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Research Article

Analysis of Carbon Footprint Calculation Methods in Line with Carbon Neutral Targets; Industrial Facility Example

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Abstract – Increasing environmental pollution concerns are one of the agenda items of the whole world. In this context, studies are being carried out to increase renewable energy, reduce fossil fuel consumption, and reach a carbon neutral target. One of the steps taken towards becoming carbon neutral is carbon footprint studies. Many studies are being carried out in the world and in EU countries to reduce carbon footprint. The most important of these are; European Green Agreement, Emission Trading System, Fit for 55 package, Renewable energy investments, carbon footprint monitoring and limitation methods, individual and institutional awareness studies. In this study conducted in line with the targets of carbon footprint monitoring and limitation, the carbon footprint of an example industrial facility was calculated and it was determined that the majority of this footprint was due to electrical consumption, and renewable energy applications that could reduce this electrical consumption were determined.

Keywords – Carbon Footprints, Carbon Neutral, Decarbonization

I. INTRODUCTION

The rising world population, the increasing and diversifying human needs, and the increasing clarity of energy needs with advancing technology are increasing the emission of harmful gases in the world day by day. Harmful gases negatively affect human life with the damage they cause to the environment. In this context, environmental pollution concerns are increasing in the world. The main precautions that can be taken in this context are the determination and reduction of carbon footprints. In this study, within the scope of carbon footprint tracking and classification targets; Carbon footprint calculation methods, standards and methods used are examined in detail. Sample carbon footprint calculations and applications that can be done to reduce carbon footprint values are determined.

A. Carbon Footprint

Carbon footprint is a concept that allows the measurement and control of the amount of carbon emitted into the atmosphere as a result of production, consumption, transportation, heating, meeting human life needs, etc. Another expression of carbon footprint is the total of carbon emissions. Carbon footprint is divided into two categories. These are; Primary carbon footprint and Secondary carbon footprint[1]. The carbon

footprint approach is important because it is a measure of greenhouse gas emissions. Greenhouse gas is all the gases that absorb heat in the atmosphere, thus greenhouse gas is the main determinant of atmospheric temperature and all related conditions. The main greenhouse gases are expressed as carbon dioxide, water vapor, methane, dinitrogen monoxide, hydrofluoride carbon, nitrogen trifluoride, perfluorocarbon gases. Carbon equivalent values are used in carbon footprint calculation methods.

B. Carbon Footprint Calculation Methods

Carbon footprint is divided into two parts. The first is the direct carbon footprint and the second is the indirect carbon footprint. In the direct footprint calculation, the actions that directly cause gas emissions in daily life are used. For example, the footprint resulting from electricity and natural gas used at home is the direct (primary) carbon footprint. Secondary carbon footprints are the carbon footprints that indirectly cause greenhouse gas emissions during daily life. For example, the carbon footprints caused by greenhouse gases that occur during the production, transportation, etc. stages of consumed food, used clothing, living spaces used for shelter[2].

C. Carbon Footprint Protocols and Standards

There are many standards and protocols in carbon footprint studies. These are; Greenhouse Gas Protocol (GHG) protocols, ISO standards, PAS2050, CDP, IPCC, SBTI standards[4].

1. Greenhouse Gas Protocol (GHG)

It is the most common greenhouse gas protocol used worldwide. It is widely used in the carbon footprint calculation of institutions or businesses.

2. ISO 14064 Protocol

It is a carbon footprint protocol consisting of 3 main sections. These are; Institutional emission calculation, removal (14064-1), Greenhouse gas reduction projects (14064-2), Verification and accuracy control (14064-3)

ISO 14064, ISO 14065, ISO 14066, ISO 14067 measurement and evaluation methods are shown in the table 1.

Table 1. Standards of Carbon Footprint

ISO 14064-1	2018 Standard on Guidance and Specifications for the Accounting and Reporting of Greenhouse Gas Emissions and Removals at the Establishment Level
ISO 14064-2	2019 Standard on Guidance and Specifications for Calculating, Monitoring, and Reporting Greenhouse Gas Emission Reductions or Removal Improvements at the Project Level
ISO 14064-3	2019 Standard on Guidance and Specifications for Verification of Greenhouse Gas Declarations
ISO 14065	2013 Standard on Guidelines and Specifications for Accreditation of Greenhouse Gas Verifiers
ISO 14066	2011 Standard on Guidance and Specifications for Greenhouse Gas Lead Verifiers and Verification Team Competencies
ISO 14067	2018 Standard on Guidelines and Specifications for Measuring the Carbon Footprint of Products

a. PAS2050

It is a carbon footprint method used in calculating the carbon footprint of products. This method, developed by BST (British Standard Industry), is used in determining the carbon footprint of agricultural, food, etc. products.

b. CDP (Carbon Disclosure Project)

It is a method used to determine the voluntary footprints of companies or institutions. Companies analyze their impacts on the environment and create a transparency market.

c. IPCC

It is called the intergovernmental climate change panel. It is a carbon footprint calculation method that determines the amount of CO2 released according to fuel types. IPCC standards are effectively used in carbon footprint calculations. IPCC emissions are divided into 3 categories. These are; direct emissions, indirect emissions and other emissions. There are 3 basic calculation methods in the IPCC method. These are Tier 1, Tier 2 and Tier 3 calculation methods.

D. Countries' Carbon Footprint Reduction Efforts

Many studies are being carried out in the world and in EU countries to reduce carbon footprints. The most important of these are; European Green Deal, Emission Trading System, Fit for 55 package, Renewable energy investments, carbon footprint monitoring and limitation methods, individual and institutional awareness studies.

European Green Deal covers Europe's goal of becoming carbon neutral by 2050. It is an agreement that aims to reduce greenhouse gas emissions by 2030 and change usage habits in sectors.

Emission Trading System is one of the EU's climate policies. Quotas are set for industrial facilities within this scope and those who exceed these emission values are forced to purchase carbon credits. It is a system that includes efforts to reduce carbon footprints by increasing the cost of carbon emissions to companies.

Fit for 55 package is a system that aims to reduce carbon footprints by determining carbon taxes, emission standards in sectors, and renewable usage rates.EU countries are taking initiatives to implement these and many similar goals. In this context, many targets have been established in renewable energy.

II. MATERIALS AND METHOD

The carbon footprint of an example industrial facility based on electricity and natural gas consumption was calculated in the study. Renewable applications that can be done to reduce this carbon footprint were determined. In the first part of the study, a carbon footprint study was conducted for an example industrial facility that meets its heating and hot water needs with natural gas and LNG. The carbon footprint caused by electricity and natural gas consumption was determined in the study and calculation methods established within the framework of GHG protocol, IPCC and ISO 14064 standards were used [5]. In this calculation method; Emissions are expressed as E, activity value as FD, Emission factor as EF, Oxidation value as YD, Activity data as FV[6-10]. Parameters are demonsrated table 2. Calculations are demonsrated equation 1 and equation 2.

$$E = FD \ x \ \ EF \ \ xYD \quad (1)$$

$$FV = Fuel \ \ x \ \ KD \quad (2)$$

Table 2. Carbon footprint calculation parameters

E	Emissions(tCO2)
FD	Activity Value
YD	Oxidation Value
FV	Activity Data
KD	Calorific Value
EF	Emission Factor

The emission factor was determined according to IPCC data. According to IPCC, the emission factor for natural gas was determined as 56100 (kg/TJ) for CO2, 1 (kg/TJ) for CH4, and 0.1 for N2O (kg/TJ). Calorific value (KD) was determined as 48.0 for natural gas according to IPCC data. Global warming potential is defined as the effect of each unit of gas on the atmosphere and according to GHG protocol, CO2 value was determined as 1, CH4 value as 21, N20 value as 310. The percentage of oxidized carbon is taken as 1 in IPCC Tier 1 approach[10-12].

III. RESULTS AND DISCUSSION

In the carbon footprint study conducted for the sample industrial facility, the following findings were obtained;

• CO2, CH4, N2O emissions were made.

• Electricity consumption has the highest impact rate on the carbon footprint. The carbon footprint from electricity is 67200.98 tCO2e.

• The gas with the highest global warming potential is N2O.

• The gas with the highest emission factor is CO2.

• The CO2 emission values after the study are; 36.3528, 0.013, 0.02, 67200.98, respectively.

The findings are shown in detail in Table 3.

Table 3. Carbon Footprint Calculation and Results Table

Type of Energy Consumed	Natural gas	Natural gas	Natural gas	Electricity(kwh)
Type of Greenhouse Gas Emitted	CO2	CH4	N2O	
Consumption Amount(Ton-kwh)	13500	13500	13500	138845
Calorific Value	48	48	48	
Emission Factor(kg/TJ-kg/kwh)	56100	1	0,1	0,484
Emission (Ton)	36,3528	0,000648	0,0000648	
Global Warming Potential	1	21	310	

Percentage of Carbon Oxidized	1	1	1	
CO2Emission (tCO2e)	36,3528	0,013608	0,020088	67200,98
Total Emission(tCO2e)	67237,3665			

In order to reduce the carbon footprint, a grid-connected photovoltaic energy production facility can be built on the roof of this industrial facility, thus zeroing out energy production with renewable resources and zeroing out gas emissions resulting from electricity consumption.

IV. CONCLUSION

Harmful gases released due to fossil fuels increase environmental pollution concerns. This concern directs countries to the goal of becoming carbon neutral. One of the methods determined on the way to becoming carbon neutral is carbon footprint determination and reduction studies. In this context, carbon footprint determination studies are carried out in commercial facilities, public institutions and all other organizations. This study was also created in this direction. The carbon footprint was determined by calculating the natural gas and electricity consumption data obtained from the sample industrial facility. Applications that can reduce carbon footprints were determined. It was determined that in order to reduce the carbon footprint, it was possible to meet the consumption with a renewable energy facility, thus reducing the gas emission caused by electricity consumption to zero.

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