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DEPARTMENT OF SUPPLY CHAIN & INFORMATION SYSTEMS

CALCULATING BASE YEAR CARBON FOOTPRINTS: AN ANALYSIS OF CARESTREAM HEALTH'S CARBON SUSTAINABILITY MODEL

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ABSTRACT

Academic debates over the effect of anthropogenic, man-made, carbon emissions on global climate change have intensified over the past few decades, particularly in developed countries. The increased public awareness of the greenhouse effect, that is theorized to be amplified in the presence of ever-increasing anthropogenic carbon emissions, has caused various stakeholders to demand companies to begin quantifying, reporting, and reducing their carbon footprints. This paper uses Carestream Health, Inc. as a case study for beginning to quantify a company's base year carbon footprint. After consulting publically available corporate standards, guides, and carbon emission factors, a carbon dioxide model (built from annual operations data provided by Carestream Health, Inc.) was created to quantify the company's transportation and warehousing footprint. The resulting model required unique methodology to mitigate and estimate various incomplete data, including: vehicle specifications, intermodal shipment data, and site-specific utility consumption. This paper will provide a framework for mitigating the initial data inadequacy; will discuss the assumptions, limitations, and validity of the designed model; as well as outline next steps for more complete data gathering and for building a more accurate and comprehensive model moving forward.

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Chapter 1

Introduction

Climate Change

The debate on global climate change often begins with a concept called the greenhouse effect. This is the theorized concept in which atmospheric greenhouse gases (namely water vapor, carbon dioxide, methane, nitrous oxide, and fluorinated gases) absorb infrared radiation coming from the Earth and reflect some of the radiation back to the planet's surface. One of the predominant claims in the debate on global climate change is that since the industrial revolution, continuously increasing volumes of anthropogenic, man-made, greenhouse gas (GHG) emissions have contributed to unprecedentedly high densities of total greenhouse gases in the atmosphere. Once released into the atmosphere, these anthropogenic gases amplify the greenhouse effect by reflecting more thermal energy back to the Earth thus causing global surface and ocean temperatures to rise.

As mankind's technological capability has increased over time, instruments used to collect measurements of global climate systems have become more advanced and ubiquitous than ever before. This has allowed the scientific community to collect more robust data and create more accurate climate models than what has ever historically been possible to facilitate a better understanding of the Earth's complex climate systems. Overall, the scientific community is expressing with higher and higher confidence that the Earth's average temperature is rising over time; and they are pointing to anthropogenic GHG emissions as a key contributor.

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing the existence and effects of global climate change, and is sponsored by the United Nations (UN). The IPCC, created in 1988 by the World Meteorology Organization (WMO) and the United

Nations Environmental Program (UNEP), is tasked with reviewing and assessing all scientific, technical and socio-economic information surrounding climate change with the intention of creating feasible response strategies. Today, 195 countries are members of the IPCC and thousands of scientists worldwide contribute to the IPCC reports that are publically released. Each report goes through an extensive review process that includes both expert review and governmental review ("Organization," n.d.). The most recent climate assessment report, the fifth iteration, was released in 2013: *Climate Change 2013: The Physical Science Basis*. Table 1 highlights key quotations from the "Summary for Policy Makers" section that discusses the findings from the culmination of peer and government reviewed research and analysis used throughout the report. The report makes a strong case that anthropogenic GHG emissions are a major driver for the witnessed climate trends. For additional discussion and review of the data behind the findings, the reader can access the full climate report on the IPCC website[1].

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[1] http://www.ipss.ch/report/ar5/

Table 1. Key Statements From the 2013 IPCC Fifth Assessment Report Section "Summary for Policy Makers"

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia ... Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850" (IPCC, 2013, p. 4-5).
"Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence). It is virtually certain that the upper ocean (0−700 m) warmed from 1971 to 2010 ... and it likely warmed between the 1870s and 1971" (IPCC, 2013, p. 8).
"The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia" (IPCC, 2013, p. 11).
"The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification" (IPCC, 2013, p. 11).
"Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO2 since 1750" (IPCC, 2013, p. 13).
"Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system" (IPCC, 2013, p. 15).
"Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes ... This evidence for human influence has grown since AR4. It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century" (IPCC, 2013, p. 17).
"Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions" (IPCC, 2013, p. 19).

Despite the growing evidence that humans have had an influence on the global climate, some climate change skeptics disagree. In 2009 skeptics added more fuel to the fire after a server at the Climate Research Unit (CRU) at the University of East Anglia in the UK was hacked and hundreds of emails and documents were released to the public that showed potential evidence of British and American scientists conspiring to alter data to overstate global warming. Some conspiracies within email chains included discussing whether or not to release scientific data for independent review, strategies to best combat skeptics' arguments, and employing "tricks" to cover up declines in warming. One email chain from 1999, about charts showing climate patterns over the past two millennia, drew particular interest. The correspondence was between Phil Jones, director of the CRU, and Michael Mann, director of The Pennsylvania State University's Earth System Science Center. Two sets of data had been collected for studies: one measuring temperature effects on tree ring growth and the other measuring a thermometer reading over several decades. Both data sets had shown a rise in temperature over the last century, until 1960 when the tree ring growth pointed to a decline in warming; meanwhile, the thermometer measurements continued to show a rise in temperature. Jones discussed with Mann a "trick" employed to hide the decline in warming as shown by the tree rings data over the past few decades (Revkin, 2009).

Mann is also known for creating the "hockey stick" graph that shows global temperatures to be the hottest in history. Statistical analysis of the graph, done in 2008, showed flawed methodology even though Mann's work had passed two IPCC peer review rounds before the mistakes were spotted.

The hacked documents also showed that the CRU had kept a database of information, which was used in some of the IPCC analysis. Some of the data in the database had been corrected, perhaps to compensate for errors, and the original uncorrected data was deleted due to insufficient storage room. Although this fact does not clearly demonstrate misconduct, it does mean that there is now no means of verifying the original data that supports global warming (Eccleston, 2011).

Climate skeptics claim the entire scandal, referred to as "climategate," brings into question the authenticity of many studies that the IPCC would consider when generating its reports. The scandal was quickly picked up by blogospheres and mainstream media and many commenters believed it was evidence that global warming was a hoax. A study done by Leiserowitz et al. out of Yale University and George Mason University, published in the *American Behaviorist Scientist*, empirically looked at the impact of climategate on public perception toward climate change. The study found that in 2008, 71 percent of Americans thought global warming was happening. By 2010, the number dropped to 57 percent. Those who said global warming is not happening doubled from 10 percent to 20 percent during that time. When asked if humans were behind global warming, those who answered "yes" dropped from 57 percent to 47 percent from 2008 to 2010. Lastly, trust in scientists for information about global warming dropped 9 points over the same timeframe (t = 5.85, p < .001, n = 3,076). In 2010, 22 percent of those surveyed claimed to "strongly trust" scientists, 52 percent "somewhat trusted" scientists, 19 percent "somewhat distrusted" scientists, and 7 percent "strongly distrusted" scientists (Leiserowitz et al., 2012).

Despite the controversy regarding climate change, many corporations are continuing to measure and report their carbon emissions. A report from the Carbon Disclosure Project (CDP), created by PricewaterhouseCoopers (PwC) and copyrighted in 2008, showed that 77 percent of FTSE 350, 73 percent of S&P 500, and 75 percent of Fortune Global 500 companies that responded to the survey were disclosing their GHG emissions (Carbon Disclosure Project: Quick Facts, 2008). According to data from the CDP, the number of unique CDP reporting companies has grown steadily over the past decade; this trend is illustrated in Figure 1 (Reports and Data, 2015). Moreover, the data show a 10 percent year-over-year growth in the number of companies reporting carbon emissions from 2011 to 2014, despite any public skepticism over climate change. At least for companies, tracking carbon emissions is increasingly becoming a priority.

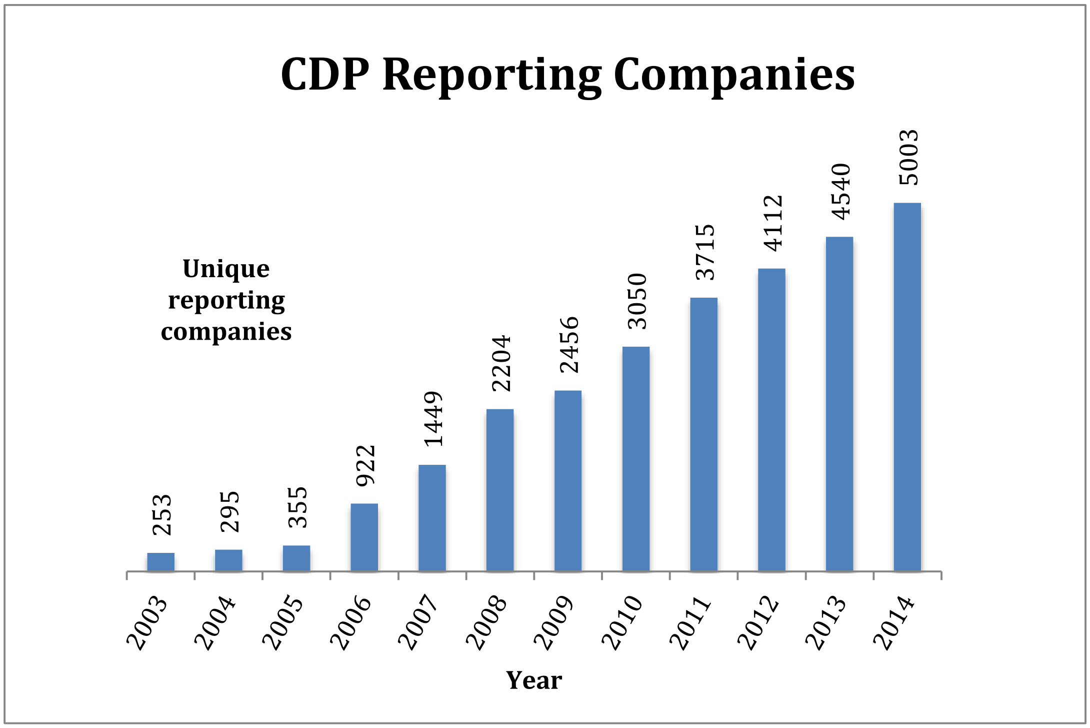

Figure 1. Number of Companies Reporting to the Carbon Disclosure Project Over the Past Decade

Chapter 2

Industry Methodology for Base Year Carbon Accounting

Background

Carbon emission reporting by today's standards has its origins from the Kyoto Protocol. The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) that was adopted in Kyoto, Japan on December 11, 1997 and began enforcement on February 16, 2005. The protocol commits its parties, national governments, to reduce carbon footprints as outlined by internationally binding emission reduction targets (Kyoto Protocol, 1997). Annex A of the protocol further outlines six greenhouse gases of interest, based on IPCC analysis for GHGs of greatest threat to the environment: Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur Hexafluoride (SF_6). In 2013, the Doha Amendment to the Kyoto Protocol added Nitrogen Trifluoride (NF_3) to the original six gases. These seven gases remain the principle greenhouse gases of interest for today's sustainability reports.

The lack of success of binding international protocols with major economic implications from its terms, that are arguably disproportionately assigned, can be seen throughout history. For the Kyoto Protocol, governmental fear of pushing big business away to other countries with less strict regulation, as well as the protocol's failure to equitably account for all GHG emitting parties, has caused hesitation or withdrawal from major international players, including the United States and Canada (Dessai, 2001).

Despite less than completely successful attempts to impose fully inclusive international regulation, individual governments still implement top-down approaches to emissions regulation. In the United States, the Clean Air Act was passed in 1963 and was amended in 1970, 1977, and 1990. Under the Act, the Environmental Protection Agency (EPA) sets limits on the allowable concentration of certain air pollutants in the air at any given location. State and local governments, who also have the authority to implement even stronger air pollution laws, must carry out and enforce, at a minimum, the limits set by the EPA. The Act also gives the EPA the authority to limit emissions from ambient, or open-air, and source-specific, or traceable, sources of air pollution (Clean Air Act Requirements and History, 2013). Over the past decade, the EPA has begun to regulate greenhouse gases as a form of air pollutant under the Clean Air Act. This movement started with the 2007 Supreme Court case, Massachusetts et al., Petitioners v. Environmental Protection Agency et al., which ruled that the EPA had regulatory duty over GHG emissions from automobiles, due to the threat of global warming, under the Clean Air Act, per Section 202 (a) (1):

> The Administrator shall by regulation prescribe (and from time to time revise) in accordance with the provisions of this section, standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.

However, the EPA's regulation of GHGs is not comprehensive and is tailored to specific emitting sources and certain exclusions that are outlined in its 2010 Tailoring Rule[2].

The non-comprehensive nature of EPA GHG regulation pushed the onus of reporting and reducing many GHG emissions onto individual companies. Today, many companies release corporate sustainability reports, which include GHG assessments, alongside annual reports. Despite the convoluted landscape of mandatory and voluntary reporting, many companies report the benefits of GHG reporting outweigh the costs. A 2010 study, sponsored by the Department for Environmental Food and Rural

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[2] http://www.epa.gov/NSR/documents/20100413fs.pdf

Affairs (DEFRA) in partnership with PwC and the CDP was aimed at surveying companies' costs and benefits from reporting and reducing GHG emissions and concluded that "companies that focus on climate change through measuring, managing and reporting GHG emissions experience benefits in terms of cost savings, brand building and stakeholder communications" (DEFRA, 2010).

Whether enticed by cost savings, pressured from stakeholders, or mandated by the government, more and more companies are reporting emissions to organizations such as the Carbon Disclosure Project, as shown in Figure 1. The CDP is an investor-backed, not-for-profit organization that works with over 4,500 companies from 80 countries, that represent over half of the market capitalization of the world's largest 30 stock exchanges, to report individual's environmental impacts, share best practices, and ultimately take action to reduce the impact. The CDP aims to bring insights that enable investors, companies, and governments to understand and act on the business case for reducing environmental impacts (CDP, n.d.). The CDP is therefore a global natural capitol disclosure system that is able to fill the role between government regulation and voluntary reporting to produce pseudo-mandatory standards for individuals wishing to report. The CDP is the predominant organization that fills this role.

Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard

The Greenhouse Gas Protocol, developed in partnership by the World Resources Institute and the World Business Council for Sustainable Development, is the most widely used emissions accounting tool. The protocol sets the global standard and provides guidance for defining, measuring, managing, and reporting GHG emissions. The Corporate Standard document[3] outlines guidelines and standards for defining organizational and operational boundaries, tracking and recalculating emissions over time, identifying and calculating GHG emissions, accounting for GHG reductions, reporting GHG emissions,

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[3] http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf

verifying GHG emissions, and setting GHG targets. The document is designed to offer guidance throughout all phases of GHG quantification, from calculating the initial base year, to tracking reductions and adjustments over subsequent years. The document then describes standards to report GHG emissions to the public; perhaps for use in corporate sustainability reports or reports to the Carbon Disclosure Project.

Getting Started

Before any data gathering or calculations can take place, it is imperative that a company defines its organizational boundary. Businesses these days may include wholly-owned operations, joint ventures, subsidiaries, and other legal designations so determining where to draw the boundary for GHG inventories is an important first step that needs to be applied consistently throughout the entire business operation. The GHG Protocol Corporate Standard outlines two major approaches for consolidating GHG emissions: the equity share and control approaches.

The equity share approach is defined as when "a company accounts for GHG emissions from operations according to its share of equity in the operation" (World Resources Institute, 2004, p. 17). This approach would divide total GHG emissions from an operation and assign them to interested parties of the operation based on the parties' share of equity in the operation; this would typically be the same percentage as the percentage of ownership of the operation. The Corporate Standard goes on to say that when this is not the case, economic substance of the relationship takes precedence over legal designations, just as with international financial reporting standards (World Resources Institute, 2004).

Under the control approach, a company accounts for all GHG emissions from operations that it has control over. For example, this approach would exclude GHG emissions from operations that the company has interest in, but no control over. Within the control approach, there are two designations: financial control and operational control. For reporting purposes companies must define whether they will follow the financial or operational definition of control when applying this approach. Per the Corporate Standard:

> [A] company has financial control over the operation if the former has the ability to direct the financial and operating policies of the latter with a view to gaining economic benefits from its activities ... the economic substance of the relationship between the company and the operation takes precedence over the legal ownership status, so that the company may have financial control over the operation even if it has less than a 50 percent interest in that operation. (World Resources Institute, 2004, p. 17)

For cases in joint ventures where both parties have joint financial control, the equity share approach should be used to account for GHG inventories. The other control category is operational control. As defined in the Corporate Standard, "A company has operational control over an operation if the former or one of its subsidiaries ... has the full authority to introduce and implement its operating policies at the operation" (World Resources Institute, 2004, p.18). It should be noted that this definition does not mean that the company has to have full authority to make every decision concerning the operation.

For more information on defining organizational boundaries, please read Chapter 3 of *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*. For an overview of how these boundaries apply to GHG inventories from various business accounting categories, please reference Appendix B. Defining the organizational boundary is an important first step and will have an influence on setting operational boundaries and GHG emission scoping.

GHG Emission Scoping and Identification

GHG emissions can be considered as either direct or indirect emissions. Direct emissions are defined as emissions that physically occur from company owned or controlled sources, whereas indirect emissions are ones that are a consequence of a company's operation but physically occur from a source owned or controlled by a different company. GHG emissions are broken down into three scopes for accounting purposes, covering the seven GHGs outlined by the Kyoto Protocol. Scope 1 is defined as all direct GHG emissions that occur from company owned or controlled sources. Scope 2 is defined as emissions resulting from the generation of purchased electricity used by sites within a company's organizational boundary. Scope 3 is all other indirect sources of GHG emissions. Companies are required to account and report Scopes 1 and 2 emissions separately, at a minimum. Therefore, for the purposes of accounting and reporting emissions, Scope 3 emissions are optional. These can be seen in Table 2.

Table 2: Examples of Emission Sources per Scope

Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
Stationary Source Fuel Combustion: • Boilers • Furnaces • Burners • Turbines • Incinerators • Engines **Mobile Source Fuel Combustion:** • Company Owned or Controlled Vehicles **Process Emissions:** • Emissions from Physical or Chemical Processes **Fugitive Emissions:** • Equipment Leaks	**Purchased Energy:** • Electricity • Steam • Heat • Cooling	**Operations Not Included in Scope 1 or 2:** • Outsourced Services • Leases • Franchises **Supply Chain Partners** • Upstream • Downstream **Transportation** • Business Travel • Employee Commuting • Product Transportation **Product** • Use of Sold Product • Product End of Life Treatment **Etc.**

Chapter 4, chapter 6, and Appendix D of the Corporate Standard outline extensive examples of emissions and sources to consider, per scope, with guidance for capturing the relevant data needed for calculating GHG inventories. The process of identifying emissions to pursue, due to its dependence on a company's specific operation and organizational boundary definition, will be unique to each company. Scope definitions of specific emission sources can also vary from company to company.

Calculating the Base Year

After a company has done an exercise to identify direct Scope 1 emission sources, indirect Scope 2 emission sources, and any optional indirect Scope 3 emission sources to pursue, a calculation approach needs to be selected. The most accurate, but rather uncommon, method would be direct measurement of emissions. In the case where direct metering is unavailable or prohibitively expensive and/or time consuming, calculations can be made to estimate emissions. The calculation method is the most widely used industry methodology. For any chemical processes that are identified, stoichiometry can be used to calculate relative quantities of reaction products, including potential GHG byproducts. In the case of fuel combustion or electricity usage, documented carbon emission factors can be used. These factors are essentially scientifically agreed upon ratios of GHG emission quantities per unit of source activity. For example, a specific emission factor for each GHG, considering fuel composition in a particular geographic region and vehicle engine efficiencies, can be applied to the volume of diesel fuel burned by a particular vehicle to calculate the quantity of GHGs produced. Likewise, emission factors that factor the unique mix of power generation (i.e. coal, wind, water, nuclear, etc.) per electric grid region can be applied to purchased-electricity consumption from the specific utility provider, or from a particular grid location, to calculate the quantity of GHGs created from producing the electricity that was consumed. When specific source details are unavailable, factors that are generalized averages, such as over an entire vehicle class or entire country's power grid, can be used. These agreed upon GHG emission factors, both specific and generalized, are the standard conversions used and are continuously updated and reviewed over time so that they accurately reflect any appropriate physical changes. A company should use the most accurate calculation approach available that is appropriate and must be transparent about the approach used (World Resources Institute, 2004).

Once emission sources within the company's organizational boundary are identified and the methodology for calculation is determined, a company can begin to collect activity data over the desired time period necessary for calculations: such as direct emission measurements or fuel usage and utilities consumption to be applied to GHG emission factors. This process will usually involve multiple facilities reporting up to the corporate level. The Corporate Standard helps provide guidance on strategies to roll up emissions to the corporate level to minimize the reporting burden, minimize reporting errors, and ensure consistency and standardization throughout the process (World Resources Institute, 2004). Outlined are two key approaches: the centralized approach and decentralized approach. In the centralized approach, each individual facility reports activity data, such as kWhs of electricity used, to the corporate level where GHG calculations are applied. In the decentralized approach, each facility collects activity data, calculates its own GHG emissions, and reports the carbon footprint to corporate for consolidation. The Corporate Standard suggests using the centralized approach for most office organizations where calculations can be performed in a routine manner from activity data, and the calculation is standard across various facilities. The decentralized approach is recommended in cases where calculations require detailed knowledge of equipment used per site, calculation methods vary across facilities, process emissions are extensive at different sites, or regulations require individual facility calculation (World Resources Institute, 2004).

Each of the three scopes of GHG emissions is accounted for and reported separately. Within GHG accounting and reporting, the standard approach is to independently consider all seven of the GHGs outlined by the UNFCCC in the Kyoto Protocol. For consolidation purposes, the final output of GHG accounting is often reported in terms of Carbon Dioxide Equivalent (CO2e). This metric is based on IPCC quantified global warming potentials (GWP) of each gas over a timeframe of 100 years. By definition, Carbon Dioxide has a GWP of 1, and each of the other gases outlined in the Kyoto Protocol can be multiplied by its particular GWP factor to convert to CO2e. Specific fluorinated gases (F-gases) may have a unique GWP associated with it that typically falls within a range for the entire F-gas category. The particular gases and GWPs, which result from a company's operations or equipment used, need to be considered when calculating CO2e; they can be seen in Table 3. The GHG Protocol has tools that can be used to determine what types of F-gas emissions certain equipment and emission sources have associated with them, if direct measurement is not available.

Table 3. GHG Global Warming Potentials

Greenhouse Gas	**Global Warming Potential (GWP)**
Carbon Dioxide (CO_2)	1
Methane (NH_4)	21
Nitrous Oxide (N_2O)	310
Hydrofluorocarbon (HFC)	140-11,700
Perfluorocarbon (PFC)	6,500-9,200
Sulfur Hexafluoride (SF_6)	23,900
Nitrogen Trifluoride (NF_3)	17,200

Source: US Environmental Protection Agency, 2013

The total consolidated and verifiable emissions inventory calculated over a determined set of time (usually one full year) will become the company's base year for accounting and reporting purposes. The base year can be used to track emission trends over time and set reduction goals against. When accounting and reporting GHG emissions over time, it may become necessary to retroactively adjust the base year calculation due to improved or more complete data, improved calculation methodology, accounting for mergers and acquisitions, accounting for spin-offs, accounting for other significant structural changes, and correction of errors. The recalculation will help keep GHG emissions consistent and relevant over time. In any case requiring retroactive base year adjustments, a recalculation policy needs to be drafted to outline when a recalculation is necessary in order to standardize the procedure. This process needs to be consistent and done in good faith to account for both GHG increases and decreases. The standard for doing retroactive base year recalculations is outlined in chapter 5 of the Corporate Standard (World Resources Institute, 2004).

Chapter 3
Carestream Carbon Model and Results

Carestream Health, Inc. Background

Carestream Health Inc., Carestream, was launched as an independent company in 2007. The company is headquartered in Rochester, New York, and also owns facilities in Windsor, Colorado and White City, Oregon. The company originated as Eastman Kodak Company's Health Group, but the group was sold to the Canadian private equity firm ONEX Corporation in 2007. ONEX Corporation (TSX: OCX) launched Carestream Health as an independent subsidiary shortly after its acquisition from Eastman Kodak.

Carestream manufactures a portfolio of products, which serve several industries, including: medical and dental imaging equipment and information systems solutions, and non-destructive testing products used for material inspection. The company serves customers globally: including healthcare systems, hospitals, imaging centers, and medical group practices. For more information on Carestream's product offerings, please visit Carestream's website[4].

Project Scope

When internal management met to discuss Carestream's corporate social responsibility initiatives, a large focus was given to the environmental impact of Carestream's operations. In order to begin assessing strategies to reduce and report the company's environmental impact, a sustainability model had

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[4] www.carestream.com

to be considered that could measure Carestream's current environmental impact, identify areas of reduction focus, and track Carestream's environmental impact over time. Carestream decided to focus on its carbon footprint as a focal point for its sustainability initiative.

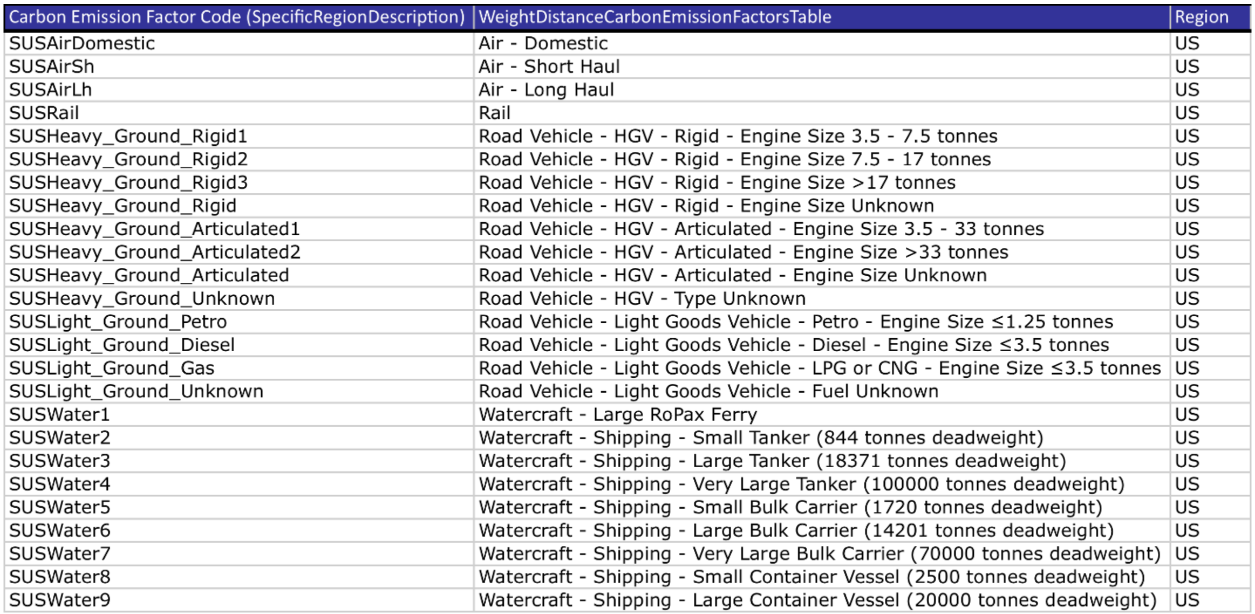
Carestream identified its transportation, warehousing, and shared services center activities as the key areas of analysis for the preliminary carbon footprint model. These were the areas with the most extensive activity data that could be retrieved at the onset of the project. The goal of the project was to quantify a base year carbon footprint of the transportation, warehousing, and shared services center activities that could then be used to identify opportunities and set reduction goals against as the sustainability initiative moves forward. The transportation portion of the model includes inbound materials transportation, inter-company materials transportation, finished goods outbound transportation, and customer returns. The warehousing and shared services center portion of the model includes purchased energy consumption and stationary combustion sources per facility. Carestream initially provided Q1 2014 operations data for the transportation piece and individual facility locations and square footage to be used for building the initial model logic and carbon footprint calculations, with the intent of scaling up the model with full 2014 activity data after the initial construction.

Methodology

Rather than using generic GHG Protocol tools for calculation purposes, a carbon model was built exclusively for Carestream. The carbon model was still developed with consideration of industry standards from the GHG Protocol; yet, building the model internally was done so that the model's calculation methodology and emission factors could be catered over time to Carestream's operations thus more accurately reflecting the company's true footprint. Carestream's operations are conducive to the centralized approach of rolling up emissions to the corporate level; therefore activity data from all aspects of the operations, within the project's scope, was sought and then transposed into GHG emissions. It should be noted that Carestream outsources its transportation activities, and has a combination of owning and insourcing, leasing and insourcing, and fully outsourcing its warehousing infrastructure and activities. Also some Carestream products require temperature-controlled environments.

For the transportation model, inbound, intercompany, outbound, and return transportation phases were kept on independent worksheets, and separate GHG emissions were independently calculated for each transportation phase with the following methodology. The calculations begin with, and rely on, Carestream's provided activity data that included each shipment's origin, destination, shipping weight, shipping distance, and utilized transportation mode. Next, the most up-to-date GHG emission factors were taken from EPA and GHG Protocol listings. The GHG Protocol provided "specific" emission factors that account for geographic region, vehicle type, vehicle engine size, or fuel type and were used for instances when more detailed information for the activity data was known. The EPA sourced factors represent "general" emission factors, such as averages across regions and vehicle differentiations for various vehicle categories, and were used for instances when more detailed information for the activity data was unknown. Emission factors used throughout the project are listed in Appendix A.

For each emission factor, an emission factor code was generated as shorthand to describe the particular factor. The form of the code was a concatenation of descriptions, for example: the emission factor table (specific or general), geographic region, vehicle, and vehicle description. At the same time, description data was generated for each line of activity data, for the purposes of defining relevant details from each shipment. The definition data included whether or not the shipment was international, whether the shipment had relevant information needed to use the specific factor table or if it had to use the general factor table, which geographic region the shipment occurred in, which vehicle was used, any known vehicle details, and whether the container was dedicated to Carestream or shared with other companies. The description data could then be concatenated to form codes for each shipment that aligned with the emission factor codes. Each table of emission factors was then used as a lookup table to automatically assign proper CO_2, CH_4, and N_2O emission factors, and label the units associated with the factor, to every individual shipment. Figure 2 shows an example of emission factor codes paired with a sample of the Specific Transportation Carbon Emission Factor Table, which can be seen in its entirety in Appendix A.



Carbon Emission Factor Code (SpecificRegionDescription)	WeightDistanceCarbonEmissionFactorsTable	Region
SUSAirDomestic	Air - Domestic	US
SUSAirSh	Air - Short Haul	US
SUSAirLh	Air - Long Haul	US
SUSRail	Rail	US
SUSHeavy_Ground_Rigid1	Road Vehicle - HGV - Rigid - Engine Size 3.5 - 7.5 tonnes	US
SUSHeavy_Ground_Rigid2	Road Vehicle - HGV - Rigid - Engine Size 7.5 - 17 tonnes	US
SUSHeavy_Ground_Rigid3	Road Vehicle - HGV - Rigid - Engine Size >17 tonnes	US
SUSHeavy_Ground_Rigid	Road Vehicle - HGV - Rigid - Engine Size Unknown	US
SUSHeavy_Ground_Articulated1	Road Vehicle - HGV - Articulated - Engine Size 3.5 - 33 tonnes	US
SUSHeavy_Ground_Articulated2	Road Vehicle - HGV - Articulated - Engine Size >33 tonnes	US
SUSHeavy_Ground_Articulated	Road Vehicle - HGV - Articulated - Engine Size Unknown	US
SUSHeavy_Ground_Unknown	Road Vehicle - HGV - Type Unknown	US
SUSLight_Ground_Petro	Road Vehicle - Light Goods Vehicle - Petro - Engine Size ≤1.25 tonnes	US
SUSLight_Ground_Diesel	Road Vehicle - Light Goods Vehicle - Diesel - Engine Size ≤3.5 tonnes	US
SUSLight_Ground_Gas	Road Vehicle - Light Goods Vehicle - LPG or CNG - Engine Size ≤3.5 tonnes	US
SUSLight_Ground_Unknown	Road Vehicle - Light Goods Vehicle - Fuel Unknown	US
SUSWater1	Watercraft - Large RoPax Ferry	US
SUSWater2	Watercraft - Shipping - Small Tanker (844 tonnes deadweight)	US
SUSWater3	Watercraft - Shipping - Large Tanker (18371 tonnes deadweight)	US
SUSWater4	Watercraft - Shipping - Very Large Tanker (100000 tonnes deadweight)	US
SUSWater5	Watercraft - Shipping - Small Bulk Carrier (1720 tonnes deadweight)	US
SUSWater6	Watercraft - Shipping - Large Bulk Carrier (14201 tonnes deadweight)	US
SUSWater7	Watercraft - Shipping - Very Large Bulk Carrier (70000 tonnes deadweight)	US
SUSWater8	Watercraft - Shipping - Small Container Vessel (2500 tonnes deadweight)	US
SUSWater9	Watercraft - Shipping - Large Container Vessel (20000 tonnes deadweight)	US

Figure 2: Example of Emission Factor Codes

Naturally, not all shipments can be summarized by one vehicle and one emission factor. In consideration of intermodal shipments, this definition process had to be run several times in order to consider emissions from the different vehicles used. At the same time, the total shipment distance had to be broken up into individual legs and assigned properly to each vehicle used for the given leg. To start this process, every origin and destination location was indexed with its latitude and longitude coordinates and each was manually assigned to its geographically closest major cargo seaport, also indexed along with its associated coordinates. Next, a great circle distance matrix between each port within the network was built with the haversine formula[5] and the radius of the Earth (6371 km). The first leg of an

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[5] =ACOS(COS(RADIANS(90-LAT1)) *COS(RADIANS(90-LAT2)) +SIN(RADIANS(90-LAT1)) *SIN(RADIANS(90-LAT2)) *COS(RADIANS(Long1-Long2))) *6371 Km

intermodal shipment credited was the water leg. Using the origin and destination of a shipment as lookup criteria to determine the seaport assignments, the model then looked at the great circle distance matrix to determine the distance between the ports, and reported it for the first mode's distance; at the same time the lookup code for the watercraft assigned the proper emission factors to the shipment leg. The total shipment distance was credited for the water leg and the remaining distance was given to ground transportation, along with the particular ground vehicle's assigned emission factors. If the shipment was not intermodal, then all distance was given to the first mode and the second was left null.

With distances of each shipment leg approximated, and all emission factors assigned, the GHG inventory could be calculated. The calculation was designed to eliminate instances where crucial activity data was incomplete or impossible (e.g., negative weight, zero total distance) due to the fact that the calculation would return either a negative or zero quantity of GHG emissions. For the data that were kept, three separate calculations were run for each leg of the shipment to determine the generated CO_2, CH_4, and N_2O emissions. The calculation had to consider the shipment weight, distance, emission factor, and unit conversions in each case when units were mismatched (the emission factor is a ratio between quantity of GHG and weight distance, or quantity of GHG and vehicle mile). Figure 3 shows examples of the types of calculations made:

$$MobileGHG = ShipmentWeight * ShipmentDis\tan ce * \frac{MassGHG}{WeightDis\tan ce}$$

$$MobileGHG = ShipmentDis\tan ce * \frac{MassGHG}{VehicleDis\tan ce}$$

Figure 3: Mobile GHG Emission Calculation

Each shipment leg was then summed to quantify the total CO_2, CH_4, and N_2O associated with the entire shipment. Finally, once individual GHG inventories per shipment were quantified, they were rolled up into one CO_2e metric for the shipment by multiplying each gas by its GWP (1, 21, 310 respectively).

For the warehousing model, the only activity data that Carestream was able to immediately provide were facility locations and building square footage. Due to the leasing nature of the majority of warehousing and shared services center space, Carestream did not have immediate access to utility bills in order to look at purchased energy consumption. Instead, short-term estimations had to be made based off of the square footage of space Carestream rents and the annual cost of operation per facility until more thorough energy consumption data could be gathered.

For the estimations, annual energy use per square foot factors for various facility types, which are based on average energy consumption of a facility type per various climate regions across the United States, were pulled from an Energy Star document[6] written by the EPA (Putting Energy Into Profits, 1997). For purposes of power consumption estimation, the model only considered usage averages from refrigerated warehouses, non-refrigerated warehouses, and office buildings to reflect Carestream's network of facilities. These estimates can be seen in Table 4.

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[6] http://www.seco.cpa.state.tx.us/TEP_Production/c/EPAEnergyStarSmallBusinessGuide.pdf

Table 4: Facilities' Average Annual Electricity Usages per Square Foot

Climate Zone	Building	Designation	Annual Energy Use kBTU/Sq. Ft	Annual Energy Cost $/sq. ft.
Climate 1	Warehouse	(non-refrig.)	59	$1.09
	Warehouse	(refrigerated)	65	$1.45
	Office		93	$1.46
Climate 2	Warehouse	(non-refrig.)	64	$0.80
	Warehouse	(refrigerated)	65	$1.45
	Office		95	$1.49
Climate 3	Warehouse	(non-refrig.)	51	$0.93
	Warehouse	(refrigerated)	65	$1.47
	Office		80	$1.59
Climate 4	Warehouse	(non-refrig.)	36	$0.83
	Warehouse	(refrigerated)	96	$2.02
	Office		72	$1.54
Climate 5	Warehouse	(non-refrig.)	33	$0.77
	Warehouse	(refrigerated)	55	$1.17
	Office		68	$1.55
Averages	Warehouse	(non-refrig.)	48.6	$0.88
	Warehouse	(refrigerated)	69.2	$1.51
	Office		81.6	$1.53
	Warehouse	Undifferentiated	58.9	$1.20
	Building	WH+O	66.46666667	$1.31

Data Source: (Putting Energy Into Profits, 1997, p. 91-92)

Without having contact with the supplying power company to provide its own measured emission factors for use, GHG emission factors (that represent average GHG emissions from the mix of various energy production methods for power supplied to electric grids per geographic region) were pulled from the GHG Protocol for estimation purposes. In the United States, the factors were specific per grid region whereas international factors represent averages of the entire country's electric grid. Emission Factors used throughout the project are listed in Appendix A.

The first step in the GHG calculation process was to estimate MWh power consumption per facility based on the available square footage data. Moreover, differentiated square foot usage of temperature controlled storage, ambient temperature storage, or office space was not provided. To mitigate the data deficiency for a square footage differentiation, the model combined the average annual power consumption of non-refrigerated warehouses, refrigerated warehouses, and office space into a whole building annual average with the assumption that any particular facility leased by Carestream may have some combination of all three. The resulting factor (66.467 kBTU per square foot from Table 4) was applied to the entire building square footage and then multiplied by a ratio of Carestream's square footage rented over the whole building's square footage in order to allocate how much of the building's power usage would go to Carestream. Unit conversions applied throughout the calculation resulted in a final MWh figure for each facility. Figure 4 demonstrates the methodology for the MWh estimation based off of facility square footage:

$$Annual\ MWh = \frac{CarestreamSq.Footage}{BuildingSq.Footage} * BuildingSq.Footage * \frac{Annual\ kBTU}{FacilitySq.Footage} * \frac{MWh}{kBTU}$$

Figure 4: MWh Estimation from Square Footage

Next, the model used the country, from activity data describing each facility's location, to look up GHG emission factor from the tables provided from the GHG Protocol, and reported the correct CO_2, CH_4, and N_2O factors from the generation of electricity that the facility was utilizing. The factors are ratios of GHG quantity per MWh. Each of CO_2, CH_4, and N_2O emission quantities were calculated separately per facility by multiplying the estimated MWh figure by the respective emission factor. Finally, once individual GHG inventories from purchased electricity were quantified, they were rolled up into one annual CO_2e metric for the facility by multiplying each gas by its GWP (1, 21, 310 respectively).

Stationary combustion emissions were considered for natural gas, heating oil, and diesel sources, per Carestream's initial analysis of stationary fuel combustion emission sources. Without knowing direct measurements or individual equipment fuel efficiencies, a method to approximate emissions based on volumes of fuel combusted and GHG emission factors associated with fuel combustions were selected for the model. As with purchased electricity, utility bills that would show purchased volumes of these fuel types were unavailable thus creating the need to also estimate fuel volumes. The mitigating strategy was ultimately done based on operational spend per facility. Each facility could report its percentage of total spend allocated to each utility and each percentage was multiplied by the total operational spend at the facility to allocate expenditure dollars per utility. In cases where the spend percentage was not estimated, a default assumption table was built that applies a default percent of total spend per utility (that can be adjusted by Carestream for further accuracy) to allocate expenditure dollars to individual utility costs. Next, a table of fuel costs per volume in 2014 was compiled from data provided from the Energy Information Administration (Energy Information Administration, n.d.). Now individual fuel volumes per facility, which were calculated from the allocated utilities expenditures, could be prepared for GHG emission conversion.

The GHG Protocol was referenced for a list of stationary combustion emission factors per fuel type. One of the methodologies for estimating stationary combustion GHG emissions, per the Corporate Standard, uses emission factors based on the weight of the fuel type that was combusted. Some quick calculations using Google's unit conversion software provided weight per unit of volume conversion factors for each fuel type. The calculated weights used were: .43105965 kg per cubic foot of natural gas, 3.71945743 kg per gallon of heating oil, and 3.220628346 kg per gallon of diesel fuel. Next, each of CO_2, CH_4, and N_2O emission quantities were calculated separately per calculated fuel weight by multiplying the estimated fuel weight by the respective emission factor. Figure 5 demonstrates the methodology for the GHG estimation from stationary combustion sources. Finally, once individual GHG inventories were quantified, they were rolled up into one CO_2e metric, per fuel type per facility, by multiplying each gas by its GWP (1, 21, 310 respectively). Emission Factors used throughout the project are listed in Appendix A.

$$StationaryGHG = FacilitySpend * \frac{UtilitySpend}{FaciltySpend} * \frac{FuelSpend}{UtilitySpend} / \frac{Cost}{Volume} * \frac{FuelWeight}{Volume} * \frac{VolumeGHG}{FuelWeight}$$

Figure 5: Stationary Combustion GHG Emission Calculation

Results

The project resulted in separate transportation and warehousing carbon models that collectively estimate Carestream's carbon footprint from distribution activities. The models were delivered to Carestream along with lists of assumptions, limitations, and next steps (discussed in Chapter 4) for full transparency. Both models were built with relative references to allow for automatic carbon calculations from new activity data. In addition, any necessary calculation inputs or critical assumptions were listed in independent worksheets from which they were referenced within the model's formulas. This separation from the calculations will allow Carestream to further refine the model's assumptions and inputs in the future without the risk of creating update anomalies.

After delivering the models, Carestream scaled up the transportation activity data for the rest of 2014 and inserted it into the model, allowing for the calculation of the full year carbon footprint beyond Q1 2014. This type of activity data scale up can continue to happen moving forward to track the carbon footprint beyond the base year. The ability to continuously add data is very useful. For example, addressing the data inconsistencies that caused eliminated shipments would further refine the model by causing those eliminated instances to be included into the carbon footprint. And again, Carestream has the ability to improve the model's accuracy by updating assumptions or inputs as data becomes available such as seaport usage, vehicle specifications, exact shipment distances, or updated GHG emission factors.

The individual inbound, intercompany, outbound, and returns worksheets were summarized on one sheet via independent pivot tables for analysis purposes. The pivot tables allow for granular analysis of the carbon footprint with considerations regarding individual GHGs, transportation modes, shipment origins, shipment destinations, and geographic regions that can help identify potential opportunities to target for reductions. Moreover, the pivot tables can create a calculated field of CO_2e per shipment weight distance. This metric can be extremely useful for analyzing shipment strategies and the impacts they have on the carbon footprint. The entire transportation carbon footprint from the model was 69,650 tonnes of CO_2e. Figure 6 demonstrates a carbon breakdown of each transportation category by transportation mode.

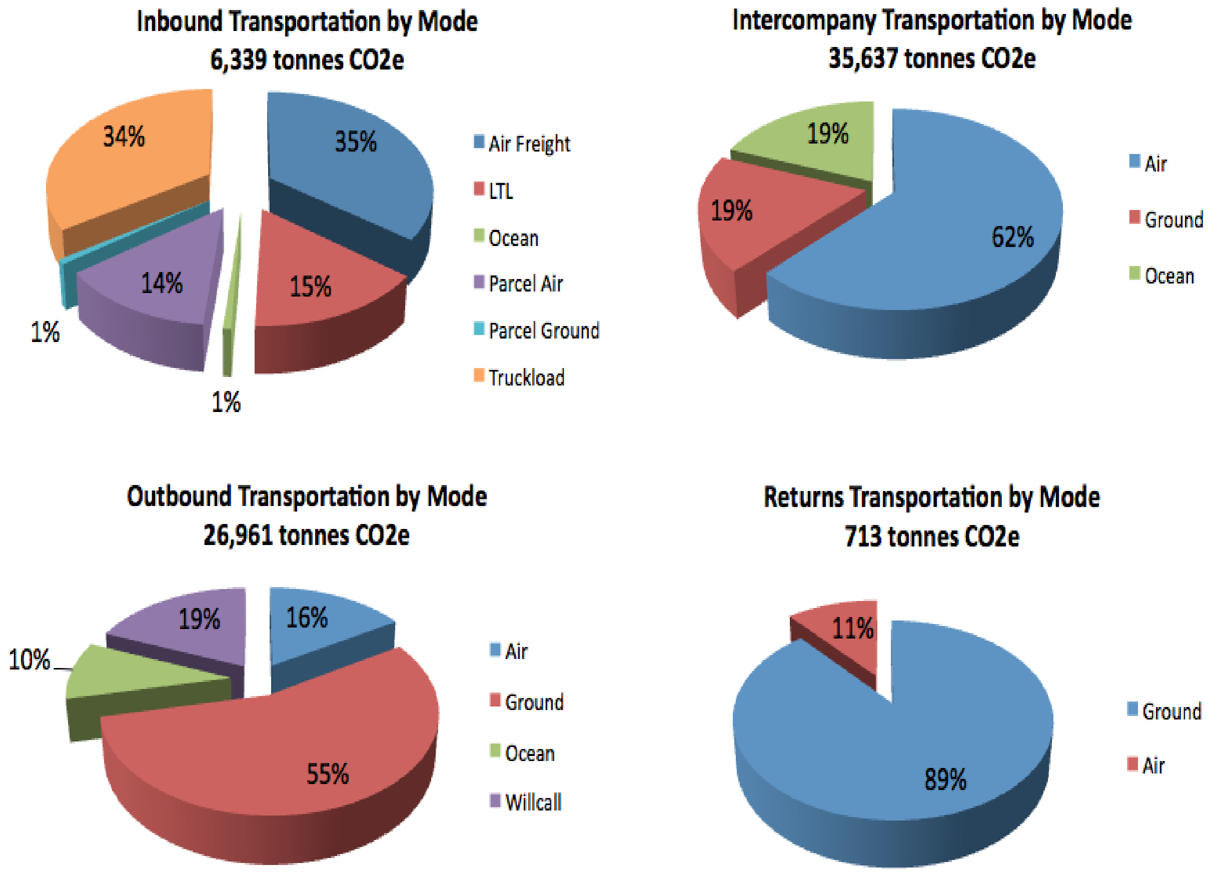

Figure 6: Transportation Carbon Footprint Breakdown

Similarly, the warehousing model is able to give a full year carbon footprint estimate for 2014. Each facility in the model is currently prepared to make emission estimations in two tiers of accuracy, based on data availability and the approach used. The first approach estimates utility consumption based on total spend at each facility location, with percentages of total spend allocated to each utility type, including electricity. The second approach runs underneath the first for instances where facility expenditure is unspecified. This approach makes an estimation based off of facility square footage and average utility consumption for similar facilities across the United States. Moving forward, Carestream can collect data for the actual utility consumption at each facility and make GHG emission calculations with the emission factors used in the model. This third method would be the most accurate and should take priority in the model before any of the previous estimation techniques are used. Moving forward, Carestream can continuously add activity data or additional facilities to track the carbon footprint beyond the base year. Carestream also has the ability to improve the model's accuracy as data becomes available by updating any inputs or assumptions such as individual utility spend allocations per facility, the default utility spend allocation, utility prices per volume, or updated GHG emission factors.

Just like the transportation model, the warehousing model has a summary worksheet with a pivot table for analysis purposes. The pivot table allows for granular analysis of the carbon footprint with considerations regarding individual GHGs, facility type, facility ownership, geographic region, country, and individual emission sources that can help identify potential targets for reduction. The entire warehousing and shared services center carbon footprint from the model was 16,985 tonnes of CO_2e. Figure 7 shows a breakdown of the warehousing and shared services center carbon footprint by geographic region.

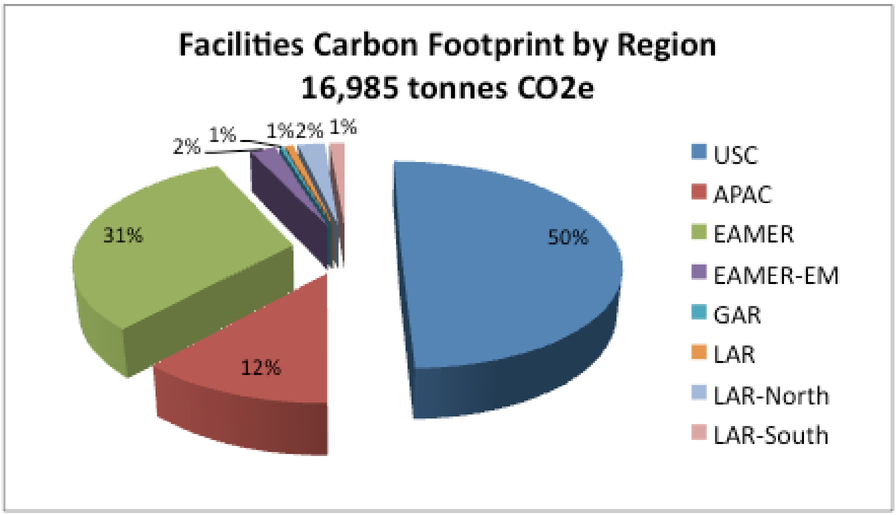

Figure 7: Facilities Carbon Footprint Breakdown

The overall goal of the project was to calculate the base year carbon footprint of Carestream's transportation, warehousing and shared services center activities. Aggregating all emission inventories from both the transportation and warehousing models yielded a total of 86,635 tonnes of CO_2e for 2014. Figure 8 demonstrates the breakdown of the base year carbon footprint by each of the examined operational categories.

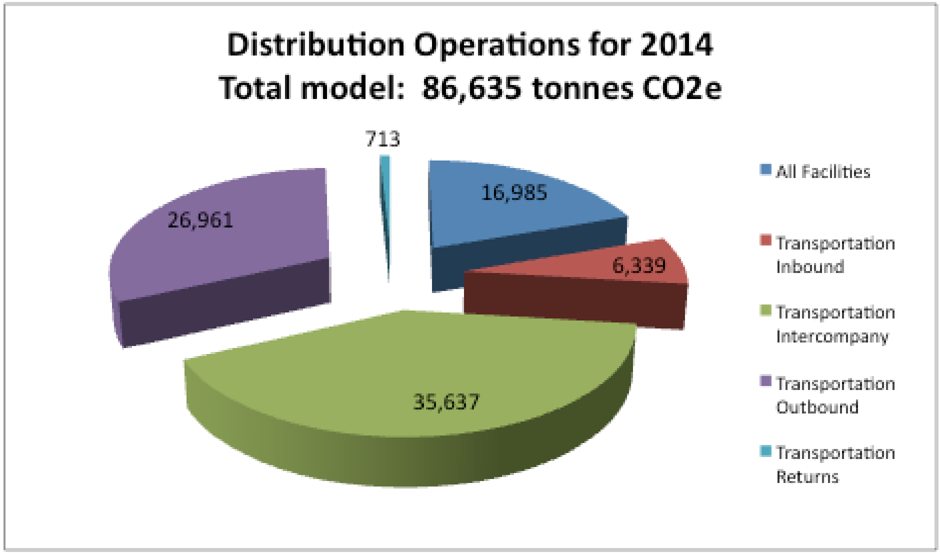

Figure 8: Base Year Carbon Footprint Breakdown

Chapter 4

Model Discussion

Assumptions

When building the initial model logic, several key assumptions had to be made and documented. The importance of documenting assumptions throughout GHG accounting cannot be overlooked, and they will be important considerations during future model updating, for validation purposes, and for transparency when reporting GHG inventories to the public.

Being the more extensive of the two, the transportation model has more key assumptions. The first concerns how emission factors are assigned. "General" emission factors were used whenever specific vehicle or regional information was unknown, such as with all watercrafts in the model. For "specific" aircraft factors used in the model, "domestic" was defined as any air shipment within the same country; "short-haul" was defined as an international shipment less than 2000 km; and "long-haul" was defined as an international shipment greater than 2000 km. For "specific" ground vehicles used in the model, heavy ground vehicles use the "unknown" engine type factor and light ground vehicles use the "unknown" fuel type factor. For regional distinction, the final destination location was used to define what "specific" regional factor to use.

The second key assumption concerns intermodal shipments. Because the activity data showed no evidence of rail usage, and shipments utilizing air were specified as such, intermodal shipments were assumed to utilize water and ground transportation exclusively. Assumptions were also made when defining shipment legs in intermodal shipment cases. The seaport assignments were made to each origin and destination location in the Carestream network based off geographic proximity to major ports, due to a lack of data defining which ports were explicitly used.

The third assumption concerns incomplete data. The model relies on shipment origin, destination, distance, weight, and mode inputs from the activity data. The model would report an error or a null in cases where any of these inputs were missing. There were also cases of impossible data, such as negative shipment weight and negative distances. It should be noted that the model in its current state is designed to eliminate instances derived from incomplete or impossible data. This was done with GHG calculation and analysis integrity in mind. Incorrectly calculating zero or negative quantities within GHG inventories would begin to skew data analysis.

The warehousing model also had assumptions associated with it. The input data for warehousing was fairly unstructured and incomplete, leading to fairly grandiose assumptions. For the initial model build, any data describing actual energy consumption was entirely unknown. Therefore, an assumption was made to calculate utility-usage estimations based off of facility square footage. This logic will run in the background of future models in the case that utility data cannot be directly inputted in order to estimate the utility usage. Another major assumption concerns the emission factors for purchased electricity used in the model. The emission factors used in the model are based on entire country averages, from the Energy Information Administration (EIA).

For direct stationary combustion emissions, estimations were derived from assumptions surrounding operational spend at each facility. The percentages of operational spend allocated to each utility had to be assumed on a generalized mix, to be determined by Carestream, in cases where the individual facility had an undetermined spend mix.

Limitations

Any time that a complex operation, such as GHG accounting, is addressed via mathematical modeling, limitations in the resulting model can be expected. Due to various definitions, assumptions, and data inadequacy mitigations both the transportation and warehousing carbon models have limitations to them.

In the transportation model, the majority of limitations arise from data deficiencies. For example, vehicle engine types and fuel used were entirely unknown and resulted in more generalized emission factors being used in the calculations; the limitation that arises is the final calculations are not as accurate as possible compared to one that uses a factor catered to the physical vehicle specifications. Also the ports used for intermodal shipments were not explicitly defined in the activity data and required assumptions to assign ports to shipments. The assumptions may not reflect actual ports used, which would alter the distances used per mode in emission calculations. In a similar way, airports used from air shipments were not provided in the activity data, which hindered the ability to break up the various transportation modes to account for ground travel to and from airports. A methodology for defining and assigning airports to every shipment origin and destination, as was done with seaports, was prohibitively time consuming to do manually and ultimately would have relied on assumptions rather than real data. Consequently, any shipments sent by air use an air emission factor for the entire duration, which overestimates the carbon footprint for all shipments that utilize air. Any drayage service between intermodal shipment modes lacked any sufficient data concerning vehicle types, distances travelled, or fuels used and therefore those emissions were not considered in the initial model build. Any emissions from vehicle idling time, such as while loading or unloading shipments, were also not explicitly accounted for due to a lack of data. Next, equipment and coolant data for refrigerated shipments were unknown, so the model does not currently account for fugitive F-gas emissions in those instances. Lastly the model is designed to eliminate data instances that have incomplete or impossible data that is crucial for building the GHG calculation; this eliminates any potential shipments that physically occurred but were recorded improperly from the overall carbon footprint.

More limitations arise from use of the haversine formula to calculate distances. The haversine formula is designed to calculate great circle distances on a perfect sphere. When applied to the Earth to calculate distance, the formula would fail to account for geologic structures and manmade infrastructure as physical constraints. The distances calculated are therefore estimations of the actual distance and have limitations in accuracy.

The last of the limitations is derived from the definitions structure in the model. Most references are relative in nature and rely heavily on a consistent input data structure and relative position. When scaling up the model, new activity data will have to be cleaned to a standardized and identical form to the initial activity data or the model will produce errors. Moreover, the model relies very heavily on using lookup tables on the conversion factors and port assignment worksheets. Any deletions, typos, or major alterations within these tables may be detrimental to the model.

The limitations for the warehousing model are more abundant due to its generalizing estimation techniques needed as a result of severe data deficiencies. Power estimations are derived from national averages from a combined three sets of facilities: refrigerated warehousing, ambient warehousing, and office space. The metric does not do an adequate job of representing Carestream's actual proportions of the three at any given facility. Moreover, the national averages are not necessarily representative of the electricity consumed by any of Carestream's facilities. For the time being, this strategy serves as a general estimation tool, at best, until robust activity data can be collected.

At the same time, stationary combustion emissions are also merely estimations, with the potential of being grossly inaccurate. Since the calculations are not derived from data defining Carestream's actual fuel consumption, the model can really only serve as an estimating tool at this point until robust activity data can be collected. The warehousing model also does not account for fugitive F-gas emissions due to a lack of equipment or coolant data needed to address them.

Validity

The models, in the current state, estimate Carestream's transportation footprint for CO_2, CH_4, and N_2O emissions and warehousing footprint for CO_2, CH_4, and N_2O emissions. Although these models were built within the assigned project scope as it was originally intended, the models do not completely cover all of Carestream's Scope 1 and Scope 2 emissions. For instance, any emissions associated with manufacturing processes fell outside of the project scope and are not accounted for in these models. Data deficiencies, particularly on the warehousing side, led to several inaccurate estimation techniques and overarching assumptions. Moreover, neither model addresses the four remaining GHGs outlined in the Kyoto Protocol. The lack of any necessary data to inventory these gases would make any estimation process produce entirely inaccurate results at this point in time. The remaining gases would be better addressed once the relevant data has been collected.

For base year carbon reporting purposes, the models alone would be insufficient for a comprehensive accounting of Carestream's carbon footprint. Moreover, both models would require further development to increase accuracy. The models are nonetheless a good start for Carestream to build off of as it moves forward in quantifying its base year carbon footprint.

Next Steps

The Carestream project was originally meant to begin quantifying the carbon footprint of its transportation and warehousing activities; but for the purposes of quantifying a fully inclusive GHG assessment for sustainability reporting purposes, more work will need to be done moving forward. In order for Carestream to align its efforts with industry best practices and standardizations when quantifying and reporting GHG emissions, the GHG Protocol's Corporate Standard should continue to be followed and referenced for relevant standards and guidance.

Per the Corporate Standard, Carestream will need to first ensure that its organizational and operational boundaries are defined uniformly throughout each level of the business for when it is considering GHG inventories, as discussed in Chapter 2. This definition process will help identify for Carestream what types of emissions will fall under direct Scope 1 emissions and indirect Scopes 2 or 3 emissions. Carestream will need to begin fully considering, at a minimum, its Scope 1 and 2 emissions beyond just those currently covered in the current transportation and warehousing models. Carestream could also consider pursuing relevant indirect Scope 3 emissions of significance. Besides showing commitment to environmental sustainability with this optional exercise, companies can also benefit from the analysis of GHG emissions along its value chain because the analysis can provide insight into potentials for greater efficiencies and ultimately lower costs for the organization. At the same time, indirect GHG emissions are often less costly to address as compared to Scope 1 emissions. Therefore, accounting for Scope 3 emissions may reveal opportunities for total GHG inventory reductions where limited resources can be allocated to provide a maximum return on investment (World Resources Institute, 2004).

Next Carestream will need to analyze the entirety of its business operations within its organizational and operational boundary to identify relevant emission sources beyond transportation of goods, purchased electricity, and stationary combustion that were covered in the models. Key areas not included in the models that Carestream will need to consider are process emissions during any manufacturing activities, and fugitive emissions (such as equipment leaks from joints, seals, packing, and gaskets; and F-gas emissions from use of refrigeration and air conditioning equipment). Any easily measured Scope 3 emissions can be considered in this process as well, per Carestream's discretion.

The project used the centralized approach of rolling up emissions; each facility reported activity data to corporate, where the total GHG calculation occurred. A major challenge when building the initial models was gathering and cleaning necessary activity data to input into the models. Thus, Carestream will need to develop an internal protocol to standardize the collection of the activity data it needs to build the most robust carbon models possible. Some data shortages to consider addressing for transportation are: vehicle specifications (engine size, fuel type), shipment details (seaports used, airports used, drayage vehicles and distances, vehicle idling time), and refrigeration (equipment model, coolant used). Some data shortages to consider addressing for warehousing are: utility bills per site (electricity consumption, stationary combustion fuel consumption), refrigeration and air conditioning (equipment model, coolant used). Analysis of process emission sources and any other emissions sources identified by Carestream will help determine what type of data will need to be collected to inventory the associated emissions. The internal collection protocol should ideally collect data in some structured format to avoid risks of incomplete instances and eliminate the need for time-intensive data cleaning that were present throughout the project.

Once activity data can be reliably sourced from each of Carestream's facilities within its boundary, the models will need to be updated to completely incorporate them. Some instances – such as vehicle specifications, seaport assignments, and facility utility expenditures – can be immediately inputted into the current models and would result in a much more accurate calculation of Carestream's base year carbon footprint. Some instances – such as drayage, vehicle idle time, airport usage, refrigeration, and actual utilities consumption – will need additional logic building to fully incorporate them into the existing models. Any emissions that fell outside of the scope of the original project – such as process emissions, Scope 3 emissions, and any others to be identified by Carestream – will need to be fully addressed.

The GHG Protocol will be an indispensable resource for Carestream to provide further guidance as the company moves forward with its GHG sustainability initiatives. Beyond quantifying a base year as covered in this paper, The GHG Protocol discusses managing inventory qualities, verifying GHG emissions, reporting GHG emissions, and setting GHG reduction targets.

Appendix A

Emission Factors

Generalized Transportation Emission Factors

Source: http://www.epa.gov/climateleadership/documents/emission-factors.pdf

Vehicle Type	CO2 Factor (kg / unit)	CH4 Factor (g / unit)	N2O Factor (g / unit)	Units[7]
Medium- and Heavy-duty Truck	1.456	0.018	0.011	vehicle-mile
Passenger Car A	0.368	0.018	0.013	vehicle-mile
Light-duty Truck B	0.501	0.024	0.019	vehicle-mile
Medium- and Heavy-duty Truck	0.296	0.0036	0.0022	Short Ton Mile
Rail	0.026	0.002	0.0007	Short Ton Mile
Waterborne Craft	0.042	0.0004	0.0027	Short Ton Mile
Aircraft	1.301	0	0.04	Short Ton Mile

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[7] Vehicle-mile factors are appropriate to use when the entire vehicle is dedicated to transporting the reporting company's product. Ton-mile factors are appropriate when the vehicle is shared with products from other companies.

Specific Transportation Carbon Emission Factors

Source: http://www.ghgprotocol.org/files/ghgp/Emission-Factors-from-Cross-Sector-Tools-(April 2014)_0.xlsx

WeightDistanceCarbonEmissionFactorsTable	Region	CO2	CO2 Unit - Numerator	CO2 Unit - Denominator
Air – Domestic	Other	1.96073	Kilogram	Tonne Kilometer
Air – Short Haul	Other	1.47389	Kilogram	Tonne Kilometer
Air – Long Haul	Other	0.61324	Kilogram	Tonne Kilometer
Rail	Other	0.0252	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size 3.5 - 7.5 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size 7.5 - 17 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size >17 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size Unknown	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size 3.5 - 33 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size >33 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size Unknown	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Type Unknown	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Petro – Engine Size ≤1.25 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Diesel – Engine Size ≤3.5 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – LPG or CNG – Engine Size ≤3.5 tonnes	Other	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Fuel Unknown	Other	0.297	Kilogram	Short Ton Mile
Watercraft – Large RoPax Ferry	Other	0.048	Kilogram	Tonne Kilometer
Watercraft – Shipping – Small Tanker (844 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Tanker (18371 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Very Large Tanker (100000 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Small Bulk Carrier (1720 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Bulk Carrier (14201 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile

Watercraft – Shipping – Very Large Bulk Carrier (70000 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Small Container Vessel (2500 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Container Vessel (20000 tonnes deadweight)	Other	0.048	Kilogram	Short Ton Mile
Air – Domestic	UK	1.96073	Kilogram	Tonne Kilometer
Air – Short Haul	UK	1.47389	Kilogram	Tonne Kilometer
Air – Long Haul	UK	0.61324	Kilogram	Tonne Kilometer
Rail	UK	0.0285	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Rigid – Engine Size 3.5 - 7.5 tonnes	UK	0.65946	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Rigid – Engine Size 7.5 - 17 tonnes	UK	0.41243	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Rigid – Engine Size >17 tonnes	UK	0.20027	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Rigid – Engine Size Unknown	UK	0.25115	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Articulated – Engine Size 3.5 - 33 tonnes	UK	0.15262	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Articulated – Engine Size >33 tonnes	UK	0.08678	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Articulated – Engine Size Unknown	UK	0.08869	Kilogram	Tonne Kilometer
Road Vehicle – HGV – Type Unknown	UK	0.12427	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Petrol – Engine Size < 1.305 tonnes	UK	1.173514123	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Petrol – Engine Size 1.305 - 1.74 tonnes	UK	0.820633386	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Petrol – Engine Size 1.74 - 3.5 tonnes	UK	0.496006632	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Diesel – Engine Size < 1.305 tonnes	UK	0.94952	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Diesel – Engine Size 1.305 - 1.74 tonnes	UK	0.87386	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Diesel – Engine Size 1.74 - 3.5 tonnes	UK	0.52197	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – LPG or CNG – Engine Size ≤3.5 tonnes	UK	0.61742	Kilogram	Tonne Kilometer
Road Vehicle – Light Goods Vehicle – Fuel and Engine Size Unknown	UK	0.58651	Kilogram	Tonne Kilometer
Watercraft – Large RoPax Ferry	UK	0.0495	Kilogram	Tonne Kilometer
Watercraft – Shipping – Small Tanker (844 tonnes deadweight)	UK	0.0333	Kilogram	Tonne Kilometer
Watercraft – Shipping – Large Tanker (18371 tonnes deadweight)	UK	0.0091	Kilogram	Tonne Kilometer

Watercraft – Shipping – Very Large Tanker (100000 tonnes deadweight)	UK	0.0059	Kilogram	Tonne Kilometer
Watercraft – Shipping – Small Bulk Carrier (1720 tonnes deadweight)	UK	0.0292	Kilogram	Tonne Kilometer
Watercraft – Shipping – Large Bulk Carrier (14201 tonnes deadweight)	UK	0.0079	Kilogram	Tonne Kilometer
Watercraft – Shipping – Very Large Bulk Carrier (70000 tonnes deadweight)	UK	0.0041	Kilogram	Tonne Kilometer
Watercraft – Shipping – Small Container Vessel (2500 tonnes deadweight)	UK	0.02	Kilogram	Tonne Kilometer
Watercraft – Shipping – Large Container Vessel (20000 tonnes deadweight)	UK	0.0125	Kilogram	Tonne Kilometer
Air – Domestic	US	1.527	Kilogram	Short Ton Mile
Air – Short Haul	US	1.527	Kilogram	Short Ton Mile
Air – Long Haul	US	1.527	Kilogram	Short Ton Mile
Rail	US	0.0252	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size 3.5 - 7.5 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size 7.5 - 17 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size >17 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Rigid – Engine Size Unknown	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size 3.5 - 33 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size >33 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Articulated – Engine Size Unknown	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – HGV – Type Unknown	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Petro – Engine Size ≤1.25 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Diesel – Engine Size ≤3.5 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – LPG or CNG – Engine Size ≤3.5 tonnes	US	0.297	Kilogram	Short Ton Mile
Road Vehicle – Light Goods Vehicle – Fuel Unknown	US	0.297	Kilogram	Short Ton Mile
Watercraft – Large RoPax Ferry	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Small Tanker (844 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Tanker (18371 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Very Large Tanker (100000 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile

Watercraft – Shipping – Small Bulk Carrier (1720 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Bulk Carrier (14201 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Very Large Bulk Carrier (70000 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Small Container Vessel (2500 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile
Watercraft – Shipping – Large Container Vessel (20000 tonnes deadweight)	US	0.048	Kilogram	Short Ton Mile

Specific Transportation Methane and Nitrous Oxide Emission Factors

Source: http://www.ghgprotocol.org/files/ghgp/Emission-Factors-from-Cross-Sector-Tools-(April 2014)_0.xlsx

Vehicle Type	Region	CH4	CH4 Unit - Numerator	CH4 Unit - Denominator	N2O	N2O Unit - Numerator	N2O Unit - Denominator
Aircraft	UK	0.0417	Gram	Short Ton Mile	0.0479	Gram	Short Ton Mile
Rail	UK	0.002	Gram	Short Ton Mile	0.0006	Gram	Short Ton Mile
HGV and Light Goods Vehicle	UK	0.0035	Gram	Short Ton Mile	0.0027	Gram	Short Ton Mile
Waterborne Craft	UK	0.0041	Gram	Short Ton Mile	0.0014	Gram	Short Ton Mile
Aircraft	US	0.0417	Gram	Short Ton Mile	0.0479	Gram	Short Ton Mile
Rail	US	0.002	Gram	Short Ton Mile	0.0006	Gram	Short Ton Mile
HGV and Light Goods Vehicle	US	0.0035	Gram	Short Ton Mile	0.0027	Gram	Short Ton Mile
Waterborne Craft	US	0.0041	Gram	Short Ton Mile	0.0014	Gram	Short Ton Mile
Aircraft	Other	0.0417	Gram	Short Ton Mile	0.0479	Gram	Short Ton Mile
Rail	Other	0.002	Gram	Short Ton Mile	0.0006	Gram	Short Ton Mile
HGV and Light Goods Vehicle	Other	0.0035	Gram	Short Ton Mile	0.0027	Gram	Short Ton Mile
Waterborne Craft	Other	0.0041	Gram	Short Ton Mile	0.0014	Gram	Short Ton Mile

Greenhouse Gas Emission Factors From Purchased Electricity (Country Averages)

Source: http://www.eia.gov/oiaf/1605/pdf/Appendix%20F_r071023.pdf

World by Country	Emission Inventory		
	Carbon Dioxide (Metric tons/MWh)	Methane (kg/MWh)	Nitrous Oxide (kg/MWh)
OECD North America			
Canada	0.223	0.0039	0.00351
Mexico	0.593	0.01676	0.0023
OECD Europe	**0.387**	**0.00694**	**0.00505**
Austria	0.197	0.00377	0.00207
Belgium	0.289	0.0042	0.00275
Czech Republic	0.604	0.00783	0.01074
Denmark	0.358	0.01181	0.00831
Finland	0.239	0.00395	0.00348
France	0.083	0.00136	0.00093
Germany	0.539	0.00637	0.00779
Greece	0.887	0.01453	0.01141
Hungary	0.437	0.01009	0.0054
Iceland	0.001	0.00003	0.00001
Ireland	0.699	0.01623	0.00765
Italy	0.525	0.01773	0.00482
Luxembourge	0.387	0.00694	0.00505
Netherlands	0.479	0.00998	0.00492
Norway	0.005	0.00003	0.00001
Poland	0.73	0.01084	0.01528
Portugal	0.511	0.01459	0.00711
Slovak Republic	0.297	0.00357	0.00324
Spain	0.443	0.00923	0.00631
Sweden	0.048	0.00092	0.00046
Switzerland	0.022	0.0003	0.00005
Turkey	0.584	0.01135	0.00628
United Kingdom	0.475	0.00793	0.00549
OECD Asia	**0.511**	**0.00787**	**0.00679**
Australia	0.924	0.01008	0.0129
Japan	0.417	0.00839	0.00465
Korea	0.493	0.00758	0.00672
New Zealand	0.159	0.00307	0.00084
Non-OECD Europe and Eurasia	**0.513**	**0.013**	**0.01309**
Albania	0.051	0.00251	0.0005
Armenia	0.23	0.0095	0.00095
Azerbaijan	0.613	0.03937	0.0071
Belarus	0.326	0.02441	0.00335

Bosnia-Herzegovina	0.77	0.01074	0.01544
Bulgaria	0.492	0.01087	0.01351
Croatiae	0.513	0.013	0.01309
Estonia	0.774	0.02085	0.0281
FYR of Macedonia	0.773	0.0181	0.02453
Georgia	0.137	0.00392	0.00052
Gibraltar	0.87	0.05168	0.01034
Kazakhstan	1.293	0.01888	0.0215
Kyrgyzstan	0.102	0.00209	0.00168
Latviae	0.513	0.013	0.01309
Lithuania	0.165	0.00629	0.00103
Malta	0.904	0.05977	0.01195
Republic of Moldovae	0.513	0.013	0.01309
Romania	0.426	0.01443	0.01135
Russia	0.351	0.01379	0.00668
Serbia and Montenegro	0.786	0.01291	0.01828
Slovenia	0.369	0.00674	0.00915
Tajikistan	0.038	0.00044	0.00004
Turkmenistan	0.858	0.01951	0.00195
Ukraine	0.345	0.01035	0.00999
Uzbekistan	0.497	0.01976	0.00366
Non-OECD Asia	**0.809**	**0.01607**	**0.01447**
Bangladesh	0.625	0.02353	0.00274
Brunei Darussalam	0.83	0.02089	0.00213
China	0.839	0.01458	0.01841
Chinese Taipei	0.631	0.01375	0.00882
Dem. People's Republic of Korea	0.63	0.00732	0.00747
Hong Kong	0.839	0.01458	0.01841
India	0.999	0.01664	0.01959
Indonesia	0.722	0.02041	0.00855
Malaysia	0.528	0.01984	0.00365
Myanmar	0.456	0.02336	0.00318
Nepal	0.013	0.00093	0.00019
Pakistan	0.482	0.03146	0.00549
Philippines	0.526	0.01554	0.00777
Singapore	0.731	0.03997	0.00743
Sri Lanka	0.384	0.02717	0.00543
Thailand	0.583	0.01967	0.00489
Vietnam	0.417	0.01297	0.00389
Other Asia	**0.469**	**0.02202**	**0.00656**
Middle East	**0.743**	**0.01917**	**0.00507**
Bahrain	0.876	0.01163	0.00116
Cyprus	0.851	0.03817	0.00763
Iraq	0.744	0.03809	0.00762
Islamic Republic of Iran	0.598	0.01874	0.00279
Israel	0.839	0.01769	0.01318
Jordan	0.775	0.03787	0.00746
Kuwait	0.79	0.03331	0.00633
Lebanon	0.754	0.04011	0.00802
Oman	0.856	0.01821	0.00258

Qatar	0.862	0.01156	0.00116
Saudi Arabia	0.816	0.02678	0.00487
Syria	0.655	0.03129	0.00564
United Arab Emirates	0.76	0.01205	0.00132
Yemen	1.029	0.05155	0.01031
Africa	**0.683**	**0.00977**	**0.00955**
Algeria	0.752	0.01506	0.00161
Angola	0.386	0.01341	0.00268
Benine	0.683	0.00977	0.00955
Botswanae	0.683	0.00977	0.00955
Cameroon	0.016	0.00079	0.00016
Congoe	0.683	0.00977	0.00955
Côte d'Ivoire	0.408	0.0098	0.00103
Democratic Republic of Congo	0.004	0.00011	0.00002
Egypt	0.436	0.01365	0.00177
Eritrea	0.736	0.03845	0.00769
Ethiopia	0.011	0.0004	0.00008
Gabon	0.311	0.01011	0.00177
Ghana	0.15	0.00693	0.00139
Kenya	0.393	0.01342	0.00268
Libya	1.146	0.03699	0.00705
Morocco	0.809	0.01874	0.01467
Mozambiquee	0.683	0.00977	0.00955
Namibiae	0.683	0.00977	0.00955
Nigeria	0.372	0.01444	0.00189
Senegal	0.892	0.03793	0.00758
South Africa	0.911	0.01085	0.01627
Sudan	0.54	0.01962	0.00392
Togoe	0.683	0.00977	0.00955
Tunisia	0.608	0.01566	0.00196
United Republic of Tanzania	0.108	0.00249	0.00105
Zambia	0.007	0.00017	0.00006
Zimbabwee	0.683	0.00977	0.00955
Other Africa	**0.431**	**0.01631**	**0.00435**
Central and South America	**0.204**	**0.0052**	**0.0017**
Argentina	0.317	0.0057	0.00101
Bolivia	0.401	0.0073	0.00115
Brazil	0.093	0.00251	0.00106
Chile	0.333	0.00586	0.00417
Colombia	0.157	0.0028	0.00185
Costa Rica	0.015	0.00057	0.00011
Cuba	1.104	0.03956	0.00791
Dominican Republic	0.771	0.04458	0.01017
Ecuador	0.256	0.01523	0.00304
El Salvador	0.302	0.01764	0.00353
Guatemala	0.418	0.02068	0.00593
Haiti	0.347	0.03417	0.00683
Honduras	0.29	0.01656	0.00331
Jamaica	0.819	0.03716	0.00743
Netherlands Antilles	0.793	0.0409	0.00818

Nicaragua	0.65	0.04223	0.00845
Panama	0.286	0.01651	0.0033
Paraguay	0	0	0
Peru	0.148	0.00534	0.00135
Trinidad and Tobago	0.751	0.00796	0.0008
Uruguay	0.055	0.00281	0.00056
Venezuela	0.251	0.00628	0.00106
Other Latin America	**0.584**	**0.03073**	**0.00614**

Greenhouse Gas Emission Factors From Purchased Electricity (USA Regional Averages)

Source: http://www.eia.gov/oiaf/1605/pdf/Appendix%20F_r071023.pdf

United States by State	Emission Inventory		
	Carbon Dioxide (Metric tons/MWh)	Methane (kg/MWh)	Nitrous Oxide (kg/MWh)
Region			
New York, Connecticut, Rhode Island,Massachusetts, Vermont, New Hampshire and Maine	0.466	0.02647	0.00616
New Jersey, Delaware, Pennsylvania, Maryland, West Virginia, Ohio, Indiana and Michigan	0.782	0.01404	0.01281
Illinois and Wisconsin	0.638	0.01231	0.01048
Missouri, Kentucky, Virginia, Arkansas, Tennessee, North Carolina, South Carolina, Louisiana, Mississippi, Alabama and Georgia	0.69	0.02556	0.01283
Florida	0.678	0.02437	0.00856
Texas	0.73	0.01351	0.00774
Oklahoma and Kansas	0.867	0.01315	0.01236
North Dakota, South Dakota, Nebraska, Minnesota and Iowa	0.875	0.01392	0.01414
Colorado, Utah, Nevada, Wyoming and Montana	0.909	0.01158	0.01377
New Mexico and Arizona	0.658	0.00762	0.00941
Oregon, Washington and Idaho	0.147	0.01345	0.00337
California	0.35	0.01831	0.00299
Hawaii	0.858	0.03443	0.00777
Alaska	0.749	0.01163	0.00461
U.S. Territories	0.858	0.03443	0.00777
U.S. Average	0.676	0.01815	0.01053

Stationary Combustion. CO_2 Emission Factors by fuel

Source: http://www.ghgprotocol.org/files/ghgp/Emission-Factors-from-Cross-Sector-Tools-(April 2014)_0.xlsx

Fuel		**Lower heating Value**	**Energy basis**	**Mass basis**
		TJ/Gg	**kg/TJ**	**kg/tonne**
Oil products	Crude oil	42.3	73300	3100.59
	Orimulsion	27.5	77000	2117.5
	Natural Gas Liquids	44.2	64200	2837.64
	Motor gasoline	44.3	69300	3069.99
	Aviation gasoline	44.3	70000	3101
	Jet gasoline	44.3	70000	3101
	Jet kerosene	44.1	71500	3153.15
	Other kerosene	43.8	71900	3149.22
	Shale oil	38.1	73300	2792.73
	Gas/Diesel oil	43	74100	3186.3
	Residual fuel oil	40.4	77400	3126.96
	Liquified Petroleum Gases	47.3	63100	2984.63
	Ethane	46.4	61600	2858.24
	Naphtha	44.5	73300	3261.85
	Bitumen	40.2	80700	3244.14
	Lubricants	40.2	73300	2946.66
	Petroleum coke	32.5	97500	3168.75
	Refinery feedstocks	43	73300	3151.9
	Refinery gas	49.5	57600	2851.2
	Paraffin waxes	40.2	73300	2946.66
	White Spirit/SBP	40.2	73300	2946.66
	Other petroleum products	40.2	73300	2946.66
Coal products	Anthracite	26.7	98300	2624.61
	Coking coal	28.2	94600	2667.72
	Other bituminous coal	25.8	94600	2440.68
	Sub bituminous coal	18.9	96100	1816.29
	Lignite	11.9	101000	1201.9
	Oil shale and tar sands	8.9	107000	952.3

	Brown coal briquettes	20.7	97500	2018.25
	Patent fuel	20.7	97500	2018.25
	Coke oven coke	28.2	107000	3017.4
	Lignite coke	28.2	107000	3017.4
	Gas coke	28.2	107000	3017.4
	Coal tar	28	80700	2259.6
	Gas works gas	38.7	44400	1718.28
	Coke oven gas	38.7	44400	1718.28
	Blast furnace gas	2.47	260000	642.2
	Oxygen steel furnace gas	7.06	182000	1284.92
Natural gas	Natural gas	48	56100	2692.8
Other wastes	Municipal waste (Non biomass fraction)	10	91700	917
	Industrial wastes	NA	143000	NA
	Waste oils	40.2	73300	2946.66
Biomass	Wood or Wood waste	15.6	112000	1747.2
	Sulphite lyes (Black liqour)	11.8	95300	1124.54
	Other primary solid biomass fuels	11.6	100000	1160
	Charcoal	29.5	112000	3304
	Biogasoline	27	70800	1911.6
	Biodiesels	27	70800	1911.6
	Other liquid biofuels	27.4	79600	2181.04
	Landfill gas	50.4	54600	2751.84
	Sludge gas	50.4	54600	2751.84
	Other biogas	50.4	54600	2751.84
	Municipal wastes (Biomass fraction)	11.6	100000	1160
	Peat	9.76	106000	1034.56

Stationary Combustion. CH_4 Emission Factors by Fuel

Source: http://www.ghgprotocol.org/files/ghgp/Emission-Factors-from-Cross-Sector-Tools-(April 2014)_0.xlsx

Fuel		Lower heating Value	Energy basis	Mass basis
		TJ/Gg	kg/TJ	kg/tonne
Oil products	Crude oil	42.3	10	0.423
	Orimulsion	27.5	10	0.275
	Natural Gas Liquids	44.2	10	0.442
	Motor gasoline	44.3	10	0.443
	Aviation gasoline	44.3	10	0.443
	Jet gasoline	44.3	10	0.443
	Jet kerosene	44.1	10	0.441
	Other kerosene	43.8	10	0.438
	Shale oil	38.1	10	0.381
	Gas/Diesel oil	43	10	0.43
	Residual fuel oil	40.4	10	0.404
	Liquified Petroleum Gases	47.3	5	0.2365
	Ethane	46.4	5	0.232
	Naphtha	44.5	10	0.445
	Bitumen	40.2	10	0.402
	Lubricants	40.2	10	0.402
	Petroleum coke	32.5	10	0.325
	Refinery feedstocks	43	10	0.43
	Refinery gas	49.5	5	0.2475
	Paraffin waxes	40.2	10	0.402
	White Spirit/SBP	40.2	10	0.402
	Other petroleum products	40.2	10	0.402
Coal products	Anthracite	26.7	10	0.267
	Coking coal	28.2	10	0.282
	Other bituminous coal	25.8	10	0.258
	Sub bituminous coal	18.9	10	0.189
	Lignite	11.9	10	0.119
	Oil shale and tar sands	8.9	10	0.089

	Brown coal briquettes	20.7	10	0.207
	Patent fuel	20.7	10	0.207
	Coke oven coke	28.2	10	0.282
	Lignite coke	28.2	10	0.282
	Gas coke	28.2	5	0.141
	Coal tar	28	10	0.28
	Gas works gas	38.7	5	0.1935
	Coke oven gas	38.7	5	0.1935
	Blast furnace gas	2.47	5	0.01235
	Oxygen steel furnace gas	7.06	5	0.0353
Natural gas	Natural gas	48	5	0.24
Other wastes	Municipal waste (Non biomass fraction)	10	300	3
	Industrial wastes	NA	300	NA
	Waste oils	40.2	300	12.06
Biomass	Wood or Wood waste	15.6	300	4.68
	Sulphite lyes (Black liqour)	11.8	3	0.0354
	Other primary solid biomass fuels	11.6	300	3.48
	Charcoal	29.5	200	5.9
	Biogasoline	27	10	0.27
	Biodiesels	27	10	0.27
	Other liquid biofuels	27.4	10	0.274
	Landfill gas	50.4	5	0.252
	Sludge gas	50.4	5	0.252
	Other biogas	50.4	5	0.252
	Municipal wastes (Biomass fraction)	11.6	300	3.48
	Peat	9.76	10	0.0976

Stationary Combustion. N_2O Emission Factors by Fuel

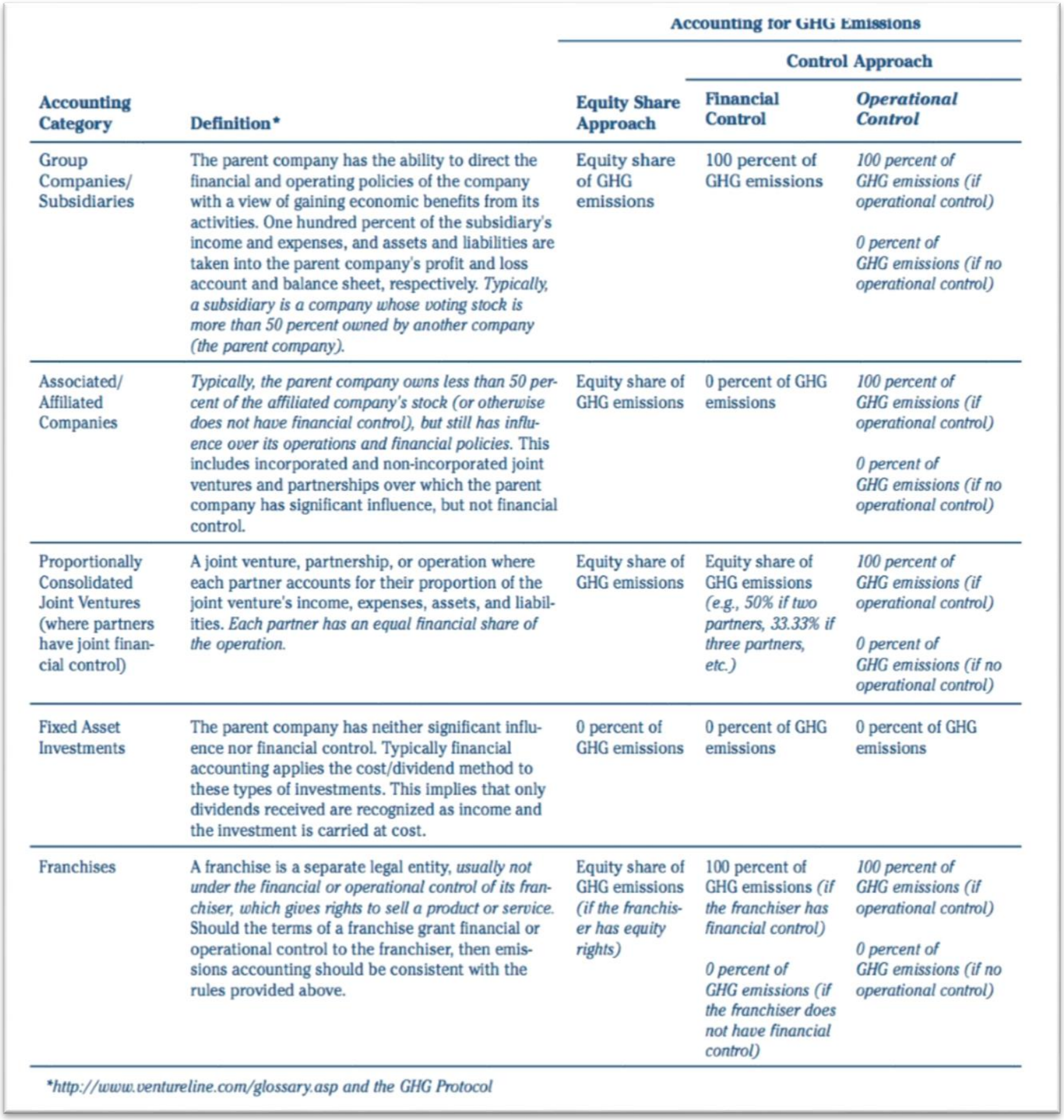
Source:http://www.ghgprotocol.org/files/ghgp/Emission-Factors-from-Cross-Sector-Tools-(April 2014)_0.xlsx

Fuel		**Lower heating Value**	**Energy basis**	**Mass basis**
		TJ/Gg	**kg/TJ**	**kg/tonne**
Oil products	Crude oil	42.3	0.6	0.02538
	Orimulsion	27.5	0.6	0.0165
	Natural Gas Liquids	44.2	0.6	0.02652
	Motor gasoline	44.3	0.6	0.02658
	Aviation gasoline	44.3	0.6	0.02658
	Jet gasoline	44.3	0.6	0.02658
	Jet kerosene	44.1	0.6	0.02646
	Other kerosene	43.8	0.6	0.02628
	Shale oil	38.1	0.6	0.02286
	Gas/Diesel oil	43	0.6	0.0258
	Residual fuel oil	40.4	0.6	0.02424
	Liquified Petroleum Gases	47.3	0.1	0.00473
	Ethane	46.4	0.1	0.00464
	Naphtha	44.5	0.6	0.0267
	Bitumen	40.2	0.6	0.02412
	Lubricants	40.2	0.6	0.02412
	Petroleum coke	32.5	0.6	0.0195
	Refinery feedstocks	43	0.6	0.0258
	Refinery gas	49.5	0.1	0.00495
	Paraffin waxes	40.2	0.6	0.02412
	White Spirit/SBP	40.2	0.6	0.02412
	Other petroleum products	40.2	0.6	0.02412
Coal products	Anthracite	26.7	1.5	0.04005
	Coking coal	28.2	1.5	0.0423
	Other bituminous coal	25.8	1.5	0.0387
	Sub bituminous coal	18.9	1.5	0.02835
	Lignite	11.9	1.5	0.01785
	Oil shale and tar sands	8.9	1.5	0.01335
	Brown coal briquettes	20.7	1.5	0.03105

	Patent fuel	20.7	1.5	0.03105
	Coke oven coke	28.2	1.5	0.0423
	Lignite coke	28.2	1.5	0.0423
	Gas coke	28.2	0.1	0.00282
	Coal tar	28	1.5	0.042
	Gas works gas	38.7	0.1	0.00387
	Coke oven gas	38.7	0.1	0.00387
	Blast furnace gas	2.47	0.1	0.000247
	Oxygen steel furnace gas	7.06	0.1	0.000706
Natural gas	Natural gas	48	0.1	0.0048
Other wastes	Municipal waste (Non biomass fraction)	10	4	0.04
	Industrial wastes	NA	4	NA
	Waste oils	40.2	4	0.1608
Biomass	Wood or Wood waste	15.6	4	0.0624
	Sulphite lyes (Black liqour)	11.8	2	0.0236
	Other primary solid biomass fuels	11.6	4	0.0464
	Charcoal	29.5	1	0.0295
	Biogasoline	27	0.6	0.0162
	Biodiesels	27	0.6	0.0162
	Other liquid biofuels	27.4	0.6	0.01644
	Landfill gas	50.4	0.1	0.00504
	Sludge gas	50.4	0.1	0.00504
	Other biogas	50.4	0.1	0.00504
	Municipal wastes (Biomass fraction)	11.6	4	0.0464
	Peat	9.76	1.4	0.013664

Appendix B

Overview of Organizational Boundaries



		Accounting for GHG Emissions		
			Control Approach	
Accounting Category	**Definition***	**Equity Share Approach**	**Financial Control**	***Operational Control***
Group Companies/ Subsidiaries	The parent company has the ability to direct the financial and operating policies of the company with a view of gaining economic benefits from its activities. One hundred percent of the subsidiary's income and expenses, and assets and liabilities are taken into the parent company's profit and loss account and balance sheet, respectively. *Typically, a subsidiary is a company whose voting stock is more than 50 percent owned by another company (the parent company).*	Equity share of GHG emissions	100 percent of GHG emissions	*100 percent of GHG emissions (if operational control)* *0 percent of GHG emissions (if no operational control)*
Associated/ Affiliated Companies	*Typically, the parent company owns less than 50 percent of the affiliated company's stock (or otherwise does not have financial control), but still has influence over its operations and financial policies.* This includes incorporated and non-incorporated joint ventures and partnerships over which the parent company has significant influence, but not financial control.	Equity share of GHG emissions	0 percent of GHG emissions	*100 percent of GHG emissions (if operational control)* *0 percent of GHG emissions (if no operational control)*
Proportionally Consolidated Joint Ventures (where partners have joint financial control)	A joint venture, partnership, or operation where each partner accounts for their proportion of the joint venture's income, expenses, assets, and liabilities. *Each partner has an equal financial share of the operation.*	Equity share of GHG emissions	Equity share of GHG emissions *(e.g., 50% if two partners, 33.33% if three partners, etc.)*	*100 percent of GHG emissions (if operational control)* *0 percent of GHG emissions (if no operational control)*
Fixed Asset Investments	The parent company has neither significant influence nor financial control. Typically financial accounting applies the cost/dividend method to these types of investments. This implies that only dividends received are recognized as income and the investment is carried at cost.	0 percent of GHG emissions	0 percent of GHG emissions	0 percent of GHG emissions
Franchises	A franchise is a separate legal entity, *usually not under the financial or operational control of its franchiser, which gives rights to sell a product or service.* Should the terms of a franchise grant financial or operational control to the franchiser, then emissions accounting should be consistent with the rules provided above.	Equity share of GHG emissions *(if the franchiser has equity rights)*	100 percent of GHG emissions *(if the franchiser has financial control)* *0 percent of GHG emissions (if the franchiser does not have financial control)*	*100 percent of GHG emissions (if operational control)* *0 percent of GHG emissions (if no operational control)*

*http://www.ventureline.com/glossary.asp and the GHG Protocol

Source: http://www.epa.gov/climateleadership/documents/resources/design_princ_ch3.pdf

Appendix C

Acronym Glossary

CDP - Carbon Disclosure Project

CH_4 - Methane

CO_2 - Carbon Dioxide

CO_2e - Carbon Dioxide Equivalence

CRU - Climate Research Unit

DEFRA - Department for Environmental Food and Rural Affairs

EIA - Energy Information Administration

EPA - Environmental Protection Agency

F-Gas - Fluorinated Gas

GHG - Greenhouse Gas

GWP - Global Warming Potential

HFCs - Hydrofluorocarbons

IPCC - International Panel on Climate Change

kBTU - Kilo British Thermal Units

MWh - Megawatt Hour

N_2O - Nitrous Oxide

NF_3 - Nitrogen Trifluoride

PFCs - Perfluorocarbons

PwC - PricewaterhouseCoopers

SF_6 - Sulfur Hexafluoride

UN - United Nations

UNEP - United Nations Environmental Program

UNFCCC - United Nations Framework Convention on Climate Change

WMO - World Meteorology Organization

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