CARBON FOOTPRINT ESTIMATION OF NUST H-12 CAMPUS.

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A thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in Environmental Science

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Dedication

I dedicate this thesis to my late grandfather and my parents, whose constant support and heartfelt prayers have been a guiding force at every step and in every circumstance, offering unwavering encouragement and direction whenever I required it.

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Aneeqa Wazir

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LIST OF ABBREVIATIONS

GHGs	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
AR6	Sixth Assessment Report
ISO	International Organization for Standardization
WMGHGs	well-mixed greenhouse gases
SLCFs	short-lived climate forcers
IEA	International Energy Agency
SDGs	Sustainable Development Goals
CF	Carbon Footprint
kgCO2e	Kilograms of Carbon dioxide equivalent
tCO2e	Tons of Carbon dioxide equivalent
MTCO2	Metric tonnes of carbon dioxide
CO2e	carbon dioxide equivalent
LCA	Life cycle assessment
HEIs	Higher Education Institutes
PCF	Product Carbon Footprint
GDP	Gross Domestic Product
UNFCCC	United Nations Framework Convention Climate Change
NDCs	Nationally Determined Contributions
HESA	Higher Education Strategy Associates
WRI	World Resource Institute
WBCSD	World Business Council for Sustainable Development
EEIOA	Extended Environmental Input-Output Analysis

BF-BOF	Blast Furnace-Basic Oxygen Furnace
EAF	Electric Arc Furnace
UNEP	United Nations Environment Program
AKDN	Aga Khan Development Network
GWP	Global Warming Potential
MBR	Membrane Bioreactor
ASTM	American Society for Testing and Materials
BSI	British Standards Institution
AASHTO	American Association of State Highway and Transportation Officials
ODU	Oxidised During Use
CC	Carbon Content
EFDB	Emission Factor Database
DEFRA	Department for Environment Food and Rural Affairs

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ABSTRACT

For the past few centuries, human activity has significantly increased and interfered with natural processes. For instance excessive greenhouse gases (GHGs)emissions have caused global warming and its accompanying effects. In the 21st century, the global temperature has already risen about 1.1°C above pre-industrial levels and would increase by an estimated 1.5°C in between 2030 and 2052. To curtail the increasing GHG emissions carbon footprint is one such method that can help keep trajectory of the GHG emissions regularly before applying techniques to reduce them. Large organizations are considered to have a major influence on the GHG emissions. To address these concerns many organizations including universities are now tracking their carbon footprint. The focus of this study is the carbon footprint estimation of the National University of Sciences and Technology (NUST) H-12 campus. The main objectives of this research were to estimate the carbon footprint of the NUST H-12 campus from 2019-2022. To pinpoint the underlying factors and stressors that contribute to the total carbon footprint of NUST. Further emphasis was to compare the carbon footprint of NUST with that of industrial sector mainly steel industry (for this purpose Fazal Steel (PVT) Limited was chosen). A Microsoft Excel based tool was also developed for the estimation of carbon footprint. The tool developed for university carbon footprint calculation followed the IPCC guidelines for estimation of carbon footprint. For the calculation of carbon footprint of NUST and Fazal Steel the GHG Protocol, ISO 14064-1 and IPCC Guidelines were used for principles and system boundaries identification. ISO 14064-1 standard was used in reporting the calculated emissions. The results obtained showed that the total carbon footprint of NUST from 2019 to 2022 was 45890.9 tCO2e. The highest carbon footprint was observed for year 2019 which was 11920.54 tCO2e. The year 2022 showed the lowest carbon footprint i.e., 11507.90 tCO2e. Scope 2 emissions were the highest to contribute for the total carbon footprint and were estimated around 24621.4 tCO2e. When compared with industrial carbon footprint Fazal Steel’s carbon emissions were estimated around 2455488.27 tCO2e, much higher than that of NUST.

CHAPTER 1

1. INTRODUCTION

For many years, human impact on the environment was limited to activities such as livestock cultivation, land conversion, and biomass burning. But, in the past few centuries, human activities have dramatically increased and disrupted natural processes. Primary reasons for this disruption are the excessive release of greenhouse gases, which leads to global warming and its associated consequences. Following the Industrial Revolution, the usage of motorized vehicles, industrial processes, and various other sources have become significant contributors to the emission of greenhouse gases (Kulkarni S. D., 2019). Greenhouse gas emissions have been labelled as one of the primary drivers of changing climate. The United Nations recognized climate change as a global issue in 1992 due to its significant adverse impact on the planet (Samara et al., 2022). According to IPCC sixth assessment report climate change induced by anthropogenic activities, has resulted in increased occurrence and severity of extreme weather events. That has caused far-reaching detrimental effects on both the environment and human populations, exceeding those of natural climate fluctuations. These impacts have led to extensive losses and damage. The global temperature already rising 1.1°C above pre-industrial levels will increase in the 21st century with the predicted estimate of 1.5°C between 2030-2052. In the absence of measures to reduce greenhouse gas emissions, the temperature of earth is projected to rise by 2°C above pre-industrial levels (Zhao et al., 2019).

The 2018 report by the Intergovernmental Panel on Climate Change (IPCC) stated that failure to decrease GHG emissions in the next 30 years would result in catastrophic consequences for the Earth (IPCC 2018a). The observed long-term climate changes of the past century are solely attributable to human activities, which release significant amounts of GHGs such as CO2, N20 and CH4 into the atmosphere. The drivers of these human-induced changes can be categorized into different types, such as "well-mixed greenhouse gases" (WMGHGs) and "short-lived climate forcers" (SLCFs) which comprise of certain hydrofluorocarbons, aerosols, and ozone, as well as albedo modifications resulting from land use. There is no doubt that human activities have caused a significant and rapid rise in the levels of "well-mixed greenhouse gases" (WMGHGs), including CO2, CH4, and N20 in the atmosphere from the pre-industrial era, with an even higher rate of increase since 2000 (Adak et al., 2023). Out of these WMGHGs, CO2 continues to be the largest contributor to total annual anthropogenic GHG emissions.

To keep global warming below 2°C in future, it is crucial to stabilize the concentration of atmospheric CO_2. A rise in the concentration levels of carbon dioxide (CO_2) in the atmosphere is considered a leading factor in rising global temperatures. IPCC reported that the atmospheric CO_2 concentration has increased by 40% since pre-industrial era, mainly due to the factors like combustion of fossil fuel and land use change (IPCC 2013). Numerous scientists reported the significant contribution of anthropogenic activities that increase CO_2 levels. According to Hertwich and Peters (2009) the everyday choices we make regarding our consumption and production have a significant impact on global emissions. The International Energy Agency (IEA) expresses leading sources of greenhouse gas (GHG) emissions are the electricity and heating sector, construction and manufacturing activities, and transportation. Approximately 80% of greenhouse gas emissions are generated in urban areas.

1.1 Sustainable Development Goals and Climate Change:

The United Nations General Assembly formulated the Sustainable Development Goals (SDGs) in 2015 to provide unambiguous directions and objectives for all nations to follow based on their own preferences and the global environmental problems. Goal 13 of the SDGs concentrates precisely on tackling climate change. To counteract the unfavorable effects of climatic changes. Goal 13 has five targets, including improving awareness among institutions and individuals regarding climate change mitigation, as well as strengthening their competence to act.

To address climate change, both mitigation (reducing emissions) and adaptation (planning for inevitable impacts) are necessary (Rolnick et al., 2022). Calculating carbon footprint of various human activities is one of the initiatives being undertaken to address this issue. Understanding the concept of carbon footprint is vital in acquiring information relevant to the environment, which can help in making sustainable decisions.

1.2Carbon Footprint and its Importance:

Derived from ecological footprint in the 90s, the term carbon footprint (CF) was developed. It relate to impact of human activities on environment precisely on the climatic conditions in terms of GHG emissions. According to 2006 guidelines of IPCC carbon footprint is described as the total quantity of greenhouse gas emissions by an organization, event, product, or a person. According to Wiedmann and Minx (2008), carbon footprint (CF) is quantification of the total amount of carbon dioxide emissions generated directly or indirectly by a particular action or throughout the various phases of a product's life. Calculating a person's carbon footprint can be used to analyze their GHG emissions before managing and reducing them.

1.3Carbon Footprint Assessment and Calculation:

The growing concern over climate change has led to increased attention towards assessing emissions and calculating carbon footprints. This is primarily viewed as a crucial initial step towards minimizing one's impact on the environment and ultimately attaining carbon neutrality (Kiehle et al., 2023). The rising level of CO2 emissions can be analyzed with the help of a carbon footprint assessment. There are various techniques for its calculation.

A carbon footprint may be evaluated in tons of carbon dioxide equivalent (tCO2e). When compared to one unit of carbon dioxide, the various greenhouse gases can be compared on an equal footing using the carbon dioxide equivalent (CO2e). The emissions of greenhouse gases are multiplied by their 100-year global warming potential to produce CO2e (Monceau, 2008). The effects of carbon footprint and the appropriate methods of calculating it have been extensively studied by scholars and environmental specialists (Samara et al., 2022).

Likewise, the IPCC methodological approach is considered as the most formalized and widely acknowledged guideline for estimating GHG released by any entity. The optimal use of IPCC database, which contains emission factors for all areas of activity at the national level, can also be utilized in organizational/individual models, including those that employ the LCA technique (Lundie et al., 2009). The ISO 14040 and 14044 Standards deal with the environmental effect of products and services during their life cycles. Whereas the ISO 14067 Standard establishes concepts, specifications, and guidelines that are constant with ISO 14040 and ISO 14044 standards for life cycle assessment (LCA) for the measurement and reporting of a product's carbon footprint (CFP). The ISO 14064-1:2018 offers guidelines for evaluating and reporting greenhouse gas (GHG) emissions and its eliminations at the organizational rank. It contains requirements for the creation, administration, reporting, and authentication of a company's GHG inventory. This standard also contributes to goal 9 and goal 13 of the SDGs.

1.4 Application of Carbon Footprint and Its Major Areas of Concern:

The carbon footprint mostly pertains to individual items, businesses, communities, and nations, etc.

- The aggregate of CO2 emanated by a person's clothes, food, accommodation etc. is their own carbon footprint.
- An organization's CF evaluates emissions of greenhouse gases from all of its work, including energy consumed in its buildings, production processes, and fleet of cars.
- A product based carbon footprint tracks the GHG emissions throughout the course of its whole life, from the extraction of raw materials and production to consumption and eventual re-use, recycling, or dumping of the product (goods or services).
- A country's carbon footprint emphasizes on emissions of CO_2 that are generated by the total consumption of supplies and energy, vegetation as well as the indirect and direct emissions brought on by imports and exports of goods (Wiedmann and Minx, 2008).

1.5 Carbon Footprint Analysis on Organizational Level:

Large organizations have been linked to a considerable impact on the quantity of GHG emissions released into atmosphere in the urban context because they consume considerable amounts of energy and cause a lot of human activity. These organizations should first assess their environmental performance if they want to reach the climate neutral goal (Battistini et al., 2023). To address the urgent requirement for mitigating climate change, numerous corporations have launched initiatives to determine their carbon footprints realizing how crucial it is to combat climate change.

1.5.1 Carbon Footprinting of Universities:

Higher Education Institutes (HEIs) are seen as significant supporters and promoters of the global plan for sustainable development in their roles as the primary contributors of higher education (Figueiro and Raufflet, 2015). This is due to the fact that they serve as significant amplifiers of sustainability information by influencing the perspectives of present and forthcoming decision-makers in business, academia, and politics (Findler et al., 2019). This is also a result of their capacity to "lead by example," (Caeiro et al., 2020). That type of integration demonstrates universities and colleges' commitment to sustainable goals (Disterheft et al., 2015), and can consequently empower the major stakeholders (Dentoni and Bitzer, 2015). United Nations Organization has developed the Higher Education Sustainability Initiative (2020) on a worldwide level. With its help universities and institutions from all around the world will be involved in achieving the Sustainable Development Goals (SDG), particularly SDG17: Collaborations for the Goals. High stakeholder prospects/anticipations mean that higher education institutions have a considerable obligation to embrace and promote sustainability projects both now and, in future (Genus and Theobald, 2015).

Additionally, HEIs often consist of a variety of buildings that are utilized as homes, canteens, offices, labs, and classrooms, all of which produce considerable amounts of greenhouse gas emissions (GHG) (Vals-Val and Bovea, 2021; Moerschbaecher and Day, 2010). According to a recent World Bank assessment, the education sector contributes between 2 and 3% of a country's emissions in higher-income countries, with most of these emissions coming from purchased power. Carbon Footprint (CF) is very helpful decision-making tool that enables institutions, including HIEs, to retain supervision over their environmentally impacting activities.

This research is designed to estimate carbon footprint of the National University of Sciences and Technology (NUST) H-12 campus. NUST has already embraced the necessary framework to become what is known worldwide as a "SDGs-engaged University" in recognition of the significance of the UN SDGs. The current study takes a bottom-up method, evaluating the carbon footprint for identification of possible emission sources on campus. An in-depth inventory analysis was carried out with respect to the three scopes established by the GHG Protocol coupled with the IPCC Guidelines and the ISO 14064-2019 standard.

1.6 Product Carbon Footprint:

A way to track, manage, and communicate greenhouse gas emissions linked with products and services is the product carbon footprint (PCF). Although centered on life cycle assessment (LCA), a carbon footprint only addresses the problem of global warming. A growing number of businesses are measuring the carbon footprint of their goods for a variety of reasons, including improving brand recognition, interacting with suppliers, clients, and other stakeholders, meeting (imminent) regulatory requirements, or taking first step towards more thorough environmental footprint. The numerous PCF standards are quite helpful since they provide organizations with direction and uphold the legitimacy of carbon footprint indicators in the marketplace.

1.6.1 Carbon Footprinting of Steel Industry:

Because no other material possesses the same special mix of strength, formability, and adaptability as steel, it is essential. Without realizing it, steel has become essential to modern society. Steel buildings and infrastructure account for more than half of the world's total steel production. By 2050, there will be an additional 2.7 billion people on the planet, and urbanization will be accelerating quickly. As a result, there will be an increase in the need for infrastructure and buildings globally in the years to come. Worldwide CO_2 emissions are notably manipulated by the steel industry. An estimated 11% of all CO_2 emissions are attributed to steel products. China produces more than half of the world's steel and, thus, most of its emissions. Pakistan's steel industry has an annual generation capacity of more than 5 million tonnes and a GDP contribution of over 5% annually. In 2019 the production of steel was 1875 million tonnes. This implies that a minimum of 3375 million tonnes of CO2 was emitted. With a potential increase in steel consumption and production there is a need to take the Paris Agreement framework into consideration.

The steel industry needs to rapidly develop and implement new steelmaking technologies on a broad scale while simultaneously increasing the effectiveness of the technologies that are already being utilized. The industry is currently under pressure to lessen its carbon footprint from both a commercial and environmental standpoint. Steel industries are a great option for decarbonization since the steel sector is now one of the topmost three carbon dioxide producers, with emissions initiating from a concentrated area. In the future, steel manufacturers must review and choose a technologically and financially feasible strategy to reduce their carbon footprint.

Since iron and steel industry significantly contribute to the to the GHG emissions data was collected from Fazal Steel (Pvt.) Limited which is located in Industrial Area, I-9 Islamabad for a comparative study with the National University of Sciences and Technology (NUST) H-12 campus. To draw a comparison between the industrial and education sectors.

1.7 Significance of Study:

Like many other countries, Pakistan has been severely impacted by climate change, tracking its GHG emissions and lowering its carbon footprint is essential for long-term sustainability. For this purpose, transitioning into a climate resilient and low carbon economy is a necessity. The country’s emission profile is greatly swayed by energy production and consumption, transportation, agriculture and industrial processes. So, tracking the carbon footprint can assist in mitigating the effects of climate change faced by the country.

1.8 Present Study:

The present Study focuses on calculating carbon footprint of National University of Sciences and Technology. With help of detailed inventory based analysis of the on campus greenhouse gas emission sources. To identify emission sources that have the highest carbon footprint contribution on campus.

1.9 Aims and Objectives:

The main objectives of this study are:

1. Carbon footprint estimation of the NUST H-12 campus.
2. To detect the sources and stressors of carbon footprint at the NUST H-12 campus.
3. To draw a comparison between carbon footprint measured at NUST and carbon footprint estimated at industrial sector mainly steel industry.
4. To formulate a Microsoft Excel based tool for the determination of carbon footprint.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Background:

According to Sixth Assessment Report of IPCC, there is a greater than 50% possibility that the rise in global temperature will be at least 1.5 degrees Celsius between 2021 and 2040 under all examined scenarios. In such a carbon-intensive scenario, the rise in global temperature by 2100 might likewise reach 3.3 to 5.7 °C. It will be necessary to drastically reduce emissions in the near future in order to alter course and keep warming to 1.5 °C or less. When the Paris Agreement was adopted in 2015, member nations of the United Nations Framework Convention Climate Change on (UNFCCC) declared the intention to keep earths temperatures from rising above 1.5 °C above pre-industrial levels(Marquardt et al., 2023). Under the post-Paris climate governance system, governments created "Nationally Determined Contributions" (NDCs), and non-state entities declared numerous commitments, plans, and projects (Marquardt et al., 2022). Through the NDC process, nations can establish distinctive decarbonization goals and gradually enhance their climate commitments, displaying their "highest possible ambition" (UNFCCC 2015).

Pakistan shares 0.88% of the global race greenhouse emissions and is ranked 146th on the climate vulnerability index ranking. According to the updated NDC submitted in October 2021 Pakistan plans to reduce its projected emissions to 50% by 2030 with a 15% decrease coming from domestic resources and a 35% reduction dependent on receiving grant funding from abroad. By 2030, Pakistan aims to switch to 60% renewable energy, 30% electric vehicles, limit its imports of coal, and increase the use of natural solutions. So in order to bring about significant changes in every aspect of society, the government and the general public must work together. Educational institutes are qualified to play important responsibilities in advancing modernization and establishing social and scientific norms (Hahn and Kühnen, 2013). Globally, it has been demonstrated that educational institutes play crucial role for instilling sustainability concepts in young minds and for increasing public awareness of those principles, which allows for the integration of sustainability into daily activities (Jain et al., 2013; Bookhart 2008).

2.2 Carbon Footprint Studies with respect to Higher Education Institutes (HEIs):

Because of their size, varied inhabitants, and abundant activities and operations that frequently take place on their campuses, educational institutions, especially universities, can also be thought of as miniature cities. Numerous colleges throughout the world have implemented initiatives to decrease their environmental impact and improve the sustainability of their operations. Approximately 235 million students are enrolled in universities worldwide. There were 88,071 HIEs open for business in 2018 according to Higher Education Strategy Associates (HESA), which represents about 91% of international enrollments. University colleges made up the greatest portion of all global HEIs (47%) followed by short-cycle HEIs (19%), specialized universities (15%), and comprehensive universities (11%) (Williams, J., and Usher, 2022).

While university-related environmental impacts are relatively minor in comparison to those of other sectors, the education sector plays a revolutionary role in global development (Purcell et al., 2019). They are the perfect locations for experimenting with and showcasing sustainable ideas, making them a living laboratory (He et al., 2018). It has already been established. HEIs can thereby demonstrate sustainability—not just in principle, but also in actual campus life. Furthermore, there is broad consensus that universities should be leaders in advertising climate-friendly practices on their campuses, such as zero carbon emissions and sustainability (Gomez et al., 2016).

But for these institutions to achieve sustainability, they must first acknowledge the harm that their carbon emissions cause to the environment and to climate change. HEIs can identify their most problematic emissions and take the necessary action to move towards an eco-friendly future by undertaking carbon footprint analyses (Samara et al., 2022). Considering that students and staff are mostly to blame for the university's carbon footprint, it is essential to use appropriate evaluation methodologies and key performance indicators when establishing targets for lowering carbon emissions in universities. To make sure that the goals specified are reasonable and attainable, this strategy should be used at the sector level (Robinson et al., 2015). Which is why many HEIs have started maintaining inventory to track their GHG emissions.

2.1.1 Role of Emission Inventory in Carbon Footprint Calculation:

It is vital to identify activities that add to climate change by generating GHG emission inventory as a first step before calculating Carbon Footprint (Bailey and LaPoint, 2016). Wiedmann and Minx (2007) claim that the carbon footprint measures all GHG emissions resulting from and connected to a system's operations. This comprises emissions that are produced directly by the system under investigation and certain indirect emissions that may be produced based on the selected system boundaries (Wiedmann and Minx, 2007). In order to demonstrate the total amount of emissions, it is essential to measure the emissions completely. As a result, the carbon footprint is typically expressed as a mass unit (Harangozo and Szigeti, 2017). Methane, nitrous oxides, and fluorocarbons (HFC and PFC) are the main additional greenhouse gases that are included in addition to carbon dioxide (IPCC, 2014). Emission inventories mostly use the concept of "CO2 equivalents" (CO2e) to account for this.

Santovito and Abiko (2018) offer advice on the GHG inventory formulation; they have categorized several pertinent sources of emission, which has improved their understanding of GHG reduction prospects. However, given that each institution has its own unique characteristics, there is no clear-cut standard process for creating the inventory and figuring out HEIs' GHG emissions. The emissions inventory is created while bearing in mind energy-related direct, indirect, and other indirect emissions. These emissions are categorized into three different scopes under the GHG protocol standard divided by World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). On organizational level the greenhouse gas protocol corporate standard (WRI and WBCSD, 2004) and ISO 14064-1 are used.

2.1.2 Commonly Used Methodologies for Estimating an Educational Institution's Carbon Footprint:

HEIs are urged to set objectives to achieve carbon neutrality in the future in order to set an example. The carbon footprint can thus serve as a crucial tool for detecting the biggest emitters and for increasing staff and student awareness of the many effects produced by routine campus activities. This holds true for all endeavors, including academic and administrative pursuits (Kiehle et al., 2023). While there are standards available for calculating the CF on an organizational level, they are not particularly suited to the requirements of institutions of higher learning. A university varies from a business primarily in terms of its infrastructure and functions (Robinson et al., 2018).

A corporation or industrial sector does not have the resources that an education institute requires. Recent example is a study carried out in University of Turku during the year 2020 where for the emission calculation relating to research equipment the institute had to develop their own concept. Adaptation to more generic standards is important when it comes to HEIs due to their unique characteristics. Which is why in the recent years several universities have developed their own guidelines and methodologies for carbon footprint estimation.

Universities frequently use the techniques of previously available case studies or establish their own guidelines because there isn't a university-specific, globally accepted norm. The institutions frequently decide to follow partially individual allocations, even while claiming international standards as primary guideline (Helmers et al., 2021). The requisites for emissions to be included in scopes 1 and 2 are explicitly outlined in the GHG Protocol Corporate Standard (WRI and WBCSD, 2004), which is principal applied guideline. The framework is less stringent for scope 3 nevertheless, and it permits the option of adoption of a person's own personal indirect, non-energy-related emissions. As a result, institutions appear to choose what emissions to incorporate in their ultimate carbon footprint based on their own experiences. Scope 1 can include fuel requirement by the university fleet as well as some emissions brought on by the on campus combustion of fossil fuels. Scope 2 may include cost of electricity purchased, heating, water use, and, if appropriate, district cooling. Emissions associated with business travel are a commonly used category for scope 3 (Valls-Val and Bovea, 2021). It is also common practice to calculate emissions in connection with the purchase of supplies and machinery required for research or the regular operation of the university. Particular categories are taken into consideration, including paper, lab chemicals, electric equipment, furniture, and office supplies (Valls-Val and Bovea, 2021; Kiehle, 2021).

Another frequently computed category is emissions linked to waste management (Valls-Val and Bovea, 2021). This is followed by upkeep of properties and facilities (Kiehle, 2021) which refers to cleaning of locations and building maintenance. Additionally, it is believed that staff and student commutes have a major impact on a HEI's overall carbon footprint and are frequently considered in the computation process (Valls-Val and Bovea, 2021). Though, the commute of students and staff is more frequently disregarded. The idea that such relates to the personal footprints of faculty and students is one of the key justifications cited for purposefully excluding specific emission categories. As a result, it is not regarded as contributing to an organization's carbon footprint (Townsend and Barrett, 2015).

2.1.3 Calculation Approaches and Tools for Carbon Footprint Estimation:

An approach that is frequently used to determine a university's carbon footprint is a mix model that combines two separate methods to assessing environmental impressions: LCA, or Life-Cycle Assessment, and Extended Environmental Input-Output Analysis (EEIOA). It mixes the finest fundamentals of each strategy and modifies the calculating model to the unique features of the university (Kiehle et al., 2023). In recent years application of this method was successfully carried out by the university of eastern Finland in 2021 (Eskelinen, 2021).

Apart from LCA the IPCC (2006) guidelines established a way to determine greenhouse gas (GHG) inventories, and this methodology has been adopted by several countries. The amount of each GHG factor's emissions is intended by multiplying the activity data by its associated emission factor. The default emission factors are also provided by the IPCC guidelines (Khan and Siddiqui, 2017).

2.3 Carbon Footprint Estimation in Universities Worldwide:

It’s a general consensus is that universities should serve as a model for society, encouraging free speech and critical thought while being inclusive, honest, and sustainable. Universities have thus been considered institutions with important obligations to aid in the resolution of sustainability challenges by putting into practice sustainable plans that include keeping an eye on the unfavorable effects of university activities (Adenle and Alshuwaikhat, 2017).

Lo-lacono, et al. (2018) carried out a study on Polytechnic University of Valencia situated in Spain. Following the ISO 14,064-1 standard the study considered three campuses for carbon footprint estimation under scope 1 and 2. The results showed that carbon emissions per student were 0.31 tCO2e and per employee they were 2.69 tCO2e. Similarly, a study carried out in 2016 at Yale University followed GHG protocol concluded that the net carbon emissions per student word 24.6 tCO2e (Almudafi and Irfan 2016).

Samara et al. (2022) conducted a study on the American University of Sharjah (AUS) from 2018- 2019 which followed the greenhouse gas protocol to categorize its emissions into the 3 scopes. It was reported that the CO2 emissions were 94,553.30 tCO2e. It was also identified that two ultimate contributors on campus were electricity consumption and transport.

Following the GHG protocol the University of Talca (Chile) determined carbon footprint on campus with the intention to identify the stressors involved. The results showed that under scope 1 and 2 the CO2 emissions were 0.03 tCO2e and 0.25 tCO2e per person. However, the scope 3 ended up being the highest contributor with emissions of 0.41 tCO2e per person. The study highlighted transport as the main stressors of GHG emissions on campus (Yañez et al., 2019).

Kulkarni (2019) used the bottom up approach to separately evaluate carbon footprint consumption from each academic department. The net carbon footprint was obtained by adding the contributions of each department individually. The evaluation of carbon footprint at the Shikshana Prasarak Mandali's Sir Parashurambhau College, Pune was carried out by collecting data for three consecutive years. The average carbon footprint calculator during this time was approximately 3630.57 tCO2e per year. Electricity, stationary, laboratory chemicals, paper waste and biodegradable and non-biodegradable waste were identified as main stressors on campus.

Record from the complete coverage of the campus was gathered for a spatial evaluation of the CO2 emissions of King Abdullah University of Science and Technology (KAUST), Saudi Arabia. According to the study, university campus's estimated total CO2 emissions were 127.7 tCO2e. The lowest emission was 0.02 tCO2e, and the highest was 20.9 tCO2e (Adenle and Alshuwaikhat, 2017). Another example may be seen in the work done by Jakarta-based Universitas Pertamina, which actively participates in an IPCC program supporting the decrease of carbon emissions. Direct sampling, questionnaire data collection, and secondary data, information on power consumption, were used as the foundation for analysis. It was determined that 1,351.98 MTCO2, or 0.52 MTCO2/person/year, represented total amount of CO2 emissions (Ridhosari and Rahman, 2020).

A particular calculating method based on GHG Protocols was used in case of University Jaume I in Spain to carry out an intriguing application. Users were able to add new emission sources, apply their own emission factors, and compute CO2 absorptions from their own offset programs. As a result, the tool discussed had been able to calculate the CF of universities, taking into account all of the emission sources that are typically found in educational facilities (Valls-Val and Bovea, 2022).

2.4 Carbon Footprint Estimation by Universities in Pakistan:

Pakistan is extremely vulnerable to climate change and is experiencing warming rates that are significantly higher than the world average, which in turn is causing extreme weather events to occur more frequently and intensely. The susceptibility of Pakistan to the consequences of changing climate is widely accepted. Extreme weather events including floods, droughts, cyclones, torrential downpours, extremely high temperatures, etc. are happening more frequently and with increasing intensity across the nation as a result of the trend of rising temperatures. The monsoon's variability has significantly increased since 2000 (Ali, et al. 2019). As a result, Pakistan has seen yearly floods of varying proportions since 2010, which have caused major property damage and killed a sizable number of people. From 1998 to 2002 and once more in 2014 and 2015, the southern part of the nation had a persistent drought; Tharparkar and neighboring districts in Sindh are currently dealing with its effects. Pakistan, including the main city of Karachi, endured a severe heat wave from June 17 to June 25, 2015. Another big heat wave hit Islamabad, Karachi, and Lahore in June 2022.

The human influence has warmed the climate and is a significant factor in many documented changes in weather and climate extremes, according to AR6 of the Intergovernmental Panel on Climate Change (IPCC) on the physical foundation of climate change (IPCC 2021). The Global Climate Risk Index put Pakistan seventh in the nation’s most susceptible to climate change in its annual report for 2020. Furthermore, the nation has been named one of three nations that have continually been heavily struck by climate whimsy based on an analysis of damages caused by hydro-meteorological extreme events from 2000 to 2020 (Germanwatch 2021). According to the World Bank, from 2000 to 2020, 173 climate-related extreme events cost the economy USD 3.8 billion. As discussed above carbon footprint assessment is one such factor that can help the country in emission tracking. In this aspect the HEIs can play their role by tracking their emissions thereby helping the country to achieve its national and international targets to combat the ever changing climatic impacts.

In Pakistan not a lot of analyses have been conducted to assess the carbon footprint of HEIs. University of Haripur (UoH) quantified its carbon footprint from economic year of July 2016 to June 2017. The study was conducted using the environmental impact modelling program SimaPro v.8.4, the carbon footprint was evaluated using IPCC 2007 greenhouse gas (GHG) protocol over a 100-year time horizon. According to the findings, UoH released 578,898 kgCO2e emissions into the atmosphere between 2016 and 2017. The purchased power was the single source with the highest GHG emissions i.e., 38% of the overall carbon footprint (I. Ullah et al., 2020).

Another study was carried out by University of the Punjab (PU) Lahore. According to the WRI/WBCSD GHG protocol corporate standard, the study was an attempt to portray consumption centric study from the perspective of transport, electricity, and waste generation. According to information gathered from fieldwork, questionnaire, sampling, and pre-existing records for the 2019–2020 academic year, electricity was leading source of CO2 emissions, accounting for 59% of net emissions, followed by transportation (36%), and garbage generation (about 5%). Around 18360.62MT of CO2 emissions were produced overall throughout the course of a year from various sources (Haseeb et al., 2022).

Hamdard university Karachi which is a private sector university in Pakistan estimated its carbon footprint for 2018. Following the methodology from IPCC and GHG protocol the total carbon footprint was calculated which was 1786.20 tCO2e. The fuel consumption by the university transport had the highest emissions (Ashraf and Shabib-ul-Hassan, 2020).

The NED University of Engineering & Technology based in Karachi calculated its carbon footprint using a carbon calculator and identified the sources that contributed the most to it. The main campus of NED University has an estimated carbon footprint of 21,500 metric tonnes of equivalent CO2 in 2017, and there were 1.79 metric tonnes of equivalent CO2 per student. Nearly 7% of the carbon footprint came from emissions under scopes 1 and 2, whereas 85.6% came from emissions under scope 3. The most effective mitigation techniques included major interventions like converting to renewable energy, using energy-efficient machines, electric vehicles, extensive tree planting both within and outside the premises of campus (Mustafa et al., 2022).

2.5 Role of Iron and Steel Industry in Increasing GHG Emissions:

Steel Industry has the potential to be one of the largest carbon emitters sectors because it is an energy-intensive sector. The business is developing quickly, but along with that, it is increasingly contributing to rising carbon emissions on a global scale. It is responsible for roughly 8% direct GHG emissions globally and about 30% of world's industrial CO2 emissions (IEA, 2021). Due to the levels of the product's life cycle, modern society's existing reliance on steel is significantly polluting the environment. The iron and steel industries have already undergone numerous upgrades to boost productivity and cut pollution.

Energy usage has decreased by half over the past 40 years, mostly due to advancements in energy efficiency and higher rates of scrap recycling (Backes et al., 2021). Although rules today are more stringent, the need for reducing emissions and efficiency improvement is anticipated to grow (García et al., 2019). Besides the enormous energy requirement that the steel industry faces, steel manufacture is a main cause of GHG emissions (Burchart-Korol, 2013). The industry is also considered as one of the largest consumers of coal which is why it can be considered as the most greenhouse gas intensive industry (Kim et al., 2022).

Carbon footprint of steel is 1.85 tonnes for every tonne of steel produced, according to IEA and the World Steel Association. This is a weighted average of the two main methods used to produce steel globally. The BF-BOF route and the EAF, which employs 105% reprocessed steel, are often denoted to as the "primary" and "secondary" techniques. These two methods have individual CO_2 footprints of 1.987 and 0.357 tonnes per tonne of steel manufactured. 1.787 tonnes of CO_2 are avoided for every tonne of recycled steel utilized. Transport is expected to increase the carbon footprint of steel by 7.9 grammes per tonne-km.

2.6 Carbon Footprint Studies With Respect to Steel Industry:

The steel sector is developing very quickly in many parts of the world, including Asia. A significant amount of carbon emissions was seen in recent years. Conferring to the United Nations Environment Program (UNEP). Top five leading countries that emit carbon dioxide are China, United States of America, India, Russia, and Japan. Pakistan is ranked on 25th spot as global carbon dioxide emitter. Around 7% of the global greenhouse gas emissions. 11% of the country’s CO_2 emissions come from the iron and steel industry.

Multiple research studies have attempted to predict how much energy and carbon dioxide the steel industry would use in the future. By means of a bottom-up approach, and economic data on both the best currently available technology and emerging innovations. For the European steel industry, potential reductions were discovered in CO2 emissions of 65% till the year 2030 (Pardo and Moya, 2013).

In another study it was observed that the main industries in China that produced CO2 were steel and iron. The Emission Factor Effect was also examined, and it was found to have had a minor adverse impact on the rising carbon dioxide (CO2) emission levels (Wen-qiang et al., 2011).

Importance of various energy production sources in the steel industry was examined, and it was discovered that the steel industry in South Asian nations uses electricity, natural gas, coal, coke, and other petroleum products. Compared to the entire power and fuel use in India's manufacturing sector, this industry uses about 30% of the overall energy. The largest exports from Nepal were iron and steel, which increased by 1.2% in 2011 compared to 2010. The importance of dissimilar energy production bases in steel industry was examined, and it was discovered that steel industry in South Asian nations uses electricity, natural gas, coal, coke, and other petroleum products. Compared to the entire power and fuel use in India's manufacturing sector, this industry uses about 30% of the overall energy. The largest exports from Nepal were iron and steel, which increased by 1.2% in 2011 compared to 2010 (Starker et al., 2013).

Another study showed that China is currently seeking the implementation of policies that might help the nation shift to low-carbon development. But there are several obstacles in its way. In order to balance carbon dioxide reduction and economic improvement in China, this study looked at three key areas: low-carbon municipalities, low-carbon practices and industries, and the evolution of China's energy system. It concluded that clean coal technologies were the best option (Wang et al., 2018).

The life cycle approach is important in reducing carbon releases from the steel sector, according to the World Steel Association's report (World Steel Association, 2018). It also takes into account the decrease in energy consumption brought on by the practice of new-generation steels, in accumulation to the emissions connected to production of steel goods. Similar to this, when choosing a material, consideration must be given to steel's inherent recyclability. Additionally, it has been noted that recycling steel lessens the need for landfill space and eliminates the buildup of otherwise abandoned steel items.

Furthermore, a noteworthy factor in determining the total emissions from the process is the technology used in steel production. Electric-arc furnaces (EAF) have excellent metallurgical control and are pollution-free. Compared to producing steel from primary sources like blast furnaces, this significantly lowers the energy consumption for steel production. Because of this, it is increasingly the first option for producing steel in developing nations. India now ranks behind China as the world's second-largest manufacturer of EAF-based steel, it produces more EAF-based steel than the United States. By 2025, 31% of steel will be produced via the EAF approach. When compared to steel generated by an induction furnace, EAF steel is also far higher in quality.

Even though blast furnaces are the predominant method of manufacturing, since 2007 there has been a significant upsurge in the quantity of steel produced globally using the electric arc furnace (EAF) method. Some experts claim that investing in EAFs is more appealing than other options because of its efficiency, feedstock flexibility, and environmental benefits, particularly considering the current and forthcoming Carbon Emission Regulations and expanding steel waste reservoirs.

CHAPTER 3

3. METHODOLOGY

3.1 Study Design for the Estimation of Carbon Footprint of NUST H-12 Campus:

For present study National University of Sciences and Technology (NUST) H-12 Islamabad, Pakistan was chosen for carbon footprint calculations under the first objective (Figure 3.1). Situated at Sector H-12 in the bustling city of Islamabad, NUST is a public sector university with a motto of Defining Futures. In 2008, the construction of the campus situated in Sector H-12 Islamabad was initiated. It covers an extensive area of 707 acres of land. The campus currently has approximately 7000 students including international and postgraduate students enrolled in 14 different departments. Out of these approximately 3456 reside on campus in the hostels. Given that students and staff come from all parts of country, a significant portion of the campus has been dedicated to hostels and employee residences. Total Faculty members are approximately 733. While the total number of support staff on campus is estimated to be 2920.

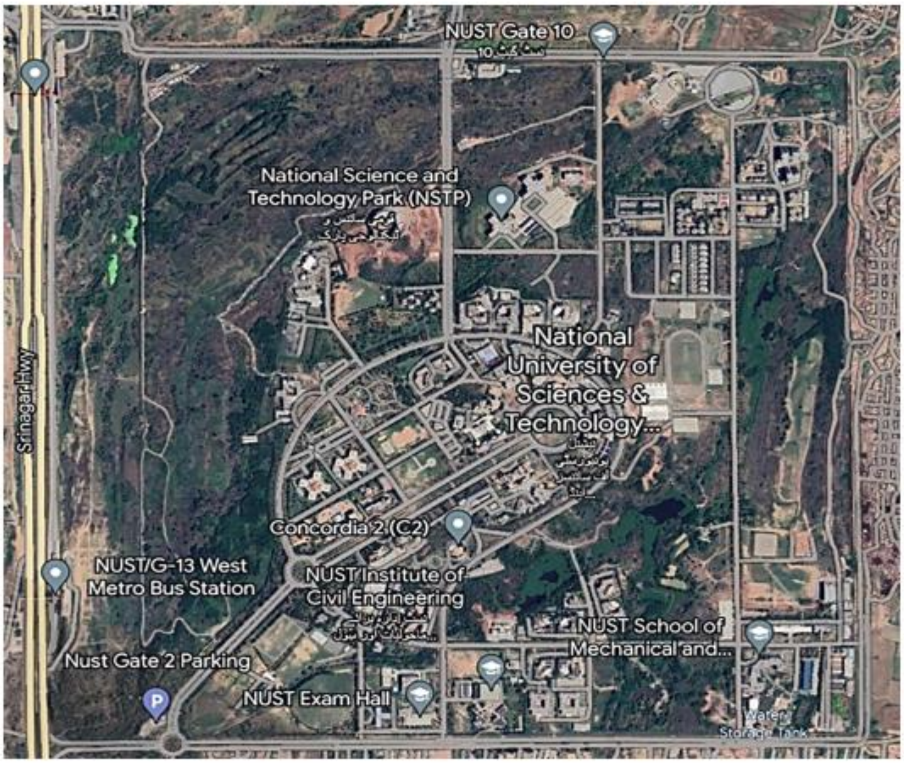


Figure 3.1 Study Area.

3.2 Data Collection:

Data collection included all facilities within the campus like the institution's main office, faculties, cafeterias, and residential area (Figure 3.2).

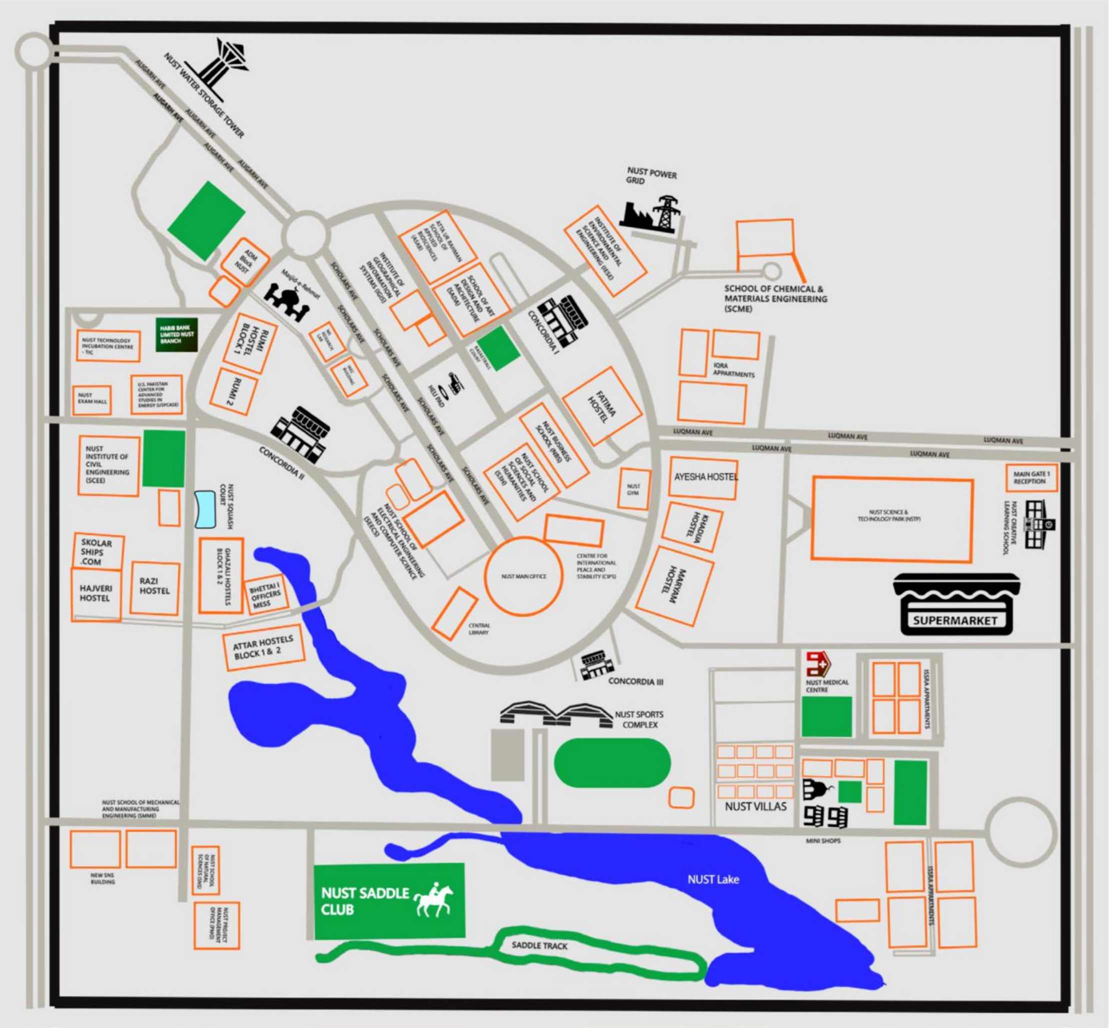


Figure 3.2: Detailed Internal map of NUST H-12 Campus Islamabad, Pakistan.

To carry out the data collection four step were involved (Figure 3.3): (1) identifying the working boundaries, (2) Collection of data, (3) Emission source identification and (4) Calculating and reporting the results (Robinson et al., 2018). Second phase was data collection after the working boundaries had been established. Data was gathered by physically visiting the departments, interacting with the stakeholders, and getting invoices for purchases like electricity. For detailed inventory analysis the data was collected for four consecutive years i.e., from 2019-2022.

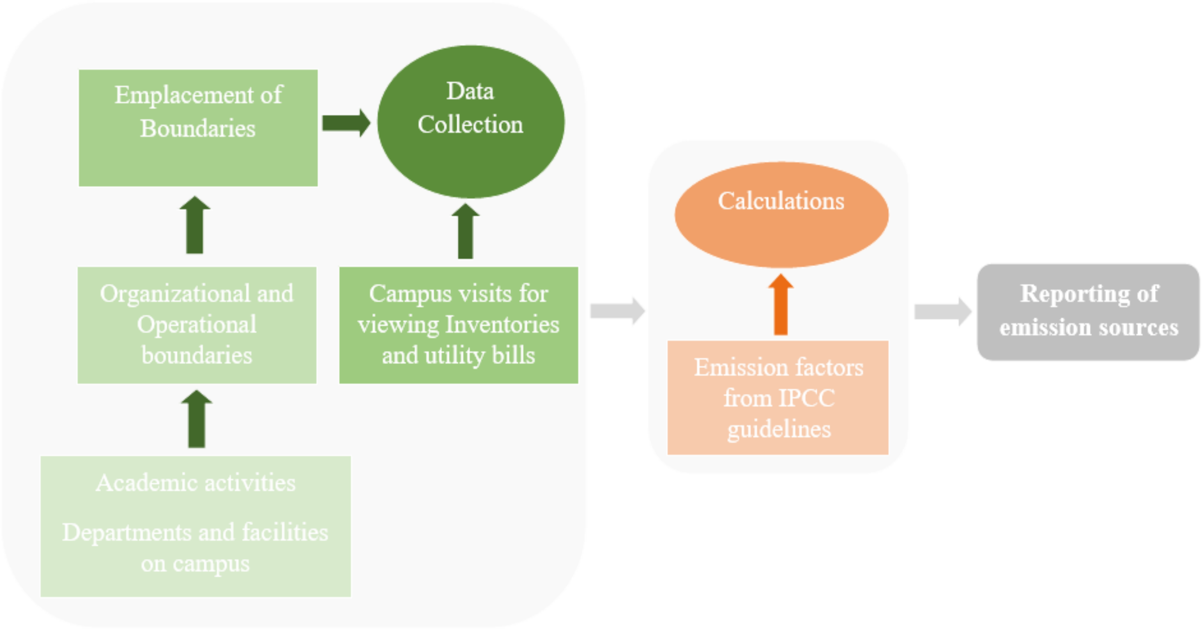


Figure 3.3: A bottom-up approach for calculation of Carbon footprint of NUST H-12 campus

Organizational, operational, and temporal boundaries were considered when creating the inventory. Information about the inventory was acquired from pertinent university departments like PMO and the university admin. These boundaries are described as follows:

3.2.1 Organizational Boundaries:

These specify if emissions are measured across the whole campus or only in a particular area or department. The facilities and buildings that should be considered in the study are chosen based on this boundary. NUST's main campus was chosen as the organizational border for this study.

3.2.2 Operational Boundaries:

The inventory's emission sources are identified as the organizational boundaries. All emission sources are alienated into three scopes rendering to the GHG protocol, which employs scopes. Scope 1 emissions are the ones that originate directly from sources possessed or controlled by university; Scope 2 emissions are coming upstream from the production of power that has been purchased; and Scope 3 emissions are the ones coming indirectly from sources that are owned or controlled by another association. According to ISO 14064-1 the operational boundaries are also known as the reporting boundaries. The quantification of the identified GFG emissions sources following the three scopes is done separately.

3.2.3 Temporal Boundaries:

For calculation of the data collection was carried out from 2019 to 2022. All the CF related calculations for NUST were made using the data of these four years. Therefore, it can also act as baseline for the institution for further calculations.

3.3 Guidelines Used f or Carbon Footprint Calculations:

For carbon footprint estimation following guidelines were followed in this study:

3.3.1 The IPCC Guidelines and GHG Protocol Corporate Accounting and Reporting Standards:

IPCC guidelines and GHG Protocol Corporate Accounting and Reporting Standards, were used for principles and system boundaries documentation. For computing carbon footprints, which take into account emissions from different sources including buildings, transportation, and purchased products and services, the IPCC offers a thorough set of guidelines. These can assist institutions in precisely calculating their carbon footprint and pinpointing places where they can cut emissions. The IPCC 2006 guidelines have established levels to categorize the technical complexity and dependability of emission components used in carbon footprint estimates.

3.3.2 The ISO 14064-1:

A set of standards called ISO-14064 is used to report and measure greenhouse gas emissions and removals. This requires universities to justify for emissions from variety of sources, including energy use, transportation, and waste management, as well as emissions from other activities, like flying and using purchased products and services. By adhering to these recommendations, institutions may more precisely calculate their carbon footprint, pinpoint areas for improvement, and share their efforts in lowering GHG emissions. The part-one of these standards specifies the reporting of greenhouse gas emissions and their removal at an administrative level. It contains conditions for the creation, management, reporting, and authentication of a firm's GHG inventory. According to the guidelines the greenhouse gas inventory has been aggregated into the following categories:

a) Direct GHG reductions and emissions.
b) Indirect emissions of GHGs from trade in energy.

c) Transportation-related indirect GHG emissions.
d) The organization's indirect GHG emissions from products used.
e) Indirect GHG emissions are brought on by using the company's products.
f) Indirect GHG emissions from other sources.

Furthermore, the quantification approach used by the organization should be such that it reduces uncertainty. For quantification of data it must include primary and secondary data. Calculations for the greenhouse gas emissions should then be carried out in accordance with the quantification approach selected. Also, the time period for which the emissions are calculated by the organization should be documented.

After calculation the organization or the institute calculating the greenhouse gas emissions should convert the quantity calculated to tonnes of CO2e (tCO2e) while using the relevent global warming potentials (GWP). For this purpose, the latest GWPs by the IPCC shall be used. The time horizon global warming potential should be 100 years. In the case of using other time horizons for global warming potential they must be reported separately. After reporting its GHG emissions the organization may also plan reduction initiatives to lower the GHG emissions and enhance its removal. Reduction initiatives must be documented by the organization if in case they are reported.

3.4 System Boundary for Inventory Analysis:

According to the IPCC and the GHG Protocol the accounting of greenhouse gases is done with the help of three scopes. Identification of potential emission sources in this study was achievable through detailed inventory analysis. Which was carried out by reviewing the records of the transport department and the invoices for the natural gas consumed on campus, for Scope 1. The service provider purchase invoices were used to conduct an inventory analysis for scope 2's purchased electricity. Detailed surveys were used to complete an inventory study for scope 3 for the quantity of renewable energy produced on campus, wastewater treatment, and annual trash generation. Figure 3.4 shows the scope wise system boundary for the inventory analysis.

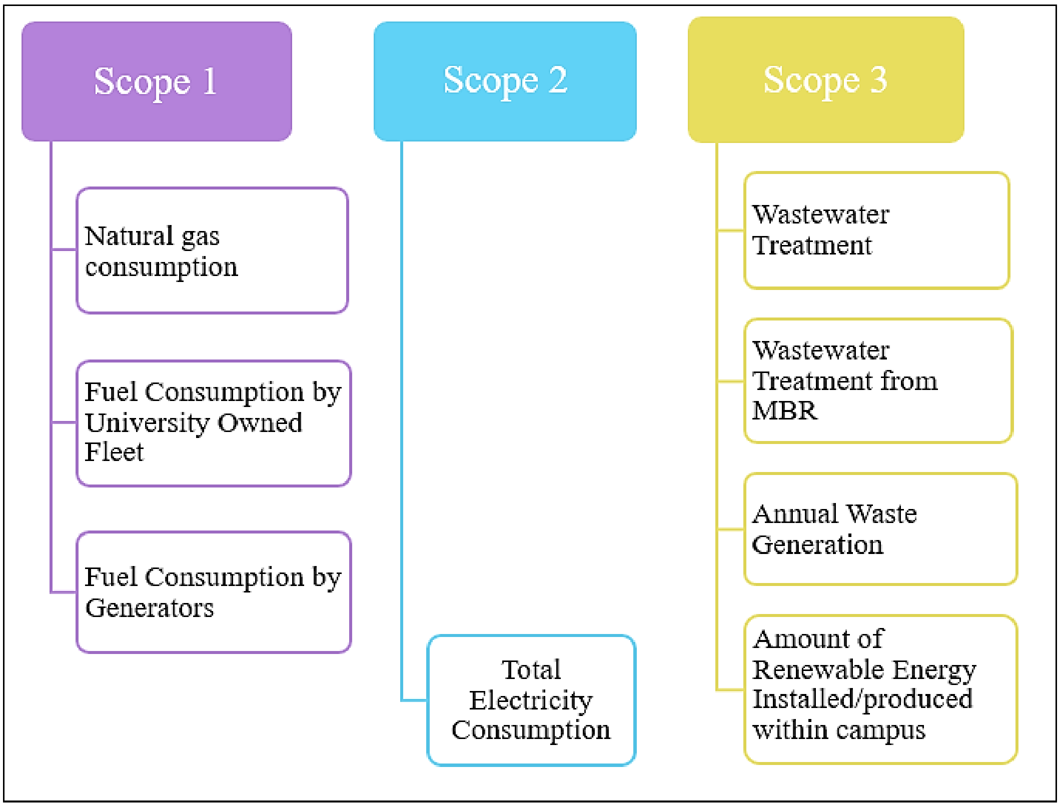


Figure 3.4: Scope wise system boundary for the inventory analysis.

3.5 Emission Factors:

The IPCC emission factor database (EFDB), which offers data particular to each country, was used to obtain the GHG emission factors. The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories can also be utilized. Tiers have been defined by the IPCC 2006 recommendations to rank the methodological complexity and dependability of emission variables. For classifying both emissions variables and activity data, three stages are described.

3.5.1 Tier 1:

These are easily accessible national or global emission factors, like those listed by the IPCC, therefore they ought to be doable for all nations. The following details are necessary for the usage of a Tier 1 emission estimate:

- Information on amount of fuel consumed.
- A standard emission factor.

3.5.2 Tier 2:

These demand for more locally focused data and a medium level of complexity. The use of a Tier 2 strategy typically necessitates:

- Information on the volume of fuel burned.
- A national emission factor for each type of fuel.

3.5.3 Tier 3:

These regulations are the most intricate and call for the most precise information. It employs emission factors that depend on different combinations of each, such as:

- Data pertaining to the quantity of fuel burned.
- A country-specific emission factor.
- Combustion technology, and maintenance standards.

Since country-specific emission factors were unavailable in the context of Pakistan the standard emission factors provided in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were used. Once the emission inventories were formed Tier 1 level assessment can be performed on the acquired data.

3.6 Evaluation of Scopes and Sources of Emission:

3.6.1 Scope 1 Emissions:

- The university fleet served as the source for the emissions that were looked at under Scope 1. This relates to the university-owned automobiles used for commuting inside or outside the university's immediate area.
- Total quantity of natural gas consumed within the campus premises i.e., in cafeterias and in residential areas were also demarcated under scope 1.
- Similarly, the fuel consumption through generators was also categorized in this scope. Emission factors used were derived from the 2019 refinement to the 2006 IPCC guidelines for national GHG inventories on stationary and mobile combustion.

3.6.2 Scope 2 Emissions:

- The total electricity consumption within the university premises was categorized under this scope.

- The emissions were determined by adding up total electricity consumed in each month on the entire campus of the institution. These numbers were taken from electricity invoices for the university that were issued by Islamabad Electric Supply Company (IESCO).
- The emission factor for this scope was country specific. As electricity transmission and distribution losses, a country's energy mix, and other factors are taken into account when determining emission factors for electricity generation and consumption (Brander et al., 2011).

3.6.3 Scope 3 Emissions:

Indirect emissions not inculcated in the preceding two scopes are calculated in this scope. Actions under scope 3 are a result of organizational actions that take place at places or with resources that are not under the university's ownership or control. It is feasible to apply the following criteria to determine which emission sources should be relevantly considered for inclusion in this scope:

1. Importance of emissions in relation to the organization's overall emissions.
2. Representativeness of the activity across the board.
3. Availability of auditable data.
4. Possibility of reducing emissions

For this scope the sources of emissions included:

- Wastewater treatment at the integrated constructed wetland (ICW) installed on campus may treat around 75,000 gallons of water per day out of which the total on campus requirement is 22000 gallons.
- Wastewater treatment at Membrane BioReactor (MBR) which has a 50m3 capacity out of which 25m3 is utilized. During the pandemic time when the campus went under lockdown the MBR was nonfunctional from March 2020 to September 2021.
- Annual waste generation and the emissions from the amount of renewable energy produced within the campus were also calculated under the scope 3. The emission factors for this scope were also obtained via the 2006 IPCC guidelines for national GHG inventories on stationary and mobile combustion.

- Generation of food waste, paper waste and plastic waste along with the amount of Renewable Energy produced within campus were also considered for scope 3 calculations.

3.7 Evaluation of Direct and Indirect Emissions:

As discussed above, the emission generation at NUST H-12 campus can be categorized under the three scopes. For the establishment of the study sources that quantified the GHG emissions were organized in the form of an emission inventory (Figure 3.4). To estimate the GHG emissions with respect to each category following steps were followed:

1. Find out how much energy is used in each category, such as how many kWh are used for electricity and how many liters of fuel are used for the purpose of transportation.
2. Locate the most recent GHG emissions factor for each group.
3. Multiply consumption by the matching category's emission factor to determine the quantity of CO2e for each category.

The data collected from throughout the campus via the inventory was then analyzed scope wise for further calculations in the Ms. Excel spreadsheets for four consecutive years. In this regard the following equation was used for the estimation of carbon footprint.

$$\mathbf{A \times EF_g = E_g} \qquad \mathbf{(1)}$$

The most important values when computing CO_2-based emissions are activity data (A) and GHGg emission factors (EFg), according to the standard. Activity data serves as a gauge for the amount of activity that (directly or indirectly) contributes to GHG emissions. For instance, activity data might include how much fuel or paper is used.

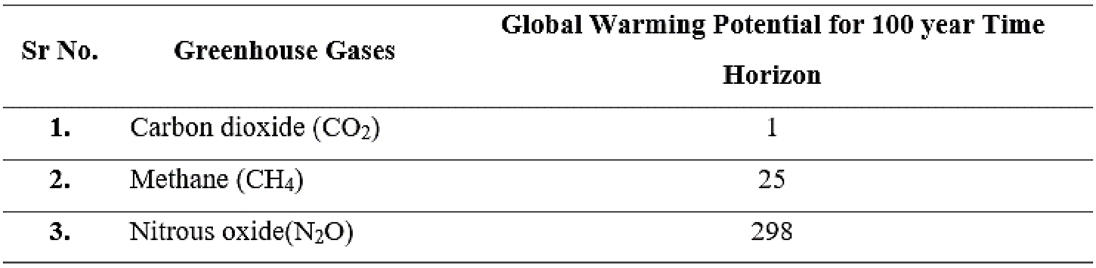
Then, an emission factor (Fg) is used to translate this data into emissions for that gas (Eg), in this case CO2 emissions. The emission factors, which are stated in terms of CO2/per unit of measurement are unique to each individual source.

$$\mathbf{GHG = \sum_g E_g \times GWP_g} \qquad \mathbf{(2)}$$

Additionally, global warming potential (GWPg) describes how much a GHGs adds to global warming in relation to CO2. The GWP of CO2 in relation to an emission source has been given a value of 1 in the IPCC 4th Assessment Report (Thurston and Eckelman, 2011).

The sum of the emissions of each gas multiplied by its GWP (Table 3.1) represents the net quantity of GHG emissions, which are stated in tonnes of CO2 equivalent, or tCO2e. The overall methodology used for the calculation is summarized in Figure 3.5.

Table 3.1: Global Warming Potential values.

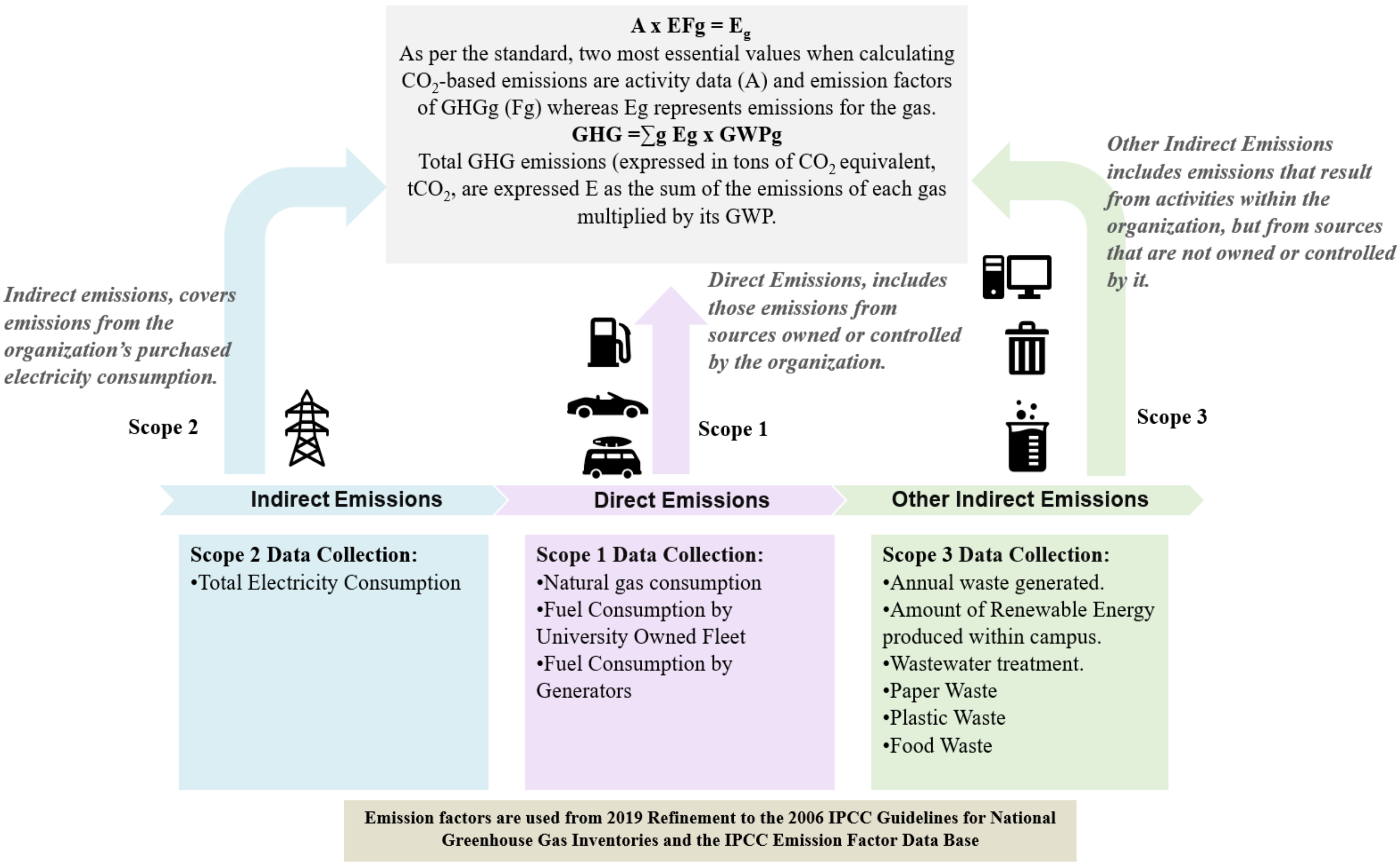


Sr No.	Greenhouse Gases	Global Warming Potential for 100 year Time Horizon
1.	Carbon dioxide (CO_2)	1
2.	Methane (CH_4)	25
3.	Nitrous oxide(N_2O)	298

(Source: IPCC Fourth Assessment Report)

3.8 Assumptions and Exclusions in the Study:

Under scope 1 the different electronic equipment used on campus like desktop computers, internet access equipment, scanners, printers etc. were omitted from the study due to data unavailability. Similarly with regard to the student and staff commuting to and from the university, which was categorized under scope 3, the data was not made available. Which is why it was excluded from the key point indicators for calculation of carbon footprint. The data for total natural gas consumption of residential areas was unavailable from January to June for the year 2019 and from August to December for the year 2022. Similarly during the lockdown the MBR was nonfunctional so there was no data available for wastewater treatment through MBR from March 2020 to September 2021



$$A \times EFg = E_g$$

As per the standard, two most essential values when calculating CO_2-based emissions are activity data (A) and emission factors of GHGg (Fg) whereas Eg represents emissions for the gas.

$$GHG = \sum g\ Eg \times GWPg$$

Total GHG emissions (expressed in tons of CO_2 equivalent, tCO_2, are expressed E as the sum of the emissions of each gas multiplied by its GWP.

Indirect emissions, covers emissions from the organization's purchased electricity consumption.

Direct Emissions, includes those emissions from sources owned or controlled by the organization.

Other Indirect Emissions includes emissions that result from activities within the organization, but from sources that are not owned or controlled by it.

Scope 2 Data Collection:
- Total Electricity Consumption

Scope 1 Data Collection:
- Natural gas consumption
- Fuel Consumption by University Owned Fleet
- Fuel Consumption by Generators

Scope 3 Data Collection:
- Annual waste generated.
- Amount of Renewable Energy produced within campus.
- Wastewater treatment.
- Paper Waste
- Plastic Waste
- Food Waste

Emission factors are used from 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the IPCC Emission Factor Data Base

Figure 3.5: Summary of the Methodology for Carbon Footprint Calculation of NUST-H12 Campus.

3.9 Study Design for the Estimation of Carbon Footprint for Fazal Steel PVT Limited:

For achieving the second objective of this study a comparative analysis was drawn between the carbon emissions from the NUST H-12 campus and from steel industry. In this context Fazal Steel (Pvt) Limited (FSL) was chosen (Figure 3.6). Situated in the industrial area of Islamabad in sector I-9 it is considered among top steel rolling mills in Pakistan. With competence in producing sectional steel products of various grades and sizes as well as steel bars for concrete reinforcement, the company has achieved success in the steel industry.

Figure 3.6: Study Area.

The industry is well renowned for its cutting-edge technology, high standards of quality, and dedication to Pakistan's progress. With a 130,000 tonne annual capacity, FSL's novel automatic re-rolling mill, built on Italian and Indian design, can manufacture steel bars in sizes ranging from 10 to 25 mm. Currently the total steel production for Fazal Steel Limited is estimated to be around 44,460 tonnes per year.

The industry produces structural steel such as girders, angles, channels, I-beams, and flat rolls in accordance with standard of American Society for Testing and Materials (ASTM) 36A as well as steel reinforcement rebars in grades 40 [280], 60 [420], 75 [520], 80 [550], and 100 [690] that confirm to standards ASTM 615A, BSI 4449, BSI 4461, and AASHTO M-31. Other products include plain rebars in sizes from 1.5" to 4". Steel rebars produced by FSL are utilized in many important construction projects, including high-rise and multi-story buildings, bridges, dams, power plants, nuclear projects, highways, airports, and cement plants throughout the country.

3.10 Data Collection:

The data was collected during the year 2022. For the purpose of primary data collection, the following techniques were used; understanding the processes to identify inputs and outputs involved in steel manufacturing. Informal interviews with the officials and questionnaires to get quantitative data for inputs and outputs at the process level.

3.10.1 Questionnaire for Data collection:

A questionnaire study was conducted at Fazal Steel to gather as much information as possible regarding material flows and to create a greenhouse gas emission inventory. A structured questionnaire with both open-ended and closed-ended queries was created for this aim. There were two sections to the questionnaire.

- The first component of the questionnaire asked questions about the company's administration, certification, contact information, and annual production.
- The second component, which is titled "Inputs and Output Profile," focused on the types of raw materials used and how much of each was consumed, including questions concerning energy, water, metals, inorganic compounds, oil, and

lubricants, among other sorts of raw materials. The amount and expense of the solid and liquid waste produced as output.

The sample questionnaire is attached Annex 1.

3.11 Guidelines for Carbon Footprint calculation:

For industrial carbon footprint calculations, the IPCC guidelines were used. Volume 3 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides guidelines for industry processes and product use. According to the guidelines there are three tiers for estimation of carbon emissions caused by the iron and steel industry.

3.11.1Tier 1:

It is based on data from total manufacturing and default emission factors. Instead of using more comprehensive activity data on process inputs, this method estimates CO2 emissions on assumptions about the amount of inputs to the manufacturing of sinter and iron and steel.

3.11.2 Tier 2:

Using countrywide statistical data on the inputs and outputs of carbonaceous materials. The Tier 2 technique for estimating CO2 emissions is centered on carbon mass balance methodology. where national fuel characteristics are used to produce country-specific data on carbon content.

3.11.3 Tier 3:

The Tier 3 technique is grounded on the use of modelling outputs. When using stack emission, it is recommended for compilers to provide documentation of the data gathering procedures and techniques used, as well as supporting data to demonstrate that assessed results accurately imitate plant performance. When models are used to assess emissions. It is advised to carry out model verification to provide proof that the model outputs accurately represent the performance of the facility. It is also best practice to completely describe the data and assumptions used in the model.

Since the data on inputs and outputs of the industrial processes was not made completely available by the industry. So only Tier 1 level assessment was performed on the collected data.

3.12 System Boundary for Inventory Analysis:

As discussed previously the IPCC and the greenhouse gas protocol have divided the accounting of GHG emissions into three different scopes. As shown in Figure 3.7.

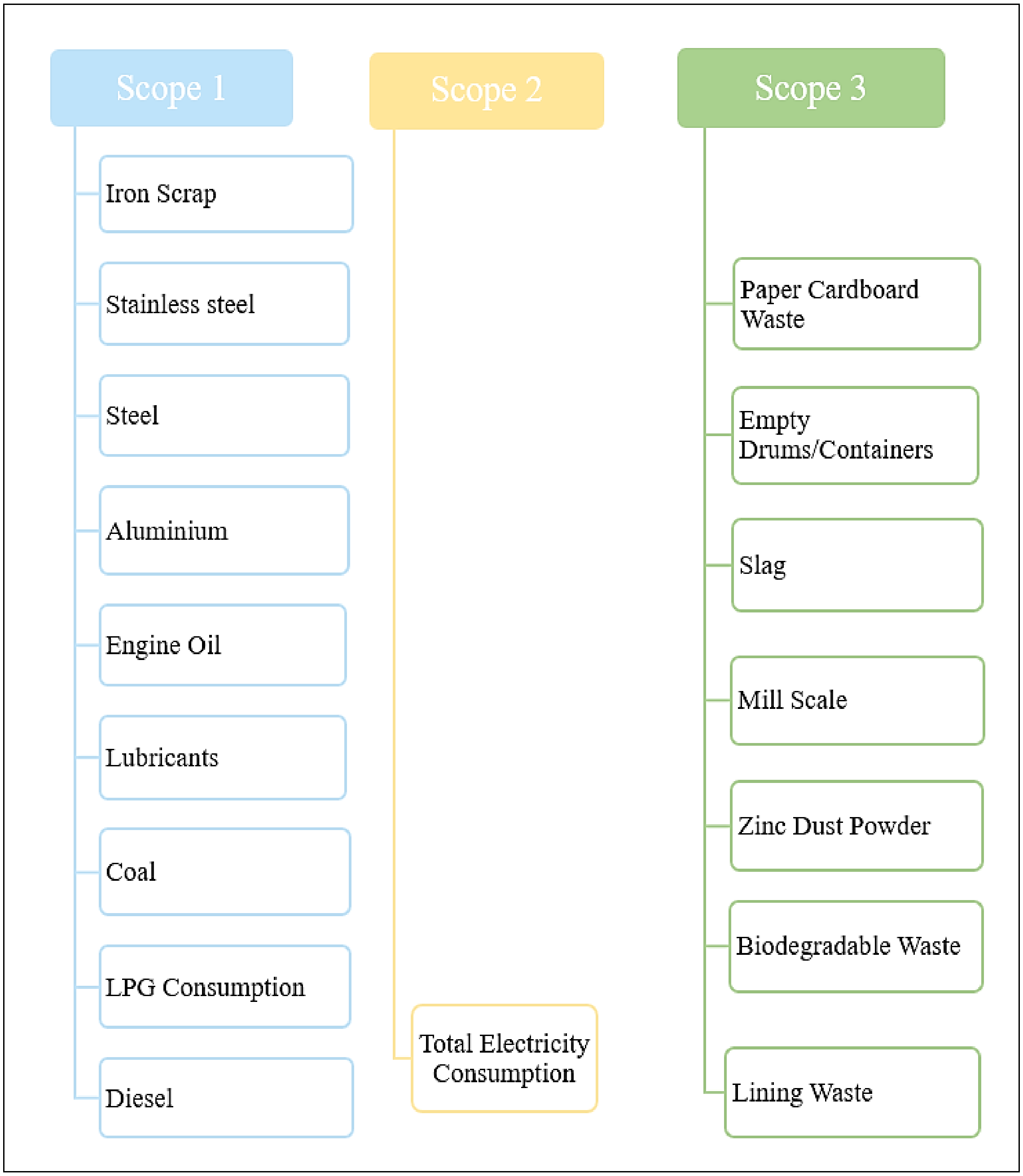


Figure 3.7: Scope Wise System Boundary for The Inventory Analysis.

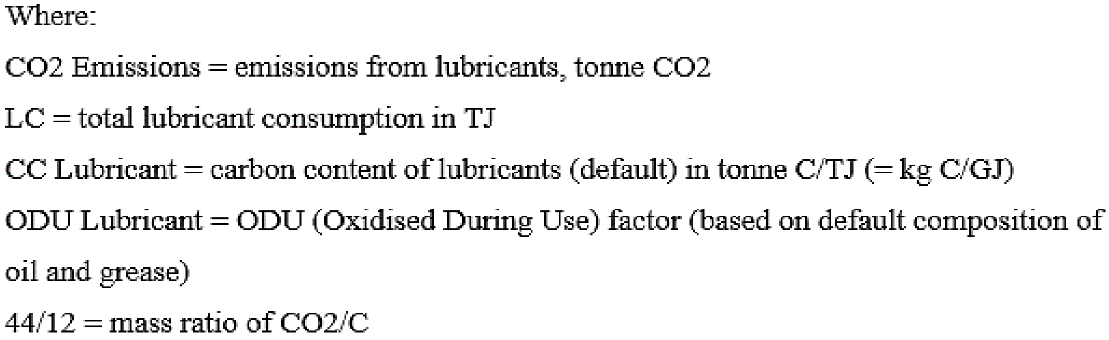
3.13 Evaluation of Direct and Indirect Emissions:

After categorizing the data acquired under the three scopes. An emission inventory was formulated to determine the greenhouse gas emissions with respect to each category. The data for one year i.e., 2022 was analyzed in Ms. Excel. The default equation given by the IPCC was used for the carbon footprint estimation.

$$\textbf{Emissions} = \textbf{AD x EF} \qquad \textbf{(3)}$$

Where AD stands for activity data and EF stands for the emission factor. For amount of lubricants used during the steel production a separate formula is given by the IPCC that also coincides with the Tier 1 calculations.

$$\textbf{CO2 Emissions} = \textbf{LC x CC}_{Lubricant}\ \textbf{x ODU}_{Lubricant}\ \textbf{x 44 /12} \qquad \textbf{(4)}$$

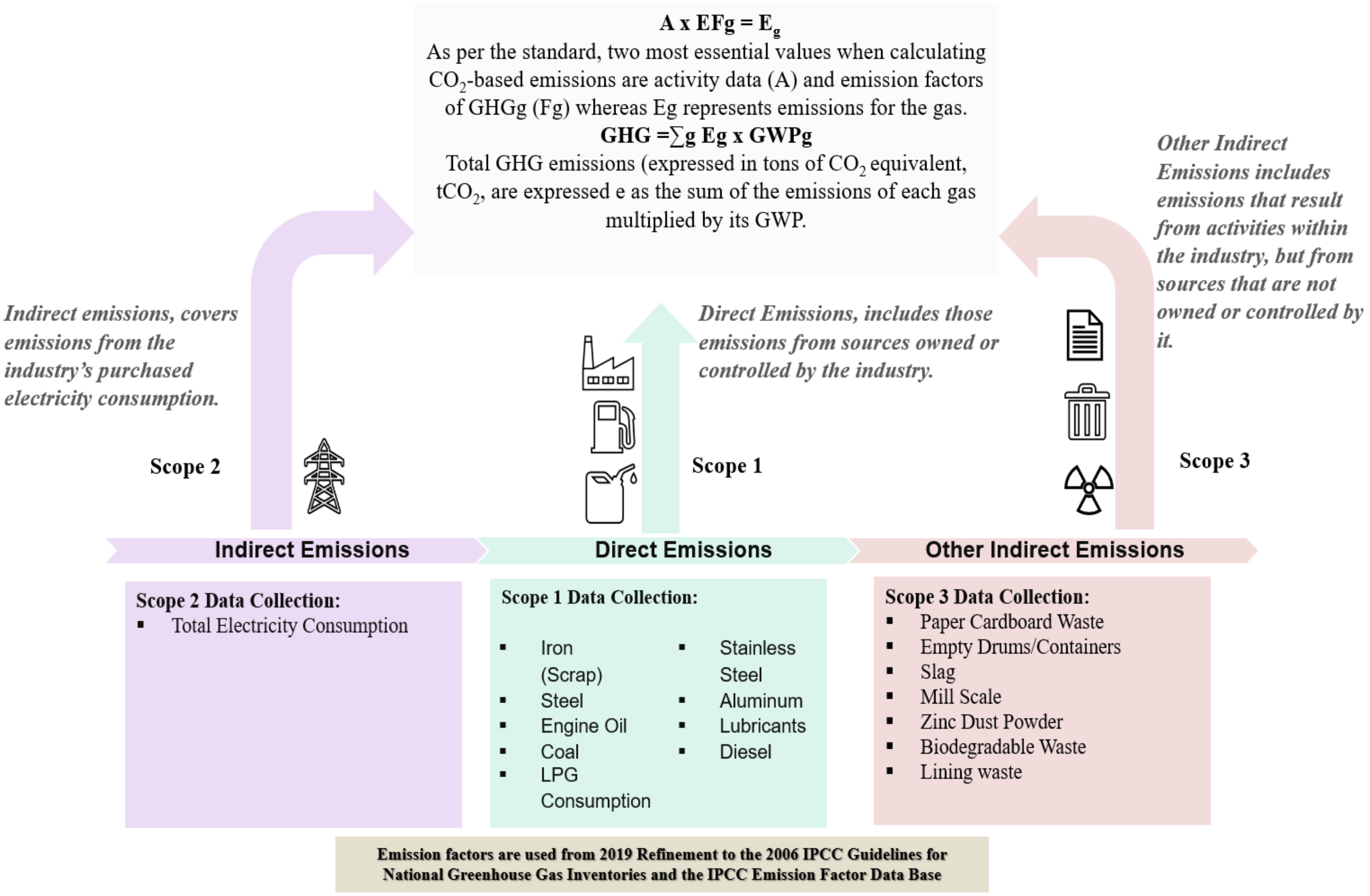


Where:
CO2 Emissions = emissions from lubricants, tonne CO2
LC = total lubricant consumption in TJ
CC Lubricant = carbon content of lubricants (default) in tonne C/TJ (= kg C/GJ)
ODU Lubricant = ODU (Oxidised During Use) factor (based on default composition of oil and grease)
44/12 = mass ratio of CO2/C

The emission factors for the calculations were taken from the IPCC Emission Factor Database (EFDB). Which is the electronic library for greenhouse gas emission factors. The overall methodology used for the calculation is summarized in Figure 3.8.

3.14 Assumptions and Exclusions made during calculations:

The questionnaire provided to the industry was not completely filled by the concerned authorities. Most of the acquired data shared for analysis was based on assumptions as the actual quantities were not shared by the authorities contacted.



A x EFg = E_g

As per the standard, two most essential values when calculating CO_2-based emissions are activity data (A) and emission factors of GHGg (Fg) whereas Eg represents emissions for the gas.

GHG =$\sum$g Eg x GWPg

Total GHG emissions (expressed in tons of CO_2 equivalent, tCO_2, are expressed e as the sum of the emissions of each gas multiplied by its GWP.

Indirect emissions, covers emissions from the industry's purchased electricity consumption.

Scope 2

Direct Emissions, includes those emissions from sources owned or controlled by the industry.

Scope 1

Other Indirect Emissions includes emissions that result from activities within the industry, but from sources that are not owned or controlled by it.

Scope 3

Indirect Emissions

Direct Emissions

Other Indirect Emissions

Scope 2 Data Collection:

- Total Electricity Consumption

Scope 1 Data Collection:

- Iron (Scrap)
- Steel
- Engine Oil
- Coal
- LPG Consumption
- Stainless Steel
- Aluminum
- Lubricants
- Diesel

Scope 3 Data Collection:

- Paper Cardboard Waste
- Empty Drums/Containers
- Slag
- Mill Scale
- Zinc Dust Powder
- Biodegradable Waste
- Lining waste

Emission factors are used from 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the IPCC Emission Factor Data Base

Figure 3.8: Summary of the Methodology for Carbon Footprint Calculation of Fazal Steel (PVT) Limited.

3.15 Development of Microsoft Excel based tool for the Calculation of University Carbon Footprint.

A Microsoft Excel based tool was developed for calculation of carbon footprint for NUST. Although there is a vast variety of calculators available online for calculation of carbon footprint, but they often miss some of the emission sources or have outdated emission factors. S. Jain et al. (2017) Divided the tool development into two essential steps.

- Selection of indicators and components of greenhouse gas emissions sources.
- Choice of calculation formulas.

3.15.1 Selection of Indicators and Components of GHG Emissions Sources:

The GHG sources of emissions were identified under the IPCC guidelines and then divided into three scopes. The default emission factors were also used from the IPCC guidelines as country specific emission factors for Pakistan remained unavailable. Results were calculated both monthly and annually by the tool. Table 3.2 shows the data used for carbon footprint computation tool. Data not made available by the university administration was exempted from the tool.

3.15.2 Choice of Calculation Formula:

The calculation formula for the tool was grounded on the guidelines of IPCC and GHG protocol for most of the emission sources. The estimation of carbon footprint is simply done by multiplying associated emission factor by the activity data obtained by data collection.

$$\mathbf{A \times EF_g = E_g}$$

Where A is the activity data and EFg is GHGg emission factors EFg. Results obtained via this tool are discussed in detail in next chapter. Obtained results were expressed both in kgCO2e and tCO2e.

Table 3.2 Components for Carbon Footprint Tool

S.no	GHG Emission Sources	Emission type
1.	Natural gas consumed in Concordia 1	Scope 1 Direct Emissions
2.	Natural gas consumed in Concordia 2	
3.	Natural gas consumed in Residential Areas	
4.	Fuel Consumption by University Owned Fleet (Petrol)	
5.	Fuel Consumption by University Owned Fleet (Diesel)	
6.	Fuel Consumption by Generators (Diesel)	
7.	Total Electricity Consumption	Scope 2 Indirect emissions
8.	Wastewater Treatment	Scope 3 Other indirect emissions
9.	Wastewater Treatment from MBR	
10.	Annual Waste Generation	
11.	Other Solid Waste Generation	
12.	Paper waste	
13.	Food Waste	
14.	Plastic Waste	
15.	Amount of Renewable Energy installed/produced on campus	

CHAPTER 4

4.RESULTS AND DISCUSSION

4.1 Scope Wise Estimation of Carbon Footprint for NUST H-12 Campus:

The total carbon footprint calculated for NUST H-12 campus from the year 2019 to 2022 was 45890.9 tonnes of carbon dioxide equivalent (tCO2e). This included both direct and indirect emissions from all scopes of emissions. Table 4.1 shows the estimated emission from all three scopes of study.

4.1.1 Scope 1 Emissions:

4.1.1.1 2019:

Among the different categories of scope 1 in 2019 the fuel consumption by the university owned fleet had the highest GHG emissions i.e., 792.18 tCO2e. Followed by the natural gas consumption by residential areas which was 310.92 tCO2e. The data for the total natural gas consumption was unavailable from January to June 2019. This was followed by the emissions from total natural gas consumption by both the cafeterias i.e., Concordia 1 and Concordia 2 and the emissions from fuel consumption by the generators were 76.27 tCO2e and 19.26 tCO2e as shown in Figure 4.1.

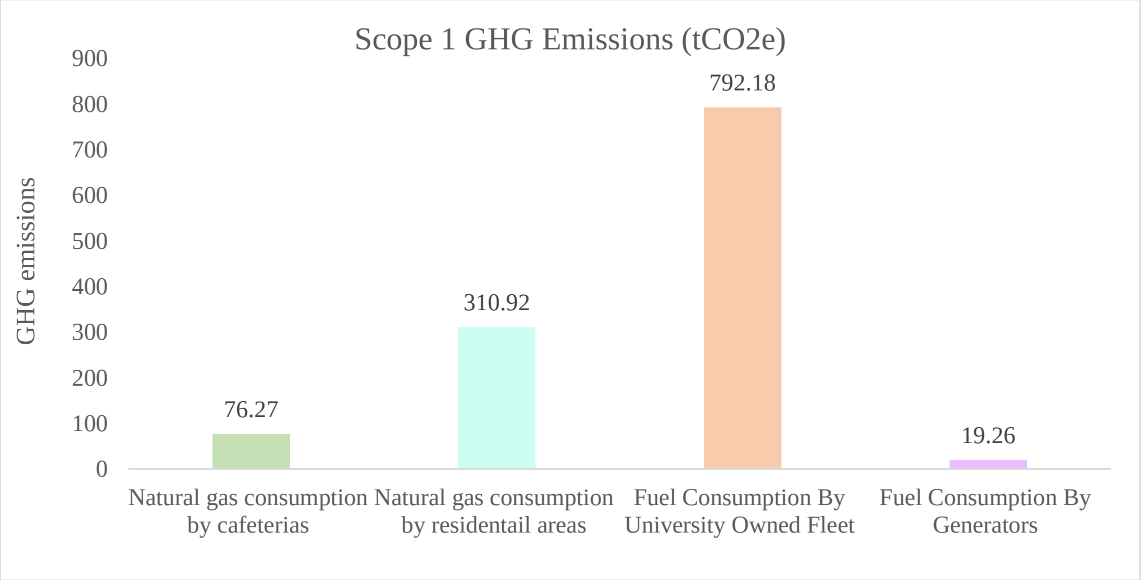


Figure 4.1: Scope 1 emissions for 2019.

Table 4.1: Estimated Carbon Footprint for NUST Subdivide by Scopes.

Scopes	Emission source	Unit	Year							
			2019		2020		2021		2022	
			Total Quantity	Carbon Footprint (tCO$_2$e)	Total Quantity	Carbon Footprint (tCO$_2$e)	Total Quantity	Carbon Footprint (tCO$_2$e)	Total Quantity	Carbon Footprint (tCO$_2$e)
Scope 1	Natural gas consumed in Concordia 1	MMBTU	598.321	49.05	513.715	30.42	410.087	24.88	283.492	44.80
	Natural gas consumed in Concordia 2	MMBTU	468.564	27.22	281.053	16.65	425.754	25.20	122.878	26.11
	Natural gas consumed in Residential Areas	MMBTU	5250.698	310.92	16702.3	989.015	20707.78	1226.19	12294.08	727.99
	Fuel Consumption by University Owned Fleet (Petrol)	Liters	133754.37	317.01	110210	261.20	144090.8	341.50	176372.2	418.01
	Fuel Consumption by University Owned Fleet (Diesel)	Liters	187501.41	475.17	143341	363.26	160241.4	406.09	165.490.8	419.39
	Fuel Consumption by Generators (Diesel)	Liters	7600	19.26	3620	9.17	5500	13.94	98,990	250.86
Scope 2	Total Electricity Consumption	KWh	19152000	7000.51	9000000	5538.37	9984000	6143.90	13608000	5938.62
Scope 3	Wastewater Treatment	Liters	5280000	3249	5280000	3249	5280000	3249	5280000	3249
	Wastewater Treatment from MBR	m^3	9000	0.0113	9000	0.00188	9000	0.00281	9000	0.0113
	Annual Waste Generation	Tons	320	160	230	115	360	180	240 (Till August)	120
	Other Solid Waste Generation	Kg	175680	87.84	78540	39.27	78540	39.27	175,680	87.84
	Paper waste	Kg	172080	223.70	76785	99.82	76785	99,82	172,080	223.70
	Food Waste	Kg	242640	0.61	107655	0.063	107655	0.27	242,640	0.61
	Plastic Waste	Kg	129600	0.15	58200	0.0068	58200	0.07	129,600	0.15
	Amount of Renewable Energy installed/produced on campus	KWh	152,052	0.09	667,372	0.40	1281263	0.78	1343037	0.81
Total Carbon footprint of NUST from 2019 to 2022										***45890.9***

4.1.1.2 2020:

For 2020 the natural gas consumption by the residential area had the highest emissions i.e., 989.01 tCO2e. Followed by the fuel consumption by the university owned fleet which was 624.46 tCO2e. The emissions from the two cafeterias collectively were 47.06 tCO2e. And the emissions from fuel consumption by generators were lowest i.e., 9.17 tCO2e as shown in Figure 4.2.

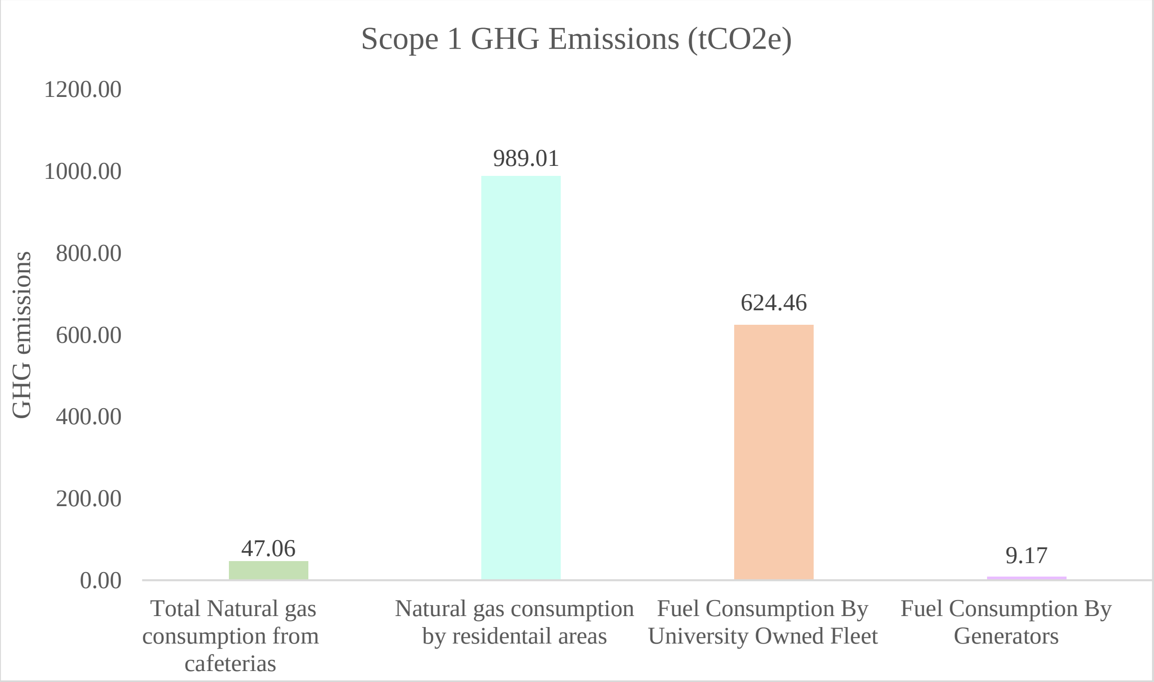


Figure 4.2: Scope 1 emissions for 2020.

4.1.1.3 2021:

Residential areas had the most number of emissions throughout the year these accounted for 1226.19 tCO2e. Fuel consumption by the university fleet had the second most number of emissions i.e., 747.59 tCO2e. Followed by natural gas consumption by cafeterias and fuel consumption by generators, these were 50.08 tCO2e and 13.94 tCO2e respectively as shown in Figure 4.3.

4.1.1.4 2022:

The university fleet used for student and staff commute had the highest amount of emissions in the year 2022 accounting for 837.4 tCO2e. Residential areas had the second most number of emissions with respect to natural gas consumption these were 727.99

tCO2e. Followed by fuel consumption by generators due to the frequent power breakdowns throughout the year these accounted for 250.86 tCO2e. The natural gas consumption by the cafeterias had the least amount of emissions under scope 1 theses were 70.91 as shown in Figure 4.4.

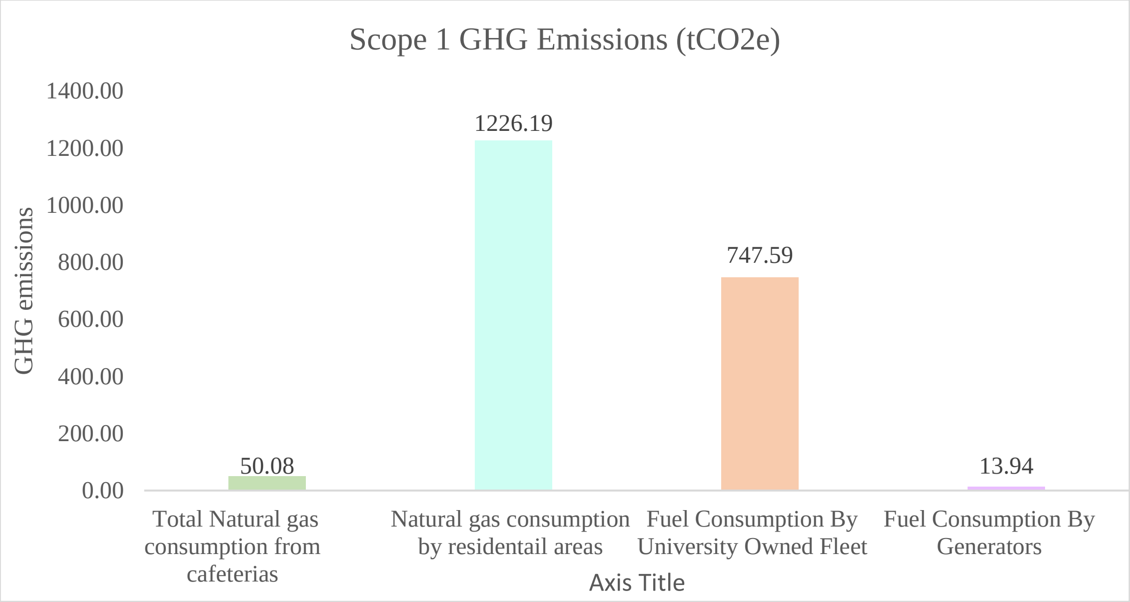


Figure 4.3: Scope 1 emissions for 2021.

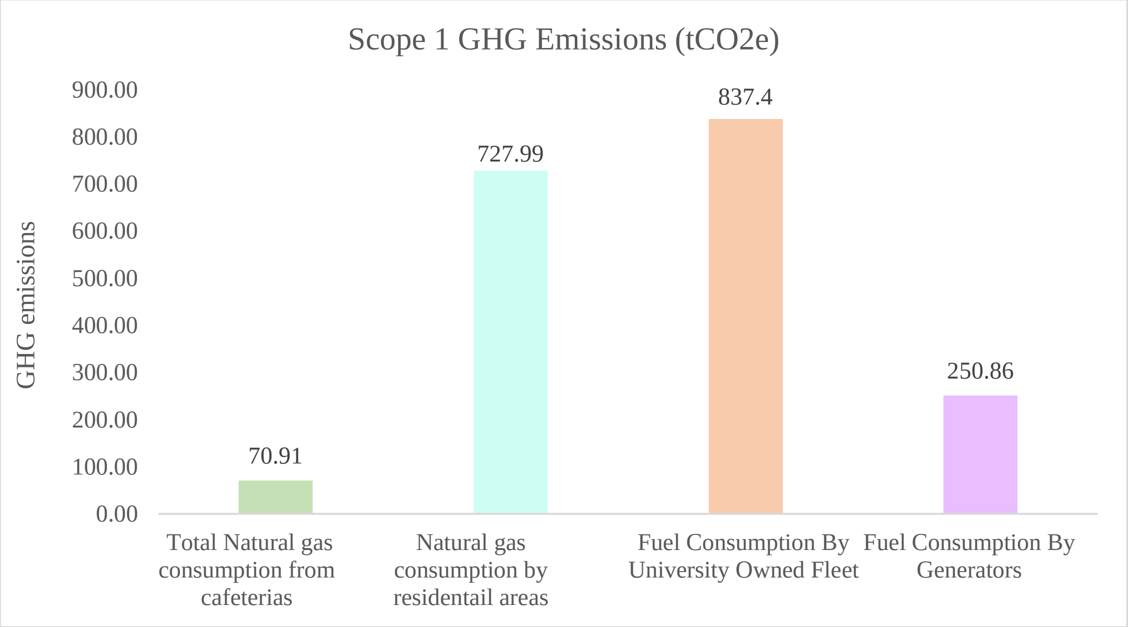
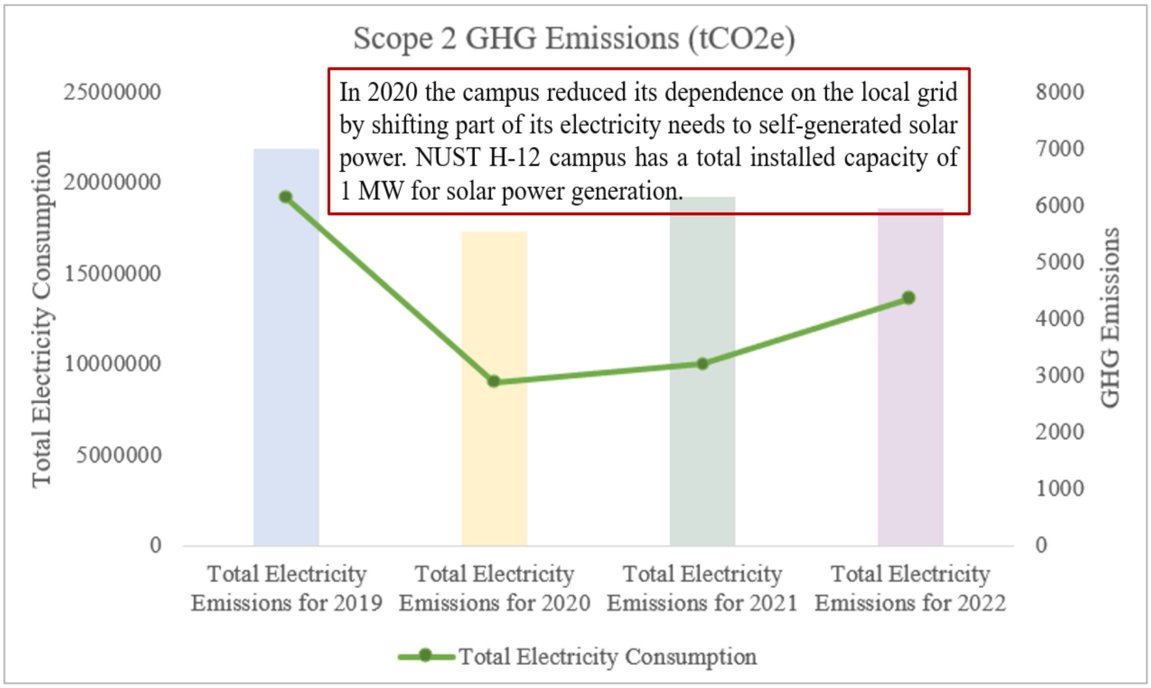


Figure 4.4: Scope 1 emissions for 2022.

4.1.2 Scope 2 Emissions:

The electricity consumption data was collected from the year 2019 to 2022 to calculate the GHG emissions. As displayed in Figure 4.5 The maximum emissions were documented for the year 2019 which were 7000.51 tCO2e. Followed by 2021 where the net emissions from electricity consumption were 6143.90 tCO2e. The year 2020 had less emissions than 2019 because the campus went under strict lockdown due to the outbreak of Covid-19 pandemic, so the emissions were 5538.38 tCO2e. In 2022 the net emissions were 5938.41 tCO2e which were considerably less than the previous two years i.e., 2019 and 2021. This was mainly because of the awareness campaigns for resource conservations and due to more usage of renewable energy resources for electricity production.



In 2020 the campus reduced its dependence on the local grid by shifting part of its electricity needs to self-generated solar power. NUST H-12 campus has a total installed capacity of 1 MW for solar power generation.

Figure 4.5: Scope 2 emissions for Electricity Consumption from 2019 - 2022.

4.2.2 Scope 3 Emissions:

The highest GHG emissions came from the wastewater treatment at the integrated constructed wetland (ICW) on campus. It accounted for 87% of the total emissions from 2019 to 2022. The paper waste generated on campus accounted for the second highest emissions under the scope 3 calculations which were 6% of the total emissions from 2019 to 2022. Followed by annual waste generation (4%) as shown in Figure 4.6.

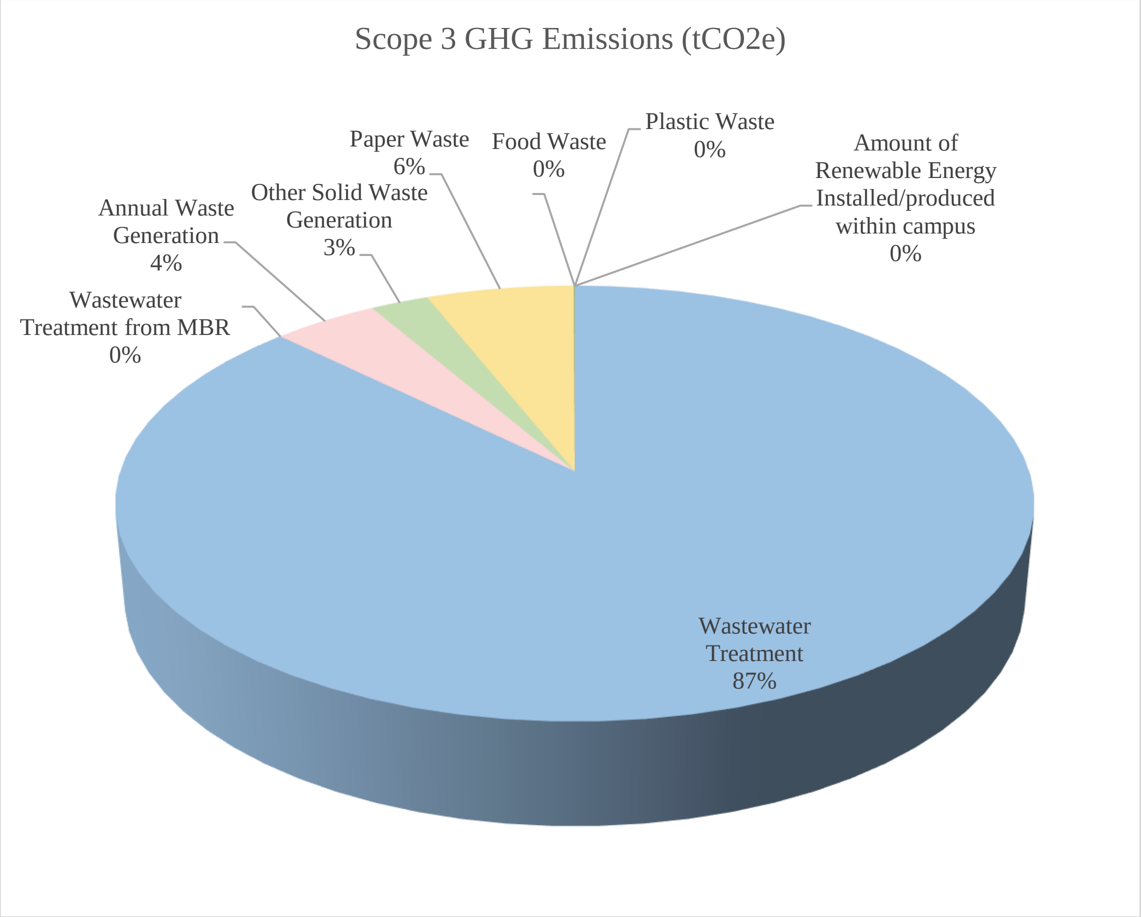


Figure 4.6: Scope 3 emissions from 2019 - 2022.

4.3 Total Carbon Footprint Analysis from 2019-2022:

The total carbon footprint calculated for NUST from 2019 to 2022 was 45890.9 tCO2e. The highest carbon footprint was observed in the year 2019 where the total carbon footprint from all three scopes was 11920.54 tCO2e. As shown in Figure 4.7. The lowest CF was observed for 2022 which was 11507.90 tCO2e. The per person carbon footprint of NUST from 2019 to 2022 was 4.31 tCO2e.

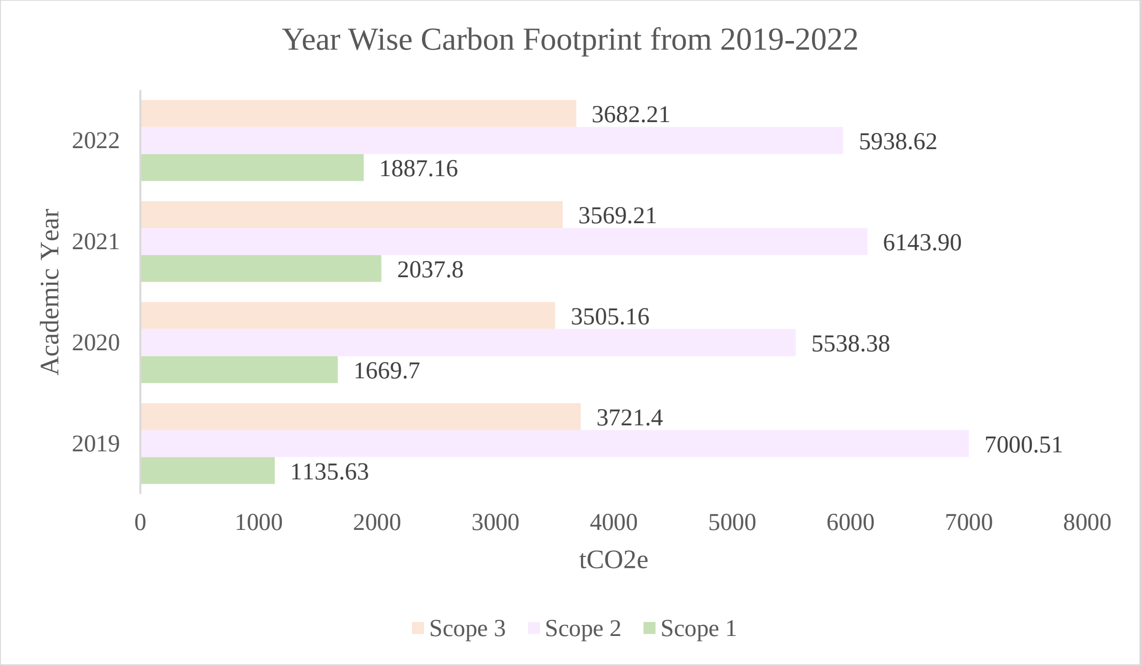


Figure 4.7 Total Carbon Footprint Calculation from 2019-2022.

Throughout the four years it was observed that electricity consumption under the scope 2 emissions had the highest carbon footprint which was 24621.4 tCO2e. Electricity consumption had the highest amount of carbon footprint from 2019-2022 as shown in Figure 4.7. However, the highest carbon footprint for scope 2 emissions were observed in 2019 where the total emissions from electricity consumptions were 7000.51 tCO2e. The second highest emissions for scope 2 were recorded in 2021 where the total emissions from electricity consumption were 6143.90 tCO2e. Compared to 2019 and 2021 the carbon footprint of scope 2 was lower in 2020 i.e., 5538.38 tCO2e. This was due to the outburst of Covid-19 epidemic due to which the campus went under strict lockdown in the middle of March. So, on campus activity was at its lowest throughout the year. The year 2022 had the least amount of carbon footprint for scope 2 which was estimated 5938.62 tCO2e. Mainly because of the resource consumption practices diligently followed on campus by the students and staff.

The scope 3 had the second highest carbon footprint which was estimated to be around 14478 tCO2e from 2019-2022. Among these the treated wastewater had the most amount of emission contribution i.e., 87%. The carbon footprint for treated wastewater was the highest from 2019-2022 i.e., 3249 tCO2e for each year.

The third highest carbon footprint was estimated for the natural gas consumption of residential areas. Where the total consumption from 2019 to 2022 was 3254.11 tCO2e. As shown in Table 4.2. The highest emissions from residential areas were observed in 2021 which were 1226.19 tCO2e. Other than this the emissions from fuel consumption by the university owned fleet had also shown high carbon footprint for all four years. The total carbon footprint calculated for fuel consumption by university transport was 3001.63 tCO2e.

Another contributor to the GHG emissions of NUST was the paper waste generated on campus due to its excessive usage in offices and departments. The total carbon footprint for the paper waste generation was 647.04 tCO2e as shown in Table 4.2.

Annual waste generation under scope 3 was another contributor to high GHG emissions on campus. The total carbon footprint from the year 2019 to 2022 was 575 tCO2e as shown in Table 4.2. The food and plastic waste generated on campus and the renewable energy generated on campus by the solar panels installed had the least amount of involvement to the total carbon footprint of NUST.

When analyzing the calculated data scope wise the lowest carbon footprint was calculated for scope 1 where the total emissions were 6730.29 tCO2e. Scope 1 emissions also remained lowest for all four years as shown in Figure 4.7. While scope 2 was observed as the highest contributor to the universities CF followed by scope 3

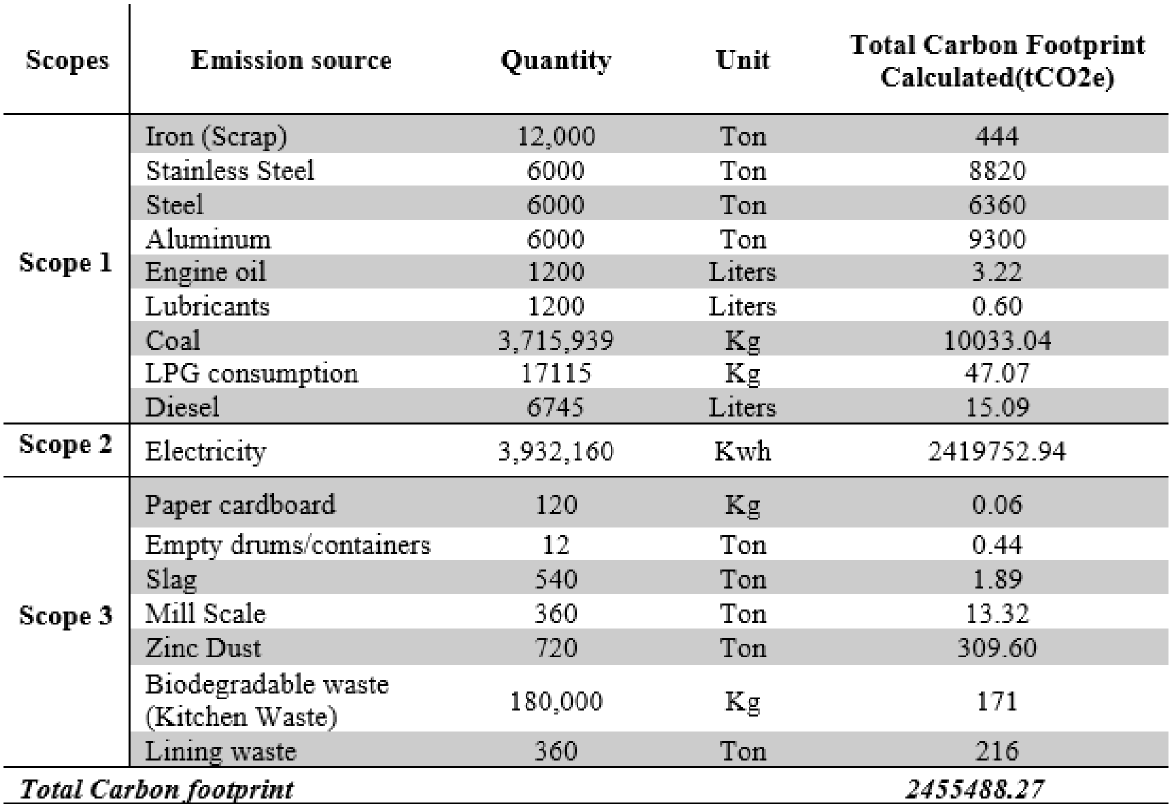
Table 4.2: Total Carbon Footprint Calculation from 2019-2022.

Scopes	**Emission source**	**Total Carbon Footprint Calculated (tCO2e)**
Scope 1	Natural gas consumed in Cafeterias	244.32
	Natural gas consumed in Residential Areas	3254.11
	Fuel Consumption by University Owned Fleet (Diesel)	3001.63
	Fuel Consumption by Generators (Diesel)	293.23
Scope 2	Total Electricity Consumption	24621.41
Scope 3	Wastewater Treatment	12996
	Wastewater Treatment from MBR	0.02461
	Annual Waste Generation	575
	Other Solid Waste Generation	254.22
	Paper waste	647.04
	Food Waste	1.553
	Plastic Waste	0.376
	Amount of Renewable Energy Installed/produced on campus	2.08
Per Person Carbon Footprint		***4.31***

4.4 Scope Wise Estimation of Carbon Footprint Fazal Steel PVT Limited:

The total carbon footprint for Fazal steel for the year 2022 was 2455488.27 tCO2e. The calculation included all direct and indirect emissions from three scopes. Total carbon footprint estimations for the industry are shown in Table 4.3 below.

Table 4.3 Estimated Carbon Footprint for Fazal Steel PVT Limited Subdivide by Scopes.



Scopes	Emission source	Quantity	Unit	Total Carbon Footprint Calculated(tCO2e)
Scope 1	Iron (Scrap)	12,000	Ton	444
	Stainless Steel	6000	Ton	8820
	Steel	6000	Ton	6360
	Aluminum	6000	Ton	9300
	Engine oil	1200	Liters	3.22
	Lubricants	1200	Liters	0.60
	Coal	3,715,939	Kg	10033.04
	LPG consumption	17115	Kg	47.07
	Diesel	6745	Liters	15.09
Scope 2	Electricity	3,932,160	Kwh	2419752.94
Scope 3	Paper cardboard	120	Kg	0.06
	Empty drums/containers	12	Ton	0.44
	Slag	540	Ton	1.89
	Mill Scale	360	Ton	13.32
	Zinc Dust	720	Ton	309.60
	Biodegradable waste (Kitchen Waste)	180,000	Kg	171
	Lining waste	360	Ton	216
Total Carbon footprint				***2455488.27***

4.4.1 Scope 1 Emissions:

The highest GHG emissions under scope 1 were estimated for coal. These were 10033.04 tCO2e. Mainly because coal is considered as an essential ingredient in steel production as it is used in the making of coke which is a primary source of carbon used in the steel production. The second highest carbon footprint was calculated for aluminum which was estimated to be around 9300 tCO2e. As aluminum is widely used to deoxidize steel. It is also used as an alloying agent and as a nitride former. As the industry uses Electric Arc Furnace the recycled stainless steel scrap along with other alloys are used for steel production. The end product is then casted into a slab or billet. The carbon footprint for stainless steel is estimated to be around 8820 tCO2e. Similarly raw materials like iron scrap had a carbon footprint of 444 tCO2e in steel production. Liquified fuels like light diesel oil and LPG are also used as sources of heat in the furnaces. Their carbon footprint was estimated to be around 15.09 tCO2e and 47.07 tCO2e respectively. Engine oil and other lubricants used in the steel industry had the lowest carbon footprint i.e., 3.22 tCO2e and 0.06 tCO2e respectively. As shown in Figure 4.8.

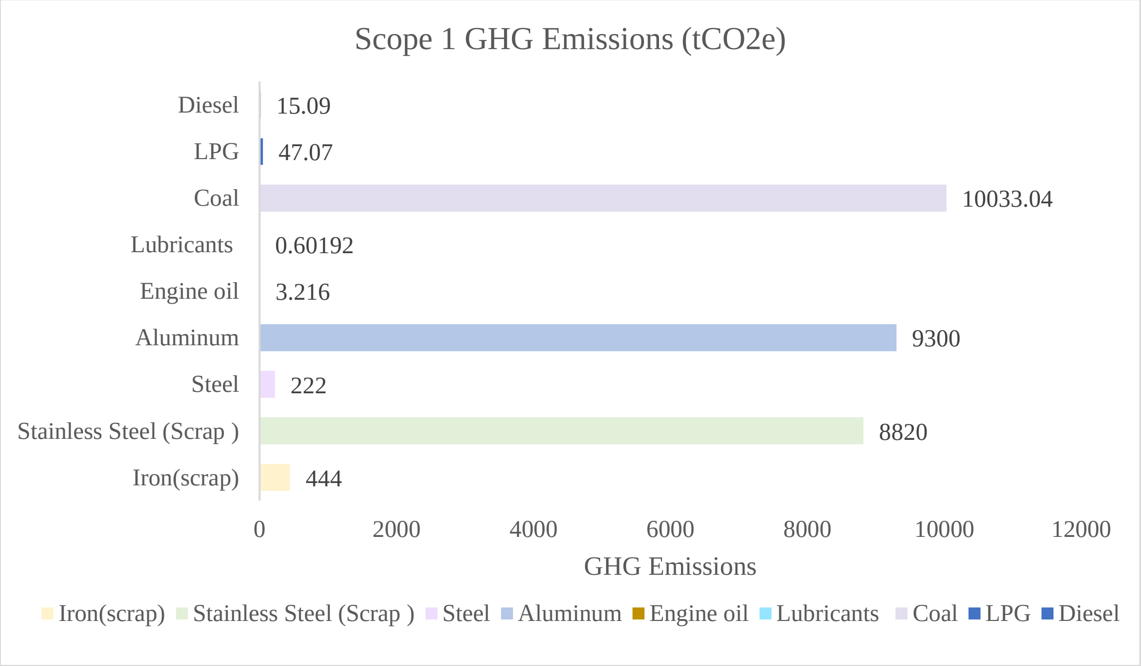


Figure 4.8: Scope 1 emissions for Fazal Steel PVT Limited

4.4.2 Scope 2 Emissions:

Scope 2 emissions for the steel industry were measured for the electricity consumed. The industry has a transmission line of 1MW from IESCO. The total consumed electricity by the industry for year 2022 was 3,932,160 KWh. The steel produced in the Electric Arc Furnace (EAF) in industry uses electricity for the melting of steel scrap. Total carbon footprint for electricity consumption was estimated around 2419752.94 tCO2e.

4.4.3 Scope 3 Emissions:

Zinc and iron dust in produced by the EAF. Zinc is also used for galvanizing steel products to prevent corrosion for longer time periods. The GHG emissions for this process were 309.60 tCO2e which were emissions under scope 3. The second highest emissions came from the biodegradable waste generated within the industry. It can be categorized as kitchen waste. The carbon footprint for this was 171 tCO2e. The lining waste generated during the different stages of steel production had a carbon footprint of 216 tCO2e. Mill scale is produced as a byproduct that forms on the surface of the hot rolled steel during its production when the steel gets in contact with the oxygen. It is a thin and flaky material with a bluish black color. The carbon footprint for mill scale was calculated 13.32 tCO2e. Another byproduct during the steel making process is the slag. Formed with impurities like limestone and iron ore during the production phase it consists of silicates and non-metallic compounds. The carbon footprint for slag was estimated around 1.89 tCO2e. The lowest GHG emissions were observed for the empty drums and containers and paper waste these were 0.44 tCO2e and 0.06 tCO2e respectively. As shown in Figure 4.9.

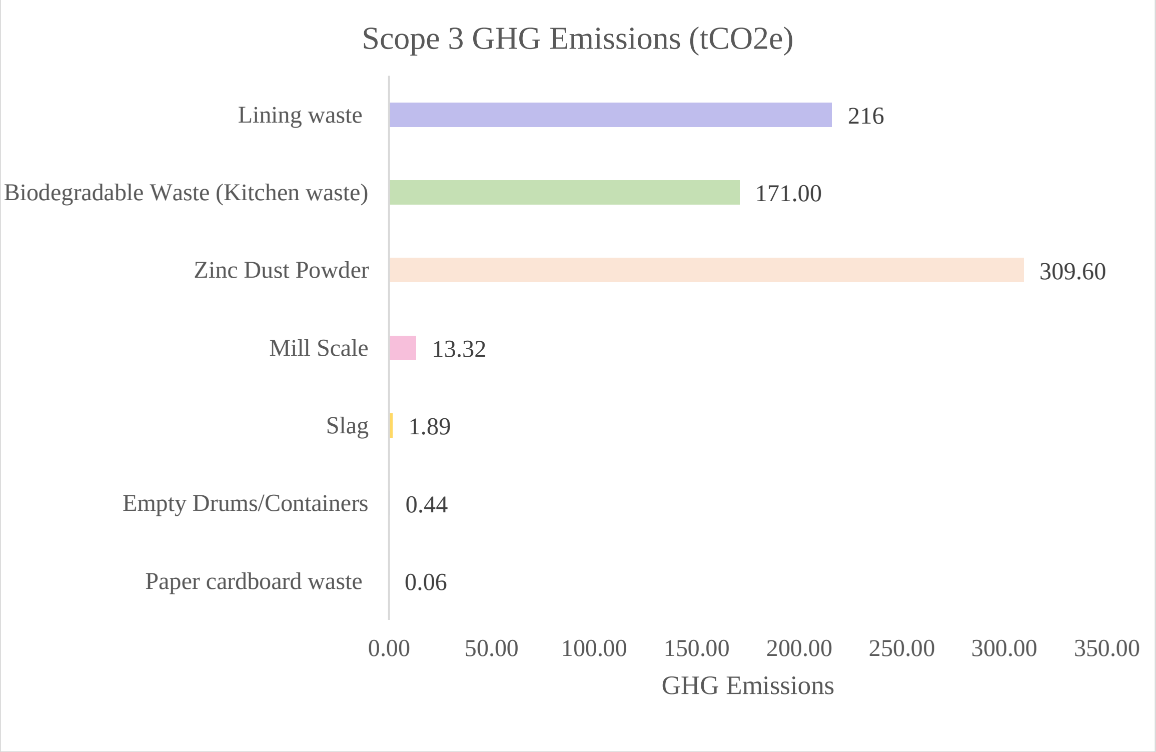


Figure 4.9: Scope 3 Emissions for Fazal Steel PVT Limited

4.5 Comparison between the Carbon Footprint of NUST and Fazal Steel PVT Limited:

Drawing a comparison between the carbon footprint of university and steel industry can help provide insights into the possible environmental impacts these two sectors have. Also, it can help analyze the scale of emissions from both the sectors. This approach can also help lower the carbon footprint of both sectors by continuous monitoring and organizing awareness campaigns.

With a similar approach a comparative analysis can be drawn between the carbon footprint calculation of NUST H-12 campus, and the Fazal Steel PVT limited. For this purpose, data from 2022 was considered from both the entities. Figure 4.10 shows the comparison of the calculated emissions from both sectors.

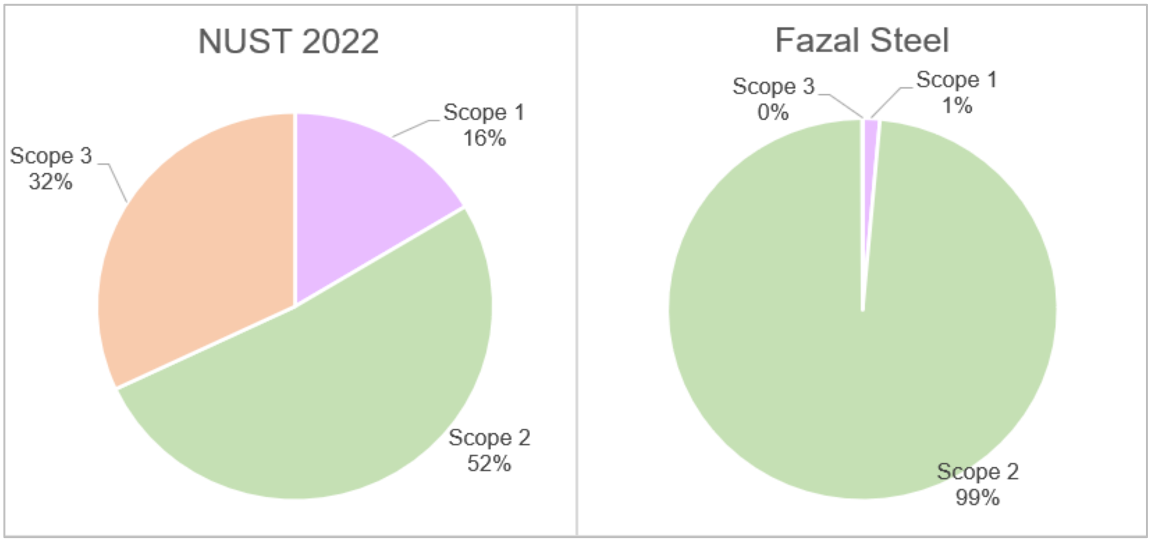


Figure 4.10 Comparison Between Carbon Footprint of NUST and Fazal Steel

As shown in Figure 4.10 the Fazal Steel had the highest carbon footprint for all three scopes. For scope 1 the emissions from Fazal Steel were 35023.01 tCO2e while NUST had 1887.16 tCO2e. The scope 2 emissions for Fazal Steel were the highest i.e., 2419752.94 tCO2e. NUST on the other hand had carbon footprint of 5938.62 tCO2e for scope 2. However, scope 3 had a different trend as the emissions were high for NUST when compared with the industry i.e., 3682.21 tCO2e and 712.31 tCO2e respectively.

4.6 Comparison of Carbon footprint Calculation of NUST with the AKDN Tool:

The Carbon Management Tool from the Aga Khan Development Network (AKDN) was created as an all-in-one tool for tracking and calculating the carbon footprint of healthcare operations. It was created by the Aga Khan Development Network's, Aga Khan University and Aga Khan Health Services. The majority of the Tool's features can be used by organizations outside of the healthcare industry. The Tool was created expressly to help managers in determining the carbon footprint of their operations and using data to develop and monitor the success of actions to minimize those emissions. The Greenhouse Gas Protocol's worldwide criteria were followed in the technique employed and the final organization of the data.

According to Scopes specified by the Global Greenhouse Gas Protocol the tool classifies the carbon emissions. Data are arranged according to Scopes to prevent duplication of the same data. Unless otherwise specified in specific sections, the majority of the emissions variables in the tool have been derived from data sets maintained by the UK government (DEFRA). The GHG protocol reporting standard is the foundation of the UK DEFRA data set, which is updated yearly. As a result, the Tool's variables are also updated. For a comparative analysis the inventory data from the year 2020 and 2021 was considered.

4.6.1 Comparison of AKND Tool Calculations with Inventory Base Calculations for Year 2020:

The total carbon footprint calculated for the year 2020 by the tool was 10888.98 mtCO2e while the carbon footprint calculated manually by using default emission factors from IPCC guidelines was 10711.7 tCO2e. The tool did not cover all the data collected during the inventory analysis. It did not calculate the carbon emissions for electricity generated via renewable energy. The total scope wise calculation is shown in Table 4.4.

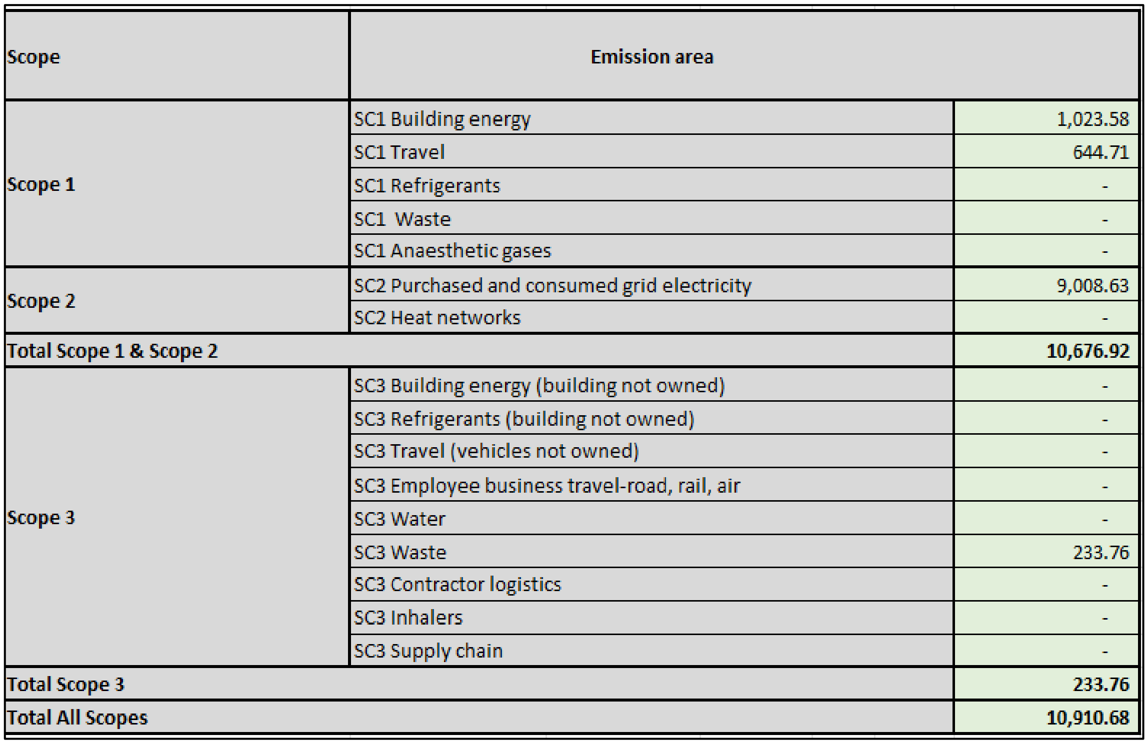
For scope 1 emissions the natural gas consumption by the cafeterias had a carbon footprint of 46,053.2 kgCO2e. While the carbon footprint estimated using the IPCC guidelines was 47,053.8 kgCO2e. The natural gas consumption by the residential area had a carbon footprint of 967,514.9 kgCO2e. The self-calculated carbon footprint for this was 988,592 kgCO2e. The tool calculated the carbon footprint for diesel consumption by the generators to be 9,986 kgCO2e. While the manually calculated carbon footprint for the same category was 9173.88 kgCO2e. Similarly, the tool calculated the carbon footprint for fuel consumption by the university owned fleet for petrol and diesel separately i.e., 257,858 kgCO2e and 386,848 kgCO2e respectively. While in the manual calculations carbon footprint for these were 261,203.81 kgCO2e for petrol and 363,256.54 kgCO2e for diesel respectively.

For scope 2 the tool calculated carbon footprint of total electricity consumption to be 3,470,260 kgCO2e. While in the manual calculations the carbon footprint for this category was 5,538,375 kgCO2e.

For scope 3 the carbon footprint of annual waste generation was only calculated to be 233756 kgCO2e. While the total carbon footprint calculated for all components for scope 3 was 384587 kgCO2e.

Scope 2 emissions were highest in both the calculation techniques as shown in Figure 4.11 and 4.12.

Table 4.4 Total Emissions Calculated by AKDN Tool for Year 2020.



Scope	Emission area	
Scope 1	SC1 Building energy	1,023.58
	SC1 Travel	644.71
	SC1 Refrigerants	-
	SC1 Waste	-
	SC1 Anaesthetic gases	-
Scope 2	SC2 Purchased and consumed grid electricity	9,008.63
	SC2 Heat networks	-
Total Scope 1 & Scope 2		**10,676.92**
Scope 3	SC3 Building energy (building not owned)	-
	SC3 Refrigerants (building not owned)	-
	SC3 Travel (vehicles not owned)	-
	SC3 Employee business travel-road, rail, air	-
	SC3 Water	-
	SC3 Waste	233.76
	SC3 Contractor logistics	-
	SC3 Inhalers	-
	SC3 Supply chain	-
Total Scope 3		**233.76**
Total All Scopes		**10,910.68**

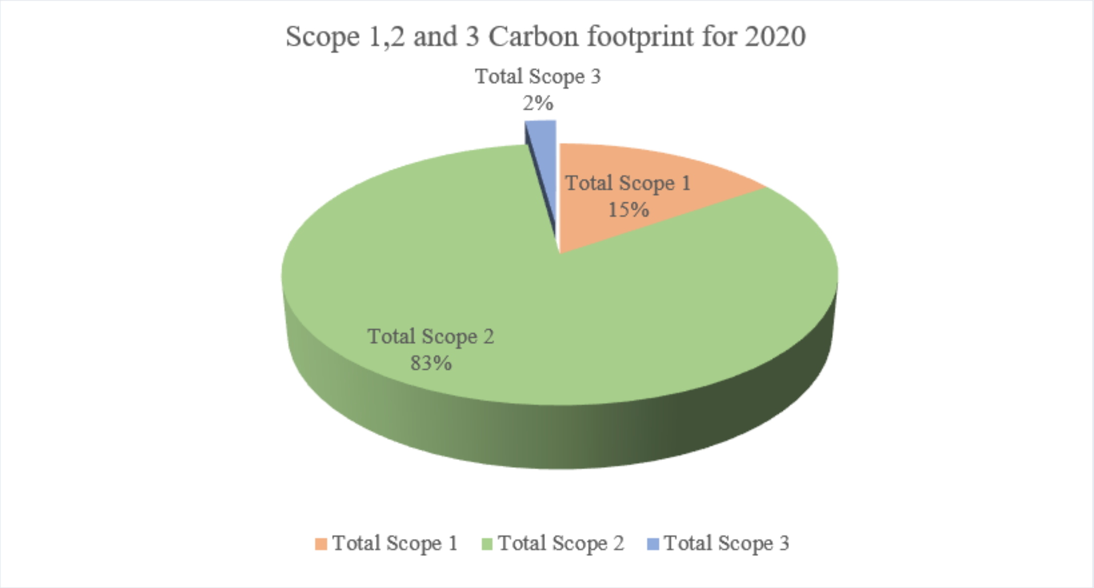


Figure 4.11 Scope Wise Contribution to the GHG emissions Using AKDN Tool.

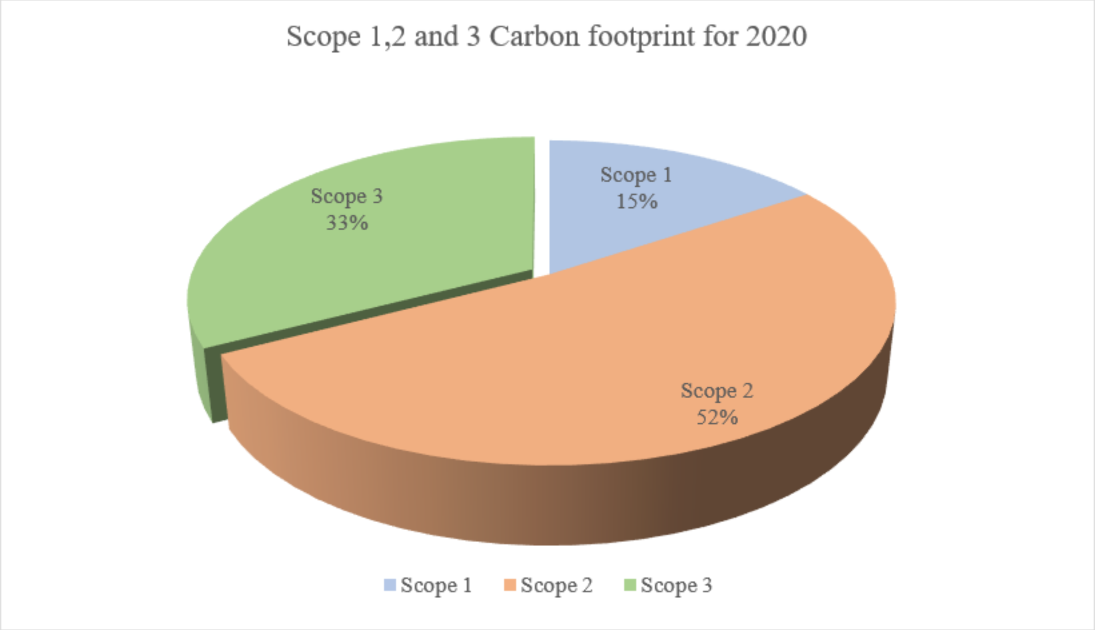


Figure 4.12: Scope Wise Contribution to the GHG emissions Using IPCC Guidelines.

4.6.2 Comparison of AKND Tool Calculations with Inventory Base Calculations for Year 2021:

Total carbon footprint of NUST calculated from the AKDN tool for the whole year was 12,358.29 kgCO2e. As Shown in Table 4.5. Whereas the CF calculated using IPCC guidelines was less than the tool's calculations i.e., 11750.90 kgCO2e.

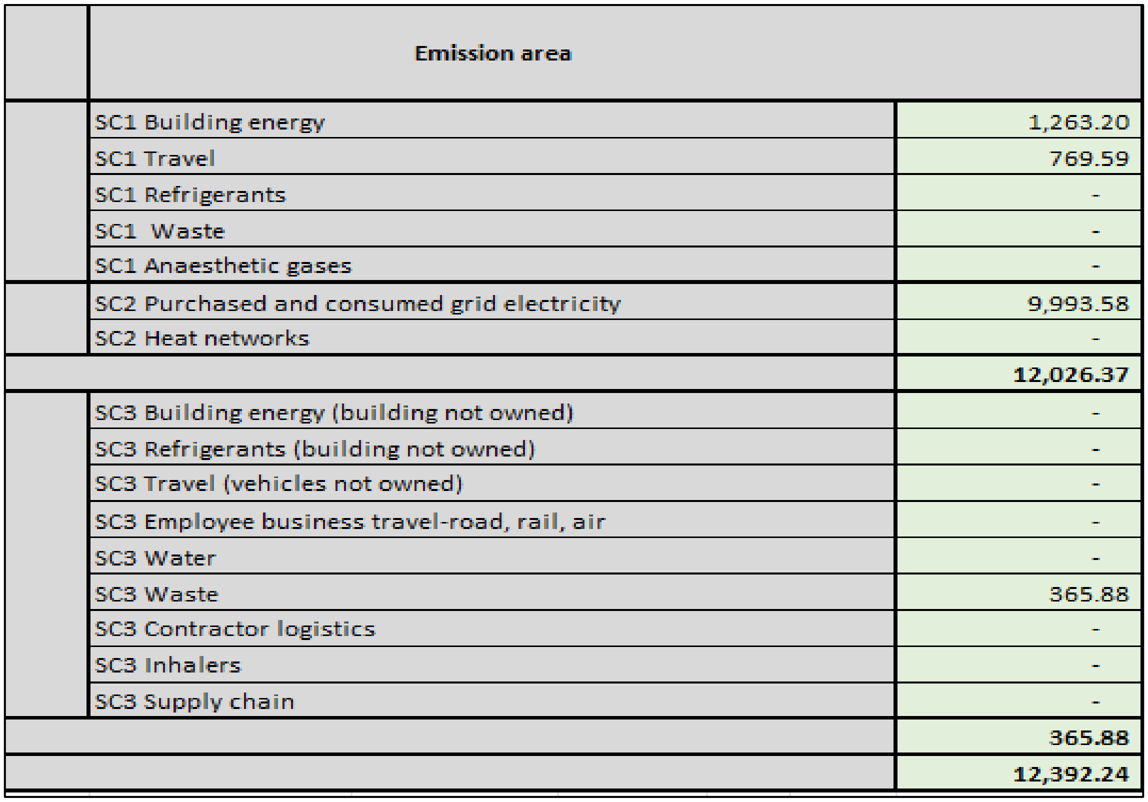
For the scope 1 emissions the residential areas had the highest carbon footprint i.e., 1199607.9 kgCO2e. Likewise the emissions calculated manually for the same component were 1225661.98 kgCO2e. The tool showed diesel fuel consumption by the university owned fleet as the second highest emission under the scope 1 the calculated emissions were 432,495 kgCO2e while the manually calculated emissions for the same category were 406,086.44 kgCO2e. Fuel consumption of university owned fleet using petrol had the third highest emission the calculated results by the tool were 337,129 kgCO2e. While the self-calculated emissions were 341,503.75 kgCO2e. The tool calculated the fuel consumed by the generators on campus to be 15,172 kgCO2e. For the same category manual calculation was 13,938.21 kgCO2e which was relatively less than the tool calculated emissions.

The AKDN tool calculated the scope 2 emissions for consumption of electricity to be 494,035 kgCO2e. Which was relatively lower than the manual calculation i.e., 6,143,903.95 kgCO2e.

Calculation of scope 3 showed the carbon footprint of annual waste generation at NUST to be around 3,65,879 kgCO2e. This result was higher than the manual calculation where the 4,50,129.88 kgCO2e.

In both calculations scope 2 showed the highest carbon footprint as shown in Figure 4.13 and 4.14.

Table 4.5 Total Emissions Calculated by AKDN Tool for Year 2021.



	Emission area	
	SC1 Building energy	1,263.20
	SC1 Travel	769.59
	SC1 Refrigerants	-
	SC1 Waste	-
	SC1 Anaesthetic gases	-
	SC2 Purchased and consumed grid electricity	9,993.58
	SC2 Heat networks	-
		12,026.37
	SC3 Building energy (building not owned)	-
	SC3 Refrigerants (building not owned)	-
	SC3 Travel (vehicles not owned)	-
	SC3 Employee business travel-road, rail, air	-
	SC3 Water	-
	SC3 Waste	365.88
	SC3 Contractor logistics	-
	SC3 Inhalers	-
	SC3 Supply chain	-
		365.88
		12,392.24

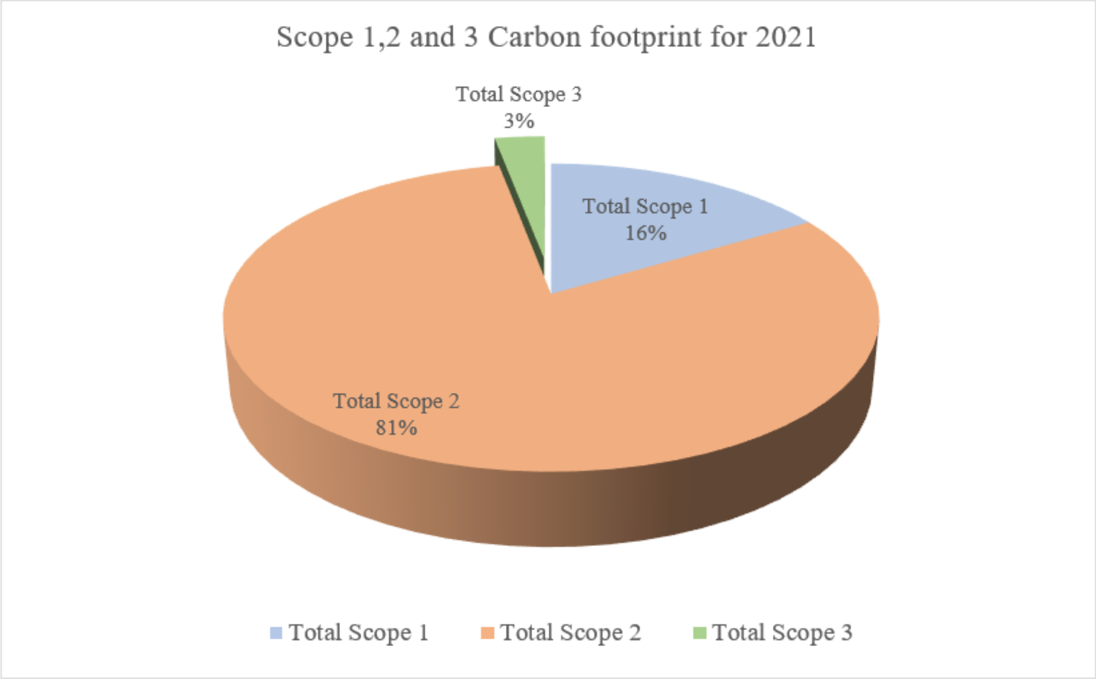


Figure 4.13 Scope Wise Contribution to the GHG emissions Using AKDN Tool.

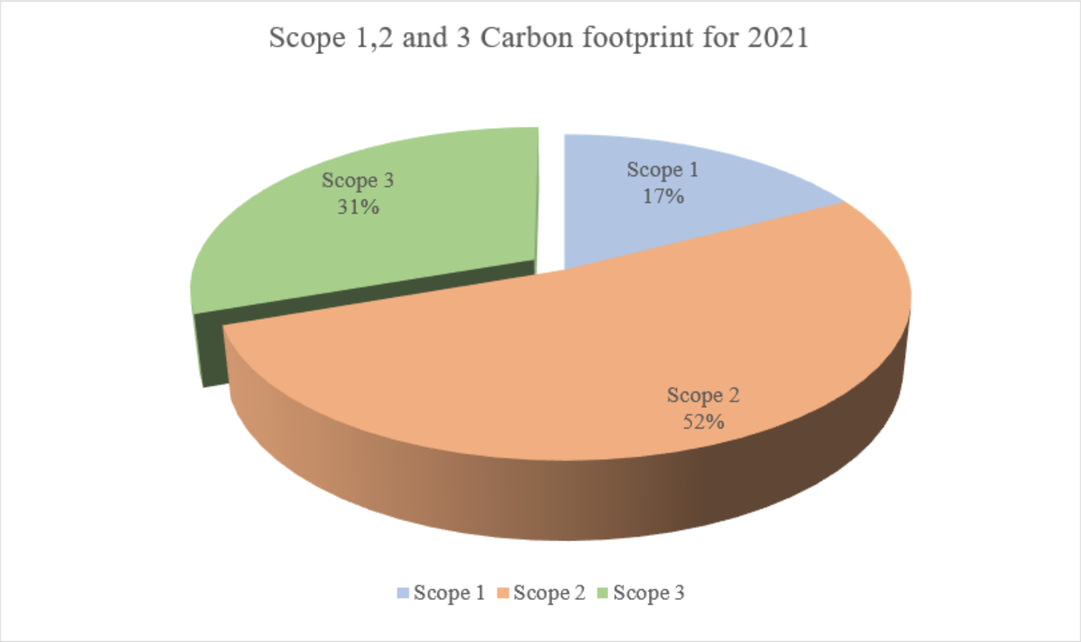


Figure 4.14: Scope Wise Contribution to the GHG emissions Using IPCC Guidelines.

CHAPTER 5

5. CONCLUSION AND RECOMENDATIONS

5.1Conclusions:

The research focused mainly on the carbon footprint estimation of the National University of Sciences and Technology (NUST), that has retained its first position for consecutive three years among the academic circles. The university carbon footprint was analyzed using the ISO 14064-1 standard and using the IPCC guidelines for calculation. The total carbon footprint calculated from 2019-2022 for the university was 45890.9 tCO2e. It was observed that the electricity consumption was the highest carbon footprint contributor for all four years i.e., 24621.41 tCO2e. This was due to the high energy demands throughout the campus. It also indicated that the university needs to reduce its electricity consumption by shifting on renewable energy resources to fulfill its electricity consumption demands. This can also help NUST revamp its way to achieve carbon neutrality.

In 2020 the campus reduced its dependence on the local grid by shifting part of its electricity needs to self-generated solar power. NUST H-12 campus has a total installed capacity of 1 MW for solar power generation. This helped the campus save 1778.62 tCO2e emissions from power generation. Scope 3 emissions were the second highest emissions on campus with a total carbon footprint of 14478 tCO2e from wastewater treatment being the highest contributor. The calculated carbon footprint can also help in carrying out mitigation measures throughout the campus via awareness campaigns. The obtained results may also highlight the areas of concern within the university premises when recommending mitigation measures. Also lack of data availability by the university administration was one of the main problems while calculating the greenhouse gas emissions. So, strategies must be introduced for easier collection of data for inventory analysis for future.

5.2 Recommendations:

For an in-depth analysis of carbon footprint, the calculations should be performed on departmental levels in the future. This can help in the identification of more appropriate adaptation and mitigation strategies. Reduction in the carbon footprint of electricity consumption is possible if light motion sensors are installed throughout the campus. Installation of solar panels in the departments and offices can also help with the reduction in consumed electricity. Similarly for reduction of carbon footprint of scope 3 that mainly focused on the emissions from waste generation within the campus can be carried out by waste sorting at source level. A comprehensive waste management plan by adapting the 7R principle i.e., Reduce, Reuse, Recycle, Rethink, Refuse, Repair and Rot can help university in effectively reducing its carbon footprint.

One of the main challenges encountered during the calculation of greenhouse gas emissions was the lack of data availability from the university administration. Therefore, it is crucial to introduce strategies that facilitate the easier collection of data for inventory analysis in the future. This will ensure a more comprehensive and accurate assessment of the university's carbon footprint and enable effective mitigation measures to be implemented. Multiple awareness campaigns within the campus can also help in carbon footprint reduction of NUST community. Continuous monitoring of the carbon footprint can also help NUST achieve its carbon neutrality target by first evaluating the carbon footprint and then formulating and implementing the required mitigation and adaptation strategies.

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ANNEXTURE-1

QUESTIONNAIRE SURVEY

Survey of Industrial Inputs and Outputs for Assessment of Carbon Footprint of Steel Industry

Dear Respondent,

Thank you for taking time to complete this questionnaire. We are calculating carbon footprint of NUST H-12 campus. For this purpose, one of our objectives is to draw a comparison between carbon emissions measured on campus with that of the industry. To carry out this study we need to calculate the carbon footprint of your industry particularly of the production stage.

We understand the need for confidentiality of this data. Data in raw form will only be disclosed to researcher and supervisor. The questionnaire is divided into six parts. Please answer all questions. Please write N/A for questions not relevant to your industry).

Your contribution is highly appreciable for us.

Section I: Business Details

1. Name of Industry:--
2. Address:---
3. Contact Person: (Phone No., Email)---
   ----
4. Number of Employees (Full Time: ------------------------------- Part Time:---------)
5. Annual Production: --

Section II: Inputs and Outputs

6. Please mark ✓ for your inputs and mention annual quantities of inputs. If annual quantities are not known, please put a question mark on the relevant input.

	Inputs	Quantity	Units
7.1 Energy			
7.1.1	Electricity		(kWh)
7.1.2	Petrol		L
7.1.3	Diesel		L
7.1.4	Oil		L
7.1.5	Gas		L
7.1.6	LPG		Kg
7.1.7	Coal		Tonnes
7.1.8	Biomass		Tonnes
7.2 Water			
7.2.1	Supply Water		L
7.2.2	Groundwater		L
7.2.3	Hot Water/Steam		m^3
7.2.4	Treated Water		m^3
7.3 Metals			
7.3.1	Iron(scrap)		Tonnes
7.3.2	Stainless Steel		Tonnes
7.3.3	Steel		Tonnes
7.3.4	Aluminium		Tonnes
7.3.5	Other		Tonnes
7.4 Plastic			
7.4.1	ABS		Tonnes
7.4.2	HDPE		Tonnes
7.4.3	LDPE		Tonnes
7.4.4	PET		Tonnes
7.4.5	PP		Tonnes
7.4.6	Mixed Plastics		Tonnes
7.4.7	Other plastics		Tonnes

	Inputs (Contd.)	Quantity	Unit
7.8 Alkalis			
7.8.1	Calcium based		
7.8.2	Sodium-based		
7.8.3	Boron-based		
7.8.4	Other Alkalis		
7.9 Solvents			
7.9.1	Halogenated		
7.9.2	Non-halogenated		
7.10 Ink & Dyes			
7.10.1	Thinners		L
7.10.2	Hydrogen peroxide		
7.10.3	Paints		L
7.10.4	Developers/Binder		L
7.10.5	**Epoxy (resin)**		L
7.10.6	Molasses		L
7.11 Oil & lubricants			
7.11.1	Engine Oil		L
7.11.2	Transmission Oil		L
7.11.3	Other Oil		L
7.11.4	Coolant		L
7.11.5	Lubricants		L
7.12 Other			
7.12.1	Compressed Air		m^3
7.12.2	Paper		Kg
7.12.3	Rubber		
7.12.4	Batteries		
7.12.5	Glass		
7.12.6	Packing material		

Wastes generated (outputs)-solid and liquid.

Type of Waste	**Quantity**	**Method of Disposal**	**Name of Waste Collector**	**Frequency of Collection**	**Cost incurred**
Solid Waste (tonnes/annum)					
Paper+Card Board					
Other packaging waste (specify)					
Rubber					
Cutting ends (Metal)					
Rolling waste (metal)					
Glass					
Oil Filters					
Wood Products					
Empty Drums/Containers					
Rags					
Batteries					
Tyers					
Pre-manufactured Components					
Slag					
Air Filter Dust					
Mill Scale					
Cuttings/scraps					
Marble Dust Powder					
Slurry					
Sludge					
Biodegradable Waste (Specify)					
Other					
Lining waste					
Liquid Waste (Liters/annum)					
Wastewater					
Hot Water					

Thinners/Solvents
Waste Oil
Transmission Oil
Other Oil
Coolant
Ink/Dye
Sludge
Other