DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

GREENHOUSE GAS INVENTORY FOR AN INDUSTRIAL WASTEWATER TREATMENT PLANT

by
Sezin KÜLAH

May, 2013
İZMİR

GREENHOUSE GAS INVENTORY FOR AN INDUSTRIAL WASTEWATER TREATMENT PLANT

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Engineering, Environmental Engineering Graduate Program

by
Sezin KÜLAH

May, 2013
İZMİR

M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**GREENHOUSE GAS INVENTORY FOR AN INDUSTRIAL WASTEWATER TREATMENT PLANT**" completed by **SEZİN KÜLAH** under supervision of **PROF. DR. DENİZ DÖLGEN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Deniz DÖLGEN

Supervisor

Prof. Dr. Necdet ALPASLAN

(Jury Member)

Asist. Prof. Dr. Hasan SARPTAŞ

(Jury Member)

Prof.Dr. Ayşe OKUR

Director

Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENTS

I would like to express my special thanks to my thesis advisor Prof Dr. Deniz DÖLGEN for her guidance and her support.

I wish to thank my parents, Aygül and Sinan KÜLAH, and my brother, Kazım KÜLAH, for their moral support and patience during my education life.

Finally, I am also particularly gratefully to Ulvi LALEOĞLU for his valuable helps, and morale motivations.

Sezin KÜLAH

GREENHOUSE GAS INVENTORY FOR AN INDUSTRIAL WASTEWATER TREATMENT PLANT

ABSTRACT

Industrial wastewater treatment plant from a food factory is taken as case study for preparing greenhouse gas inventory in Kemalpasa, Izmir. The scope of the inventory is limited to identifying sources and calculating of the gases emissions. At the conclusion part, activities beneficial that reduce emissions are explained for this wastewater treatment plant.

Community-level/ industrial inventory is prepared that includes emissions from activities in the plant of the company such as energy consumption and transportation. As a first step of this study, boundaries and activity categories of the organization are determined and activity data are collected according to “top-down” approach. In the calculation part of the study, a methodology is chosen for calculation of emissions which is called “greenhouse gas data is multiplied by the factors of greenhouse gas emissions”. According to this method, greenhouse gas emissions are calculated by collected data entering into a calculation program. The programs are defined “stationary combustion tool”, “purchased electricity tool” and “transportation tool” by Greenhouse Gas Protocol. Stationary combustion tool is used for calculating direct emissions from fossil fuel consumption. Purchased electricity tool is related to indirect emissions as electricity consumption of the equipment and transportation tool is related to other indirect emissions related to the transfer of wastewater chemical needs. In this study, direct and indirect greenhouse gas emissions is calculated as of 2178.35 tons/year (due to the fossil fuels) and 903.37 tons/year (due to the electrical consumptions) respectively.

After carbon dioxide emissions are determined for the wastewater treatment system, carbon management methods are discussed for reducing the carbon dioxide emissions. Finally tree planting method is preferred to carbon offsetting as it is the cheapest and easiest method that can be applied for the company. As a result, the company can be neutral by planting 5173 number of tree with 25865 TL cost in each year. In addition, reducing the sludge quantities that is processing in the rendering unit will be resulted in drastic decrease in fossil fuel consumption, and thus in extreme decrease in direct greenhouse gas emissions. Theoretic studies shown that transporting of the sludge to the landfill site results with 931.27 tons carbon dioxide emissions to atmosphere; the company can plant only 1552 tree and pay 7760 TL to become carbon neutral in each year.

Keywords: Greenhouse gas inventory, GHG Protocol, carbon offsetting, calculation tools, wastewater treatment plant

ENDÜSRİYEL BİR ATIKSU ARITMA TESİSİNE AİT SERAGAZI ENVANTERİ

ÖZ

İzmir Kemalpaşa'da bulunan bir gıda firmasına ait atıksu arıtma tesisi seragazı emisyon envanteri hazırlanmak üzere örnek olarak alınmıştır. Envanter çalışmasının kapsamı seragazı emisyonlarının kaynağının belirlenmesi ve hesaplamalarının yapılmasıdır. Sonuç bölümünde, bu atıksu arıtma tesisinin emisyonlarını azaltmak için faydalı olacak aktiviteler açıklanmıştır.

Enerji tüketimi ve taşıma gibi firmanın arıtma tesisine ait faaliyetlerini kapsayan kuruluş seviyesinde/endüstriyel bir envanter hazırlanmıştır. İlk aşamada organizasyonun sınırları ve faaliyet kategorileri belirlenmiş ve yukarıdan aşağıya yaklaşımı ile faaliyet bilgileri toplanmıştır. Hesaplama bölümünde, emisyonların hesaplanması için seragazı verilerinin seragazı faktörleri ile çarpımı olarak adlandırılan yöntem seçilmiştir. Bu yönteme göre toplanan bilgiler bir hesaplama programına işlenerek seragazı emisyonları hesaplanmaktadır. Bu programlar, GHG Protokolü tarafından "sabit yanma aracı", "satın alınan elektrik aracı", "taşıma aracı" olarak adlandırılmıştır. "Sabit yanma aracı" fosil yakıtlardan kaynaklanan doğrudan sera gazı emisyonlarının hesaplandığı programdır. "Satın alınan elektrik aracı", ekipmanların elektrik kullanımından kaynaklanan dolaylı sera gazı emisyonlarına ve "taşıma aracı", atıksu kimyasallarının taşınmasından kaynaklanan diğer dolaylı sera gazı emisyonlarına aittir. Çalışmada, doğrudan ve dolaylı seragazı emisyonları sırasıyla 2178,35 ton/yıl (fosil yakıtlardan) ve 903,37 ton/yıl (elektrik kullanımından) olarak hesaplanmıştır.

Atıksu arıtma tesisine ait karbondioksit emisyonları belirlendikten sonra, karbondioksit emisyon giderimi için karbon yönetim metotları tartışılmıştır. Sonuç olarak, incelenen tesis için uygulanabilecek en ucuz ve en kolay karbon dengeleme metodu ağaç dikmek olarak tercih edilmiştir. Sonuç olarak, tesis yılda 25865 TL maliyetle 5173 adet ağaç dikerek karbon dengeleyebilir. Buna ek olarak, parçalama ünitesinde işlemden geçen çamur miktarını azaltmak fosil yakıt tüketiminde ve dolayısıyla doğrudan seragazı emisyonlarında önemli azalma sağlayacaktır. Teorik çalışmalar, çamurun depolama sahasına gönderilmesinin atmosfere verilen karbondioksit emisyonlarında 931,27 ton azalma sağlayacağını, tesisin yılda sadece 7760 TL ödeyerek 1552 ağaç dikmek suretiyle karbon dengelemesi yapabileceğini göstermiştir.

Anahtar sözcükler: Sera gazı envanteri, GHG Protokolü, karbon dengeleme, hesaplama araçları, atıksu arıtma tesisi.

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER ONE
INTRODUCTION

Continuous rise in the Earth's average surface temperature is being hastened global warming. Increase in the greenhouse gas concentrations is the most important factor for global warming .Global warming is one of the main contributing factors that effects climate pattern changes. The climate pattern change refers to any significant change in the measures of climate lasting for an extended period of time. That is to say, climate change involves major changes in weather events like precipitation, temperature and wind patterns that occur over several decades.

It is clear that Earth is warming. "Earth's average temperature has risen by 0.8°C (1.4°F) over the past century, and it has been projected to rise another 1.1 to 6.4 °C (2 to 11.5°F) over the next hundred years"(United States Environmental Protection Agency [USEPA], 2007).Even a small change in the planet's average temperature can cause dangerous and large climate related events on the Earth.

Weather and climate changes are associated with increasing global temperature. Visible changes occurred in climate, for instance in most rainy places, the intense rainfalls cause floods whereas in many places facing the problem of droughts. And also some changes observed in glaciers and oceans of the planet depending on severe heat waves. Oceans are warming, glaciers are melting thus oceans are becoming more acidic and sea levels are rising. If the global warming continues, the negative changes on the environment will be more severe in the future.

Over the recent years, large quantities of greenhouse gases are released to air from human activities like industrial and agricultural activities. The biggest cause of greenhouse gas emissions is the fossil fuels. While fossil fuels are burned to produce energy, large amounts of emissions are released to atmosphere. In addition, some agricultural activities and cutting and burning of trees to provide land also released greenhouse gases to air.

Governments, industrialists and people will face the climate change as one of the biggest difficulty in future. The climate change effect natural system and people's life in addition to causing change on the use of resources, production and economic activities. Kyoto Protocol was signed to provide a fight against global warming and climate change by the countries in the world. Purpose of the Kyoto protocol is to keep atmospheric greenhouse gas concentrations in not significant levels. The first step is inventory preparations, which are required to keep greenhouse gases under control or to reduce them. For this reason, companies, institutions and organizations requires some methods for calculating released greenhouse gas emissions.

One of the methods is ISO 14064-2007 standard for quantifying, calculating and managing of the emissions. The standard guides some industries and companies about design and development of greenhouse gas inventories. Also, it includes calculation of the greenhouse gas emissions and suspensions, while defining the specific activities of the company and finally guides them for reporting.

Another method is also available. The method is named Greenhouse Gas Protocol (GHG Protocol). Governments and lots of companies use calculating tools of the protocol for quantifying and managing greenhouse gas emissions. The GHG Protocol is working with businesses, governments, and environmental groups around the world to build a new generation of credible and effective programs for tackling climate change. The GHG Protocol also offers developing countries an internationally accepted management tool to help their businesses to compete in the global marketplace.

In this study, an industrial wastewater treatment plant is chosen for determining its greenhouse gas emissions. Literature survey is presented in Chapter Two. In this chapter, greenhouse gases, their characteristics and effects on climate change are mentioned. Also direct and indirect emissions of greenhouse gases and their inventories are explained. In Chapter Three, the chosen industries' greenhouse gas emissions and activities of the companies are defined before the greenhouse gas inventory is calculated. Then reduction methods for greenhouse gas emissions are mentioned in the Chapter Four. The conclusions are included in Chapter Five.

CHAPTER TWO
GREENHOUSE GASES

2.1 Greenhouse Gases

Gases which catch heat in the atmosphere are called greenhouse gases. A greenhouse gas absorbs and emits radiation within the thermal infrared range. This process is cause of the greenhouse effect.

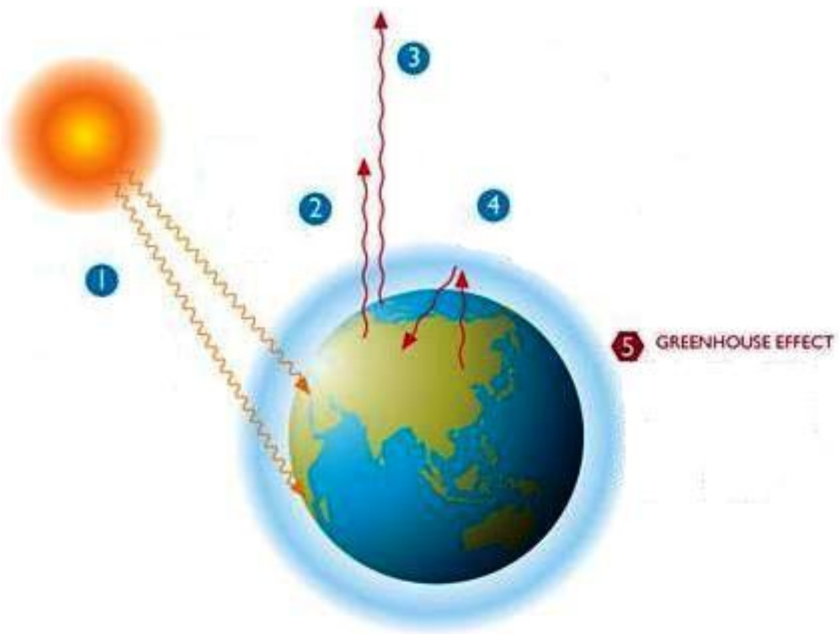


Figure 2.1Greenhouse effect

Effect of greenhouse gasses is illustrated in Figure 2.1. Everything starts with the sun's radiation. Overtime, energy is sent from the sun to the Earth's surface. The sunlight passes through the atmosphere and warms the earth. Some of the energy is absorbed by the Earth however; infrared radiation is given off by the Earth to the atmosphere. Most of the infrared lights escape to outer space, allowing the Earth to cool down but some of the infrared radiation is prevented by gases in the air keeping them inside the atmosphere. This trapped radiation keeps the Earth warm. All these gases are named greenhouse gases and the phenomenon is called greenhouse effect.

Greenhouse gases act like a blanket around the earth. The greenhouse effect is natural and necessary to support life on Earth. However, the buildup of greenhouse gases can change Earth's climate and result in drastic effects to human health and to ecosystems.

The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases in the Earth's atmosphere. Water vapor and ozone (O_3) are other gases which also have an effect on the global warming.

The sources of these gases are explained below

2.1.1 Carbon Dioxide (CO_2)

Carbon dioxide is primary and most effective greenhouse gas. Carbon dioxide is used in carbon cycle naturally. People or animals emit CO_2 while respiration and plants absorb CO_2 while photosynthesis. Besides volcanic activities and ocean-atmosphere exchange release CO_2 to the atmosphere. Some human activities like fossil fuel consumption and deforestation for providing agricultural land releases big quantities CO_2 emissions to air.

Carbons cycle and concentrating in the atmosphere is described below step by step;

1. The primary greenhouse gases, carbon dioxide (CO_2) include the element carbon in its atomic structure. Carbon is a natural element which can be found in the atmosphere, biosphere, water bodies, and rocks and sediments.

2. The exchange of carbon among the Earth's components involves in the processes which remove carbon from the atmosphere, such as photosynthesis and processes which release carbon into the atmosphere as respiration and other exchanges, for instance exchange between the ocean and atmosphere.

Prior to the industrial revolution, these exchanges were approximately in balance.

3. Certain human activities release carbon into the atmosphere as carbon dioxide (CO_2). Carbon that was gradually stored in coal, oil, and gas over millions of years is being released back to the atmosphere in only a few centuries due to human activities. Biosphere and oceans absorbs almost half of the carbon dioxide and the rest remains in the atmosphere.

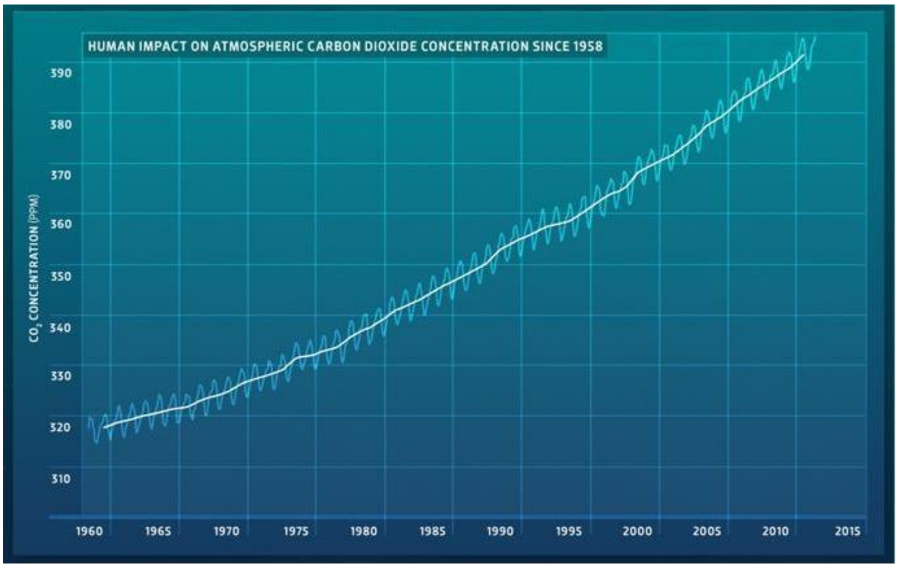


Figure 2.2 The graph is called a Keeling Curve. It shows increasing of carbon dioxide concentration in the atmosphere (US EPA, 2012).

4. The CO_2 that humans have released to the atmosphere has caused an increase in the atmospheric concentration of CO_2.

CO_2 concentrations in the atmosphere increased from approximately 280 parts per million by volume (ppmv) in pre-industrial times to 390 ppmv in 2010, a 39.2% increase (The Intergovernmental Panel on Climate Change, [IPCC], 2007).

The IPCC states that "the present atmospheric CO_2 increase is caused by anthropogenic emissions of CO_2" (IPCC, 2001) (see Fig.2.2). The predominant source of anthropogenic CO_2 emissions is the combustion of fossil fuels. Forest clearing, other biomass burning, and some non-energy production processes (e.g., cement production) also emit notable quantities of CO_2. In its Fourth Assessment Report, the IPCC stated "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increased in anthropogenic greenhouse gas concentrations," of which CO_2 is the most important (IPCC, 2007).

Some volcanic eruptions has released large quantities of CO_2 in the distant past. However, the U.S. Geological Survey (USGS) reports that each year human activities now emit more than 135 times as much CO_2 as volcanoes have emitted. Every year human activities currently release over 30 billion tons of CO_2 into the atmosphere. (National Research Council [NRC], 2010)

2.1.2 Methane (CH_4)

CH_4 is another important greenhouse gas. It is generally sourced from anaerobic activities. Anaerobic decomposition of organic matter emits methane. Some agricultural activities like rice breeding, enteric fermentation in animals, and the decomposition of animal wastes emit CH_4. Also CH_4 is released to the atmosphere during decomposition of solid wastes. Natural gas production and distribution also cause emitting methane gas. The IPCC has estimated that "slightly more than half of the current CH_4 flux to the atmosphere is anthropogenic, from human activities such as agriculture, fossil fuel use, and waste disposal" (IPCC, 2007). "Methane is more abundant in Earth's atmosphere now than at any time in at least the past 650,000 years. Due to human activities, CH_4concentrations increased sharply during most of the 20th century and are now more than two-and-a-half times more than the pre-industrial levels. In recent decades, the rate of increase has slowed considerably" (IPCC, 2007).

2.1.3 Nitrous Oxide (N_2O)

Nitrous oxide is caused especially human activities. Main anthropogenic sources are agricultural lands and activities such as using synthetic fertilizers and producing nitrogen fixing crops. The other sources are manure deposition by livestock; fossil fuel combustion, especially from mobile combustion; adipic (nylon) and nitric acid production; wastewater treatment and waste incineration; and biomass burning. “The atmospheric concentration of N_2O has increased by 19 percent since 1750, from a pre-industrial value of about 270 ppb to 322-323 ppb in 2010, a concentration that has not been exceeded during the last thousand years. N_2O is primarily removed from the atmosphere by the photolytic action of sunlight in the stratosphere” (IPCC, 2007).

2.1.4 Fluorinated Gases

Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes like aluminum smelting, electric power transmission, semiconductor manufacturing and distribution. HFCs, PFCs, and $SF_6$are not ozone depleting substances, and therefore are not covered under the Montreal Protocol. HFCs are primarily used as replacements for ozone depleting substances. Currently, the relative impact of PFCs and SF6 are small, but they have a significant growth rate, extremely long atmospheric lifetimes, and are strong absorbers of infrared radiation, and therefore have the potential to influence climate far into the future

Halocarbons are man-made chemicals which have both direct and indirect radiative forcing effects. Halocarbons of chlorine included are CFCs, HCFCs, carbon tetrachloride, methyl chloroform and bromine included ones are halons, methyl bromide, and hydrobromofluorocarbons. Halocarbons that contain chlorine and bromine result in stratospheric ozone depletion. Therefore they are controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer. Although CFCs and HCFCs include potent global warming gases, their net radiative forcing effect on the atmosphere is reduced because they cause stratospheric ozone depletion, which itself is an important greenhouse gas in addition to shielding the Earth from harmful levels of ultraviolet radiation. Under the Montreal Protocol, the United States phased out the production and importation of halons by 1994 and of CFCs by 1996.

2.1.5 Other GHG Gases

Water Vapor (H_2O); Overall, the most abundant and one of the most important greenhouse gas in the atmosphere is water vapor. Water vapor is not long-lived and well mixed in the atmosphere. Also, the atmospheric water can exist in several physical states including gaseous, liquid, and solid. The global concentration of water vapor is not directly related to human activities, but, the radioactive forcing produced by the increased concentrations of other greenhouse gases may indirectly affect the hydrologic cycle. While a warmer atmosphere has increased water holding capacity, high concentrations of water vapor affects the formation of clouds, which can both absorb and reflect solar and terrestrial radiation.

Ozone (O_3), which also do not has a long atmospheric lifetime, is a potent greenhouse gas. Chemical reactions create ozone from emissions of nitrogen oxides and volatile organic compounds from automobiles, power plants, and other industrial and commercial sources in the presence of sunlight. In addition to the heat trapping effect, ozone is a pollutant that can cause respiratory health problems and damage crops and ecosystems.

Ozone is located in both the troposphere and the stratosphere. It is present in stratosphere for shielding the Earth from harmful levels of ultraviolet radiation. It is also present at lower concentrations in the troposphere as the main component of anthropogenic photochemical smog.

During the last two decades, emissions of anthropogenic chlorine and bromine-containing halocarbons, such as CFCs, have depleted stratospheric ozone concentrations. This loss of ozone in the stratosphere has caused in negative radioactive forcing. Increase in tropospheric ozone, which is also a greenhouse gas caused an increase in the direct radioactive forcing since the pre-industrial era. Tropospheric ozone is produced from complex chemical reactions of volatile organic compounds mixing with NOx in the presence of sunlight. The tropospheric concentrations of ozone and these other pollutants are short-lived and, therefore, spatially variable.

Effect of each gas on the climate change depends on three main factors:

- Concentration of these gases is in the atmosphere (see Fig.2.3): Concentration, or abundance, is the amount of a particular gas in the air. Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere. Greenhouse gas concentrations are measured in parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car).

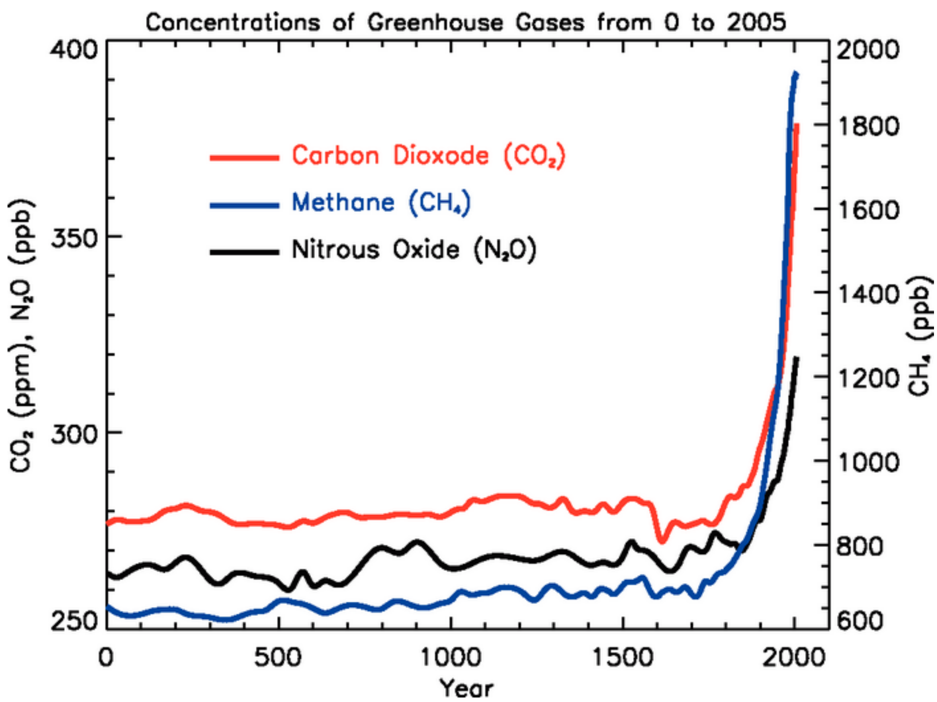


Figure 2.3 the graph shows concentration how much increased of greenhouse gases in the atmosphere over the last 2000 years (USGCRP, 2009).

- Staying period in the atmosphere: Each of these gases can remain in the atmosphere for a different amount of time, ranging from a few years to thousands of years. All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured at any location in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

- Impact on global temperatures. Some gases are more effective than others at making the planet warmer and "thickening the Earth's blanket. “For each greenhouse gas, a Global Warming Potential (GWP) has been calculated to reflect how long it remains in the atmosphere, on average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy, per pound, than gases with a lower GWP, and thus contribute more to warming. (US EPA, 2012)

2.2 Natural and Anthropogenic Sources of Greenhouse Gases

The primary greenhouse gases are naturally can be found in the Earth's atmosphere, biosphere, water bodies, and rocks and sediments. Before the industrial revolution, the largest fluxes have occurred between the atmosphere and terrestrial biota, and between the atmosphere and surface water of the oceans in balance. If an example is given to the balance for the most important greenhouse gas; carbon dioxide gas has released from respiration process, the carbon dioxide gas has removed with photosynthesis processes and other exchanges has occurred between the ocean and atmosphere. They were all in balance until the industrial revolution. Volcanic activities, biomass burnings and some natural fires are releases CO_2 and other greenhouse gases to atmosphere. These activities are all another natural sources of GHGs.

After the industrial revolution, the balance is broken. Concentrations of existing gases have increased in the atmosphere. Human activities have added more greenhouse gases to the atmosphere. The largest source of greenhouse gas emissions from human activities, which is called anthropogenic sources , are from burning fossil fuels for electricity, heat, and transportation.

The primary sources of greenhouse gas emissions are explained below and depicted as pie diagram at Figure 2.4.

- Electricity production (34% of 2010 greenhouse gas emissions) - Electricity production generates the largest share of the greenhouse gas emissions. Over 70% of our electricity is produced by burning fossil fuels, mostly coal and natural gas. (US Energy Information Administration [US EIA], 2011)

- Transportation (27% of 2010 greenhouse gas emissions) - Greenhouse gas emissions from transportation primarily come from burning the fossil fuels in our cars, trucks, ships, trains, and planes. About 90% of the fuel used for transportation is petroleum based, which includes gasoline and diesel. (US EIA, 2011)

- Industry (21% of 2010 greenhouse gas emissions) - Greenhouse gas emissions from industry primarily generated by burning fossil fuels for energy as well as greenhouse gas emissions generated during certain chemical reactions necessary to produce goods from raw materials. Using of chlorofluorocarbons (CFCs) in refrigeration systems and using of CFCs and halons in fire suppression systems and manufacturing processes causes greenhouse gas emissions.

- Commercial and Residential (11% of 2010 greenhouse gas emissions) - Greenhouse gas emissions from businesses and homes arise primarily due to the fossil fuels burned for heat, the use of certain products that contain greenhouse gases, and the handling of waste.

- Agriculture (7% of 2010 greenhouse gas emissions) - Greenhouse gas emissions from agriculture come from livestock such as cows, agricultural soils, and rice production. Agricultural activities, including the use of fertilizers, leads to higher nitrous oxide (N_2O) concentrations. Livestock enteric fermentation and manure management, paddy rice farming, wetland changes, pipeline losses, and covered vented landfill emissions are increased atmospheric concentrations of methane.

Many of the septic systems and the fermentation processes are also the sources of atmospheric methane.

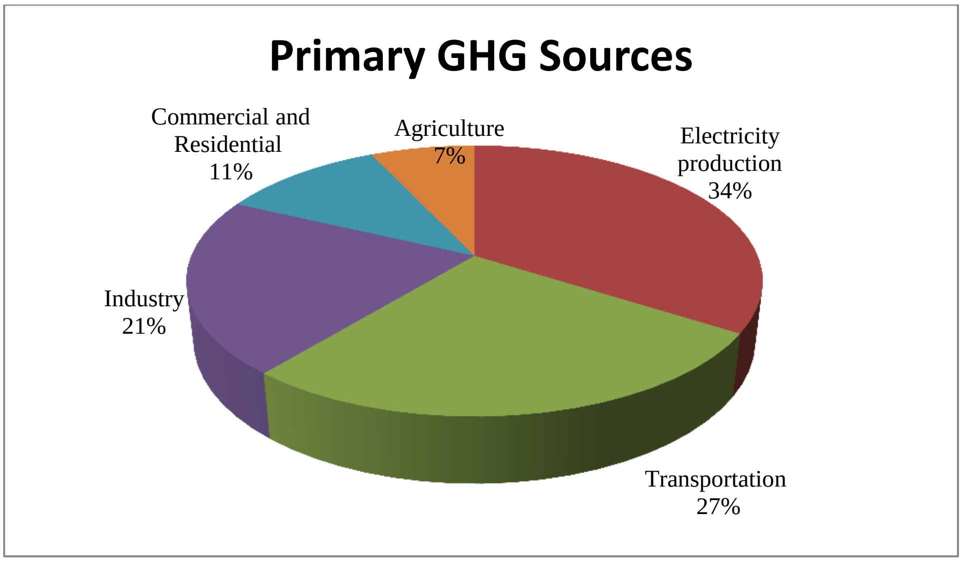


Figure 2.4 Pie diagram for primary GHG sources

- Land Use and Forestry (offset of 15% of 2010 greenhouse gas emissions) - Land areas can act as a sink (absorbing CO_2 from the atmosphere) or a source of greenhouse gas emissions. Managed forests and other lands have absorbed more CO_2 from the atmosphere than they emit.(US EPA, 2012)

2.3 Global Warming Potentials

A global warming potential is a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. The following table (Table 2.1) presents the direct 100-year time horizon global warming potentials (GWP) relative to CO_2. This table is adapted from table IPCC Second assessment report values (1995). The used reference gas isCO_2, and therefore GWP-weighted emissions are measured in trigrams of CO_2 equivalent (TgCO_2Eq.)

Greenhouse gases with relatively long atmospheric lifetimes tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined. The short-lived gases such as water vapor, carbon monoxide, tropospheric ozone are varying regionally. Therefore it is difficult to quantify their global radiative forcing impacts.

Table 2.1 Global warming potentials (US EPA, 2009)

Chemical formula	Name	Global warming potential (100 yr.)
CO_2	Carbon dioxide	1
CH_4	Methane	21
N_2O	Nitrous oxide	310
CHF_3	HFC–23	11,700
CH_2F_2	HFC–32	650
CH_3F	HFC–41	150
C_2HF_5	HFC–125	2,800
$C_2H_2F_4$	HFC–134	1,000
CH_2FCF_3	HFC–134a	1,300
$C_2H_3F_3$	HFC–143	300
$C_2H_3F_3$	HFC–143a	3,800
CH_2FCH_2F	HFC–152	53
CH_3CHF_2	HFC–152a	140
CH_3CH_2F	HFC–161	12
C_3HF_7	HFC–227ea	2,900
$CH_2FCF_2CF_3$	HFC–236cb	1,340
CHF_2CHFCF_3	HFC–236ea	1,370
$C_3H_2F_6$	HFC–236fa	6,300
$C_3H_3F_5$	HFC–245ca	560
$CHF_2CH_2CF_3$	HFC–245fa	1,030
$CH_3CF_2CH_2CF_3$	HFC–365mfc	794
SF_6	Sulfur hexafluoride	23,900
CF_4	PFC–14 (Perfluoromethane)	6,500
C_2F_6	PFC–116 (Perfluoroethane)	9,200
C_4F_{10}	PFC–3–1–10 (Perfluorobutane)	7,000
C_6F_{14}	PFC–5–1–14 (Perfluorohexane)	7,400

CHAPTER THREE
GREENHOUSE GAS INVENTORY

A greenhouse gas (GHG) inventory is a project report which is the accounting of greenhouse gases emitted to or removed from the atmosphere over a period of time. GHG inventories are used for developing atmospheric models, strategies and policies for emission reductions by scientists. An inventory is usually the first step taken by entities that want to reduce their GHG emissions. An inventory can help governments and businesses in:

- Identifying the sectors, sources, and activities within their jurisdiction that are responsible for greenhouse gas emissions
- Understanding emission trends
- Quantifying the benefits of activities that reduce emissions
- Establishing a basis for developing a local action plan
- Tracking progress in reducing emissions
- Setting goals and targets for future reductions

Unlike some other air emission inventories, greenhouse gas inventories include not only the sources of emissions, but also the reduction of greenhouse gases. These reductions are typically referred to carbon management as carbon sinks.

“Local governments can choose to estimate the emissions of government operations only, emissions estimated community-wide, or estimated with other municipalities to create a regional inventory.

- **Government operations inventories** include emissions of all the operations that a local government owns or controls. Common sectors in a government operations inventory include local government buildings and other facilities, streetlights and traffic signals, waste, and water delivery facilities. After completing a government operations inventory, the local governments can establish mitigation efforts as an example that illustrates the possibilities of mitigation actions to the community.

- **Community-level inventories** include emissions from community activities within the local government's jurisdiction, including emissions from sources and/or activities in that community, such as energy, transportation, agricultural, industrial, and waste. A community-wide inventory is a useful planning tool in developing mitigation actions for the entire community. For community inventories, energy used in the residential and commercial sectors and transportation are likely to be among the biggest contributors to emissions. Also community-level inventory contains residential, commercial/institutional and industrial inventories.

- **Regional inventories** include emissions from multiple communities. Local governments may join with other communities in the area to create a regional inventory. This option can be valuable for small communities that may not have the capacity or resources to conduct inventories individually." (USEPA, 2012)

The steps below apply to regional, community-wide, and local government operation inventories. In this study, ISO 14064 Standard and GHG Protocol get as reference and according to the references, preparation rules of greenhouse gas inventory are explained respectively.

3.1 Determination of Boundaries

First step for a greenhouse gas inventory is determining boundaries of a government, business, region or other organization. While setting boundaries of an entity, physical, organizational, and operational boundaries are defined.

An establishment which issued greenhouse gas inventory may include one or more facilities. The facilities, single or multiple, are selected from a group of greenhouse gas sources and sinks or individual greenhouse gas emissions and removals. The establishment is responsible of all the greenhouse gas emissions from these selected facilities and self-removals of these financial and administrative facilities.

While a GHG inventory is preparing, a baseline year is chosen to provide a comparison on progress. When choosing a baseline year, two points are considered, whether data for that year are available and if the chosen year is representative. The year which data was available for greenhouse gas inventory is usually determined as the baseline year. If inventory data is related to the current year, the current year can be selected as the baseline year. And also the baseline year emissions can be calculated in a time intervals in the base year or in several times during the base year.

After organizational boundaries are defined and the baseline year determined, the scope and operational boundaries must be determined. Operational boundaries are related to activity limits which are located under the responsibility of the facility. In activity limits, emissions sources and/or activity categories and subcategories should be included in the inventory as well as which specific GHGs.

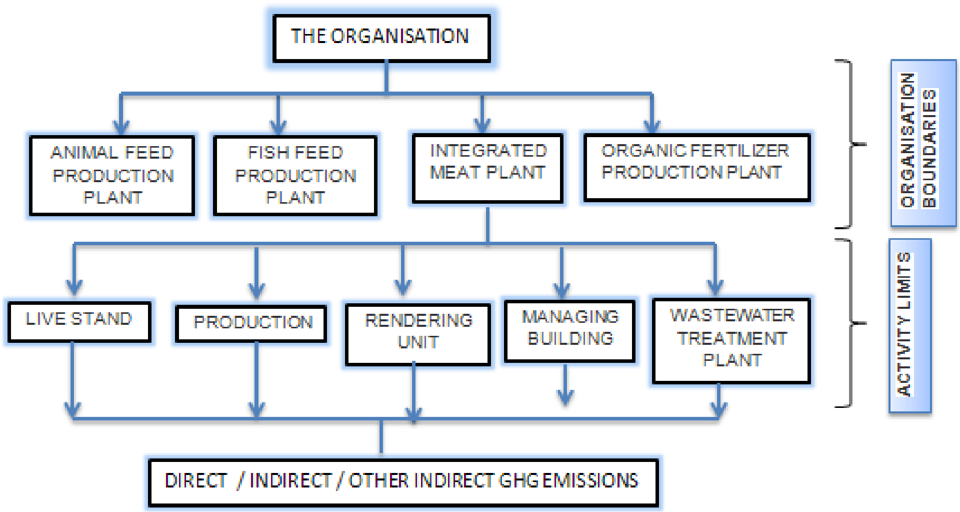


Figure 3.1 Determining boundaries and activity limits of an organization as an example

As an example boundaries and activity categories of an organization are shown in the Figure 3.1. First, sub-companies under the main company are defined for determining the boundaries of the organization. Then greenhouse gas inventory will be prepared for the sub-companies that will be determined. After that the working conditions in sub-companies are taken into account while specifying the direct and indirect greenhouse gas emissions for determining of activity limits. In the next section, data will be collected on sources for greenhouse gas emissions.

3.2 Data Collection

After determining the activity limits and boundary of organization, the next step of the inventory is collecting data for the greenhouse gas report.

There are two approaches for collecting activity data: "top down" and "bottom up."

- Top-down inventories rely on data collected and aggregated by some national and international agencies or offices that attempts to provide information (e.g., fuel consumption).

- Inventories that use a bottom-up approach generally collect and aggregate data from utility bills or other locally provided information sources. Since local government inventories have a smaller geographic and operational scope than other types of inventories, they often take a bottom-up approach.

In the following section, greenhouse gas sources which cause emissions are specified in detail. Sources are classified according to their features in reference to The Greenhouse Gas Protocol.

The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool by government and business leaders to understand, quantify, and manage greenhouse gas emissions. A decade-long partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), the GHG Protocol is working with businesses, governments, and environmental groups around the world to build a new generation of credible and effective programs for tackling climate change.

WRI and WBCSD have partnered with governments, businesses, and non-government organizations in both developed and developing countries to promote the broad adoption of the GHG Protocol as the foundation for sound climate change strategies.

The GHG Protocol also offers developing countries an internationally accepted management tool to help their businesses to compete in the global marketplace and their governments to make informed decisions about climate change.

Since 2001, the GHG Protocol has built upon the Corporate Standard by developing a suite of calculation tools to assist companies in calculating their greenhouse gas emissions. GHG Protocol is an important climate program in the successful measurement and management of climate change by using a suit of calculation tools.

3.2.1 Direct GHG Sources (Scope 1)

Direct greenhouse gas emissions occur from sources that are owned and/or controlled by a company, for example, emissions from combustion in the owned or controlled boilers, furnaces, vehicles, etc. Direct GHG emissions are classified as "scope 1" emissions in GHG Protocol. GHG emissions from the combustion of fossil fuels in stationary combustion units should be classified and reported as "scope 1" direct emissions by the company that owns or controls the stationary combustion units.

The combustion process is defined by the rapid oxidation of substances (i.e., fuels) with the release of thermal energy (i.e., heat). During the combustion process greenhouse gases are formed and emitted. The combustion of fuels produces emissions of the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The focus of Scope 1 is on the direct emissions of CO_2 from fossil fuel combustion. Carbon dioxide accounts for the majority of greenhouse gas emissions from most of the stationary combustion units.

The approach used to estimate CO_2 emissions varies significantly from approaches required to estimate CH_4 and N_2O emissions. Methane and N_2Oemissions depend on upon fuel characteristics, the combustion technology type, conditions within the combustion chamber, usage of pollution control equipment, and ambient environmental conditions. Emissions of these gases also vary with the size, efficiency, and vintage of the combustion technology, as well as maintenance and operational practices. As a result of this added complexity, a greater effort is required to accurately estimate CH_4 and N_2O emissions from stationary combustion sources compared to the estimation carbon dioxide emissions.

Scope 1 focuses on the combustion of fuels to produce electricity, heat or steam. Most of the stationary combustion devices can be classified into one of the following categories:

- Boilers
- Burners
- Turbines
- Heaters
- Furnaces, including blast furnaces
- Incinerators
- Ovens
- Dryers
- Internal combustion engines
- Thermal oxidizers

• Open burning (e.g., fireplaces)

• Flares

• Any other equipment or machinery that combusts carbon bearing fuels or waste streams.

The company must determine which stationary combustion devices are available in their own facility.

3.2.2 Indirect GHG Sources (Scope 2)

Indirect GHG emissions are emissions that are the consequences of the activities of a company but occur at sources owned or controlled by another company. Indirect emissions include “scope 2” emissions. Scope 2 emissions account for GHG emissions from the consumption of purchased electricity, heat, and/or steam at a facility that falls within a company’s organizational boundary. Scope 2 associated with the consumption of purchased electricity, heat, and/or steam.

Electricity, heat, and/or steam are produced when fossil fuels are burned in stationary combustion units to produce energy. GHG emissions that result from the consumption of purchased electricity, heat, and/or steam, are emitted directly through the combustion of fossil fuels in stationary combustion units. These GHG emissions include carbon dioxide, methane and nitrous oxide. Sources of the emissions from stationary combustion include boilers, heaters, furnaces, kilns, ovens, dryers, and any other equipment or machinery that uses fuel.

While GHG emissions that result from the consumption of purchased electricity, heat, and/or steam are physically emitted at the facilities where the electricity, heat, and/or steam are generated, the emissions are still a consequence of the activities of the consumer that purchases the electricity, heat, and/or steam. Therefore, GHG emissions from the consumption of purchased electricity, heat, and/or steam are considered to be “indirect” emissions, as they are the indirect consequence of the purchase and consumption of electricity, heat, and/or steam, although the emissions physically occur at sources owned or controlled by another company.

In this section the company must determine, which electrical devices available in their own facility.

3.2.3 The Other Indirect GHG Sources (Scope 3)

Scope 3 emissions include all other indirect GHG emissions, whether or not they fall within a company's organizational boundary.

The Scope 3 Standard categorizes scope 3 emissions into 15 distinct categories, as detailed in Figure 3.2 and Table 3.1, as well.

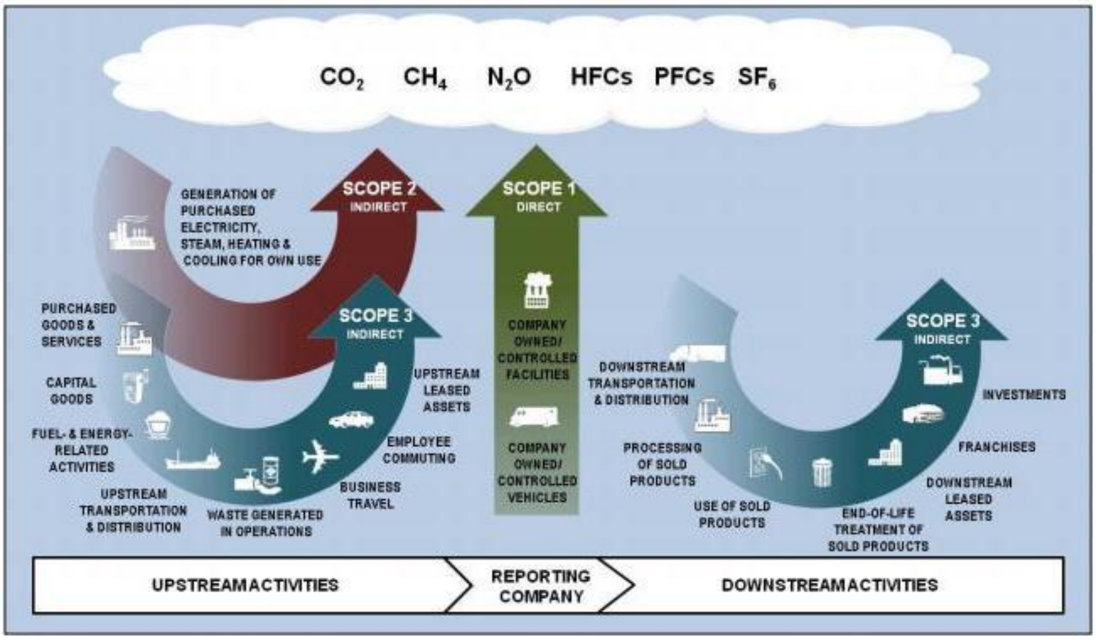


Figure 3.2 Overview of scopes and emissions across the value chain

Table 3.1 Scope 3 emissions categories

Upstream Scope 3 Emissions	Downstream Scope 3 Emissions
Purchased goods and services	Use of sold products
Investment goods	Processing of sold products
Fuel- and energy-related activities (not included in scope 1 or scope 2)	Downstream transportation and distribution
Upstream transportation and distribution	End-of-life treatment of sold products
Waste generated in operations	Downstream leased assets
Business travel	Franchises
Employee commuting	Investments

3.3 Greenhouse Gas Emissions Calculation

After an organization's boundaries are identified and activity data are collected, methodology of calculation for GHG emissions must be chosen.

A methodology should be selected and used to ensure accurate and consistent results and to minimize uncertainty from calculation methods. Calculation methodologies are generally defined by the programs of greenhouse gases and also they can be classified according to the ISO-14064 standard in the following headings.

i) Calculation

- Greenhouse gas data is multiplied by the factors of greenhouse gas emissions,
- The use of models
- Facility-specific correlations,
- Mass balance approach.

ii) Measurement

- Continuous
- Batch

iii) A combination of measurement and calculation

An explanation about which calculation model is selected with reasoning must be given to the organization.

In this thesis, the methodology which is called 'greenhouse gas data is multiplied by the factors of greenhouse gas emissions' is chosen. This method implements with collected greenhouse gas data entering a GHG calculating program and as a result achieved emission values are obtained with reference to the GHG Protocol.

In 2006, the International Organization for Standardization (ISO) adopted the Corporate Standard as the basis for its *ISO 14064-I: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals*. This milestone highlighted the role of the GHG Protocol's Corporate Standard as the international standard for corporate and organizational GHG accounting and reporting.

The methodology is chosen for calculating GHG emissions from the organization, because GHG Protocol accounting tools are widely used for businesses and governments around the world. Hundreds of GHG inventories are prepared by largest companies by using GHG Protocol. And also ISO adopted GHG protocol as the basis for its ISO 14064-I.

Calculating emissions is a multi-step process. An accurate and useful inventory can only be developed after careful attention is paid to quality control issues and to the required activity data. Only then the emissions estimations should be carried out.

GHG Protocol tools enable companies to develop comprehensive and reliable inventories of their GHG emissions. "GHG Protocol tools" refers to greenhouse gas emissions calculation programs. These tools provide step-by-step guidance and electronic worksheets to help users calculate the GHG emissions from specific sources or industries. Each tool reflects the best practice methods that have been extensively tested by industry experts. GHG calculation tools are chosen by companies and organizations according to their business activities. Most companies will need to apply more than one tool to cover their all emissions.

During the calculation, the organization may not take into account some direct or indirect GHG emissions but reasoning must be given about why they were excluded.

The organization must use tons as a unit of measurement and translated tons to the amount of value CO_2 e by using the appropriate Global Warming Potentials (GWPs)

The following points should be separately calculated and documented by the organization;

- Direct greenhouse gas emissions for each greenhouse gas,
- Indirect greenhouse gas emissions which related to energy,
- Other indirect greenhouse gas emissions.

3.3.1 Direct GHG Emissions

To calculate GHG emissions of Scope 1 "Stationary Combustion Tool" is chosen. This tool calculates the CO_2, CH_4 and N_2O emissions from the combustion of fuels in boilers, furnaces and other stationary combustion equipment. It can be used by organizations from any sector. Most of time information on the type and amount of burnt fuel, as well as the industry sector is sufficient. Emissions are then automatically calculated using default emission factors, chosen to reflect this information. A sector must be selected before the CH_4 and N_2O emission calculations are carried out.

Steps which must be followed to use this tool are explained below;

1. Select a fuel from types of fuels, i.e. brown coal, coking coal, gas, biodiesel, lignite and other bituminous coal.

2. Select a sector from many types of sectors, i.e. construction, energy, manufacturing, agriculture and residential.

3. Select a Global Warming Potential (GWP) set. GWPs compare the climate impact of different GHG gases with respect toCO_2, and are used to calculate emissions in terms of CO_2 equivalents. One of the GWP sets must be chosen. Several GWP sets are defined in 1995 IPPC Second Assessment Report, 2001 IPPC Third Assessment Report and 2007 IPPC Fourth Assessment Report.

4. Then supplied data is used as an input to the Table 3.2.

Table 3.2 Calculating tool of stationary combustion for GHG emissions

GHG Emissions			
CO_2 (tones)	**CH_4 (tones)**	**N_2O (tones)**	**All GHGs CO_2e(tones)**

- Source ID is one of GWP sets.
- Sector is one of the sectors mentioned above.
- Fuel type is one of the solid, liquid, gaseous fossil fuels
- Fuel part change according to fuel type.
  - For solid fossil fuels, the fuel part can be selected as brown coal, coking coal, lignite, other bituminous coal, etc.
  - For liquid fossil fuels, the fuel part can be selected as crude oil, diesel oil, motor gasoline, etc.
  - For gaseous fossil fuels, the fuel part can be selected as blast furnace gas, coke oven gas, liquefied petroleum gas, etc.
- Amount of fuel data is taken from the organization.
- Unit is one of the fuel units that are kWh, kg, t, lb., etc.

5. GHG emissions are then automatically calculated on Table 3.3 after the supplied data were processed.

Table 3.3 Calculated GHG emissions from stationary combustion

User Supplied Data					
Source ID	**Sector**	**Fuel Type**	**Fuel**	**Amount of Fuel**	**Units**

Separately CO_2, CH_4 and N_2O gas emissions and total GHG emissions in the form ofCO2e can be calculated from fossil fuels by using stationary combustion tool of GHG Protocol.

3.3.2 Indirect GHG Emissions

“Purchased Electricity Tool” calculates the greenhouse gas (GHG) emissions associated with the generation of electricity. It implements default emission factors, either for individual countries or for regions within countries. The default emission factors cover at least CO_2, the principal GHG emitted by power facilities.

Users need to supply data on the amount of electricity that they have consumed over the accounting period. Sometimes, an organization may be a co-tenant of a building and lack data about exact amount of electricity which it has consumed excluding the other tenants. In these cases, the GHG emissions can be estimated using proxies for the proportion of the building's electricity use that the reporting organization has consumed. One proxy is the percentage of the building's total floor area that is occupied by the reporting organization. In relevant cases, users should enter this percentage information into the spreadsheet alongside data on the entire building's electricity usage.

In this tool, first one of the global warming potential set is selected as the stationary combustion tool. One of the GWP sets must be chosen. The GWP sets are defined severally in 1995 IPPC Second Assessment Report, 2001 IPPC Third Assessment Report and 2007 IPPC Fourth Assessment Report.

This tool is divided to three parts. Steps, which must be respectively implemented in each part are explained below;

1. In this part facility information handle in Table 3.4

Table 3.4 Facility information part of purchased electricity tool

Facility Information			
Facility Description	**% of electricity used by the facility**	**Country**	**Region**

- In Facility Description step, areas in which electricity is used are defined.
- In % of Electricity Used by the Facility step is explained above in detail. It is about sharing or owning a building. If the organization is a joint tenant of a building the percentage of the electricity it uses can be estimated based on the proportion of the occupied space in the building.
- Country, in which the organization reside.
- Region, in which the organization reside.

2. Then supplied consumption data is processed to the Table 3.5

Table 3.5 Consumption data part of purchased electricity tool

Consumption data			
Year	**Fuel Mix**	**Amount**	**Units**

- The base year was adopted in the early part of inventory which is explained in year step.
- Fuel mix part consists of four options. These options are coal, oil, gas and all. One of the options which is used for producing electricity in the country is chosen.
- Amount of purchased electricity data is taken from the organization.
- Unit is the amount of purchased in the units of kWh and MWh.

- GHG emissions are then automatically calculated on following table after the supplied data were processed.

3. GHG emissions and also emission factors are then automatically calculated on Table 3.6 after the supplied data were processed.

Table 3.6 Calculated GHG emissions and emission factors

Emission Factor (kg GHG/kWh)				**GHG Emissions**			
CO_2	**CH_4**	**N_2O**	**CO_2e**	**CO_2 (tons)**	**CH_4 (kg)**	**N_2O (kg)**	**CO_2e (tons)**

Separately CO_2, CH_4 and N_2O gas emissions and total GHG emissions in the form of CO_2e can be calculated from Purchased Electricity Tool of GHG Protocol.

3.3.3 The Other Indirect GHG Emissions

Scope 3 emissions include all other indirect GHG emissions, whether they fall within a company's organizational boundary or not. Other indirect GHG emissions are divided into two main parts. The first one is upstream activities and the other one is downstream activities. These activities are explained above in detail. Transport and distribution are the focal point of these activities. Transportation and distribution of purchased goods, capital goods, sold product, etc. compose the most important part of upstream and downstream activities. Therefore, "Transport Tool" (mobile combustion tool) is used for calculating other directive GHG emissions.

This tool calculates the CO_2, CH_4 and N_2O emissions from:

- Vehicles those are owned/controlled by company, including freight Lorries.
- Public transport by road, rail, air and water.
- Mobile machinery, such as agricultural and construction equipment.

The tool uses default emission factors, which vary by country. Currently, separate sets of emission factors are available for the UK and US. For other countries, companies should select the 'Other' category. This category uses global default values.

Fuel use data are the most accurate for calculating CO_2 emissions, while distance-traveled data are the most accurate for calculating CH_4 and N_2O emissions. Therefore, for non-public transport sources, the recommended approach is to provide both used amount of fuel and distance data. As a result, companies should strive to improve their fuel usage records.

Please note that the emission from on-road freight transport can be calculated using vehicle distance or weight-distance data.

This tool is divided into three parts. Steps which must be respectively implemented in each part are explained below;

1. In this part general data handle in Table 3.7

Table 3.7 General data part for transport tool.

Source Description	Region	Mode of Transport	Scope	Type of Activity Data

- In source description section, purposes of vehicles are written to calculate greenhouse gas emissions.

- Region part contains three sections. The sections which are UK, US and Other can be chosen according to the country. If organization which of greenhouse inventory is being prepared is not in UK or US, 'Other' section must be chosen.

- In mode of transport section, Transport type is chosen from one of road, rail, water or aircraft sections.

- Scope section is generally chosen as ‘Scope 3’. If the organization is a transportation company, Scope must be chosen as ‘Scope 1’.

- In type of activity data part, sections must be chosen according to data which is obtained from the organization. These sections are vehicle distance (e.g. road transport), weight distance (e.g. freight transport), passenger distance (e.g. public transport), custom fuel and custom vehicle.

2. Then supplied activity data is processed to the Table 3.8

Table 3.8 Activity data part of transportation tool.

Activity Data							
Vehicle Type	**Distance Travelled**	**Total Weight of Freight**	**# of Passenger**	**Units of Measurement**	**Fuel Used**	**Fuel Amount**	**Unit of Fuel Amount**

- Vehicle Type is chosen in this section from given types of vehicles.
- Travelled distance with the vehicle is entered in Distance Travelled part.
- Total Weight of Freight part only used for weight distance activities.
- # Of Passenger part only used for Passenger Distance activities as number of passenger.
- Units of measurement according to the Type of Activity Data.
- Fuel Used section is only active with Custom Fuel in Type of Activity Data part. Its options are LNG, Petrol, Fuel Oil, LPG, etc.
- Fuel Amount data is taken by the organization.
- Unit is changeable according to fuel is used in Unit of Fuel Amount.

3. GHG emissions are then automatically calculated on Table 3.9 after the supplied data were processed.

Table 3.9 Calculated GHG emissions from Transport Tool.

GHG Emissions			
Fossil Fuel CO_2 (kg)	**CH_4(kg)**	**N_2O (kg)**	**Total GHG Emissions CO_2e**

Separately CO_2, CH_4 and N_2O gas emissions and total GHG emissions as CO_2e can be calculated from Transport Tool of GHG Protocol.

CHAPTER FOUR
INVENTORY STUDY FOR AN INDUSTRIAL WASTEWATER TRETAMENT PLANT

4.1 Determination of Boundaries

The greenhouse gas inventory is prepared for a commercial sector in community-levels inventories type. In this study, greenhouse gas inventory is prepared for an industrial wastewater treatment plant. In this context, a food production company's wastewater treatment plant is taken as subject for calculating greenhouse gas emissions.

The first step of a greenhouse gas inventory is to determine the boundaries of the company. The mentioned company is a factory located under an organization, consists of four different factories. The organization includes four different factories and four brands in different sectors. These sectors are animal feed; fish feed; organic fertilizer and integrated meat plant.

In 2006, the integrated meat plant was put into operation in Kemalpaşa in Izmir. Facility based on a covered area of 100,000 m^2, per hour cutting capacity is 24 000 units. From this facility, Fresh and frozen chicken meat and so many kinds of meat products are offered to consumers.

The aim of this study is to evaluate the contribution to greenhouse gas emissions from this facility, depending on factors such as: wastewater treatment plants, capacity or preferred process and design etc.

In this facility a wastewater treatment plant with a treatment capacity of 6000 m^3/day is implemented. The wastewater treatment plant treats industrial wastewaters with desired quality and high efficiency by using physical, chemical and biological processes. In the following sections, wastewater treatment plant specifications and greenhouse gas emissions from the plant are described in detail.

Greenhouse gas emissions from the company's wastewater treatment plant and treatment plant operational buildings' activities were investigated. Carbon dioxide gas is the most important and most abundant atmosphere according to other greenhouse gases; therefore, in this thesis for the treatment plant emission investigation only carbon dioxide emissions are calculated in the inventory report.

4.2 Data Collection

In entity –level scale inventory, data of the year 2012 were used in all the studies of the treatment plant of the company. Data for wastewater treatment plant collected according to top down approach and identified all of the emission sources.

4.2.1 The Wastewater Treatment Plant

The wastewater treatment plant is a concrete facility designed with 6000 m^3/day capacity and it treats industrial and domestic wastewaters of the factory. 6000 m^3water is drawn every day from wells belonging to the factory. 5930 m^3 of this water is used during the production process, and the remaining portion of 70 m^3 is used for domestic use by personnel working at the site. 6000 m^3/day wastewater, after passed through physical, chemical and biological treatment units, are discharged the Nif Creek. Flow scheme of the wastewater treatment plant is shown in Figure 4.1.

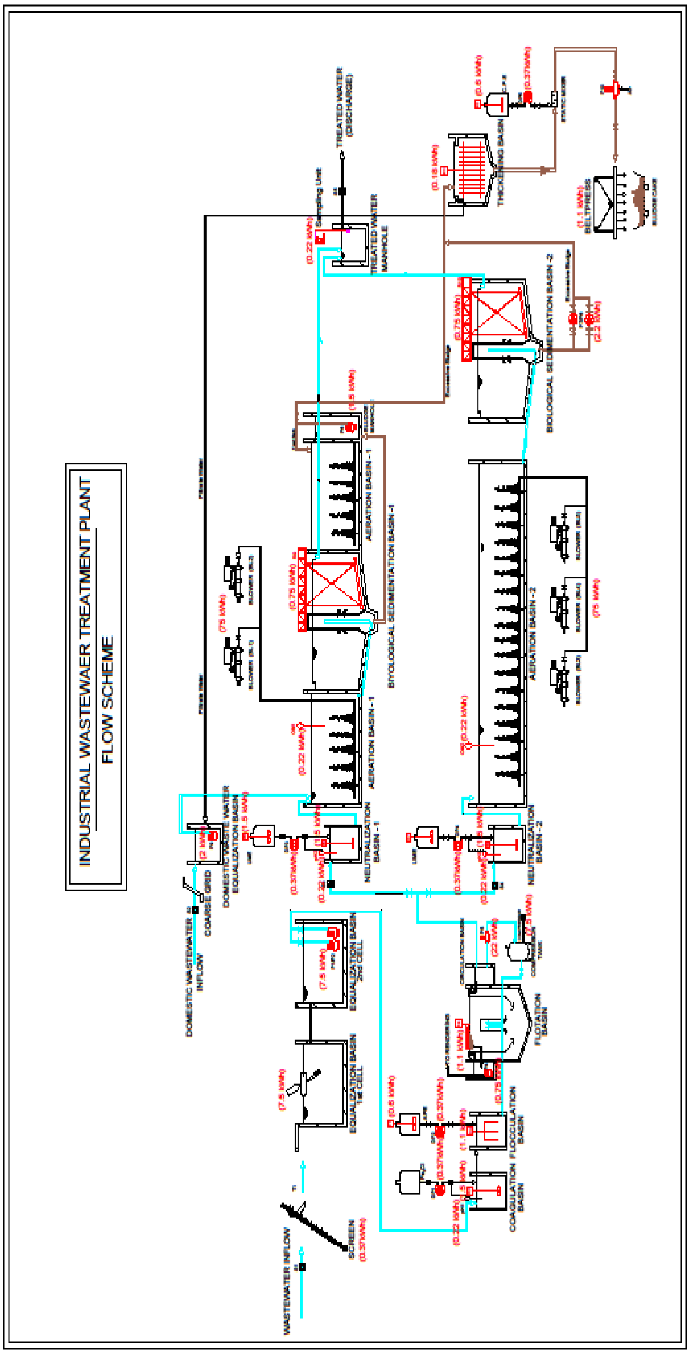


Figure 4.1 Flow scheme of the wastewater treatment plant

In order to identify sources of greenhouse gas emissions, waste water treatment plant units should be examined. Wastewater treatment plant units, respectively, are described in detail below.

Pre- treatment units;

- Screening
- Equalization Basin

Chemical Treatment Units;

- Coagulation
- Flocculation
- Flotation
- Neutralization

Biological Treatment Units;

- Activated Sludge
- Sedimentation

Sludge Treatment Units;

- Sludge Thickening
- Beltpres Unit

4.2.1.1 Pre-Treatment Units

Industrial wastewaters produced during the production process first flow through the pre-treatment units. Pre-treatment is a process in which solid materials in waste water are removed by physical methods. The purpose of this process is to increase efficiency of chemical and biological treatment units by removing coarse solids from wastewater

Consists of the following sections;

- Screening

A screen unit is located in the entrance of the equalization basin. Wastewater inflows the wastewater treatment plant after passing through a plastic conveyor belt screen in the screen channel. Coarse solids which could damage plant and equipment contained are removed with screen unit.

Plastic conveyor belt screen has a capacity of 250 m^3/h and uses 0.37 kWh of energy.

- Equalization Basin

Equalization basin is a concrete structure in which industrial wastewater is collected and also flow of wastewater and wastewater homogenization is provided inside the equalization basin. Equalization basin is designed as a two cell structure. Wastewater firstly flows into first cell of equalization basin after passing the screen unit, than flows second cell from first-cell. These two cells work in serial and are filled simultaneously. There is a jet aerator in first-cell of equalization basin for mixing wastewater to prevent odor. Jet aerator uses 7.5 kWh of energy.

After wastewater balanced in the basin, it is pumped to the chemical treatment units with submersible pumps in second-cell of the basin. The submersible pumps have a capacity of 132 m3/hand in total three pumps are located in the facility. Two of them are used as main pumping operation and one of them is for emergency situations. Energy consumption of one of the pumps is 7.5 kWh.

4.2.1.2 Chemical Treatment Units

The purpose of the chemical treatment processes is to remove oil- grease and other materials which cannot be removed with biological processes. First, in this process some chemicals are added to wastewater. After this stage oil-grease floats up to the basin. Chemical treatment units consist of the following sections;

- Coagulation

Wastewater is pumped to coagulation basin with lifting pumps from equalization basin. Coagulation is performed by dosing coagulant to wastewater, with the help of dosing pump in coagulation unit. $FeCl_3$ is used as a coagulant in there. Added $FeCl_3$ is mixed with vertical shaft speed mixer and so contact with the wastewater coagulant is maintained. The amount of energy consumed by the mixer is 1.5 kWh.

Coagulant stored in a chemical tank and provided in liquid form. It is added to wastewater with the help of the dosing pump. 0.37 kWh power is used by dosing pump. Coagulated wastewater passes to flocculation basin from coagulation basin.

- Flocculation

Flocculation process is implemented by adding the flocculants to the wastewater which comes from coagulation unit. Polymer is used as flocculants in there.

Flocks are formed with the addition of $FeCl_3$, and then they get bigger and stronger with the addition of polymer. The added polymer is mixed gently by vertical shaft mixer. Power consumption of the mixer is 1.1 kWh.

Polymer stored in a polythene chemical tank and mixed with vertical shaft speed mixer. Energy consumption of the mixer is 0.6 kWh. Prepared polymer solution is added to wastewater with dosing pump. The power consumption of the pump is 0.37 kWh. Flocculated wastewater passes to the flotation basin from flocculation basin.

- Flotation

After flocculation basin, the wastewater goes through the flotation basin. The big and light flocks and oils are floated up to the basin. For floating these materials, pressurized water and air mixture is supplied to the wastewater from the bottom of the basin. The mixture is formed by combining pressurized water from the circulation pump with air from the compressor.

The surface layer of oil-sludge is collected by scraping the surface and collected oil-sludge layer sent to an oil collection tank. The collected oil-sludge mixture is sent to rendering unit with oil pump. The scraper's power is 1.1 kWh in flotation basin. The power of the equipment which are used for pressurized water to basin are as follows; compressor is 7.5 kWh and circulation pump is 22 kWh. Pump power of waste oils is 0.75 kWh.

After big flocks and oils are removed from wastewater, the wastewater is divided into two lines for neutralization units. It is passes to the basins with equal flows.

- Neutralization

After passing through flotation basin, wastewater flows to the neutralization basin. Total flow is divided into two parts and flows in two separate neutralization basins.

Before biological treatment units, wastewater is neutralized by dosing lime in neutralization basins. Lime is added with dosing pumps to wastewater. The dosing pumps are controlled by pH meters. After pH meter is reached the appropriate value, lime dosing pumps are switched off automatically. There are high-speed vertical mixers with a capacity of 1.5 kWh power in the neutralization basins. Lime solutions are prepared in different polythene tanks for each neutralization basins. During the preparation of lime solutions, vertical shaft speed mixers are used with a capacity of 0.75 kWh. Lime dosing pumps with 0.37 kWh power capacity are used. Wastewater enters to aeration basins after neutralization basins.

4.2.1.3 Biological Treatment Units

After neutralization basins, wastewater flows into the biological treatment units, which is designed in two separate units. Activated sludge process is implemented in biological treatment units.

- Activated sludge

After pH balancing, wastewater passes to the activated sludge unit with two separate lines. Also domestic wastewater from the company’s toilets, kitchen etc.is pumped with the help of submersible pump with a capacity of 2 kWh into one of the basins. The development of microorganisms is provided by supplying oxygen to the wastewater in the basins. Oxygen required by the system, is provided by blowers.

Five blowers were chosen with a capacity of 75 kWh for aerating the system. By running all of blowers 10 hours in a day, desired efficiency of the system are achieved by supplying required aeration to the basins. The blowers give 3500 m^3 /h amount of air at 500 mbar against pressure.

Rubber membrane disc diffusers are laid on the bottom of aeration basins and they provide homogeneous small bubbles of oxygen into wastewater. Thus, the oxygen solubility in wastewater treatment is enhanced and high efficiency is obtained. Diffusers are mounted the bottom of basins on the branches and take air from main air line.

The wastewater passes through to sedimentation basins from activated sludge.

- Sedimentation

After activated sludge unit, wastewater flows in the sedimentation basins. With laminar hydraulic conditions in sedimentation basins, the activated sludge precipitates and accumulates in the bottom the basins. The treated water flows through flat and trapezoidal spillways on the surface of basins and reaches to the treated water manhole. Treatment process was completed in this way and treated water is discharged to Nif Creek.

Sludge in the bottom of basins; send back to activated sludge tanks with sludge pumps to keep the activated sludge concentration constant in the basins. One 1.5 kWh capacity and two of 2.2 kWh capacity sludge pumps are used in the system. Sometimes excessive sludge is pumped to the sludge thickening basin with the same sludge pumps. Sludge scrapers which provide sludge skimming in the bottom of sedimentation basins have a power requirement of 0.75 kWh.

4.2.1.4 Sludge Treatment Units

Accumulated sludge in the bottom of the basin is taken to sludge treatment units with the help of sludge pumps. These units are described below;

- Sludge Thickening

Cationic polyelectrolyte is dosed on the line in order to increase the solid content of sludge which comes from the sedimentation basin to the sludge thickening basin. Cationic polyelectrolyte added sludge is mixed slowly with vertical mixer of 0.18 kWh capacities. In this way, the necessary sludge settling and thickening process is carried out. Intensive sludge is collapsed at the bottom of basin; filtrate water is separated from sludge and flows to domestic wastewater manhole.

Cationic polyelectrolyte solution is prepared in a storage tank by mixing with a vertical speed mixer with a capacity of 0.6 kWh. Then the prepared solution is added to thickening purpose with a 0.37 kWh capacity dosing pump. Accumulated intensive sludge is sent to belt press unit by sludge feed pump with an air-operated diaphragm.

- Belt press Unit

Thickened sludge is pumped to belt press unit with a sludge feed pump with the air-operated diaphragm. Sludge trapped between belts, is removed from the system in the form of sludge cake. The filtrate water is given to domestic wastewater manhole. The belt press unit used in the plant consumes 1.1 kWh. Treated sludge was analyzed. According to the sludge analysis, the sludge was found to contain fat and protein intensively. For this reason, treated sludge is send to the rendering unit.

4.2.2 GHG Source

4.2.2.1 Direct GHG Source (Scope 1)

The company owns a boiler as a stationary combustion unit for rendering process. Rendering unit is a process in which valuable substances such as tallow and blood meal are obtained from animal bodies and body parts. Purpose of the rendering unit in the company is to dispose of slaughterhouse residues and to produce animal feed from the wastes. This process is realized by providing steam to the animal wastes in large tanks.

Additionally, wastes from screen unit, flotation unit and treatment sludge which taken to the rendering unit are turned into animal feed. Amount of treatment sludge is 6 tons per every day from the wastewater treatment plant. Sludge analysis was conducted, if high amount of fat and protein content is detects, sludge is send to the rendering unit. Due to disposal of the wastes from treatment plant in the rendering unit, steam boiler was taken as a source of direct greenhouse gas emissions. Amount of coal required for the operation of the steam boiler and the total coal burned for waste was calculated.

Steam is used from boiler for rendering system operation. In the boiler about 18 or 20 tons of coal is burned every day according to the data provided by the company's engineers. It is assumed that 20 tons of coal burns in every day.

Coal amount: 20tons/ day x 30 day/ month = 600 tons/month

About 90 tons provender is comprised from rendering unit in a month. The engineers estimate that this 20-25 % of the provender is comprised from wastewater treatment plants wastes like screening system wastes, floated oil and scum of some units and sludge cake. 25 % of this provender is assumed to be coming from wastewater treatment plant.

If it is assumed that 25% of 600 tons/ month coal is used for wastewater treatment plant wastes,

600 x 0.25 = 150 tons/month x 12 month /year =1800 tons/year coal are burned in a year for the wastes.

GHG emissions are calculated in Part 4.3.1 as a result of 1800 tons/year of coal is burned in boiler.

4.2.2.2 Indirect GHG Sources (Scope 2)

While calculating indirect GHG emissions of the company, the electricity consumption of the wastewater treatment plant are taken into consideration. Electricity consumption of the wastewater treatment plant is explained in two parts.

4.2.2.2.1 Equipment in Wastewater Treatment Plant. Three processes, which are pre-treatment, chemical and biological, are operating all together in the wastewater treatment plant improve the quality of treated water. The number of equipment increases with the addition of each process. Thus electricity consumption increases in the plant.

All equipment, their units in which they are used, amount of electrical power of the equipment are presented in Table 4.1. Also electrical power of each equipment shown in flow scheme in Figure 4.1. Total electrical consumption of the system in one day was calculated in kWh in the table. Based on daily use, the annual energy use was calculated as MWh.

5122 kWh/ day x 365 day/year =1869530 kWh =1870 MWh

According to table above, the equipment of the wastewater treatment plant use 5122 kWh each day. For one year consumption total consumed energy is calculated as **1870 MWh** for this plant.

Table 4.1 Total Energy Consumption of Equipment in the W.W.T.P.

Equipment	No	Unit Power Of Motor kWh	Total Power Of Motor kWh	Daily Working Time (h)	Daily Energy Consumption (kWh)
Screening System	1	0,37	0,37	24	8,88
Jet Aerator	1	7,5	7,5	5	37,5
Coagulation Basin Mixer	1	1,5	1,5	24	36
Flocculation Basin Mixer	1	1,1	1,1	24	26.4
Flotation Scraper	1	1,1	1,1	24	26.4
Compressor	1	7,5	7,5	24	180
Circulation Pump	1	22	22	24	528
Oil Pump	1	0,75	0,75	2	1,5
Domestic W.Water Pump	1	2	2	2	4
$FeCl_3$ Dosage Pump	1	0,37	0,37	5	1,85
A.P.E. Dosage Pump	1	0,37	0,37	5	1,85
C.P.E. Dosage Pump	1	0,37	0,37	5	1,85
Chemical Prep. Tanks Mixer	2	0,6	1,2	2	2,4
Sludge Pump/a	1	1,5	1,5	2	3
Equalization Basin Pump	2	7,5	15	24	360
Sludge Pump/b	2	2,2	4,4	2	8,8
Blower	5	75	375	10	3750
Neutralization Basin Mixer	2	1,5	3	24	72
Lime Dosage Pump	2	0,37	0,74	5	3,7
Sedimentation Basin Scraper	2	0,75	1,5	24	36
Lime Prep. Tank Mixer	2	0,75	1,5	2	3
Sludge Thickening Basin Mixer	1	0,18	0,18	2	0,36
Belt press	1	1,1	1,1	2	2,2
Oxygen Meter	2	0,22	0,44	24	10.56
pH Meter	3	0,22	0,66	24	15.84
Sampling Unit	1	0,22	0,22	1	0,22
Total Consumption :					**5122 kWh/day**
					1870MWh/year

***** One year is assumed 365 days

4.2.2.2.2 Operational Building. The other electric appliances are located in operating building of wastewater treatment plant. In the wastewater treatment plant area an operations building is included which consist of two floors.

The first floor is used for preparing chemicals for the treatment system. These chemicals are anionic polyelectrolyte, cationic polyelectrolyte and $FeCl_3$. Anionic and cationic polyelectrolyte is provided in granular form. Therefore, they are prepared as solutions in this floor and utilized equipment's electrical consumption is explained in Table 4.1. Also $FeCl_3$ dosing units' electrical consumption is explained in the same table. In the floor two fluorescent operates for 12 to 15 hours in a day and 7 days in a month. On time is assumed as 12 hours per day.

Second floor is divided two parts. One part is in use for an environmental engineer who is responsible for controlling and operating the treatment system. The environmental engineer works 8 hours in a day and 5 days in a week. (8.30 am to 5.30 pm). The engineer’s room contains one computer, one air conditioner and one fluorescent. The computer and air conditioner function 8 hours beside the fluorescent lights only 1 or 2 hour in a day. It is assumed that 2 hour in a day.

The other part of second floor is in use for dressing room of employees. There is a fluorescent in the room. One employee certainly exists in building 24 hours in a day for operating the system. Therefore, the fluorescent operates about 12 to 15 hours per day and 7 day per week. On time is assumed as 12 hours per day.

In addition to these, two halogen lamps light up waste water treatment system at nights. One can be easily interfere, when a breakdown occurs in the treatment system with the help of these halogen lamps. Thus they shine 12 to 15 hours in a day and 7 day. On time is assumed as 12 hours per day.

Table 4.2 Total Energy consumption of electrical appliances

Electric Appliance	**Number**	**Power (Piece) kWh**	**Working Period**	**Energy Consumption kWh /year**
Computer	1	0,35	8h/d x 261d/y	730,8
Air Conditioner	1	1,1	8h/d x 261d/y	2296,8
Halogen Lamp	2	1	12 h/d x 365d/y	8760
Fluorescent	1	0,04	2 h/d x 261d/y	20,88
Fluorescent	3	0,04	12 h/d x 365d/y	525,6
			TOTAL :	**12334 kWh/year**
				12.3 MWh/year

* Working periods like hours and days are assumed suitable the facilities working principles.

**Powers of electric appliance are taken by the facility engineers.

According to table above, electric appliance of the operating building of treatment plant use 12334 kWh in every year. 12334 kWh is equal to **12.3 MWh** for one year.

4.2.2.3 Other Indirect GHG Sources (Scope 3)

Other indirect GHG emissions include "scope 3"emissions, whether they fall within a company's organizational boundary or not. Transport and distribution are the focal point of other indirect GHG emissions.

While calculating the other indirect GHG emissions, amount of distance traveled by vehicles for wastewater treatment plant is considered. This section consists of 3 parts.

4.2.2.3.1 Vehicle Usage for Chemical Requirement. $FeCl_3$, lime, anionic and cationic polymers are used for treatment in this wastewater treatment plant. All chemicals are bought from a company located 50 km away which sells chemical materials. $FeCl_3$ is bought in liquid form with a tanker truck once a week. Lime is bought in granulated form with a truck once a week. Anionic and cationic polymers are bought in granular form with truck once o month. Total distance traveled by the vehicles while carrying chemicals to treatment plant is presented in Table 4.3.

Table 4.3 Vehicle usage for chemical requirement

Chemicals	**Period**	**Vehicle Type**	**Distance**	**Total Distance**
$FeCl_3$	Once a week	Tanker	50 km/week	2600 km/year
Lime	Once a week	Truck	50 km/week	2600 km/year
Anionic Polymers	Once a month	Truck	50 km/month	600 km/year
Cationic Polymers	Once a month	Truck	50 km/month	600 km/year
			TOTAL :	**6400 km/year**

According to table 4.3, total 6400 distance is travelled for chemical logistic requirements of the wastewater treatment plant in a year.

4.2.2.3.2 Vehicle Usage for Employees Transportation. Three personnel are responsible for operating the wastewater treatment plant. One of them is environmental engineer and the other ones are employees. All workers for treatment plant come from different locations with different vehicles. The distance travelled by workers to reach the facility was specified and total distance was also calculated in Table 4.4.

Table 4.4 Vehicle usage for employee

Personnel	Town	Distance from Work	Distance	
			km/week	km/year
1. Engineer	Bornova	29 km	174	9048
2. Employee	Kemalpaşa	5 km	30	1560
3. Employee	Turgutlu	30 km	180	9360
			TOTAL :	**19968km/year**

*One employee works 6 day in a week.

According to table above, a total of 19968 km distance is travelled by employees of the wastewater treatment plant in a year.

4.2.2.3.3 Vehicle Usage for Rendering Unit. As it is explained in part 4.2.2, about 90 tons provender comprises from rendering unit in a month. 20-25 % of this provender is comprised from wastewater treatment plants wastes. 25 % of this provender is assumed to be coming from wastewater treatment plant.

90 tons/month x 0.25 =22.5 tons/month 12 month/year =270 tons/year provender

The provender sent to another facility which distance is 10 km from the treatment plant. One truck is able to carry about 15-20 tons. It is assumed that 18 tons of provender can be carried with a truck. Thus, 270 tons of provender can be carried with 15 number of truck to another fabric that is located 10 km away.

10km x 15 truck/ year = **150 km/ year** for provender

As it is calculated in part 4.2.2, 1800 tons/year coal is burned each year for the wastes in the rendering unit.

If it is assumed that one trucks carrying capacity is 18 tons, the 1800 tons of coal is able to carry with 100 trucks.

All of the coals are bought from coal operation in Soma. The total distance is 134 km between Kemalpaşa and Soma. 100 trucks travelled **13400 km** in total only for the coal used for wastes which are coming from the wastewater treatment plant. Thus **13550 km (13400 km + 150 km)** is wended for rendering unit related to wastewater treatment plant in a year.

Table 4.5 Vehicle usage for rendering unit

Rendering Unıt Data	Pct	Month	Year	Truck Number	Distance	Total Distance
90 tons/m of provender	25 %	22.5tons	14.4 tons	15	10 km	150 km/year
600 tons/m of coal	25 %	1800tons	144 tons	100	134 km	13400 km/year
					TOTAL :	**13550km/year**

GHG emissions calculated in Part 4.3.3 as a result of vehicle usage for wastewater treatment plant.

4.3 Greenhouse Gases Emissions Calculation

Before starting the calculation of GHG emissions of the organization, emission sources are identified, greenhouse gas data are collected and methodology of calculation is selected. As explained in Part 3.3, the methodology which is called ‘greenhouse gas data is multiplied by the factors of greenhouse gas emissions’ is chosen in the thesis. This method implements with collected greenhouse gas data entering a GHG calculating program and so emission values are obtained with a reference of the GHG Protocol.

According to the method, the following points of the organization were separately calculated and documented;

• Direct greenhouse gas emissions for each greenhouse gas,
• Indirect greenhouse gas emissions which related to energy,
• Other indirect greenhouse gas emissions.

4.3.1 Direct GHG Emissions

Direct greenhouse gas emissions occur from sources that are owned or controlled by the company. It includes emissions from combustion in the owned or controlled boilers, burners, turbines, ovens etc. As explained in Part 4.2.2, the company owns a boiler as stationary combustion units for rendering process. In rendering process, 1800 tons coal is burnt for wastes from wastewater treatment units.

Steps which are respectively implemented for this tool are explained below;

1 -Fuel type was selected. Lignite is burnt in boiler of rendering unit. Lignite (brown coal) is a non-agglomerating **coal with a gross calorific value of less than** 17435 kJ / kg and greater than 31 percent volatile matter on a dry matter free basis.

2 - Sector of the company was selected. Manufacturing is sector of the company. All industries involved in the manufacture of products such as metals, chemicals, equipment and machinery, foods, and textiles etc.

3- 2007 IPPC Fourth Assessment Report was selected as a GWP set. GWPs compare the climate impact of different GHG gases with that of CO_2, and they are used to calculate emissions in terms of CO_2 equivalents.

4- Then supplied data is processed to the Table 4.6

Table 4.6 Calculating tool of stationary combustion for GHG emissions

User Supplied Data					
Source ID	**Sector**	**Fuel Type**	**Fuel**	**Amount of Fuel**	**Units**
2007 IPPC	Manufacturing	Solid Fossil	Lignite	1800	Metric tons

- Source ID is one of GWP sets. 2007 IPPC Fourth Assessment Report was selected.
- Sector is manufacturing of food.
- Fuel type is one of solid, liquid, gaseous fossil fuels. The boiler produces steam with solid fossil which is lignite.
- Lignite is used as fuel in the boiler.
- Amount of fuel data was calculated in Part 4.2.2. as 1800 tons/ year.
- Unit is metric tons in a year.
- GHG emissions were then automatically calculated on Table 4.7 after the supplied data were processed.

Table 4.7 Calculated GHG emissions from boiler of the rendering unit

User Supplied Data						GHG Emissions	
Source ID	**Sector**	**Fuel Type**	**Fuel**	**Amount of Fuel**	**Units**	**CO_2 (tons)**	**CO_2e (tons)**
2007 IPPC	Manufacturing	Solid Fossil	Lignite	1800	Metric tons	2178.35	2178.35
					TOTAL:	**2178.35**	**2178.35ton/year**

CO_2 is the significant gas and the most abundant atmospheric GHG gas. Therefore, only CO_2 emissions were calculated as the GHG emissions in this thesis. Consequently 2178.35 tons of CO_2 emissions are produced from fossil fuels in a year by using stationary combustion tool of the GHG Protocol.

4.3.2 Indirect GHG Emissions

Electricity consumption of the wastewater treatment plant is taken into consideration for calculating indirect GHG emissions of the company. Electricity consumption of the wastewater treatment plant is calculated in two parts. First part is for the equipment of wastewater treatment plant, the other part is for operating the building of treatment plant. As calculated in Part 4.2.3, equipment of wastewater treatment plant consume 1870 MWh and electrical appliances of operating building consume 12.3 MWh of electricity per year. According to the base data CO_2 emissions are calculated in following tables.

In this tool first a global warming potential set was chosen as stationary combustion tool. Being the last and the most recent GWP set, 2007 IPPC Fourth Assessment Report was preferred.

This tool is divided into three parts. Steps which were respectively implemented in each part are explained below;

1. In the first part facility information handled in Table 4.8.

Table 4.8 Facility information part of purchased electricity tool

Facility Information			
Facility Description	**% of electricity used by the facility**	**Country**	**Region**
Equipments of W.W.T.P.	100	Turkey	-
Operating Building	100	Turkey	-

- In Facility Description step, equipment in the wastewater treatment plant and electrical appliances in operating building that use electricity.

- In % of Electricity Used by the Facility step is related either owning the facility or sharing it with another company. If the organization is a joint tenant of a facility the percentage of the electricity it uses can be estimated based on the proportion of the space it occupies inside the facility. The treatment plant and operating building is not a shared building. Therefore 100 percentages is suitable there.

- The food company of the organization resides in Turkey.

- Do not need the region part because of country was written.

2. Supplied consumption data was processed to the Table 4.9 calculating table.

Table 4.9 Consumption data part of purchased electricity tool

Consumption data			
Year	**Fuel Mix**	**Amount**	**Units**
2009	All	1870	MWh
2009	All	12.3	MWh

- 2009 was chosen because the calculating program has been updated in 2012 for 2009 emission factors. So 2009 emission factors give the most recent data about emissions.

- Fuel mix part consists of four options. These options are coal, oil, gas and all. One of the options which are used for producing electricity in the country is chosen. In Turkey all of the fuel types are used for producing electricity. So "all" was chosen there.

- Amount of the purchased electricity was calculated in Part 4.2.3. These data was written in this section.

- Unit was MWh.

3. GHG emissions and also emission factors were then automatically calculated on following tables after the supplied data were processed.

In Table 4.10, CO_2 emissions were calculated as **903.37 CO_2e tons** according to fuels used to generate electricity in Turkey. Coal, oil and gas are all used as fuel in

Turkey to generate electricity. If only coal was used for generating electricity, **1922.32 CO_2e tons** emissions would be released to atmosphere as presented in Table 4.11.

Table 4.10 Coal + Oil + Gas for producing electricity

Facility Information			**Consumption data**				**Emission Factor (kg GHG/kWh)**		**GHG Emissions**	
Facility Description	**% of electricity used by the facility**	**Country**	**Year**	**Fuel Mix**	**Amount**	**Units**	**CO_2**	**CO_2e**	**CO_2 (tons)**	**CO_2e (tons)**
Equipment of W.W.T.P.	100	Turkey	2009	*All*	1870	MWh	0,479929	N/A	897.47	897.47
Operating Building	100	Turkey	2009	*All*	12,334	MWh	0,479929	N/A	5.90	5.90
								TOTAL :	**903.37**	**903.37 tons/year**

- Fuel mix was chosen <u>all</u>. (It refers Coal + Oil + Gas.)

Table 4.11Coal for producing electricity

Facility Information			**Consumption data**				**Emission Factor (kg GHG/kWh)**		**GHG Emissions**	
Facility Description	**% of electricity used by the facility**	**Country**	**Year**	**Fuel Mix**	**Amount**	**Units**	**CO_2**	**CO_2e**	**CO_2 (tons)**	**CO_2e (tons)**
Equipment of W.W.T.P.	100	Turkey	2009	*Coal*	1870	MWh	1.021262	N/A	1909.76	1909.76
Operating Building	100	Turkey	2009	*Coal*	12,334	MWh	1.021262	N/A	12.56	12.56
								TOTAL :	**1922.32**	**1922.32 tons/year**

- Fuel mix was chosen <u>coal</u>.

4.3.3 Other Indirect GHG Emissions

Other indirect GHG emissions which are called Scope 3 include transport and distribution in this inventory.

While calculating the other indirect GHG emissions, amount of distance that vehicles travel for wastewater treatment plant are considered. The amount of distance was calculated in Part 4.2.4. All calculated data are given below.

- 6400 km distance travelled for chemical requirement of the wastewater treatment plant in a year.
- 19968 km distance travelled for employees of the wastewater treatment plant in a year.
- 13550 km distance wended for rendering unit related to wastewater treatment plant in a year.

According to the data, GHG emissions were calculated with the transportation tool step by step in following tables.

This tool is divided to three parts. Steps which were respectively implemented in each part are explained below;

1. In this part general data is handled in Table 4.12.

Table 4.12 General data part for transport tool

Source Description	Region	Mode of Transport	Scope	Type of Activity Data
Chemical transport	Other	Road	Scope 3	Vehicle Distance
Worker service	Other	Road	Scope 3	Vehicle Distance
Transport for rendering unit	Other	Road	Scope 3	Vehicle Distance

- In source description section, purposes of vehicles were written for calculation of greenhouse gas emissions.

- Region part contains three sections. The sections, which are UK, US and Other, can be chosen according to countries. Because of the organization is not in UK or US, 'Other' section was chosen. This category uses either global default values.

- In mode of transport section, Transport type is chosen from one of the road, rail, water or aircraft sections. Because of all transportation is by road, road section was chosen.

- Scope section was chosen as 'Scope 3'. If the organization is a transportation company, Scope would be chosen as 'Scope 1'.

- In type of activity data part, there are five sections. 'Vehicle distance (e.g. road transport)' section is most suitable for this part. Because the purpose of the tool is to calculate GHG emissions using vehicle distance.

2. Then supplied activity data was processed to the Table 4.13 calculating table.

Table 4.13 Activity data part of transportation tool.

Activity Data		
Vehicle Type	**Distance Travelled**	**Units of Measurement**
Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	6400	km
Light Goods Vehicle - Diesel - Year 1983-1995	19968	km
Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	13550	km

- Vehicle Type was chosen from a possible of vehicle types in this section. Trucks of chemical transport and rendering unit have big engine. They are also large and powerful vehicles. Thus, heavy duty vehicle section was chosen. Heavy duty vehicles category consist of vehicles like tanker truck, fire truck and concrete mixer. Vehicle of employees has smaller engine. Thus, section of light goods vehicle was chosen. All vehicles use diesel as fuel.

- Travelled distance with the vehicle was calculated in Part 4.2.4.

- Units of measurement according to Type of Activity Data. Because of all distances were calculated as km, section of km was chosen.

3. GHG emissions were then automatically calculated on following table after the supplied data were processed.

In Table 4.14, CO_2 emissions were calculated as **22 CO_2e tons** according to transportation for wastewater treatment plant.

Table 4.14 Calculated GHG emissions from transport tool

Activity Data							GHG Emissions	
Source Description	**Region**	**Mode of Transport**	**Scope**	**Type of Activity Data**	**Vehicle Type**	**Distance Travelled**	**CO_2 (tons)**	**CO_2e (tons)**
Chemical transport	Other	Road	Scope 3	Vehicle Distance	Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	6400 km	4.58	4.58
Worker service	Other	Road	Scope 3	Vehicle Distance	Light Goods Vehicle - Diesel - Year 1983-1995	19968 km	7.76	7.76
Coal transport for rendering unit	Other	Road	Scope 3	Vehicle Distance	Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	13550 km	9.69	9.69
						TOTAL :	**22**	**22 tons/year**

4.3.4 Total GHG Emissions

All GHG sources were determined and emissions from the sources were calculated in parts above. All data collected in following table. In Table 4.15, total CO_2 emissions were calculated as **3103.7 CO_2e tons** from wastewater treatment plant.

Table 4.15 Total GHG emissions

GHG Emissions		
GHG Source	**CO_2 (tons)**	**CO_2e (tons)**
Direct	2178.35	2178.35
Indirect	903.37	903.37
Other indirect	22	22
	Total:	**3103.7tons/year**

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Reduction of GHG Emissions

For institutions, agencies and businesses that require reducing the impact of climate change, the reduction process consists of two stages: The first stage is to prepare an inventory of greenhouse gases which are required to be kept under control or to reduce greenhouse gases. For this reason, companies, institutions and organizations should calculate their existing greenhouse gas emissions. Then, in the second stage, reduction of greenhouse gas emissions or offsetting methods is defined according to the values obtained from the calculations.

In this thesis, the wastewater treatment plant's all GHG sources are determined and GHG emissions of these sources are calculated in section four. Total CO_2 emissions were calculated as **3103.7 CO_2e tons** from wastewater treatment plant. As you can see in Table 5.1 direct GHG emissions are 2178.35 CO_2e tons, indirect GHG emissions are 903.37 CO_2e tons and other indirect GHG emissions are 22 CO_2e tons.

Table 5.1 Total GHG emissions

GHG Emissions		
GHG Source	**CO_2 (tons)**	**CO_2e (tons)**
Direct	2178.35	2178.35
Indirect	903.37	903.37
Other indirect	22	22
	Total:	**3103.7 tons/year**

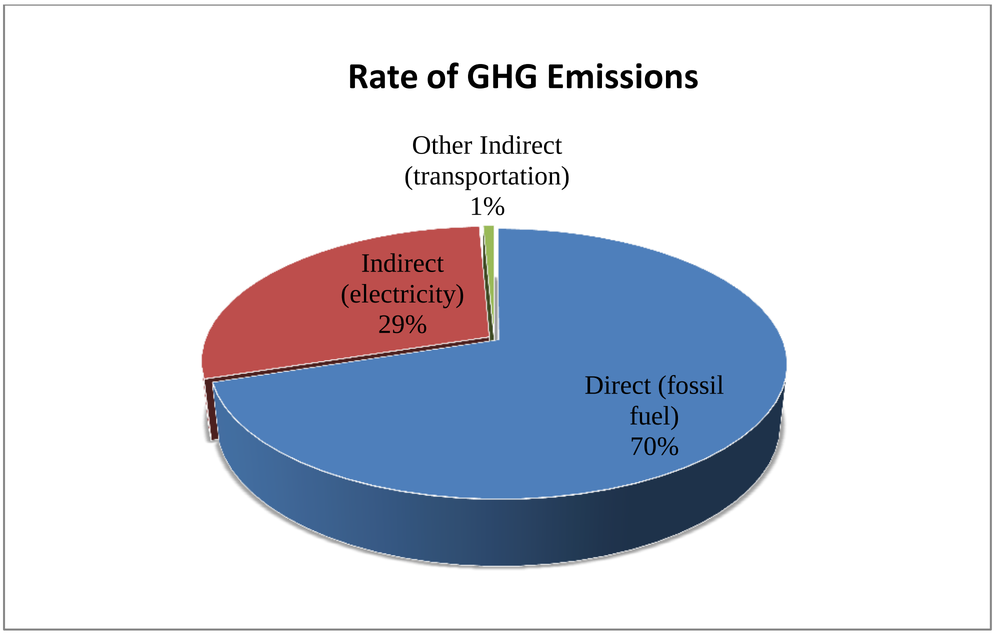


Figure 5.1 Rate of GHG emissions according to sources.

Figure 5.1 shows that GHG emissions from fossil fuels constitute to a large part of all GHG emissions. 70% of all emissions refer to amount of emissions derived from rendering unit. 29% of all emissions refer to amount of emissions derived from electrical consumption of the wastewater treatment plant. The graphics shows that after fossil fuel consumption, the most significant source of GHG emission is electrical consumption. The last and the smallest part of the graphic refer to the other GHG emissions which derived from vehicle usage for operating the wastewater treatment plant. This part, 1% of all emissions, can be omitted, because it is negligible compared to the other parts.

In this thesis, it is proved that that the most effective source of GHG emissions is the fossil fuels which cause global warming. Also the most significant source of GHG emissions is the fossil fuels that are burnt in rendering unit. Therefore, improvements in the rendering unit fossil fuel usage will be more effective in reducing the GHG emissions of the company. As explained in the previous sections, the screening unit's wastes consist of chicken body parts, scum and oily layer of flotation unit and sludge cake from belt press unit. The waste is sent to the rendering unit from treatment plant.

For reducing GHG emissions which derived from rendering unit, the following improvements could be utilized;

5.1.1 Changing of Fuel Type

First of all, fuel alternatives should be considered instead of lignite. In the unit, if liquefied natural gas (LNG) or natural gas is used instead of lignite, GHG emissions could be reduced significantly. The burning process must also be changed. Before changing the burning process, amount of reduction in GHG emissions should be calculated and cost of the process change should be determined.

5.1.2 Sludge Management

The other method is reducing amount of wastes that come to the rendering unit. First a study should be done for reducing amount of treated sludge from plant, because big solid particles and scum-oil amounts are negligible compared to the amount of the treated sludge. For example, treated sludge can be sent to a landfill which is suitable for municipal authority. After sending the treated sludge to a landfill, the fossil fuel consumption will drastically reduce. Thus GHG emissions will reduce.

If the company decides to send the treated sludge to Harmandalı landfill, GHG emissions should be calculated for the transportation of treated sludge.

6 tons of treated sludge generated from the treatment plant each day. It assumed that one truck carries about 12 tons sludge in a single trip to the landfill. Truck also goes to Harmandalı Landfill in one day intervals. Harmandalı is 45km away from Kemalpaşa.

365 days/year x 1 trip/2 days x 45 km / 1 trip = **8212.5 km/ year**

GHG emissions are calculated as **5.88 CO_2e tons/ year** from transportation of treated sludge in the Transportation Tool.

If the GHG emissions are compared with rendering unit and transportation for treated sludge, it is observed that GHG emissions from rendering unit are too high compared to the transportation emissions of sludge. Thus treated sludge can be sent to a landfill to reduce GHG emissions of the treatment plant.

Table 5.2 Total GHG emissions if rendering unit is excluded.

GHG Emissions		
GHG Source	**CO_2 (tons)**	**CO_2e (tons)**
Direct	-	-
Indirect	903.37	903.37
Other indirect	22	22
Other indirect for sludge	5.88	5.88
	Total:	**931.25tons/year**

The total GHG emissions are **3103.7 tons CO_2** from sources of the wastewater treatment plant. If treated sludge from treatment plant is send to a landfill, emissions will be reduces to **931.27 tons CO_2** per year. Indirect emissions are categorized in Table 5.3 and Figure 5.2 shows CO_2 emissions' distribution in detail.

Table 5.3Categorized GHG emissions if rendering unit is excluded

GHG Emissions		
GHG Source Type	**GHG Source**	**CO_2e (tons)**
Direct	-	-
Indirect	Blowers	657.07
	Pumps	160.21
	Scraper and Mixers	35.48
	Compressor	31.53
	Jet Aerator	6.57
	Measuring Devices	4.66
	Screening	1.56
	Beltpress	0.39
	Operation Building	5.90
Other indirect	Other Vehicles	22
	Sludge Transport	5.88
	Total:	**931.25 tons/year**

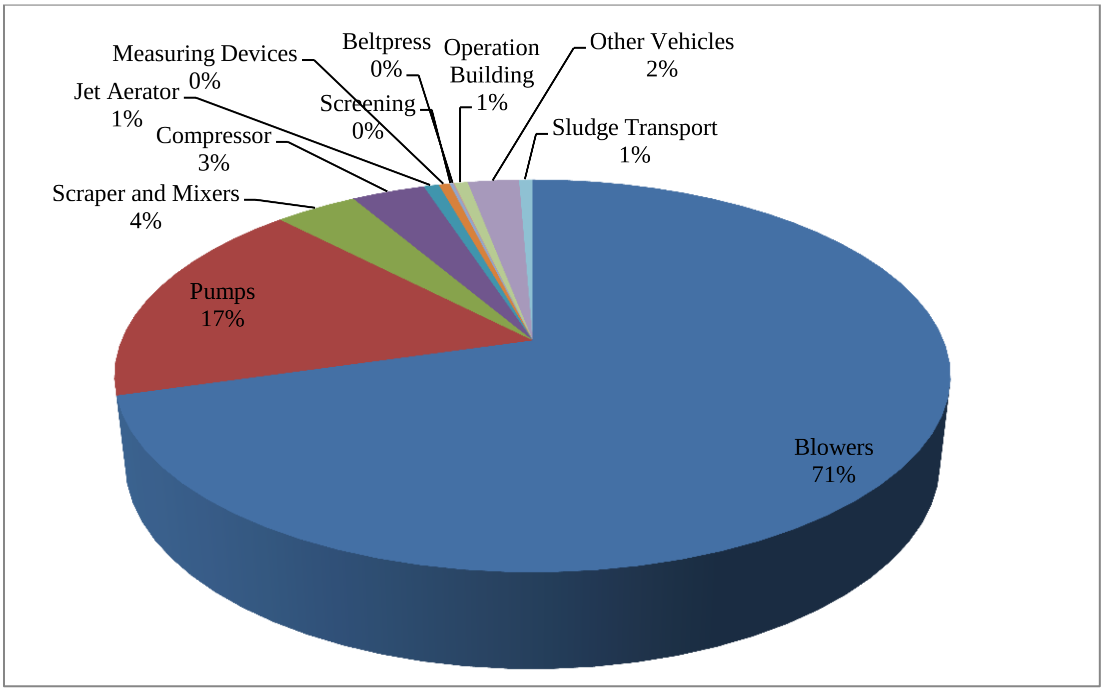


Figure 5.2 Rate of GHG emissions for all sources

However, if we look at the financial side of the case; after the treated sludge is send to the rendering unit, products from the unit is sold as provender. If the sludge is not send to rendering, amount of produced provender will reduce. Consequently, this will cause financial defeats. Additionally, transporting of sludge to the landfill will result in an additional transportation cost. On the other hand, if sludge is send to the landfill, purchase cost of coal will be reduced due to reduced requirement for fossil fuels. This is a positive situation for the company in the financial aspect.

In summary, Before deciding not to use the treatment sludge in the rendering unit as a raw material, all costs must be evaluated before deciding whether this approach is more advantageous for the company or not.

5.1.3 The Advanced Coal Technologies

If the methods that are explained and suggested in the previous section are not preferred by the company as improvements or not approved due to the financial aspect, new approaches to reduce the required coal should be investigated.

Mechanical system of rendering unit should be controlled to determine new approaches to improve the system for reduction of the used coal. Also, operating conditions of the unit should be investigated and maximum efficiency must be provided with minimum coal usage.

5.1.4 Energy Saving Technologies

The other important emission source of wastewater treatment plant is the electrical consumption consisting 29% of all emissions. It is in the second position when the amounts of GHG emissions are compared. The GHG emissions occur while fossil fuels are burned for electricity production. Thus, equipment which are used in wastewater treatment plant consume electricity and cause GHG emissions indirectly. In Table 5.4 all equipment are ordered based on the CO_2 emissions. Thus, impact of equipment to the GHG emissions also presented in Figure 5.3.

Table 5.4 Order of equipment based on CO_2 emissions

Order	Equipment	kWh/year	CO_2e (tons)
Very low	Sampling Unit	80	0.04
	Sludge Thickening Basin Mixer	131	0.06
	A.P.E. Prep. Tank Mixer	438	0.21
	C.P.E. Prep. Tanks Mixer	438	0.21
	Oil Pump	548	0.26
	$FeCl_3$ Dosage Pump	675	0.32
	A.P.E. Dosage Pump	675	0.32
	C.P.E. Dosage Pump	675	0.32
	Belt press	803	0.39
	Lime Prep. Tank Mixer	1095	0.53
	Sludge Pump/a	1095	0.53
	Lime Dosage Pump	1351	0.65
	Domestic W.Water Pump	1460	0.70
Low	Sludge Pump/b	3212	1.54
	Screening System	3241	1.56
	Oxygen Meter	3854	1.85
	pH Meter	5782	2.78
Medium	Flocculation Basin Mixer	9636	4.63
	Flotation Scraper	9636	4.63
	Coagulation Basin Mixer	13140	6.31
	Sedimentation Basin Scraper	13140	6.31
	Jet Aerator	13688	6.57
	Neutralization Basin Mixer	26280	12.61
High	Compressor	65700	31.53
	Equalization Basin Pump	131400	63.06
	Circulation Pump	192720	92.49
	Blower	1368750	657.07

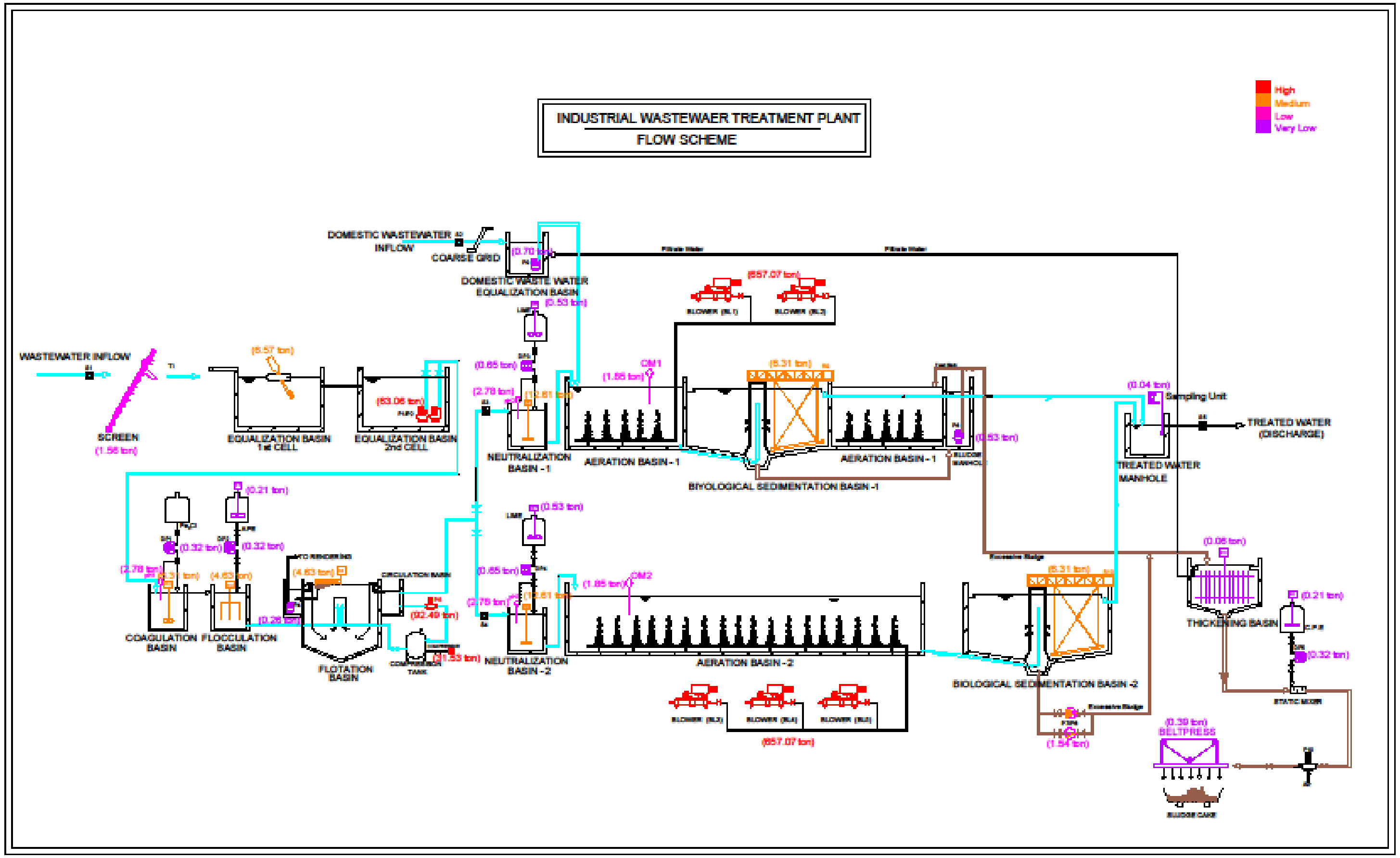


Figure 5.3 Impact of equipment in flow scheme

Table 5.4 shows that most of the electricity is consumed by the biological treatment units or in detail, by the blowers in the plant. Blowers that are used in the aeration of aerobic basins require most of the consumed power. Blowers are used to supply oxygen to the wastewater in aerations basins for microorganisms. Microorganisms use oxygen for their vital activities. They take in the oxygen and the organic compounds from the wastewater than converts these ingredients to carbon dioxide and water. Thus, treatment processes completed by microorganisms in aeration units. There are five blowers found with 75 kW motors in the treatment plant. Three of them are used in one aeration basin and the other two blowers are used in the other aeration basin. One blower's capacity is 3500 m^3/h in 500 mbar pressure. The blowers were chosen based on the selection criterion; to supply at least 2 mg dissolved oxygen per liter in one aeration basin. Investigations should be carried out about reducing the blower electrical consumption, because of being the most power consuming equipment in the treatment plant.

The most effective improvement is to fix the inventers on blowers' motors to control motor rpms. The inventers regulate engine speed and prevent excessive operations. So, they reduce power consumption. There are two options with the inverter usage.

The first option is to operate inverters associated with oxygen meters in aeration basins. Inverters will calibrate the blower's rpm according to oxygen meter signals. Minimum oxygen level in the basin must be at least 2 mg/L, because microorganisms cannot alive under this oxygen level. When oxygen level is read as 2 mg/L in an aeration basin with oxygen meter probes, a signal is sent to inverters and thus blowers start operating.

After necessary oxygen is supplied to the basin with an oxygen level of 4-5 mg/L, blowers are switched off automatically. So that blowers cannot work more than necessary and energy saving is achieved.

However inventers are expensive equipment, as a result upgrading the inventers with oxygen meters can cause financial burden on the company. But, if they are used in the treatment plant both energy saving will be achieved and GHG emissions will be reduced.

The second option is to operate inventers with manual adjustment mode on blowers. Blower speed can be manually adjusted via the inventers connected on them. If motor speed is reduced from high rpms to low rpms, the motors' electricity consumption will be reduced. However, after inverter was adjusted manually, supplied air levels should be checked inside the basin. This control can be done from discharged water. If for the discharged treated water some parameters are under the discharge limits, especially COD and BOD parameters, these values can be used as an indicator for the blowers supplying necessary air to biological units. If the parameters are not under the discharge limits, the blower motor rpm must be increased to supply more oxygen. The optimum working rpm of blowers can be adjusted manually with this trial and error method.

Thereby, energy saving can be achieved and GHG emissions will be reduce with this method.

In addition to the blowers, to achieve energy saving in all the treatment plant, all equipment should be maintained periodically. For example, equipment should be maintained once in every six months. Especially the frictional parts should be lubricated and speed adjustments should be made. The equipment should be operated with maximum efficiency and minimum energy consumption.

On the other hand, maintenance will cause financial burden on the company. However, if maintenance is done, the equipment will operate in optimum levels, while using less energy and will not break down easily. In addition, GHG emissions will be reduced.

The another basic methods for reducing the GHG emissions are listed below;

1 - Some equipment that is operated manually like chemical preparation tank mixer should not be operated more than required. They should be used only when chemicals are being prepared.

2 - Electric tolls that in the operating building, like fluorescent, computer and air conditioning should be switched off when not required.

3 - Halogen lamps illuminated the treatment plant should be switched on with nightfall and should be switched off after sun rise.

4 - The most appropriate route should be determined for vehicle services of the workers and for other heavy duty vehicles used thus the fuel usage could be reduced.

As a result, for the reduction of greenhouse gas emissions in treatment plant usage of fossil fuels should be reduced or other fuels should be used instead of fossil fuels and electrical energy consumption of the plant should be reduced. Improvements for GHG emission reduction will cause financially defeat to the company. But, after these investments are considered by the company total spend amount will be compensated by fuel and energy savings in long term.

5.2 Carbon Offsetting

GHG emissions, which are caused by any activity, are reduced with another activity to provide carbon offsetting. The carbon offsetting process is not required to be in the same region with the emission source. Because GHG emissions do not affect only one region or only the source, but also the whole world is affected. These emissions are spread all over the world therefore area of carbon offsetting does not matter. Positive impact on the environment will be the same.

An example for carbon offsetting; A company gives 100 t CO_2e GHG emissions to the atmosphere by consuming electricity and fossil fuel for heating. The company can offset the emissions by choosing the following methods to reduce 100 t CO_2e GHG emissions from atmosphere. If the company provides reduction of 100 t CO_2e GHG emissions, it can be referred as a carbon neutral company.

Carbon offsetting, is a cost-based application that is used to prevent the climate change. While companies making long-term plans to implement carbon emission reduction procedures, they can become carbon neutral instantly by paying the price of carbon offsets.

In other words, carbon offsetting is a mechanism that is achieved by providing financial support to carbon-saving projects or by purchasing carbon certificates. However, it is important that the companies should carry out an on-site carbon reducing precautions with high priority.

Even if one company makes certain improvements in order to reduce GHG emissions, carbon emissions will not be zero. It is almost impossible. Therefore, after achieving reduction in GHG emissions, the remaining emissions can be compensated with carbon offsetting method. Generally, carbon offsetting is preferred in the cases where carbon reducing improvements are very expensive or not profitable.

Carbon market created certificates are bought and sold for companies which become carbon neutral. Carbon markets provide buying and selling carbon credits obtained within certain rules and standards for the purpose of preventing or reducing GHG emissions. Carbon markets are divided into two classes. First one is Certified Emission Reduction (CER) second one is Voluntary Emission Reduction (VER). The terms "carbon markets" and "carbon credits" are being used in the literature; these terms represent all greenhouse gases.

5.2.1 Certified Emission Reduction

The certified emission reduction procedure is extremely clear. Legal markets, which are certified carbon credits, are bought and sold by the countries included in the Kyoto protocol. Kyoto protocol is the most effective mechanism to combat climate change. The countries, who have signed the Kyoto protocol, are under certain obligations. They have promised to reduce carbon dioxide and other greenhouse gas emissions to a certain level or if it is not possible to increase the rights through carbon trading. It is very difficult for some countries to comply with the Kyoto protocol. Such countries must purchase certified carbon credits. Each CER credits, is represented by 1 ton CO_2e. In countries where CER credits are being sold through carbon trading, efforts to reduce emissions are encouraged because of the possibility to earn money with the method. Countries purchasing carbon credits want to get the cheapest credit and countries selling carbon credits want to sell credit with the highest rates.

5.2.2 Verified Emission Reduction

The verified emission reduction is a market where the voluntary reduction of greenhouse gas emissions by individuals, companies, institutions is the main purpose without profit organizations. The main purpose is to achieve voluntary carbon offsetting by companies. The voluntary carbon market operates independently of the Kyoto Protocol. In contrast to the certified carbon reduction, there is not a compulsory rule or standard determined in the voluntary markets yet. Verified emission reduction is applied in developed countries under the obligations of the Kyoto Protocol as well as in countries not covered by the Kyoto Protocol. Turkey is one of the developed countries. Many projects are being developed by voluntary carbon markets in our country. It provides ease of offsetting carbon emissions for sensitive to institutions, organizations, companies and individuals within the framework of social responsibility about the global climate change. Developed projects in the voluntary carbon markets are divided into two categories as clean energy, and tree planting programs.

5.2.2.1 Clean Energy

Clean energy is a safe and inexhaustible resource that is not harmful to the environment. However, the usage of clean energy in the world and in Turkey is not very common yet. Clean energy projects cause less compared to non-renewable energy sources used in projector no emissions. The most preferred ones in Turkey and in the world, solar energy, wind energy and water energy. In addition, bio-fuels, waste-to-energy generation and geothermal projects are being developed in the new application examples.

In verified emission reduction procedure works like this; licensed firms develop projects that reduce greenhouse gas emissions for energy and industrial companies. As a result of these projects voluntary carbon certificates are obtained. These credits are offered to the world market. Licensed companies try to sell these credits at the best price possible and provide an income for companies investing in renewable energy. Companies purchase these credits to neutralize the GHG emissions. Therefore, carbon offsetting is achieved. Each VER credits, is represented by 1 ton CO_2e.

5.2.2.2 Tree Planting

Another project developed in the voluntary carbon markets, is tree planting programs. With the process known as photosynthesis trees take in carbon dioxide from the air, and instead give oxygen to atmosphere. As a result of this feature, the trees remove the greenhouse gases from atmosphere by the photosynthesis process. So, trees take part as carbon sinks in the universe due to carbon capture properties. Forests are the most common form of sink, in addition to soils, peat, permafrost, ocean water and carbonate deposits in the deep ocean. In addition to this feature trees are very important for the validity of the continuity of ecological habitats. Forests create a natural habitat for wildlife, increase biodiversity and beautify the environment.

In voluntary carbon markets, by purchasing certificates of tree planting programs, companies, institutions and organizations may become carbon neutral. When they province the tree planting regardless location in the world, according to their spread GHG emissions to the atmosphere, they can neutralize their emissions and offset the carbon.

CHAPTER SIX
CONCLUSIONS

In this thesis an analysis was performed to determine of GHG emissions originated from a wastewater treatment plant. First of all, a company is taken as reference, than source of GHG emissions from the company's wastewater treatment plant are determined. After all research is completed, direct, indirect and other indirect GHG emissions of the plant are calculated. At the end of the calculations direct GHG emissions are obtained as 2178.35 tons/year CO_2e; indirect GHG emissions are obtained as 903.37 tons/year CO_2e and the other indirect emissions are obtained as 22tons/year CO_2 efor the industrial wastewater treatment plant. The other indirect emissions are omitted because of considerably small amounts compared to given results.

This research and calculations revealed that the cause of 2178.35 tons/year CO_2edirect GHG emissions is the fossil fuels and the cause of 903.37 tons/year CO_2e indirect GHG emissions is the electrical consumption.

Although purpose of the thesis is only determining GHG emissions of the industrial wastewater treatment plant, improvements and offsetting methods of the emissions are also discussed.

In summary the company may improve GHG emission by conducting reduction projects. The improvements can be totalized as the projects below;

For reduction of direct GHG emissions;

- Changing of fuel type
- Sludge management
- The advanced coal technologies

For reduction of indirect GHG emissions;

- Only energy saving and efficiency projects

In general, projects of emission reduction at source requires high cost to the company except energy saving and efficiency projects.

Even though the company selects and implements one of the reduction methods by selecting the most economical and most beneficial one in terms of efficiency, the remaining GHG emissions will still be given to the atmosphere. Therefore, one of the carbons offset activities should be performed. Two methods are applied to carbon offset processes.

Certified Emission Reduction; In February 2009, Turkey signed the Kyoto Protocol provided that not to enforce reduction of carbon emissions until 2013 by the decision of the parliament. Confusions about the case are not clear yet by the year 2013. For these reasons, Turkey has no obligation to comply with the Kyoto Protocol; certified carbon market has not yet developed in our country. Depending on these facts, the referenced company needs to implement a method for carbon offsets except certified emission reduction.

Verified Emission Reduction; although our country has not placed in certified emission reduction within the framework of the Kyoto protocol though, verified emission reduction projects which established under the principle of environmental and social responsibility are developed and implemented regardless of the protocol in Turkey. Verified emission reduction projects are clean energy projects and tree planting projects in our country. Especially wind power, hydroelectric power plants, geothermal plants, tree planting and biogas projects are focused.

The referenced company in the thesis will prefer one of the verified emission reduction projects to become carbon neutral. Accordingly, the company will purchase voluntary carbon certificates from either renewable energy projects or tree planting projects.

Consequently, purchasing certificates from tree planting projects or planting trees to somewhere to eliminate the emissions is the most simple and least expensive method for the company. In addition, the other benefits of tree planting will be provided. The benefits are listed below;

- Trees provide habitat for birds and other wildlife.
- Trees support biodiversity.
- Trees also help to reduce ozone levels in urban areas.
- Trees reduce urban runoff and erosion by storing water and breaking the force of rain as it falls.
- Trees also absorb sound and reduce noise pollution.
- Trees provide additional services such as food, materials and medicinal products.

In addition to all of these given facts, although there is no obligation for carbon reducing or offsetting, a carbon neutral company will have benefits in financial aspects like prominence in the media on sustainability and green practices in case of creating and promoting carbon neutral image correctly, ensuring differences from its competitors as consumers become more conscious, increasing its market share and lastly provides a competitive advantage to the company.

The number of trees required for carbon offsetting of the company;

“1 tree absorbs **0.6 tons** of CO_2 in its life.”(Ege Orman Vakfı)
TotalCO_2 emissions of the company: **3103.7 CO_2e tons**
Total GHG emissions of the company for one year can be absorbed **5173 trees.**
The company can be neutral with planting 5173 number of tree in each year.

The total cost of trees required for carbon offsetting of the company;
“The price of 1 oak tree is **5 TL**.”(TemaVakfı)
Total price of oak trees: 5173tree x 5 TL/tree = **25865 TL/ year**
As a result, the company can be neutral by planting **5173 number of tree** with **25865 TL** cost in each year.

In case of sending treated sludge to landfill, **931.27 tons CO_2** will emit to atmosphere from wastewater treatment plant. Simply the company will plant only **1552 tree** and pay **7760 TL** to become carbon neutral in each year.

REFERENCES

Civan, G. (2011). *Karbon ticareti ve dünya karbon piyasaları üzerine bir inceleme*. Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı, Tezsiz Yüksek Lisans Projesi.

Climate change. Retrieved March 15, 2013 from http://www.epa.gov/climatechange/

Çevre ve Orman Bakanlığı (2008). *Kyoto protokolü esneklik mekanizmalar ve diğer uluslararası emisyon ticareti sistemleri özel ihtisas komisyon raporu*

Çevre ve Orman Bakanlığı (2010). *Sera gazı emisyon azatlımı sağlayan projelere ilişkin sicil işlemleri tebliği*

Electricity explained basics. Retrieved May 10, 2013 from http://www.eia.gov/electricity/

Greenhouse Protocol Initiative Calculation Tool (2007). *Indirect CO_2 emissions from the consumption of purchased electricity, heat, and/or steam guide.*

Gillenwater, M. (2005). *Calculation tool for direct emissions from stationary combustion* (3th ed.). Washington DC.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer M., Van der Linden, P.J., Dai, X., Maskell, K. & Johnson, C.A. (eds.) (2001). *Integrated pollution prevention control third assessment report: climate change 2001*. Cambridge: Cambridge University Press

Mandatory reporting rule. Retrieved May 20, 2013 from http://www.epa.gov/ghgreporting/

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. & Meyer, L.A. (eds.) (2007). *Transport and its infrastructure. In climate change 2007: Mitigation*. *Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge, United Kingdom: Cambridge University Press.

National Research Council (2010). *Advancing the science of climate change*. Washington, DC, USA: The National Academies Press

Ormanlar çevresine hayat verir. Retrieved May 15, 2013 from http://web.ogm.gov.tr/birimler/merkez/egitim/Dokumanlar

Reay, D., Hewitt, N., Smith, K., & Grace, J. (Eds.) (2007). *Greenhouse gas sinks.* London, United Kingdom: Cabi Publishing

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M.& Miller, H.L. (eds.) (2007). *Contribution of working group I to the fourth assessment report of the ıntergovernmental panel on climate change.* Cambridge: Cambridge University Press

Trees cost. Retrieved May 15, 2013 from https://online.tema.org.tr/web_14966_1/member_panel_company

The greenhouse gas protocol calculation tools. (n.d.). Retrieved May 10, 2012 from http://www.ghgprotocol.org/calculation-tools.

Tremblay, A., Varfalvy, L., Roehm, C. & Garneau, M. (Eds.) (2005). *Greenhouse gas emissions- fluxes and processes hydroelectric reservoirs and natural environments.* Newyork: Springer Press

Turkish Standard Organization (2007). *ISO 14064-1 Greenhouse gases part 1: specification with guidance at the organization level for quantifications and reporting of greenhouse gas emissions and removals.*

Turkish Standard Organization (2007). *ISO 14064-2 Greenhouse gases part 2: specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emissions reductions and removal enhancements.*

Turkish Standard Organization (2007). *ISO 14064-3 Greenhouse gases part 3: specification with guidance forth validation and verification of greenhouse gas emissions assertions.*

United States Department of State (2007). *Fourth climate action report to the United Nations framework convention on climate change: Projected greenhouse gas emissions* (2007). U.S. Department of State, Washington, DC, USA.

United States Environmental Protection Agency (2013). *Inventory of U.S. greenhouse gas emissions and sinks: 1900-2010.*

United States Global Change Research Program. (2009). *Global climate change impacts in the United States.* Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson (eds.) New York, USA : Cambridge University Press.

Volcanic gases and their effects (n.d.). Retrieved November 13, 2012 from http://volcanoes.usgs.gov/hazards/gas/index.php

APPENDICES

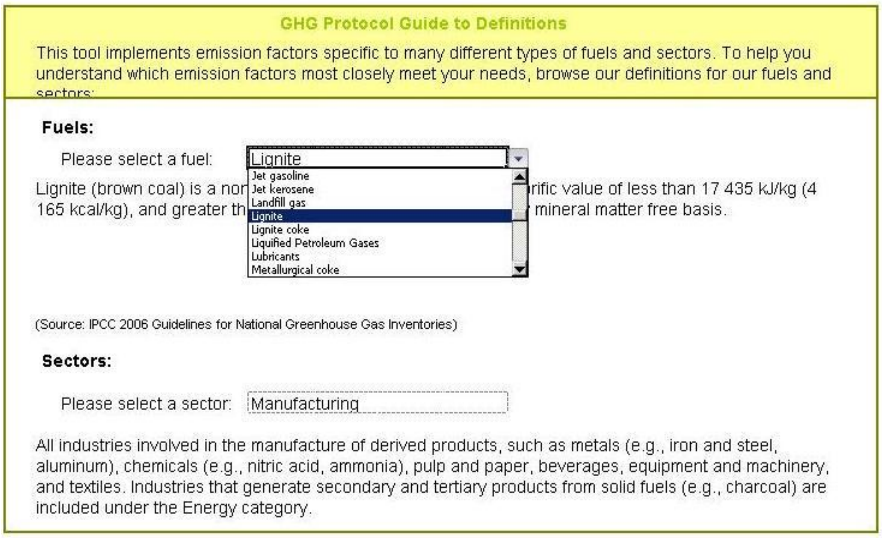


Figure 1 Fuel selection in stationary combustion tool

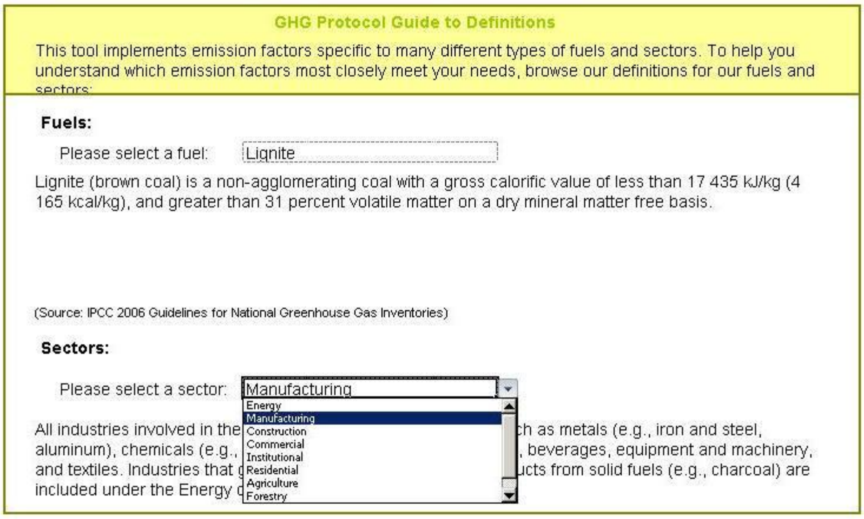


Figure 2 Sector selection in stationary combustion tool

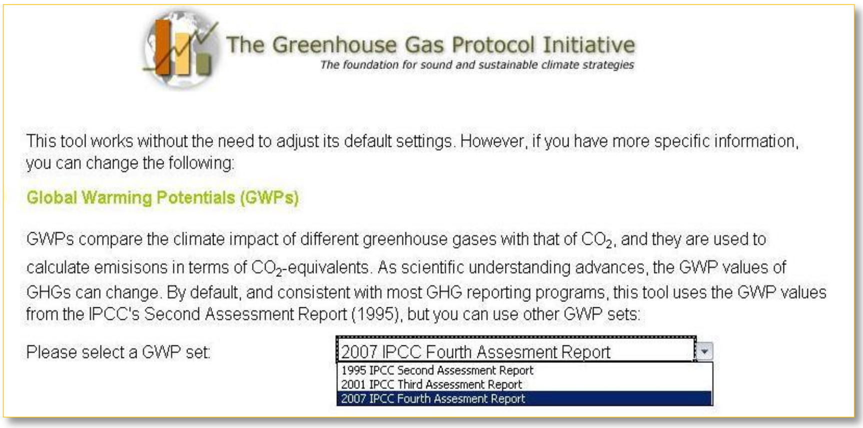
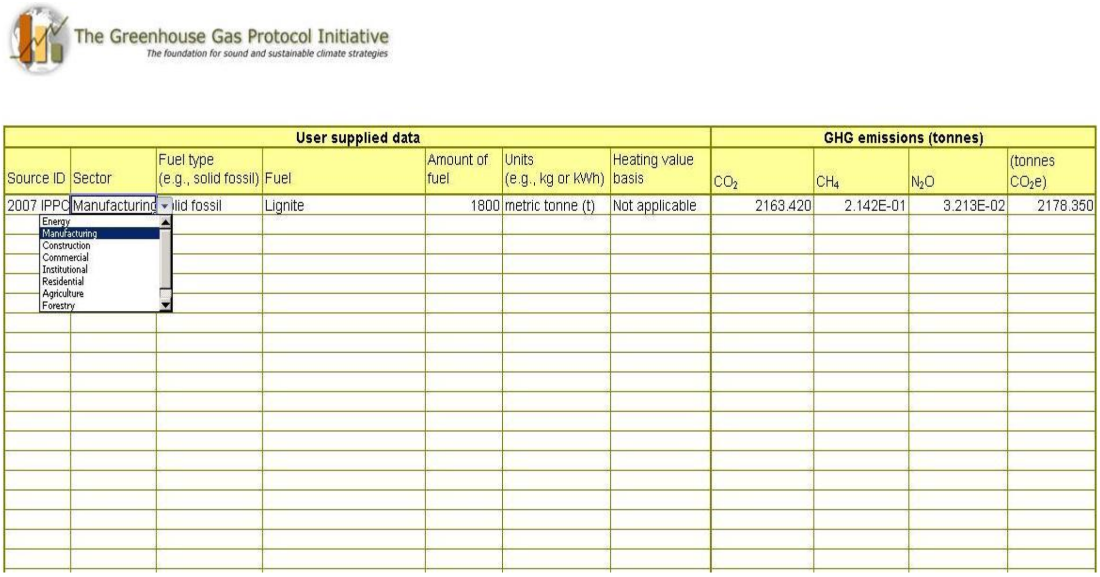
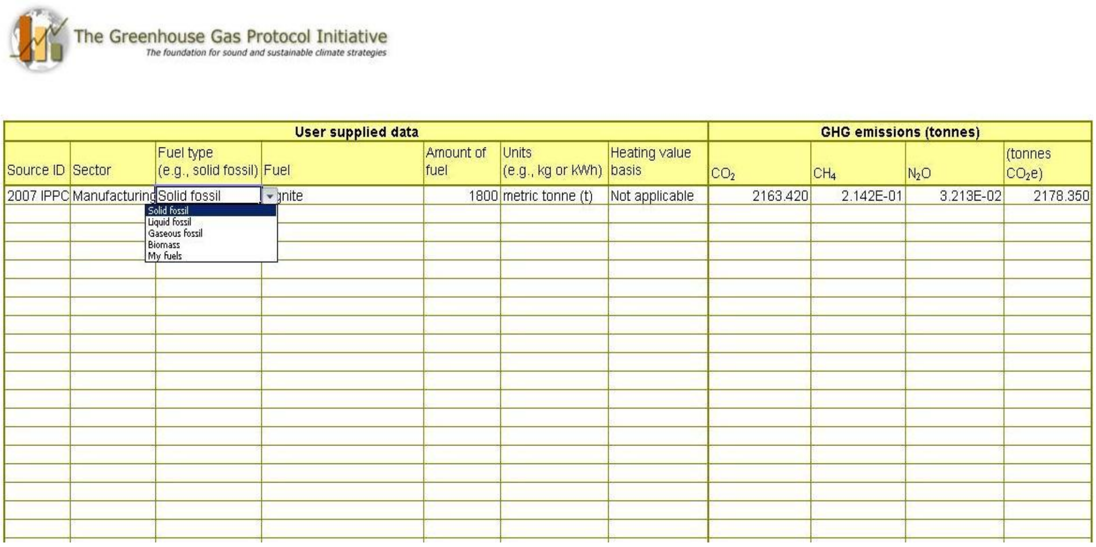


Figure 3 GWP selection in stationary combustion tool



User supplied data							GHG emissions (tonnes)			
Source ID	Sector	Fuel type (e.g., solid fossil)	Fuel	Amount of fuel	Units (e.g., kg or kWh)	Heating value basis	CO_2	CH_4	N_2O	(tonnes CO_2e)
2007 IPPC	Manufacturing	lid fossil	Lignite	1800	metric tonne (t)	Not applicable	2163.420	2.142E-01	3.213E-02	2178.350

Figure 4 Sector selection in spreadsheet part instationary combustion tool



User supplied data							GHG emissions (tonnes)			
Source ID	Sector	Fuel type (e.g., solid fossil)	Fuel	Amount of fuel	Units (e.g., kg or kWh)	Heating value basis	CO_2	CH_4	N_2O	(tonnes CO_2e)
2007 IPPC	Manufacturing	Solid fossil	gnite	1800	metric tonne (t)	Not applicable	2163.420	2.142E-01	3.213E-02	2178.350

Figure 5 Fuel type selection in spreadsheet part instationary combustion tool

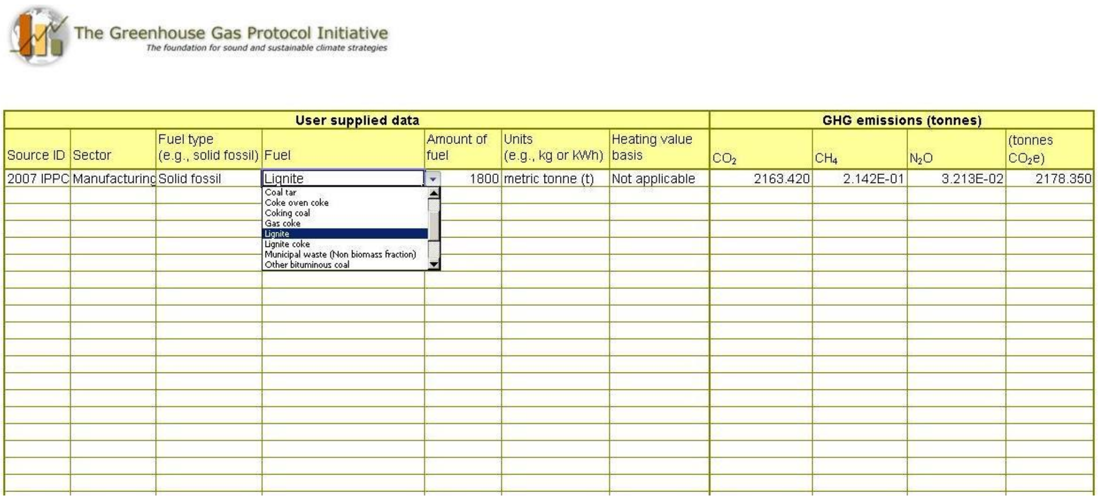


Figure 6 Fuel selection in spreadsheet part instationary combustion tool

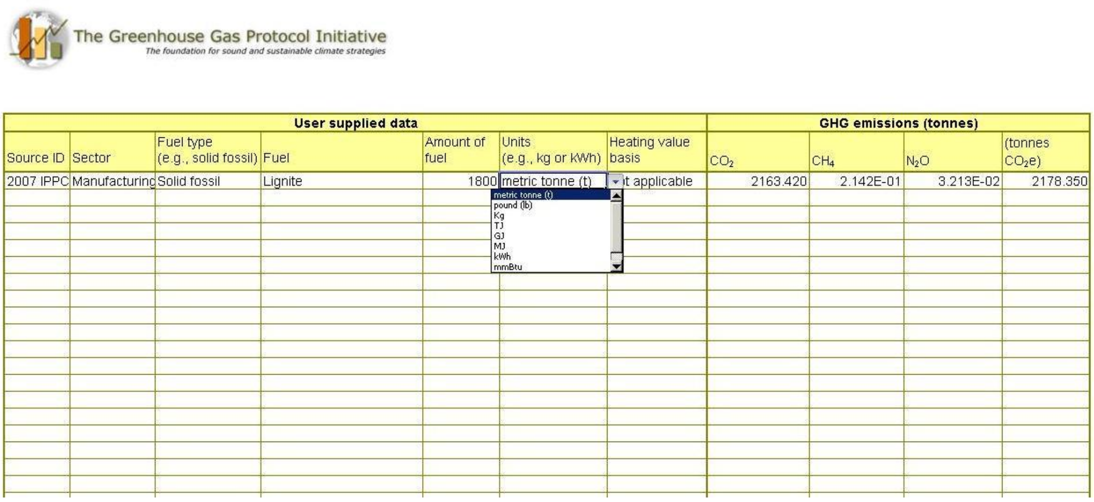


Figure 7 Unit selection in spreadsheet part instationary combustion tool

The Greenhouse Gas Protocol Initiative

The foundation for sound and sustainable climate strategies

User supplied data							GHG emissions (tonnes)			
Source ID	Sector	Fuel type (e.g., solid fossil)	Fuel	Amount of fuel	Units (e.g., kg or kWh)	Heating value basis	CO_2	CH_4	N_2O	All GHGs (tonnes CO_2e)
2007 IPPC	Manufacturing	Solid fossil	Lignite	1800	metric tonne (t)	Not applicable	2163.420	2.142E-01	3.213E-02	2178.350
							Total GHG emissions from fossil fuels (tonnes CO_2e):			2178.350
							Total CO_2 emissions from biomass (tonnes):			0.000

Figure 8 GHG emissions in stationary combustion tool

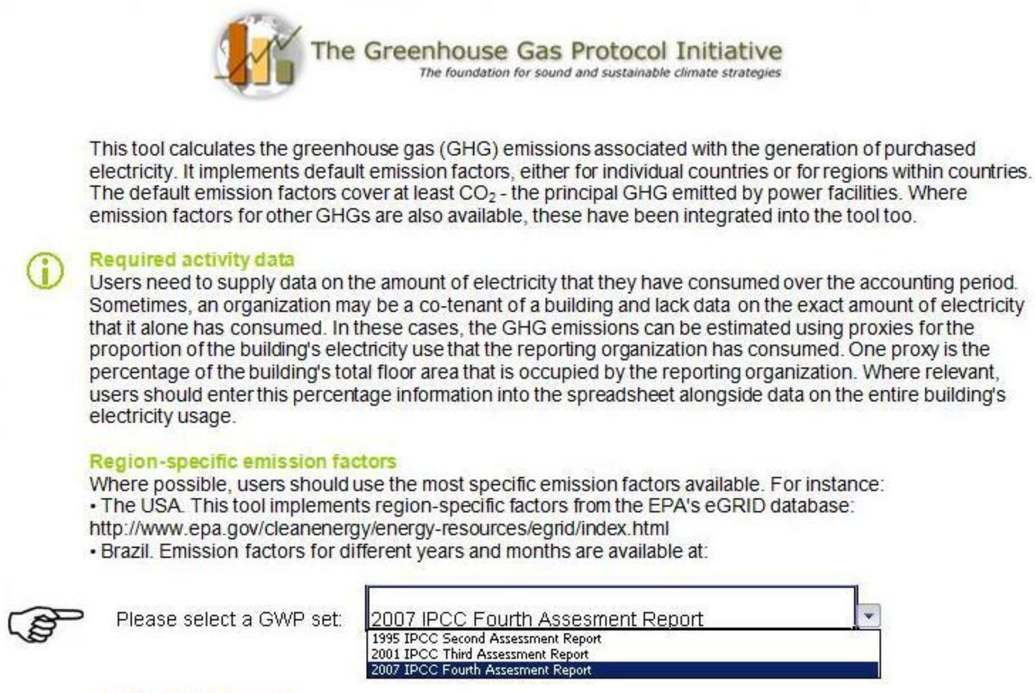


Figure 9 GWP selection in purchased electricity tool

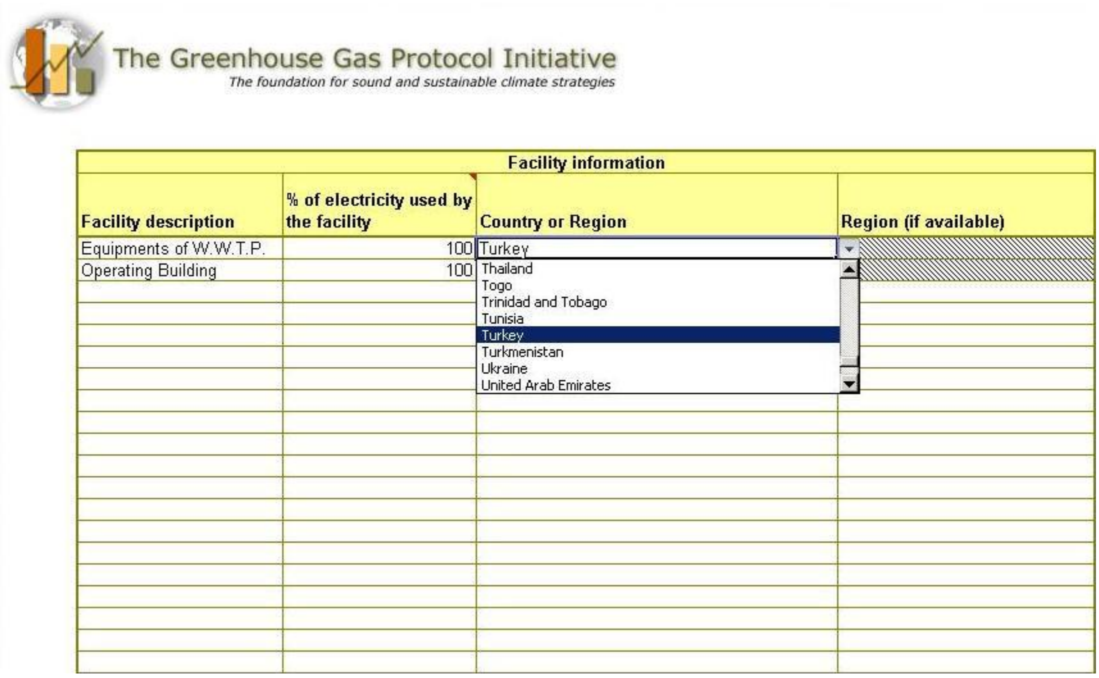
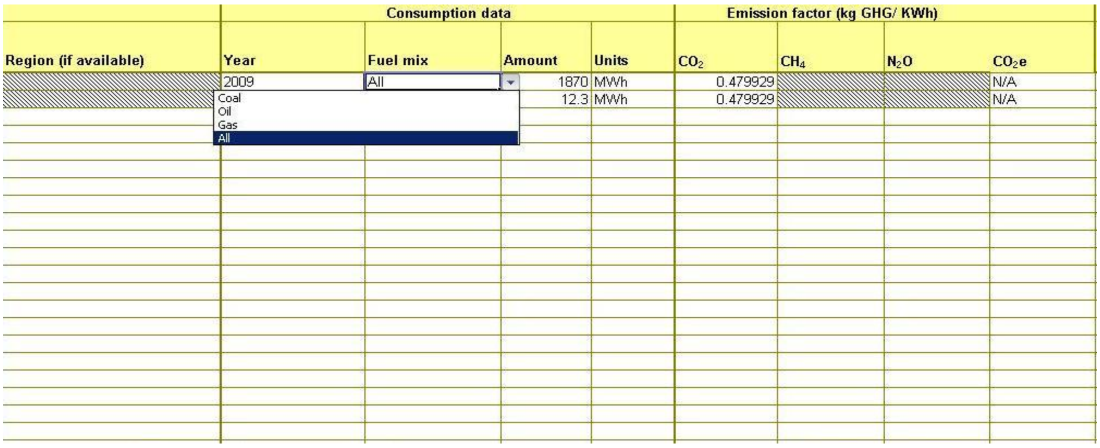


Figure 10 Country selection in purchased electricity tool

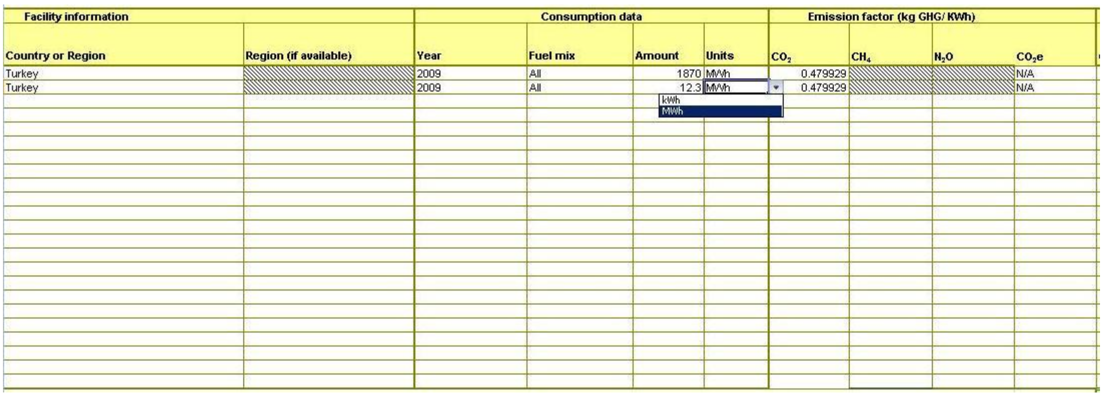
	Consumption data				Emission factor (kg GHG/ KWh)				
Region (if available)	Year	Fuel mix	Amount	Units	CO_2	CH_4	N_2O	CO_2e	CO_2 (tonnes)
	2009		1870	MWh	0.479929			N/A	897.467
			12.3	MWh	0.479929			N/A	5.903

Figure 11 Year selection in purchased electricity tool



	Consumption data				Emission factor (kg GHG/ KWh)			
Region (if available)	Year	Fuel mix	Amount	Units	CO_2	CH_4	N_2O	CO_2e
	2009	All	1870	MWh	0.479929			N/A
			12.3	MWh	0.479929			N/A

Figure 12 Fuel mix selection in purchased electricity tool



Facility information		Consumption data				Emission factor (kg GHG/ KWh)			
Country or Region	Region (if available)	Year	Fuel mix	Amount	Units	CO_2	CH_4	N_2O	CO_2e
Turkey		2009	All	1870	MWh	0.479929			N/A
Turkey		2009	All	12.3	MWh	0.479929			N/A

Figure 13 Unit selection in purchased electricity tool

Emission factor (kg GHG/ KWh)				Emissions				Notes
CO_2	CH_4	N_2O	CO_2e	CO_2 (tonnes)	CH_4 (kg)	N_2O (kg)	CO_2e (tonnes)	
0.479929			N/A	897.467			897.467	
0.479929			N/A	5.903			5.903	
				903.370	0.000	0.000	903.370	

Figure 14 GHG emissions in purchased electricity tool

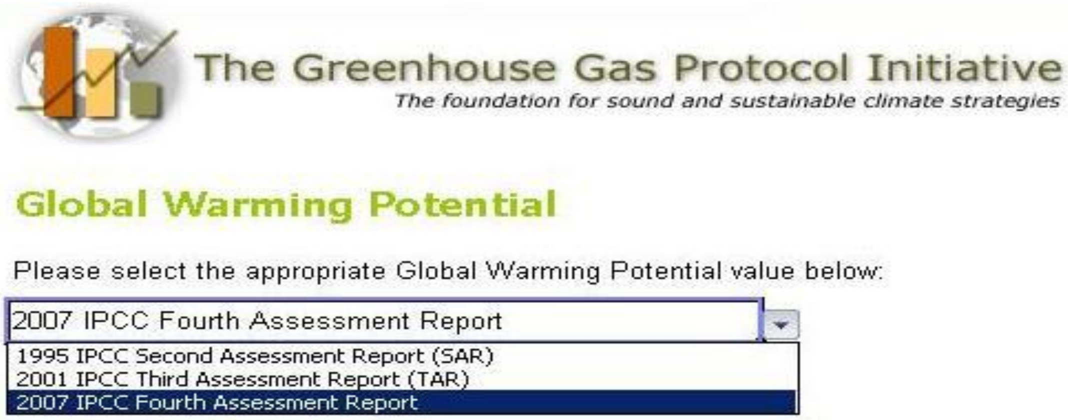


Figure 15 GWP selection in transportation tool

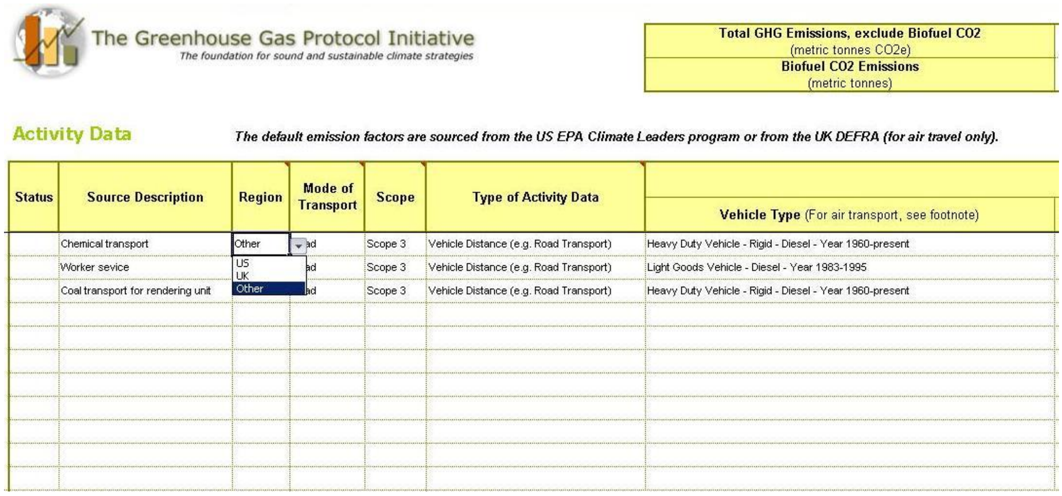


Figure 16 Region selection in transportation tool

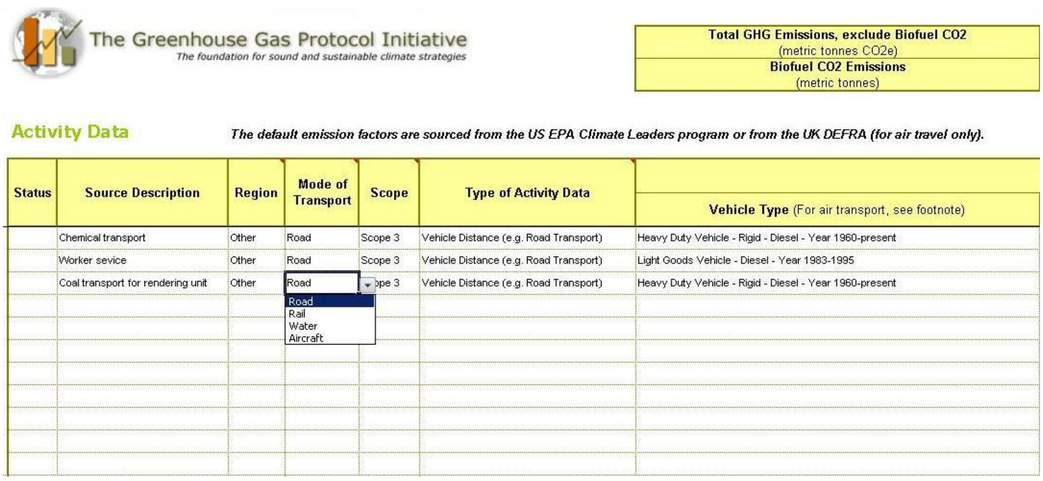


Figure 17 Mode of transport selection in transportation tool

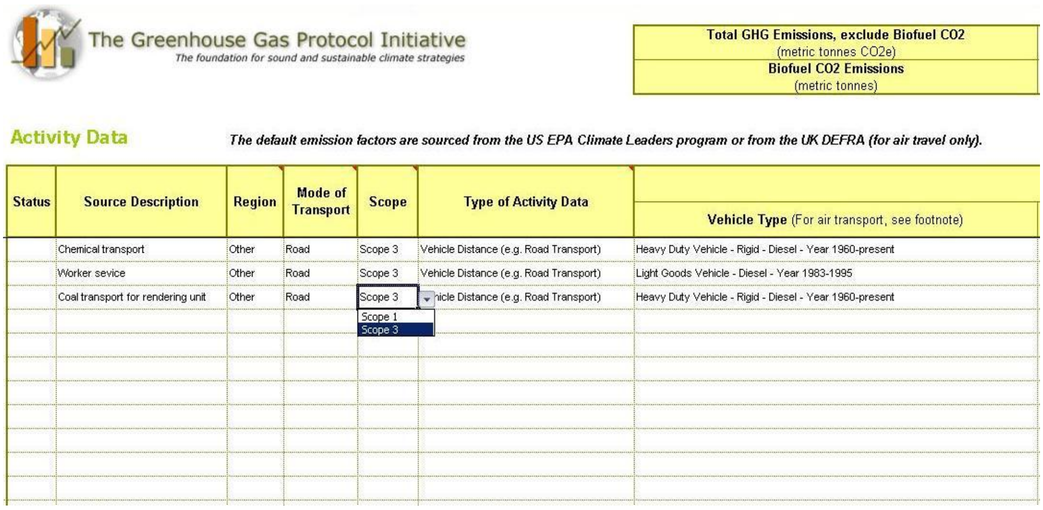


Figure 18 Scope selection in transportation tool

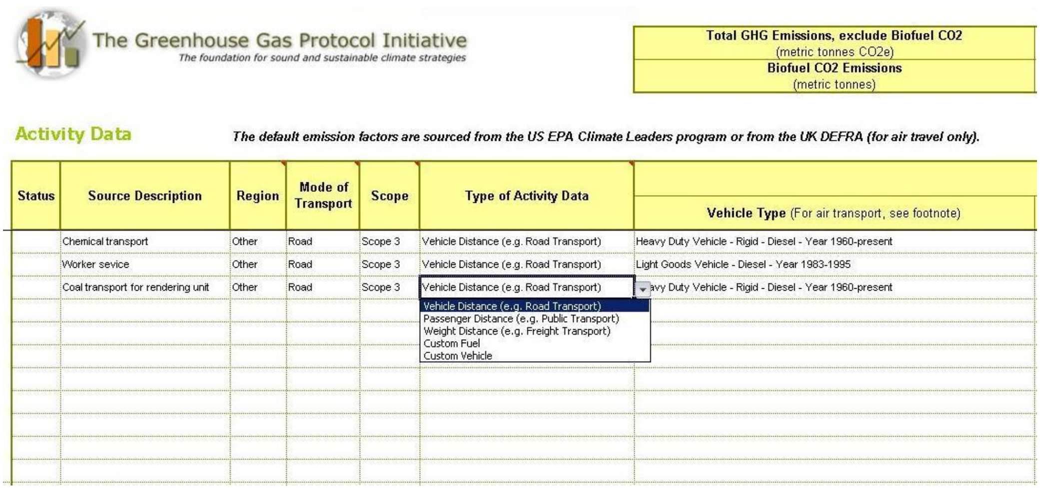


Figure 19 Type of activity data selection in transportation tool

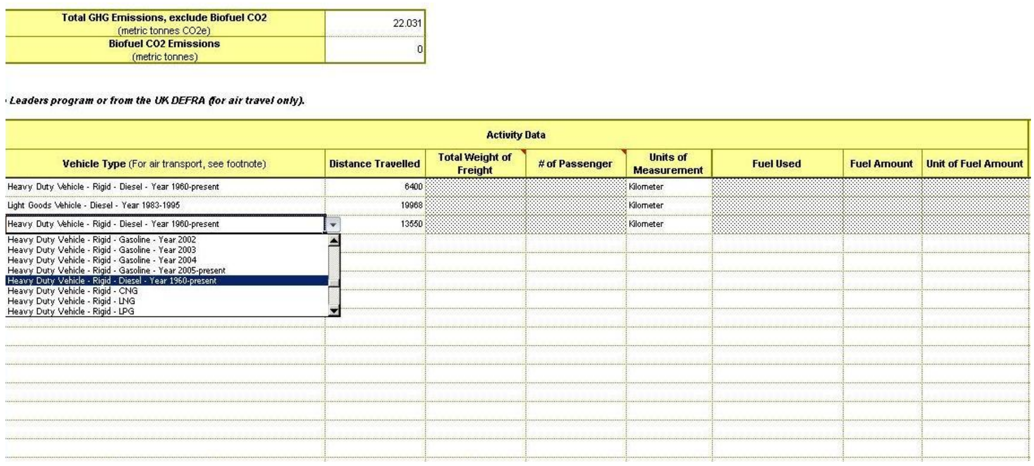


Figure 20 Vehicle type selection in transportation tool

Total GHG Emissions, exclude Biofuel CO2 (metric tonnes CO2e)	22.031
Biofuel CO2 Emissions (metric tonnes)	0

Leaders program or from the UK DEFRA (for air travel only).

Activity Data							
Vehicle Type (For air transport, see footnote)	**Distance Travelled**	**Total Weight of Freight**	**# of Passenger**	**Units of Measurement**	**Fuel Used**	**Fuel Amount**	**Unit of Fuel Amount**
Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	6400			Kilometer			
Light Goods Vehicle - Diesel - Year 1983-1995	19968			Kilometer			
Heavy Duty Vehicle - Rigid - Diesel - Year 1960-present	13550			Kilometer			

Mile
Kilometer

Figure 21 Unit selection in transportation tool

GHG Emissions				
Fossil Fuel CO2 (metric tonnes)	**CH4** (kilograms)	**N2O** (kilograms)	**Total GHG Emissions, exclude Biofuel CO2** (metric tonnes CO2e)	**Biofuel CO2 Emissions** (metric tonnes)
4.578			4.578	0
7.759			7.759	0
9.693			9.693	0

Figure 22 GHG emissions in transportation tool