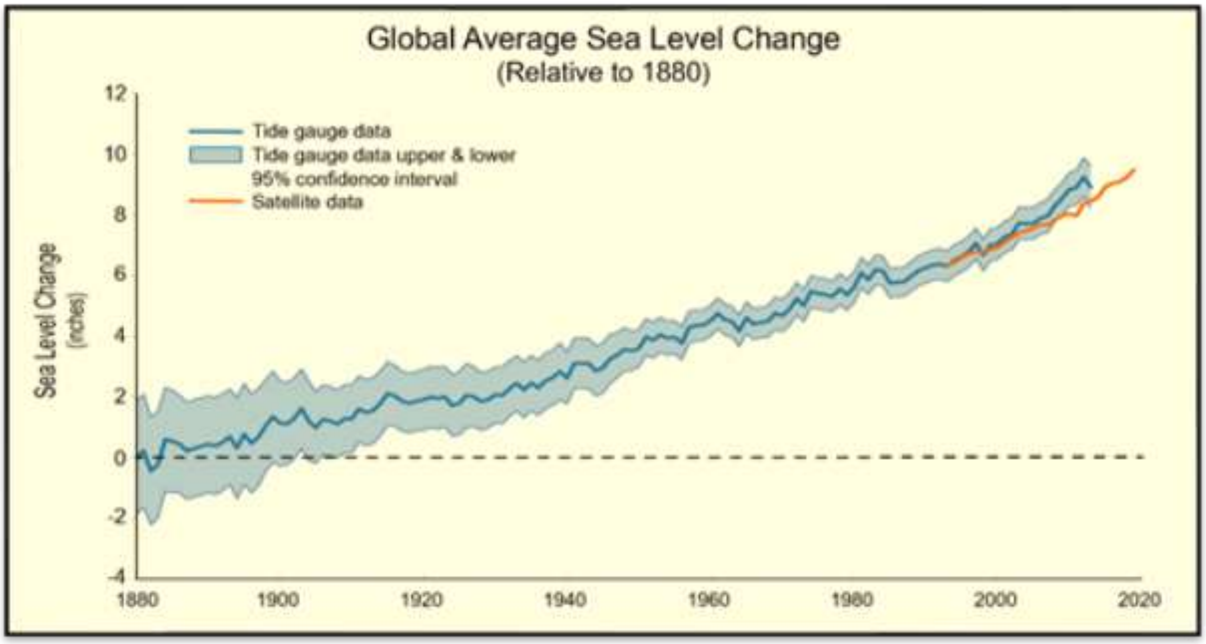

Figure 3. Global average sea level increase relative to 1880 (U.S Global Change Research Program, 2021)

The riverbanks and coastal regions are the birth and cradle for all the ancient and present human civilizations; according to Forbes, about 600 million people live in the coastal or riverbank region in the whole world. According to NASA's Sea-level projection tool, several cities like Tampa, Houston, Galveston, and Boston are to be partially or entirely flooded with seawater.

Flash floods and hurricanes have become more intense, and with high frequency in recent times, this can also be related to climate change and rising sea levels. According to the Center for climate and energy solutions, the number of tropical cyclones is projected to increase globally by 1% to 10% for a 2℃ global temperature increase.

The heat island effect is the phenomenon of high-temperature weather or climate conditions in a highly populated or urbanized area. This high temperature is caused due to the high number of urban buildings and less forestry and landscaping in these regions. These infrastructures tend to absorb more heat and reemit the radiation more than the landscape and forestry. High temperatures are more common at night than in the day.

Increasing global warming has changed the earth's moisture supply and demand; because of this, about two-thirds of the worldwide population will experience a prolonged drought in the coming years. The global draught period is to increase with a rate of 2 months per ℃ increase in global temperature and a 3 ℃ increase in global mean temperature will prolong a mean draught period to 4.2 months (Naumann et al., 2018). The state of California has experienced about a 20% increase in the frequency of wildfires in recent years. It has been found that the autumn temperature has increased to 1 ℃ Celsius, with a 30% decrease in precipitation, over the past four decades (Goss et al., 2020).

Global warming not only affects the earth by its climate change, but it also affects the earth from a socio-economical prospect. It is reported that the impacts like real estate losses, energy costs, and hurricane damages created by global warming will have a 1.9 trillion annually, or 1.8 percent of U.S GDP, by 2100.

2.3 Chemistry behind greenhouse gas production

Fossil fuels are the major source of greenhouse gases; the production of greenhouse gases during combustion of these fuels are listed below:

1. Methane during combustion:

$$\mathbf{CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)}$$

Natural gas is 70-90% methane. Methane is generally captured from landfills; it has an alternative name as landfill gas. Landfill gas is about 50% methane and 50% carbon dioxide. This methane gas is used as a source of energy with the help of a turbine or engine.

2. Propane during combustion:

C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$(g)

Propane is generally used for home and water heating and cooking purposes. It is also widely used in various industries as fuel to forklifts.

3. Coal during combustion:

Coal has a composition of carbon, hydrogen, oxygen, sulfur, and ash. Showing only the carbon content of the coal, its combustion can be simplified as:

$C + O_2 \rightarrow CO_2 + 33.94$ kJ /g of C

The amount of heat generated by one gram of coal depends on the composition of the coal and the amount of air supplied to the system. Likewise, the quality of the pollutants released during this exothermic reaction also depends on the type of coal and the amount of oxygen supplied.

The amount of heat required to ignite the coal to produce heat energy is also based on the composition of the coal. For example, a gram of bituminous coal will have more heat energy as a source than peat coal.

4. Diesel during combustion:

Diesel based on petroleum has 75% saturated hydrocarbons (both iso and cyclo paraffins) and 25% aromatic hydrocarbons like naphthalenes and alkylbenzenes. The average chemical formula for common diesel fuel is $C_{12}H_{23}$, ranging from approximately $C_{10}H_{20}$ to $C_{15}H_{28}$. $C_{13}H_{28}$ (tridecane) is widely used in jet fuel research. Using a simplified formulation of diesel, diesel combustion can be represented as:

$$\mathbf{4\ C_{12}H_{23} + 71\ O_2 \rightarrow 48\ CO_2 + 46\ H_2O}$$

or

$$\mathbf{C_{13}H_{28} + 20O_2 \rightarrow 13CO_2 + 14H_2O}$$

Energy is released in a series of small explosions (combustion) as fuel reacts chemically with oxygen from the air.

5. Gasoline during combustion:

Considering octane as a representative compound in gasoline.

$$\mathbf{2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)}$$

2.4 Impact of higher education institutions on greenhouse gas emissions

Higher education is a form of education that occurs once secondary education is completed; it consists of doctoral universities, colleges, polytechnic, and teacher training institutes. According to the 2017 UNESCO report, the number of students attending higher education has risen from 100 million to 207 million between 2000 and 2014 globally (Hanson, 2021). The higher education enrollment in the year 2019 is about 19.6 million, which is approximately 6% of the U.S population (Hanson, 2021). This is a large sample of the population with a daily routine of activities that contribute to the annual emissions of the U.S; according to the U.S Institutions of Higher Education, approximately about 121 million MTCDE or 2% of the U.S greenhouse gasses are due to the student population (USIHE, 2021). An average full-time equivalent (FTE) student in the U.S higher education has an emission of 7.67 MTCDE (Sinha et al., 2021).

The number of higher educational institutions has increased by about 12 % from the year 1990 (3,706) to 2019 (3,982) (NCES, 2021). This increase may lead to increasing the global and U.S annual emissions. The Metroplex region of Texas had a university student population of 309,686 and 344,167 in the year 2010 and 2020, respectively. This is forecasted to grow to about 436,564, making the Metroplex region the highest student enrollment (THECB CBM001; Texas Demographic Center Population Projections, 2018).

Higher education institutions are growing at a faster rate in developing countries like China and India than the developed countries like the U.S and United Kingdom, as developed countries already have an established education organization (Marginson, 2016). For example, the number of universities in China increased from 2,305 to 2,688 in the time frame of 10 years from 2009 to 2019. The country currently holds about 30.3 million students in 2019 (Textor, 2020). This increase has a positive aspect of social and economic growth, but it will also negatively impact if the emissions are left unchecked.

There is a direct link between the higher education system and greenhouse gas emissions. Higher education is a place where several students, faculty, and staff work to promote academic excellence and research. This is a place where energy resources are used all day and all week throughout the year. More than 75% percent of the students in an average U.S university are commuters (Horn, 1998).

Several factors determine a higher education initiation's emissions inventory. The location of the higher education institution is essential and its connection with major cities along with a public transportation transit. According to data collected from previous reports on AASHE STARS, universities near large metropolitan cities have fewer emissions than the universities which are located far from the major cities with no public transportation. The University of Illinois Chicago, which is in the heart of the city of Chicago, has lesser emissions (294,424 MTCDE) compared to the emissions (383,298 MTCDE) at the University of Illinois, Urbana-Champaign, located in a college town of Champaign, Illinois. (AASHE STARS reports, 2021)

There are several college towns in the U.S; a college town is a town that is dominated by its university population. Emissions from these towns are likely also dominated by emissions from the college/university.

The large student population associated with college towns will increase energy requirements. The grid systems at cities and towns depend on electricity located miles away (ECRPC, 2014). The energy losses due to the electrical power transmission are researched by the U.S. Energy Information Administration (EIA) that about 5% percent of the total energy produced by the U.S power plants is lost due to transmission.

Considering that about 6% percent of the U.S population is attending universities, the emissions inventory for this sector is needed to access the progress of higher education on its road towards carbon neutrality and zero emissions. There are about 3,982 higher education institutions in the U.S. Considering that higher education institutions are the place where students, the future generation of humans thrive, experience, and learn, it is important for universities to educate students about why climate change is a concern. It is estimated that a graduate student with a course on carbon emissions and its impacts will reduce their individual carbon emissions by 2.86 tons per year. (Little et al., 2014).

Higher education institutions that estimate their emissions inventory will have a basic idea of how they perform compared to other institutions. It is researched that institutions that periodically estimate their GHG emissions inventory have managed to reduce their GHG emissions better than institutions that have not regularly tracked them.

2.5 Greenhouse gas emissions inventory data sources for higher education institutions

Higher education institutions generally include all three scopes to determine the GHG emissions of the institution, according to the World Resources Institute (WRI) international GHG protocol. Scope 1 emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Scope 3 includes all other indirect emissions that occur in a company's value chain. A pictorial representation of various major contributors to all three scopes as per the WRI/ WBCSD standard is depicted in **Figure 4.**

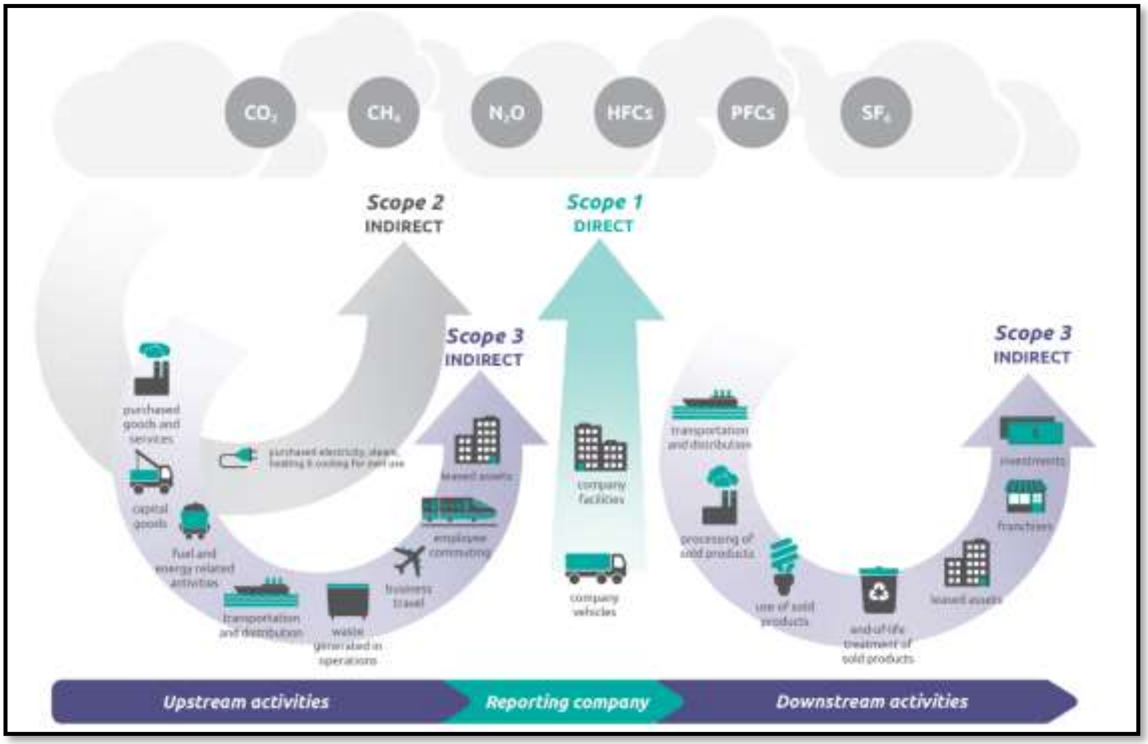

Figure 4. Representation of major contributors to all three scopes *(Adapted from WRI/WBCSD GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard)*

2.6 An overview of UT Arlington

History about the University

UT Arlington was founded in the year 1895 and was part of the Texas A&M University system until it joined the University of Texas System in 1965. The university is in the heart of the city of Arlington, about 0.62 miles from downtown. UT Arlington makes the city of Arlington a college town. The university was classified as a tier-one university in the year 2021 and R1: Doctoral Universities – Very high research activity. (Carnegie Classification of Institutions of Higher Education, 2021) According to the fall 2019 census, the university has a total enrolment of

43,863 students, making it the largest higher education institute in the North Texas region and the fourth most prominent in the whole state of Texas (UTA, 2021).

In 2019, UT Arlington had a total student enrolment of 48,635, with 34,820 undergraduates and 13,815 graduate students. The university has a faculty and staff count of 1004 and 2,165, respectively. The institution offers about 180 majors and a student-to-faculty ratio of 24: 1.

UT Arlington’s student population has grown 7.3% over fall 2015. The city of Arlington's population growth rate is also at a growing rate, which can be related to the university's growth. UT Arlington has an increase in area from 4,993,909 square feet to 6,181,543 square feet from the year 2009 to 2019, which is estimated to be about a 24% increase; this is due to the rise in enrollment. The increase in area and population will influence the GHG emissions inventory of the university in the coming future.

The city of Arlington was founded in the year 1876. Currently, the city is expanded to an area of about 99.44 Square miles, including both land and water masses, with a population of about 394,266, making it the 50th most populous city in the U.S. between 1980 and 2013. Arlington voters rejected three separate ballot proposals to bring public transportation to the city. However, certain political and economic realities particular to North Texas made successful passage of those measures arguably more demanding in Arlington than in other parts of the state or country. The City of Arlington has a lower average percentage of households without a car, only 3.7 percent in 2016, which is lower than the national average of 8.7. The average number of vehicles per household is 1.89, also higher than the national average of 1.8. This is mainly due to the lack of reliable public transportation and connectivity; a bus service was introduced in 2013 as a pilot program but was shut down. In December 2017, Via was introduced; Via is a shuttle service with a minivan vehicle. The only train station in the city of Arlington is the CentrePort station which connects the city with the two large cities nearby, Dallas and Fort Worth.

2.7 Need for greenhouse gas emissions inventory at UT Arlington

UT Arlington is a major part of the city of Arlington. UT Arlington's student population of 48,635 is 12 % of the whole City of Arlington's population. Accessing the GHG emissions inventory and making changes in the university will influence the entire City of Arlington's GHG emissions.

Of the 50 major higher educational institutions in the region of North Texas, UT Arlington has the largest student population. The university accounts for about 11% of the overall student population in the North Texas region.

2.8 Various tools and methods to assess greenhouse gas emissions

The AASHE stars report specifies the various green and sustainable initiatives taken on campus to tackle climate change; currently, about 1,045 institutions are reporting to this platform. AASHE awards platinum, gold, silver or bronze badge to universities according to the number of sections that are reported to the platform. AASHE reports serve as a vital benchmarking tool for comparing universities' greenhouse gas emissions. AASHE relies on self-reporting, which may limit the accuracy of the stars report.

The AASHE report presents the type of GHG emissions calculator each higher education institution uses. **Table 1** presents a sample of the calculator information from the AASHE report for 25 universities.

Table 1. Comparison of several University and method of estimating GHG emissions (*AASHE Stars Report, 2021)*

Higher Educational Institution	**Location**	**AASHE Rating**	**Type of Calculator Used**
Arizona State University	United States, Arizona	Platinum	SIMAP
Cornell University	United States, New York	Platinum	SIMAP
Stanford University	United States, California	Platinum	The Climate Registry’s (TCR) General Reporting
University of Houston	United States, Texas	Gold	SIMAP
University of California, Berkeley	United States, California	Platinum	SIMAP
University of California, Irvine	United States, California	Platinum	The Climate Registry’s (TCR) General Reporting
The State University of New York College of Environmental Science and Forestry	United States, New York	Platinum	EPA Calculator
University of Connecticut	The United States, Storrs, CT	Platinum	EPA Calculator
University of New Hampshire	The United States, New Hampshire	Platinum	SIMAP
Carnegie Mellon University	The United States, Pittsburgh, Pennsylvania	Gold	SIMAP
Columbia University	United States, New York	Gold	The Climate Registry's (TCR) General Reporting
Iowa State University	The United States, Ames, Iowa	Gold	Independent carbon calculation method
George Mason University	The United States, Fairfax, Virginia	Gold	SIMAP
Pennsylvania State University	The United States, University Park, Pennsylvania	Gold	Independent carbon calculation method
George Washington University	The United States, Washington, DC	Gold	SIMAP

Based on the data in the table above, it is found that about 50 % of the higher educational institutions use SIMAP as their primary GHG emissions calculating tool. Other methods include the EPA Calculator and Climate Registry's (TCR) General Reporting. Each of these is discussed in more detail below.

2.8.1 SIMAP:

SIMAP® (Sustainability Indicator Management and Analysis Platform) is a carbon and nitrogen-accounting platform that can track, analyze, and improve campus-wide sustainability. The carbon and nitrogen footprints include emissions in carbon dioxide (CO_2), methane (CH_4), nitric oxide (N_2O), nitrogen oxides (NO_x) and other forms of N, along with refrigerants/chemicals. The calculations for determining the GHG emissions are based on Greenhouse Gas Protocol based on Corporate Accounting and Reporting Standard (Greenhouse Gas Protocol, 2021). The primary source of nitrogen-based emissions calculations was based on the EPA US GHG inventory.

2.8.1.1 Method:

SIMAP provides a Campus Data Collection Template as a spreadsheet tool to help higher education institutions record their annual data from each data source. This spreadsheet can be imported into SIMAP's online platform, which will make the data entry process more efficient and less time-consuming. SIMAP is also currently piloting a projections and scenarios tool and interactive graphs. The graphs have features like direct download and displaying specific categories and labels.

SIMAP also uses factors like carbon dioxide sinks; sinks are carbon reservoirs that act as an opposite of a carbon emissions source. Natural sinks are oceans, which absorb CO_2 into the water, and plants, which use photosynthesis to remove carbon from the atmosphere by accumulation in the form of biomass.

The SIMAP tool integrates both carbon and nitrogen footprint for a higher educational institution. The nitrogen footprint calculation, along with carbon footprint, broadens the environmental impacts and helps in the assessment of reduction strategies.

SIMAP uses weighted campus users to determine emissions per capita, according to the AASHE STARS.

Weighted campus users = (A + B + C) + 0.75 [(D - A) + (E - B) – F] (SIMAP, 2021)

- A= number of students resident on-site
- B= number of employees resident on-site
- C= number of other individual's resident on-site and/or staffed hospital beds
- D= Total full-time equivalent student enrollment
- E= Full-time equivalent of employees (staff + faculty)
- F= Full-time equivalent of students enrolled exclusively in distance education."

2.8.1.2 Scope:

The GHG Protocol suggests choosing one of two approaches to set organizational boundaries: the control approach or the equity share approach. The control approach means that emissions are estimated for any operations over which the university has reasonable control, whether the facilities are owned or leased.

Since there are greenhouse gas emissions and nitrogen losses associated at some point with nearly every action we take and every product we use, this counting could go on forever.

Selecting operational boundaries is crucial for carbon and nitrogen management because it dictates how ambitious and comprehensive the carbon and nitrogen management efforts will be.

Scope 1 includes the following emissions sources:

- On-Campus Stationary Sources Emissions from all on-campus fuel combustion, excluding vehicle fuels
- Direct Transportation Sources Emissions from all fuel used in the institution's fleet (the vehicles it owns)
- Agriculture N_2O emissions from fertilizer use and CH_4 emissions from animals (cattle, horses, etc.)
- Refrigeration and other Chemicals Fugitive emissions from refrigerants and other sources

Scope 2 – Indirect emissions from sources that are neither owned nor operated by the institution but whose products require energy consumption. Scope 2 includes emissions from the production of electricity, steam purchased off-campus, and chilled water from off-campus. Renewable Energy Certificates (REC) are also a part of Scope 2 according to SIMAP's methodology.

According to EPA, an REC is a tradeable, market-based instrument that represents the legal property rights to the "renewable-ness"—or all non-power attributes—of renewable electricity generation.

Scope 3 includes other emissions attributed to a university, deemed "optional" emissions by corporate inventories. This includes emissions from sources that are neither owned nor operated by the university but are either directly financed (i.e., commercial air travel paid for by the institution) or otherwise linked to the campus via influence or encouragement. Scope 3 includes the following emissions sources:

- Student, staff, and faculty commuting
- Study abroad air travel
- Transportation and distribution losses from purchased electricity
- Food- emissions from producing, transporting, preparing, consuming, and composting.
- Solid waste and wastewater
- Upstream emissions- emissions associated with the production of paper, food, and fuel extraction.
- Financed outsourced travel- emissions associated with business trips

SIMAP is used by higher educational institutions like Arizona State University, Cornell University, and the University of Houston.

2.8.2 EPA Calculator

The Environmental Protection Agency (EPA) formulated a simple tool to track GHG inventories at a corporate level. The tool was prepared by the Center for Corporate Climate Leadership with the guidance of The Greenhouse Gas Protocol and Reporting Standard (GHG Protocol Corporate Standard) developed by the World Resources Institute and the World Business Council for Sustainable Development (WBCSD), which is a widely used common corporate GHG emissions standard.

2.8.2.1 Method:

The method is formulated according to the GHG Protocol Corporate Standard, including defining inventory boundaries, identifying GHG emission sources, tracking emissions, defining the boundary, and adjusting the base year for inventory study.

The GHG inventory development process includes:

- Review accounting standards and methods, determine the operational boundary, and a base year for the study.
- Collection and quantification of data and GHG emissions.
- Setting a target for GHG emissions reduction.

2.8.2.2 Scope:

Scope 1: These emissions are direct GHG emissions that occur from sources controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles).

Scope 2: These emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling.

Scope 3: These emissions result from activities not owned or controlled by the reporting organization, but that the organization indirectly impacts its value chain. Scope 3 emissions include all sources not within an organization's scope 1 and 2 boundaries. Scope 3 emissions, also referred to as value chain emissions, often represent most of an organization's total GHG emissions.

Both SIMAP and EPA share the same scopes; however, the tools are used for different sectors. The EPA's calculator is widely used in the corporate sector and is designed to fit the needs for industrial sector emissions quantification. Hence, EPA's carbon calculator tool can be used for a higher education institution's carbon inventory, but the results cannot be very meaningfully compared with another university's carbon inventory based on another tool.

Universities that have used EPA's carbon calculator include the University of Connecticut and The State University of New York College of Environmental Science and Forestry.

2.8.3 Climate Registry Information System (CRIS) by the Climate Registry:

The Climate Registry Information System is a public online reporting tool for higher educational institutions and facilities in the U.S. This online reporting platform structure can be compared to the AASHE stars reporting. The AASHE reporting is committed to writing all the sustainability activities and data, but the Climate Registry Information System focuses explicitly on GHG emissions inventory.

The CRIS is the Climate Registry's greenhouse gas measurement, reporting, and verification platform. Unlike SIMAP, this tool allows the user to compare similar GHG inventory reports and data. It is also to be noted that all the GHG reports, and data are in open access in the CRIS. The tool uses both location-based and market-based approaches to increase the accuracy for Scope 2 emissions (emissions due to purchased electricity).

2.8.3.1 Method

Several cities and counties have historically used the California Climate Action Registry's Online Tool (CARROT) to calculate and report greenhouse gas emissions. However, the California Climate Action Registry no longer registers greenhouse gas emission inventories. The California Climate Action Registry formed The Climate Registry, which offers the next generation of online reporting through The Climate Registry Information System (CRIS). Cities and counties can use CRIS to report their greenhouse gas emission inventories, which are third-party certified and available for public review.

Both SIMAP and CRIS share the same scope of carbon emissions quantifications. The CRIS calculator is widely used in the industrial and higher education sectors and is designed to support the needs of both industrial and higher educational institution sector emissions quantification. Hence, CRIS tool can be used for a higher education institution's carbon inventory, but the number of universities using this method is lower when compared to SIMAP. A more uniform way and tool to calculate GHG emissions inventories will be more accurate to compare.

2.8.3.2 Scope:

The three scopes are the same for CRIS as the other two tools mentioned above. Universities that use the CRIS tool include the University of California, Irvine, and Columbia University.

2.8.4 Choice of tool for this study

A decision-making matrix was used to choose the best tool for estimating GHG emissions for UTA (Table 2). Decision-making criteria were assigned weightings based on the importance of the category. Ratings were assigned based on how well each software alternative fulfilled each criteria.

2.8.4.1 Ease of data input and import: 15 points

A GHG emissions inventory process requires a lot of data collection and input. A good tool must meet this need and provide a user-friendly interface. This interface should be simple and should be able to take in Excel-based data sheets and upload them into the tool’s data storage. Thus, this criterion is given fifteen (15) points.

SIMAP - Awarded 12 points for its ease of input and import by a designed Excel-based template. This template can be filled and directly uploaded onto the online portal to fill in the data. The excel-based template is complex to understand with high number of input data making it a drawback, thus awarded with 12 points.

EPA Calculator - Awarded 7 points for its simple Excel-based format but lacked a user interface.

CRIS - Awarded 10 points for its ease of input and import but still lacks the Excel-based import function present on SIMAP.

2.8.4.2 Cloud-based storage: 15 points

A GHG emissions calculator must have ease of data input and output and have a solid database to store the previously entered data. This improves the user-friendliness and will lead to reliability. Furthermore, a cloud-based storage will make sure that the data are not tied under the user's storage but into a more reliable provider's server. This provides protection and ease of storage of GHG emissions data input/output, and thus is given fifteen(15) points.

SIMAP - Awarded 15 points for its online cloud-based data storage, which gives reliable data storage.

EPA Calculator - Awarded 1 point due to its basic Excel-based storage, which gives a risk of data loss or less security.

CRIS - Awarded 15 points for its online cloud-based data storage, which gives reliable storage of data.

2.8.4.3 Bench marking: 10 points

A GHG emissions calculator with a database that has all the Higher Educational Institutions around the world will be of great benefit to compare institution performance in terms of emissions. Thus, this criterion is given ten (10) points.

SIMAP - Awarded 7 points due to the higher cost for this feature.

EPA Calculator - Awarded with 1 point due to the lack of benchmarking feature.

CRIS - Awarded 8 points for its good benchmarking data sets. Emissions data from additional universities can be made available to improve its data set.

2.8.4.4 Trajectory or future projections: 10 points

The role of the GHG emissions calculator not only includes calculating emissions for the Higher Educational Institution but also projecting future anticipated GHG emissions. This will be helpful in the stakeholder policy making and hence is given ten (10) points.

SIMAP - Awarded 7 points for its new development on future projections, which was lacking in its counterparts. Future projections can be matched once the real-time emissions are calculated and reinforce the reliability of the projections. Early to award 10 points, as the feature is newly developed.

EPA Calculator - Awarded 1 point due to no future projections.

CRIS - Awarded with 1 point due to lack of future projections as a feature.

2.8.4.5 Relation to AASHE STARS reporting guidelines: 15 points

AASHE STARS is a recognized benchmarking tool and is closely connected with the SIMAP tool. Thus, this criterion is weighted fifteen (15) points.

SIMAP - Awarded 15 points for to its wide usage on universities awarded with AASHE STARS reporting badges.

EPA Calculator - Awarded 1 point due to lack of link with AASHE STARS reporting requirements.

CRIS - Awarded 1 point due to lack of link with AASHE STARS reporting requirement.

2.8.4.6 Usage among Higher Education Institutions: 20 points

This criterion was given the maximum points of twenty (20) due to higher usage among Higher Education Institutions as a primary GHG emissions inventory tool. A standardized tool will ease comparison and benchmarking for research and policy making as the methodology and emission factors used remain the same.

SIMAP - Awarded 15 points for its higher usage as a GHG emissions tool on the AASHE STARS university reporting data.

EPA Calculator - Awarded 5 points due to its less usage as a GHG emissions tool on the AASHE STARS university reporting data.

CRIS - Awarded 10 points for its moderate usage as a GHG emissions tool on the AASHE STARS university reporting data.

2.8.4.7 Cost: 5 points

The cost was given the minimum weightage points of five (5) because it is assumed that the university budget can easily cover the cost of the GHG emissions tool ($500-$1000), so this is not a significant factor in the decision-making.

SIMAP - Awarded 3 points due to its cost of around $ 600 for tier 2 and $400 for tier two. Even though SIMAP has a price for its software, the team gives researchers and universities a free access for a year upon filling out a request form.

EPA Calculator - Awarded 5 points for its being free.

CRIS - Awarded 2 points due to its cost of approximately $ 700 or a donation of $1000 to join as a CRIS member.

Table 2. Decision-making matrix for determining the best tool for estimating GHG emissions for UTA

		SIMAP		**EPA Calculator**		**CRIS**	
Criteria	Weight-age points	Rating	Weightage * Rating	Rating	Weightage * Rating	Rating	Weightage * Rating
Ease of data input and import	15	12	180	7	105	10	150
Cloud based storage	15	15	225	1	15	15	225
Bench marking	10	7	70	1	10	8	80
Trajectory or future projections	10	7	70	1	10	1	10
Relation with AASHE STARS reporting guideline	15	15	225	1	15	1	15
Usage among Higher Education Institutions	20	15	300	5	100	10	200
Cost	5	3	15	5	25	2	10
Total points			**1085**		**280**		**690**

SIMAP was selected as the best tool for UTA's GHG emissions inventory, as it has the highest score in Table 2, and for the following reasons:

- More universities use SIMAP as their primary GHG emissions inventory tool than the other tools, making it easier to compare and benchmark GHG emissions from several universities.
- Requirements for AASHE STARS emissions reporting is met with the help of SIMAP.
- Ability to manage and compare campuses and buildings,
- Customizable report templates with interactive auto-generated graphs,
- Complete Scope 3 reporting module (based on the WRI Scope 3 Protocol),
- "Projections" and "solutions" analysis to assist with Climate Action Planning,
- Dedicated one-on-one inventory support and advise available,
- University friendly user interface and guidance,
- Features like cloud storage, data collection import, benchmarking, and trajectory analyses.

2.10. Additional literature review

Table 3 summarizes additional literature concerning GHG emissions inventories for a higher education institution.

Table 3. Literature concerning greenhouse gas emissions inventories for higher education institutions

Author: Matthew Moerschbaecher and John W. Day Jr., 2010		**CO_2-eq./student (MTCDE per Student):** 6.1
Name of the University: Louisiana State University		**State of the University:** Louisiana, USA
Scopes: Scope 1,2,3	**GHGs (MTCDE):** 162,74	**Software:** CACP calculator (SIMAP)
Reduction Strategies: • Metasys and Building Automation System • Developing safe, accessible bicycle transportation corridors and more convenient public transportation • Decreasing air travel can be accomplished by increasing conference calls and telecommunications technology such as videoconferencing. • The transition from a five-day to a four-day workweek. • Solar is a viable way to generate renewable energy on campus **Additional information:** • Electricity produced with natural gas at the cogeneration facility results in less GHG emissions than electricity purchased from the local utility with variable source production including natural gas, coal, nuclear, and distillate oil.		

Author: Raeanne Clabeaux, Michael Carbajales-Dale, David Ladner, Terry Walker, 2020		**CO_2-eq./student (MTCDE per Student):** 4.4
Name of the University: Clemson University		**State of the University:** South Carolina, USA
Scopes GHGs (MTCDE): Scope 1,2,3	**GHGs (MTCDE):** 95,418	**Software:** Streamlined life cycle

Reduction Strategies:

- As a major electricity customer, HEI can also encourage and even partner with energy providers to add more renewable energy to their electricity generation resource mix to dramatically decrease their carbon footprint.
- Forestry management.
- Due to the various operations at HEIs, it is encouraged that future carbon footprint studies report all their GHG emission sources, discuss data assumptions, and state the life cycle phases included in their evaluation. This will enable more thorough comparisons and benchmarking between HEI's carbon footprint.

Additional information:

- GHG emission sources that could be assessed include composting, agriculture, food, beverages, furniture, laboratory supplies, maintenance supplies, machinery, infrastructure, and construction activities.
- Natural gas leakage
- Landfilling and recycling

Author: Pablo Yañez, Arijit Sinha, Marcia Vásquez, 2019		**CO_2-eq./student (MTCDE per Student):** 0.41
Name of the University: The University of Talca (UT)		**State of the University:** Talca, Chile
Scopes GHGs (MTCDE): Scope 1,2,3	**GHGs (MTCDE):** 5,472	**Software:** GHG Protocol, WRI and WBCSD

Reduction Strategies:

- energy management system (ISO 50001)
- creating a fully residential campus
- carpooling and traveling by bike should be encouraged
- accurate maintenance of boilers

Additional Information:

According to Ugle et al.:

- one ton of carbon storage in a tree represents the removal of 3.67 t of carbon from the atmosphere and
- the release of 2.67 t of oxygen back into the atmosphere.

Author: Amy Thompson, Matthew Altonji 2011	**CO_2-eq./student (MTCDE per Student):** 1.77
Name of the University: The University of New Haven, Loyalton 2008	**State of the University:** Connecticut, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **GHGs (MTCDE):** 7169.9	**Software:** WRI /WBSCD Clean Air-Cool Planet (CA-CP) (SIMAP)
Reduction Strategies: **Additional Information:** • includes new categories such as commuting, fertilizer usage, university-related travel.	

Author: Cynthia Klein-Banai, Thomas L. Theis, Thomas A. Brecheisen, Alona Banai **CO_2-eq./Square Footage (MTCDE per Student):** 18.4	
Name of the University: The University of Illinois in Chicago (UIC) 2004 -2008	**State of the University:** Illinois, Chicago, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **Software:** Greenhouse Gas Protocol By WBCSD/WRI, 2001 Clean Air-Cool Planet (SIMAP)	**GHGs (MTCDE):** 275,000 (2008)
• Meter the largest and most energy-consuming buildings on campus through state-of-the-art electronic meters for electricity, chilled water, high temperature hot water, and steam. light-emitting diodes LEDs • Leadership in Energy and Environmental Design LEED Silver standard • Solar photovoltaic system on the roof of one of the classroom buildings. seeking a biogas or other renewable energy source for UIC's gas fired power plants.	

Author: Matthew J. Eckelman	**CO_2-eq./student (MTCDE per Student):** N/A
Name of the University: Yale University 2003 -2008	**State of the University:** New Haven, Connecticut, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **Software:** Campus Carbon Calculator/ Clean Air-Cool Planet (CA-CP) (SIMAP)	**GHGs (MTCDE):** 325,000
• Economic input-output-LCA (EIO-LCA), which allows the analyst to consider the complete supply chain of each item without onerous data requirements.	

Author: Sustainability operations Fiscal year 2019 Review and AASHE reporting **CO_2-eq./student (MTCDE per Student):** 1.50 and 4.53 per GSF		
Name of the University: Arizona University, 2020		**State of the University:** Arizona, USA
Scopes GHGs (MTCDE): Scope 1,2,3	**GHGs (MTCDE):** 110,164	**Software:** SIMAP
Reduction Strategies: • Electronic Product Environmental Assessment Tool (EPEAT) to buy and sell environmentally preferable electronic products. • ASU's solar power generation • Ditch the dumpster • Carbon offsets and renewable energy certificates • Tree plantings • Low on food chain, self-grown gardens • Lean Path Food waste tracking system for the reduction in pre-consumer food waste • Water meters and Hydrogel and injection technique for a reduction in water consumption • Replacing water fixtures • Volunteers for sorting program		

Author: The Climate Action Plan (CAP) 2013, AASHE STARS reports	**CO_2-eq./student (MTCDE per Student):** 8.63
Name of the University: Cornell University, 2019	**State of the University:** New York City, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **GHGs (MTCDE):** 203,000	**Software:** SIMAP

Reduction Strategies:

- Solar power
- Regional wind generation capacity and integrate wind power
- Enhanced Geothermal System (EGS) hybridized with biogas
- Utilize supply and demand management technologies to optimize the campus electrical system
- Cornell's online Procurement Gateway to facilitate purchasing of sustainable office equipment and supplies, recycled paper, remanufactured toner, EPEAT certified computers
- Consider sustainability criteria, including locality and GHG emissions

Author: AASHE campus sustainability hub, Megan Zanella-Litke 2018		**CO_2-eq./student (MTCDE per Student):** 1.59
Name of the University: American University 2018- 2020		**State of the University:** Washington D.C, USA
Scopes GHGs (MTCDE): Scope 1,2,3	**GHGs (MTCDE):** 21,424	**Software:** SIMAP
Reduction Strategies: •Solar thermal panels •Transitioned from a centralized steam plant to a decentralized low-temperature hot water system, substantially decreasing natural gas and electricity use. •Landfill gas capture projects turn garbage into power. Organic waste breaks down without oxygen, it releases methane, a greenhouse gas 28 times more powerful than carbon dioxide. • A.U. also purchases Green-e certified renewable energy credits • Local tree plantings •Study Abroad travel emissions are offset by energy efficient cookstoves		

Author: Colorado State University report, 2019 **CO_2-eq./student (MTCDE per Student):** 4.8
Name of the University: Colorado State University, 2019 **State of the University:** Colorado, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **GHGs (MTCDE):** 178,300 (On AASHE STARS portal) **Software:** SIMAP

Author: UC Berkeley 2019 **CO_2-eq./student (MTCDE per Student):** N/A
Name of the University: UC Berkeley **State of the University:** California, USA
Scopes GHGs (MTCDE): Scope 1,2,3 **GHGs (MTCDE):** 178,300 (On AASHE STARS portal) **Software:** SIMAP

Author: Leonardo Vasquez, Alfredo Iriarte, María Almeida, Pablo Villalobos, 2015 **CO_2-eq./student (MTCDE per Student):** 1.0
Name of the University: Universidad de Talca. **State of the University:** Talca, Chile
Scopes GHGs (MTCDE): Scope 1,2,3 **GHGs (MTCDE):** 1568.6 **Software:** (WRI/WBCSD)
Reduction Strategies: • High use of public transportation by students • Replace the use of motorized vehicles (bus, automobile, and motorcycle) for bicycles Additional Information: • Compared the developing nation universities

Author: Julien Arsenault, Julie Talbot, Lama Boustani, Rodolphe Gonzalès, Kevin Manaugh		**CO_2eq./student (MTCDE per Student):** 3.85
Name of the University: Université de Montréal, 2019		**State of the University:** Montréal, CA
Scopes GHGs (MTCDE): Scope 1,2,3	**GHGs (MTCDE):** 67,603	**Software:** SIMAP

Reduction Strategies:

- Promote virtual conferences and reduce on-site meetings and possible work from home research

Additional Information:

- Compared the developing nation universities
- Has insights into SIMAP and its methodologies
- Includes a global map with the most travelled locations by the student, faculty, and staff

2.10.1 Summary based on the additional literature review:

Based on the literature review on several research papers and articles the following information were deduced. A summary of the GHG emissions per student is listed in **Table 4.**

- Reducing all possible conferences and travel that can be completed on an online video conference setup. The effect of this new type of interaction has led to the decrease in 2020 post pandemic emissions.
- To recognize a global standard GHG emissions inventory calculator tool and a global benchmarking portal like AASHE STARS to compare various GHG emissions. This will help in the stakeholder decision-making policies and find new insights on how to tackle GHG emissions on particular scopes.
- Use of transportation on a Higher Educational Institution and its importance on GHG emissions. A reliable public transportation system near a Higher Educational Institution was an extensively proposed reduction strategy.
- Implement renewable sources on energy to suffice the Higher Educational Institution's energy demand. Placement of solar panels on possible locations to generate solar energy.
- We are introducing environmental awareness groups to promote the raising concern of climate change and GHG emissions.
- Use of unused land cover at the Higher Educational Institution for tree planting initiatives.
- Purchase and maintenance of carbon offsets and renewable energy certificates

Table 4. Summary of CO_2 equivalents per student at various universities based on literature review:

Name of the university	**CO_2 equivalent per student (MTCDE per Student):**
American University	1.59
Arizona University	1.5
Clemson University	4.4
Colorado State University	4.8
Cornell University	8.63
Louisiana State University	6.1
The University of Illinois in Chicago (UIC)	18.4
The University of New Haven	1.77
The University of Talca (UT)	0.41
Université de Montréal	3.85

Chapter 3 Methodology for Emissions Inventory

3.1 Software

The SIMAP software uses an Excel-based format to calculate the carbon inventory of a campus. All the emissions factors which are used in SIMAP are taken from US EPA (Environmental Protection Agency) official website and other references, as mentioned at the reference section.

SIMAP guides universities in estimating emissions in 3 areas or scopes:

SCOPE 1: DIRECT CAMPUS EMISSIONS

- Stationary and mobile sources (energy used in buildings and fleets)
- Fugitive emissions (from fertilizers, animal husbandry and chemicals)

SCOPE 2: INDIRECT CAMPUS EMISSIONS

- Purchased electricity
- Purchased and sold renewable energy

SCOPE 3: INDIRECT TRANSPORTATION EMISSIONS

- Daily commutes to/from campus by students, faculty, and staff.
- Air travel associated with campus study abroad programs.
- Production, distribution, and/or provision of specific goods or services purchased by the university. These include business trips (by ground and air); food production and distribution; paper production (several types).
- Fugitive emissions are generated from the treatment of wastewater, or municipal solid waste storage sent to a landfill or stationary emissions from burning municipal solid waste sent to a waste-to-energy plant.

3.2 Base Year

The fiscal year 2005-06 was selected as the base year since it was the most recent year for which complete information was available for all indicators. For some indicators, data is available going back to 1990, but not for all indicators. Reduction goals in the Action Plan will use 2005-06 as the benchmark year.

3.3 Institutional Boundaries and Exclusions

Institutional boundaries were set to include all operations over which the university has control. All these entities work for the betterment of the university. Operations included within institutional boundaries were:

- Buildings owned and leased by UTA,
- Students, faculty, and staff commuting to and from campus,
- UTA shuttle, university fleet vehicles and other vehicles,
- Food raw materials purchased in Connection Café, Pie Five, and Starbucks represent food outlets within a 1.5-mile radius and with 90% or more UTA community walk-in, and for which data were available.
- Refrigerants used at UTA,
- Paper used at UTA.

Certain emissions were excluded due to insufficient input data or emissions not falling within the institutional boundaries listed above. Exclusions were:

- UTA’s remote campus activities and emissions,
- Emissions associated with UTA’s wastewater (which is conveyed to the Trinity River Authority Central Regional Wastewater System),
- Emissions associated with UTA’s landfilled waste (which is conveyed to the City of Arlington Landfill),
- Most of UTA’s food outlets were not considered (only Connection Café was included),
- Most food outlets within a 1.5-mile radius and with 90% or more UTA community walk in were not included because they did not have data available (only Pie Five and Starbucks had data available).
- Private food outlets outside the 1.5-mile radius from UTA with less than 90% UTA community walk-in,
- All other recyclable solid waste other than paper, since SIMAP only includes recycling of paper waste,
- All student/faculty/staff travel other than academic-based travel, e.g., a commute to a nearby restaurant.

3.4 Data Sources

Table 5 lists sources of data used as inputs to SIMAP. Specific categories of data are discussed in the sections below.

Table 5. Sources of data used as inputs to SIMAP

No.	Type of data	Source	Contact	Period of data received
1	• Total operating budget • Research budget • Energy budget • Total space • Laboratory space • Full time and part-time faculty count • Full time and part-time staff count	Bobby Childress, Associate Director of Data Analytics	childress@uta.edu	2015 -2018
2	• Full-Time-Equivalent Students • In-Seat Only - Headcount • Mixed Mode - Headcount • Online Only – Headcount	Bobby Childress, Associate Director of Data Analytics	childress@uta.edu	Fall 2016 – Fall 2019
3	• Connection Café product frequency data	David Aldape, Senior Executive, Compass Group	David.Aldape@compass-usa.com	2019
4	• Pie Five restaurant product frequency data	Outlet Manager	NA	2019
5	• Starbucks product frequency data	Jacqueline Meza, Outlet Manager	1511mgr@follett.com	2019
6	• UTA's energy data • UTA's athletic space	Patty Goodloe, Energy Analyst, Office of Facilities Management	patty@uta.edu	2016-2019
7	• UTA's international travel data	UTA Office of Public Records	publicrecords@uta.edu	2016- March 2020

NA- Not Available

3.4.1 General data

3.4.1.1 Budgets

Types of budgets at UTA include:

- Research budget - To calculate emissions per dollar research expenditure.
- Operating budget, which includes the energy budget- To calculate emissions per dollar of operating or energy expenditure.

The operating budget consists of all funding sources UTA has financial control over and is plainly considered the cost to operate the institution. The research budget includes all sources of financial funding for UTA research expenditures. The energy budget is the total spent on supplying the energy needs of all operations. The combined energy budget includes the budget for electricity, steam and chilled water, and on-campus stationary sources (heating, etc.). All 3 budgets were available for 2017 – 2019. The Office of Data Analytics provided the operational, research, and energy budgets, Office of Finance, and Administration, Office of Facilities Management, respectively.

3.4.1.2 Space

SIMAP uses the total space square footage values to determine the emissions per square foot. Types of space at UTA include:

- Overall space includes all space owned by UTA irrespective of its being used or unused. This includes building, open, research, and athletic space at UTA.
- Building space: all building space, including its exterior walls' outside faces. Including all vertical penetration areas for air circulation, e.g., shaft areas that connect one floor to another.
- Open space: all spaces including pavements, parks, and parking lots.

- Research space: all building and laboratory spaces that help UTA in its science and research endeavors.
- Athletic space includes all the space owned by UTA to help its athletic endeavours.

Total building size data and research building data were provided by the Office of Data Analytics for the fiscal years 2017 to 2019 in units of GSF (Gross Square Footage). GSF is defined as the sum of all areas on all floors of a building which are included within the outside faces of its exterior walls, including all vertical penetration areas, such as areas for circulation or ventilation and shaft areas that connect one floor to another. The open and athletic space data were obtained from UTA's Office of Facilities Management.

3.4.1.3 Population

Population data were not considered in the previous emissions reports due to the exclusion of scope 3 (commuting emissions). For UTA's 2019 emissions report, the population is considered to determine the Scope 3 commuting emissions. Commuting information is discussed in the section below.

The spring, fall and summer population were considered, including full-time and part-time students. Each category includes both graduate and undergraduate students. Faculty data also includes full-time and part-time. Staff data was also included. The information was produced by the Institutional Research, Planning and Effectiveness Office and provided to the research team by the Office of Data Analytics at UTA.

3.4.2 Energy and Fuel Data – Non-Transportation

3.4.2.1 Electricity Data

The e-grid sub-region was chosen as "ERCT" under the region "ERCOT (Electric Reliability Council of Texas) ALL" for pre- and post-2006 e-GRID sub-region choices. An e-grid sub-region represents a portion of the US power grid contained within a single North America

Electric Reliability Council (NERC) region and generally represents sections of the power grid that have similar emissions and resource mix characteristics may be partially isolated by transmission constraints. E-grid's emissions represent emissions from fuel only used for generating electricity. The UTA's electricity consumption data was obtained from the Office of Facilities Management.

Chilled water is generated using electricity and has already been accounted for in the "Purchased Electricity"; therefore, no data was entered for this section.

3.4.2.2 Stationary Fuel Data

All stationary fuel inputs which produce energy to power UTA-owned buildings and equipment were considered for this data input in SIMAP. The Office of Facilities Management at UTA provided data for fuel consumption of distillate oil and other stationary fuels (gasoline and diesel) used to maintain the facility equipment and generators for the fiscal years 2017 to 2019. UTA purchases its natural gas from various third-party contractors. Data for UTA's natural gas purchases from 2016-2019 were obtained from the Office of Facilities Management.

3.4.3 Transportation Data

3.4.3.1 International Travel Data

For the first time, international travel data is included in the UTA's GHG emissions report. This data was acquired from the Office of Public Records at UTA by officially filing a petition to access the data source. The data include all air travel by the UTA community (student/faculty/staff), which was reimbursed between the period of January 2016 to May 2020. The data was presented in travel origin and destinations. Travel distance was estimated with the help of an application called "distance.to" for bulk calculations," and miles travelled input into SIMAP. There was also a possibility in SIMAP application to feed the data in dollars spent for flight travel, but this possibility was ruled out due to its being less accurate. The cost of a trip can vary based on the choice of class (business or regular) or airline. In addition, the value of the dollar can either inflate or deflate each year; hence, the miles per dollar spent will vary for each year. However, the SIMAP tool does not have an inflation/deflation function to account for this.

3.4.3.2 Commute Data

This category includes annual miles traveled by faculty, staff, and students in commuting to and from campus. The software also has places for the user to input the distribution percentage of various commutes at UTA. Emissions from commuting are an integral part of the inventory because the university can influence this travel in the future by offering alternatives like buses, shuttles, or a car-sharing program.

A transportation survey conducted during summer 2020 for this report determined commute distances and the distribution of various commute modes. Survey Monkey formulated an interactive survey to determine the distance and modes that students, staff, and faculty travel to reach UTA. UTA's newspaper, *The Shorthorn* ran an article about the carbon emissions inventory and its importance, including an interview with UTA's Chief Sustainability Officer Meghna Tare (Shorthorn, 2020). The survey was sent to students, faculty, and staff in the College of Engineering by a direct email with the help of Jeremy Agor, Senior Director of Communications and Marketing for the College of Engineering. The survey was also included several times in the faculty/staff e-newsletter "Mav Wire" and the student e-newsletter "Trail Blazer."

According to the survey, the average days traveled by students, faculty, and staff together was approximate three days a week to UTA campus. Hence, an average of 6 commute trips per week (one to and one from campus each day) were taken into consideration for the group of students, faculty, and staff. To estimate commute emissions, spring and fall semesters were taken to be 16 weeks each, according to the university calendar, and summer was assumed to be 8 weeks (an average of the 5- and 11-week sessions). Summer commutes had been excluded from earlier UTA GHG emissions reports.

SIMAP did not have a separate input for electric/hybrid automobiles but assumed that all automobiles were in a single category. The option of separate emissions calculations for hybrid/electric automobiles and conventional automobiles will be available in the upcoming UTA carbon assessment tool. SIMAP also does not have features that compare emissions from one commute mode to another, e.g., car vs. bike.

3.4.3.3 UTA Vehicle Transportation Fuel Data

UTA operates various transportation services for its community, including shuttle services, Tap Ride safety escort cart service, and vehicle maintenance services. The Office of Facilities Management periodically recorded all the diesel and gasoline fleet data at UTA; this helped us assess the emissions for the fiscal year 2017- 2019.

Information provided by the Office of Facilities Management included gallons of gasoline and diesel fuel used by the university fleet for 2017 to 2019.

3.4.4 Water Consumption Data

The Office of Sustainability tracks annual clean water consumption for UTA, as shown in **Figure 5.** Emissions were calculated based on the EPA's GHG emissions calculator due to clean water consumption. Unfortunately, this function was not available in SIMAP; hence, the research team had to use the other tool. The input provided to this tool was UTA's annual water usage for each fiscal year.

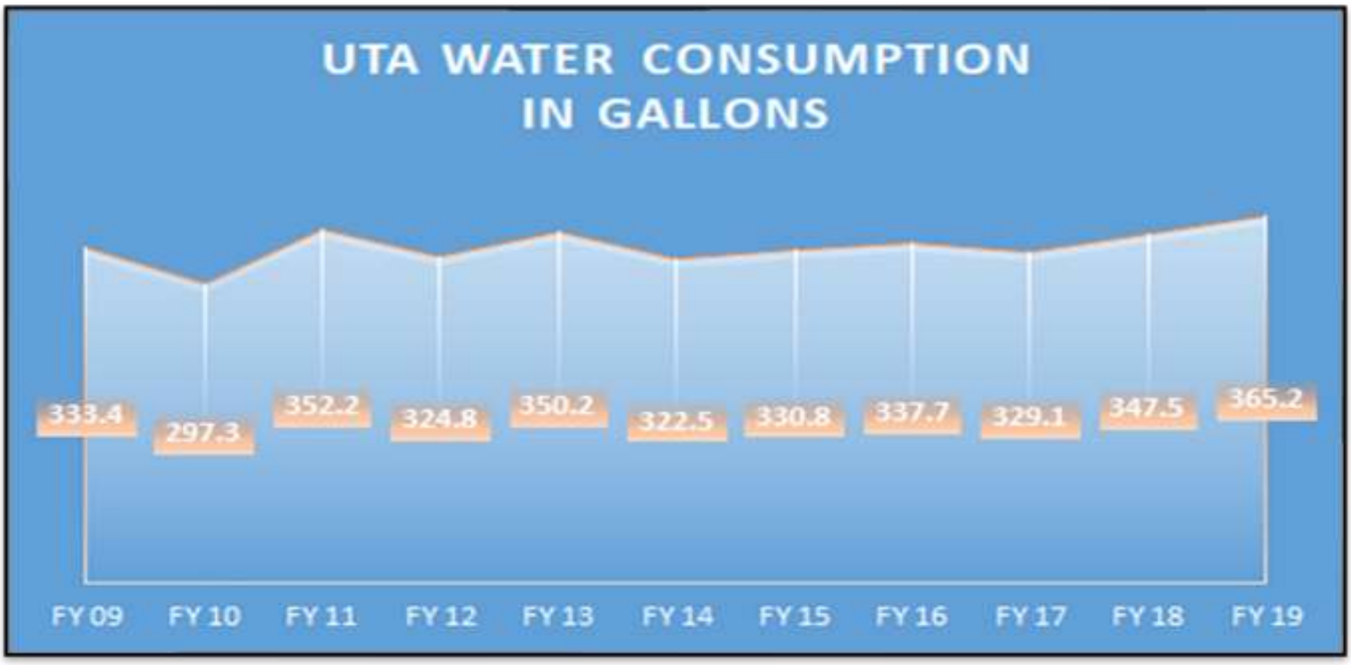

Figure 5. Annual water consumption at UTA from fiscal year 2009-2019

3.4.5 Material Consumption and Waste Data

3.4.5.1 Food Data

Two types of food data were collected: food purchase data and food waste data. The UTA has several food outlets, some owned directly by UTA and others owned privately by other companies. The data collection boundary was set such that only food outlets in a radius of 1.5 miles from the epicenter of UTA, with a UTA student, staff, and faculty walk-in of 90%, were considered. The 90% -in was based on the manager's data for the research study. Of the food outlets included within the boundary, only three have data available – Connection Café, Starbucks, and Pie Five – so the report included these three. Old School Pizza, New York Eats, etc., were excluded, despite some hotspots for UTA students and staff. This was due to a lesser percentage of UTA community walk in; these places had a lot of external community population walking.

Pie Five and Starbucks had food consumption data by weight as provided by their outlet managers. Food data produced by Chartwells group (food manager at UTA for 2019) for Connection Café was given in total dollars spent on food raw materials and products. A sorting program was formulated with the help of Python computer programming language to separate this large data source. The dollar values were converted into respective case weights in pounds (references for the conversions are provided at the end of the report).

Based on EPA national average data, SIMAP estimates GHG emissions associated with growing and transporting food.

3.4.5.2 Refrigerant Losses

Chlorodifluoromethane, or difluoromonochloromethane, is a hydrochlorofluorocarbon (HCFC) employed in space conditioning applications at the Thermal Energy Plant on campus. This colorless gas is better known as HCFC-22, R-22. The losses of R-22 were obtained for the fiscal year 2017 to 2019 from the Office of Facilities Management and entered for HCFC-22 into SIMAP. Refrigerants HCFC, HFC 134a HCFC 22 and HCFC 22 410A were also included.

3.4.5.3 Recycling

SIMAP inputs include all paper waste which is collected officially by both UTA and third-party companies (Balcones and Republic Services). It calculates the GHG emissions from producing the paper, transporting it, and recycling it. The Office of Sustainability provided paper collection data for the fiscal year 2017 to 2019. Paper waste and shredded paper waste are sent to various waste recycling companies for rebates.

Although other recyclable wastes (including plastic bottles and aluminum cans) are collected at UTA and transferred to Balcones recycling company, SIMAP only includes recycling of paper waste, so other recyclables were excluded from the study. In addition, SIMAP does not have any offsets or sinks for recycling activities. Offsets are operations or activities that the organization undertakes to compensate for environmental damage.

3.4.5.4 Composting Waste Data/Offsets/Sinks

Although UTA composts grass clippings and leaves, SIMAP only estimates emissions from composting of food waste, so only food waste composting was included in this study. The composting program overseen by UTA's Office of Sustainability accepts only pre-consumer food waste produced by the UTA campus. The post-consumer food waste is taken to a third-party company for composting processes. The weights of the composted material were obtained from the Recycling Coordinator for offsets in SIMAP.

3.5 Method for Forecasting Future Emissions

The research study estimated the future growth and decreases of emissions, student enrollment and building area with time, based on exponential smoothing forecasting. This forecast method was used in Microsoft Excel and is based on the AAA version (additive error, additive trend, and additive seasonality) of the *Exponential Triple Smoothing* (ETS) algorithm, which smooths out minor deviations in past data trends by detecting annual patterns and confidence intervals. There was a constant confidence interval of 95% to have a uniformity in the forecast results for each prediction.

Chapter 4: Results of Emissions Inventory

4.1 Transportation Survey Results

Seven hundred eighty-seven survey responses were received, of which 670 were completed. The 670 respondents included 263 students, 47 faculty, and 360 staff. **Table 6** shows the distribution of commute modes among survey participants. This distribution was input into SIMAP software to determine the overall emissions due to commuting at UTA.

Table 6. Distribution of commute modes among UTA students, faculty, and staff

Type	Automobiles %	Carbon free modes (Walk/Bike/Skateboard) %	Public Train %	Public bus/UTA shuttle %
Staff	98.05	1.66	0.27	0.00
Students	59.31	37.65	0.00	3.04
Faculty	100.00	0.00	0.00	0.00

4.2 Carbon Inventory Results

4.2.1 UTA Emissions due to Water Consumption

Table 6. shows UTA water consumption and GHG emissions according to EPA’s GHG emissions calculator. Within 2010 to 2019 (10 years), UTA’s gross square footage (GSF) per full-time equivalent student increased by 24%, but the GHG emissions due to water consumption only increased by 18%. This slower rate of increase in water consumption may be due to UTA’s water conservation initiatives on campus.

As shown in **Table 7**, greenhouse gas emissions from water consumption are forecast to increase slightly from 2020 to 2022. It is estimated in the time frame of 2020 to 2022, there would be a 12% increase in campus space and a significant increase in student population, but the increase in water consumption is only 7%. This may be due to UTA's increasing commuting student population and decreasing residential or on-campus students; it could also be due to sustainable measures to control water consumption.

Table 7. GREENHOUSE GAS EMISSIONS DUE TO UTA WATER CONSUMPTION

Fiscal Year	Water consumed in a million gallons (10^6)	MTCDE$^{\Delta}$ due to water consumed	Gross square footage per FTE*	Gallons Consumed per GSF per FTE*	MTCDE$^{\Delta}$ due to water consumed per GSF per FTE
FY 10	297	533	4.9	61	8.7
FY 11	352	631	5.2	68	9.3
FY 12	325	582	5.8	56	10.4
FY 13	350	627	5.8	60	10.5
FY 14	323	578	5.7	57	10.1
FY 15	331	593	5.7	58	10.2
FY 16	338	605	5.7	59	10.3
FY 17	329	590	5.7	58	10.2
FY 18	348	623	5.7	61	10.2
FY 19	365	654	6.1	60	10.9
FY 20**	N/A	640	N/A	N/A	N/A
FY 21**	N/A	646	N/A	N/A	N/A
FY 22**	N/A	656	N/A	N/A	N/A

FTE - FULL TIME EQUIVALENT STUDENT, FACULTY, AND STAFF*
*FY** - Emissions forecast in MTCDE for future years*
GSF° - GROSS SQUARE FOOTAGE
MTCDE$^{\Delta}$ - METRIC TONS OF CARBON DIOXIDE EMISSIONS
Terminology used in this report is described in Appendix A

4.2.2 UTA Emission Results from SIMAP, 2017-2019

Table 8 provides SIMAP estimates of UTA GHG emissions for 2017 to 2019, except for emissions from water consumption, discussed in the previous section. Annual GHG emissions from water consumption were at most 656 MTCDE, which is very small compared to the emission estimates in **Table 8** (18,000 MTCDE and greater). Of the 3 scopes in Table 5, the most significant emissions come from electricity purchased at UTA (Scope 2). **Figure 6** shows the distribution of emissions from the 3 scopes for 2019. Again, 51% of emissions are due to electricity consumption.

Table 8. UTA GHG emissions by scope, 2017 - 2019

Fiscal Year	Emissions based on	CO_2 (kg)	CH_4 (kg)	N_2O (kg)	GHG MTCDE
2017	Direct campus emissions (e.g., stationary fuel) (Scope 1)	17,398,826	1,696	62	18,059
2017	Indirect campus emissions (electricity consumption) (Scope 2)	54,116,025	4,076	590	54,386
2017	Indirect transportation emissions (e.g., commuting) (Scope 3)	30,955,631	1,466	868	31,479
2017	**Total Emissions**	**102,470,482**	**7,238**	**1,520**	**103,924**
2018	Direct campus emissions (e.g., stationary fuel) (Scope 1)	19,430,327	1,900	63	19,832
2018	Indirect campus emissions (electricity consumption) (Scope 2)	50,902,593	3,606	492	51,134
2018	Indirect transportation emissions (e.g., commuting) (Scope 3)	27,135,977	1,324	779	27,671
2018	**Total Emissions**	**97,468,897**	**6,830**	**1,334**	**98,637**
2019	Direct campus emissions (e.g., stationary fuel) (Scope 1)	21,600,672	2,121	64	22,052
2019	Indirect campus emissions (electricity consumption) (Scope 2)	51,566,537	3,653	498	51,801
2019	Indirect transportation emissions (e.g., commuting) (Scope 3)	27,049,268	1,314	772	27,467
2019	**Total Emissions**	**100,216,477**	**7,088**	**1,334**	**101,320**

The terminology used in this report is described in Appendix A.

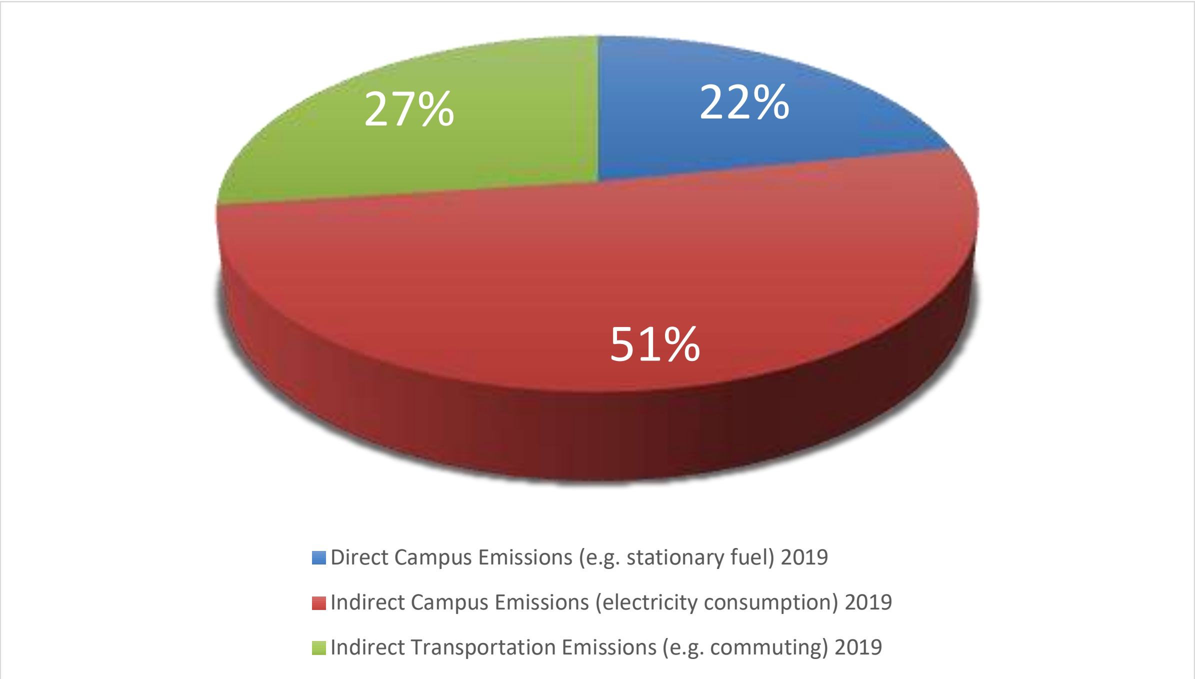

Figure 6. UTA GHG emissions by source, 2019

4.2.3 UTA Emission Inventory Estimates, 2005-2022

Figure 7 summarizes UTA emissions (total and for each of the 3 scopes) from 2005 through 2022. Estimates from **Table 8** for 2017-2019 are included, along with emissions from past inventories and projections for Years 2020-2022. Emissions due to stationary fuel and mobile sources (except commuting) (***Scope 1***) decreased from 2005 to 2017. This decrease was due at least in part to UTA contracting out bus transportation services. Scope 1 (Direct campus emissions) increased from 2017 to 2019, with an additional increase projected for 2020 to 2022. The increase was due to the increased use of natural gas on campus for heating. Campus natural gas consumption increased by 26% from 2016 to 2019, from 314 million cubic feet (MMCF) to 399 MMCF.

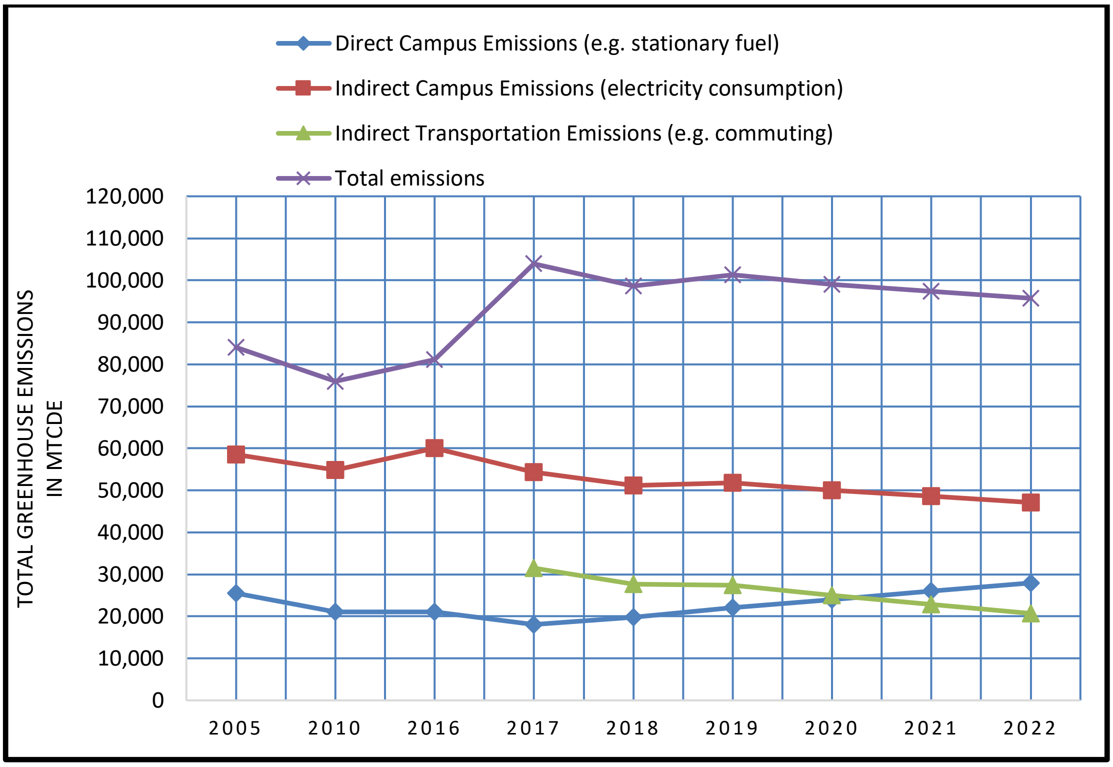

Figure 7. GHG emissions for fiscal years 2005 to 2019, along with forecast until 2022

As shown in **Figure 7**, between 2016 and 2019, greenhouse gas emissions for electricity consumption (***Scope 2***) decreased by 13% (from 60,032 MTCDE to 51,801 MTCDE), although campus square footage increased by 7% during this same period. In addition, the quantity of power purchased increased 3.2% from 118,223 MWh to 122,022 MWh between the years 2017 and 2019, but emissions due to purchasing power decreased by 4.7% from 54,386 MTCDE to 51,801 MTCDE. UTA's purchased electricity is acquired from the Electric Reliability Council of Texas (ERCOT). **Table 9** shows the distribution of various power sources in the ERCOT mix from 2017 to 2019. Decreased use of coal and increased use of solar and wind reduced overall CO_2 emissions from ERCOT's power mix during this period, which would have reduced UTA's emissions associated with electricity.

Table 9. Distribution of electricity sources for the ERCOT mix

Year	**Units**	**Biomass**	**Coal**	**Gas**	**Gas-CC**	**Hydro**	**Nuclear**	**Other**	**Solar**	**Wind**	**Total Electricity**
2017	%	0.15%	32%	5%	34%	0.23%	11%	0.00%	0.63%	17%	100%
	MWh	177	37,831	5911	40,196	272	13,005	0.0	745	20,098	118,223
2018	%	0.14%	25%	6%	38%	0.21%	11%	0.00%	0.86%	19%	100%
	MWh	169	30,113	7227	45,771	253	13,250	0	1036	2286	120,451
2019	%	0.10%	20%	7%	40%	0.24%	11%	0.56%	1.10%	20%	100%
	MWh	122	24,404	8542	48,809	293	13,422	683	1342	24,404	122,022

Resource for ERCOT mix- http://www.ercot.com/gridinfo/generation

Note that in **Figure 6**, Indirect Transportation Emissions (***Scope 3***) are included for the first time in 2017. They show a decrease from 2017 to 2019, and a projected decrease from 2020 to 2022. **Figure 8** shows UTA's enrollment for fiscal years 2017 – 2019. Enrollment for Fall, Spring, and summer was combined so that trends by year could be observed; plotting enrollment by semester would obscure trends. Spring enrollment was typically lower than Fall, and summer was lower than Spring. In-class enrollment decreased 6.3% from 2017 to

2019, while online enrollment increased. Therefore, a decrease in Indirect Transportation Emissions is consistent with a decrease in in-class enrollment.

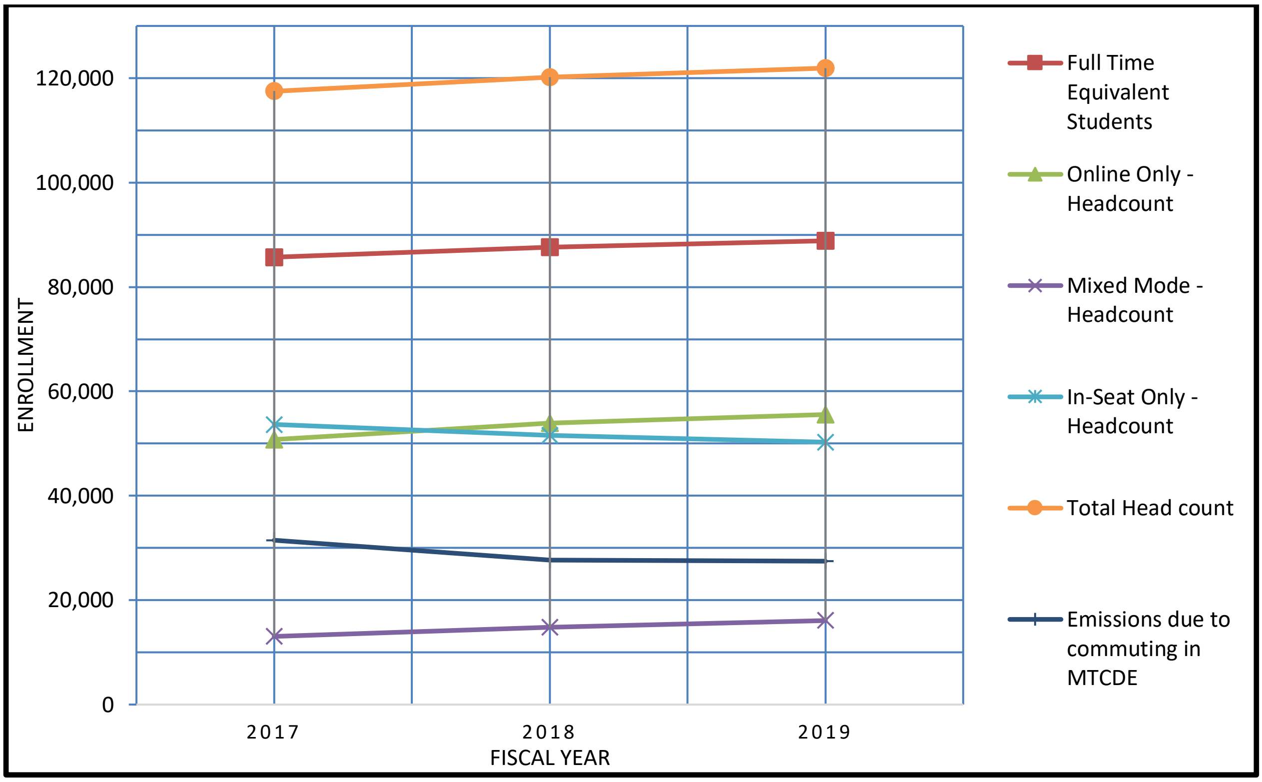

Figure 8. Enrollment history for UTA from 2017 to 2019, along with emissions from commuting

Total emissions in **Figure 7** decreased by 2.5 % from 2017 to 2019. This reduction was due to several factors, such as cleaner purchased electricity from ERCOT increased online education population. This decrease is especially noteworthy given that the overall building area at UTA increased by 7% during this time frame.

Figure 9 shows total emissions per GSF (gross square footage) at UTA from 2010 to 2019. GHG emissions per GSF 2010 remain approximately the same over this period. The increase from 2016 to 2017 was due to the inclusion of Indirect Transportation Emissions (Scope 3) emissions for the first time in 2017. During the period 2010 and 2019, UTA's total gross square footage (GSF) increased from 6,421,914 to 7,224,010, an increase of 12.5%. The emissions per GSF per FTE have decreased by 4.2% from 0.01445 MTCDE per GSF to 0.01384 MTCDE from 2010 to 2019.

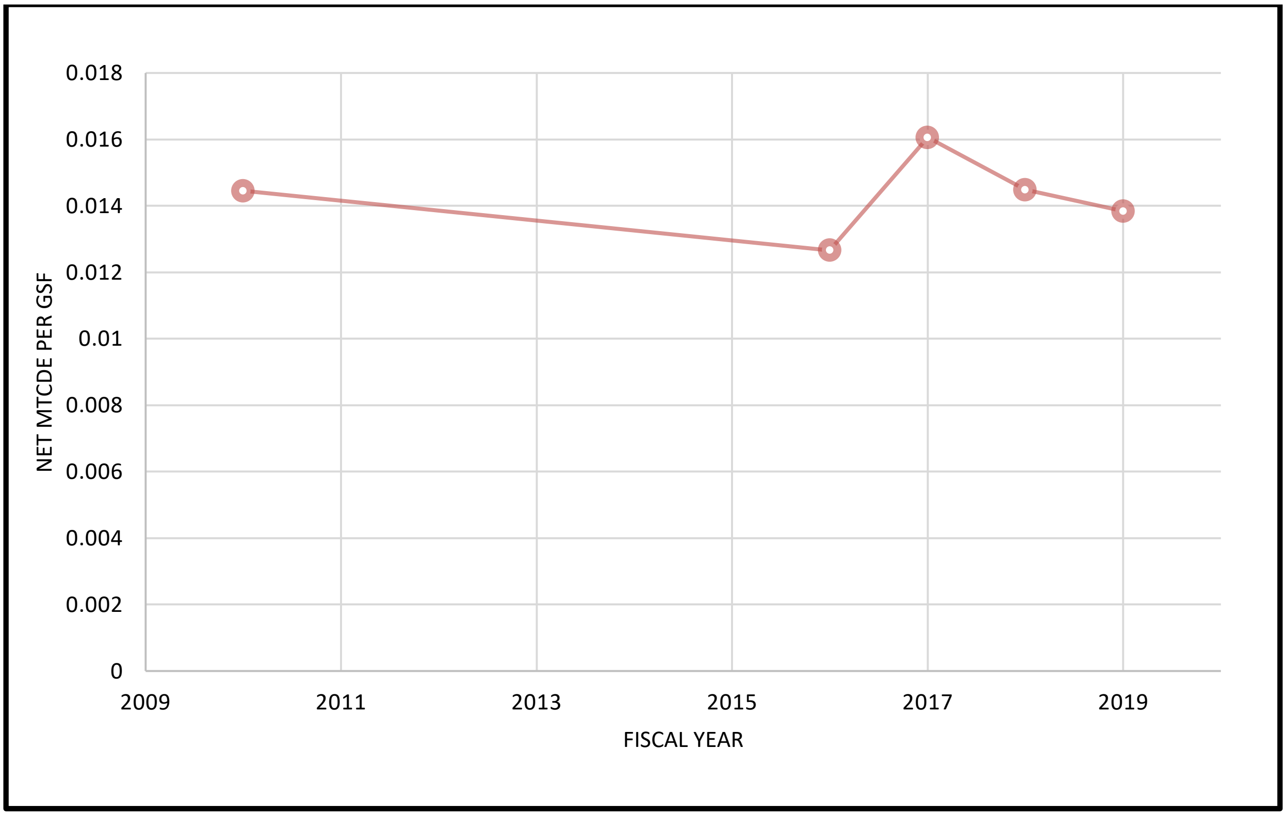

Figure 9. UTA greenhouse gas emissions per gross square foot

Figure 10 shows UTA greenhouse gas emissions per full-time equivalent (FTE) student from 2017-2019, along with projections for 2020-2022. According to **Figure 10**, GHG emissions per FTE student for 2019 were slightly lower than 2017. This reduction was likely due to an increase in distance learning students and a decrease in in-person class students at UTA, which decreased the commuting and utility usage emissions. Between 2017 and 2019, UTA in-class student enrollment decreased by 6% and online class enrollment increased by 9%. This decreases in in-class enrollment affected not only mobile emissions (Scope 1) but also stationary fuel combustion (Scope 1), purchased electricity (Scope 2), and commuting emissions (Scope 3). In addition, fewer in-person students mean less use of shuttle services, natural gas, and electricity.

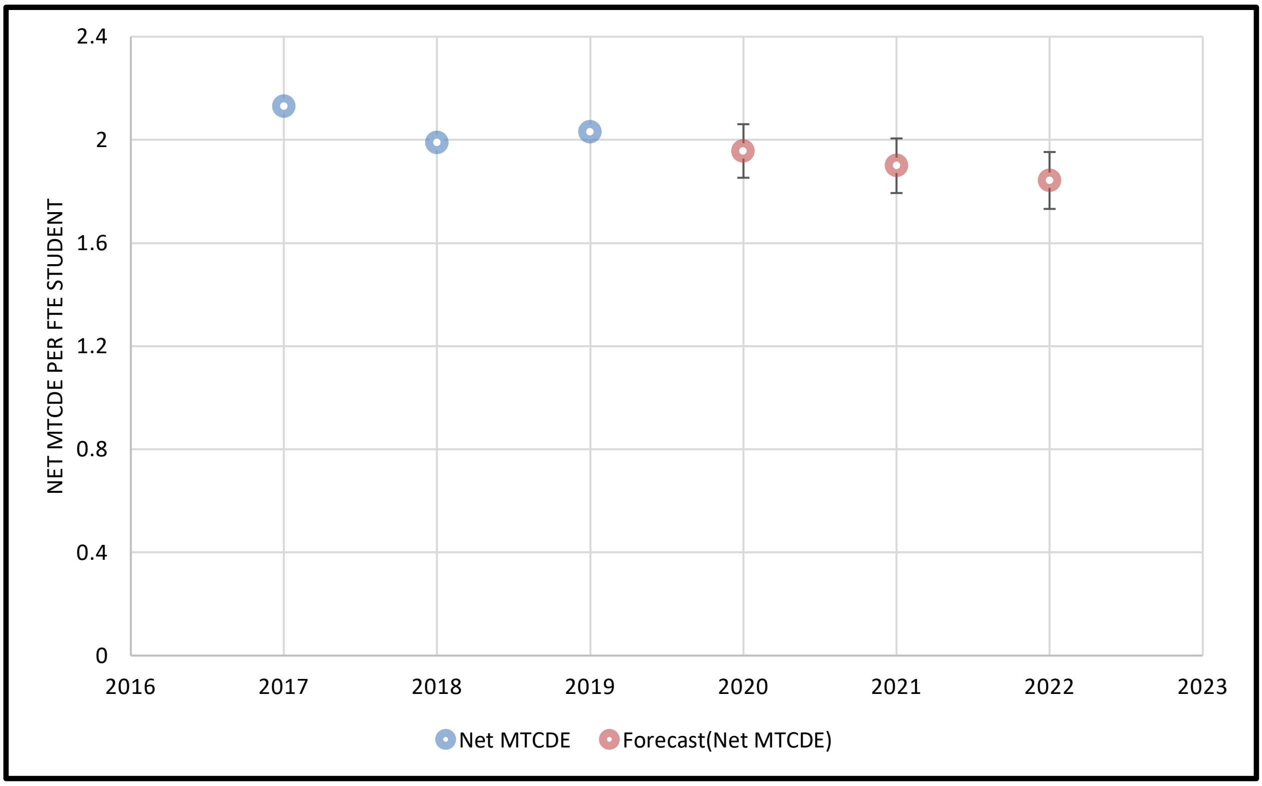

Figure 10. UTA greenhouse gas emissions per full-time equivalent student

4.2.4 Comparison of UTA Carbon Emissions with Other Universities

Table 10 compares UTA's GHG emissions with those of other universities. The average GHG per FTE was 11.7 (excluding UTA). UTA's emissions of 2.0 GHG per FTE student were substantially below average**.**

Table 10. Comparison of UTA's 2019 GHG emissions per full time equivalent student with several universities around the world

University	**Metric tons CO_2-eq. (MTCDE) per FTE student**
The University of Texas at Arlington	2.0
University of Cape Town (Pablo Yañez, 2020)	4.0
Norwegian University of Science and Technology (Pablo Yañez, 2020)	4.6
University of Delaware (Pablo Yañez, 2020)	7.9
University of Pennsylvania (Pablo Yañez, 2020)	13.1
Yale University (Pablo Yañez, 2020)	24.6
Massachusetts Institute of Technology (Pablo Yañez, 2020)	36.4
National Autonomous University of Mexico (Pablo Yañez, 2020)	1.5
Western University (Alghamdi, 2019)	1.7
Overall mean (excluding UTA)	11.7

Chapter 5: GHG Reduction Strategies for UTA

5.0 Recommendations for Reducing GHG Emissions

The American College & University President's Climate Commitment (ACUPCC) recommends all American universities measure their GHG emissions annually and develop an action plan to become a carbon-neutral campus in the future. This section discusses two ideas for further reducing GHG emissions from UTA: solar panel installation and afforestation.

5.1 Solar panel installation

5.1.1 Idea

According to the GHG inventory results above, the highest contributor to the carbon footprint at UTA was found to be Scope 2 (Indirect Campus Emissions, electricity from external source purchase). Production of renewable electricity on campus by solar panels or PV cells can reduce this contribution. Panels can be placed on unused building rooftops.

5.1.2 Method and software

Helioscope, a geospatial software tool (*https://www.helioscope.com/)*, was used to estimate solar energy output. The software uses GIS to determine the project's location along with the terrain details and includes factors such as solar insolation. The software gives a wide range of solar panel choices according to the total investment or maximum efficiency with minimum space provided.

The software includes shader models, which the software uses to assess the amount of solar energy efficiency drop due to shade from nearby buildings over the entire year at the location.

The shader and irradiance data are processed with the project rooftop area and the type of solar panels; thus, the overall electricity output is estimated.

The GHG emissions offset for the electricity produced by this solar panel design was based on EPA's carbon emissions calculator (EPA, 2021). A detailed pictorial representation of the solar panel with a depiction of all the angles is shown in **Figure 11.**

Software inputs and outputs include:

Inputs:

- The boundary for the building roof (using an aerial photo)
- Type of panel to be installed - Panel used for the study: TSM-PD14 320 (May 16), Trina Solar
- Orientation of the panels or azimuth angle - The azimuth angle (see **Figure 11**) is the compass direction from which the sunlight is coming. The azimuth angle is important to capture a maximum of sunlight and therefore produce a maximum of energy. The panels were oriented to the south for maximum energy output for this study.
- Lookouts and obstructions
- Type of wiring and transformers
- The angle of inclination or tilt angle - To obtain the most energy from solar panels, they need to point them in the direction that captures the most sun. The tilt angle (**Figure 11**) is when the panel is tilted when facing the sun.

Outputs:

- Area and number of solar panels,
- Performance ratio and power output: Performance ratio (PR) is the ratio of measured output to expected output for a given reporting period based on the system name-plate rating of the solar panel.

A sample solar panel design output is shown in **Figure 11.**

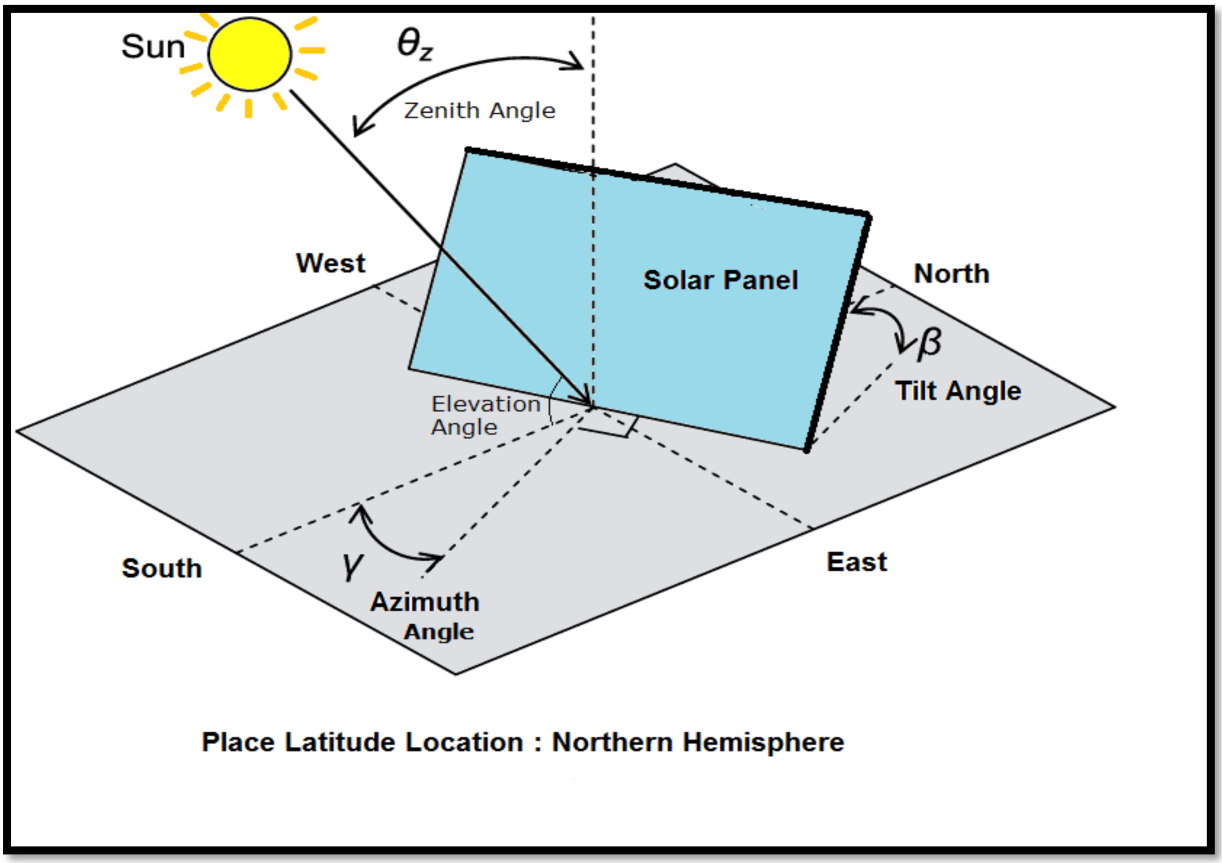

Figure 11. Azimuth angle and tilt angle of a solar panel (GoGreenSolar, 2021)

The panels were set at various angles from 0° up to 90° to find each panel's best possible energy output. After trial and error, it was found that a fixed tilt (10°) provided maximum power output. A 0° angle will not have a better energy output and will increase the number of panels in the design. The 90° angle had a good energy output but there has to be a double panel to accomplish this design.

The fourteen (14) buildings chosen for the study were selected based on the total available roof area and the building's assumed electricity consumption. In addition, the major buildings with extensive classroom and laboratory activity and greater building space were considered. The buildings were also selected based on their height; it was assumed that there will be greater solar insolation in high-rise buildings due to less tree cover over the roof tops.

Investment, savings, and years for return: The investment was calculated based on costs of the solar panel module, wiring material, and inverter. This calculation was determined by a manual method because the software does not give any investment outputs. According to investment tax credit, 22% of the investment will be returned as tax credits and rebates for both commercial and residential solar powered buildings. Factors such as labor and installation were excluded because they are variable according to the contractor and type of materials used. Maintenance costs were also excluded.

According to UTA's geographic location, annual savings were calculated based on the average electric rates in Tarrant County, Texas. The average electric rates were multiplied by the expected power output from the solar panels. Total returns were calculated based on the number of years taken for the annual savings to reach the capital investment for each building.

There was an interest calculation performed for the investment based on engineering economics. The investment was subdivided into 1 year and a fraction of the second year. Interest rates of 5%, 2.5% and 0.5% were used to provide a range for analysis. The average US interest rate for the 10 years pre-pandemic was 2 to 2.5%, and current interest rates are close to 0.5%.

5.1.3 Results

Tables 11-13 summarize the evaluation results of installing solar panels on 14 buildings at UTA. The installation would reduce annual GHG emissions by 3301 MTCDE, which is 6.4% of Indirect Campus Emissions due to electricity consumption (Scope 2). The investment would cost $2.9 million but would save $1.6 million annually in electricity costs for a pay-back time of 1.94 years, 1.89 years, and 1.79 years for interest rates of 5%, 2.5%, and 0.5%, respectively. An aerial view of the designed solar panel layout is shown in **Figure 12.**

Figure 12. Aerial photo with designed solar panels at the Engineering Research Building (ERB)

Table 11. Analysis of solar panel installation on UTA rooftops- 5% interest rate

Building	Area (ft^2)	Power output (MWh)	Number of solar modules	Annual savings ($)	Investment ($)	Investment at the end of returns year (5% interest) ($)	Total years for return	Total reduction in MTCDE	Percent reduction in UTA's emissions due to purchased electricity
Aerodynamics Building	9,154	82	164	28,872	36,111	38,475	1.33	58.5	0.11%
UTA Bookstore	12,076	108	215	37,800	72,136	79,143	2.09	76.5	0.15%
Davis Hall	11,937	109	217	38,045	72,867	79,945	2.10	77.2	0.15%
University Center	58,813	673	1344	235,445	408,978	444,347	1.89	477	0.92%
Engineering Research Building	25,699	256	512	89,635	182,576	201,290	2.25	181	0.35%
Mavericks Activity Center Swimming pool	22,320	210	424	73,465	131,948	144,061	1.96	149	0.29%
Mavericks Activity Center	107,185	1189	2387	416,150	719,094	781,281	1.88	843	1.63%
Science & Engineering Innovation & Research Building	42,233	511	1020	178,850	305,283	331,684	1.85	362	0.70%
The Commons at UTA	14,280	154	305	53,725	99,765	109,456	2.04	109	0.21%
UTA College of Nursing and Health Innovation	29,824	229	456	80,010	137,507	149,398	1.87	162	0.31%
UTA Business Building	18,502	190	378	66,570	123,744	135,763	2.04	135	0.26%
UTA Central Library	28,906	250	497	87,360	156,078	170,405	1.95	177	0.34%
UTA Testing Building	31,877	352	770	123,340	238,167	261,301	2.12	249	0.48%
Wolf Hall UTA	27,013	346	628	120,960	202,572	220,090	1.82	245	0.47%
Total	439,819	4,659	9,317	1,630,226	2,886,826	3,146,640	1.94	3301.2	6.37%

Table 12. Analysis of solar panel installation on UTA rooftops- 2.5% interest rate

Building	Area (ft^2)	Power output (MWh)	Number of solar modules	Annual savings ($)	Investment ($)	Investment at the end of returns year (2.5% interest) ($)	Total years for return	Total reduction in MTCDE	Percent reduction in UTA's emissions due to purchased electricity
Aerodynamics Building	9,154	82	164	28,872	36,111	37,072	1.28	58.5	0.11%
UTA Bookstore	12,076	108	215	37,800	72,136	76,694	2.03	76.5	0.15%
Davis Hall	11,937	109	217	38,045	72,867	77,475	2.04	77.2	0.15%
University Center	58,813	673	1344	235,445	408,978	433,738	1.84	477	0.92%
Engineering Research Building	25,699	256	512	89,635	182,576	194,350	2.17	181	0.35%
Mavericks Activity Center Swimming pool	22,320	210	424	73,465	131,948	144,107	1.91	149	0.29%
Mavericks Activity Center	107,185	1189	2387	416,150	719,094	762,493	1.83	843	1.63%
Science & Engineering Innovation & Research Building	42,233	511	1020	178,850	305,283	323,553	1.81	362	0.70%
The Commons at UTA	14,280	154	305	53,725	99,765	106,029.08	1.97	109	0.21%
UTA College of Nursing and Health Innovation	29,824	229	456	80,010	137,507	145,779.74	1.82	162	0.31%
UTA Business Building	18,502	190	378	66,570	123,744	131,514.76	1.98	135	0.26%
UTA Central Library	28,906	250	497	87,360	156,078	165,698.11	1.90	177	0.34%
UTA Testing Building	31,877	352	770	123,340	238,167	253,262.88	2.05	249	0.48%
Wolf Hall UTA	27,013	346	628	120,960	202,572	214,576.89	1.77	245	0.47%
Total	439,819	4,659	9,317	1,630,226	2,886,826	3,062,343	1.89 (Average)	3301.2	6.37%

Table 13. Analysis of solar panel installation on UTA rooftops- 0.5% interest rate

Building	Area (ft^2)	Power output (MWh)	Number of solar modules	Annual savings ($)	Investment ($)	Investment at the end of returns year (0.5% interest) ($)	Total years for return	Total reduction in MTCDE	Percent reduction in UTA's emissions due to purchased electricity
Aerodynamics Building	9,154	82	164	28,872	36,111	$36,302	1.26	58.5	0.11%
UTA Bookstore	12,076	108	215	37,800	72,136	$72,669	1.92	76.5	0.15%
Davis Hall	11,937	109	217	38,045	72,867	$73,406	1.93	77.2	0.15%
University Center	58,813	673	1344	235,445	408,978	$411,804	1.75	477	0.92%
Engineering Research Building	25,699	256	512	89,635	182,576	$183,964	2.05	181	0.35%
Mavericks Activity Center Swimming pool	22,320	210	424	73,465	131,948	$132,892	1.81	149	0.29%
Mavericks Activity Center	107,185	1189	2387	416,150	719,094	$724,038	1.74	843	1.63%
Science & Engineering Innovation & Research Building	42,233	511	1020	178,850	305,283	$307,353	1.72	362	0.70%
The Commons at UTA	14,280	154	305	53,725	99,765	$100,497	1.87	109	0.21%
UTA College of Nursing and Health Innovation	29,824	229	456	80,010	137,507	$138,447	1.73	162	0.31%
UTA Business Building	18,502	190	378	66,570	123,744	$124,651	1.87	135	0.26%
UTA Central Library	28,906	250	497	87,360	156,078	$157,188	1.80	177	0.34%
UTA Testing Building	31,877	352	770	123,340	238,167	$239,934	1.95	249	0.48%
Wolf Hall UTA	27,013	346	628	120,960	202,572	$203,923	1.69	245	0.47%
Total	439,819	4,659	9,317	1,630,226	2,886,826	$2,907,069	1.79 (Average)	3301.2	6.37%

5.2 Afforestation at UTA

5.2.1 Idea:

Afforestation would involve introducing trees and tree seedlings to UTA's areas previously not forested. Studies also show that planting trees near buildings will reduce energy consumption due to the trees' cooling effect during summers. Trees will also reduce noise pollution, along with dust and soot damage to building paints.

5.2.2 Method:

The current afforestation area available and current distribution of various geographical information such as roads, building area, soil/ground, trees, and grass at UTA was approximated with the help of i-tree canopy (*https://canopy.itreetools.org/*). A random sampling process that classifies ground cover types, I-tree canopy estimates tree cover and tree benefits for a given area. i-Canopy tree used around 1000 sampling points (shown in **Figure 13**) inside the input boundary and determined what cover was present at each exact location.

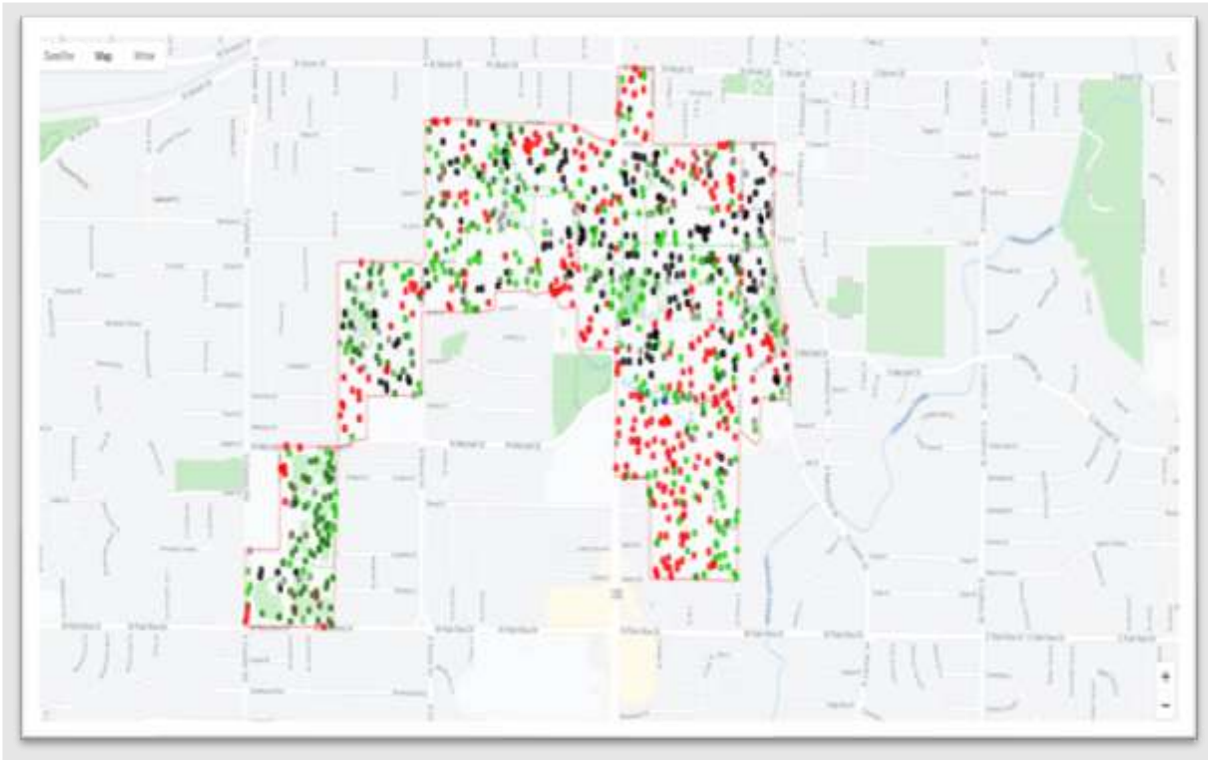

Figure 13. i-Canopy tree sampling points at UTA

Note - Colors in Figure 13 are based on the legend provided in Figure 14.

5.2.3 Results

Table 14 and **Figure 14** present i-tree canopy results for UTA. The top two cover categories are impervious roads, which include both asphalt roads and concrete pavements, and tree/shrubs. Using the tree/shrub cover areas from **Table 14,** i-Canopy tree determined the annual carbon sequestration and its monetary value, as shown in **Table 15.**

Table 14. Cover areas based on i-canopy outputs using 2019 UTA total GSF area

Type of cover	Total geographic points taken	Percent of cover	Cover area at UTA (square feet)
Grass/Herbaceous	155	15.5%	1,131,389
Impervious Buildings	193	19.2%	1,408,927
Impervious Other	70	7.0%	511,139
Impervious Roads	292	29.1%	2,131,699
Soil/Bare Ground	52	5.2%	379,327
Tree/Shrub	240	23.9%	1,752,372

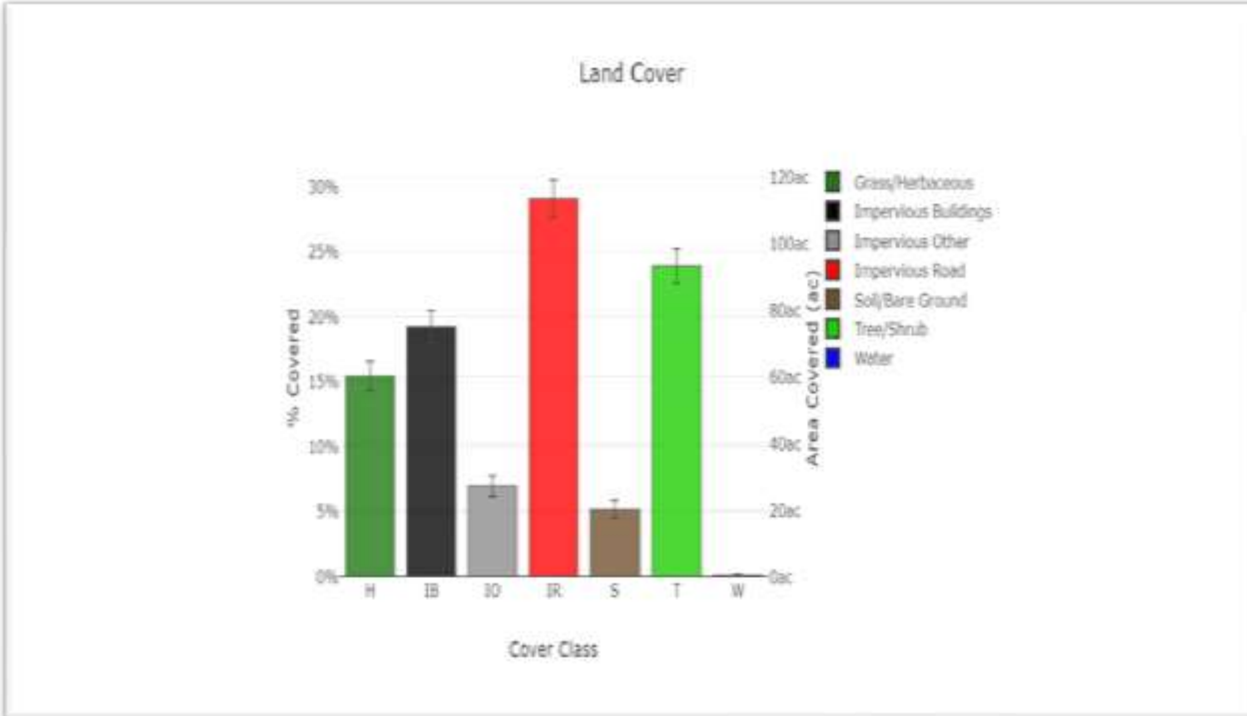

Figure 14. Land cover distribution at UTA

Table 15. Estimated tree benefits - carbon

Description	Carbon (tons)	CO_2 Equiv. (tons)	Value (USD)
Sequestered annually in trees	127	467	$10,869
Stored in trees (Note: this benefit is not an annual rate)	3,201	11,737	$272,972

Notes: *Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Amount sequestered is based on 1.365 T of Carbon, or 5.005 T of* CO_2*, per ac/yr and rounded. Amount stored is based on 34.281 T of Carbon, or 125.697 T of* CO_2*, per ac and rounded. Value (USD) is based on $85.28/T of Carbon, or $23.26/T of* CO_2 *and rounded. (English units: tons (2,000 pounds), ac = acres)*

In addition to estimating carbon sequestration, i-Canopy tree uses the tree/shrub cover area to estimate the amount of traditional air pollutants - carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter (PM) 10 and PM 2.5 - removed from the atmosphere. Maximum removal was estimated for ozone and PM 10, as shown in **Table 16**. Breathing elevated concentrations of ozone can trigger a variety of responses, such as chest pain, coughing, throat irritation, and airway inflammation. It also can reduce lung function and harm lung tissue. Ozone can worsen bronchitis, emphysema, and asthma, increasing medical care. PM10 is small enough to penetrate deep into the lungs. These particles can adversely impact respiratory and cardiovascular systems.

Table 16. Estimated tree benefits - traditional air pollution

Abbreviation	Air Pollutant	Amount removed annually (lb)		Value (USD)	
		Mean	Standard Error	Mean	Standard Error
CO	Carbon Monoxide	96	5	$47	$3
NO_2	Nitrogen Dioxide	493	28	$105	$6
O_3	Ozone	4,289	241	$3,542	$199
SO_2	Sulfur Dioxide	122	7	$8	$0
PM10*	Particulate Matter <10 microns	968	55	$2,185	$123
PM2.5	Particulate Matter <2.5 microns	167	9	$4,301	$242
Total		6,136	345	$10,188	$574

Notes: *Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Air Pollution Estimates are based on these values in lb/ac/yr @ $/lb/yr and rounded:*

CO 1.033 @ $0.49 | NO_2 5.280 @ $0.21 | O_3 45.936 @ $0.83 | SO_2 1.308 @ $0.07 | PM10 10.366 @ $2.26 | PM2.5 1.793 @ $25.70 (English units: lb = pounds, ac = acres)* i-Canopy tree also estimates avoided runoff as well as other hydrological values, as shown in **Table 17**. The avoided runoff is the water runoff used by the trees. i-Canopy tree provides a monetary value only for avoided runoff and not other factors like evaporation, interception, transpiration, potential evaporation, and potential evapotranspiration.

Table 17. Estimated annual tree benefits - Hydrological

Abbreviations	Benefits	Amount (kgal)	±SE	Value (USD)	±SE
AVRO	Avoided Runoff	994	±56	$8,886	±500
E	Evaporation	4632	±261	N/A	N/A
I	Interception	4632	±261	N/A	N/A
T	Transpiration	24,866	±1,400	N/A	N/A
PE	Potential Evaporation	81,572	±4,592	N/A	N/A
PET	Potential Evapotranspiration	63,453	±3,572	N/A	N/A

Note Table 17: *Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Hydrological Estimates are based on these values in kgal/ac/yr @ $/kgal/yr and rounded:*

AVRO 10.650 @ $8.94 | E 49.602 @ N/A | I 49.602 @ N/A | T 266.294 @ N/A | PE 873.575 @ N/A | PET 679.535 @ N/A (English units: kgal = thousands of gallons, ac = acres)

Chapter 6: Conclusions and Recommendations for Future Work

6.1 Conclusions

- SIMAP is the most practiced GHG emissions calculator in a higher educational institute. According to this research, about 50% of universities that maintain carbon emissions use SIMAP as their primary tool.
- The major contributors to UTA's 2019 GHG emissions were:
  1. Indirect Campus Emissions (electricity consumption): 51%,
  2. Indirect Transportation Emissions (e.g., commuting): 27%,
  3. Direct Campus Emissions (e.g., stationary fuel): 21%.
- UTA's 2019 emissions were 2.0 metric tons of carbon dioxide equivalents (MTCDE) per full-time equivalent (FTE) student, which compares favorably with other universities. Emissions for eight other universities worldwide ranged from 1.5 to 36.4 MTCDE per FTE student, with an average of 11.7.
- UTA emissions decreased from 2017 to 2019, despite increased student enrollment and a 7% increase in building area. Although UTA electricity consumption increased during this period, emissions from electricity decreased due to reduced coal generation and increased wind power. In addition, emissions from commuting decreased due to a 9% increase in online enrollment, coupled with a 6% decrease in on-campus enrollment.
- The transportation survey found that 38% of students use carbon-free modes, compared to an estimated 100% carbon-based mode of commute by faculty.
- The ERCOT mix for North Texas Region has been switching to cleaner fuels for generating energy. The use of coal dropped from 32% in 2017 to 20% in 2019. Wind

energy increased from 17% in 2017 to 20% in 2019, and natural gas increased from 34% in 2017 to 40% in 2019.

- UTA's major GHG emissions contributor was found to be emissions due to purchased electricity (Scope 2). As a reduction strategy, onsite electricity production with a rooftop solar panel design was studied. It was found that a solar panel rooftop layout would reduce emissions due to purchased electricity by 6.32% with an initial investment return period of 1.94, 1.89, 1.79 years for interest rates of 5%, 2.5% and 0.5%, respectively.
- It was found that about 23.9% of UTA's campus is covered with trees, which absorb 467 tonnes of CO_2 emissions annually. Traditional air pollutants are also removed, providing an estimated $10,000 benefits. UTA's trees also provide benefits of almost $9000 per year in terms of avoided runoff. Planting 20.7% of UTA's land currently covered by soil or grass would approximately double the tree benefits at UTA.

6.2 Recommendations for future work

General Recommendations

- Higher educational institutions' carbon inventory methodology and tools should be standardized. A single standardized tool to estimate the carbon inventory will ease study, benchmarking, and more accurate comparisons. Use of SIMAP will lead to ease of AASHE reports and tracking, as SIMAP has the data requirements needed for the reporting which other tools lack. The higher education institution's GHG emissions data will be an open record and facilitate decision-making.
- A separate category for hybrid automobiles should be added to SIMAP.

- UTA-Specific Recommendations
- The number of food outlets can be increased in the research boundary, increasing the accuracy of the overall GHG emissions due to food consumption. This can be achieved by increasing the radius search from the campus and decreasing the UTA population walk in.
- An Excel-based spreadsheet to store the annual data needed to calculate the GHG emissions using SIMAP can be formulated. This will decrease the time consumption and increase the procedure efficiency of collecting the annual data.
- The energy efficiency of major buildings at UTA can be studied. New energy reduction strategies can be formulated and implemented in these high energy consumption buildings.
- The area of tree cover at UTA can be increased; the number of trees near campus buildings will lead to reduced energy consumption.
- An annual study of commuter mode distribution can be conducted. This will show the impact of commuting on UTA's GHG emissions and what remedial measures can be taken to reduce the impact.
- An increase in carbon trade-offs and certifications can be implemented to offset the present GHG emissions at UTA.
- Impact of psychological awareness can be studied. Awareness with frequent posters regarding energy conservation at hotspots like resident halls will likely reduce the GHG emissions due to energy.

- A separate estimation of GHG emissions due to water consumption should be included every year. However, SIMAP does not have a feature of calculating GHG emissions due to water consumption.
- A study of the purity of the recycle and trash waste on the separate dumpster is needed.

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Appendix A

Table A.1. Descriptions of terminologies

Terminology	Description
Gross MTCDE	Total greenhouse gas (GHG) emissions including all activities at UTA
Offsets MTCDE	A GHG emissions offset is a reduction in emissions of carbon dioxide or other greenhouse gases made to compensate for emissions made elsewhere.
Compost MTCDE	GHG emissions due to composting
Non-Additional Sequestration (MTCDE)	Change in GHG emissions due to carbon capture at UTA
Biogenic (MTCDE)	Biogenic emission sources are emissions that come from natural sources, mainly due to natural occurrences like combustion, harvest, digestion, fermentation, decomposition, or processing of biologically based materials.
Net MTCDE	The remaining GHG emissions after all offsets are deducted from the gross GHG emissions.
FTE student	A measurement equal to one student enrolled full time for one academic year. Total FTE enrollment includes full time plus the calculated equivalent of the part-time enrollment. For example, two half-time students add up to one FTE student.

Appendix B

Terminology used in this Appendix are described in Appendix A

Table B.1. Net metric tons of carbon dioxide emissions per gross square foot at UTA

Fiscal year	Net MTCDE per GSF
2010	0.01445
2016	0.01266
2017	0.01606
2018	0.01448
2019	0.01384

Table B.2 Overall GHG emissions per FTE in-class student

Fiscal Year	CO_2 (kg)	CH_4 (kg)	N_2O (kg)	Gross MTCDE	Offsets MTCDE	Compost MTCDE	Non-Additional Sequestration (MTCDE)	Biogenic (MTCDE)	Net MTCDE
2017	2,098	0	0	2.13	0	0	0	0	2.13
2018	1,969	0	0	1.99	0	0	0	0	1.99
2019	2,009	0	0	2.03	0	0	0	0	2.03

Table B.3 Overall GHG emissions per weighted population

Fiscal Year	CO_2 (kg)	CH_4 (kg)	N_2O (kg)	Gross MTCDE	Offsets MTCDE	Compost MTCDE	Non-Additional Sequestration (MTCDE)	Biogenic (MTCDE)	Net MTCDE
2017	3,111	0	0	3.15	0.00	0.00	0.00	0.00	3.15
2018	3,044	0	0	3.08	0.00	0.00	0.00	0.00	3.08
2019	3,142	0	0	3.18	0.00	0.00	0.00	0.00	3.18

Table B.4 GHG emissions for Stationary fuel (1), Electricity and energy consumption (2), and Commute fuel (3) **at UTA**

Fiscal year	Stationary fuel (1)	Electricity and energy consumption (2)	Commute fuel (3)	Total emissions
	In MTCDE	In MTCDE	In MTCDE	In MTCDE
2005	25,522	58,456	N/A	83,978
2010	21,092	54,857	N/A	75,949
2016	21,079	60,032	N/A	81,112
2017	18,059	54,386	31,479	103,924
2018	19,832	51,134	27,671	98,637
2019	22,052	51,801	27,467	101,319
2020 (Forecast)	23,991	50,002	24,995	98,987
2021 (Forecast)	25,970	48,553	22,846	97,369
2022 (Forecast)	27,948	47,105	20,697	95,751