The Restaurant GHG Guidelines: An Operational Greenhouse Gas Emissions Accounting Protocol for Restaurants

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Dedication

This thesis is dedicated to Shengyin Xu for her continued support and inspiration in the pursuit of this research.

Abstract

This thesis proposes the Restaurant GHG Guideline, a holistic protocol, to document and assess the greenhouse gas emissions generated by processes that occur both directly and indirectly in the operation of a restaurant. Existing greenhouse gas (GHG) accounting protocols either have a narrow focus on emissions from processes that occur directly on the site of the building and indirectly as a result of purchased energy consumption on site or offer only general guidance for identifying emissions sources throughout organizations' supply chains. For restaurant operations, many offsite processes are necessary to produce goods or services that are critical to their economic success, and therefore carry much weight in management decisions. By including emissions sources throughout a restaurant's supply chain, this guideline identifies significant hot-spot emissions sources. It provides calculation methods for identifying GHG emissions generated at the scale of individual components, creating a more effective inventory for operators to develop targeted reduction initiatives. Historic operational data from a test case restaurant is used to illustrate how the specificity of the tool can help restaurant operators identify GHG emissions hot-spots at the level of individual components. By utilizing this guideline to identify these emission sources, restaurant operators can then create targeted reduction strategies.

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THESIS STATEMENT AND RESEARCH GOALS

This thesis proposes the Restaurant GHG Guideline, a holistic protocol, to document and assess the greenhouse gas emissions generated by processes that occur both directly and indirectly in the operation of a restaurant. Existing greenhouse gas (GHG) accounting protocols have a narrow focus on emissions from processes that occur directly on the site of the building or indirectly as a result of purchased energy consumption on site. Newer protocol tools like the GHG Protocol Scope 3 Guidelines are helping organizations map the emissions generated throughout their supply chains. For restaurant operations, many offsite processes are necessary to produce goods or services that are critical to their economic success. Combined, these additional offsite processes make up a large portion of the costs associated with operating a restaurant, and therefore carry much weight in management decisions. By including emissions sources throughout a restaurant's supply chain, this guideline identifies significant hot-spot emissions sources. It provides calculation methods for identifying GHG emissions generated at the scale of individual components, creating a more effective inventory for operators to develop targeted reduction initiatives.

Key aspects of the Restaurant GHG Guideline Include:

- Holistic inventory boundary based on existing GHG accounting protocols, tailored to the unique operations of a restaurant
- GHG emissions inventory organized around a restaurant-centric supply chain
- Calculation methods for estimating GHG emission generation at the level of individual components (food ingredients, food prep equipment, waste streams, etc.)

INTRODUCTORY TOPICS

The following sections provide context to the proposal for a GHG inventory tool focused on restaurant operations. They are included to answer the question of what is the broad GHG emission context, why should they be important to restaurants, and what are the unique GHG operational characteristics of restaurants that make them a good typology deserving of a dedicated GHG tracking guideline. They outline a brief history of GHG emissions tracking efforts, identify the critical GHGs that would be covered under this proposal, and discuss the current state of US national emissions. Additionally there is a section that expands on why the restaurant building type is a typology that deserves attention in the field of sustainable design architecture.

GHG Emissions AND THE NATIONAL INVENTORY AS IT RELATES TO RESTAURANTS

Greenhouse gases (GHGS) AND GLOBAL WARMING POTENTIALS

Global warming and its potential impact on human populations has been a driver for much work in the field of sustainable building design. Specifically, the Intergovernmental Panel on Climate Change (IPCC) has identified six gasses, N_2O, CH_4, CO_2, SF_6, HFCs, and PFCs which when emitted to the atmosphere have a significant potential to increase the global temperature. These six gasses are often referred to as greenhouse gasses (GHG) given their potential for increasing the global temperature. In its identification of these six gases, the IPCC has also produced ratios that equate a given amount of each gas to an equivalent amount of CO_2 in terms of how much potential that gas has for impacting climate change. According to the IPCC,

> “GHGs differ in their warming influence (radiative forcing) on the global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2” [1]

These equivalencies are known as global warming potentials (GWP), which have been revised by the IPCC in reports from 1995, 2001, 2007, and most recently in 2014. These GWPs are useful for reporting all greenhouse gas emissions of all six gases in relation to the impacts of CO_2 with a single unit, Carbon Dioxide equivalent emissions (CO_2e) that are usually reported in metric tons per year. This proposed method follows this practice. Furthermore, not all six GHGs are produced through the typical actions of a restaurant, for example PFCs are exclusively emitted as a result of Aluminum production. SF6 and many of the HFCs are utilized in industrial processes that are not applicable to restaurants. Figure 1 highlights the four GHGs and corresponding GWPs that are included for this tool with a green border.

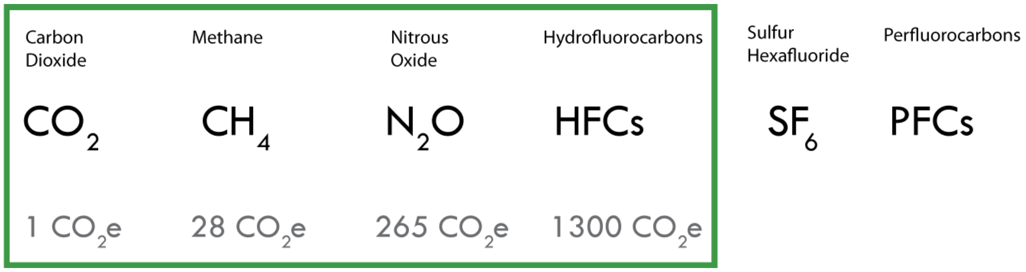

Figure 1. Greenhouse Gasses and Global Warming Potentials (Box indicates those gasses considered for a the restaurant’s Inventory)

The U.S. Environmental Protection Agency (U.S. EPA) produces an annual report that inventories the greenhouse gas emissions and sinks as part of a ratified agreement from United Nations Framework Convention on Climate change in 1992. This inventory follows a set of guidelines and best practices outlined by the Intergovernmental Panel on Climate Change (IPCC) that help to "identif[y] and quantif[y] a country's primary anthropogenic sources and sinks of greenhouse gases"[2]. The inventory covers the six greenhouse gases identified by IPCC and reports the emissions of all gases in

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[1] (Pachauri & Reisinger, 2007)

[2] (U.S. Environmental Protection Agency, 2015)

teragrams of CO_2 equivalents (Tg CO_2e) based on the global warming potentials of the IPCC Second Assessment report. This inventory is important in the context of this proposed protocol for the correlation between significant sources of national GHG emissions and those processes that a restaurant utilizes in its operations.

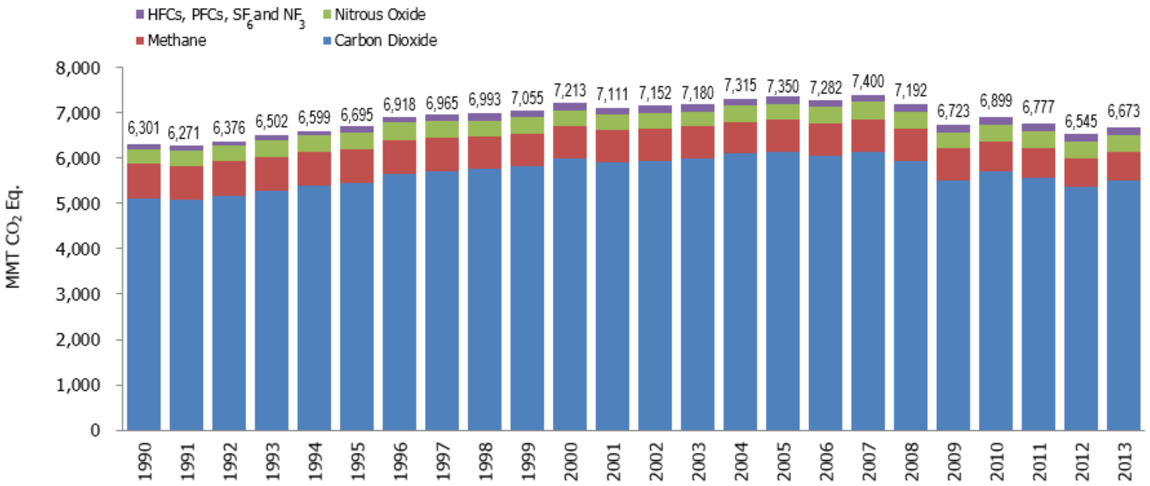
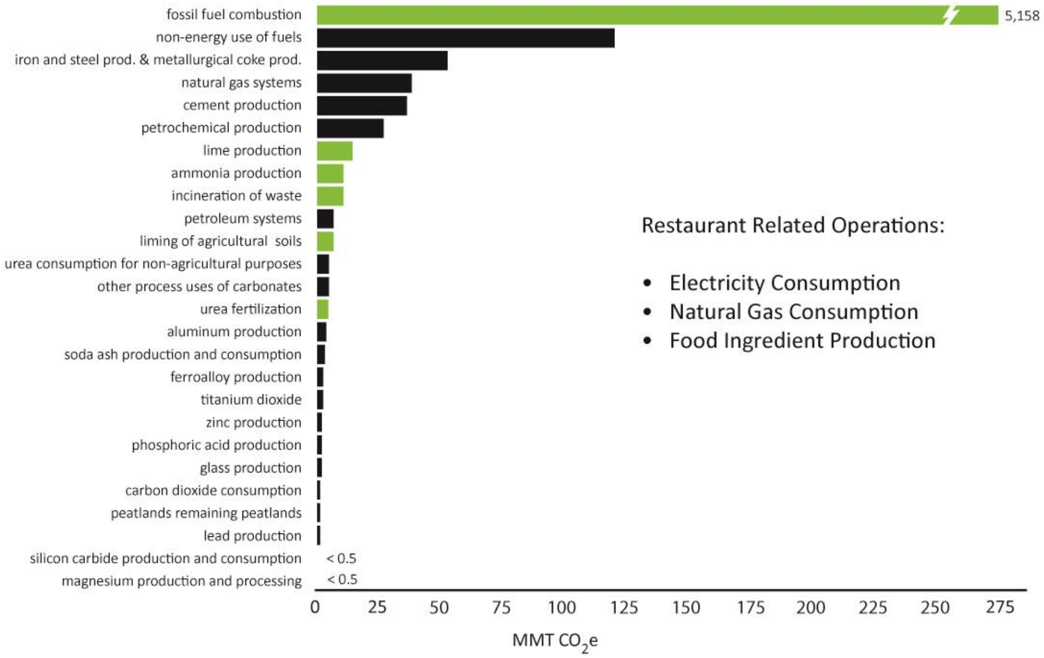


Figure 2. US Emissions CO_2 Equivalent Emissions 1990 - 2013

In general, significant connections between a restaurant's GHG inventory and the national GHG inventory include:

CO_2 emissions from building operations and transportation,
CH_4 emissions from Agriculture production and Waste treatment
N_2O emissions from Agriculture production,
HFCS emissions from refrigeration equipment

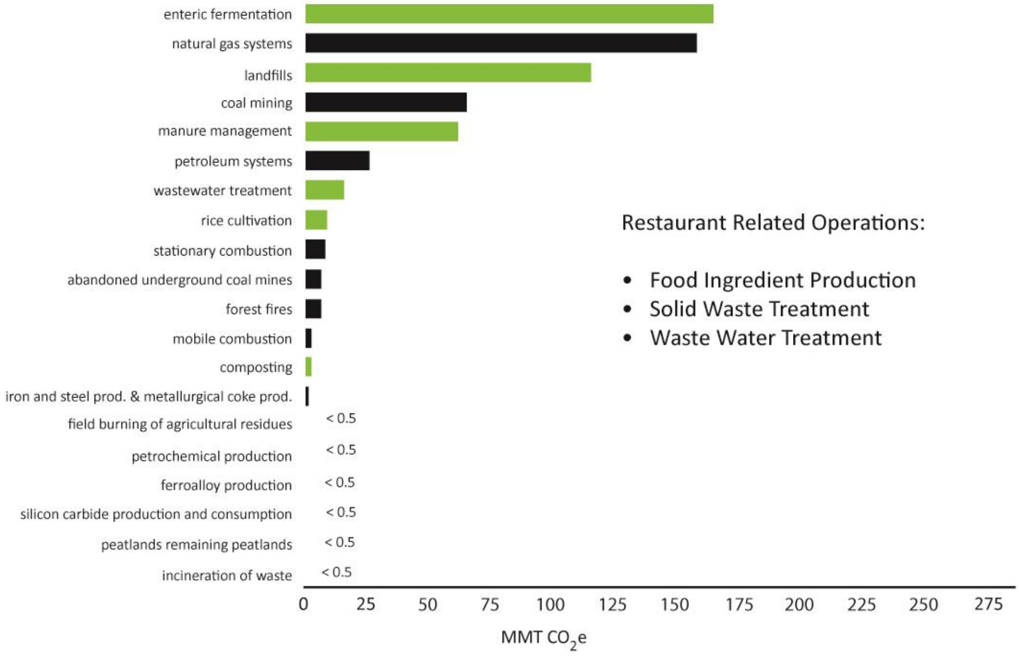
The following figures depict the top emissions sources for each GHG. Activities that have a connection to the operations of restaurants are highlighted in green.



Restaurant Related Operations:

- Electricity Consumption
- Natural Gas Consumption
- Food Ingredient Production

Figure 3. U.S. Sources of CO_2 Emissions in 2013



Restaurant Related Operations:

- Food Ingredient Production
- Solid Waste Treatment
- Waste Water Treatment

Figure 4. U.S. Sources of CH_4 Emissions in 2013

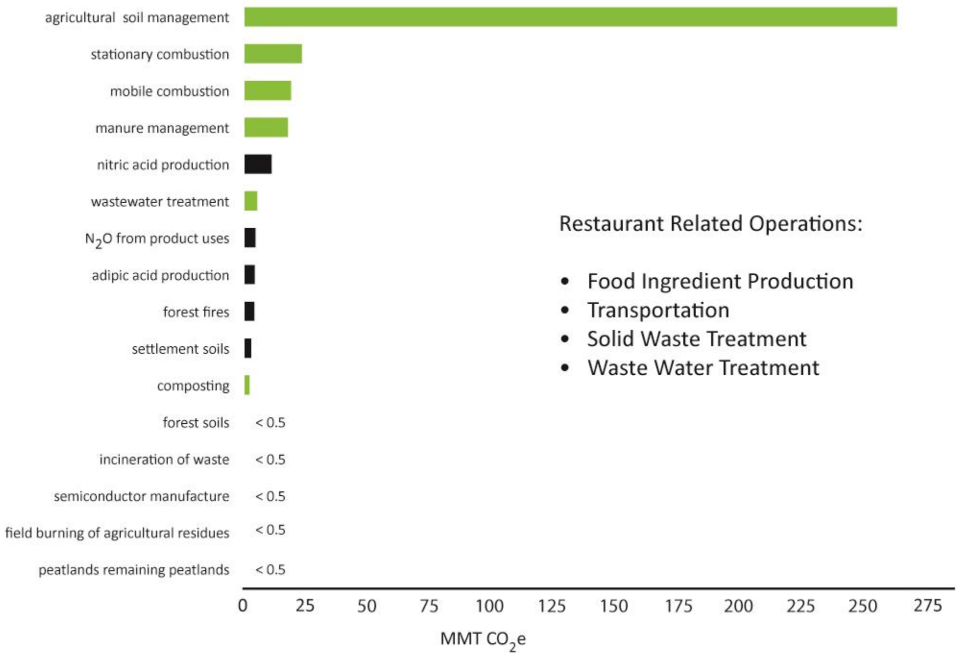


Figure 5. U.S. Sources of N_2O Emissions in 2013

On a whole, the sources identified for their potential correlation with restaurant operational processes make up a significant proportion of the sources included in the US GHG emissions and sinks inventory. While the amount of emissions generated by restaurants may or may not be significant in terms of the whole national emissions inventory, the correlation suggests that restaurants operations rely on processes that are significant sources of GHG emissions and therefore the use of GHG emissions as a metric for assessing the efficiency of a restaurant's operations may be useful.

THE IMPACT OF GHG EMISSIONS ON RESTAURANT OPERATIONS

The concern of the business community for tracking and reducing GHG emissions can be attributed to the perception of risk. This risk associated with GHG emissions comes from several sources. The National Restaurant Association’s annual sustainability report cites sustainability as being the most important menu trend in for 2015 as well as an important factor in customers’ decisions on where to dine (NRA). Remaining on trend with customers might be the initial motivation behind a restaurant operator measuring and discussing GHG emissions, however missing out on market trends is not the only risk associated with GHG emissions and restaurant operations.

In the case of global agricultural and fishery production, climate change is projected to have mixed impacts on yields and food availability. According to the IPCC, moderate temperature rise would have differing impacts to food production depending on the climatic zone. For farming in low-latitude regions, “moderate temperature increases (1°-2°C) are likely to have negative yield impacts for major cereals”[3]. In mid-latitude to high-latitude regions, “moderate to medium local increases in temperature (1°-3°C), along with associated carbon dioxide increase and rainfall changes, can have small beneficial impacts on crop yields”[4]. However, if the temperature rise is greater than 3°C this disparity is no longer evident and the climate change has “increasingly negative impacts on all regions”[5]. Furthermore, the IPCC forecasts that the climate change will also have negative impacts on the production of crops and livestock due to increases in the frequency and severity of heat stress, droughts, and flooding events[6]. Fisheries also face adversity as the rise in temperatures is expected to effect the distribution and productivity of fish species, particularly freshwater and diadromous species like salmon. The overall result of these climate change induced impacts on the global food production networks could be an increased reliance on the transportation of crops from productive regions to those made less productive along with greater production volatility due to the extreme climate events.

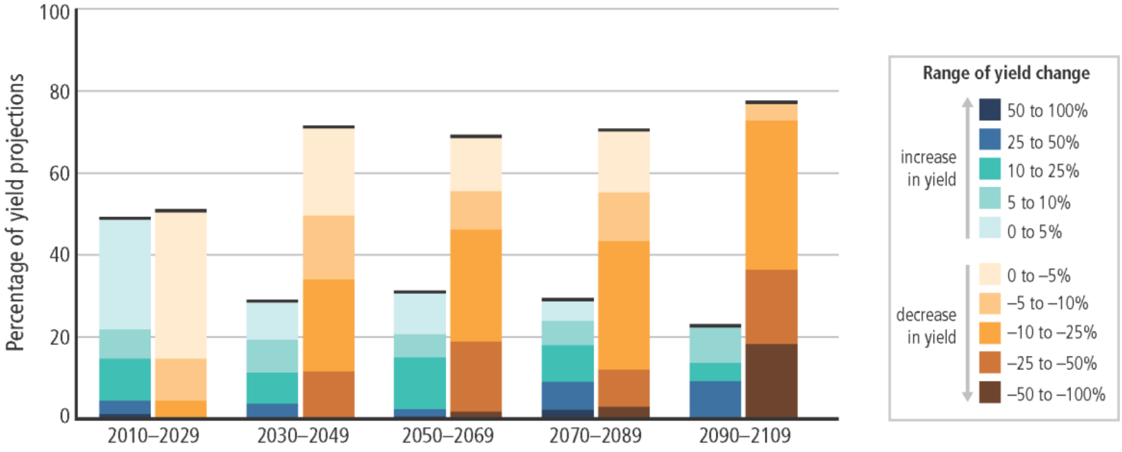


Figure 6: Potential impact on global crop yields

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[3] (Easterling, et al., 2007)

[4] (Easterling, et al., 2007)

[5] (Easterling, et al., 2007)

[6] (Easterling, et al., 2007)

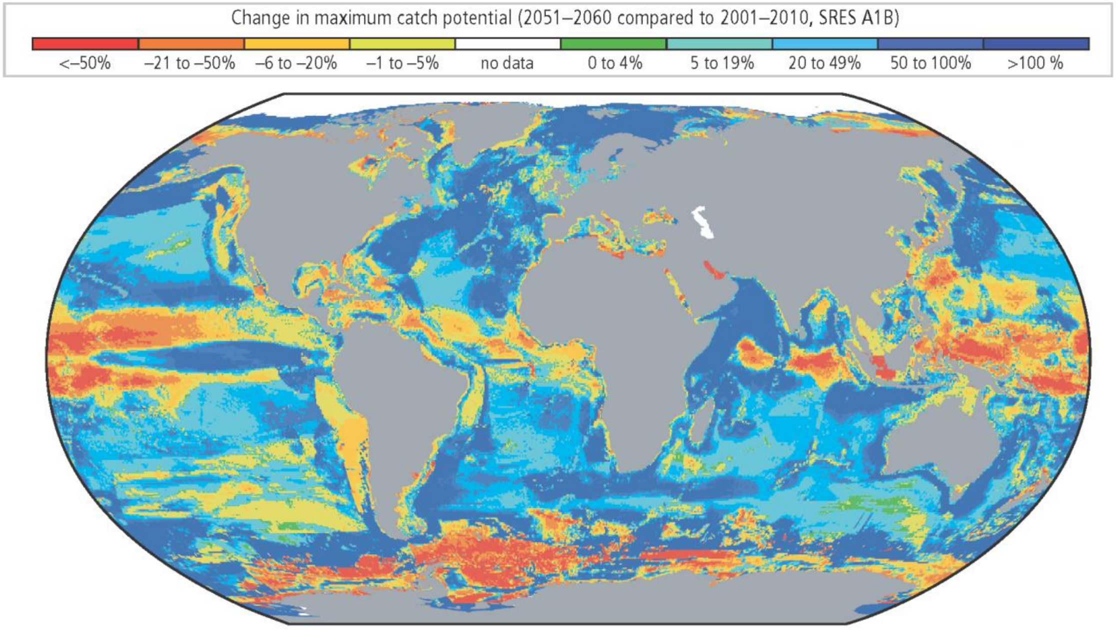

Figure 7: Potential impact on global fisheries, source IPCC Fifth Assessment Report Synthesis Report

Customer approval of changes in menu items and actual climate change impacts on food item production are two sources of risk that restaurant businesses face in addition to the impact of emissions reduction legislation. While a global consensus is growing and individual countries, states and cities have begun to set targets for reducing their GHG emissions. The emerging strategy for achieving these reductions is to associate the emissions with an actual financial cost that must be paid by the emitter. Both cap and trade, where a limit is set and a market is created for trading emissions credits, as well as carbon taxation proposals could have financial implications for businesses. Businesses are looking to GHG emissions accounting programs to help them access this financial risk and prepare to operate within "carbon-constrained" markets[7].

Accessing a company's GHG emissions also has additional benefits for business owners. The process often serves as an indirect energy audit since the focus of most GHG emissions accounting tools is on the emissions associated with on-site fuel combustion or purchase of offsite - generated energy. Examining annual energy consumption of equipment and operational inefficiencies can be performed using the same data that is gathered during a GHG emissions assessment. Thus GHG emissions accounting can both prepare a business for financial risk associated with future emissions legislation, but also help to improve short term efficiency.

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[7] (Gell, 2008)

RESTAURANT BUILDING TYPE

The restaurant building type is the subject for this GHG accounting tool. This type has not received much attention from the sustainable design community, yet the potential impact from its intense operations and position at the apex of building design, agriculture production, social interaction, and community identity suggests that this type of building is a good candidate for a customized tool. Today most of the sustainability discussion around restaurants deals with the food ingredients that are being served and how they are produced on farms. Though this is an important aspect of the operations, the physical building and equipment is rarely addressed. Furthermore, designers often concentrate exclusively on the theme or aesthetic atmosphere of the building without much regard for the resource intensive operations that are required for the success of the restaurant. This oversight on the part of the design community and building operators is not intentional but more likely the result of priorities focused on maintaining financial sustainability over a more broad approach to economic, environmental and social sustainability.

ENERGY INTENSITY

The intense operations of restaurant buildings are not often understood by designers. According to national surveys of commercial building types, food service buildings used for preparation and sale of food and beverages for consumption are among the most energy intensive (kbtu/sf) commercial building type (see figure 8).

> *Food Service Buildings are those buildings used for the preparation and sale of food and beverages for consumption. They include restaurants, cafeterias, bars; catering service or reception hall; coffee, bagel, and doughnut shops; ice cream and frozen yogurt shops*[8]

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[8] (U.S. Energy Information Administration)

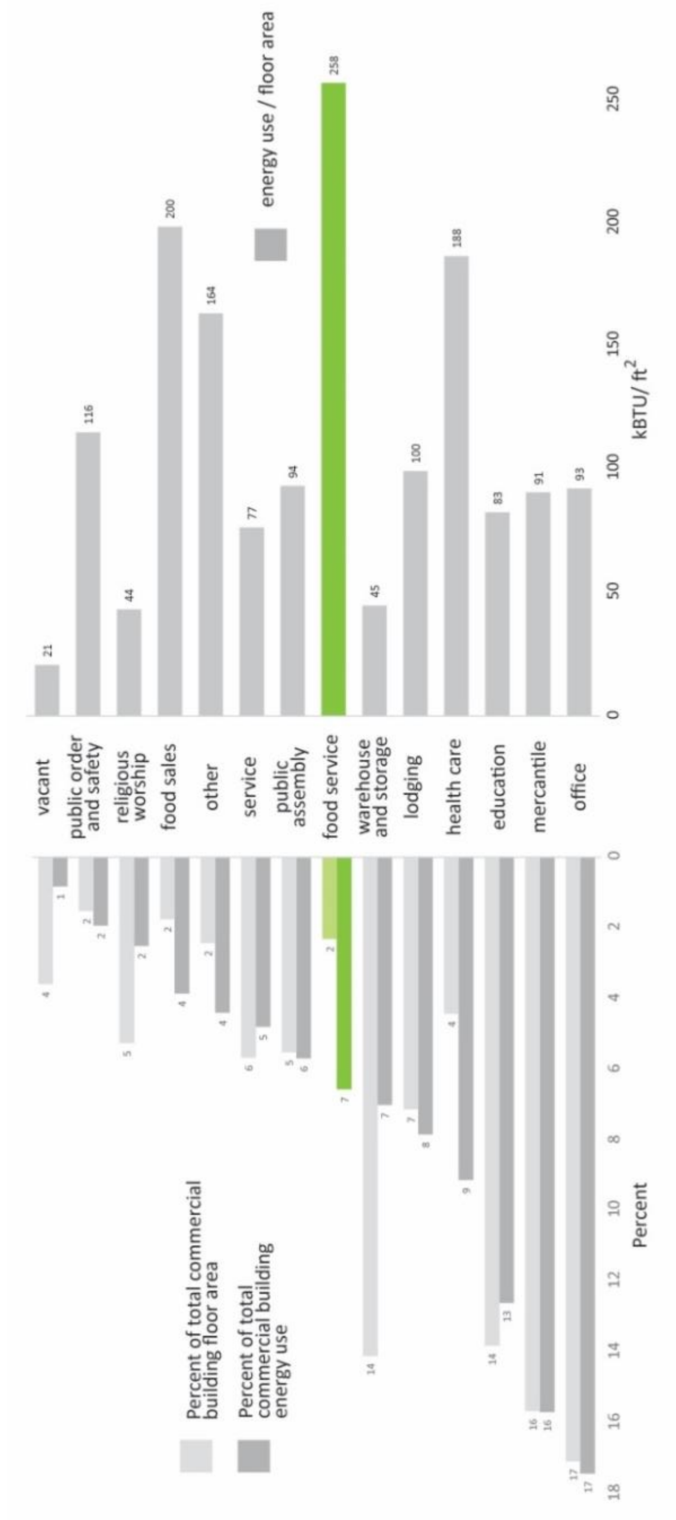

Figure 8. Energy Intensity of Food Service Buildings Compared to other Commercial Buildings

GHG emissions associated with this energy consumption might vary based on the type of energy, but overall significant energy consumption often results in significant GHG emissions. There are several aspects of restaurant operations that contribute to its consumption of energy. The Food Service Technology Center in collaboration with Pacific Gas and Electric has conducted several energy audits of restaurants in the State of California. Their research suggests that food preparation and HVAC are the main categories of energy consumption. Additionally, food storage, lighting, space heating, domestic water heating, and ventilation can all be considered as significant sources for energy consumption.[9]

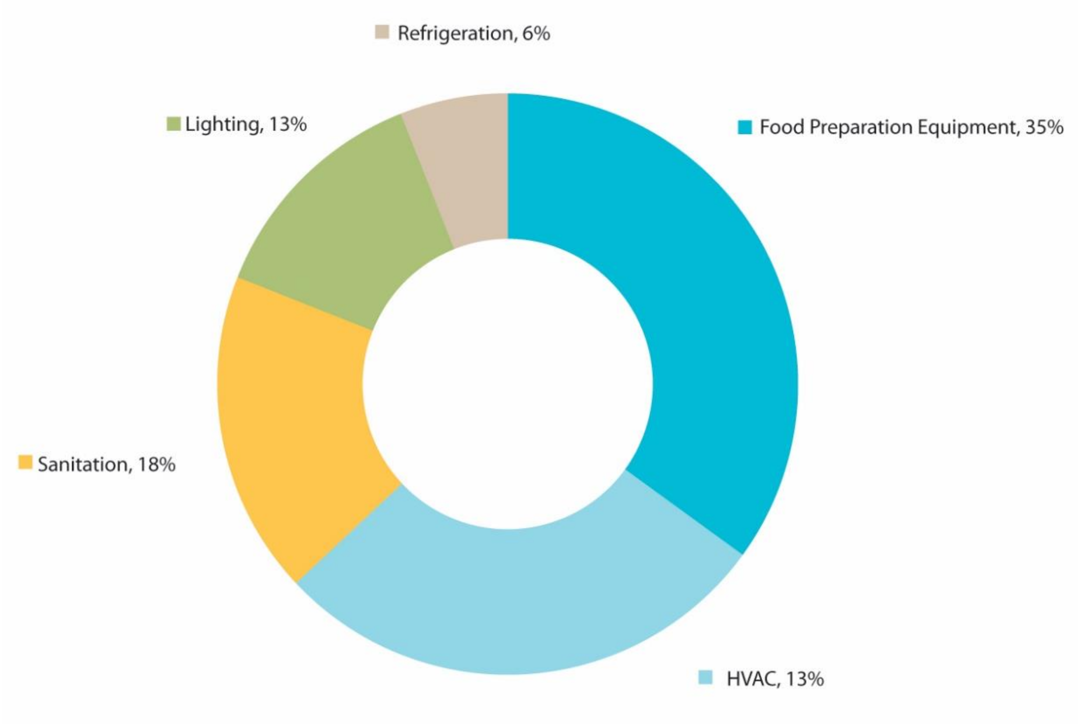

Figure 9. Typical Energy End Use by Restaurants

Food Preparation Equipment

The type, size and quantity of food preparation equipment can vary significantly by type of restaurant, however, the equipment itself is often the main source of energy consumption. Restaurant equipment used in the preparation of food is typically relies upon through the combustion of fossil fuel, usually natural gas, or electricity. The amount of energy consummed by an appliance is determined by the efficiency of the equipment but also by the energy type. Energy consumption ratios are frequently used in the Food Service industry to compare operational costs associated with equipment[10]. In its

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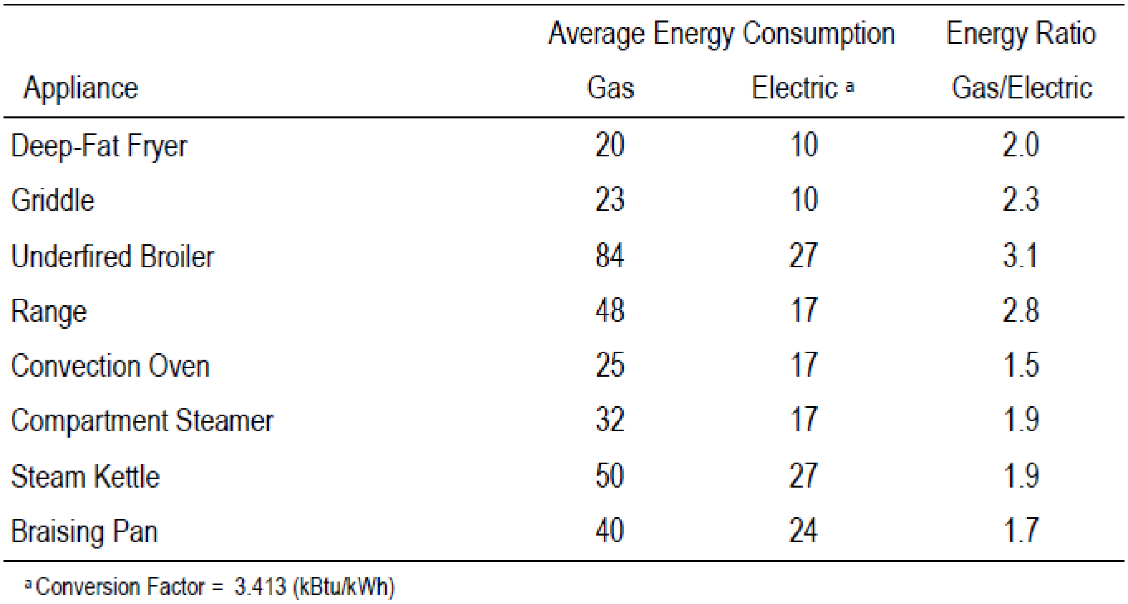
[9] (Bell, 2006)

[10] (Fischer, et al., 2002)

assesment of food service equipment technology, the FSTC provides average energy consumption ratios that depict the common trend of electric equipment operating at more efficient levels than their natural gas based counterparts. These ratios along with the cost of each energy source are helpful information for restaurant owners and chefs decisions in purchasing pieces of equipment. However, the GHG emissions associated with the energy consumption could also be used to influcence the decision since electricity is more GHG intensive than natural gas.



	Average Energy Consumption		Energy Ratio
Appliance	Gas	Electric [a]	Gas/Electric
Deep-Fat Fryer	20	10	2.0
Griddle	23	10	2.3
Underfired Broiler	84	27	3.1
Range	48	17	2.8
Convection Oven	25	17	1.5
Compartment Steamer	32	17	1.9
Steam Kettle	50	27	1.9
Braising Pan	40	24	1.7

[a] Conversion Factor = 3.413 (kBtu/kWh)

Figure 10. Gas and Electric Equipment Energy Consumption Ratios

In addditon to the national trends in energy intensity, restaurant energy consumption is also influcenced by local building and health regulations. These codes outline several requirements for food establishments that can directly impact the amount of energy consumed by the restaurant. In particular the regulations of the Mechanical Code effect the ventilation exhaust and supply rates necessary for maintaining safe food preparation while the Department of Health requires specific amounts of illumination throughout spaces within the restaurant.

Ventilation

Ventilation for restaurant operations requires a significant amount of energy. The use of fans, coils, and ducts for tempering and supplying fresh air to the dining space is comparable to most building types. However, the kitchen requires additional ventilation equipment including exhaust hoods to remove harmful gasses and excess heat as well as supply ducts, coils and fans for tempered make up air to replace the volume of air that is exhausted. There are different performance requirements for exhaust hoods depending upon the type of food and the process by which it is being cooked. The Minnesota State Building Code distinguishes between Type I hoods which are necessary for cooking food items that contain fat and produce smoke and grease versus the Type II hoods used for other food ingredients to remove heat and water vapor[11]. Both of these types require that make up air be supplied at a rate equivalent to the rate of exhaust to maintain neutral air pressure inside the building. Furthermore the method for calculating ventilation rates follows the Minnesota mechanical code and ASHRAE standards.

Illumination

The Minnesota Department of Health also has regulations that impact the energy consumption by restaurants. The Department of Health regulates the amount of illumination in various spaces within food service establishements. While it does not restrict the type of lamp or light fixture, it does define a minimum level of illumination which will in turn require energy consumption depending on the efficency of the light fixture.

Space	Required Minimum Amount of Illumination (foot candles)
Food Preparation	50
Utensil Cleaning	50
Walk-in Refrigerators and/or Freezers	10
Bar Sinks	20
Food Storage	20
Utensil Storage	20
Toilets	20
Dressing rooms	20
All remaining rooms	20 minimum

Figure 11. Minimum Illumination Requirements for Spaces within Restaurants

WATER INTENSITY

In addition to consuming large amounts of energy per building area, restaurants also consume large amounts of water in their operations. This water consumption can be broken down into cooking and food preparation, domestic water uses, and sanitation. Water consumption is an integral part of the food preparation process where it is used

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[11] (Girard, et al., 2009)

directly for washing produce or thawing frozen items, as well as also indirectly in cooking equipment like combination ovens, steamers, and ice makers. Domestic water uses include lavatories and toilets for patrons and employees, which are regulated by building codes at ratios based on the size of the restaurant and the number of seats. The sanitation uses cover cleaning dishes, glassware, utensils, table linens, as well as all food preparation equipment and work station surfaces.

Water usage for sanitation is of particular interest because it relies on hot water delivered at very high temperatures as regulated by the Federal Food and Drug Administration as well as the Minnesota Department of Health. The hot water for sanitation is a significant portion of a restaurant's water consumption and it also requires additional energy to heat the water[12]. The hot water demand can be shaped by both the efficiency of the equipment selected by the restaurant and the code regulations from the Minnesota Department of Health. These codes regulate minimum temperatures of water for the use in hand sanitizing and dish cleaning, where 110 degrees Fahrenheit must be supplied from sinks used for hand cleaning, 170 degrees from sinks used for manual dish cleaning, and 180-195 degrees in automated dish washing machines.[13]

Restaurant water consumption rates are usually reported or discussed in terms of gallons consumed per day. The actual consumption can vary greatly between restaurants depending on the type of equipment and the size and type of the restaurant, however, the EPA’s Manual of Individual Water Supply Systems proposes 7-10 gal per patron per day for the consumption of a full service restaurant which could result in a wide range of consumption depending on the size of the restaurant.[14] Similarly, the Pacific Gas and Electric Food Service Technology Center restaurant audits report that the daily consumption of water in restaurants can range from 300 – 3000 gallons per day.[15]

ECONOMIC STRUCTURE & IMPORTANCE OF FOOD INGREDIENTS

The food ingredients are an operational input that is intense both in terms of associated GHG emissions and monetary investment by the owner, and therefore makes them an important category in this protocol. Given that the main unit of production and revenue are the food items created by the restaurant, much of the business operations are designed around the goal of producing high quality items to serve patrons. Issues of cost and quality are understandably important when selecting food ingredients. Furthermore, while chefs and restaurant owners would be concerned with food products, building designers rarely address these items in their design of the restaurant building. In fact, in terms of the total operational costs for full service restaurants, the food ingredients

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[12] (Wallace, Fischer, & Karas, 2007)

[13] (Girard, et al., 2009)

[14] (U.S. Environmental Protection Agency, 1991)

[15] (Bell, 2006)

typically account for over a third of the total cost.[16] While cost, quality, and reliability are the main drivers when determining where to source each item, more chefs are beginning to consider additional criteria focused on the environmental impacts of the farming practices, geographic proximity, and seasonality of the food items which can have indirect impacts on the GHG emissions generated to produce the food items.

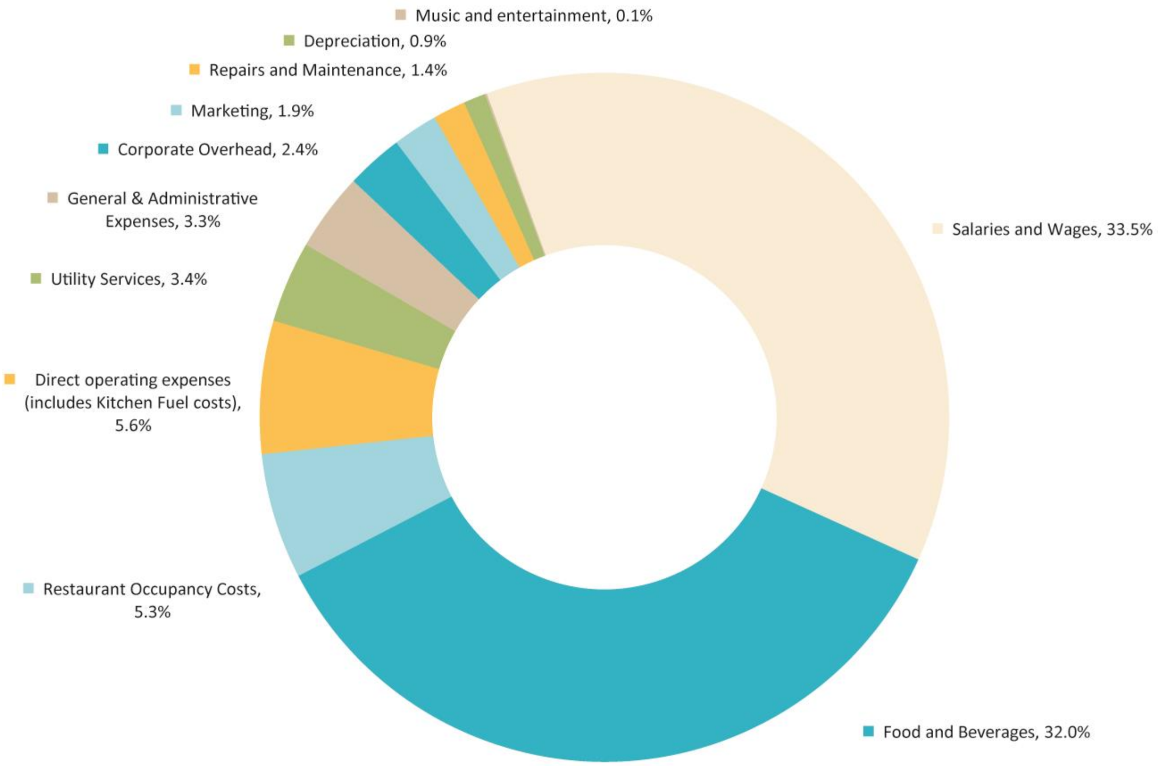

Figure 12. Average Expenses for a Full Service Restaurant (Expressed as a Percentage of Total Sales)

In addition to its economic implications, the selection and utilization of food ingredients also have indirect implications for GHG emissions generating activities. The selection of menu items and the cooking production steps required to create a dish impact the energy required to prepare the meal. As previously mentioned, ventilation hood energy consumption is directly related to the type of hood used which is dictated by the type of food and preparation equipment. Foods that produce grease and smoke when cooked require a more energy intensive hood than those which only generate heat and steam. Food selection can also lead to increased needs for refrigeration and/or freezing both of which impact total electricity consumption by a restaurant. Even food preparation technique can impact the amount of food scraps and waste that is generated in the production of dishes. This food waste can then lead to additional methane emissions if it decomposes in a landfill.

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[16] (National Restaurant Association and Deloitte LLP, 2010)

AGRICULTURE PRODUCTION OF FOOD ITEMS AND THEIR GHG EMISSIONS

The production of food ingredients used by the restaurant potentially makes up a significant portion of the total GHG emissions associated with the restaurant operations. While the restaurant may not have direct control over the farm's methods for producing crops or livestock, which become critical components of the menu items produced and sold by the restaurant, the environmental impacts from the production stage of food ingredient life cycle are considered relevant. The large quantity of food ingredients purchased by restaurants suggests that even if the GHG emissions associated with the farming practices are small compared to those associated with other restaurant operational processes like the combustion of natural gas, the volume of food ingredient consumption will inevitably make it a significant contributor of GHG emissions.

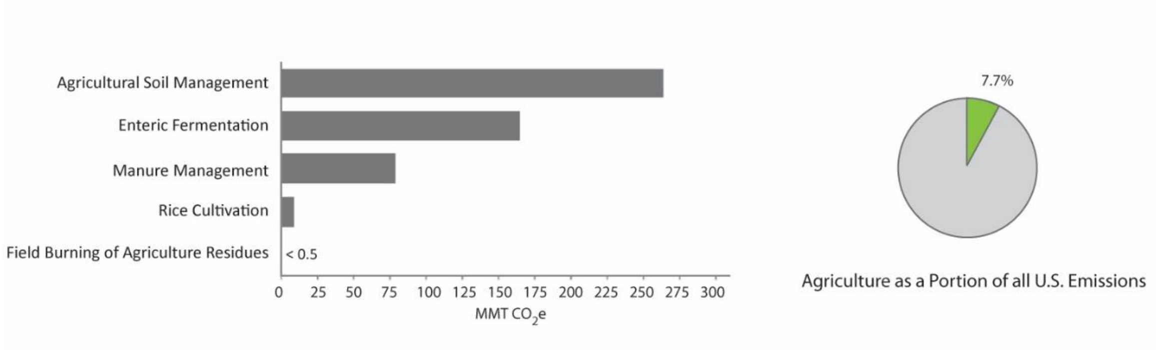

Figure 13. US 2013 Emissions Sources from Agriculture Sector

Specifically, the GHG emissions associated with farming practices varies greatly depending on the type of food ingredient and the complexity of its production chain. The following is a brief explanation of farming practices that have a significant contribution to GHG emissions based on the EPA’s GHG Emissions and Sinks report for 1990 - 2013.

Synthetic Fertilizer Production

Synthetic fertilizers are utilized on farms to add nitrogen to the soil and increase plant growth. They are generated from fossil fuels, either coal or natural gas, and transported to the farm, thus they are an external energy source introduced to the farm. The production of synthetic fertilizers generates large quantities of CO_2 emissions, while their excessive application to fields can generate N_2O emissions. According to a 2006 study by the United Nations, synthetic fertilizers require 7 to 65 mega joules of energy to produce 1 kg of Nitrogen depending on the mode of manufacturing.[17] Additional research estimated the total amount of fertilizer applied globally to farms in a year to be around 77,400,000,000 kg (77.4 Tg).[18] According to the USDA, about 10,800,000,000

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[17] (Steinfeld, et al., 2006)

[18] (Moiser, Duxbury, Freney, Heinemeyer, & Minami, 1996)

kg of fertilizer is used per year in the United States.[19] The production, transportation, storage, and transfer of fertilizers generate 0.03 to 1.8 kg CO_2e per 1 kg of fertilizer.[20] However, these emissions are only a portion of the emissions that can be generated by the use of synthetic fertilizers.

Soil Management and Application of Synthetic Fertilizers

The emissions of N_2O from soil management and the application of synthetic fertilizers represent the largest source of GHG emissions in the U.S. agriculture system (EPA N_2O emissions occur naturally from soil through nitrification and denitrification cycles which are driven by microbial processes.[21] However, if applied to the land in excessive amounts, synthetic fertilizers can lead to increased rates of N_2O emissions.[22] The excessive application of synthetic fertilizers can pollute water with excessive Nitrogen in the form of water runoff and leeching (infiltration into ground water) which in turn leads to increased N_2O emissions from the surface water bodies or soil. The application of synthetic fertilizers is utilized in vegetable and fruit production directly but is also an indirect component of livestock and aquiculture through the production of feed which can consist of corn, soybeans, and/or barley grains. .

Livestock Related Methane (CH_4) Emissions

In the United States livestock usually refers to beef and dairy cattle, swine, poultry, horses, sheep, and goats. Of these animals a subgroup, ruminants are of particular consideration in their impact on GHG emissions. Ruminants, cattle, sheep, and goats, have the genetic ability to consume and break down proteins found in grasses via a unique microbial digestive process. This distinct ability to consume grasses "allows ruminants to utilize land and feed that would otherwise be un-used for human food production".[23] However, this unique digestive process also contributes to GHG emissions as CH_4 is a primary byproduct produced via the microbial fermentation of the fibrous feed which occurs in the fore-stomach of the animal.[24] The amount of CH_4 that is generated by enteric fermentation depends on the type of animal and the type of diet consumed. In the United States, corn based high energy concentrate feeds are used to minimize the amount of CH_4 that is produced by enteric fermentation in beef and dairy cattle.[25] However, while the change in diet can have positive impacts on the amount of CH_4 emitted from enteric fermentation (belching) it also has negative impacts in terms of the CH_4 emissions generated from manure.

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[19] (Climate Change Program Office, Office of the Chief Economist, U.S. Department of Agriculture, 2011)

[20] (Lal, 2004)

[21] (Khalil, Mary, & Renault, 2004)

[22] (Bouwman, 1996)

[23] (Pitesky, Stackhouse, & Mitoehner, 2009)

[24] (Pitesky, Stackhouse, & Mitoehner, 2009)

[25] (Johnson & Johnson, 1995)

CH_4 emissions are also generated by all types of livestock (ruminants and non-ruminant) through the manure that the animals produce. The CH_4 emissions occur via anaerobic decomposition of manure. Anaerobic conditions are those in which oxygen is not present which leads to the generation of CH_4 as opposed to aerobic decomposition which usually produces CO_2. The way in which animal manure is managed determines which type of decomposition will occur. According to the EPA as sited by Pitesky et al, "when livestock manure is stored or treated in lagoons, ponds, or tanks (i.e. anaerobic conditions), CH_4 emissions are produced in higher amounts than when manure is handled as a solid (e.g., stacks or drylot corrals), or deposited on pasture where aerobic decomposition occurs thereby reducing CH_4 emissions".[26]

Rice Cultivation Methane (CH_4) Emissions

In the U.S. Inventory of Agriculture related emissions, much of the impact from the agriculture production of grains, vegetables, and fruits is already accounted for in the category of soil management and production/application of synthetic fertilizers. Rice production is singled out for its unique method of production, where fields are flooded with water which creates an anaerobic condition and generates methane. According to the EPA inventory, rice cultivation in the U.S. is typically done in fields that are continuously flooded with shallow depths of water. In this condition, Methane (CH_4) is produced by methanogenic bacteria that decompose the soil organic matter in the anaerobic conditions, though most of it is oxidized by aerobic methanotrophic bacteria in the soil. The CH_4 that escapes to the atmosphere is believed to be transported “from the submerged soil to the atmosphere primarily by diffusive transport through the rice plants”.[27] In this way, the shallow flooding of rice cultivation fields in the US tend to generate more CH_4 emissions than deep flooded production (water depth of one meter or more) that occurs in other countries because the base of rice plant dies, preventing the transfer of CH_4 from the soil to the atmosphere.

Energy consumption in mechanized equipment

The use of mechanized equipment on farms aids in productivity of the farm, but also relies on the input of fossil fuels, usually in the form of diesel fuel, or on electricity that is generated by the off-site combustion of fossil fuels. The amount of fuel and electricity used varies depending on the type of crops grown or animals raised on a given farm. Furthermore, the GHG emissions generated can vary greatly depending on some key variables. For instance, in the case of the amount of GHG emissions generated by the combustion of fuels in on farm equipment depends on the type of fuel used, (i.e. diesel, biodiesel, ethanol, etc.) and the type of engine in which it is combusted. Similarly, the indirect emissions generated by the consumption of electricity onsite will vary depending on the source of the electricity.

Furthermore, the manufacturing of farm equipment consumes energy even before it can be used to produce food or regulate climatic conditions on the farm. The emissions released from the generation of that embodied energy can also vary greatly depending

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[26] (Pitesky, Stackhouse, & Mitoehner, 2009)

[27] (U.S. Environmental Protection Agency, 2015)

on the type of equipment and the region in which it is manufactured. Given that there is so much variability in terms of these emissions, they have been excluded from this study and focused has been placed on the direct fuel combustion and electricity consumption that occurs on each farm.

Land-Use Change

The conversion of land for use in agricultural production is a significant source of global greenhouse gas emissions. The change of land often occurs to create new land for livestock uses either directly as pastureland or indirectly for the production of feed crops. Forested lands are often the target for conversion to agricultural lands and it is estimated that this land change produces 2400 Tg CO_2e per year.[28] [29] Overgrazing of land can also lead to the desertification of arid, semiarid, and dry sub humid grazing areas which "causes a net loss of C to the atmosphere, ultimately leading to land with reduced biological productivity".[30] Globally, desertification by livestock is estimated to generate 100 Tg CO_2e per year.[31] While both desertification and deforestation lead to significant global increases to GHG emissions, the agricultural practices in the United States do not follow the same trend and therefore these categories of emissions are not applicable to food produced within the U.S.

Transportation and Processing

Additional GHG emissions associated with food ingredients are generated through the transportation and processing phase during which the ingredients travel from the farm to the restaurant. Activities in this phase can vary greatly depending upon the type of food ingredient and the source used by the restaurant, from direct contracting with local farms that use personal vehicles for deliveries, to national food product vendors with networks of distribution vehicles. A study by Christopher L. Weber and H. Scott Matthews noted that food ingredients travel on average 6760 km, within their supply chain and 1640 km, on average, for the final delivery.[32] However, this same study also notes that despite the long distances of travel in the transportation phase of the food ingredient’s life cycle, “the GHG emissions associated with food are dominated by the production phase.[33] For food products with fewer emissions generated in the upstream production like fruits and vegetables, the transportation phase emissions make up a larger portion of the ingredient’s total GHG emissions impact as opposed to ingredients with high production GHG emissions impacts like ruminant livestock.

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[28] (Pitesky, Stackhouse, & Mitoehner, 2009)

[29] (Steinfeld, et al., 2006)

[30] (Pitesky, Stackhouse, & Mitoehner, 2009)

[31] (Steinfeld, et al., 2006)

[32] (Weber & Matthews, 2008)

[33] (Weber & Matthews, 2008)

RELATION TO EXISITNG GHG EMISSIONS ACCOUNTING PROTOCOLS AND RESEARCH

As the growth of research in the field of GHG emissions accounting continues to grow, an organizational hierarchy of protocols and guidelines has begun to emerge. The field of GHG accounting research has grown considerably in the past decade. There are a number of significant resources available to guide organizations in their inventory of emissions. This section describes how the proposed restaurant operation GHG emissions accounting guidelines fit into that developing hierarchy.

NATIONAL INVENTORY GUIDELINES

With the adoption of the Kyoto Protocol in 1997 and the need for Countries to document their efforts to reduce GHG emissions, the United Nation's Intergovernmental Panel on Climate Change developed a series of guidelines in 1996 for countries to use for the preparation of national inventories of GHG emissions. The most current edition, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, outlines a comprehensive list of emissions producing activities that should be addressed by each country's inventory organized into four sectors, energy; industrial processes and product use; agriculture, forestry and other land use; and waste.

THE USE OF TIERS IN CALCULATION METHODS

The IPCC guidelines are a broad, top-level guideline that outline a standard for compliance but also establish a tiered approach to its calculation methods which allows countries to develop additional tools and guidelines for estimating emissions from sectors that are of particular importance to a country. In general the tiers are used to allow countries to tailor the calculation formulas to reflect conditions unique to the country or the geographic region. Tier one serves as a generic default approach to be used by any country that does not have country specific data for the calculations. Tier two allows countries to substitute country or region specific emissions factors that better reflect the type of activities that are occurring within the country and the emissions that they generate. Tier three allows for countries to develop and utilize specific calculation models that can account for additional variables that influence the amount of emissions generated by a given activity.

In the United States, the EPA produces an annual report of the national GHG inventory that complies with the IPCC guidelines. This report, The US Inventory of GHG Emissions and Sinks, is emblematic of how a country can develop a country specific methodology that complies with the IPCC guidelines, but also utilizes tier two and tier three calculation methods to more accurately reflect the emission generating activities. In the agriculture sector specifically, The EPA deploys two tier three calculation tools, The DAYCENT Model and the Cattle Enteric Fermentation Model (CEFM) to estimate the N_2O emissions from soil management and CH_4 emissions from the production of cattle.

GUIDELINES FOR COMPANIES AND NON-GOVERNMENTAL ORGANIZATIONS

The International Organization for Standardization (ISO) has established the standard 14064-1:2006 as the standard guidance for quantifying and reporting greenhouse gas emissions at the scale of an individual company or organization. This standard was developed in conjunction with the World Resources Institute's (WRI) 2004 Greenhouse Gas Protocol Corporate Standard which is also an internationally accepted guideline for accounting and reporting GHG emissions. While the IPCC guidelines are intended for use by countries producing GHG emissions inventories for compliance with the Kyoto Protocol, the WRI GHG Protocol Corporate standard is intended for use by companies and non-governmental organizations. Furthermore, in 2011 the WRI released two additional standards, the GHG Protocol Corporate Value Chain Standard and the GHG Protocol Product Standard that complement the original protocol providing additional guidance for tracking emissions that occur at various stages of an organization's value chain. The WRI GHG Protocol standards have been adopted by many GHG emissions accounting programs like the Europe's Carbon Disclosure Project and North America's Climate Registry.

In addition to the efforts by the WRI and ISO, the British Standards Institute has also developed a Publicly Available Specification (PAS) for assessing the carbon footprint of goods and services known as PAS 2050. Similar to WRI's Corporate Value Chain Standard, the PAS 2050 examines the emissions generated throughout the full life cycle of products and services following the supply chain of an item. [34]

Top-level vs regional specific guides

Similar to the IPCC national inventory guidelines, the WRI GHG Protocols are top-level guidelines in that they serve as overarching frameworks under which more specific guidelines can be developed that address unique emissions accounting challenges faced by specific regions or corporate sectors. Region specific guidelines like Seattle Climate Partnership's *Curbing Your Climate Impact* resource guide provide additional guidelines that reflect unique aspects of the region that influence the amount of emissions generated by activities in that location. For example, the Seattle Climate Partnership guidelines include GHG emissions factors for the consumption of electricity that is generated by their unique hydroelectric energy source provided by their regional utility.

Top-level vs sector specific guides and Calculation Tools

Sector specific guidelines produced by the WRI provide additional interpretation of the Corporate Standard to address emissions inventory challenges that are unique to a particular sector. The WRI has provided seven sector specific guidelines that supplement the overarching Corporate Standard including; GHG Protocol Product Life Cycle Accounting and Reporting Standard, Information and Communication Technology Sector Guidance, GHG Protocol for Public Sector and GHG Protocol Agriculture Guidance. These guidelines can be useful for organizations within a given sector as well

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[34] (BSI British Standards, 2008)

as for companies that operate downstream or upstream of other organizations in one of the sectors. The sector specific guidelines often address how to define organizational emissions inventory boundaries, or which emissions categories should be the focus of organizations within a sector given their relative importance to that sector.

However, the WRI also provides calculation methods for specific emissions producing activities as separate calculation tools. These activities might apply to several sectors, so they are intended to be standalone tools that can be used by a variety of organizations. Examples include the production of cement, wood products, and semi-conductors. These calculation tools are not an exhaustive list like those provided by the IPCC, but rather have evolved out of necessity for each sector and are usually dedicated to activities which the WRI or IPCC have identified as significant contributors of GHG emissions.

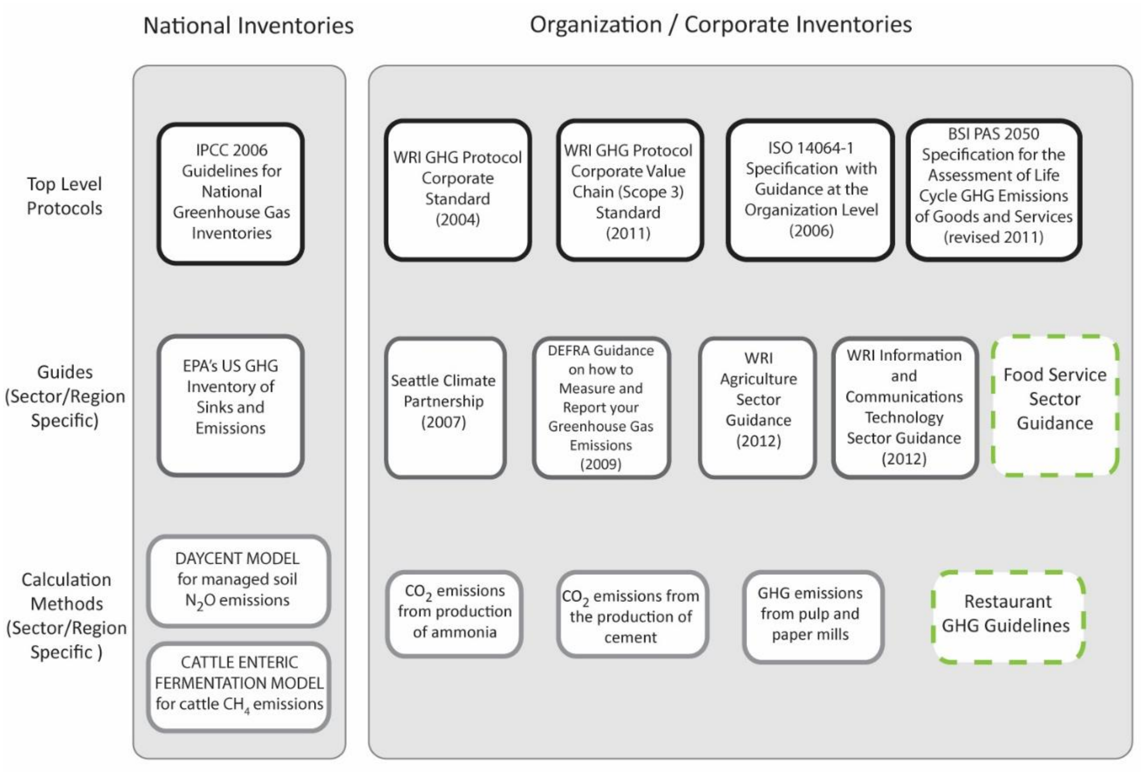

Figure 14. Existing GHG Accounting Guidelines

CRITIQUES OF EXISITING GUIDELINES

The MN restaurant GHG emissions protocol serves as a tool within the broad scope of accounting Guidelines provided both by the IPCC and the WRI. It builds upon those guidelines to address gaps which make those existing tools less effective for restaurant operators that want to determine emissions hotspots within their company's operation.

The development of the restaurant GHG emissions inventory protocol has been driven by the limited applicability of the existing tools for the operational boundaries of restaurants. Top level tools based on the GHG Protocol limit the scope of emissions generating processes by defined levels of ownership, direct and indirect control, with the goal of avoiding double counting of emissions by reporting organizations. This focuses the emissions counted by an organization to those processes over which the organization has financial control. In reality this limits the scope of emissions to those from the combustion of fossil fuels in company-owned equipment and purchased energy that is generated from the combustion of fossil fuels. These limitations on scope are important for companies engaged in carbon trading structures where avoiding double-counting of emissions by multiple companies is critical for maintaining accurate value of carbon trading credits.

This limitation of scope and boundary can unintentionally focus emissions reduction strategies on efforts to reduce energy consumption since fossil fuel combustion directly in equipment or for generation of electricity are the primary sources of GHG emissions included in these boundaries. For restaurants in particular, the focus on energy efficiency is important, but not exhaustive. The consumption of water and food ingredients and the generation of organic and inorganic waste are important processes that can be reduced by operational decisions.

The goal of the protocol is to reveal the areas of operations that have considerable impact on the environment through the generation of GHG emissions. Therefore, the boundary of processes included in this protocol are based on a typical restaurant operational structure including processes that extend beyond those that are under direct control of the restaurant management. More detail on the boundary for the restaurant GHG emissions inventory protocol is described in a later section.

AGGREGATION OF EMISSIONS FOR REPORTING PURPOSES

Aggregation of emissions from various sources and processes is another common attribute of the precedents. The aggregation of emissions from all sources into scopes based on control of processes is effective for creating a snap shot of a company's total emissions inventory that can be benchmarked and used to document future company progress in making reductions. The aggregation of emissions into scopes is also a common practice for compatibility with existing carbon reporting and trading programs. The aggregated approach can be a fast summary especially when it is based upon consumption data sources that are also aggregated such as electric utility bills which provide a total consumption over a given time period. The disadvantage of this approach is that an aggregated value is blunt and does not provide insight into which factors influence the activity that generates the emissions. Again in the case of the electric utility bill, if an owner only knows that electricity consumption is higher in one month as compared to the previous, he or she cannot use this information to change operations to reduce energy consumption. The electricity consumption must be allocated amongst consumption activities to help restaurant operators develop reduction strategies. This link is critical for analyzing the emissions inventory and prioritizing the deployment of resources for reducing emissions generated by specific processes. The restaurant operational GHG emissions protocol provides methods for estimating consumption activities at a fine grain level that can reveal how specific activities contribute to the larger emissions inventory.

HEAVY RELIANCE ON UTILITY BILL DATA SOURCE

As described previously, many existing emissions inventory tools rely heavily on consumption data sourced from utility bills. For restaurants this can be a particular challenge since they often reside in leased spaces where sub-metered utilities that reflect only the restaurant's activity are not always available. The estimation tools provided by this protocol help restaurants in this situation to estimate their consumption activity at the individual equipment level which can then be confirmed and adjusted if utility bills are available.

RESTAURANT OPERATIONS GHG EMISSIONS GUIDELINES

INTENDED AUDIENCE

The Restaurant Operations GHG Emissions Guidelines (Restaurant GHG Guidelines) is a guide for restaurateurs to develop an operational GHG emissions inventory. The protocol can be extended to a wide range of restaurants or locations, however, the database of emissions factors provided in the appendix are tailored to the United States. Furthermore, the guidelines outlined in this thesis could also be used by building performance researchers who are interested in applying the guidelines to a sample of restaurants to discern trends in restaurant operations that have strong correlations with increases or decreases in the generation of GHG emissions. In this sense this guideline could also serve as a post-occupancy evaluation tool for architects and building systems engineers to measure the performance of their work.

CONCEPTS AND REPORTING PRINCIPLES

As a sector specific guideline within the broader WRI corporate standard this protocol adopts the same reporting principles and concepts set by the WRI Corporate standard. The five reporting principles; relevance, completeness, consistency, transparency, and accuracy are derived from "generally accepted financial accounting and reporting principles" that are offered as guidance for organizations in their greenhouse gas emissions accounting.[35] The concept of distinguishing between direct and indirect emissions along lines of ownership and influence over emissions generating activities is also acknowledged as critical in establishing the boundary around activities to include in the inventory. This restaurant protocol also adds a time period concept that addresses the importance of measuring emissions across an entire year, and allocating emissions to activities that occur within that year.

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[35] (Ranganathan, et al., 2004)

RELEVANCE

> *Ensure the GHG Inventory appropriately reflects the GHG emissions of the company and serves the decision-making needs of users – both internal and external to the company*

This principle was the origin for the development of a restaurant focused protocol as the existing GHG inventory protocols do not have enough relevance for restaurant operators. The additions of calculation tools and the organization of the inventory aim to make the resulting GHG emissions inventory relevant for internal operation decision making by restaurant organizations.

COMPLETENESS

> *Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusions.*

This protocol is intended to be used to guide operational decisions made by restaurant owners. Given that goal, the scope of emissions included in the inventory admittedly extends beyond the direct control of the restaurant ownership. While this will lead to double counting by suppliers and restaurants, the emissions inventories produced by this tool are not intended to be aggregated up into a broader inventory where this double-counting would be detrimental. However, a holistic inventory that extends up and down a restaurant's supply chain gives operators a better understanding of the magnitude of impacts associated with decisions that can have indirect impacts on the amount of GHG emissions generated to support the restaurant operations. For example, understanding the GHG emissions associated with farm production up stream could lead to seeking alternative food ingredients. Also, understanding the impact of customer transportation could influence the owner's decision to expand bicycle parking spaces.

CONSISTENCY (COMPARABILITY)

> *Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series.*

The goal of this tool is to be used to compare progress of a single restaurant's reduction of emissions over time as well as the comparison between two or more restaurants. Therefore it is important that all emissions categories are included in each inventory and that the aggregated emissions are normalized per a unit of restaurant productivity (meals served).

TRANSPARENCY

> *Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions*

> *and make appropriate references to the accounting and calculation methodologies and data sources used.*

This guide strives to provide estimation tools that allow users to understand their emissions portfolio at a finer level. However, this flexibility and customization means that assumptions will be made by individual restaurants to tailor the protocol to their specific operations. Given the complexity and depth of the calculations in this protocol it is important that all steps of calculations and assumptions are clearly documented and within the recommendations. To achieve many of these calculations, detailed information must be gathered from suppliers, vendors, and customers through surveys, which again require that those parties also maintain a level of transparency that allows restaurant operators conducting this inventory access to information about the way food ingredients, are produced.

ACCURACY

> *Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.*

The reliance upon consumption activity estimation calculations and emissions factors in lieu of direct emissions monitoring makes it critical for the users of this protocol to pursue the greatest level of accuracy. Users should select the estimation methods that most closely reflect the actual activities in the restaurant and always use direct measurement data to check estimations whenever possible. For example, if a restaurant does have monthly utility bills, this data should be used to check the accuracy of estimated consumption of various appliances and equipment that consume the fuel monitored by the utility.

While accuracy is an important principle of this guide, it is understood that the guidelines are a preliminary proposal and therefore are open for improvement. The database of emissions factors serves as defaults for which site-specific emissions factors could be substituted to improve accuracy.

DIRECT AND INDIRECT EMISSIONS - CONTROL VS INFLUENCE

WRI’s GHG Protocol establishes an important distinction of direct vs indirect to organize the emissions that are reported by organizations. As discussed earlier, one of the main uses of the GHG Protocol is for companies to publicly report emissions for use under regulatory requirements or carbon trading markets where avoiding double-counting of emissions by two organizations is critical. Therefore, the GHG protocol inventory is organized into direct emissions and indirect emissions where the direct emissions are “emissions from sources that are owned or controlled by the reporting company” and the indirect emissions are “emissions that are a consequence of the activities of the reporting company, but occur at sources owned or controlled by another company".[36] The organization has "control over its direct emissions" and "it has influence over its indirect emissions".

In the MN restaurant protocol, the emissions inventory is organized into upstream, onsite, and downstream emissions where those occurring onsite are the direct emissions and those upstream or downstream of the restaurant are the indirect emissions over which the restaurant can have influence. All emissions are included in the restaurant's emissions inventory, but disaggregated to maintain transparency in case the restaurant wants to report their direct emissions separate from those which are only influenced by their activities.

TIME PERIOD

The tool is also intended to operate on a twelve month time period. While the basic calculations could be applied to any amount of activity data, a complete annual cycle is important for conducting analysis of how the GHG emissions relate to restaurant operational fluxes throughout the year. These fluxes are especially important for restaurants operating in Minnesota as the seasonal weather changes can have various impacts on the restaurant operations, from the types of foods that are available, to the heating and cooling needs of the space, and even in the travel behavior of customers and employees who might bike to the restaurant in the summer and drive in the winter.

Measurement over the course of twelve months is also important to align with accounting practices that may already be in place with existing restaurants, or are proposed for new restaurants. Counting emissions over the same period that other data is collected and analyzed makes it easier for restaurant owners to utilize this tool. It also makes it easier to reveal how emissions generating processes impact other metrics of the restaurant operations.

While the twelve month time period applies to the activity that occurs at the restaurant, some of the emissions generated by that activity may be produced outside of time boundary. For example, a restaurant may consume a certain amount of chicken thighs within twelve months, but the emissions generated by the production of feed and growth of the chickens before they arrived at the restaurant might have occurred outside of the time period. These upstream emissions should still be counted within the time period when the chicken was used by the restaurant. This also applies for downstream emissions associated with waste produced by the restaurant that might generate emissions in future time periods. These emissions should still be counted in the time period in which the waste was produced by the restaurant.

CONTRIBUTION OF HUMAN ACTIVITY

The focus of this protocol is on the GHG emissions generated by human activity. However, it should be understood that the fluxes of GHG amounts in the atmosphere are

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[36] (Bhatia, et al., 2011)

also a natural occurrence by which carbon and nitrogen are transformed through biological processes. There is a natural cycle of CO_2 through plant biomass, where it is absorbed out of the atmosphere during photosynthesis and either stored within the plant or released back to the atmosphere through respiration. N_2 is fixed from the atmosphere by bacteria and converted into a usable form for plants, in a process known as nitrification. When plants decay, additional bacteria return the nitrogen to the atmosphere first through mineralization and then through a process known as denitrification. The level of CH_4 is influenced by ruminant animal digestion, animal manure, and decay in soils. All of these cycles occur naturally influencing the levels of CO_2, N_2O, and CH_4 in the atmosphere, however, human activities like the combustion of fossil fuels, the production of livestock, and the application of synthetic fertilizers now play a significant role in contributing additional amounts of GHGs to the atmosphere.

Kyoto Protocol and the IPCC, as well as this research focus on anthropogenic emissions. This distinction is especially important in the context of this research given that some of the indirect processes associated with restaurants, mainly growing food and disposing of organic waste, are similar to natural processes that would typically be excluded from most greenhouse gas estimations. However, this project takes the overarching viewpoint that if the restaurant's ability to serve food relies on a process that is managed by humans, then its related emissions should be included. Detailed discussion about the boundary of the included emissions sources will be discussed later in the methodology section.

METHOD FOR DEFINING THE GHG EMISSIONS INVENTORY ACTIVITIES AND BOUNDARY

For any GHG emissions inventory, the aspects of determining what activities to include and how to assign ownership of those emissions to an organization or entity that has influence over the activities is a critical step to maintain legitimacy of the emissions accounting. In the case of this protocol, the focus is less on generating a GHG emissions inventory for national inventory reporting, and more about influencing the operational decision making of a restaurant. The determination of activities to include in the inventory is based on a review of activities included by the IPCC guidelines, the WRI's Corporate Standard Protocol, the WRI's Corporate Value Chain Accounting and Reporting Standard, and the WRI's Agriculture Sector Guideline.

The list of GHG emissions generating activities included in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* is considered as an exhaustive list from which subsets of activities are selected for inclusion in the Restaurant GHG Guidelines. As highlighted in the introduction, several activity categories within a national IPCC based GHG emissions inventory can be linked to the operation of a restaurant.

In addition to the IPCC inventory, the activity categories outlined in the WRI's standards and guidelines also influenced what activities are included in this guideline for restaurants. As described in the previous critique of the WRI tools, the Corporate Standard's focus on on-site fossil fuel combustion and off-site fossil fuel combustion for electricity generation are too narrow for restaurant operations, so additional categories from the Corporate Value Chain Accounting and reporting standard as well as the Agriculture sector guidelines are also included in this guide. See Figure 15 for the lists of these activities.

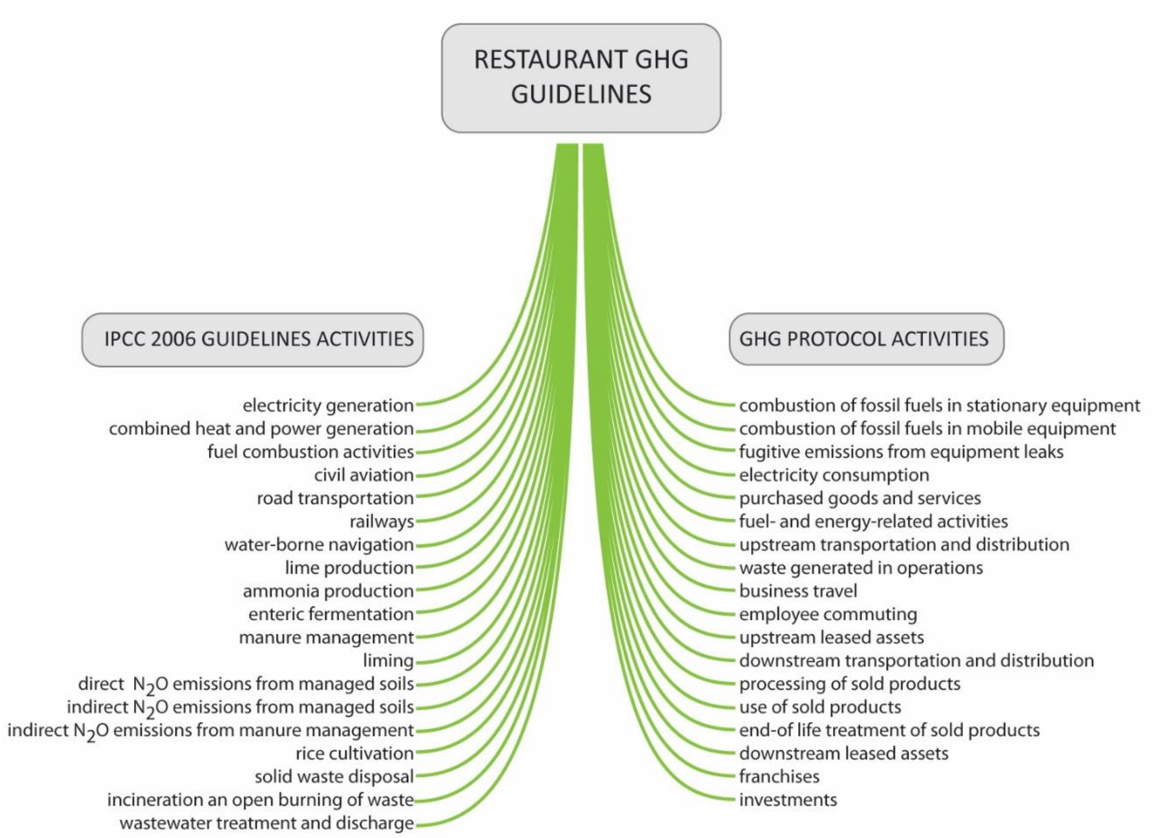

Figure 15. Activities Included from Existing GHG Guidelines

The list of activities to be included in a restaurant's GHG inventory is meant to be comprehensive so that some categories may not be applicable to all restaurants. Furthermore, some of the activities included may not be accessible to restaurants, due to limitations in data or calculation methodologies especially when considering activities along the supply chain that occur outside of the direct control of the restaurant. The calculations sections of the document identify some of these categories that currently require complex calculations and allocation methods which have yet to be developed. However, additional activities could also be added as new developments arise. Furthermore, this protocol serves as a proposal that should be refined with future real world testing by with pilot accounting projects in restaurants to attain feedback.

ORGANIZATION OF GHG EMISSIONS INVENTORY

RESTAURANT -CENTRIC SUPPLY CHAIN INVENTORY

The boundary is drawn around a typical restaurant-centric supply chain, extending upstream and downstream to capture emissions from activities that are directly controlled and indirectly influenced by the restaurant. The activities contribute value to the restaurant and generate emissions that are attributable to that value. As discussed in the critiques of existing GHG emissions inventory accounting tools, limiting the inventory of emissions to those activities under direct control of the restaurant would not give restaurant operators a complete picture of how their operations influence activities that produce emissions. The indirect emissions associated with upstream activities around food ingredient production and downstream activities around the consumption of the restaurant's food products are assumed to be significant and are therefore included in the inventory.

This supply chain diagram (Figure 16) differs from both the IPCC inventory organization by economic sectors (Figure 17), and the WRI GHG protocol value chain inventory (Figure 18). The IPCC inventory organization aggregates most of the activities under the energy sector which may make it difficult for operators to compare the relative impact of the activities within that sector. In the value chain inventory, activities are arranged based on the value relationship to the restaurant where items and services that are purchased by the restaurant are arranged on one side and those related to products or services sold by the restaurant are placed on the other side. Though valuable from an accounting standpoint, the value chain organization is confusing for a restaurant organization since the products sold have a short life cycle (often consumed on-site) and therefore influence very few GHG emission activities that occur after the product has been sold. Figure 19 offers a complete depiction of the Restaurant GHG Guidelines emissions inventory, including lists of activities included in each phase of the supply chain.


RESTAURANT GHG GUIDELINES:
SUPPLY CHAIN INVENTORY ORGANIZATION
RESTAURANT
Upstream (indirect)
On-Site (direct)
Downstream (indirect)

Figure 16

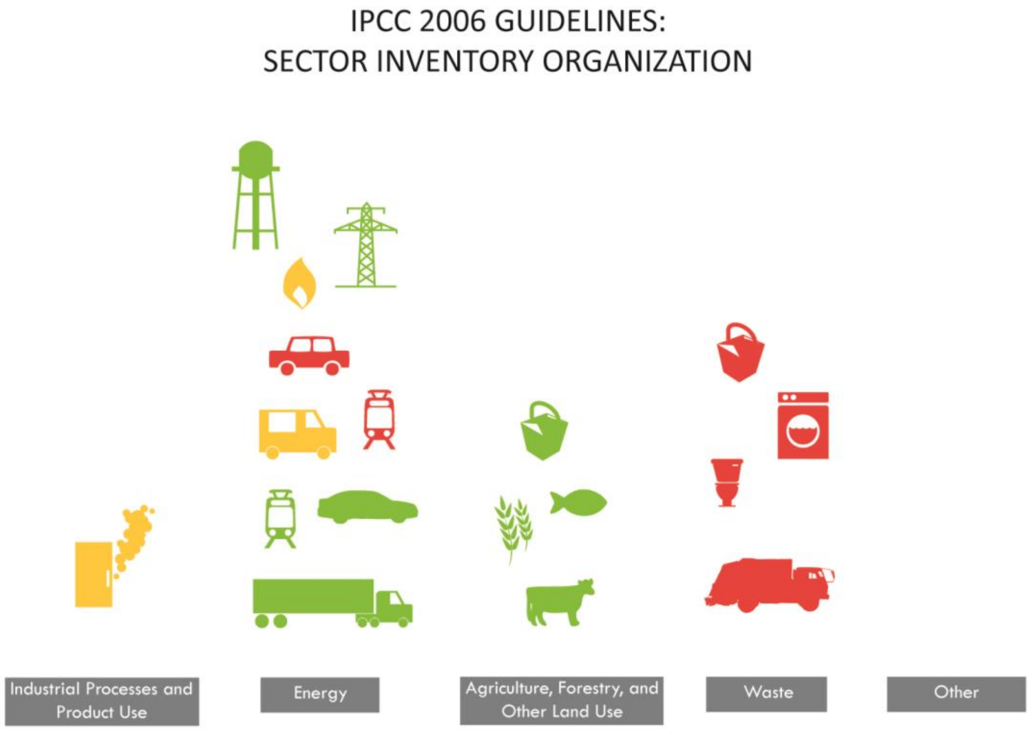

Figure 17

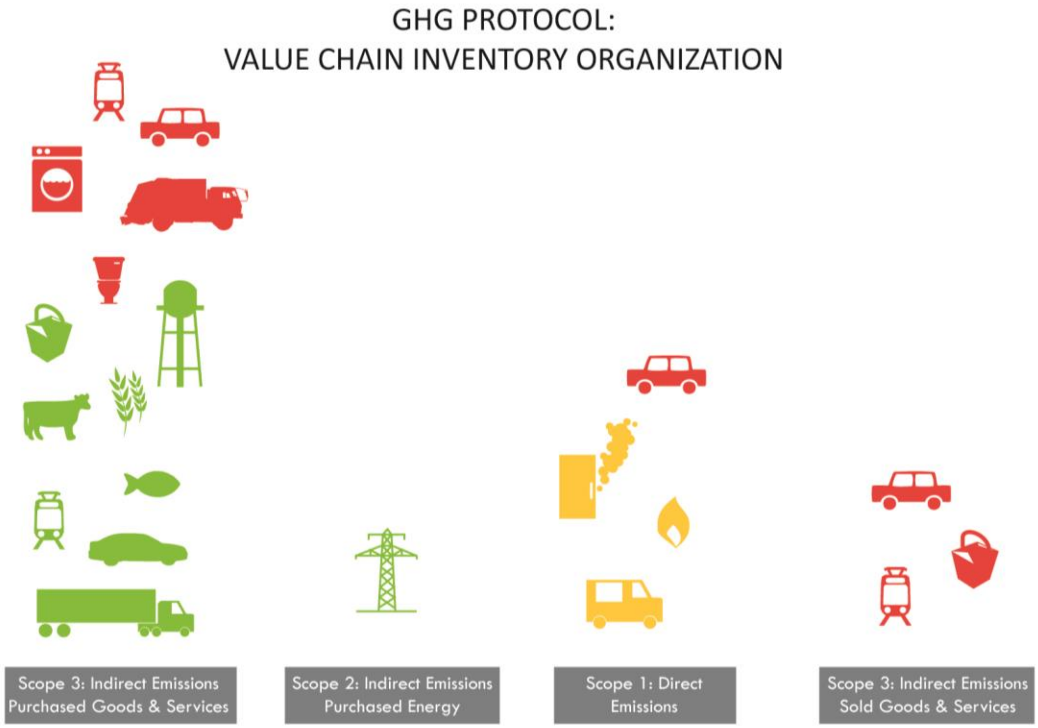

Figure 18

RESTAURANT GHG GUIDELINES: INVENTORY BOUNDARY

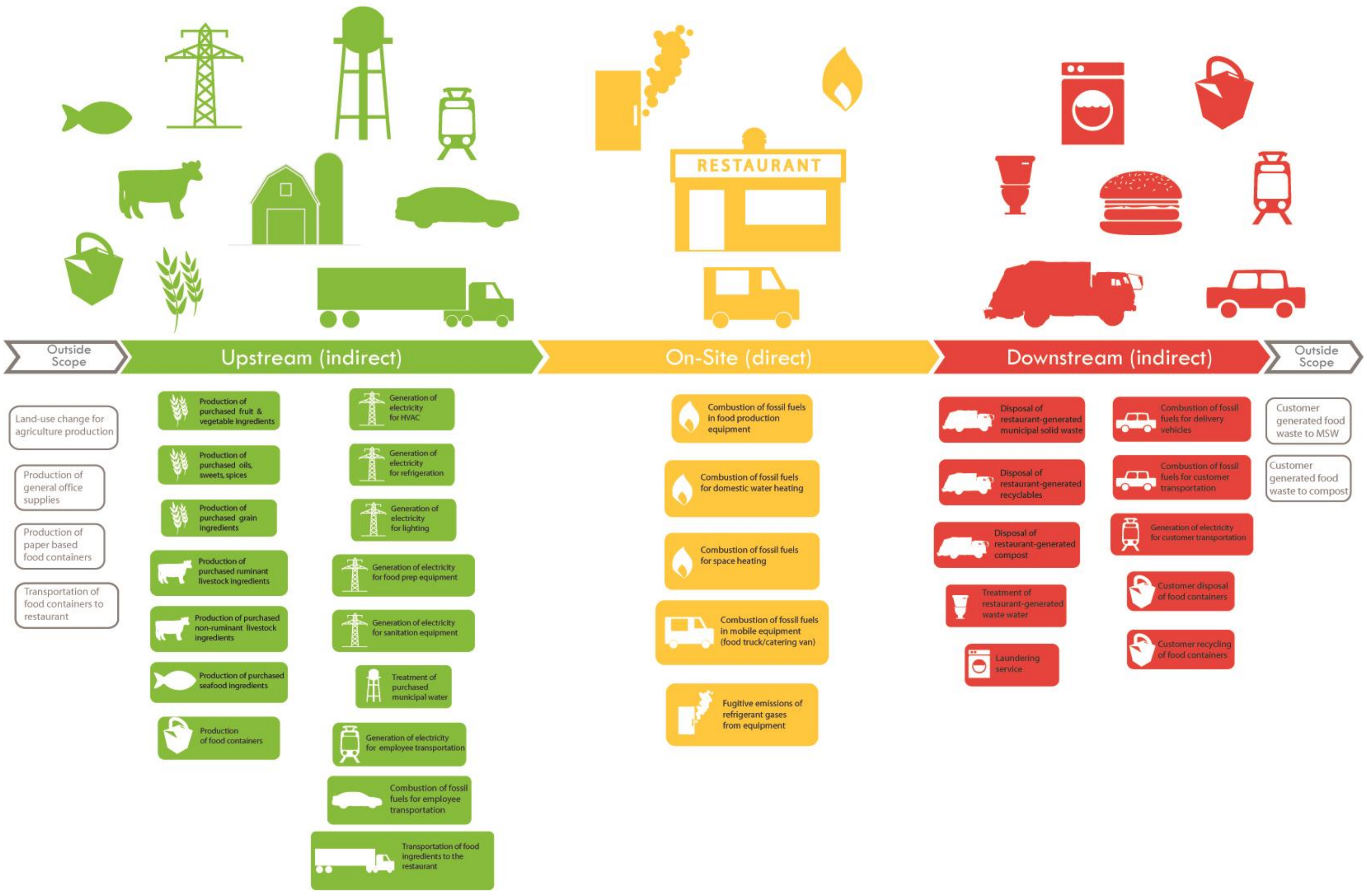

Figure 19

UPSTREAM EMISSIONS FROM RESTAURANT INFLUENCED ACTIVITIES

The upstream emissions are generated by activities that fall into subcategories of utility generation, transportation, and the production of food products. Each of these subcategories has additional sub groups that address specific goods or services. These emissions are calculated by multiplying activity data by emissions factors. However, estimating these emissions generated upstream from the restaurant are more complex as the processes are often supplying a larger customer base than the individual restaurant. For example the restaurant purchases an annual amount of electricity, but the regional electrical generation plants burn fuels to generate electricity for many customers. Therefore each of these calculations must be quantified in some way to represent the percentage of emissions that are associated with the consumption at the restaurant.

Production of Food Ingredients

The cradle to gate processes required for the production of food ingredients which are included in boundary of the restaurant upstream supply chain include synthetic fertilizer production, soil management, rice cultivation, enteric fermentation by ruminant livestock, manure management, combustion of fossil fuels in farm equipment, and the generation of electricity consumed by farm equipment. Emissions generating activities vary for each food ingredient; therefore a meta-data analysis of LCA studies for each food ingredient is used to account for the emissions generated in the production of each of the seventy-eight food ingredients included in the inventory.[37] The specific boundary of activities for each food ingredient therefore varies, as the emissions factor is a representative average for the global production of that food ingredient. A complete list of the seventy-eight food ingredients is included in the appendix.

Production of Food Take-out Containers

The inventory also includes the emissions generated by activities necessary for the production of three types of take-out food containers; polystyrene (PS) foam, polyethylene (PET) plastic, and polylactic acid (PLA) plastic. Emissions from the production of resin, the transportation of resins to container manufactures and from the manufacturing process are included within this inventory category via the emissions factor provide in the appendix.

Fossil Fuel Combustion for Transportation

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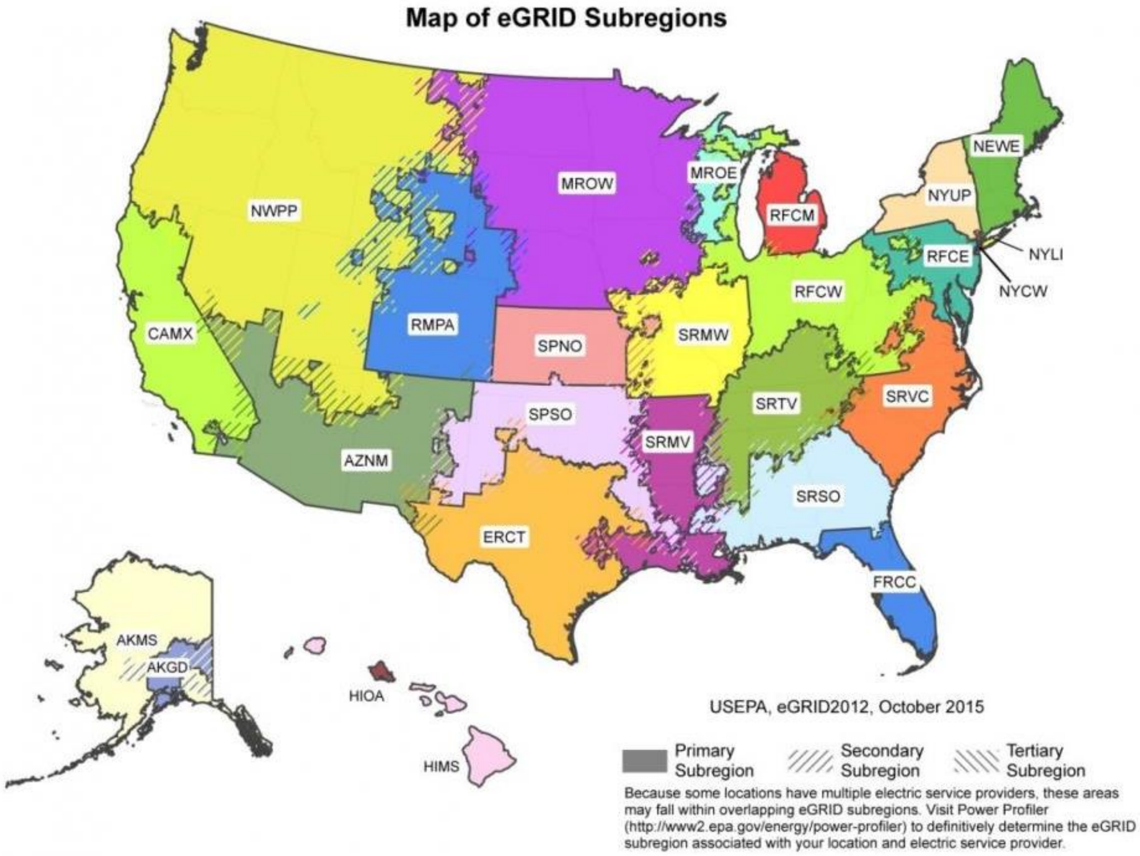
[37] (Heller & Keoleian, 2015)

The generation of emissions by combustion of fossil fuels in mobile sources is an activity that occurs in several instances along the supply chain of a restaurant. Upstream from the restaurant, combustion of fossil fuels occurs in vehicles that are delivering food products to the restaurant as well as in vehicles that employees use to travel to and from the restaurant. While the restaurant might not have direct control over the type of vehicle used by vendors delivering food ingredients, the deliveries are a vital part of the operations and the frequency and distance of the deliveries can be influenced by the restaurant depending on the vendor selection.

The location of the restaurant can also have an indirect influence on the type of transportation utilized by employees, for example if the restaurant is located adjacent to a bus stop, employees might be more likely to utilize the bus to travel to the restaurant. Personal vehicles, like cars, trucks, or motorcycles as well as mass transit vehicles like busses or trains that combust fossil fuels are all included in this upstream activity.

Emissions from Generation of Electricity

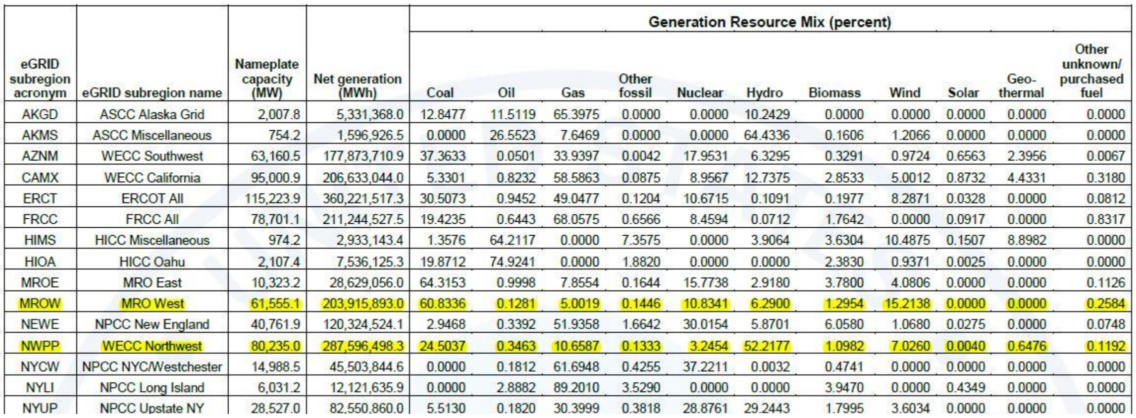
As discussed in the introduction, a restaurant’s operations rely heavily upon inputs of energy. While the electricity is consumed on site in restaurant equipment, the emissions associated with the electricity are the result of combustion of fossil fuels at the power generation plant. Emissions associated with electricity vary throughout the country based on power generation sources and the mix of fuel types that may be combusted to generate the electricity. For example electricity consumed in the Pacific North West is generated via a mix of hydro plants and coal gas fired power plants where as in the upper Midwest, electricity is generated via wind turbines, natural gas fired power plants, and predominately coal fired power plants. Emissions factors are derived for subregions of the national power grid to reflect these variations. Figure 20 depicts the subregions and Figure 21 lists the generation resource mix for the subregions.



USEPA, eGRID2012, October 2015

Because some locations have multiple electric service providers, these areas may fall within overlapping eGRID subregions. Visit Power Profiler (http://www2.epa.gov/energy/power-profiler) to definitively determine the eGRID subregion associated with your location and electric service provider.

Figure 20



				Generation Resource Mix (percent)										
eGRID subregion acronym	eGRID subregion name	Nameplate capacity (MW)	Net generation (MWh)	Coal	Oil	Gas	Other fossil	Nuclear	Hydro	Biomass	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AKGD	ASCC Alaska Grid	2,007.8	5,331,368.0	12.8477	11.5119	65.3975	0.0000	0.0000	10.2429	0.0000	0.0000	0.0000	0.0000	0.0000
AKMS	ASCC Miscellaneous	754.2	1,596,926.5	0.0000	26.5523	7.6469	0.0000	0.0000	64.4336	0.1606	1.2066	0.0000	0.0000	0.0000
AZNM	WECC Southwest	63,160.5	177,873,710.9	37.3633	0.0501	33.9397	0.0042	17.9531	6.3295	0.3291	0.9724	0.6563	2.3956	0.0067
CAMX	WECC California	95,000.9	206,633,044.0	5.3301	0.8232	58.5863	0.0875	8.9567	12.7375	2.8533	5.0012	0.8732	4.4331	0.3180
ERCT	ERCOT All	115,223.9	360,221,517.3	30.5073	0.9452	49.0477	0.1204	10.6715	0.1091	0.1977	8.2871	0.0328	0.0000	0.0812
FRCC	FRCC All	78,701.1	211,244,527.5	19.4235	0.6443	68.0575	0.6566	8.4594	0.0712	1.7642	0.0000	0.0917	0.0000	0.8317
HIMS	HICC Miscellaneous	974.2	2,933,143.4	1.3576	64.2117	0.0000	7.3575	0.0000	3.9064	3.6304	10.4875	0.1507	8.8982	0.0000
HIOA	HICC Oahu	2,107.4	7,536,125.3	19.8712	74.9241	0.0000	1.8820	0.0000	0.0000	2.3830	0.9371	0.0025	0.0000	0.0000
MROE	MRO East	10,323.2	28,629,056.0	64.3153	0.9998	7.8554	0.1644	15.7738	2.9180	3.7800	4.0806	0.0000	0.0000	0.1126
MROW	MRO West	61,555.1	203,915,893.0	60.8336	0.1281	5.0019	0.1446	10.8341	6.2900	1.2954	15.2138	0.0000	0.0000	0.2584
NEWE	NPCC New England	40,761.9	120,324,524.1	2.9468	0.3392	51.9358	1.6642	30.0154	5.8701	6.0580	1.0680	0.0275	0.0000	0.0748
NWPP	WECC Northwest	80,235.0	287,596,498.3	24.5037	0.3463	10.6587	0.1333	3.2454	52.2177	1.0982	7.0260	0.0040	0.6476	0.1192
NYCW	NPCC NYC/Westchester	14,988.5	45,503,844.6	0.0000	0.1812	61.6948	0.4255	37.2211	0.0032	0.4741	0.0000	0.0000	0.0000	0.0000
NYLI	NPCC Long Island	6,031.2	12,121,635.9	0.0000	2.8882	89.2010	3.5290	0.0000	0.0000	3.9470	0.0000	0.4349	0.0000	0.0000
NYUP	NPCC Upstate NY	28,527.0	82,550,860.0	5.5130	0.1820	30.3999	0.3818	28.8761	29.2443	1.7995	3.6034	0.0000	0.0000	0.0000

Figure 21 eGRID2012 Subregion Resource Mix

Transportation by restaurant employees can also occur in vehicles or modes that generate GHG emissions indirectly through the consumption of electricity. Electric vehicles and trips using electrified mass transit like light rail trains rely on electricity that is assumed to be generated by the same sub regional grid as the electricity purchased by the restaurant.

Emissions Associated with Municipal Water

The treatment and distribution of potable water to restaurants relies on energy, usually in the form of electricity that is consumed by the municipal water facility. The emissions generated by the production of the electricity consumed at the municipal water facility are attributed to the water purchased by the restaurant. The emissions profile of the electricity generation is assumed to be similar to that of the electricity purchased by the restaurant. In other words it is assumed that both the local municipal water facility and restaurant get their electricity from the same regional electric grid.

ON-SITE EMISSIONS FROM RESTAURANT CONTROLLED ACTIVITIES

Fossil Fuel Combustion in Stationary Equipment

This on-site category includes the emissions generated by the combustion of fossil fuels in equipment used for food preparation, domestic hot water heating, and space heating. Natural gas combustion is the most common fuel type to be included in this category given its use in all three categories of equipment. However, propane, anthracite coal, and wood could also be combusted in ovens or other food preparation equipment.

Fossil Fuel Combustion in Mobile Equipment

While the majority of the fuel combustion activities might occur within the restaurant property, fuels combusted in restaurant vehicles for catering, or food truck service which operate outside of the physical restaurant are also included as onsite emissions generating activities because of the direct control that restaurants have over the equipment. The fuel consumption by mobile vehicles could vary from gasoline or diesel fuel for driving and powering electric generators to propane combusted in onboard kitchen equipment.

Fugitive Emissions of Refrigerant gasses

In addition to the combustion of fossil fuels, GHG emissions can also occur by unintended release of HFCs from refrigeration equipment. While the amount of refrigerant gas that could leak from equipment might be small, and undetectable from month to month, the global warming potential of HFCs are very high, 1300 times that of CO_2, and therefore should be included in the inventory. The calculations methods section goes into further detail as to how to estimate the fugitive emissions based on maintenance records to provide an accurate amount of HFCs that have leaked.

DOWNSTREAM EMISSIONS FROM RESTAURANT INFLUENCED ACTIVITIES

Continuing down the supply chain of a typical restaurant operation, there are several activities that occur after the onsite restaurant production activities. These downstream activities support the consumption of the meals that the restaurant produces as well as the treatment of waste generated by the restaurant and customers.

Fossil Fuel Combustion - Transportation by Customers and/ or Delivery Vehicles

For most restaurants to sell their products, some form of transportation is required, either a customer must travel to the restaurant, or a meal is delivered to the customer from the restaurant. This activity is considered downstream of the restaurant, as it is part of the distribution of the product which is sold by the restaurant. Emissions sources include combustion of fossil fuels in the vehicles of customers or restaurant delivery

Generation of Electricity – Transportation by Customers and/or Delivery Vehicles

Similar to the upstream category for emissions from generation of electricity, this downstream category accounts for emissions from the generation of electricity consumed by transportation vehicles. These electrified vehicles may include mass transit modes like light rail trains as well as personal electric vehicles. As with the upstream emissions category, the emissions produced to generate this electricity is assumed to have a similar emissions profile as that of the electricity generated throughout the regional grid.

Waste Generated by the Restaurant

Treatment of waste generated by the operations of the restaurant is included as a downstream activity in the supply chain of a restaurant. Forms of waste can vary from food scraps to recyclable food packaging and even paper products from the management office. The destination of the waste be it composting, recycling facilities, solid waste landfill or even municipal solid waste to energy (incineration) facilities ultimately determines the emissions generated from the waste.

Similar to the treatment of incoming water, the downstream treatment of water that leaves the restaurant also relies on energy, usually in the form of electricity that is consumed by the municipal treatment facility. The emissions generated by the production of the electricity consumed at the facility are again attributed to the water consumed by the restaurant. The emissions profile of the electricity generation is assumed to be similar to that of the electricity purchased by the restaurant.

Laundering of table linens and uniforms is an additional waste related activity included in the downstream inventory. Emissions generating activities from the laundering service include the consumption of electricity, the production of detergents, and the treatment of both municipal source water and waste water.

Waste Generated by customers

This subcategory addresses emissions related to the disposal of the restaurants' products and any packaging associated with the food. While most meals are consumed within a full service restaurant, some patrons might choose to take portions of their meal home. Additionally, some full service restaurants may provide take-out service in addition to their primary dine-in function. This guideline assumes that all food products taken offsite are consumed by customers and thus do not end up in the waste stream. Furthermore, the restaurant has limited influence over the way customers choose to dispose take-out containers, however, they can select container materials that give customers options to recycle or compost the waste in addition to the typical solid waste disposal.

METHOD FOR CALCULATING EMISSIONS

The following section provides a detailed description of the calculation methods that are utilized to estimate the emissions from the categories previously discussed in the inventory boundary section. The calculations are organized to align with the upstream, onsite, downstream supply chain to avoid confusion, however this leads to some duplication of similar calculation methods, for example the calculation methods for mobile combustion emissions from vendors, and customers are similar but fall in separate categories (upstream vs downstream).

Activity Data and Emissions Factors Approach

The general calculation approach of this tool is similar to those outlined by guides like the IPCC, GHG Protocol, DEFRA, and Seattle Climate Partnership tools, where activity data is collected or estimated and multiplied by emissions factors to produce an estimate of the actual GHG emissions that are generated. This approach does not directly measure actual emissions generated by each process of the restaurant's operations because direct measurements of all emissions would be cost prohibited and nearly impossible for most restaurants. The following sections outline methods for estimating activity data that can be converted to GHG emissions using emissions factors listed in the appendix.

Identifying Emissions Generating Hotspots by Disaggregating Activity Data

These calculation methods look to achieve a greater level of specificity so that restaurants can better understand which areas of their operations are the most significant contributors of GHG emissions. As identified in the critiques of existing guidelines, the calculation methods attempt to provide an inventory with fine-grain level of detail that reveals the impacts of individual activities.

While this data accurately reflects the total amount of fuel and energy purchased, there are two flaws with using aggregated utility bill date for this protocol. A monthly aggregated amount of consumption in the form of a utility bill can help to ensure the estimates in the calculations are accurate, but additional steps are necessary to help identify specific activities that have significant contributions to the emissions. These calculations aim to identify hotspots rather than an accurate aggregated total amount of emissions. Therefore the approach for estimating the consumption of basic utilities like natural gas, electricity, and potable water are provided in a way that will estimate the consumption of individual components within the restaurant operations and then confirm that the aggregated sum of these estimates is reasonably accurate compared to the utility invoices. In cases where estimating the fuel energy consumption data of a particular piece of equipment is too complex, the energy consumption data provided by the utility bills can be used to estimate the energy used by these complex systems once the energy consumed by other equipment is allocated.

In general the emissions should be estimated for the twelve month time period. Estimations on a monthly time interval would be preferred to reveal seasonal variation, however the task of estimating emissions for each category or piece of equipment on a monthly basis would be onerous and therefore the annual total for each should be examined first before considering disaggregating over a month to month basis. Furthermore, a few activities, like the fugitive release of refrigerant HFCs, cannot be tracked on a monthly scale and need to be allocated as an average amount of emissions per year.

Surveys

For transportation related activity by employees, and customers, the Restaurant GHG protocol follows the model of the GHG Protocol Corporate Standard, by using surveys to collect travel activity data from these groups. Similar to the other fuel consumption activity, this data is then converted to GHG emissions using emissions factors found in the appendix.

For restaurants in climates like Minnesota, it is important that the surveying of employees and customers be done for a typical summer/spring month and a typical winter/fall month to reflect the influence of weather on the choice of transportation mode as well as fluctuation in patronage throughout the year. The number of tips and mode choice for each sample can then be extrapolated for the remaining summer/spring months and fall/winter months.

CALCULATING EMISSIONS GENERATED UPSTREAM

Emissions from the production of purchased goods

This section of calculations addresses the estimation of GHG emissions that result from the production of goods that are purchased by the restaurant. Purchased goods include food ingredients and food takeout or delivery containers which are the primary materials that are transformed into the food products sold by the restaurant. Though the calculations are extensive, inevitably they will not cover every food ingredient or type of food container used by restaurants. Instead they focus on common food categories with reputable emissions factors from published studies on food production Life Cycle Assessments as were described in the previous chapter addressing the inventory boundary. The calculation method applies these emissions factors to the quantity of items purchased by the restaurant.

Food Ingredients

As identified in the previous chapter, this inventory includes emissions related to the production of food ingredients from several categories including grains, vegetables, fruits, livestock, seafood, dairy, and added sweeteners and oils. In general, the calculation method for all food ingredients attempt to equate the amount of the food ingredient consumed by the restaurant to their appropriate proportion of the GHG emissions generated through the agricultural production. Therefore the calculations for all ingredients require the restaurant to collect consumption data from delivery invoices. A complete list of food ingredients addressed by this protocol is included in the appendix.

The current emissions factors utilized by this guideline are averages calculated through a meta-review of hundreds of LCAs for individual food items. At this time the number of LCA studies for individual food ingredients produced in the United States is low, and therefore these numbers are global averages that account for variation in food production methods from around world. Ideally, in future iterations of this guideline, more studies will be conducted to provide emissions factors that reflect specific farming practices, for example organic orange production in California versus traditional production in Florida, can be incorporated and help restaurants better understand how sourcing of ingredients and various farming practices impact the emissions inventory.

Ideally the restaurant will have a close relationship with farms that produce its ingredients so that the amounts of emissions generating activities could be obtained. However, this level of investigation is not likely to be part of a restaurant's initial GHG emissions inventory. A restaurant may want to investigate a farm specific emissions factor for a particular ingredient if the initial emissions inventory identifies ingredients as hotspots of emissions. This guideline takes the approach of identifying current, published emissions factors for food ingredients that reflect an average of emissions given a wide range of production and farming methods. Currently the emissions factors for food ingredients are sourced from the meta-analysis of GHG emissions factors by M.C. Heller and G.A. Keoleian.[38]

To estimate the upstream emissions associated the cradle to gate production of various food ingredients, the total weight of each purchased good must be multiplied by its associated emissions factor, found in the appendix:

$$\boxed{\begin{array}{c}\text{Food Ingredient}\\\text{Purchases}\\\text{(kg)}\end{array}} \times \boxed{\begin{array}{c}\text{Emissions factor}\\(\text{kg } CO_2\text{e/kg})\end{array}} = \boxed{\text{kg } CO_2\text{e}}$$

Food take-out containers

This section of calculations addresses the estimation of GHG emissions that result from the production of food take-out containers that are purchased by the restaurant. Emissions factors from Life Cycle Assessments are included in the appendix for various types of containers. The calculation method is similar to the food ingredients where the amount of purchased containers, by weight, is multiplied by the emissions factor.

$$\boxed{\begin{array}{c}\text{Food take-out}\\\text{containers per}\\\text{(kg)}\end{array}} \times \boxed{\begin{array}{c}\text{Emissions factor}\\(\text{kg } CO_2\text{e/kg})\end{array}} = \boxed{\text{kg } CO_2\text{e}}$$

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[38] (Heller & Keoleian, 2015)

Transportation of Food Ingredients

Calculating emissions associated with the activity of delivering food ingredients to the restaurant is done to reflect possible variations in emissions based on the type of food ingredient that is being delivered. Emissions factors are sourced from published LCA data[39], which provides emissions factors based on the amount of food ingredients purchased. Monthly invoices should be used to estimate the total amount of purchased in each of the food ingredient categories listed in Figure 22.

Food Category	Common Food Ingredient Examples
Red Meat	Beef, pork
Chicken /Fish/Eggs	Poultry, seafood, non-red meat proteins
Dairy Products	Milk, butter, cheese
Cereals /Carbs	Breads, pasta, rice
Fruit/Vegetables	Fresh, canned, dried fruit and vegetables
Oils/Sweets/Condiments	Sugar, sauces, oils
Beverages	Coffee, tea, soft drinks
Other Misc	Snack foods, processed foods, spices

Figure 22

These quantities, in dollars, can then be converted into transportation related emissions using the following equation, and the emissions factors listed in the appendix.

$$\boxed{\text{Food Category Purchases (\$)}} \;\text{X}\; \boxed{\text{Emissions factor (kg CO}_2\text{e/\$)}} = \boxed{\text{kg CO}_2\text{e}}$$

Fossil Fuel Combustion by Employee Commutes

Calculations of emissions from fossil fuel combustion in mobile vehicles used for employee transportation fall under two categories, travel in personal vehicles and travel by mass transit. Surveys of employees can be used to collect information regarding travel distance, frequency, and vehicle type which can then be used in the following equations to estimate the amount of fuel consumed. The fuel consumption can then be

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[39] (Weber & Matthews, 2008)

converted into GHG emissions using combustion emissions factors listed in the appendix.

For personal vehicles, cars, trucks, and motorcycles, the fuel consumption rate is the fuel economy rating of a vehicle, which is usually reported in miles per gallon. The EPA maintains a Fuel Economy Database that reports fuel efficiency ratings for most cars and trucks.[40] Specific fuel economy rates can be found based on the vehicle year, model type, and manufacturer. The database includes fuel economy values for highway and city travel as well as a combined value representative of mixed travel on highway and city conditions. Similar to the approach recommended by the EPA Climate Partnership GHG Accounting tool, this guide recommends the use of the combined fuel economy value.[41] To calculate the fuel consumed by personal vehicles the following equation is used:

$$\frac{\boxed{\text{Distance traveled (miles)}} \times \boxed{\text{Number of trips}}}{\boxed{\text{Fuel Economy (mile/gal)}}} = \boxed{\text{Fuel consumed (gal)}}$$

For travel that is conducted on transit modes that combust fuel, usually by bus, commuter rail, or air plane, the specific details about the engine types are not often available. These modes could be utilized by employees and customers but these modes of transportation move large numbers of passengers in single trips of which only a fraction are actually employees. Therefore the vehicle fuel economy for transit buses, commuter rail, or air planes must be in terms of passenger miles traveled not total miles. Fuel economy values for busses, commuter rail trains, and air planes are provided in the appendix based on national statistics provided in the US Department of Energy's *Transportation Energy Data Book 29th edition.* To calculate the amount of fuel consumed per individual employee, vendor, or customer that utilizes buses, commuter rail, or air planes the following equation should be used for each mode of transportation:

$$\frac{\boxed{\text{Distance traveled (passenger miles)}} \times \boxed{\text{Number of trips}}}{\boxed{\text{Fuel Economy (passenger mile/gal)}}} = \boxed{\text{Fuel consumed (gal)}}$$

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[40] (U.S. Department of Energy, 2016)

[41] (U.S. Environmental Protection Agency, 2008)

Generation of Electricity Consumed by Stationary Equipment at the Restaurant

At the restaurant electricity is consumed by a variety of equipment from preparing food, to lighting, to creating dining area ambiance. The following subcategories outline the method for estimating the amount of electricity consumed by equipment in these categories. The emissions from the electricity consumption are then calculated based on the emissions factor for the generation of the electricity which occurs upstream from the restaurant.

Food Preparation Equipment

To estimate the amount of electricity consumed by the equipment the first step is to inventory the pieces of equipment. A list of the types of equipment that could be included is in figure 19. Just as in the calculations for fuel combustion, all of these pieces of equipment follow a similar calculation method with the exception of water heating equipment which requires the total amount of hot water generated to determine the electricity consumed. Once this has been done manufacturer specifications should be collected for each piece of equipment to determine the rated energy input value (maximum electricity consumption) for each. This information will be used along with the duty cycle which represents the portion of the rated energy input value that is actually consumed throughout the operation of the equipment during a typical day. This protocol uses duty cycle factors that have been published by the Food Service Technology Center based on laboratory tests, which are listed in the table below for various types of equipment. Additionally an estimate of the number of hours that a piece of equipment operates for each day is also required. If there is a significant difference in operation on a given day, for example the equipment is used for lunch and dinner on weekends but only dinner on weekdays, then the hours of operation for both of these types of days (weekend versus weekday) should be noted.

These values should be used to estimate the total amount of fuel consumed for each piece of equipment per day using the following equation:

$$\boxed{\begin{array}{c}\text{Rated energy}\\ \text{input value}\\ \text{(kW)}\end{array}} \times \boxed{\begin{array}{c}\text{Duty cycle}\\ \text{(\%)}\end{array}} \times \boxed{\begin{array}{c}\text{Daily Usage}\\ \text{(hours/day)}\end{array}} = \boxed{\begin{array}{c}\text{Electricity}\\ \text{consumed per}\\ \text{day (kWh/day)}\end{array}}$$

Once the electricity consumption per day is determined for each piece of equipment then the total consumption should be determined by multiplying the daily consumption by the number of days in the twelve month period that the equipment was utilized. If there are two or more types of operational days as described above, then the daily estimate for each day type should be multiplied by the number of those types of days in the inventory period.

Equipment	**Sample of Rated Energy Input Values for Electricity (see specific equipment model specifications for actual value)** Source: (Fischer, et al., 2002)	**Duty Cycle (Average rate of energy consumption expressed as a percentage of the rated energy input)** Source: (Fischer, et al., 2002)
Fryers	12 - 17 kW (Open Deep Fat) 9 - 14 kW (Pressure/ Kettle) 20 - 28 kW (flat bottom - Chicken/Fish) 10 -18 kW (flat bottom - donut)	20% (Open Deep Fat) 33% (Pressure/ Kettle) 20% (Flat Bottom - Chicken/Fish) 14% (Flat Bottom - Donut)
Ovens	Standard/ Convection/ Combination 10 - 40 kW (full-size) 6 - 10 kW (half-size) 2 - 6 kW (countertop) 6 - 12 kW (Deck) 35 - 45 kW (Conveyor) 4 - 12 kW (Rotisserie)	Standard/ Convection/ Combination 25% (full-size) 25% (half-size) 25% (countertop) 20% (Deck) 50% (Conveyor) 65% (Rotisserie)
Broilers	10 - 12 kW (underfired) 2 - 17 kW (overfired)	70% (underfired) 70% (overfired)
Range Tops	12 kW (range top) 8 kW (range oven)	25% (range top) 25% (range oven)
Griddles	8 - 16 kW	25%
Steamer	36 - 48 kW (Pressure - Boiler-Based) 18 - 36 kW (Pressureless - Boiler-Based) 12 - 24 kW (Pressureless - Connectionless)	12% (Pressure - Boiler-Based) 20% (Pressureless - Boiler-Based) 14% (Pressureless - Connectionless)
Steam Kettle	6 - 21 kW	40%
Braising Pan	6 - 18 kW	60%

Figure 23

The energy consumption rate of some kitchen equipment is reported by manufacturers in units that are unique to the way in which the appliance is operated. Figure 23 lists common examples of these pieces of equipment and the following sections outline specific equations to calculate the amount of electricity that each consumes per day given the units for energy consumption data that are commonly reported on manufacturer’s specification documents.

Equipment	**Typical Energy Consumption Units Reported by Manufacturers**
Water heater	kW energy input gph (gallons per hour) water generation/recovery rate gpm (gallons per min) water generation rate for tankless water heaters
Warewasher	kWh/cycle
Freezer	kW (continuous 24 hour operation)
Ice Maker	kWh/100 lb of ice (continuous 24 hour operation)
Refrigerator	kW (continuous 24 hour operation)

Figure 24

Water Heating

To estimate the electricity consumption used by water heating equipment additional calculations must be made to first estimate the amount of hot water at various temperatures that is consumed by other fixtures and pieces of equipment like warewashing machines and pre rinse sprayers. Methods for estimating the amount of hot water consumed by these appliances and fixtures are included in the calculation methods section on municipal water consumption.

Once the total amount of hot water demand per is determined (the sum off all of the hot water consumption of each fixture and appliance) the amount of electricity consumption by hot water heating equipment can be estimated. Hot water heating equipment specifications sheets usually provide rated energy input of the equipment as well as a rate, usually gallons per hour, at which the equipment can produce hot water at a given temperature. These values along with the estimated amount of hot water consumed per day can be used to estimate the amount of time the equipment operates each day, and therefore the kWh of electricity consumed each day. The following equation illustrates this calculation.

$$\frac{\boxed{\text{Daily hot water generation (gal/day)}}}{\boxed{\text{Hot water Generation/recovery rate (gal/hr)}}} \times \boxed{\text{Rated energy input value (kW)}} = \boxed{\text{Electricity consumed (kWh/day)}}$$

The annual electricity consumption by the water heating equipment can then be determined by multiplying the daily electricity consumption by the number of operational days within the twelve month inventory period.

Warewasher

The electricity consumption of the warewashing equipment is usually reported by manufacturers in terms of the energy per cycle as well as the energy consumption when the equipment is idle. The number of cycles per day must be estimated to calculate the amount of electricity consumed per day. This value depends on the number of customers served per day and can vary greatly depending on the type of day. If the restaurant patronage fluctuates throughout the week, for example weekends are much busier than weekdays, the restaurant should estimate the electricity consumption for a regular day (usually a weekday), and for a peak day (usually a weekend). To calculate the annual amount of electricity consumed by the warewashers, the daily consumption is multiplied by the number of operational days within the twelve month inventory period. If different types of days (regular versus peak) are used then the total number of operational days should be subdivided per those types and multiplied by the respective daily consumption.

$$\boxed{\text{Number of cycles per day}} \times \boxed{\text{Time per cycle (sec)}} \times \boxed{\text{Conversion factor (hr / sec)}} = \boxed{\text{Operating time (hr/day)}}$$

$$\boxed{\text{Rated operating energy input value (kW)}} \times \boxed{\text{Operating time (hr/day)}} + \boxed{\text{Idle time (hr/day)}} \times \boxed{\text{Rated idle energy input value (kW)}} = \boxed{\text{Electricity consumption (kWh/day) (hr/day)}}$$

Some appliances will operate every hour of every day even when the restaurant is not open. For these the rated energy input value is assumed to be consistent throughout the full twenty-four hours of each day and therefore does not require a duty cycle load factor. The daily electricity consumption for each of these types of appliances is calculated by using the following equations:

Ice Makers

Daily ice production (lbs/24hrs) X Rated energy input value (kWh/lbs) X Conversion factor (24hrs/day) = Electricity consumed (kWh/day)

Coolers and Freezers

Rated energy input value (kW) X Conversion factor (24hrs/day) = Electricity consumed (kWh/day)

Entertainment and Lighting Equipment

The subdivision encompasses the purchased electricity that is consumed by any equipment or appliance used for the creation of ambiance in the spaces where guests are served food as well as all lighting fixtures used throughout the restaurant. Entertainment equipment will vary between restaurants, but it can include televisions or other forms of visual media displays, audio systems, and even animatronics utilized in themed restaurants. Furthermore, the lighting equipment should include all lighting fixtures used to illuminate the guest seating areas (indoor and exterior), restrooms, lobbies, kitchen, and storage closets. The energy consumption rating for entertainment equipment can be obtained from manufacturing specifications. This data along with an estimated number of daily operational hours is used to calculate the amount of electricity consumed by each piece of equipment per day using the following equation:

Rated energy input value (kW) X Daily Usage (hours/day) = Electricity consumed per day (kWh/day)

The rated energy input value for lighting fixtures depends on the number and type of lamp used in each fixture. Manufacturing specifications will often include this information as well, but the energy input value of the lamps should be confirmed by examining the actual fixture. This data along with an estimated number of daily operational hours is used to calculate the amount of electricity consumed by each fixture per day using the following equation.

Lamp’s Rated energy input value (kW) X Number of lamps per fixture X Daily Usage (hours/day ` = Electricity consumed per day (kWh/day)

The annual electricity consumption for each piece of equipment or light fixture is estimated by multiplying the daily consumption by the number of operational days within the twelve month inventory period. As discussed in the previous subdivisions, daily usage might vary by type of day, for instance weekends versus weekdays. If this is the case, then a daily electricity consumption amount should be determined for each day type for the equipment of light fixture prior to calculating the total annual consumption. Additionally some pieces of equipment or light fixtures, like security lighting will operate continuously even when the restaurant is not open. Special care should be taken in estimating the daily hours of operation for these items.

Electricity Consumption by Exhaust, Makeup Air, and HVAC equipment

The calculations for electricity consumption by exhaust, makeup air, and HVAC equipment focus primarily on consumption by fan motors utilized in these pieces of equipment. These consume a significant amount of electricity which is easy to estimate given accurate data on hours of operation and information from the equipment manufacturer’s product specifications. For these calculations, accurate hours of operations for the ventilation equipment should be determined on a daily basis and then extrapolated for annual estimations. Special care should be taken to estimate hours of use for each individual piece of equipment, for example, a restaurant's kitchen might have two exhaust hoods, a primary hood utilized continuously throughout the day and a secondary hood that is only utilized during peak hours. The hours of operation for each of these exhaust hoods would likely be very different over the course of a year and thus consume different amounts of electricity.

Fan Motor Electricity Consumption

The first step in estimating electricity consumption of exhaust ventilation, makeup air units, and HVAC units is to estimate the amount of energy consumed by fan motors from each piece of equipment. Manufacturer specification sheets for each piece of equipment should be used to determine the rated horsepower of the fan motor. This rating is then converted into units of electricity and an efficiency factor is applied to account for the fact that field tests demonstrate that motors typically consume less than their horsepower rating.[42] [43]This efficiency factor could also be included in the manufacturers’ specifications; however a default value found in Figure 25 can be used if none is provided.

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[42] (Herzog, 1997)

[43] (Design and Engineering Services Customer Service Business Unit Southern California Edison, 2009)

Equipment	**Sample of Rated Energy Input Values for Electricity (see specific equipment model specifications for actual value)**	**Motor Efficiency Factor (Average rate of energy consumption expressed as a percentage of the rated energy input)**
Kitchen Exhaust Fans (hoods, warewashers, etc.)	HP * 0.746 kW/hp * motor efficiency factor = kW (converting the horse power directly to kW overestimates the amount of energy. Most manufacturer specifications provide motor efficiency factors that should be used. Herzog recommends using the factor 0.55kW/hp, which is about 74% efficiency, based on field measurements of actual constant rate motors that can be substituted if the manufacturer specifications do not include motor efficiency factors.) VOLTS * AMPS / 1000 = kW (use if direct measurement of amps is possible)	53% (Apply if fan motor is part of demand control ventilation system) Source: (Design and Engineering Services Customer Service Business Unit Southern California Edison, 2009)
Kitchen Makeup Air Unit Fan	HP * 0.746 kW/hp * motor efficiency factor = kW VOLTS * AMPS / 1000 = kW	53% (Apply if fan motor is part of demand control ventilation system) Source: (Design and Engineering Services Customer Service Business Unit Southern California Edison, 2009)
HVAC Fan (for remainder of building)	HP * 0.746 kW/hp * motor efficiency factor = kW VOLTS * AMPS / 1000 = kW	70% (Only apply if fan motor is variable speed) Source: (Herzog, 1997)
Restroom Exhaust Fan	HP * 0.746 kW/hp * motor efficiency factor = kW VOLTS * AMPS / 1000 = kW	70% (Only apply if fan motor is variable speed) Source: (Herzog, 1997)

Figure 25

The calculation to determine the electricity input value for each fan then is as follows:

Rated hp for motor (hp) X Conversion factor (kW/hp) X Motor efficiency factor (%) = Electricity Input (kW)

Once the electricity input value is determined for each piece of equipment, then the corresponding hours of operation are multiplied to estimate the amount of kWh consumed per day. This is then multiplied by the number of operating days per year to determine annual electricity consumption estimates.

If a restaurant utilizes a demand control ventilation system, the hours of specific fan operations will be difficult to document given the dynamic nature of the system. Instead a factor based on field research analyzing the performance of demand control ventilation systems in actual restaurants is provided for exhaust hoof fans and makeup air fans used along with the total number of hours over which the fans could have operated.

Electricity Input (kW) X Duty Cycle for DCV or Variable speed motors (%) X Hours of possible operation (hr) = Electricity consumption (kWh)

Electricity Input (kW) X Hours of operation (hr) = Electricity consumption (kWh)

Similar to previous calculations, if the restaurant operates on different schedules for a select number of days during the week then peak and non-peak operational hour estimates should be made and the corresponding number of peak and non-peak days per year should be used to extrapolate the daily estimates.

While fan energy consumption can be estimated via previously described calculations, the electricity consumption utilized by makeup air and HVAC equipment to satisfy a restaurant's heating and cooling loads is difficult to calculate due to the dynamic nature of heating and cooling demands. These demands are impacted by external weather conditions, thermal resistance of the building's exterior envelope, thermal capacity of interior materials, heat generated by internal equipment, and temperature set points of the interior thermostats.[44] All of these factors impact the interior temperature of the restaurant which in turn impacts the amount of time that HVAC equipment must operate. Furthermore, kitchen exhaust hoods expel conditioned air which in turn needs to be replaced by both the makeup air units and the HVAC system which means kitchen productivity can also impact the amount of electricity consumed to meet the heating and cooling loads. Given the complex nature of this relationship, the amount of electricity utilized by HVAC and makeup air units to meet the heating and cooling loads should be estimated by subtracting the total electricity consumption of all other items covered in this section from the total amount of purchased electricity for the inventory period. If the amount of purchased electricity is unknown because the restaurant does not have utility invoices, then this area of electricity consumption should not be included in the inventory and noted as an omission given that traditional methods for estimating the electricity consumption associated with meeting the heating or cooling demand utilize several assumptions can be inaccurate.

Electricity is often delivered by utility providers. Depending upon the restaurant’s leasing arrangements utility invoices may be available to calculate the total amount of electricity consumed during the twelve month inventory period. If available, this data can be used to confirm the accuracy of estimations about the operational hours of use for various pieces of equipment. If the estimated total consumption of electricity is significantly different (+ or - %10) then the estimated hours of operation for each piece of equipment that consume electricity should be adjusted. There could also be some discrepancy in the data on the invoices and in the use of duty cycle values based on averages for all models of a particular piece of equipment so it is unlikely that the estimated total consumption of purchased electricity will precisely match the invoice data.

Converting to GHG emissions and GWPs

Once the quantity of purchased electricity is determined for each type of equipment it can be converted to emissions of CO_2, CH_4, and N_2O using the appropriate emissions factors for the region in which the electricity is generated. These factors are listed in the appendix organized by geographic location. For electricity specifically, the emissions factors are those provided by the EPA’s eGRID database for the Midwest Reliability Organization West (MROW) subregion of the national electrical grid. This approach assumes that electricity consumed in the state of Minnesota can be generated by any power generation facility that supplies this portion of the energy grid and therefore the emissions factors for electricity are calculated based on the fuels combusted in all of the power generation plants that supply this subregion.

Generation of Electricity consumed by mobile vehicles transportation

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[44] (Fischer D. , 2003)

Electricity consumption by employee transportation can occur both in electric personal vehicles as well as via transit rides on electrified modes of transportation. For personal vehicles the calculation method is similar to that for the estimating fossil fuel consumption by employees. The EPA's fuel economy website database can be used to look up the energy efficiency rating for the vehicle and survey data can be collected for the distance traveled and the number of trips per year.

$$\boxed{\text{Energy Efficiency (kWh/100 mile)}} \times \boxed{\text{Distance traveled (miles)}} \times \boxed{\text{Number of trips}} = \boxed{\text{Electricity consumed (kWh)}}$$

Light rail transit is similar to bus and commuter rail however this mode is usually powered by electricity. The calculations therefore result in the amount of electricity consumed by each individual. This value can then be converted into GHG emissions using the conversion factors that reflect the region of the electrical grid in which the electricity was generated. These are described in the next section, emissions from the consumption of purchased electricity. Energy efficiency values for light rail trains are provided in the appendix based on national statistics provided in the US Department of Energy's *Transportation Energy Data Book t*o calculate the amount of electricity consumed per individual employee, vendor, or customer that utilizes light rail the following equation should be used:

$$\frac{\boxed{\text{Distance traveled (passenger miles)}} \times \boxed{\text{Number of trips}}}{\boxed{\text{Energy Efficiency (passenger mile/kWh)}}} = \boxed{\text{Electricity consumed (kWh)}}$$

Treatment of municipal water consumed by the restaurant

This section of calculations is used to estimate emissions related to the supply of municipal potable consumed by the restaurant. The general approach of the calculations is to estimate the amount of water consumed per fixture or appliance and then convert that quantity into equivalent GHG emissions.

Similar to electricity and other forms of energy, potable water is often delivered by utility providers. Depending upon the restaurant's leasing arrangements utility invoices may be available that document the total amount of municipal potable water purchased on a monthly basis. If available, this data can be used to confirm the accuracy of estimations about the operational hours of use for various fixtures and pieces of equipment. If the estimated total consumption of water is significantly different (+ or - %10) then the estimated hours of operation for each piece of equipment that consumes water should be adjusted. It is unlikely that the estimated total consumption of each purchased energy type will precisely match the invoice data but it should not be greater than the invoice data.

Once the total potable water consumption is estimated, it can be divided into heated and non-heated water based on the fixture type or appliance. The estimated amount of hot water consumption can be used to calculate the emissions from the water heating equipment as described the electric or natural gas water heater sections.

Potable Water Consumption by Plumbing Fixtures

To estimate the amount of potable water used by the restaurant, data must be collected for all of the fixtures and appliances that consume water. The fixtures that should be included are kitchen utility sinks, hand washing sinks, and employee showers from the back of house, and lavatories, water closets, and urinals from the front of house. If there restaurant has a bar, the water consuming fixtures in the bar should also be included. For sinks, showers, and faucets data should be collected for the flow rate of each fixture, the typical time per use, and the number of uses per day. For water closets and urinals the average daily occupancy is needed along with the flow rate for each fixture which is typically in gallons per flush.

Most of the data needed for these calculations can be found from the manufacturer specifications for each fixture and monitoring of usage in the restaurant. The appendix includes a table of average flow rates for typical fixtures that can be consulted if a restaurant is unable to determine specific values for each fixture. Generic daily usage values are also included in the appendix. The restaurant should strive to determine the daily usage and fixture flow rates of its specific fixtures first before relying upon the values in the appendix as they may decrease the accuracy of the estimations. To calculate the water consumption by plumbing fixtures the following equations are used:

Sinks, Showers, Faucets:

$$\boxed{\begin{array}{c}\text{Fixture}\\ \text{flow rate}\\ \text{(gal/min)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Duration}\\ \text{(min)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Visitor}\\ \text{Daily}\\ \text{Usage}\\ \text{(uses/day)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Daily}\\ \text{Visitors}\\ \text{(persons)}\end{array}} = \boxed{\begin{array}{c}\text{Visitor}\\ \text{Water}\\ \text{consumed}\\ \text{per day}\\ \text{(gal/day)}\end{array}}$$

$$\boxed{\begin{array}{c}\text{Fixture}\\ \text{flow rate}\\ \text{(gal/min)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Duration}\\ \text{(min)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Employee}\\ \text{Daily}\\ \text{Usage}\\ \text{(uses/day)}\end{array}} \text{ X } \boxed{\begin{array}{c}\text{Daily}\\ \text{Employees}\\ \text{(persons)}\end{array}} = \boxed{\begin{array}{c}\text{Employee}\\ \text{Water}\\ \text{consumed}\\ \text{per day}\\ \text{(gal/day)}\end{array}}$$

Visitor Water consumed per day (gal/day) + Employee Water consumed per day (gal/day) = Water consumed per day (gal/day)

Water Closets (female/male):

Fixture flow rate (gal/flush) X Visitor Daily Usage (flushes/day) X Number of female / male visitors = Visitor Water consumed per day (gal/day)

Fixture flow rate (gal/flush) X Employee Daily Usage (flushes/day) X Number of female / male employees = Employee Water consumed per day (gal/day)

Visitor Water consumed per day (gal/day) + Employee Water consumed per day (gal/day) = Water consumed per day (gal/day)

Prewash Sprayer

Pre-rinse sprayers and wash down sprayers are used for cleaning dishes and kitchen areas. Unlike the previously listed fixtures, amount of time per each use of pre-rinse sprayers can vary greatly, a study conducted by the EPA WaterSense program measured individual uses ranging from 15-26 seconds at various restaurants.[45] Furthermore, the number of times the fixture is used does not necessarily correlate with the number of occupants. Therefore restaurants should use caution when estimating the number of uses per day and the average duration per use. If water utility bills are available, then the consumption by other fixtures and appliances should be estimated

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[45] (U.S. Environmental Protection Agency Watersense, 2011)

first and the remaining amount of purchased water can be used to guide the pre-rinse consumption estimation. Also confirm that the estimate does not exceed the actual purchased amount. The following equation is used to calculate the water consumption per sprayer:

Pre-rinse Sprayers and Wash down Sprayers:

$$\boxed{\text{Fixture flow rate (gal/min)}} \text{ X } \boxed{\text{Duration (min/use)}} \text{ X } \boxed{\text{Daily Usage (uses/day)}} = \boxed{\text{Water consumed per day (gal/day)}}$$

Potable Water Consumption by Appliances

In the restaurant operations several appliances both in food preparation and sanitation consume water. Typically these may include ice makers, woks, and steam ovens. The manufacturer's data needed to estimate water consumption by each appliance is slightly different and the following sections provide unique calculation methods for each appliance.

The warewashing appliances are the most significant consumer of water. While most units will heat water internally to reach required temperatures to ensure proper sanitation, they also usually require preheated water be supplied to the unit. To estimate the amount of water consumption rate per cycle or operating minute must be determined from manufacturer specifications. If water per minute is used, then the length of a typical cycle must also be obtained from the specifications. Furthermore, data concerning the estimated number of cycles per day should be gathered. As discussed in previously, if the daily usage varies significantly throughout the week as more customers attend on specific days (peak days vs non-peak days) the average number of cycles should be estimated for both days. There are two equations for calculating the heated water consumption from warewashers depending on the units for water consumption rate data gathered from the manufacturer specifications:

$$\boxed{\text{Water consumption rate (gal/min)}} \text{ X } \boxed{\text{Time per cycle (min)}} \text{ X } \boxed{\text{Daily Usage (cycles/day)}} = \boxed{\text{Water consumed per day (gal/day)}}$$

$$\boxed{\text{Water consumption rate (gal/cycle)}} \text{ X } \boxed{\text{Daily Usage (cycles/day)}} = \boxed{\text{Water consumed per day (gal/day)}}$$

Ice makers, can consume water for two purposes depending on the type of appliance. If the unit is air-cooled then water is only consumed to transform into ice. However, if it is water-cooled, then in addition to transforming water into ice, the appliance also uses water to cool the temperature. To calculate the amount of non-heated water consumed per day by ice machines data must be collected from the manufacture specifications including the amount of ice produced in a day, the amount of water consumed per unit of ice, and the amount of water used in cooling per unit of ice if the appliance is water-cooled. The following equation can then be used to estimate the daily amount of water consumed by each ice maker:

Daily Ice production rate (lbs/24 hr) X Water transformed into ice (gal/lbs) X Water for cooling (gal/lbs) [If applicable] = Water consumed per day (gal/day)

Steamers also consume amounts of water, the amount of which can vary greatly depending on the type of steamer. There is a significant difference between boilerless steamers that have an internal water reservoir that is filled manually versus boiler-based steamers which have a plumping connection with a pressurized water supply line. The boiler-based type utilize water both for transforming into steam as well as for condensing the steam back into water that is drained from the unit. To estimate the amount of water consumed by each steamer, data about the number of compartments, the number of operational hours per day, and the type of steamer are needed. If the water consumption rate is not available from manufacture specifications the average consumption rates provided in the appendix can be used however this will decrease the accuracy of the estimation. The following equation is used to calculate the daily amount of non-heated water supplied to the steamers:

Water consumption Rate (gal/hr) X Number of compartments X Daily Usage (hr/day) = Water consumed per day (gal/day)

Annual consumption of potable water is estimated by multiplying the daily consumption by the number of operational days within the twelve month emissions inventory period. Careful attention should be paid to select the correct number of days if different daily consumption and generation values are created for peak and non-peak days.

Estimating Heated Water Consumption.

Once the total potable water consumption per fixture and appliance is calculated, the portion of that water which is heated must be determined for use in the energy consumption calculations for the water heating equipment. To estimate the amount of heated water, the total potable water consumption by each figure and /or appliance should be multiplied by a factor based on the percentage of heated water used by that fixture or appliance. See the list below of hot water percentage factors for each appliance or fixture.

Sink	50%
Water Closet	0%
Urinal	0%
Shower	50%
Pre-rinse Sprayer	50%
Warewasher	100%
Icemaker	0%
Steamer	50%

CALCULATING EMISSIONS GENERATED ON-SITE

Calculations in this section focus on three subcategories; the emissions from combustion that occurs within stationary equipment that is on the restaurant site, emissions from the combustion in mobile vehicles that are owned or associated with the restaurant, and fugitive emissions released by refrigeration equipment. For the first two categories the approach is to determine the amount of fossil fuel that is combusted by equipment during the twelve month inventory period and then convert those quantities of fuel into emissions based on factors that are specific to the type of fuel. The following sections outline the methods for calculating and estimating the amount of fuel consumed in the operation of various pieces of equipment.

Combustion within kitchen equipment

To estimate the amount of fuel combusted by the various pieces of equipment within the restaurant the first step is to inventory the pieces of equipment. A list of the types of equipment that could be included is in Figure 26. All of these pieces of equipment follow a similar calculation method with the exception of water heating equipment which is described at the end of this section. Manufacturer specifications should be collected for each piece of equipment to determine the rated energy input value (maximum fuel consumption rate) for each. This information will be used along with a load factor referred to as the duty cycle which represents the portion of the rated energy input value that is actually consumed throughout the operation of the equipment during a typical day. This proportion of the maximum fuel consumption rate takes into account the fact that a piece of equipment will not be consuming the rated energy input value during all of its hours of operation. For example, an oven might only consume natural gas at the rated energy input value during start up when it is attempting to reach its set temperature. Once it has achieved that temperature the amount of gas consumed to maintain that temperature is less than the rated energy input value. This protocol uses duty cycle factors that have been published by the Food Service Technology Center based on laboratory tests, which are listed in Figure 26 for various types of equipment. Additionally an estimate of the number of hours that a piece of equipment operates for each day should also be noted. If there is a significant difference in operation on a given day, for example the equipment is used for lunch and dinner on weekends but only dinner on weekdays, then the hours of operation for both of these types of days (weekend versus weekday) should be noted.

These values should be used to estimate the total amount of fuel consumed for each piece of equipment per day using the following equation:

Rated energy input value (kBTU) X Duty cycle (%) X Daily Usage (hours/day) = Fuel consumed per day (kBTU/day)

Once the fuel consumption per day is determined for each piece of equipment then the annual consumption should be determined by multiplying the daily consumption by the number of days in the twelve month period that the equipment was utilized. If there are two or more types of days (i.e. weekends versus weekdays) as described above, then the daily estimate for each day type should be multiplied by the number of those types of days in the twelve month inventory period.

Once the annual fuel consumption is determined for each piece of equipment that consumes the same type of fuel, the accuracy of the hours of operations estimations can be evaluated if invoices for purchases of each specific fuel are available for the twelve month inventory period. For example once all of the fuel consumption is determined for equipment that consumes natural gas the total estimated amount of gas consumed can be compared to the total amount of natural gas purchased which is determined from the invoices that cover the twelve month inventory period. If the estimated total consumption of a fuel is significantly different (+ or - %10) then adjust the estimated hours of operation for each piece of equipment. There could also be some discrepancy in the data on the invoices and in the use of duty cycle values based on averages for all models of a particular piece of equipment so it is unlikely that the estimated total consumption of each fuel will precisely match the invoice data.

Figure 26

Equipment	**Common Fossil Fuel Types**	**Sample of Rated Energy Input Values for Natural Gas (see specific equipment model specifications for actual value)** Source: (Fischer, et al., 2002)	**Duty Cycle (Average rate of energy consumption expressed as a percentage of the rated energy input)** Source: (Fischer, et al., 2002)
Fryers	Natural Gas	80 - 120 kBtu/h (Open Deep Fat) 40 - 80 kBtu/h (Pressure/ Kettle) 180 kBtu/h (flat bottom - Chicken/Fish) 60-76 kBtu/h (flat bottom - donut)	20% (Open Deep Fat) 30% (Pressure/ Kettle) 30% (Flat Bottom - Chicken/Fish) 20% (Flat Bottom - Donut)
Ovens	Natural Gas Propane Gas Coal	Standard/ Convection/ Combination 40 - 100 kBtu/h (full-size) 20 - 40 kBtu/h (half-size) 15 - 20 kBtu/h (countertop) 20 - 120 kBtu/h (Deck) 120 - 150 kBtu/h (Conveyor) 40 - 60 kBtu/h (Rotisserie)	Standard/ Convection/ Combination 35% (full-size) 40% (half-size) 40% (countertop) 30% (Deck) 50% (Conveyor) 60% (Rotisserie)
Broilers	Natural Gas Propane Gas Coal	90 - 120 kBtu/h (underfired) 20 - 110 kBtu/h (overfired)	80% (underfired) 70% (overfired)
Range Tops	Natural Gas Propane Gas	120 - 210 kBtu/h (range top) 35 - 45 kBtu/h (range oven)	20% (range top) 40% (range oven)
Griddles	Natural Gas Propane Gas	60 - 80 kBtu/h	34%
Steamers	Natural Gas	170 - 250 kBtu/h (pressure) 170 - 250 kBtu/h (pressureless)	15% (pressure) 15% (pressureless)
Steam Kettles	Natural Gas	50 - 125 kBtu/h	40%
Braising Pans	Natural Gas	6 - 120 kBtu/h	45%
Hot water generation for Pre rinsing Warewashing	Natural Gas Propane Gas	Btuh energy input gph (gallons per hour) water generation/recovery rate gpm (gallons per min) water generation rate for tankless water heaters	

Combustion by Water Heating Equipment

Fuel consumption by water heating equipment is based on the amount of hot water generated and the temperature of the heated water. To estimate the fuel consumption additional calculations must be made to first estimate the amount of hot water at various temperatures that is consumed by other fixtures and pieces of equipment like dishwashing machines and pre rinse sprayers. Methods for estimating the amount of hot water consumed by these appliances and fixtures are included in the calculation methods section on municipal water consumption.

Once the total amount of hot water consumed per day by a piece of equipment is determined (sum off all hot water consumption of each fixture and appliance) the amount of operating time required for the water heater to generate the daily amount of hot water can be calculated. The operational time can then be used to estimate the amount of fuel consumed. The manufacturer provided rate of hot water generation at a given temperature varies depending upon the type of equipment. For tankless, on-demand water heaters, the rate of hot water generation is usually in gallons per minute. For water heaters with a storage tank, the recovery or generation rate is usually in gallons per hour. If various rates are provided for different temperatures, assume at least 120 F, though the water delivered to sanitizing equipment may be higher around 180F. Depending upon the type of equipment the following equations can be used to determine the daily operation time required to generate the estimated daily hot water demand:

$$\boxed{\text{Daily hot water generation (gal)}} \div \boxed{\text{Tankless Generation/ Recovery Rate (gal/min)}} \times \boxed{\text{Conversion Factor (hr/min)}} = \boxed{\text{Daily Operation time (hr)}}$$

$$\boxed{\text{Daily hot water generation (gal)}} \div \boxed{\text{Storage Tank Generation/ Recovery Rate (gal/hr)}} = \boxed{\text{Daily Operation time (hr)}}$$

The operational time per day can then be used to estimate the amount of energy consumed by the water heating equipment using the following calculation:

$$\boxed{\text{Daily Operation time (hr)}} \times \boxed{\text{Rated energy input (Btuh)}} = \boxed{\text{Daily Fuel Consumption (Btu)}}$$

The annual energy consumption by the water heating equipment can then be determined by multiplying the daily consumption by the number of operational days within the twelve month inventory period.

Combustion by Space Heating Equipment

The natural gas consumption utilized by makeup air and HVAC equipment to satisfy a restaurant's space heating is difficult to calculate due to the dynamic nature of heating demands. Just as was discussed in the calculations section for electricity consumption by HVAC equipment, there are many factors that contribute to the demand for space heating which is further complicated by the tempered makeup air demand to balance kitchen exhaust hoods. . Given the complex nature of this relationship, the amount natural gas combustion utilized by HVAC and makeup air units to meet the heating loads should be estimated by subtracting the total combustion by all other items covered in this section from the total amount of purchased natural gas for the twelve month inventory period. If the amount of purchased natural gas is unknown because the restaurant does not have utility invoices, then this area of natural gas consumption should not be included in the inventory and noted as an omission.

Combustion within restaurant owned mobile sources

Similar to the approach taken for estimating the emissions associated with the combustion of fossil fuels in vehicles used by employees for commuting to and from the restaurant, the emissions from combustion by restaurant vehicles requires data about the fuel consumption rates of the vehicles, distances traveled, and the number of trips made. Some restaurants may directly track the amount of fuel purchases for each vehicle, which can be used instead of estimating fuel consumption. If estimating fuel consumption based on travel distance and fuel economy rating of the vehicle, then travel distance data should be collected for restaurant owned vehicles.

The total distance traveled in the twelve month inventory period can then be multiplied by the average fuel economy value for the vehicle to determine an estimated amount of fuel consumed by the travel.

Converting to GHG emissions and GWPs

Once the annual quantity of fuel combusted is determined for each type of fuel combusted in stationary equipment and mobile sources, the quantity of fuel can be converted to emissions of CO_2, CH_4, and N_2O using the appropriate emissions factors for each fuel type. These factors are listed in the appendix organized by fuel type. This approach assumes that fuel burned in any engine emits the same mixture of GHGs. In reality differences in the conditions within the combustion chamber in which the fuel is combusted can impact the percent of N_2O or CH_4 that are created.[46] However, just as was the case in the fuel combustion in the restaurant equipment, the assumption of uniform combustion across engine types is made given that detailed monitoring of the emissions from each vehicle used by vendors, employees, the restaurant, and customers is impractical.

Emissions from Fugitive Release of Refrigerant Gasses

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[46] (Gillenwater, et al., 2005)

As described in the inventory boundary section, refrigerant gas emissions can have a significant impact on the total restaurant emissions inventory given their high potential for global warming in the atmosphere. Therefore special care should be taken in estimating the amount of refrigerant gases that have escaped equipment operated by the restaurant. Data specific to the actual installation and maintenance of the restaurant's equipment should be used so as not to over or under estimate the impact of the refrigerant gases.

The amount of fugitive refrigerant emissions should be reported from installation or annual maintenance records for the equipment which documents how much new refrigerant is purchased to recharge the equipment. If and when the units are maintained, the amount of refrigerant added should be assumed to be equal to the amount that has leaked out of the equipment in the time since the previous maintenance. To determine the annual amount of fugitive gasses the recharge amount for each must be divided by the number of years since the previous maintenance. This should be repeated for all of the equipment that uses a particular refrigerant gas. The equation for estimating the fugitive refrigerant gases per year is:

$$\frac{\boxed{\text{Refrigerant gas added to equipment (kg)}}}{\boxed{\text{Time since previous recharge (year)}}} = \boxed{\text{Leakage of refrigerant gas (kg/year)}}$$

This emissions data in kilograms of gas can then be converted to GWPs for each gas using GWPs found in the appendix for the most common refrigerants. For refrigerants not listed, GWPs can be sourced from alternative GHG calculation tools including the GHG Protocol or IPCC.

CALCULATING EMISSIONS GENERATED DOWNSTREAM

Mobile Combustion of Fossil Fuels by Customers and Delivery Vehicles

The calculation method for estimating the emissions generated by fossil fuel combustion in customer and delivery vehicles is identical to the method for estimating the emissions from combustion by employee commutes. Surveys of customers and delivery vehicle drivers can be conducted to gather the necessary information about the vehicle types, travel distances and frequency of travel. If customers travel via mass transit modes that combust fossil fuels, the calculation method in employee commutes by mass transit should be utilized.

Generation of Electricity Consumed by transporting Customers

Calculation methods used for estimating emissions from the transportation of employees via electric vehicles or electrified mass transit modes should also be used to estimate emissions associated with the generation of electricity that is consumed in electric vehicles used by customers.

Restaurant Generated Waste

The following subcategories address calculation methods for estimating the GHG emissions associated with various forms of waste generated by the restaurant.

Emissions from solid waste

Within the preparation and serving of food products, waste is generated that can be composted, recycled, or disposed of through municipal solid waste facilities. The general approach for calculating these emissions is to determine the total weight of materials in each end use stream and convert them to equivalent GHG emissions that result from the type of waste processing (composting, recycling, or various forms of municipal solid waste disposal).

End Use Stream	**Common Types of Waste (if applicable)**
Organic Composting	Food scraps
Aluminum Recycling	Aluminum cans
Steel Recycling	Steel Cans
Glass Recycling	Glass jars
Corrugated box Recycling	Food ingredient packaging
Mixed Paper Recycling	Office paper
High Density Polyethylene (HDPE) Plastic Recycling	#2 Plastic containers
Low-Density Polyethylene (LDPE) Plastic Recycling	#4 Plastic containers
Polyethylene Terephalate (PET) Plastic Recycling	#1 Plastic containers
Municipal Solid Waste (MSW) Landfill	NA
MSW Waste-to Energy (WTE)	NA

Figure 27

The annual weight of each type of waste should be estimated from invoices provided by the waste removal servicer. If this data is not directly available from the invoice, most servicers can provide an audit to assess the restaurant’s waste needs which will provide an estimated monthly weight. If volumes are provided or known based on the size of waste containers, it can be converted to weight using factors provided in the appendix. The total weight for each end use stream should then be multiplied by the corresponding emissions factor also provided in the appendix.

The portion of restaurant generated waste that goes to the MSW end use stream in Minnesota is processed in landfills or waste-to-energy (WTE) facilities throughout the state. Factors have been derived from the Minnesota Pollution Control Agency SCORE

Report on municipal solid waste resource recovery and disposal to determine how much MSW goes to landfills or WTE facilities.[47]

Total restaurant generated MSW (lbs) X MSW Landfill factor (%) = Restaurant generated MSW sent to landfill (lbs)

Total restaurant generated MSW (lbs) X MSW WTE factor (%) = Restaurant generated MSW sent to WTE (lbs)

Once the amount of MSW going to landfill or WTE facilities is determined emissions factors from the EPA's Waste Reduction Model (WARM) are used to equate the amounts of waste processed to GHG emissions. Given that the specific landfill where the waste is processed is usually unknown, the national average landfill emissions factor is used to account for possible flaring or energy recovery that might be utilized at the facility where the landfilled waste is processed. The emissions factor for mixed MSW processed at a WTE facility is also sourced from the EPA's WARM model.

Waste Water Generation

The protocol assumes that all of the potable water consumed by a restaurant eventually leaves the restaurant as waste water. Therefore the daily amount of waste water generated by a restaurant is equal to the amount of potable water consumed per day. Calculation methods for daily potable water consumption are included in the upstream calculation section.

Daily potable water consumption (gal) = Daily waste water generation (gal)

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[47] (Vee, 2010)

Off-site Laundry Services

For restaurants that utilize table settings and uniforms that are laundered off-site, the emissions associated with that activity are calculated based on the amount of items that are laundered throughout the year. The weight of items laundered during the twelve month inventory period should be determined based on invoices from the laundering service and average weights of individual items, if the invoices are based on quantity of specific items. The weight of laundered items is multiplied by the laundry GHG emissions factor provided in the appendix that accounts for the emissions generated by the activities associated with a typical offsite laundry service.

Customer Generated Waste

Emissions related to the disposal of take out or delivery containers by customers require estimating the weight of materials that are processed in various end use streams. State specific factors which reflect the likelihood of customers recycling, composting, or disposing of waste are used to determine how much of each type of waste is ultimately processed by each end use stream. Data must be collected for the annual quantity of food containers sold through take-out or deliveries. Greater detail about calculating the percentage of total sold product weight that enters the various end use streams is provided in the following sections.

The end use options for take-out containers vary by region and availability of waste treatment programs like recycling, composting, and MSW landfills. The calculation methods in this protocol are based on the programs available in the state of Minnesota, and therefore limit the types of containers that can go to recycling versus municipal solid waste. Containers made of PET, HDPE, or LDPE (#1, #2, and #4 resin identification codes) can be recycled in Minnesota, however plastic coated papers and polystyrene containers are not currently recyclable and will be processed either in an MSW landfill or WTE facility. All three possible end use destinations generate different amounts of GHG emissions. For the calculations, the first step is to estimate the weight of each type of food container sold via takeout and/or delivery by multiplying the number of takeout or delivery containers that are sold in the year by the average weight of the food container.

Number of PET, HDPE, LDPE food containers sold X Average weight per food container (lbs) = Recyclable food container waste (lbs)

Plastic Coated Paper, Polystyrene food containers sold X Average weight per food container (lbs) = Non-recyclable food container waste

The recyclable food container waste generated downstream by customers is then multiplied by the plastics recycling emissions factor found in the appendix. For non-recyclable food containers, the annual weight is multiplied by factors based on Minnesota waste end use statistics to estimate how much is sent to each type of waste destination.

Non-recyclable Food Container Waste (lbs) X MSW Landfill factor (%) = Food Container waste sent to Landfill (lbs)

Non-recyclable Food Container Waste (lbs) X MSW WTE factor (%) = Food Container Waste sent to WTE (lbs)

The emissions from the downstream food container waste are calculated by multiplying the amount of waste sent to each type of processing by the respective emissions factor found in the appendix.

APPLICATION OF THE TOOL - TEST USING DATA FROM AN EXISTING RESTAURANT

Historic operational data from a local restaurant is used to test the proposed tool, review the calculation methods, and understand the potential outputs. This data was collected by the author as a private consultant prior to this thesis research. The name of the restaurant is withheld and only basic identifying information has been included. The following sections describe the emissions inventory (upstream, on-site, and downstream) for the test case restaurant.

DESCRIPTION OF RESTAURANT

The test case restaurant is located in Minneapolis, MN. The data is from operations conducted during the twelve month period of March 2008 – February 2009. Utility invoices were available for purchased electricity, natural gas, municipal water, and waste removal. Invoices for food purchases were included for the top ten vendors based on dollars spent. Transportation data for commutes by employees and customers was collected through surveys conducted by the restaurant during two months within the twelve month operational period. The restaurant's characteristics are summarized below:

Building Size: 4000 ft^2 (2500 ft^2 Dining area / 1500 ft^2 Back of house)
Menu type: American (includes meat, seafood, and vegetarian options)
Operation type: Dine in only (no take-out or delivery service)
Average # Meals served per day: 148
Days of Operation per year: 360
Peak Day Operational hours: 17 (Kitchen operates 15.5 hours)
Non- Peak Day Operational hours: 15 (Kitchen operates 14 hours)

EMISSIONS INVENTORY

Overall the emissions inventory is dominated by emissions associated with activities upstream from the restaurant. As depicted in Figure 28, the upstream emissions are responsible for over 75% of the annual emissions associated with the restaurants operations while the on-site activities generate the majority of the remaining emissions with downstream activities contributing the least amount of GHG emissions. The following sections provide greater detail about the activities within each section of the supply chain that generate the emissions as well as identifying activities that were not applicable to this specific restaurant and therefore were excluded from the inventory.

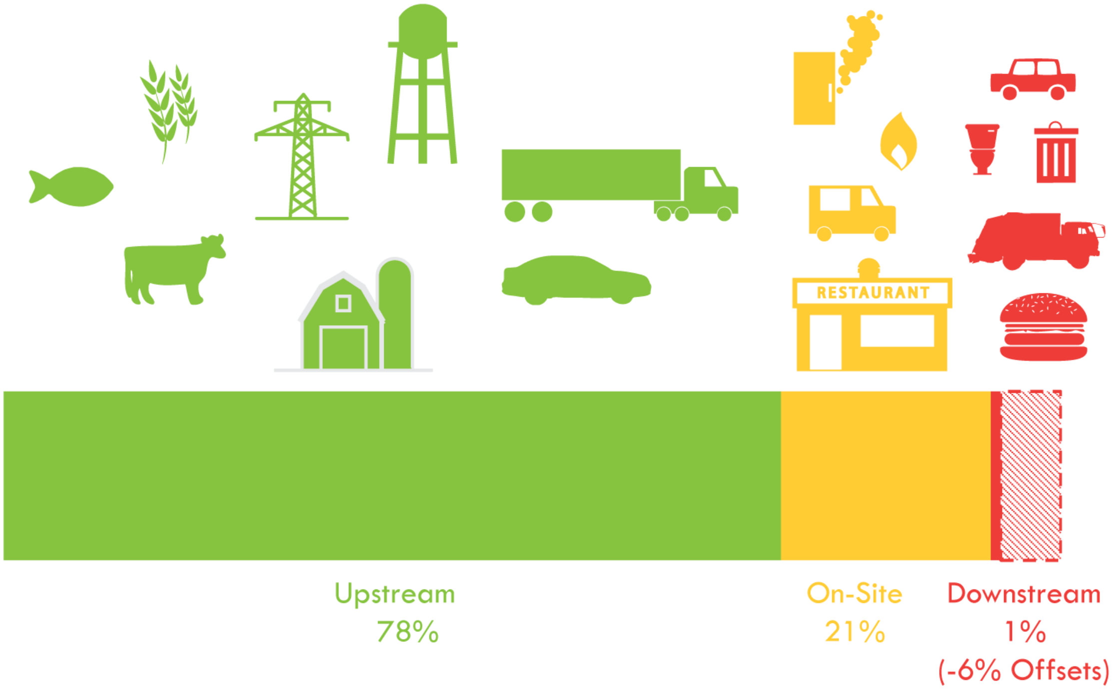

Figure 28

UPSTREAM EMISSIONS

Some categories from the tool were excluded from the upstream emissions inventory as they did not apply to the restaurant or data was not available. The test case restaurant is a dine-in operation without delivery or take-out services so the production of food containers is excluded. Furthermore, domestic hot water generation within the restaurant via an on-demand tankless water heater that uses natural gas. Rated energy input values for some of the smaller under counter coolers were not available so daily energy consumption estimates were sourced from the product manufacturers.

Specific equipment information was also limited for the air handlers and ventilation fans, so the unallocated portion of purchased electricity was assigned to these items after quantities were allocated for all other electricity consuming activities.

The chart below summarizes the categories and associated annual GHG emissions from each category.

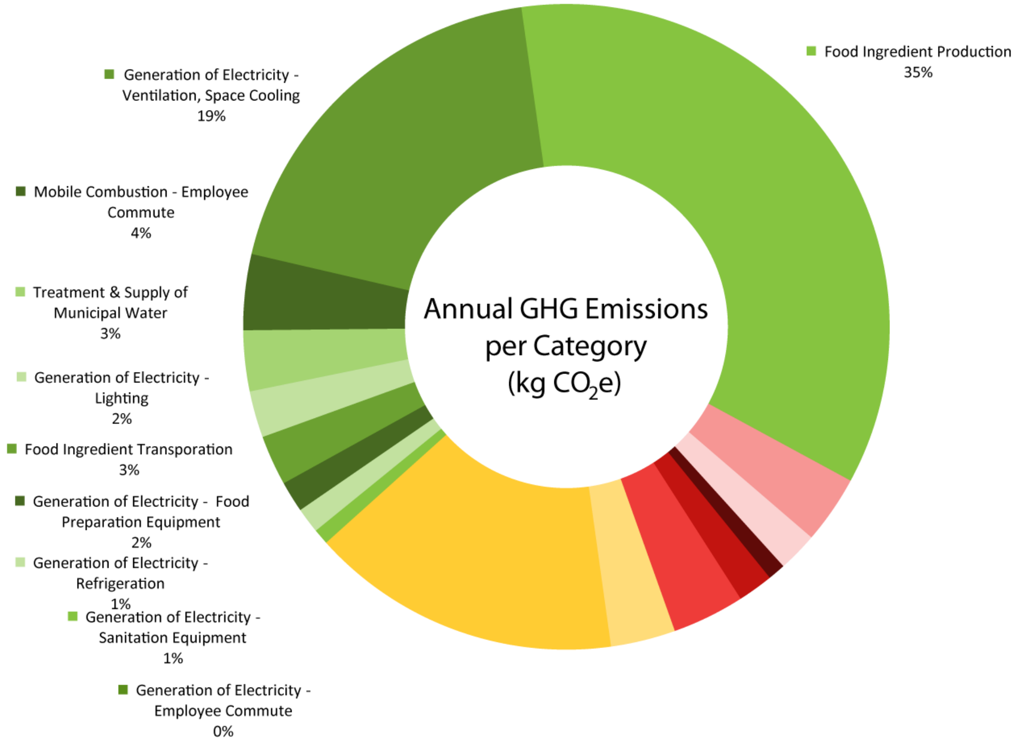

Figure 29

The food production related emissions dominate the upstream portion of the inventory with the generation of electricity for ventilation and space cooling as the second highest emissions generating activity.

At a more fine grain disaggregated level it is clear that the high level of emissions generated in the food production category are associated with only a few key ingredients related to the production of livestock (beef and pork), by-products of livestock (butter), and seafood. The generation of electricity associated with ventilation and space cooling was not able to be broken out by individual pieces of equipment due to lack of data for the exhaust ventilation fans so the emissions associated with this category are likely an overestimation as they are based on the remained of purchased electricity after estimated quantities were allocated to all other electricity consuming activities contributing to the electricity utility invoice.

ON-SITE EMISSIONS

Of the five onsite emissions generating activities included in the proposed tool, three were applicable to the test case restaurant. Mobile fossil fuel combustion within restaurant owned vehicles is not applicable as the restaurant does not own or operate any vehicles. Furthermore, the fugitive refrigerant gasses activity is also excluded as the restaurant recently opened and the new equipment did not yet need any refill of refrigerant gas. Within the remaining three categories, the stationary fossil fuel combustion within food preparation equipment generated the majority of emissions. The test case restaurant uses tankless on demand water heaters for all hot water needs, however specific equipment information was not available. The total amount of natural gas that remained after estimating consumption by all the food preparation equipment is therefore assigned to space heating and the domestic water heating.

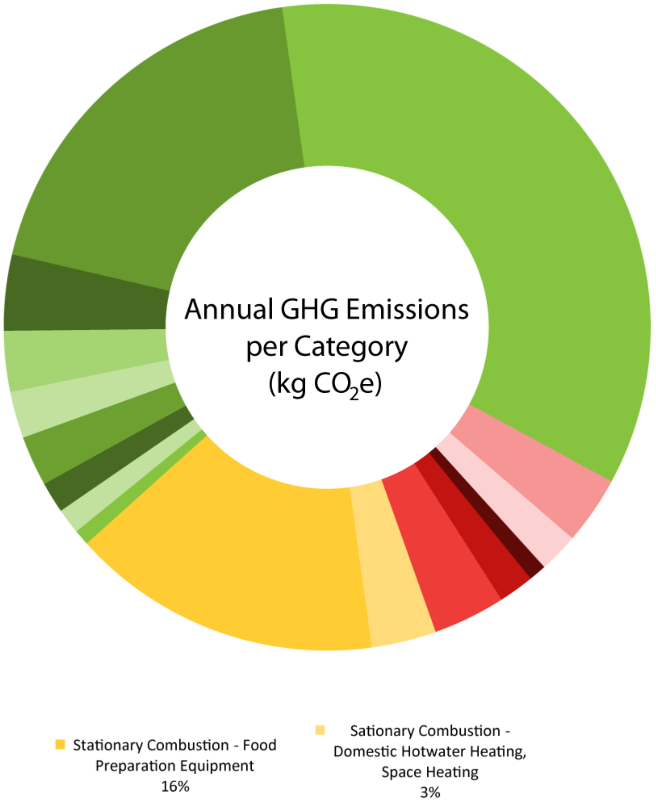

Figure 30

At the fine-grain disaggregated level, the emissions from fossil fuel combustion in food preparation equipment is mostly associated with the large range/oven and the grill both of which generated more emissions than those emissions associated with space heating and domestic hot water heating.

DOWNSTREAM EMISSIONS

As a dine-in only restaurant, some downstream emissions generating activities were not applicable to the test case restaurant. Restaurant delivery vehicles and customer generated waste from take-out containers were excluded. Furthermore, data on off-site laundry service usage was not available and the customer transportation survey revealed that no customers used electrified mass transit or electric vehicles to visit the restaurant. Of the activities that were applicable, the test case restaurant's downstream emissions inventory includes significant emissions from waste water treatment as well as significant emissions offsets from waste composting and recycling services.

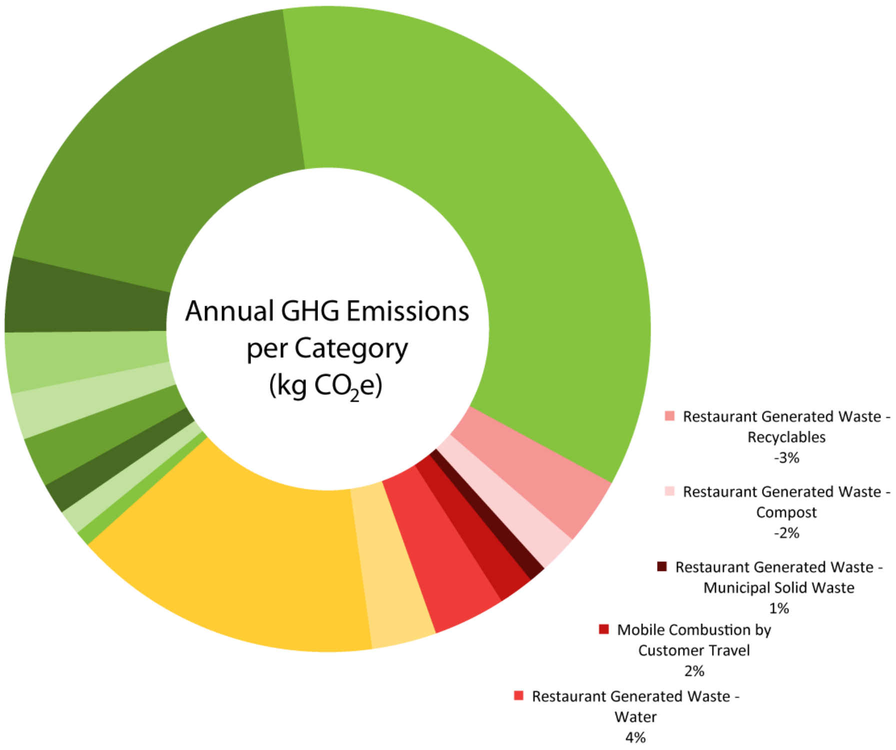

Figure 31

At the fine-grain disaggregated level, the emissions offsets from organic composting and mixed paper recycling are shown to be significant and nearly balance out the emissions associated with the treatment of the waste water generated by the restaurant.

ANALYSIS

The proposal for a GHG emissions inventory protocol for restaurant operations is based in part on the criticism that existing tools and protocols do not provide an inventory that can help restaurant managers identify the activities within the restaurant that generate the most significant amounts of emissions and therefor develop targeted actions to reduce or offset emissions associated with specific activities or equipment.

The following figures reveal how the utilization of the calculation methods in this protocol can help reveal specific activities that are the hotspots for generating emissions. This series of figures depicts the emissions inventory at three levels of aggregation, top level supply chain, activities categories, and individual components to demonstrate the depth of insight that is achievable by disaggregating the data to find hotspots.

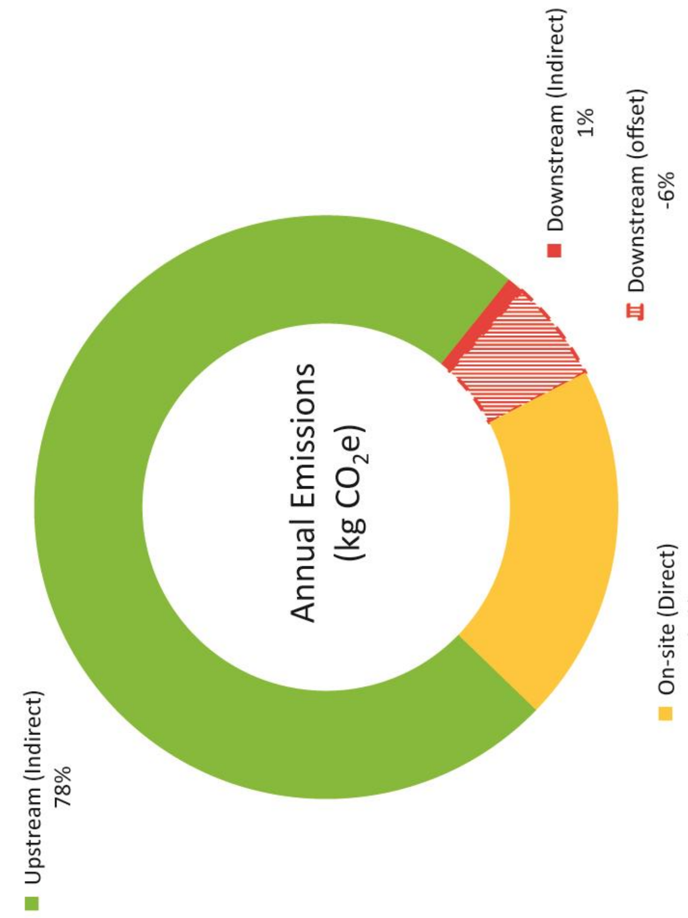
Annual Emissions (kg CO_2e)
Upstream (Indirect) 78%
On-site (Direct) 21%
Downstream (Indirect) 1%
Downstream (offset) -6%

Figure 32

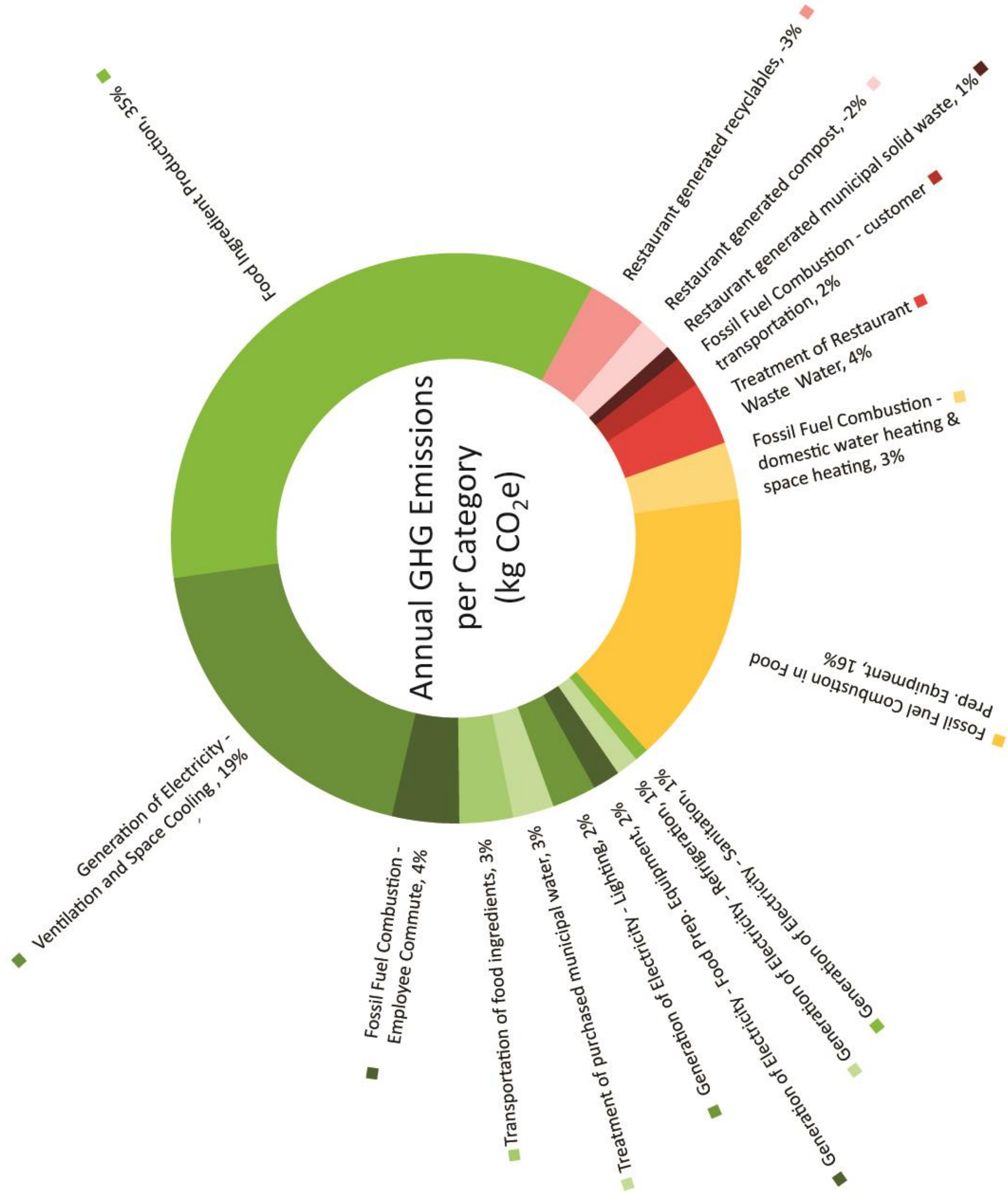
Annual GHG Emissions per Category (kg CO_2e)
Food Ingredient Production, 35%
Restaurant generated recyclables, -3%
Restaurant generated compost, -2%
Restaurant generated municipal solid waste, 1%
Fossil Fuel Combustion - customer transportation, 2%
Treatment of Restaurant Waste Water, 4%
Fossil Fuel Combustion - domestic water heating & space heating, 3%
Fossil Fuel Combustion in Food Prep. Equipment, 16%
Generation of Electricity - Sanitation, 1%
Generation of Electricity - Refrigeration, 1%
Generation of Electricity - Food Prep. Equipment, 2%
Generation of Electricity - Lighting, 2%
Treatment of purchased municipal water, 3%
Transportation of food ingredients, 3%
Fossil Fuel Combustion - Employee Commute, 4%
Generation of Electricity - Ventilation and Space Cooling , 19%

Figure 33

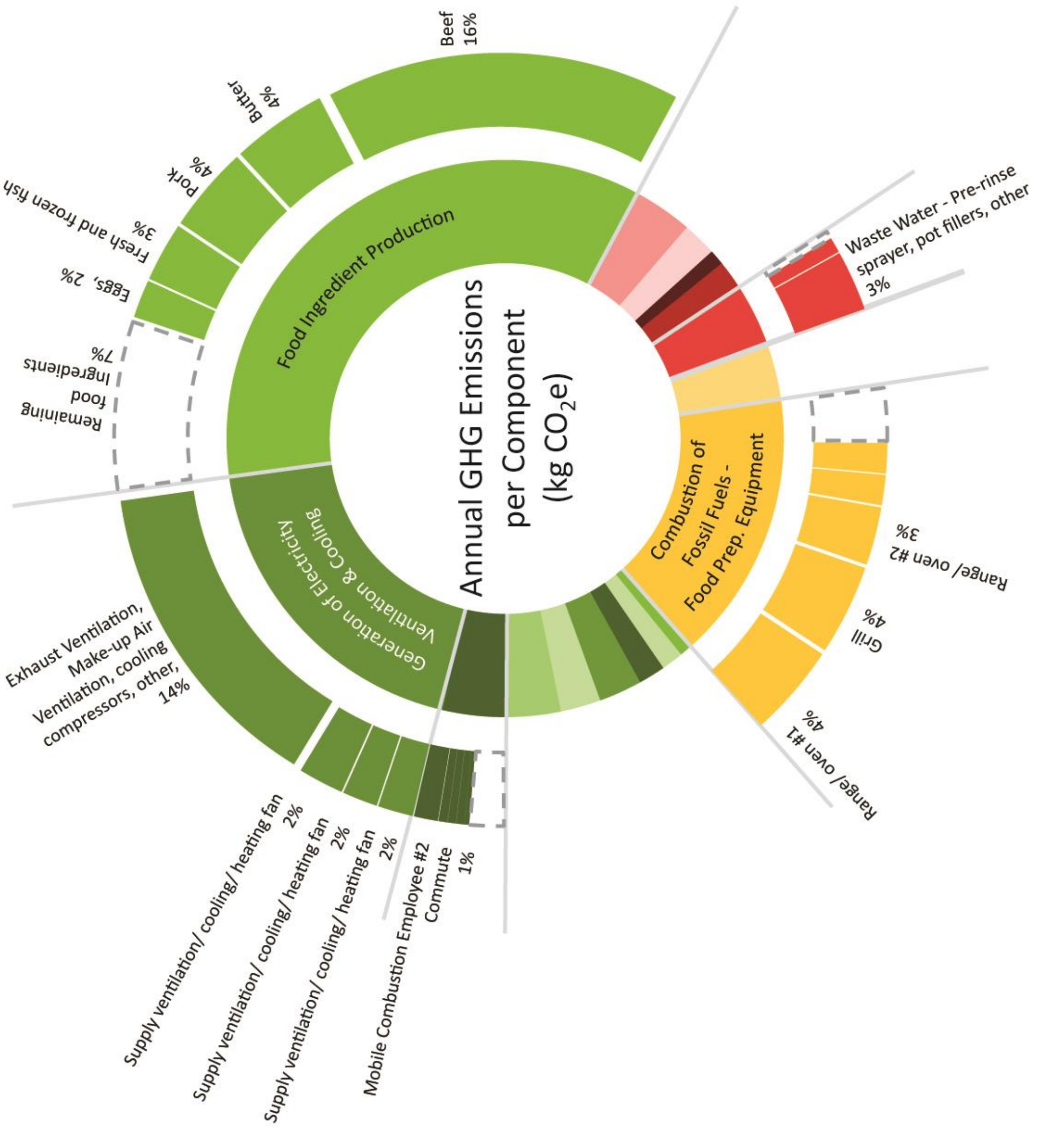
Annual GHG Emissions per Component (kg CO$_2$e)
Food Ingredient Production
Generation of Electricity Ventilation & Cooling
Combustion of Fossil Fuels - Food Prep. Equipment
Beef 16%
Butter 4%
Pork 4%
Fresh and frozen fish 3%
Eggs, 2%
Remaining food ingredients 7%
Exhaust Ventilation, Make-up Air Ventilation, cooling compressors, other, 14%
Supply ventilation/ cooling/ heating fan 2%
Supply ventilation/ cooling/ heating fan 2%
Supply ventilation/ cooling/ heating fan 2%
Mobile Combustion Employee #2 Commute 1%
Range/ oven #1 4%
Grill 4%
Range/ oven #2 3%
Waste Water - Pre-rinse sprayer, pot fillers, other 3%

Figure 34

OBSERVATIONS

Menu selection and cooking technique can have a significant impact on the emissions generated by the restaurant. In the inventory of the test-case restaurant, the top five emissions generating activities which account for 44% of the total emissions are electricity consumption by ventilation supply and exhaust fans, the production of beef and butter, and the combustion of natural gas in the range/oven and the grill. While this is only a single case and definitive assertions would have to be based on larger studies of more restaurants, these results are driven by the menu which includes red meats cooked on energy intensive grills and ranges that produce high amounts of effluent and grease that require high volumes of exhausted air and tempered make-up air. In fact, these results are not too surprising given the known energy intensity of restaurant operations and the significant GHG emissions factors for cattle production, electricity generation, and natural gas combustion.

Electricity consumption is significant and therefore the amount of GHG emissions associated with each unit of electricity can make electricity consuming activities more or less significant in a restaurant's emissions inventory. For example a kWh of electricity generated in the Midwest Regional Electric grid produces 650 g CO_2e while the same kWh generated in Seattle would produce 418 g CO_2e/kWh.

IMPLICATIONS FOR RESTAURANT DESIGNERS

Designers should be mindful of the GHG emissions intensity of the electricity for the region in which the restaurant is to be located. While the collaboration with the chef will focus on designing a kitchen and dining area that allows for the proper execution of menu items, it should also minimize the energy consumption of cooking equipment and ventilation supply/exhaust.

Comparison with other restaurant GHG emissions footprints

In the last three years a hand full of GHG emissions inventories for restaurants have been published in non-peer reviewed sources. These inventories have been undertaken by group of restaurateurs, chefs and GHG emissions researchers with the organizations Zero Foodprint and Origin Climate. Their work has produced GHG emissions inventories for a few restaurants, most notably Noma, of Copenhagen, Denmark and Prime Meats of Brooklyn, New York.[48] Though their methodology is not published and cannot be compared to the methodology proposed here in the Restaurant GHG Guideline, the results do show some correlations between the GHG emissions inventories. Some categories in the Restaurant GHG Guideline are not covered by the Zero Foodprint

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[48] (Ying, 2016)

study, most notably, treatment of municipal water, waste water treatment, employee and customer. To compare the test case restaurant inventory with the two inventories by Zero Foodprint, these additional categories are excluded. Figure 35 is a hybrid graphic comparing the emissions inventory of the test case restaurant created by the author to those of Noma and Prime Meats created by Zero Foodprint.

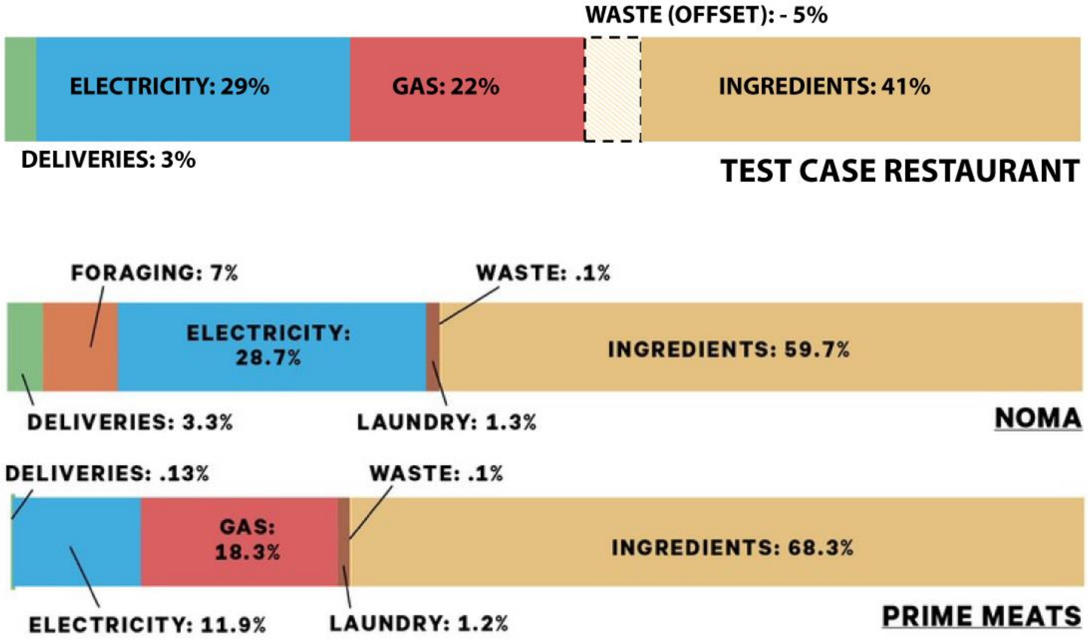

Figure 35

FUTURE IMPROVEMENTS TO THE TOOL

The test of the tool via data from the Minneapolis based restaurant revealed some areas for improvement to the calculation methods for future iterations of the tool. Improving methods for estimating emissions associated with space heating, space cooling, ventilation, and exhaust would be valuable as these activities consume significant amounts of energy. These activities are particularly hard to disaggregate given the interdepend nature of using energy to heat and cool outside air that is supplied to the building both to provide space conditioning as well as equalize pressure within the restaurant while significant volumes of air are being exhausted from above cooking equipment. Design of the restaurant and proximity of kitchen exhaust fans to dining areas as well as the design of exhaust hoods and variable speed exhaust fans can all play a role in the amount of energy and ultimately emissions associated with these processes.

Similar to the ventilation, and space cooling, water consumption by pre wash sprayers and pot fillers was shown to be a significant activity in terms of total water consumption.

Calculation methods for estimating usage of these fixtures are not currently provided in the tool as they could vary greatly restaurant to restaurant based on training of personnel.

CONCULSION

This thesis proposal for a GHG emissions inventory protocol for restaurant operations identifies critical operational areas to include in the inventory and provides resources to help restaurants estimate emissions to identify potential hot-spots of emissions generation across their operational supply chain. The proposal serves to fill a gap in existing GHG emissions estimation tools that are currently too general to have much application to the restaurant building typology. This typology is unique in that it sits at the nexus between a building type that consumes large quantities of resources in its operations and relies upon the investment of additional resources offsite for the production of food ingredients to be used to create its products.

Future application of this tool with a variety of restaurants could yield valuable information as designers and chefs strive to reduce the environmental impact of the restaurant operations. However, it is important to not compare strictly based on GHG emissions to avoid a misinterpretation of data where a drop in productivity (i.e. lower patronage of a restaurant) and its resulting drop in GHG emissions would be misinterpreted as a favorable trend. Rather, the most successful restaurant should be the one that increases GHG emissions efficiency whereby increasing productivity while decreasing the amount of GHG emissions generated in the production.

The unit of metric tons CO_2e per number of meals served could be one metric for comparison that specifically relates the emissions to a comparable measurement across restaurants. However, even this metric could be misleading as a meal served at one restaurant may not be comparable to another in terms of calories or nutritional value. Emissions per calorie could be a more accurate reflection of the value of a restaurant's product, but again, some might argue that the value of a restaurant's meal is not simply the number of calories in the food, but also the nutrients that patrons receive that reflects the quality of the food ingredients.

Regardless of the specific metric, a standardized measure that balances both productivity and environmental impacts would aid in the comparison of a restaurant performance over time, or between different restaurants.

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APPENDIX

APPENDIX A - CALCULATION EMISSIONS FACTORS

This appendix provides emissions factors and estimation figures referenced throughout the calculation methods sections. Data sources are provided with each data table.

Emissions Factors	Unit	CO_2e (kg/unit)	CO_2e (lbs/unit)	SOURCE
Electricity				
MROW Grid (kWh)	kWh	0.65		1
MROW Grid (kBtu)	kBtu	0.19		1a
Stationary Combustion				
Natural gas (TJ)	TJ	56266.50		2
natural gas (kBtu)	kBtu	0.06		2a
Liquified Petroleum Gases (propane, butane) (TJ)	TJ	63266.50		2
Liquified Petroleum Gases (propane, butane) (kBtu)	kBtu	0.07		2a
Anthracite coal (TJ)	TJ	98725.50		2
Anthracite coal (kBtu)	kBtu	0.10		2a
Wood (TJ)	TJ	13100.00		2
Wood (kBtu)	kBtu	0.13		2a
Mobile Combustion				
gasoline (gal)	gal	8.81		3
diesel (gal)	gal	10.15		3
jet fuel (gal)	gal	8.32		3
Water				
Water supply (gal)	gal	0.03	0.06	4
Waste Water Treatment (gal)	gal	0.03	0.08	5
Waste				
MSW - landfill (lbs)	lbs	0.98		6
MSW - waste to energy recovery (lbs)	lbs	-0.04		6
Aluminum recycling (lbs)	lbs	-8.89		6
Steel recycling (lbs)	lbs	-1.80		6
glass recycling (lbs)	lbs	-0.28		6
Corrugated box recycling (lbs)	lbs	-3.11		6
HDPE Plastic Recycling (lbs)	lbs	-0.86		6
LDPE Plastic Recycling (lbs)	lbs	-1.71		6
PET Plastic Recycling (lbs)	lbs	-1.11		6

Mixed paper recycling - general (broad definition) (lbs)	lbs	-3.52	6
Mixed paper recycling - primarily from offices (lbs)	lbs	-3.59	6
Mixed metals (lbs)	lbs	-3.97	6
Mixed plastics (lbs)	lbs	-0.98	6
Mixed recyclables (lbs)	lbs	-2.80	6
Food Scraps compost (lbs)	lbs	-0.20	6
Food Transportation			
Red Meat ($)	$	0.06	7
Chicken/Fish/Eggs ($)	$	0.06	7
Dairy Products ($)	$	0.08	7
Cereals/Carbs ($)	$	0.13	7
Fruit/Vegetable ($)	$	0.21	7
Oils/Sweets/Cond ($)	$	0.10	7
Beverages ($)	$	0.11	7
Other Misc ($)	$	0.07	7
Food Production			
added sugar and sweeteners	kg	0.96	8
avg fresh fruit	kg	0.49	8
avg fresh vegetables	kg	0.73	8
apples	kg	0.36	8
apricots	kg	0.36	8
artichokes	kg	0.73	8
asparagus	kg	8.87	8
avocados	kg	1.27	8
beef	kg	26.45	8
bell peppers	kg	0.88	8
berries	kg	0.33	8
blueberries	kg	0.33	8
broccoli	kg	0.40	8
brussels sprouts	kg	0.33	8
butter	kg	11.92	8
cabbage	kg	0.12	8
canned fish and shellfish	kg	4.11	8
canned fruit	kg	1.05	8
canned vegetables	kg	1.10	8
cantaloupe	kg	0.27	8
carrots	kg	0.53	8
cauliflower	kg	0.39	8
celery	kg	0.73	8

cherries	kg	0.36	8
citrus	kg	0.50	8
collards	kg	0.33	8
corn products	kg	0.66	8
cream cheese	kg	1.92	8
cucumbers	kg	0.66	8
cured fish	kg	4.11	8
dried fruit	kg	1.03	8
eggplant	kg	1.30	8
eggs	kg	3.54	8
endive	kg	1.46	8
escarole	kg	1.46	8
fluid milk	kg	1.34	8
fresh and frozen fish	kg	3.83	8
fresh and frozen shellfish	kg	11.74	8
fruit juices	kg	1.03	8
garlic	kg	0.33	8
grapes	kg	0.29	8
half and half	kg	3.77	8
head lettuce	kg	1.08	8
honeydew	kg	0.27	8
kale	kg	0.33	8
legumes	kg	0.78	8
light and heavy cream	kg	3.77	8
lima beans	kg	0.73	8
mushrooms	kg	0.73	8
mustard greens	kg	0.33	8
okra	kg	0.73	8
onions	kg	0.39	8
peaches	kg	0.36	8
pears	kg	0.29	8
pineapples	kg	0.31	8
plums	kg	0.36	8
pork	kg	6.87	8
potatoes	kg	0.21	8
poultry	kg	5.05	8
pumpkin	kg	0.09	8
radishes	kg	0.33	8
raspberries	kg	0.33	8
rice	kg	1.14	8
romaine leaf lettuce	kg	1.08	8

snap beans	kg	0.73	8
sour cream	kg	2.60	8
spinach	kg	0.13	8
squash	kg	0.09	8
strawberries	kg	0.35	8
sweet corn	kg	0.73	8
sweet potatoes	kg	0.33	8
tomatoes	kg	0.67	8
total cheese	kg	9.78	8
total tree nuts	kg	1.17	8
total wheat flours	kg	0.58	8
turnip greens	kg	0.33	8
watermelon	kg	0.27	8
yogurt	kg	2.02	8
Food Container Production			
Recycled Paper	kg		
Polylactic Acid (PLA) Plastic	kg	4.21	9
Polystyrene (PS) Foam	kg	5.40	9
Polyethylene (PET) Plastic	kg	4.88	9
Laundry			
linens washed (kg)	kg	0.17	10

[1] EPA eGRID 2012

[1a] Converted from kg CO_2e/kWh to kg CO_2e/kBtu by author

[2] IPCC 2006 Guidelines for reporting National Greenhouse Gas Inventories (assumes higher heating value)

[2a] Converted from kg CO_2e/TJ to kgCO_2e/kbtu by author

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[6] EPA WARM Waste Emissions Factors Updated 2012

[7] Weber & Mattews 2008

[8] Heller, M.C. and G.A. Keoleian. 2014

[9] Madival, S. et al. Assessment of the environmental profile of PLA, PET and PS clamshell containers using LCA methodology, Journal of Cleaner Production, volume 17, issue 13, September 2009 pp 1183-1194

[10] Eberle, U., A. Lange, J. Dewaele, and D. Schowanek, LCA Study and Environmental Benefits for Low Temperature Disinfection Process in Commercial Laundry, International Journal of Life Cycle Assessment v 12, issue 2, March 2007, pp 127-138

APPENDIX B – ADDITIONAL FACTORS FOR CALCULATIONS

The following tables include factors used for various calculations as referenced in the calculations section of the main document.

Electrified Transit Efficiency Factors	
Mode	Energy Efficiency (passenger mile/kWh)
Light Rail	2.98

Source: Davis, Stacy C.; Diegel, Susan W.; Boundy, Robert G.; Oak Ridge National Laboratory; Vehicle Technologies Office Office of Energy Efficiency and Renewable Energy U.S. Department of Energy. (2015). Transportation Energy Data Book 34th Edition. Washington D.C.: U.S

Bus Transit Efficiency Factor	
Mode	Energy Efficiency (passenger mile/gal)
Bus	31.86

Source: Davis, Stacy C.; Diegel, Susan W.; Boundy, Robert G.; Oak Ridge National Laboratory; Vehicle Technologies Office Office of Energy Efficiency and Renewable Energy U.S. Department of Energy. (2015). Transportation Energy Data Book 34th Edition. Washington D.C.: U.S

Minnesota Municipal Solid Waste Stream Factor	
Waste Stream	% of MSW Diverted
Landfill	62%
Waste to Energy	38%

Source: Vee, A. (2010). Report on 2009 Score Programs: A Summary of Recycling and Waste Management in Minnesota. Saint Paul: Minnesota Pollution Control Agency

APPENDIX C - TABLES FROM TEST CASE CALCULATIONS

The following tables include the data and calculations from the test case restaurant.

Overview tables

Upstream Activity	Annual Emissions (kg CO_2e)	% of Upstream Emissions	% of Annual Emissions Inventory
Food Ingredient Production	231763.54	50.12%	36.93%
Food Ingredient Transportation	20076.35	4.34%	3.20%
Mobile Combustion - Employee Commute	25049.39	5.42%	3.99%
Generation of Electricity - Employee Commute	45.36	0.01%	0.01%
Generation of Electricity - Food Preparation Equipment	10236.72	2.21%	1.63%
Generation of Electricity - Sanitation Equipment	5190.44	1.12%	0.83%
Generation of Electricity - Refrigeration	8401.99	1.82%	1.34%
Generation of Electricity - Lighting	15391.82	3.33%	2.45%
Generation of Electricity - Ventilation & Cooling	126268.84	27.30%	20.12%
Treatment & Supply of Municipal Water	20031.51	4.33%	3.19%

On-site Activity	Annual Emissions (kg CO_2e)	% of Downstream Emissions	% of Annual Emissions Inventory
Stationary Combustion - Food Preparation Equipment	102458.15	82.74%	16.43%
Stationary Combustion - Domestic Hot Water Heating, Forced Air Space Heating	21368.02	17.26%	3.43%

Downstream Activity	Annual Emissions (kg CO_2e)	% of Downstream Emissions	% of Annual Emissions Inventory
Mobile Combustion by Customer Travel	614.66	0.93%	0.10%
Restaurant Generated Waste - Compost	-13068.00	19.87%	2.10%
Restaurant Generated Waste - Recyclables	-22457.04	34.14%	3.60%
Restaurant Generated Waste - Municipal Solid Waste	5786.90	8.80%	0.93%
Restaurant Generated Waste - Water	23850.02	36.26%	3.82%

DETAILED DATA TABLES – UPSTREAM ACTIVITIES

Upstream - Food Production

Food Category	Quantity Purchased (kg)	Emissions Factor (kg CO_2e/kg food)	GHG Emissions (kg CO_2e)
added sugar and sweeteners	0.45	0.96	0.44
all fresh fruit	117.93	0.49	57.45
all fresh vegetables	2603.32	0.73	1898.44
apples	549.16	0.36	197.70
apricots	89.36	0.36	32.17
artichokes	171.91	0.73	125.50
asparagus	172.82	8.87	1532.90
avocados	463.46	1.27	588.59
beef	3881.18	26.45	102657.28
bell peppers	67.59	0.88	59.47
berries	103.96	0.33	34.31
blueberries	28.12	0.33	9.28
broccoli	441.25	0.40	176.50
brussels sprouts	168.51	0.33	55.61
butter	2321.26	11.92	27669.38
cabbage	740.15	0.12	88.82
canned fish and shellfish	10.10	4.11	41.50
canned fruit	17.04	1.05	17.89
canned vegetables	105.32	1.10	97.40

cantaloupe	14.06	0.27	3.80
carrots	786.48	0.53	416.84
cauliflower	389.03	0.39	151.72
celery	1025.12	0.73	748.34
cherries	36.29	0.36	13.06
citrus	3108.14	0.50	1554.07
collards	115.21	0.33	38.02
corn products	11.34	0.66	7.48
cream cheese	13.61	1.92	26.13
cucumbers	49.44	0.66	32.63
cured fish	2.49	4.11	10.25
dried fruit	84.82	1.03	87.37
eggplant	129.27	1.30	168.06
eggs	3102.57	3.54	10983.10
endive	34.47	1.46	50.33
escarole	189.60	1.46	276.82
fluid milk	1529.72	1.34	2049.82
fresh and frozen fish	4486.29	3.83	17182.48
fresh and frozen shellfish	833.63	11.74	9786.86
fruit juices	436.81	1.03	449.91
garlic	357.43	0.33	117.95
grapes	68.04	0.29	19.73
half and half	727.90	3.77	2744.19
head lettuce	343.73	1.08	371.23
honeydew	19.50	0.27	5.27
kale	339.97	0.33	112.19
legumes	86.18	0.78	67.22
light and heavy cream	1254.24	3.77	4728.48
lima beans	124.74	0.73	91.06
mushrooms	844.91	0.73	616.78
mustard greens	84.85	0.33	28.00
okra	4.54	0.73	3.31
onions	3115.72	0.39	1215.13
peaches	174.18	0.36	62.70
pears	340.48	0.29	98.74
pineapples	9.75	0.31	3.02
plums	12.93	0.36	4.65
pork	3618.80	6.87	24861.17
potatoes	12169.87	0.21	2555.67
poultry	1786.46	5.05	9021.62
pumpkin	123.49	0.09	11.11

radishes	57.61	0.33	19.01
raspberries	61.69	0.33	20.36
rice	4.54	1.14	5.17
romaine leaf lettuce	357.43	1.08	386.02
snap beans	114.53	0.73	83.61
sour cream	439.08	2.60	1141.60
spinach	309.35	0.13	40.22
squash	2001.20	0.09	172.35
strawberries	175.09	0.35	61.28
sweet corn	186.88	0.73	136.42
sweet potatoes	54.43	0.33	17.96
tomatoes	1594.60	0.67	1068.38
total cheese	225.24	9.78	2202.85
total tree nuts	18.14	1.17	21.23
total wheat flours	69.63	0.58	28.94
turnip greens	29.48	0.33	9.73
watermelon	365.14	0.27	98.59
yogurt	65.77	2.02	132.86

Food Transportation			
Food Categories	Quantity ($)	Emissions Factor (kg CO2e/$ food)	GHG Emissions (kg CO2e)
Cereals/Carbs	81.88	0.13	10.41
Chicken/Fish/Eggs[1]	29541.21	0.06	1917.58
Dairy Products	17286.35	0.08	1457.47
Fruit/Vegetable	62282.96	0.21	13234.76
Oils/Sweets/Cond	0.00	0.10	0.00
Other Misc	0.00	0.07	0.00
Red Meat[1]	58737.08	0.06	3456.13

[1] Invoice data for fish and red meat purchases was not available for all vendors. The quantities reported are less than the actual total quantity purchased by the test case restaurant during the time period. While the inclusion of these additional quantities would increase the emissions associated with transportation, it likely would not move up in ranking of hot-spots given the low emissions factors for red meat and fish transportation.

Treatment of Municple Water - Consumption by Plumbing Fixtures

Fixture Type	Flow Rate (Gal per min / Gal per flush)	Duration (min)	Employee Daily Usage	Visitor Daily Usage	Employees	Visitors/ Customers	Daily Consumption (gal)	Annual Consumption (gal)	Annual GHG emissions (kg CO_2e)
restroom water closet #1 - female	1.6		3.0	0.5	5	74	83.20	30284.80	879.17
restroom water closet #2 -female	1.6		3.0	0.5	5	74	83.20	30284.80	879.17
restroom urinal - male	1		2.0	0.4	5	74	39.60	14414.40	418.45
restroom water closet - male	1.6		1.0	0.1	5	74	19.84	7221.76	209.65
restroom sink #1 - women	2.2	0.5	3.0	0.5	5	74	57.20	20820.80	604.43
restroom sink #2 - women	2.2	0.5	3.0	0.5	5	74	57.20	20820.80	604.43
restroom sink - male	2.2	0.5	3.0	0.5	5	74	57.20	20820.80	604.43
handwash sink - bar	2.2	0.5	1.0	0.0	10	148	11.00	4004.00	116.24
handwash sink - front kitchen	2.2	0.5	1.0	0.0	10	148	11.00	4004.00	116.24
handwash sink - rear kitchen	2.2	0.5	1.0	0.0	10	148	11.00	4004.00	116.24
OTHER (Pre-rinse sprayers, pot filler, ice maker)								504177.84[1]	14636.24

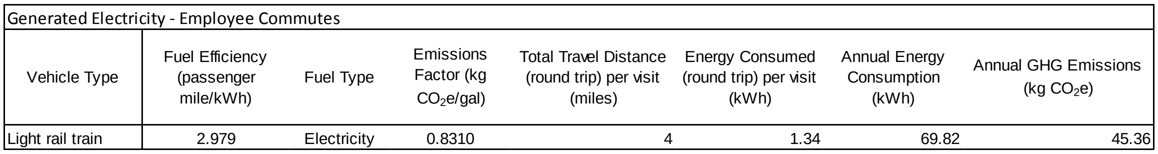
[1] Detailed use information was not available for these fixtures/pieces of equipment so this number reflects the remaining unallocated gallons of water from annual utility invoices

Treatment of Municple Water - Consumption by Equipment

Equipment	Water Usage (gal per cycle/rack)	Non-Peak Usage (cycles/day)	Peak Day Usage (cycles/day)	Non Peak Day Consumption (gal)	Peak Day Consumption (gal)	Annual Consumption (gal)	Annual GHG emissions (kg CO_2e)
Warewasher - bar	1.7	25	40	42.50	68.00	18122.00	526.08
Warewasher - dish room	0.85	30	50	25.50	42.50	11050.00	320.78

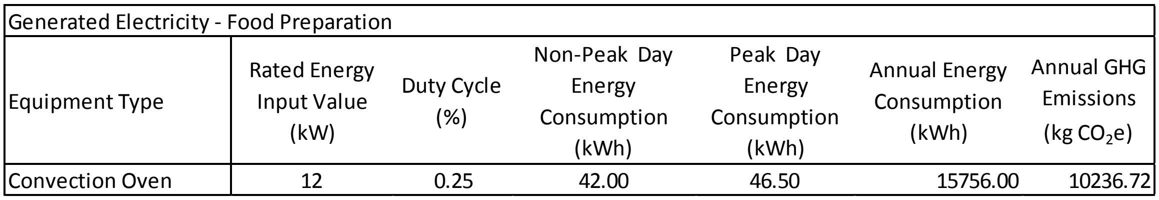
Mobile Combustion by Employee Commutes

Vehicle Type	Fuel Efficiency (miles/gal) (miles/passenger mile)	Fuel Type	Emissions Factor (kg CO_2e/gal)	Total Travel Distance (round trip) per visit (miles)	Fuel Consumed (round trip) per visit (gal)	Annual Fuel Consumption (gal)	Annual GHG Emissions (kg CO_2e)
car/truck/motorcycle/scooter	22.500	gas	9.0166	4	0.18	46.22	416.77
car/truck/motorcycle/scooter	22.000	gas	9.0166	84	3.82	763.64	6885.40
car/truck/motorcycle/scooter	21.000	gas	9.0166	14	0.67	138.67	1250.30
car/truck/motorcycle/scooter	41.200	gas	9.0166	14	0.34	45.87	413.63
car/truck/motorcycle/scooter	17.750	gas	9.0166	4	0.23	23.44	211.32
car/truck/motorcycle/scooter	29.857	gas	9.0166	12	0.40	60.29	543.58
car/truck/motorcycle/scooter	70.000	gas	9.0166	12	0.17	12.86	115.93
car/truck/motorcycle/scooter	19.500	gas	9.0166	74	3.79	256.15	2309.64
car/truck/motorcycle/scooter	19.000	gas	9.0166	74	3.89	262.89	2370.42
car/truck/motorcycle/scooter	23.250	gas	9.0166	26	1.12	279.57	2520.77
car/truck/motorcycle/scooter	20.667	gas	9.0166	10	0.48	50.32	453.74
car/truck/motorcycle/scooter	29.667	gas	9.0166	10	0.34	67.42	607.86
car/truck/motorcycle/scooter	19.500	gas	9.0166	10	0.51	102.56	924.78
car/truck/motorcycle/scooter	21.833	gas	9.0166	6	0.27	68.70	619.46
car/truck/motorcycle/scooter	22.250	gas	9.0166	4	0.18	37.39	337.16
car/truck/motorcycle/scooter	22.600	gas	9.0166	6	0.27	66.37	598.45
bus	31.860	Diesel	10.3927	30	0.94	94.16	978.59
bus	31.860	Diesel	10.3927	12	0.38	39.17	407.09
bus	31.860	Diesel	10.3927	6	0.19	47.08	489.29
bus	31.860	Diesel	10.3927	18	0.56	29.38	305.32
bus	31.860	Diesel	10.3927	5	0.16	31.39	326.20
bus	31.860	Diesel	10.3927	7	0.22	57.12	593.68
bus (summer)	31.860	Diesel	10.3927	12	0.38	37.66	391.44
bus (winter)	31.860	Diesel	10.3927	12	0.38	94.16	978.59



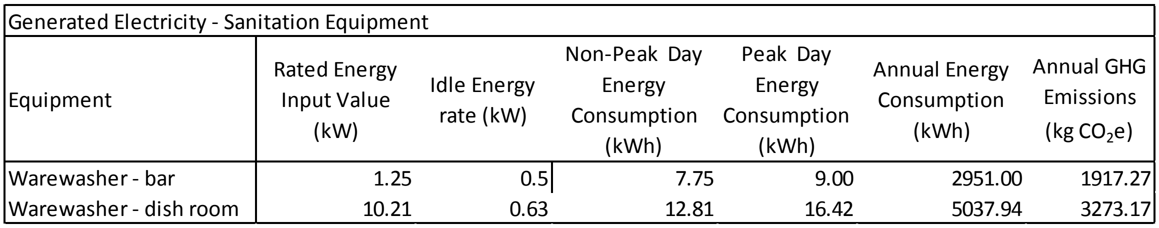
Generated Electricity - Employee Commutes

Vehicle Type	Fuel Efficiency (passenger mile/kWh)	Fuel Type	Emissions Factor (kg CO_2e/gal)	Total Travel Distance (round trip) per visit (miles)	Energy Consumed (round trip) per visit (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
Light rail train	2.979	Electricity	0.8310	4	1.34	69.82	45.36



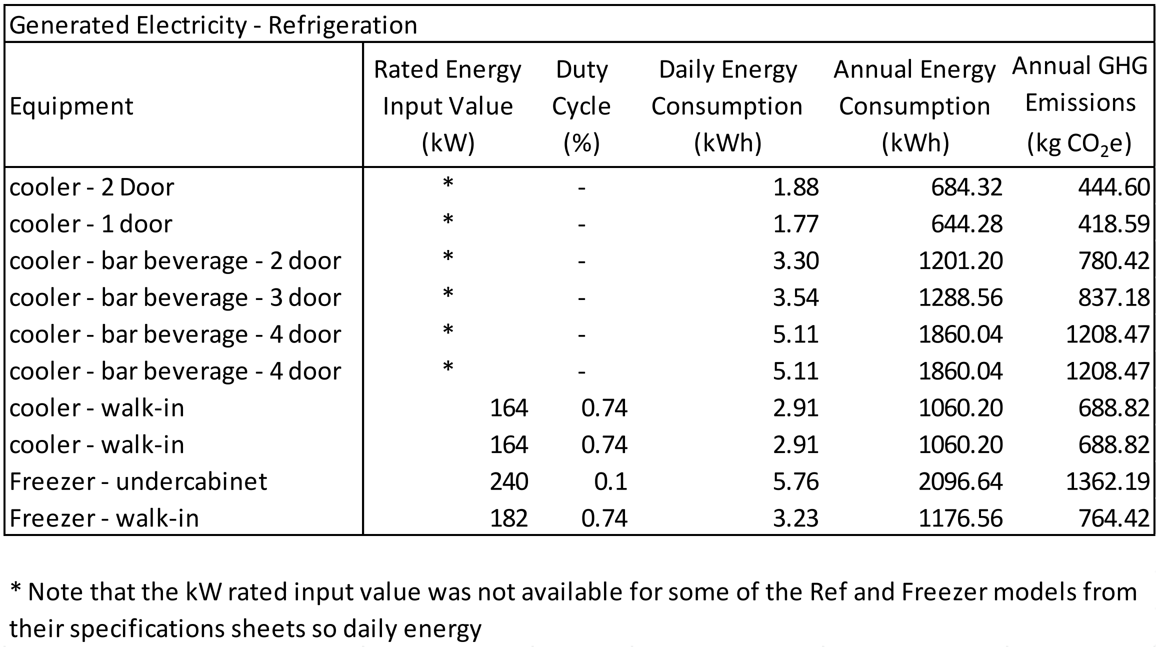
Generated Electricity - Food Preparation

Equipment Type	Rated Energy Input Value (kW)	Duty Cycle (%)	Non-Peak Day Energy Consumption (kWh)	Peak Day Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
Convection Oven	12	0.25	42.00	46.50	15756.00	10236.72



Generated Electricity - Sanitation Equipment

Equipment	Rated Energy Input Value (kW)	Idle Energy rate (kW)	Non-Peak Day Energy Consumption (kWh)	Peak Day Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
Warewasher - bar	1.25	0.5	7.75	9.00	2951.00	1917.27
Warewasher - dish room	10.21	0.63	12.81	16.42	5037.94	3273.17



Generated Electricity - Refrigeration

Equipment	Rated Energy Input Value (kW)	Duty Cycle (%)	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
cooler - 2 Door	*	-	1.88	684.32	444.60
cooler - 1 door	*	-	1.77	644.28	418.59
cooler - bar beverage - 2 door	*	-	3.30	1201.20	780.42
cooler - bar beverage - 3 door	*	-	3.54	1288.56	837.18
cooler - bar beverage - 4 door	*	-	5.11	1860.04	1208.47
cooler - bar beverage - 4 door	*	-	5.11	1860.04	1208.47
cooler - walk-in	164	0.74	2.91	1060.20	688.82
cooler - walk-in	164	0.74	2.91	1060.20	688.82
Freezer - undercabinet	240	0.1	5.76	2096.64	1362.19
Freezer - walk-in	182	0.74	3.23	1176.56	764.42

* Note that the kW rated input value was not available for some of the Ref and Freezer models from their specifications sheets so daily energy

Generated Electricity - Illumination & Audio Visual Equipment

Equipment	Fixture Rated Energy Input Value (kW)	Quantity of Fixtures	Daily Energy Consumption (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
Exterior lighting	0.0135	21	6.80	2476.66	1609.09
Front of house (ambient) - Light fixture type A	0.0136	18	5.88	2138.57	1389.44
Front of house (ambient) - Light fixture type B	0.0215	12	6.19	2253.89	1464.36
Front of house (ambient) - Light fixture type C	0.0268	26	16.72	6087.24	3954.90
Front of house (ambient) - Light fixture type D	0.0318	10	7.63	2778.05	1804.91
Front of house (ambient) - Light fixture type E	0.0241	3	1.74	631.61	410.36
Front of house (ambient) - Light fixture type F	0.0189	5	2.27	825.55	536.36
Front of house(dining)/Back of house (restrooms)	0.004	40	3.84	1397.76	908.13
Back of house (kitchen)	0.1	6	10.20	3400.80	2209.51
Back of House (Storage)	0.1	3	5.10	1700.40	1104.76

Generated Electricity - Ventilation and Space Cooling

Equipment	Equipment Category	Rated Fan Motor Power (hp)	Duty Cycle (%)	Estimated Electricity Input (kW)	Non-Peak Day Electricity Conumption (kWh)	Peak Day Electricity Conumption (kWh)	Annual Energy Consumption (kWh)	Annual GHG Emissions (kg CO_2e)
Roof Top Mech Unit 1 - fan	Fan - Supply Ventilation /Cooling /Heating	2.4	1.0	1.79	42.97	42.97	15640.93	10161.97
Roof Top Mech Unit 2 - fan	Fan - Supply Ventilation /Cooling /Heating	2.4	1.0	1.79	42.97	42.97	15640.93	10161.97
Roof Top Mech Unit 3 - fan	Fan - Supply Ventilation /Cooling /Heating	3.1	1.0	2.31	55.50	55.50	20202.87	13125.87
Exhaust Fan - Kitchen Hood #1 Exhaust Fan - Kitchen Hood #2 Make-Up Air Fan- Kitchen Hood Exhaust Fan - Dishwasher Exhaust Fan - toilet Roof Top Units - Cooling Compressor	OTHER (Exhaust ventilation, Make-up Air ventilation, cooling compressors)	-	-	-	-	-	142863.74[1]	92819.04

[1] This value is based on the remainder of purchased electricity based on utility bills

DETAILED DATA TABLES – ON-SITE ACTIVITIES

Stationary Fossil Fuel Combustion - Food Preparation Equipment

Equipment Type	Rated Energy Input Value (BTU/hr)	Duty Cycle (%)	Non-Peak Day Energy Consumption (kBTU)	Peak Day Energy Consumption (kBTU)	Annual Energy Consumption (kBTU)	Annual GHG Emissions (kg CO_2e)
Range/Oven	215000	0.4	1204.0	1333.0	451672.0	26798.66
Range/Oven	135000	0.4	756.0	837.0	283608.0	16827.07
Broiler	40000	0.7	392.0	434.0	147056.0	8725.15
Grill	105000	0.8	1176.0	1302.0	441168.0	26175.44
Fryer #1	122000	0.2	341.6	378.2	128148.8	7603.34
Fryer #2	122000	0.2	341.6	378.2	128148.8	7603.34
Fryer #3	140000	0.2	392.0	434.0	147056.0	8725.15

Stationary Fossil Fuel Combustion - Domestic Hot Water Generation and Space Heating

Equipment Type	Rated Energy Input Value (BTU/hr)	Duty Cycle (%)	Non-Peak Day Energy Consumption (kBTU)	Peak Day Energy Consumption (kBTU)	Annual Energy Consumption (kBTU)	Annual GHG Emissions (kg CO_2e)
Other (On-demand water heater, Forced-air space heating)	-	-	-	-	360142.4 [1]	21368.02

[1] Detailed equipment specifications were not available for this equipment. This number reflects the remaining unallocated kBTU of purchased natural gas from annual utility invoices

DETAILED DATA TABLES – DOWNSTREAM ACTIVITIES

Mobile Fossil Fuel Combustion - Customer Owned Vehicle and Mass Transit Travel

Vehicle Type	Fuel Efficiency (miles/gal) (passenger miles/gal)	Fuel Type	Emissions Factor (kg CO_2e/gal)	Total Travel Distance (round trip) per visit (miles)	Fuel Consumed (round trip) per visit (gal)	Annual Fuel Consumption (gal)	Annual GHG Emissions (kg CO_2e)
car/truck/motorcycle/scooter	23.25	gas	9.0166	10	0.43	0.43	3.88
car/truck/motorcycle/scooter	22.50	gas	9.0166	12	0.53	0.53	4.81
car/truck/motorcycle/scooter	21.00	gas	9.0166	0.5	0.02	0.02	0.21
car/truck/motorcycle/scooter	12.00	gas	9.0166	20	1.67	1.67	15.03
car/truck/motorcycle/scooter	31.50	gas	9.0166	8	0.25	0.25	2.29
car/truck/motorcycle/scooter	31.50	gas	9.0166	50	1.59	3.17	28.62
car/truck/motorcycle/scooter	23.25	gas	9.0166	86	3.70	7.40	66.70
car/truck/motorcycle/scooter	30.00	gas	9.0166	4	0.13	0.27	2.40
car/truck/motorcycle/scooter	28.00	gas	9.0166	2	0.07	0.07	0.64
car/truck/motorcycle/scooter	18.50	gas	9.0166	16	0.86	0.86	7.80
car/truck/motorcycle/scooter	22.75	gas	9.0166	4	0.18	0.18	1.59
car/truck/motorcycle/scooter	18.75	gas	9.0166	1.6	0.09	0.43	3.85
car/truck/motorcycle/scooter	18.00	gas	9.0166	2	0.11	0.22	2.00
car/truck/motorcycle/scooter	25.25	gas	9.0166	12	0.48	0.48	4.29
car/truck/motorcycle/scooter	20.50	gas	9.0166	18	0.88	0.88	7.92
car/truck/motorcycle/scooter	23.00	gas	9.0166	12	0.52	0.52	4.70
car/truck/motorcycle/scooter	28.00	gas/electric	9.0166	12	0.43	0.43	3.86
car/truck/motorcycle/scooter	21.00	gas	9.0166	20	0.95	38.10	343.49
car/truck/motorcycle/scooter	17.14	gas	9.0166	40	2.33	93.33	841.55
car/truck/motorcycle/scooter	27.00	gas	9.0166	14	0.52	0.52	4.68
car/truck/motorcycle/scooter	24.00	gas	9.0166	14	0.58	0.58	5.26
car/truck/motorcycle/scooter	20.00	gas	9.0166	18	0.90	1.80	16.23
car/truck/motorcycle/scooter	28.50	gas	9.0166	3	0.11	0.63	5.69

car/truck/motorcycle/scooter	23.00	gas	9.0166	14	0.61	3.65	32.93
car/truck/motorcycle/scooter	20.00	gas	9.0166	16	0.80	3.20	28.85
car/truck/motorcycle/scooter	22.00	gas	9.0166	2	0.09	0.27	2.46
car/truck/motorcycle/scooter	27.33	gas	9.0166	30	1.10	2.20	19.79
car/truck/motorcycle/scooter	27.33	gas	9.0166	10	0.37	0.73	6.60
car/truck/motorcycle/scooter	22.13	gas	9.0166	4	0.18	8.68	78.25
car/truck/motorcycle/scooter	20.00	gas	9.0166	6	0.30	6.00	54.10
car/truck/motorcycle/scooter	21.40	gas	9.0166	10	0.47	3.74	33.71
car/truck/motorcycle/scooter	23.25	gas	9.0166	6	0.26	2.58	23.27
car/truck/motorcycle/scooter	27.40	gas	9.0166	14	0.51	5.11	46.07
car/truck/motorcycle/scooter	18.00	gas	9.0166	36	2.00	4.00	36.07
car/truck/motorcycle/scooter	20.00	gas	9.0166	20	1.00	1.00	9.02
car/truck/motorcycle/scooter	28.33	gas	9.0166	20	0.71	0.71	6.36
car/truck/motorcycle/scooter	23.25	gas	9.0166	4	0.17	0.17	1.55
car/truck/motorcycle/scooter	20.00	gas	9.0166	9	0.45	0.45	4.06
car/truck/motorcycle/scooter	25.20	gas	9.0166	26	1.03	4.13	37.21
car/truck/motorcycle/scooter	19.75	gas	9.0166	4	0.20	0.81	7.30
car/truck/motorcycle/scooter	21.00	gas	9.0166	4	0.19	1.71	15.46
car/truck/motorcycle/scooter	20.50	gas	9.0166	4	0.20	1.76	15.83
car/truck/motorcycle/scooter	25.00	gas	9.0166	20	0.80	291.20	2625.63
car/truck/motorcycle/scooter	18.67	gas	9.0166	8	0.43	12.86	115.93
car/truck/motorcycle/scooter	24.00	gas	9.0166	9	0.38	1.31	11.83
car/truck/motorcycle/scooter	21.50	gas	9.0166	8	0.37	1.49	13.42
car/truck/motorcycle/scooter	28.00	gas	9.0166	4.5	0.16	0.16	1.45
car/truck/motorcycle/scooter	27.33	gas	9.0166	4.5	0.16	0.16	1.48
car/truck/motorcycle/scooter	20.00	gas	9.0166	20	1.00	2.00	18.03
car/truck/motorcycle/scooter	23.20	gas	9.0166	20	0.86	10.34	93.28
car/truck/motorcycle/scooter	22.83	gas	9.0166	12	0.53	0.53	4.74
car/truck/motorcycle/scooter	20.00	gas	9.0166	12	0.60	0.60	5.41
car/truck/motorcycle/scooter	22.83	gas	9.0166	40	1.75	1.75	15.80
car/truck/motorcycle/scooter	22.00	gas	9.0166	10	0.45	1.36	12.30
car/truck/motorcycle/scooter	20.33	gas	9.0166	10	0.49	0.98	8.87
car/truck/motorcycle/scooter	23.25	gas	9.0166	40	1.72	3.44	31.02
car/truck/motorcycle/scooter	18.33	gas	9.0166	40	2.18	4.36	39.35
car/truck/motorcycle/scooter	20.50	gas	9.0166	10	0.49	0.49	4.40
car/truck/motorcycle/scooter	28.00	gas	9.0166	2	0.07	0.07	0.64
car/truck/motorcycle/scooter	28.00	gas	9.0166	10	0.36	0.36	3.22
car/truck/motorcycle/scooter	21.00	gas	9.0166	16	0.76	0.76	6.87
car/truck/motorcycle/scooter	21.67	gas	9.0166	10	0.46	0.46	4.16
car/truck/motorcycle/scooter	30.00	gas	9.0166	2	0.07	0.80	7.21
car/truck/motorcycle/scooter	19.33	gas	9.0166	32	1.66	3.31	29.85

car/truck/motorcycle/scooter	21.00	gas	9.0166	10	0.48	1.90	17.17
car/truck/motorcycle/scooter	19.67	gas	9.0166	25	1.27	2.54	22.92
car/truck/motorcycle/scooter	26.00	gas/electric	9.0166	5	0.19	0.19	1.73
car/truck/motorcycle/scooter	19.00	gas	9.0166	7	0.37	3.68	33.22
car/truck/motorcycle/scooter	15.33	gas	9.0166	6	0.39	0.78	7.06
car/truck/motorcycle/scooter	25.40	gas	9.0166	3	0.12	0.24	2.13
car/truck/motorcycle/scooter	18.00	gas	9.0166	23	1.28	8.94	80.65
car/truck/motorcycle/scooter	20.00	gas	9.0166	8	0.40	1.60	14.43
car/truck/motorcycle/scooter	15.40	gas	9.0166	30	1.95	1.95	17.56
car/truck/motorcycle/scooter	19.33	gas	9.0166	2	0.10	0.21	1.87
car/truck/motorcycle/scooter	24.50	gas	9.0166	18	0.73	1.47	13.25
car/truck/motorcycle/scooter	22.00	gas	9.0166	1	0.05	0.27	2.46
car/truck/motorcycle/scooter	21.67	gas	9.0166	8	0.37	3.69	33.29
car/truck/motorcycle/scooter	12.00	gas	9.0166	2	0.17	0.17	1.50
car/truck/motorcycle/scooter	19.50	gas	9.0166	6	0.31	0.31	2.77
car/truck/motorcycle/scooter	46.00	gas/electric	9.0166	12	0.26	0.26	2.35
car/truck/motorcycle/scooter	23.00	gas	9.0166	7	0.30	1.22	10.98
car/truck/motorcycle/scooter	42.00	gas/electric	9.0166	40	0.95	0.95	8.59
car/truck/motorcycle/scooter	25.80	gas	9.0166	14	0.54	0.54	4.89
car/truck/motorcycle/scooter	20.00	gas	9.0166	6	0.30	0.30	2.70
car/truck/motorcycle/scooter	23.00	gas	9.0166	1	0.04	0.13	1.18
car/truck/motorcycle/scooter	27.33	gas	9.0166	4	0.15	0.29	2.64
car/truck/motorcycle/scooter	30.00	gas	9.0166	20	0.67	0.67	6.01
car/truck/motorcycle/scooter	20.50	gas	9.0166	2	0.10	0.39	3.52
car/truck/motorcycle/scooter	21.25	gas	9.0166	6	0.28	1.41	12.73
car/truck/motorcycle/scooter	22.83	gas	9.0166	3	0.13	19.71	177.70
car/truck/motorcycle/scooter	17.00	gas	9.0166	6	0.35	1.06	9.55
car/truck/motorcycle/scooter	20.75	gas	9.0166	40	1.93	9.64	86.91
car/truck/motorcycle/scooter	21.25	gas	9.0166	6	0.28	1.69	15.28
car/truck/motorcycle/scooter	22.25	gas	9.0166	4	0.18	0.18	1.62
car/truck/motorcycle/scooter	20.75	gas	9.0166	40	1.93	5.78	52.14
car/truck/motorcycle/scooter	23.50	gas	9.0166	2	0.09	0.26	2.30
car/truck/motorcycle/scooter	14.00	gas	9.0166	2	0.14	0.57	5.15
car/truck/motorcycle/scooter	29.00	gas	9.0166	8	0.28	0.55	4.97
car/truck/motorcycle/scooter	12.00	gas	9.0166	5	0.42	0.83	7.51
car/truck/motorcycle/scooter	22.00	gas	9.0166	40	1.82	7.27	65.58
car/truck/motorcycle/scooter	22.33	gas	9.0166	10	0.45	1.34	12.11
car/truck/motorcycle/scooter	22.00	gas	9.0166	2	0.09	0.27	2.46
car/truck/motorcycle/scooter	20.67	gas	9.0166	8	0.39	0.39	3.49
car/truck/motorcycle/scooter	22.50	gas	9.0166	18	0.80	0.80	7.21
car/truck/motorcycle/scooter	22.33	gas	9.0166	6	0.27	0.27	2.42

car/truck/motorcycle/scooter	21.67	gas	9.0166	62	2.86	11.45	103.21
car/truck/motorcycle/scooter	23.75	gas	9.0166	8	0.34	0.67	6.07
car/truck/motorcycle/scooter	29.86	gas	9.0166	24	0.80	0.80	7.25
car/truck/motorcycle/scooter	27.00	gas	9.0166	8.2	0.30	1.82	16.43
car/truck/motorcycle/scooter	21.00	gas	9.0166	1.4	0.07	0.07	0.60
car/truck/motorcycle/scooter	21.00	gas	9.0166	10	0.48	0.48	4.29
car/truck/motorcycle/scooter	28.33	gas	9.0166	1	0.04	0.04	0.32
car/truck/motorcycle/scooter	14.50	gas	9.0166	8	0.55	8.28	74.62
car/truck/motorcycle/scooter	23.40	gas	9.0166	10	0.43	2.56	23.12
car/truck/motorcycle/scooter	46.00	gas/electric	9.0166	20	0.43	5.22	47.04
car/truck/motorcycle/scooter	30.00	gas	9.0166	6	0.20	0.80	7.21
car/truck/motorcycle/scooter	21.00	gas	9.0166	20	0.95	0.95	8.59
car/truck/motorcycle/scooter	14.50	gas	9.0166	1	0.07	0.07	0.62
car/truck/motorcycle/scooter	20.00	gas	9.0166	2	0.10	0.30	2.70
car/truck/motorcycle/scooter	17.00	gas	9.0166	6	0.35	0.35	3.18
car/truck/motorcycle/scooter	20.00	gas	9.0166	24	1.20	1.20	10.82
car/truck/motorcycle/scooter	27.00	gas/electric	9.0166	40	1.48	8.89	80.15
car/truck/motorcycle/scooter	24.33	gas	9.0166	10	0.41	2.47	22.23
car/truck/motorcycle/scooter	23.25	gas	9.0166	10	0.43	5.16	46.54
car/truck/motorcycle/scooter	30.00	gas	9.0166	40	1.33	1.33	12.02
car/truck/motorcycle/scooter	19.00	gas	9.0166	40	2.11	12.63	113.89
car/truck/motorcycle/scooter	22.00	gas	9.0166	2	0.09	0.18	1.64
car/truck/motorcycle/scooter	23.25	gas	9.0166	22	0.95	1.89	17.06
car/truck/motorcycle/scooter	22.00	gas	9.0166	22	1.00	2.00	18.03
car/truck/motorcycle/scooter	25.25	gas	9.0166	15	0.59	0.59	5.36
car/truck/motorcycle/scooter	25.25	gas	9.0166	15	0.59	1.78	16.07
car/truck/motorcycle/scooter	17.50	gas	9.0166	20	1.14	1.14	10.30
car/truck/motorcycle/scooter	17.00	gas	9.0166	6	0.35	3.53	31.82
car/truck/motorcycle/scooter	22.25	gas	9.0166	2	0.09	0.18	1.62
car/truck/motorcycle/scooter	22.00	gas	9.0166	8	0.36	0.91	8.20
car/truck/motorcycle/scooter	15.00	gas	9.0166	14	0.93	0.93	8.42
car/truck/motorcycle/scooter	25.25	gas	9.0166	50	1.98	3.96	35.71
car/truck/motorcycle/scooter	15.00	gas	9.0166	40	2.67	2.67	24.04
car/truck/motorcycle/scooter	29.33	gas	9.0166	8	0.27	0.95	8.61
car/truck/motorcycle/scooter	20.67	gas	9.0166	24	1.16	3.48	31.41
car/truck/motorcycle/scooter	22.00	gas	9.0166	24	1.09	5.45	49.18
car/truck/motorcycle/scooter	22.60	gas	9.0166	6	0.27	1.33	11.97
car/truck/motorcycle/scooter	20.00	gas	9.0166	4	0.20	0.20	1.80
car/truck/motorcycle/scooter	16.50	gas	9.0166	20	1.21	14.55	131.15
car/truck/motorcycle/scooter	21.50	gas	9.0166	35	1.63	21.16	190.82
car/truck/motorcycle/scooter	26.00	gas	9.0166	12	0.46	0.46	4.16

car/truck/motorcycle/scooter	24.60	gas	9.0166	6	0.24	0.24	2.20
car/truck/motorcycle/scooter	22.50	gas	9.0166	10	0.44	0.89	8.01
car/truck/motorcycle/scooter	21.00	gas	9.0166	5	0.24	2.38	21.47
car/truck/motorcycle/scooter	30.00	gas	9.0166	10	0.33	2.00	18.03
car/truck/motorcycle/scooter	16.00	gas	9.0166	10	0.63	0.63	5.64
car/truck/motorcycle/scooter	17.83	gas	9.0166	6	0.34	0.34	3.03
car/truck/motorcycle/scooter	22.00	gas	9.0166	4	0.18	0.18	1.64
car/truck/motorcycle/scooter	22.00	gas	9.0166	30	1.36	1.36	12.30
car/truck/motorcycle/scooter	21.67	gas	9.0166	30	1.38	1.38	12.48
car/truck/motorcycle/scooter	15.00	gas	9.0166	40	2.67	32.00	288.53
car/truck/motorcycle/scooter	20.50	gas	9.0166	2	0.10	1.17	10.56
car/truck/motorcycle/scooter	24.60	gas	9.0166	16	0.65	13.66	123.15
car/truck/motorcycle/scooter	27.67	gas	9.0166	2.4	0.09	0.17	1.56
car/truck/motorcycle/scooter	20.50	gas	9.0166	10	0.49	0.98	8.80
car/truck/motorcycle/scooter	23.33	gas	9.0166	10	0.43	1.29	11.59
car/truck/motorcycle/scooter	22.75	gas	9.0166	30	1.32	1.32	11.89
car/truck/motorcycle/scooter	30.00	gas	9.0166	5	0.17	8.67	78.14
car/truck/motorcycle/scooter	20.67	gas	9.0166	8	0.39	0.39	3.49
car/truck/motorcycle/scooter	28.25	gas	9.0166	29.4	1.04	1.04	9.38
car/truck/motorcycle/scooter	25.00	gas	9.0166	36	1.44	1.44	12.98
car/truck/motorcycle/scooter	36.00	gas	9.0166	16	0.44	5.33	48.09
car/truck/motorcycle/scooter	15.50	gas	9.0166	16	1.03	12.39	111.69
car/truck/motorcycle/scooter	20.00	gas	9.0166	20	1.00	1.00	9.02
car/truck/motorcycle/scooter	24.14	gas	9.0166	4	0.17	0.17	1.49
car/truck/motorcycle/scooter	18.00	gas	9.0166	52	2.89	150.22	1354.49
car/truck/motorcycle/scooter	20.00	gas	9.0166	16	0.80	4.00	36.07
car/truck/motorcycle/scooter	46.00	gas/electric	9.0166	40	0.87	0.87	7.84
car/truck/motorcycle/scooter	23.67	gas	9.0166	0	0.00	0.00	0.00
car/truck/motorcycle/scooter	21.00	gas	9.0166	4	0.19	1.90	17.17
car/truck/motorcycle/scooter	18.33	gas	9.0166	4	0.22	2.18	19.67
car/truck/motorcycle/scooter	22.00	gas	9.0166	20	0.91	10.91	98.36
car/truck/motorcycle/scooter	23.17	gas	9.0166	20	0.86	0.86	7.78
car/truck/motorcycle/scooter	28.00	gas	9.0166	5	0.18	35.71	322.02
car/truck/motorcycle/scooter	21.00	gas	9.0166	60	2.86	2.86	25.76
car/truck/motorcycle/scooter	21.25	gas	9.0166	7	0.33	0.33	2.97
car/truck/motorcycle/scooter	22.83	gas	9.0166	20	0.88	0.88	7.90
car/truck/motorcycle/scooter	23.25	gas	9.0166	6	0.26	0.26	2.33
car/truck/motorcycle/scooter	26.80	gas	9.0166	20	0.75	4.48	40.37
car/truck/motorcycle/scooter	20.00	gas	9.0166	1	0.05	0.20	1.80
car/truck/motorcycle/scooter	26.50	gas/electric	9.0166	16	0.60	2.42	21.78
car/truck/motorcycle/scooter	31.00	gas	9.0166	1	0.03	0.39	3.49

car/truck/motorcycle/scooter	28.33	gas	9.0166	44	1.55	3.11	28.00
car/truck/motorcycle/scooter	21.00	gas	9.0166	2	0.10	0.10	0.86
car/truck/motorcycle/scooter	21.00	gas	9.0166	9.8	0.47	9.33	84.15
car/truck/motorcycle/scooter	20.50	gas	9.0166	20	0.98	0.98	8.80
car/truck/motorcycle/scooter	46.00	gas/electric	9.0166	40	0.87	0.87	7.84
car/truck/motorcycle/scooter	21.00	gas	9.0166	4	0.19	0.95	8.59
car/truck/motorcycle/scooter	31.50	gas	9.0166	8	0.25	0.76	6.87
car/truck/motorcycle/scooter	23.25	gas	9.0166	2	0.09	0.17	1.55
car/truck/motorcycle/scooter	25.00	gas	9.0166	5	0.20	0.60	5.41
car/truck/motorcycle/scooter	19.57	gas	9.0166	2	0.10	0.31	2.76
car/truck/motorcycle/scooter	21.00	gas	9.0166	60	2.86	2.86	25.76
car/truck/motorcycle/scooter	21.00	gas	9.0166	60	2.86	2.86	25.76
car/truck/motorcycle/scooter	20.00	gas	9.0166	20	1.00	1.00	9.02
car/truck/motorcycle/scooter	23.25	gas	9.0166	4	0.17	2.06	18.61
car/truck/motorcycle/scooter	27.50	gas	9.0166	20	0.73	0.73	6.56
car/truck/motorcycle/scooter	26.25	gas	9.0166	10	0.38	0.38	3.43
car/truck/motorcycle/scooter	30.50	gas	9.0166	30	0.98	0.98	8.87
car/truck/motorcycle/scooter	19.00	gas	9.0166	8	0.42	0.42	3.80
car/truck/motorcycle/scooter	21.33	gas	9.0166	24	1.13	1.13	10.14
car/truck/motorcycle/scooter	16.50	gas	9.0166	13	0.79	2.36	21.31
car/truck/motorcycle/scooter	27.33	gas	9.0166	16	0.59	0.59	5.28
car/truck/motorcycle/scooter	19.25	gas	9.0166	24	1.25	1.25	11.24
car/truck/motorcycle/scooter	24.67	gas	9.0166	24	0.97	3.89	35.09
car/truck/motorcycle/scooter	19.00	gas	9.0166	8	0.42	0.84	7.59
car/truck/motorcycle/scooter	20.50	gas	9.0166	8	0.39	0.78	7.04
car/truck/motorcycle/scooter	24.60	gas	9.0166	10	0.41	0.41	3.67
car/truck/motorcycle/scooter	27.25	gas	9.0166	21	0.77	1.54	13.90
car/truck/motorcycle/scooter	18.00	gas	9.0166	70	3.89	3.89	35.06
car/truck/motorcycle/scooter	23.50	gas	9.0166	3	0.13	0.13	1.15
car/truck/motorcycle/scooter	23.00	gas	9.0166	20	0.87	4.35	39.20
car/truck/motorcycle/scooter	29.86	gas	9.0166	4	0.13	1.61	14.50
car/truck/motorcycle/scooter	21.00	gas	9.0166	10	0.48	0.95	8.59
car/truck/motorcycle/scooter	21.50	gas	9.0166	2.8	0.13	0.13	1.17
car/truck/motorcycle/scooter	20.50	gas	9.0166	14	0.68	1.37	12.32
car/truck/motorcycle/scooter	17.70	gas	9.0166	3	0.17	1.02	9.17
car/truck/motorcycle/scooter	20.00	gas	9.0166	60	3.00	9.00	81.15
car/truck/motorcycle/scooter	35.50	diesel	10.3927	340	9.58	28.73	298.61
car/truck/motorcycle/scooter	24.14	gas	9.0166	6	0.25	0.25	2.24
car/truck/motorcycle/scooter	15.17	gas	9.0166	64	4.22	4.22	38.05
car/truck/motorcycle/scooter	18.50	gas	9.0166	44	2.38	4.76	42.89
car/truck/motorcycle/scooter	27.00	gas/electric	9.0166	5	0.19	0.19	1.67

car/truck/motorcycle/scooter	21.50	gas	9.0166	20	0.93	37.21	335.50
car/truck/motorcycle/scooter	15.50	gas	9.0166	4	0.26	0.26	2.33
car/truck/motorcycle/scooter	35.50	diesel	10.3927	1	0.03	0.03	0.29
car/truck/motorcycle/scooter	21.00	gas	9.0166	14	0.67	0.67	6.01
car/truck/motorcycle/scooter	22.50	gas	9.0166	200	8.89	8.89	80.15
car/truck/motorcycle/scooter	20.50	gas	9.0166	4	0.20	4.88	43.98
car/truck/motorcycle/scooter	46.00	gas/electric	9.0166	4	0.09	0.30	2.74
car/truck/motorcycle/scooter	30.00	gas	9.0166	5	0.17	0.58	5.26
car/truck/motorcycle/scooter	23.25	gas	9.0166	6	0.26	0.90	8.14
car/truck/motorcycle/scooter	23.25	gas	9.0166	3	0.13	0.39	3.49
car/truck/motorcycle/scooter	16.75	gas	9.0166	3	0.18	0.54	4.84
car/truck/motorcycle/scooter	21.25	gas	9.0166	10	0.47	0.47	4.24
car/truck/motorcycle/scooter	22.75	gas	9.0166	30	1.32	1.32	11.89
car/truck/motorcycle/scooter	22.75	gas	9.0166	56	2.46	2.46	22.19
car/truck/motorcycle/scooter	27.00	gas	9.0166	20	0.74	0.74	6.68
car/truck/motorcycle/scooter	28.50	gas	9.0166	24	0.84	0.84	7.59
car/truck/motorcycle/scooter	40.50	gas/electric	9.0166	10	0.25	0.25	2.23
car/truck/motorcycle/scooter	22.80	gas	9.0166	8	0.35	2.11	18.98
car/truck/motorcycle/scooter	23.00	gas	9.0166	2	0.09	0.09	0.78
car/truck/motorcycle/scooter	14.50	gas	9.0166	6	0.41	8.28	74.62
car/truck/motorcycle/scooter	24.80	gas	9.0166	40	1.61	1.61	14.54
car/truck/motorcycle/scooter	21.20	gas	9.0166	25.25	1.19	1.19	10.74
car/truck/motorcycle/scooter	24.75	gas	9.0166	10	0.40	4.85	43.72
car/truck/motorcycle/scooter	24.00	gas	9.0166	20	0.83	6.67	60.11
car/truck/motorcycle/scooter	18.44	gas	9.0166	3	0.16	2.44	22.00
car/truck/motorcycle/scooter	20.00	gas	9.0166	10	0.50	2.50	22.54
car/truck/motorcycle/scooter	20.50	gas	9.0166	4	0.20	1.17	10.56
car/truck/motorcycle/scooter	19.25	gas	9.0166	30	1.56	1.56	14.05
car/truck/motorcycle/scooter	46.00	gas	9.0166	140	3.04	6.09	54.88
car/truck/motorcycle/scooter	19.33	gas	9.0166	2.2	0.11	0.68	6.16
car/truck/motorcycle/scooter	17.57	gas	9.0166	8	0.46	9.11	82.10
car/truck/motorcycle/scooter	22.00	gas	9.0166	1	0.05	0.14	1.23
car/truck/motorcycle/scooter	24.67	gas	9.0166	2	0.08	0.08	0.73
car/truck/motorcycle/scooter	18.25	gas	9.0166	30	1.64	1.64	14.82
car/truck/motorcycle/scooter	19.50	gas	9.0166	1	0.05	0.46	4.16
car/truck/motorcycle/scooter	23.00	gas	9.0166	8	0.35	0.35	3.14
car/truck/motorcycle/scooter	28.25	gas	9.0166	14	0.50	0.99	8.94
bus	31.860	diesel	10.3927	5	0.16	1.88	19.57
bus	31.860	diesel	10.3927	5	0.16	1.88	19.57
bus	31.860	diesel	10.3927	14	0.44	1.32	13.70
bus	31.860	diesel	10.3927	14	0.44	1.32	13.70

Restaurant Generated Waste - Compost and Recycled Non-organics			
Waste End Use Stream	Annual Volume Collected (gal)	Annual Weight (lbs)	Annual GHG Emissions (kg CO_2e)
Organic Composting	-	65340	-13068.00
Mixed Paper Recycling (broad definition)	4191.50	5009.05	-17631.86
Glass Recycling	1057.50	2617.57	-732.92
Mixed Plastics	1057.50	167.52	-164.17
Mixed Metals	1057.50	989.44	-3928.09

Restaurant Generated Waste - Municipal Solid Waste					
Waste End Use Stream	Annual Volume Collected (gal)	Annual Weight (lbs)	MN % Diversion to MSW End Use Streams	Annual Weight per MSW End Use (lbs)	Annual GHG Emissions (kg CO_2e)
MSW - Landfill	6577.50	9768.56	62%	6056.51	5935.38
MSW - Waste to Energy (WTE)	6577.50	9768.56	38%	3712.05	-148.48

Waste Water Treatment - Consumption by Plumbing Fixtures and Equipment			
Fixture/Equipment Type	Daily Consumption (gal)	Annual Consumption (gal)	Annual GHG emissions (kg CO2e)
restroom water closet #1 - female	83.20	30284.80	1046.76
restroom water closet #2 -female	83.20	30284.80	1046.76
restroom urinal - male	39.60	14414.40	498.22
restroom water closet - male	19.84	7221.76	249.61
restroom sink #1 - women	57.20	20820.80	719.64
restroom sink #2 - women	57.20	20820.80	719.64
restroom sink - male	57.20	20820.80	719.64
handwash sink - bar	11.00	4004.00	138.39
handwash sink - front kitchen	11.00	4004.00	138.39
handwash sink - rear kitchen	11.00	4004.00	138.39
Warewasher - bar	68.00	18122.00	626.36
Warewasher - dishroom	42.50	11050.00	381.93
OTHER (Pre-rinse sprayers, pot filler, ice maker)		504177.84	17426.27

APPENDIX D - ADDITIONAL CONTEXT FOR THE GUIDELINE

BRIEF HISTORY OF THE PRACTICE OF MEASURING AND REPORTING EMISSION OF GASSES THAT IMPACT THE ATMOSPHERE

The act of creating an inventory of potentially harmful gas emissions into the atmosphere is not a novel phenomenon unique to GHGs. Previous actions dating back to the 1980's initiated the inventorying of specific gases released to the atmosphere in human controlled processes.

In 1987 an international agreement known as the Montreal Protocol, was signed by 27 countries who committed to reduce the amount of chlorofluorocarbon (CFC) emissions. This restriction came after scientific research showed that CFC emissions were harmful as they led to the depletion of ozone which caused irregular exposure to solar radiation.

In 1990 with the creation of the Acid Rain Program within the Clean Air Act, the EPA required electricity generation plants to monitor and report their emission of sulfur dioxide (SO2) and nitrogen oxides (NOx). This came after the realization that in the atmosphere, SO2 and NOx have adverse reaction with water vapor in the atmosphere to produce acid rain. The EPA continues to regulate the amount of SO2 and NOx that can be produced by power generation utilities through a cap and trade program.

Since 2005, the practice of estimating Greenhouse gas emissions has grown. Global standards and methodologies have emerged to help countries estimate their annual emissions as they move toward achieving reduction goals under the Kyoto Protocol. Tools have also been developed to help individual companies or households to estimate their emissions. The depth and complexity of these tools vary greatly because of the vast difference in the scale of emissions that are quantified by each tool (that of a country versus and individual household). Yet the purpose behind the tools is the same; to measure and document the emissions bringing awareness to their existence. The hope is that this awareness will be the first step followed by developing reduction targets and strategies to reduce the emissions that individuals or countries are generating and ultimately reducing the global emissions and averting dangerous rise of the global temperature.

EXPANDED SUMMARY OF U.S. GHG EMISSIONS INVENTORY CATEGORIES CONNECTED TO RESTAURANT OPERATIONS

The following sections provide greater details to highlight the correlation between significant sources of national GHG emissions and those processes that a restaurant utilizes in its operations. The processes identified in the national inventory also served as a preliminary list of processes to include within the boundary of the restaurant emissions protocol.

CO_2 emissions are the most prevalent in the national inventory with a total of 5505.2 Tg CO_2e. The emissions of CO_2 are almost ten times greater than that of the next most prevalent gas, CH_4. The emissions of CO_2 come from a variety of sources presented in

Figure 3. Of these sources, several are processes that restaurants rely upon either directly in the consumption of resources onsite or indirectly in the production of goods or services used by the restaurant. Most notably is the generation of electricity (2154.o Tg CO_2e) which accounts for almost 2/5ths of the CO_2 emissions. Second is the combustion of transportation fuels (1719.7 Tg CO_2e) which includes fuel that is combusted in large equipment like tractors utilized in agriculture production; freight vehicles, like those which transport food ingredients and goods; and individual automobile use, like that of potential customers traveling to a restaurant. Other notable sources of CO_2 emissions are the incineration of municipal solid waste (12.3 Tg CO_2e) and the production of ammonia and urea (11.8 Tg CO_2e) which are primary chemicals in synthetic fertilizers used for crop production.

Methane (CH_4) is the second most prevalent GHG, with emissions accounting for 686.3 Tg CO_2e in 2009. Many of the national sources of methane are connected with food production. The most significant source, enteric fermentation (139.8 Tg CO_2e), occurs through the raising of ruminant livestock. Landfills (117.5 Tg CO_2e) are an additional source of CH_4 emissions which result from the anaerobic decomposition of vegetation and food waste. In addition to enteric fermentation, livestock production also contributes CH_4 emissions from the management of manure (49.5 Tg CO_2e) produced by the animals. Other notable sources of CH_4 emissions with potential connection to restaurant operations are waste water treatment (24.5 Tg CO_2e), mobile combustion of fuels (2.0 Tg CO_2e) and composting (1.7 Tg CO_2e).

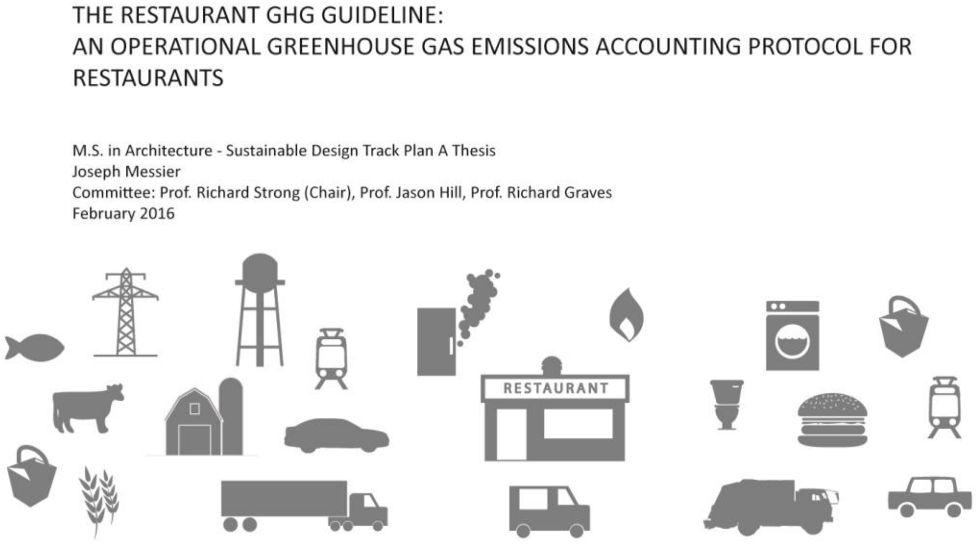
The third most prevalent greenhouse gas emitted in the U.S. is N_2O, accounting for 295.6 Tg CO_2e in 2009. Similar to CH_4 and CO_2, several of the primary sources are linked with processes that are part of a restaurant's operational supply chain. Agriculture soil management (204.6 Tg CO_2e) accounts for the majority of the N_2O emissions which result from the application of synthetic nitrogen to agricultural fields for producing crops. Other sources of N_2O emissions are processes that produced CO_2 or CH_4 in addition to N_2O. Most notable, Mobile combustion (23.9 Tg CO_2e, manure management (17.9 Tg CO_2e), waste water treatment (5.0 Tg CO_2e), and composting (1.8 Tg CO_2e) are processes that also generate N_2O emissions in addition to the previously acknowledged CH_4 emissions. Additional processes that generate N_2O emissions possibly connected with restaurant operational processes include stationary combustion (12.8 Tg CO_2e), incineration of municipal solid waste (0.4 Tg CO_2e) and field burning of agricultural residues (0.1 Tg CO_2e).

In addition to the three primary GHGs, the EPA's annual inventory also includes emissions levels of HFCs and PFCs of which the primary HFC emissions source correlates with emissions sources from restaurant operations. As a whole, emissions from HFCs account for 125.7 Tg CO2e and the primary source is substitution ozone depleting substances (120.0 Tg CO2e). This source is the result of leaked HFCs used as replacements for CFCs in refrigeration and air conditioning equipment. The majority of these leaked emissions come from equipment manufacturing processes but can also occur from the operation of refrigeration equipment which is how restaurants operations could produce HFC emissions.

Though the challenge of accounting GHG emissions is global, it is one in which owners, building designers, and operators have taken a special interest given that their work has a significant impact. Buildings are the objects produced by architects yet their operation is a significant source of GHG emissions throughout the world. In the United States alone the building sector accounts for 49.1% of the total annual emissions (US EIA, 2009). This prominence of the building sector in contributing to GHG emissions is a result of its role as the largest energy consuming sector at 50.1% of the total annual energy consumed in the United States (US EIA, 2009). More specifically the building sector consumes the majority of electricity generated in the United States (74.5%) , which is the predominant source of GHG emissions generated by the combustion of fossil fuels in power generation plants (US EIA, 2009).

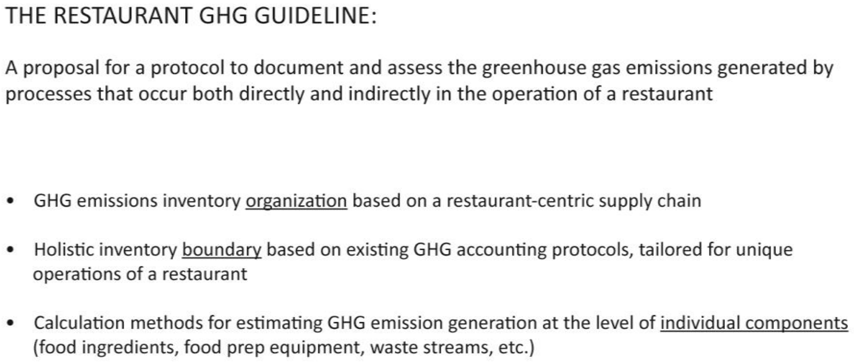
While the statistics listed above are the result of the operation of buildings, owners, architects, engineers, and construction professions are ultimately responsible for planning and executing the design. They have the requirements to design buildings that meet the needs of their client, but also the opportunity to address the global need to reduce emissions. Several tools have emerged in the last decade to help architects analyze their designs prior to construction to determine potential energy consumption and resulting emissions. These tools, including Autodesk Ecotect, Archicad Ecodesigner, IES Virtual Environment (for operating energy), and Athena Institute EcoCalculator (for embodies energy), calculate the total GHG emissions. From the GHG emissions that occur through the manufacturing individual building elements to the envelope's performance in reducing energy consumption and even full building operations that include the various pieces of mechanical equipment inside the building that contribute to its energy consumption, today's designers can have a more precise understanding of how their choices contribute to the global GHG emissions. Similarly, this proposal is intended to serve as a tool to monitor actual operations. The hope is that an inventory of GHG emissions throughout a restaurants operational supply chain could then feedback to owners, designers, and engineers so that they might better understand the outcome of their design decisions.

APPENDIX E – SLIDES FROM FINAL PRESENTATION



THE RESTAURANT GHG GUIDELINE: AN OPERATIONAL GREENHOUSE GAS EMISSIONS ACCOUNTING PROTOCOL FOR RESTAURANTS

M.S. in Architecture - Sustainable Design Track Plan A Thesis
Joseph Messier
Committee: Prof. Richard Strong (Chair), Prof. Jason Hill, Prof. Richard Graves
February 2016



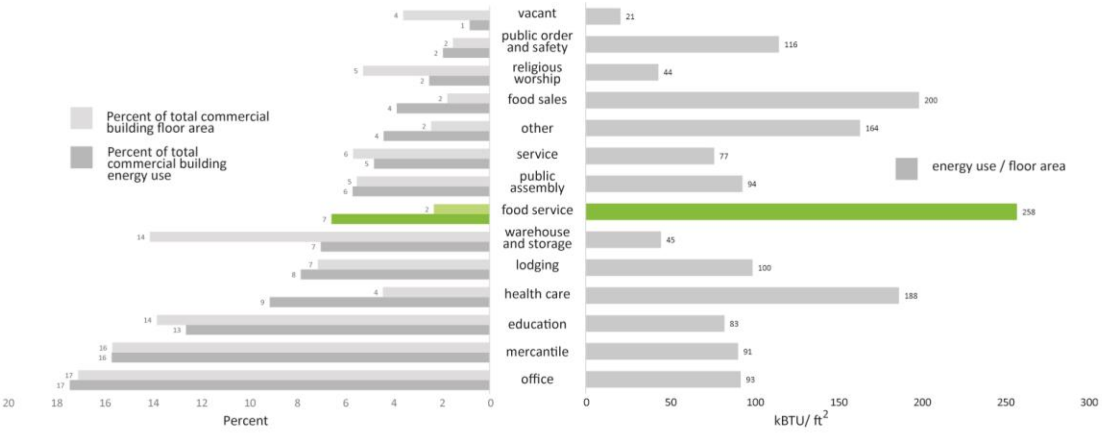
THE RESTAURANT GHG GUIDELINE:

A proposal for a protocol to document and assess the greenhouse gas emissions generated by processes that occur both directly and indirectly in the operation of a restaurant

- GHG emissions inventory organization based on a restaurant-centric supply chain
- Holistic inventory boundary based on existing GHG accounting protocols, tailored for unique operations of a restaurant
- Calculation methods for estimating GHG emission generation at the level of individual components (food ingredients, food prep equipment, waste streams, etc.)

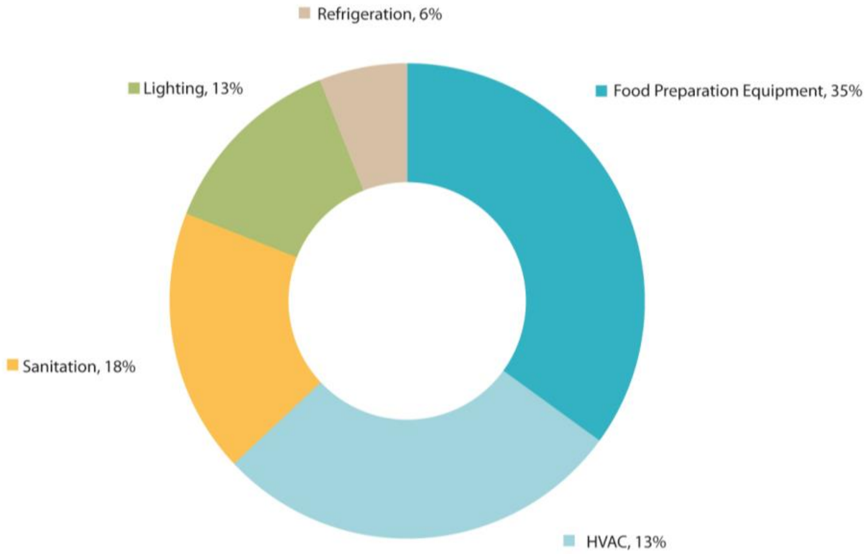
WHY RESTAURANTS?

RESTAURANTS ARE THE MOST ENERGY INTENSIVE COMMERCIAL BUILDING IN THE UNITED STATES



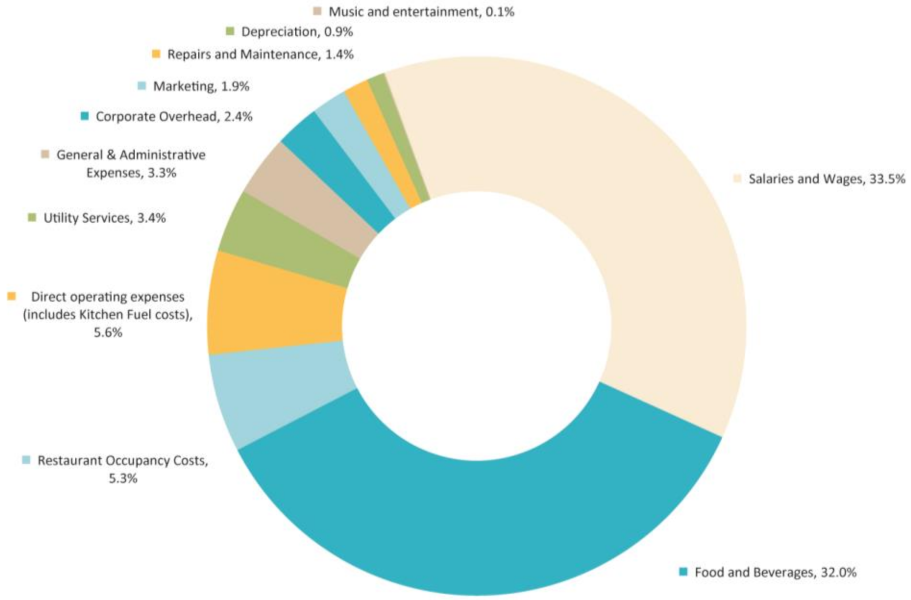
source: EIA Commercial Building Energy Survey, 2004

ENERGY IS CONSUMED IN SEVERAL RESTAURANT OPERATION ACTIVITIES



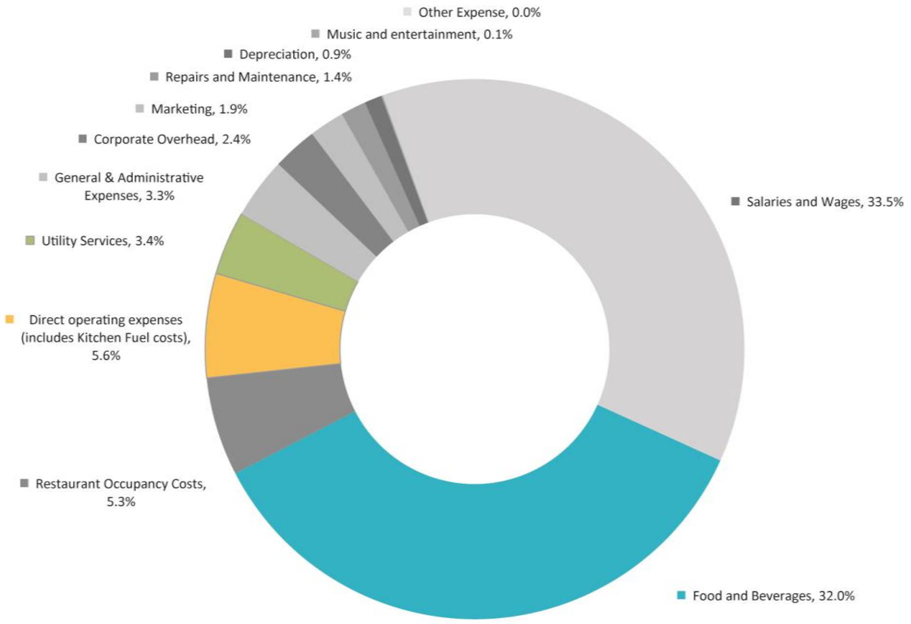
source: "Where Does the Energy Go?" Presentation slides by Food Service Technology Center
San Diego Gas and Electric Saving Water and Energy Seminar, Feb. 2009

ENERGY CONSUMPTION MAKES UP ONLY A SMALL PORTION OF RESTAURANT EXPENSES



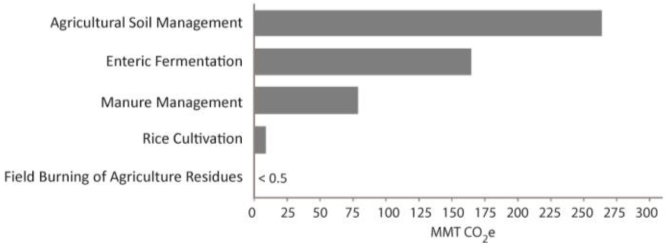
source: National Restaurant Association *Restaurant Industry Operations Report 2010, averages across all restaurant types*

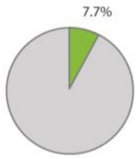
ENERGY CONSUMPTION MAKES UP ONLY A SMALL PORTION OF RESTAURANT EXPENSES



source: National Restaurant Association *Restaurant Industry Operations Report 2010, averages across all restaurant types*

RESTAURANTS INVEST IN FOOD PRODUCTION BY THE AGRICULTURE SECTOR





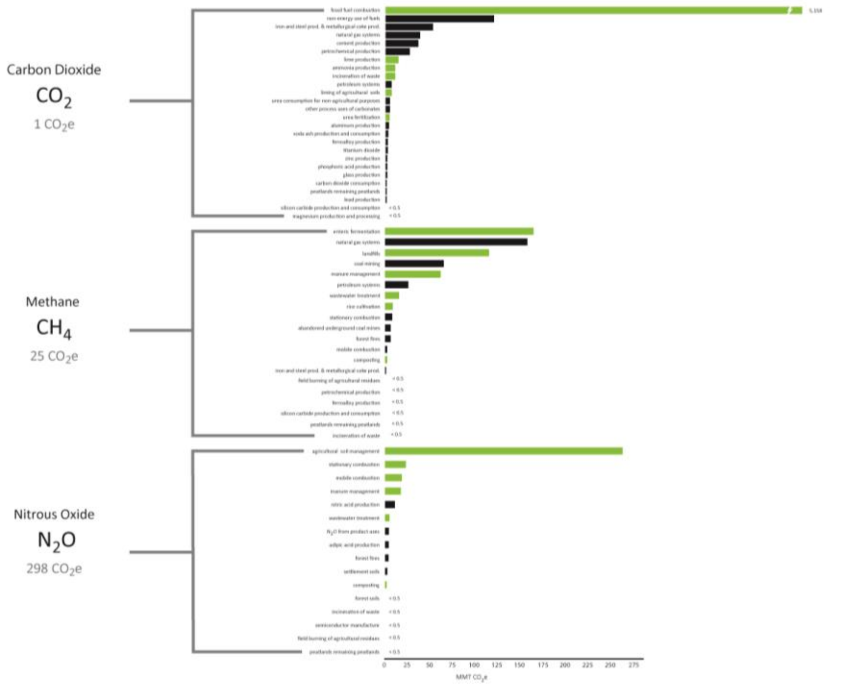
Agriculture as a Portion of all U.S. Emissions

GHG emissions generated by the Agriculture Sector Include:

- N_2O emissions - Application of synthetic fertilizers to soils
- CH_4 emissions - Livestock production (enteric fermentation by ruminants and manure management for ruminants and non-ruminants
- CH_4 emissions - Crop production methods that create anaerobic conditions (flooded rice fields)

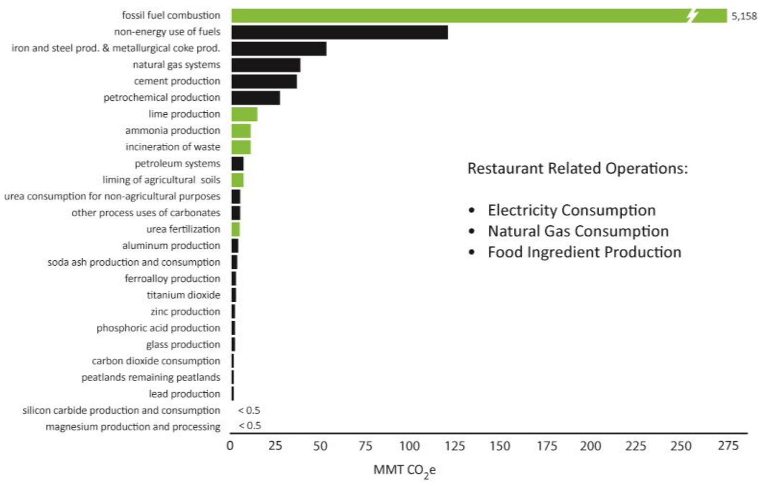
source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2013

U.S. GHG EMISSIONS LINKED TO RESTAURANT OPERATIONS



source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2013. Global Warming Potentials from IPCC 4th Assessment Report

U.S. CO_2 EMISSIONS LINKED TO RESTAURANT OPERATIONS



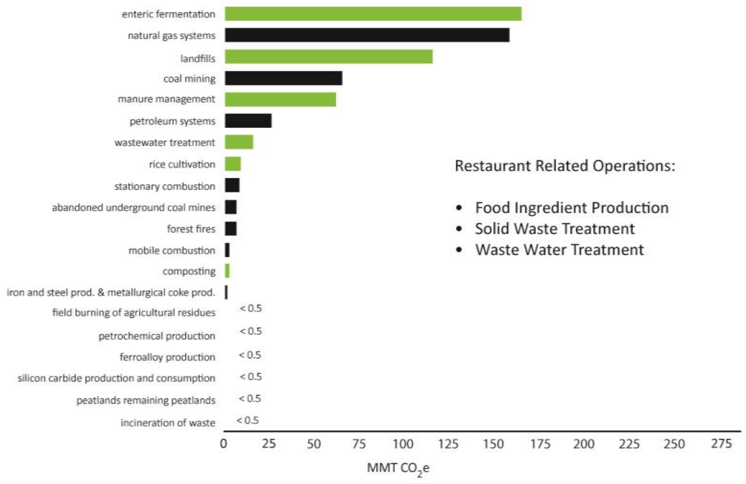
Carbon Dioxide

CO_2

1 CO_2e

source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2013. Global Warming Potentials from IPCC 4th Assessment Report

U.S. CH_4 EMISSIONS LINKED TO RESTAURANT OPERATIONS



Methane

CH_4

25 CO_2e

source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2013. Global Warming Potentials from IPCC 4th Assessment Report

U.S. N_2O EMISSIONS LINKED TO RESTAURANT OPERATIONS

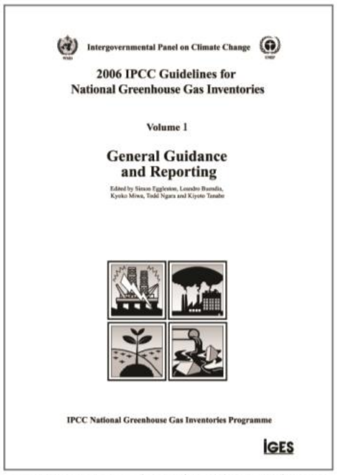
Nitrous Oxide

N_2O

298 CO_2e

source: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2013. Global Warming Potentials from IPCC 4th Assessment Report

WHAT GUIDELINES EXIST?


Intergovernmental Panel on Climate Change

2006 IPCC Guidelines for National Greenhouse Gas Inventories

Volume 1

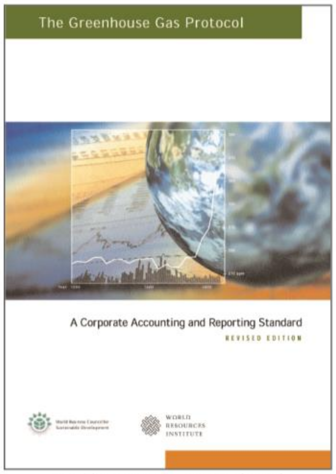
General Guidance and Reporting

Edited by Simon Eggleston, Leandro Buendia, Kyoko Miwa, Todd Ngara and Kiyoto Tanabe

IPCC National Greenhouse Gas Inventories Programme

IGES

Intergovernmental Panel on Climate Change (2006)


The Greenhouse Gas Protocol

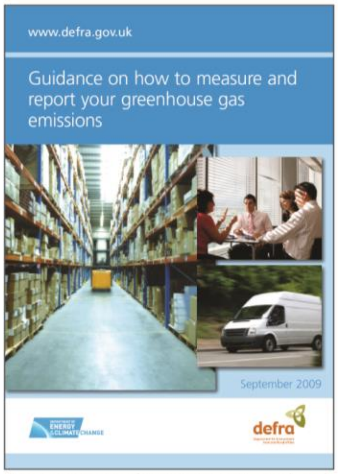
A Corporate Accounting and Reporting Standard

REVISED EDITION

World Business Council for Sustainable Development

WORLD RESOURCES INSTITUTE

World Resources Institute (2004)


www.defra.gov.uk

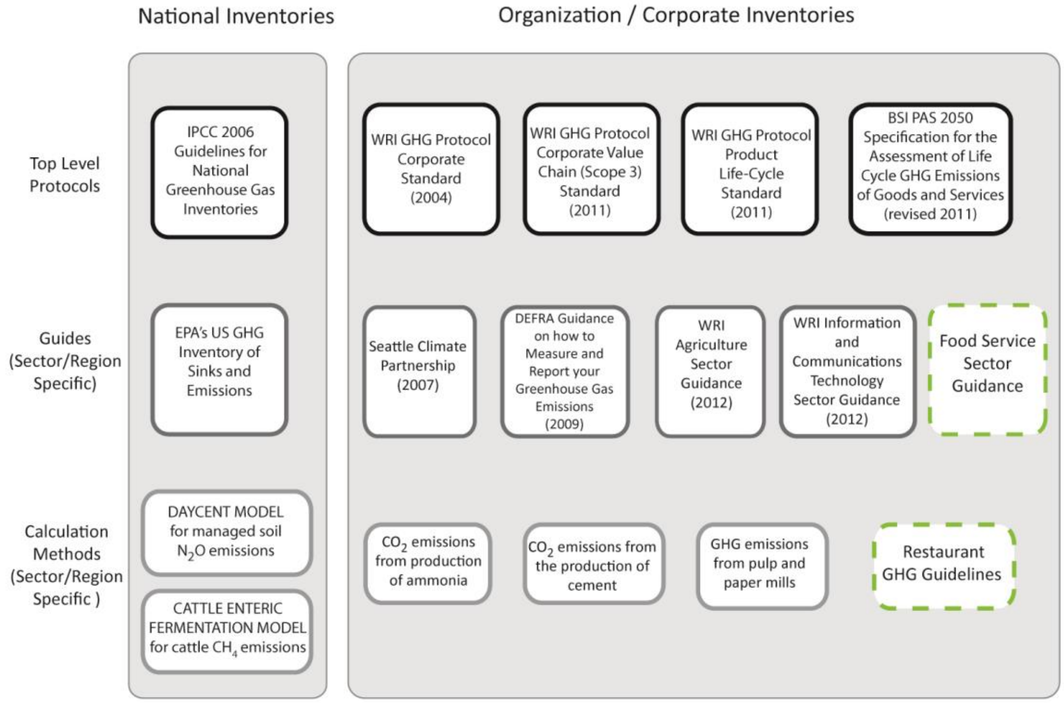
Guidance on how to measure and report your greenhouse gas emissions

September 2009

defra

U.K. Department for Environment, Food, and Rural affairs (2009)

EXISTING GHG EMISSIONS ACCOUNTING GUIDELINES


National Inventories

Organization / Corporate Inventories

Top Level Protocols

- IPCC 2006 Guidelines for National Greenhouse Gas Inventories
- WRI GHG Protocol Corporate Standard (2004)
- WRI GHG Protocol Corporate Value Chain (Scope 3) Standard (2011)
- WRI GHG Protocol Product Life-Cycle Standard (2011)
- BSI PAS 2050 Specification for the Assessment of Life Cycle GHG Emissions of Goods and Services (revised 2011)

Guides (Sector/Region Specific)

- EPA's US GHG Inventory of Sinks and Emissions
- Seattle Climate Partnership (2007)
- DEFRA Guidance on how to Measure and Report your Greenhouse Gas Emissions (2009)
- WRI Agriculture Sector Guidance (2012)
- WRI Information and Communications Technology Sector Guidance (2012)
- Food Service Sector Guidance

Calculation Methods (Sector/Region Specific)

- DAYCENT MODEL for managed soil N_2O emissions
- CATTLE ENTERIC FERMENTATION MODEL for cattle CH_4 emissions
- CO_2 emissions from production of ammonia
- CO_2 emissions from the production of cement
- GHG emissions from pulp and paper mills
- Restaurant GHG Guidelines

CRITIQUES OF EXISTING GUIDELINES

Limitation on scope and boundaries:

- Existing corporate accounting tools aim to avoid double counting and limit scope based on ownership of operations that generate emissions
- Limitations based on ownership unintentionally focuses reduction strategies toward reducing energy consumption (may not be the largest source of GHG emissions for restaurant operations)

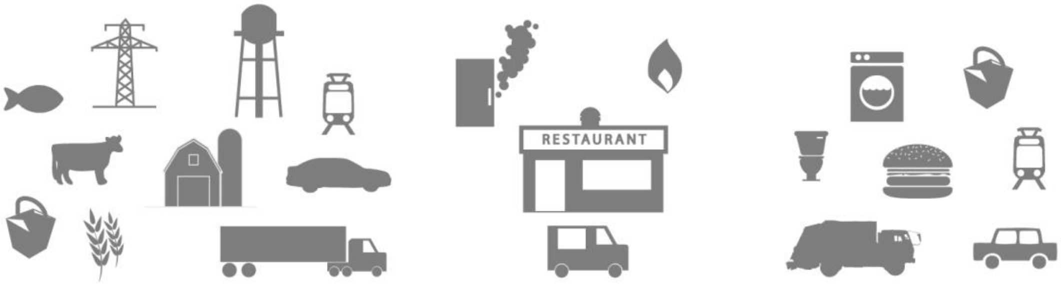
Aggregation of emissions for reporting and accuracy:

- Aggregation based on utility bill data is used to ensure greater accuracy and create an inventory for comparisons from year to year and between similar organizations
- Aggregation makes it difficult for operators to create targeted reduction strategies

Heavy reliance on utility bill data source:

- Restaurant leasing structures do not always ensure that they have access to utility bills for their portion of consumption

RESTAURANT GHG GUIDELINES



Restaurant-Centric Inventory organization:

- Organized around the supply chain of a restaurant with upstream, on-site, and downstream activities

Holistic inventory boundary:

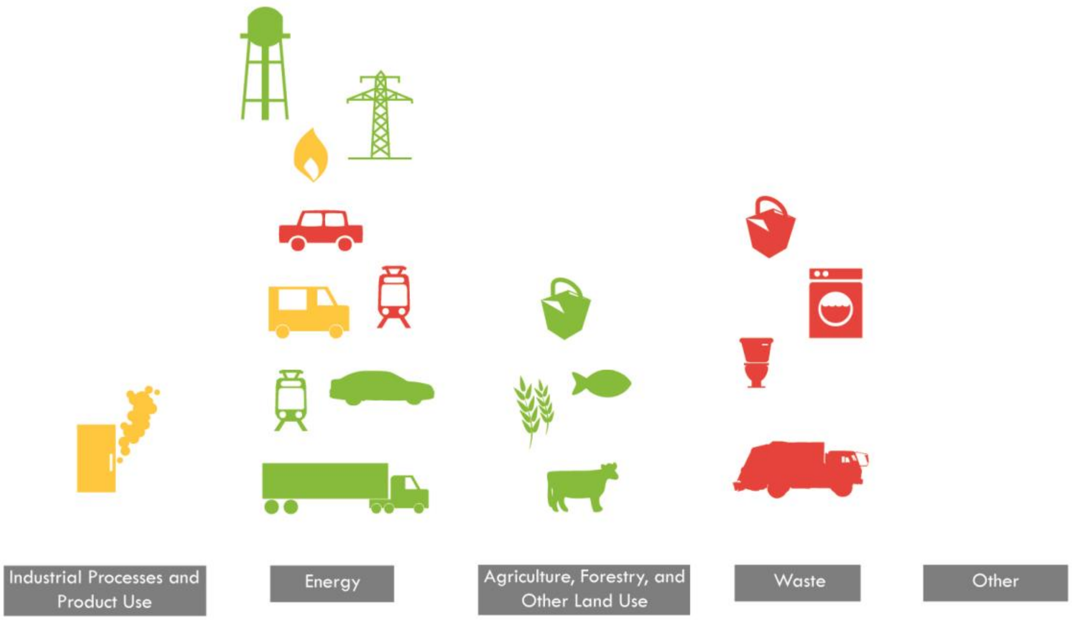
- Based on existing GHG accounting protocols
- Tailored for unique operations of a restaurant

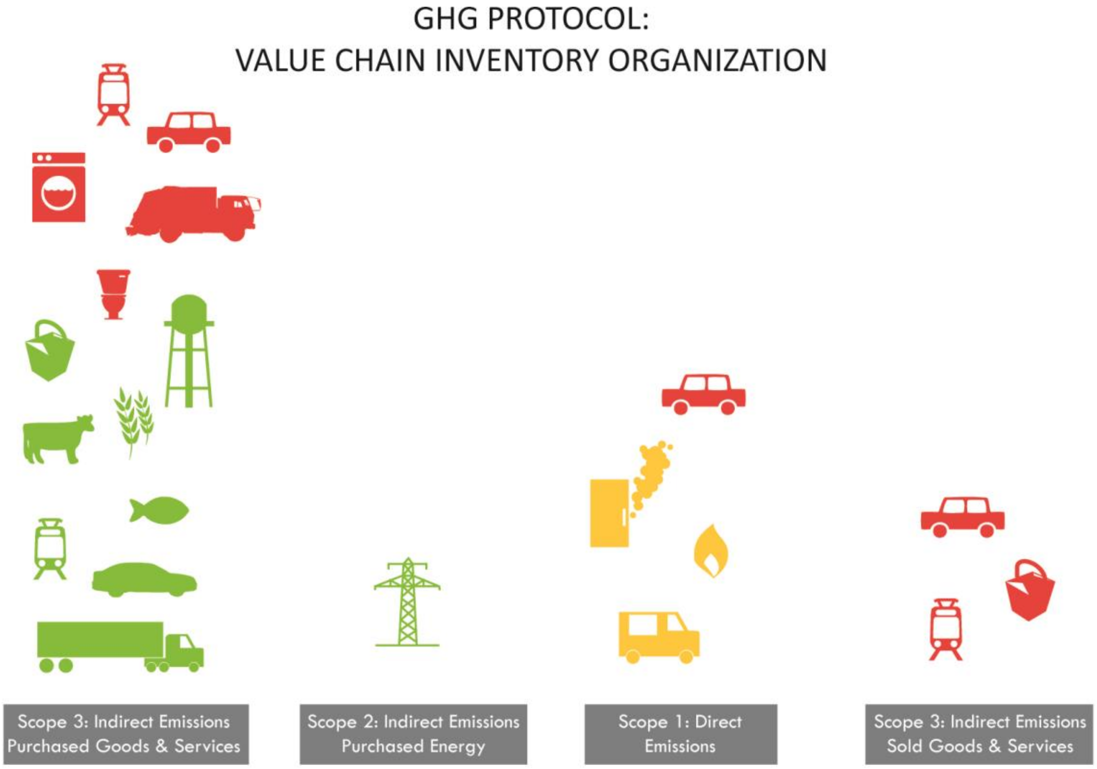
Calculation methods for estimating GHG emissions generation at the level of individual components:

- Identifies hot-spots of emissions generation
- Promotes development of targeted emissions reduction strategies
- Allows for estimating emissions even without utility bills

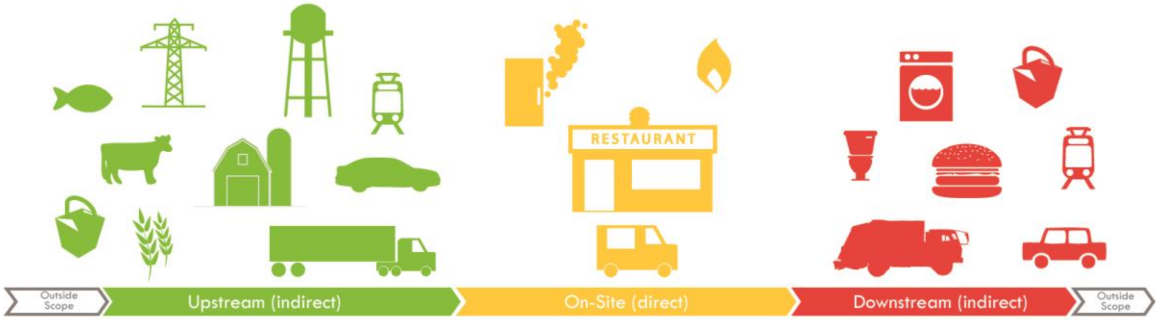

RESTAURANT GHG GUIDELINES:
SUPPLY CHAIN INVENTORY ORGANIZATION
RESTAURANT
Upstream (indirect)
On-Site (direct)
Downstream (indirect)

IPCC 2006 GUIDELINES:
SECTOR INVENTORY ORGANIZATION

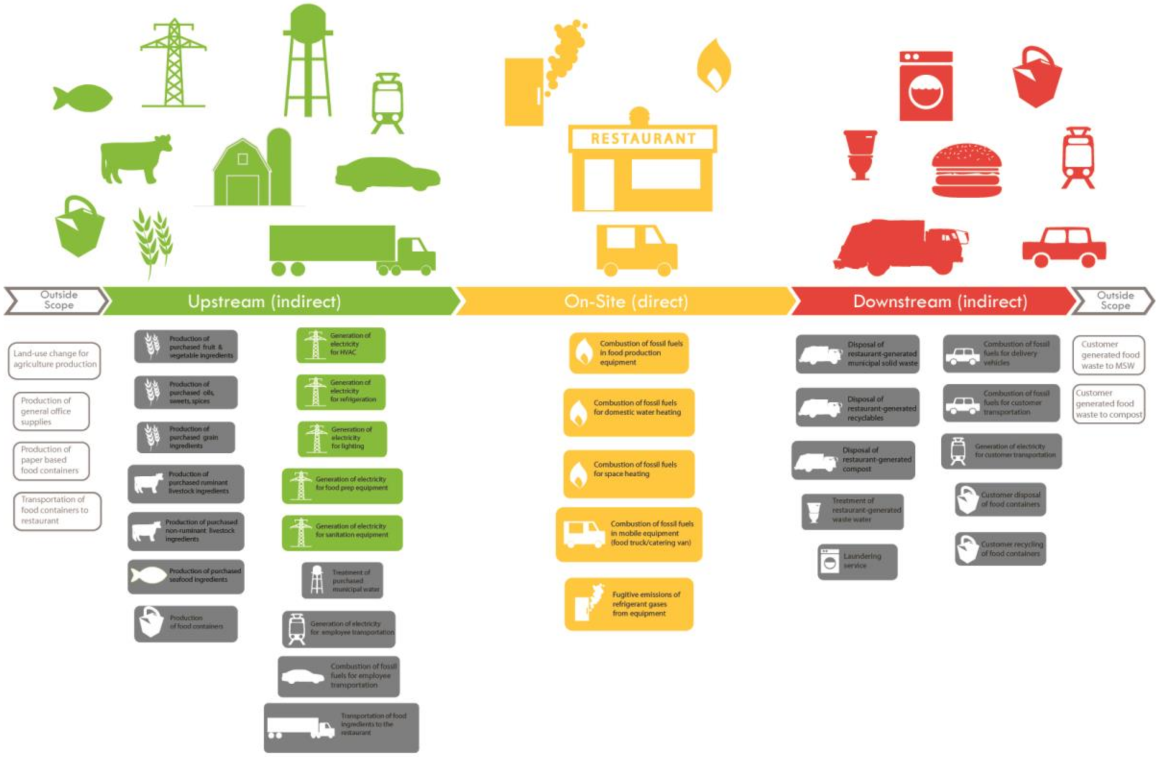



GHG PROTOCOL:
VALUE CHAIN INVENTORY ORGANIZATION
Scope 3: Indirect Emissions Purchased Goods & Services
Scope 2: Indirect Emissions Purchased Energy
Scope 1: Direct Emissions
Scope 3: Indirect Emissions Sold Goods & Services

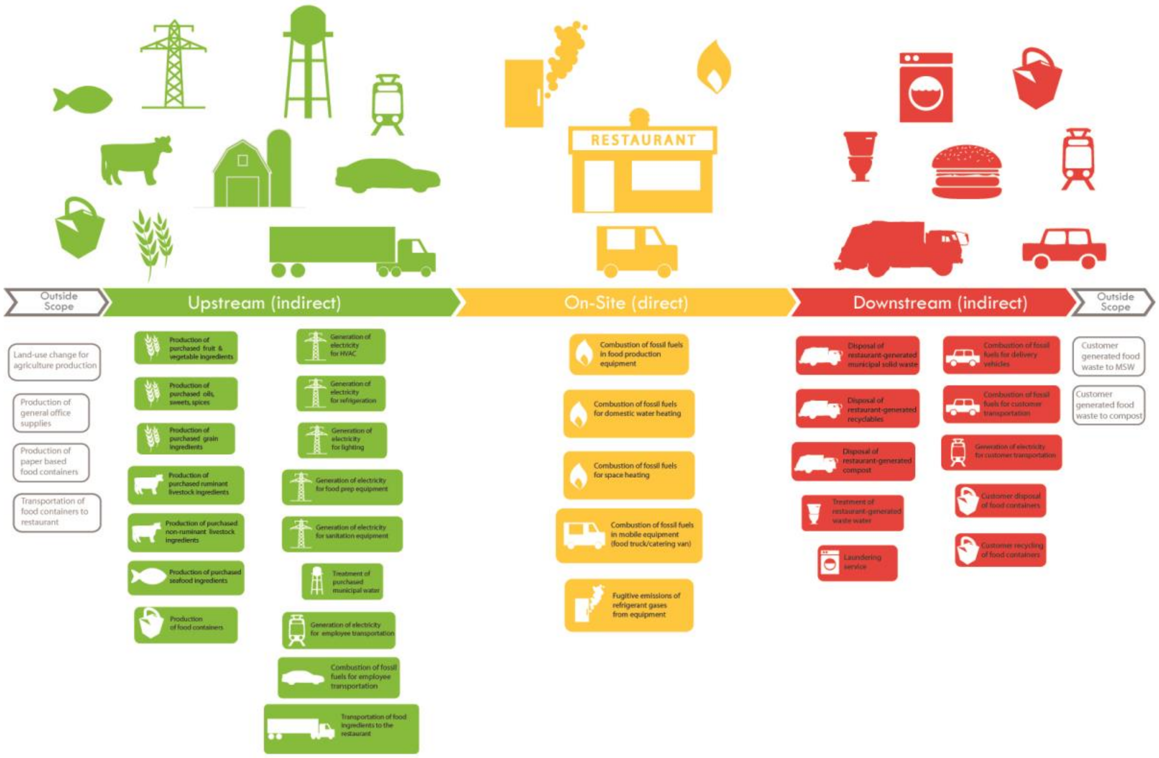
RESTAURANT GHG GUIDELINES: INVENTORY BOUNDARY



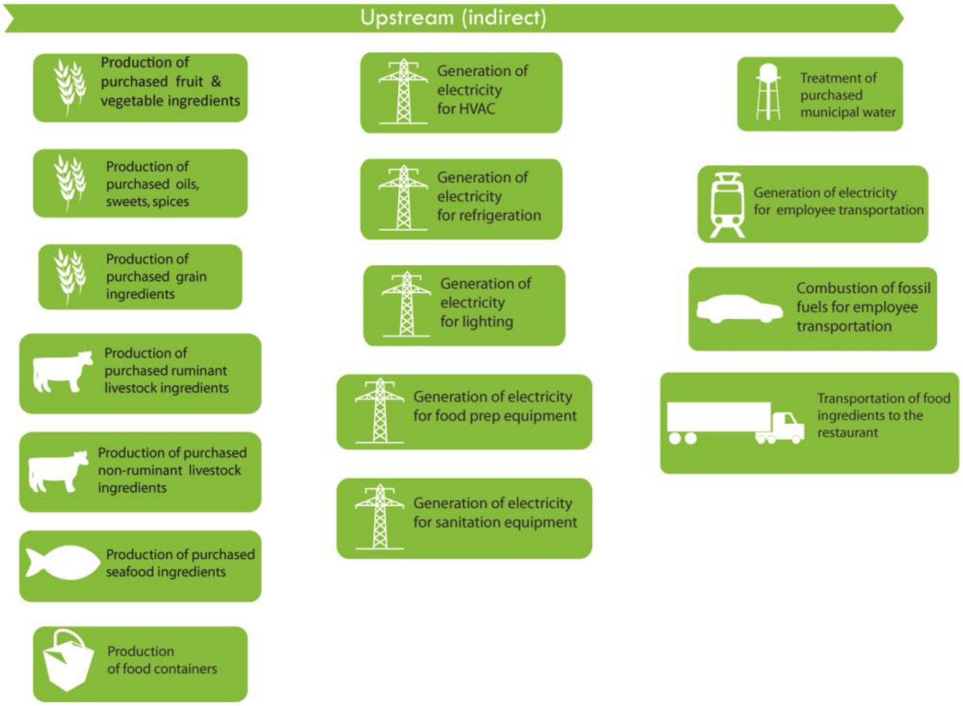
GHG PROTOCOL STANDARD INVENTORY BOUNDARY



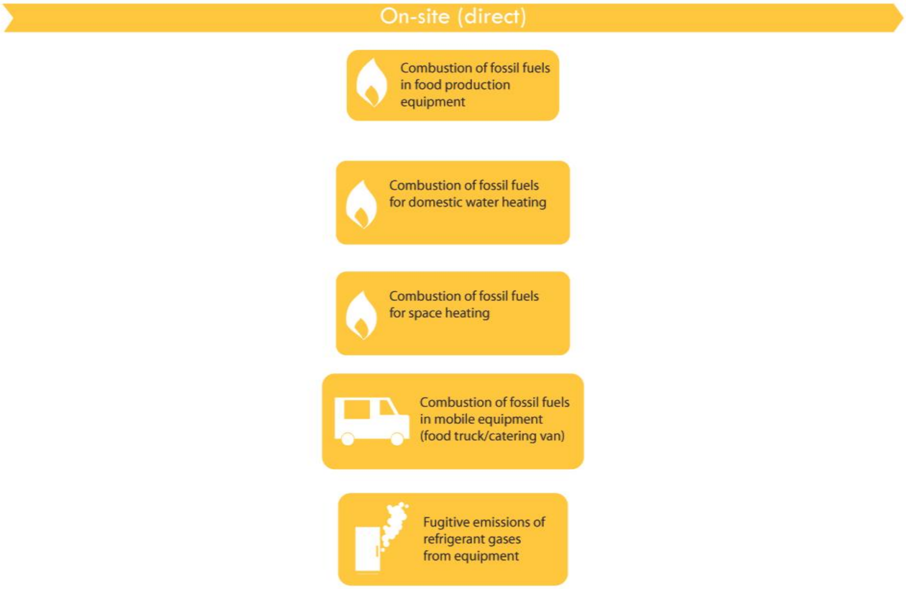
RESTAURANT GHG GUIDELINES: INVENTORY BOUNDARY



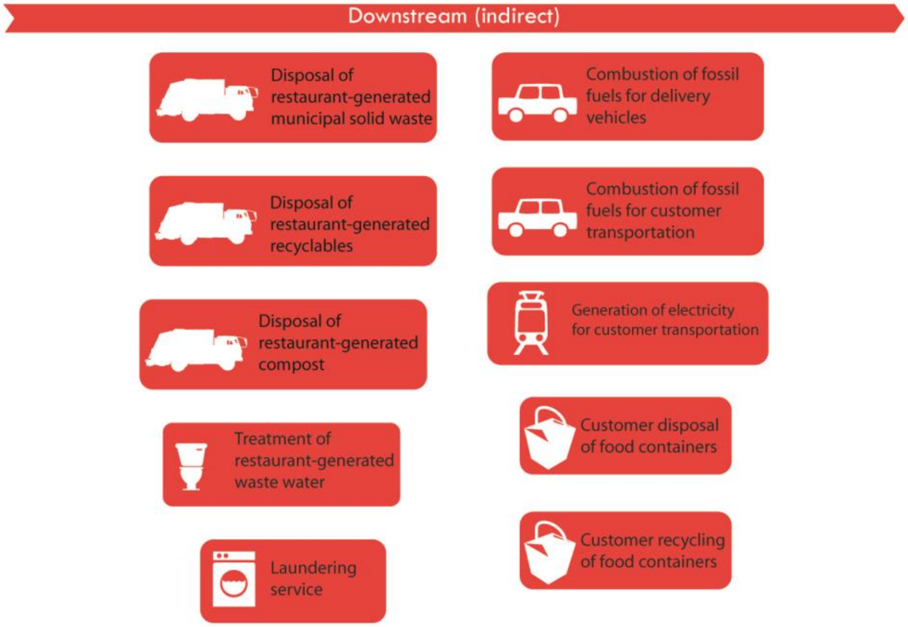
RESTAURANT GHG GUIDELINES BOUNDARY: UPSTREAM ACTIVITIES



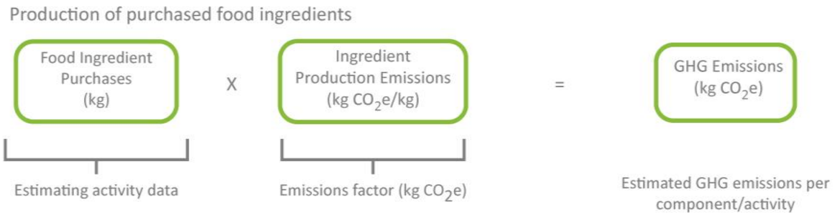
RESTAURANT GHG GUIDELINES BOUNDARY: ON-SITE ACTIVITIES

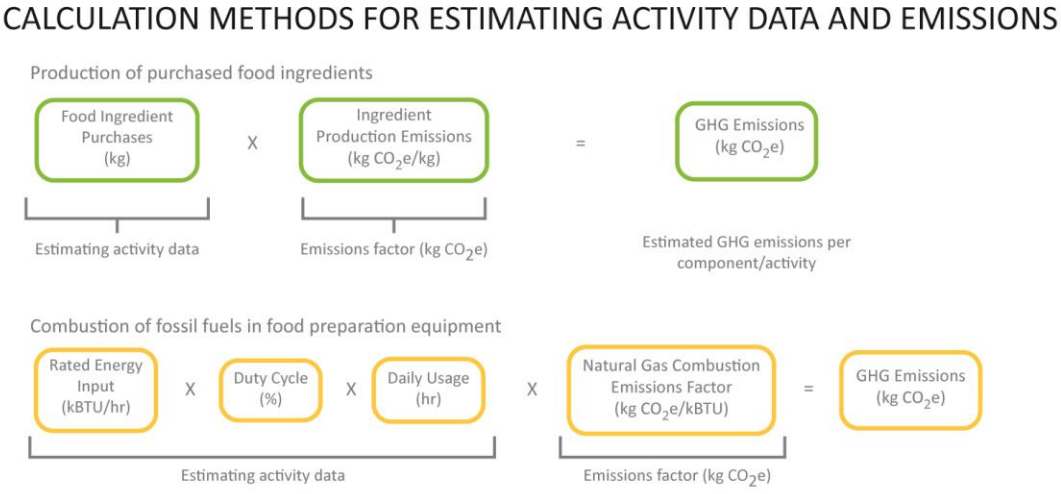


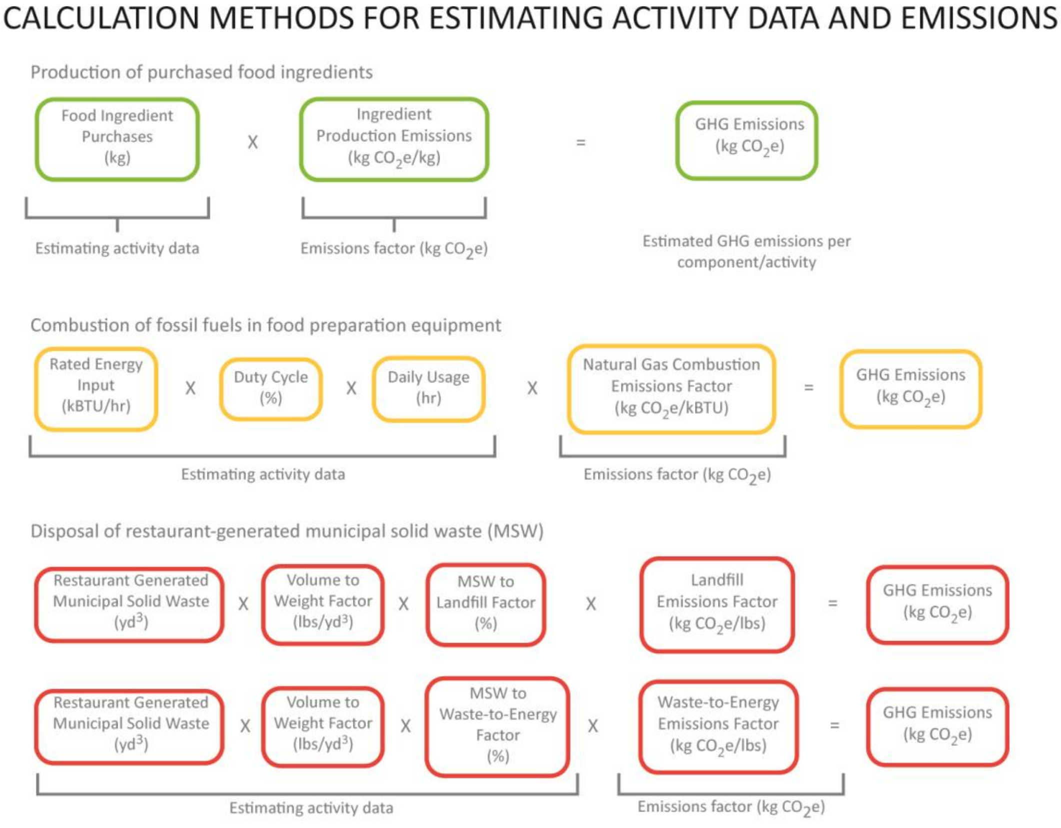
RESTAURANT GHG GUIDELINES BOUNDARY: DOWNSTREAM ACTIVITIES



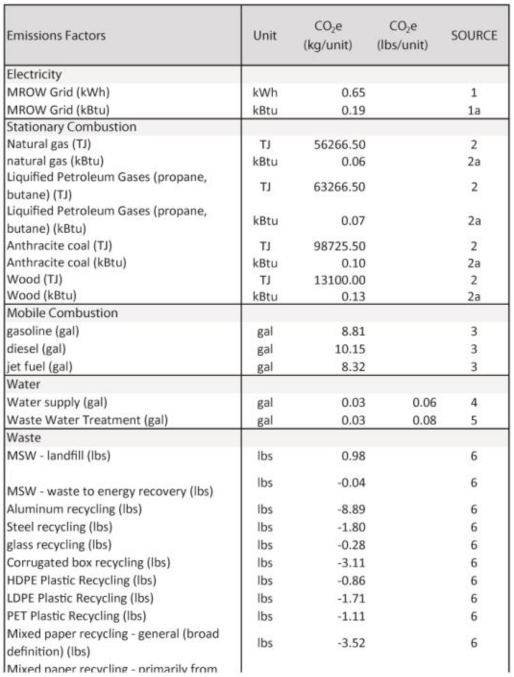
CALCULATION METHODS FOR ESTIMATING ACTIVITY DATA AND EMISSIONS




CALCULATION METHODS FOR ESTIMATING ACTIVITY DATA AND EMISSIONS
Production of purchased food ingredients
Food Ingredient Purchases (kg)
X
Ingredient Production Emissions (kg CO$_2$e/kg)
=
GHG Emissions (kg CO$_2$e)
Estimating activity data
Emissions factor (kg CO$_2$e)
Estimated GHG emissions per component/activity
Combustion of fossil fuels in food preparation equipment
Rated Energy Input (kBTU/hr)
X
Duty Cycle (%)
X
Daily Usage (hr)
X
Natural Gas Combustion Emissions Factor (kg CO$_2$e/kBTU)
=
GHG Emissions (kg CO$_2$e)
Estimating activity data
Emissions factor (kg CO$_2$e)


CALCULATION METHODS FOR ESTIMATING ACTIVITY DATA AND EMISSIONS
Production of purchased food ingredients
Food Ingredient Purchases (kg)
X
Ingredient Production Emissions (kg CO$_2$e/kg)
=
GHG Emissions (kg CO$_2$e)
Estimating activity data
Emissions factor (kg CO$_2$e)
Estimated GHG emissions per component/activity
Combustion of fossil fuels in food preparation equipment
Rated Energy Input (kBTU/hr)
X
Duty Cycle (%)
X
Daily Usage (hr)
X
Natural Gas Combustion Emissions Factor (kg CO$_2$e/kBTU)
=
GHG Emissions (kg CO$_2$e)
Estimating activity data
Emissions factor (kg CO$_2$e)
Disposal of restaurant-generated municipal solid waste (MSW)
Restaurant Generated Municipal Solid Waste (yd^3)
X
Volume to Weight Factor (lbs/yd^3)
X
MSW to Landfill Factor (%)
X
Landfill Emissions Factor (kg CO$_2$e/lbs)
=
GHG Emissions (kg CO$_2$e)
Restaurant Generated Municipal Solid Waste (yd^3)
X
Volume to Weight Factor (lbs/yd^3)
X
MSW to Waste-to-Energy Factor (%)
X
Waste-to-Energy Emissions Factor (kg CO$_2$e/lbs)
=
GHG Emissions (kg CO$_2$e)
Estimating activity data
Emissions factor (kg CO$_2$e)

RESTAURANT GHG GUIDELINES: EMISSIONS FACTORS



Emissions Factors	Unit	CO_2e (kg/unit)	CO_2e (lbs/unit)	SOURCE
Electricity				
MROW Grid (kWh)	kWh	0.65		1
MROW Grid (kBtu)	kBtu	0.19		1a
Stationary Combustion				
Natural gas (TJ)	TJ	56266.50		2
natural gas (kBtu)	kBtu	0.06		2a
Liquified Petroleum Gases (propane, butane) (TJ)	TJ	63266.50		2
Liquified Petroleum Gases (propane, butane) (kBtu)	kBtu	0.07		2a
Anthracite coal (TJ)	TJ	98725.50		2
Anthracite coal (kBtu)	kBtu	0.10		2a
Wood (TJ)	TJ	13100.00		2
Wood (kBtu)	kBtu	0.13		2a
Mobile Combustion				
gasoline (gal)	gal	8.81		3
diesel (gal)	gal	10.15		3
jet fuel (gal)	gal	8.32		3
Water				
Water supply (gal)	gal	0.03	0.06	4
Waste Water Treatment (gal)	gal	0.03	0.08	5
Waste				
MSW - landfill (lbs)	lbs	0.98		6
MSW - waste to energy recovery (lbs)	lbs	-0.04		6
Aluminum recycling (lbs)	lbs	-8.89		6
Steel recycling (lbs)	lbs	-1.80		6
glass recycling (lbs)	lbs	-0.28		6
Corrugated box recycling (lbs)	lbs	-3.11		6
HDPE Plastic Recycling (lbs)	lbs	-0.86		6
LDPE Plastic Recycling (lbs)	lbs	-1.71		6
PET Plastic Recycling (lbs)	lbs	-1.11		6
Mixed paper recycling - general (broad definition) (lbs)	lbs	-3.52		6
Mixed paper recycling - primarily from				

Partial Screen Shot of Emissions Factor Table

Electricity Generation	EPA eGRID, 2012
Stationary Combustion	IPCC 2006 Guidelines for reporting National Greenhouse Gas Inventories
Mobile Combustion	World Resources Institute GHG Protocol tool for mobile combustion. Version 2.6., 2015
Municipal Water Treatment	Racoviceanu, Alina I., et al, Life-Cycle Energy Use and Greenhouse Gas Emissions Inventory for Water Treatment Systems, *Journal of Infrastructure Systems*, 2007
Waste Water Treatment	M. Bani Shahabadi, L. Yerushalmi, and F. Haghighat, 'Impact of process design on greenhouse gas (GHG) generation by wastewater treatment plants', *Water Research*, 2009
Waste	EPA Waste Reduction Model (WARM), 2012
Food Ingredient Transportation	Weber, C.L. and H. Scott Matthews, 'Food-Miles and the Relative Climate Impacts of Food Choices in the United States', *Environmental Science & Technology*, 2008
Food Ingredient Production	Heller, Martin C. and Gregory A. Keolian, 'Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss', *Journal of Industrial Ecology*, 2014

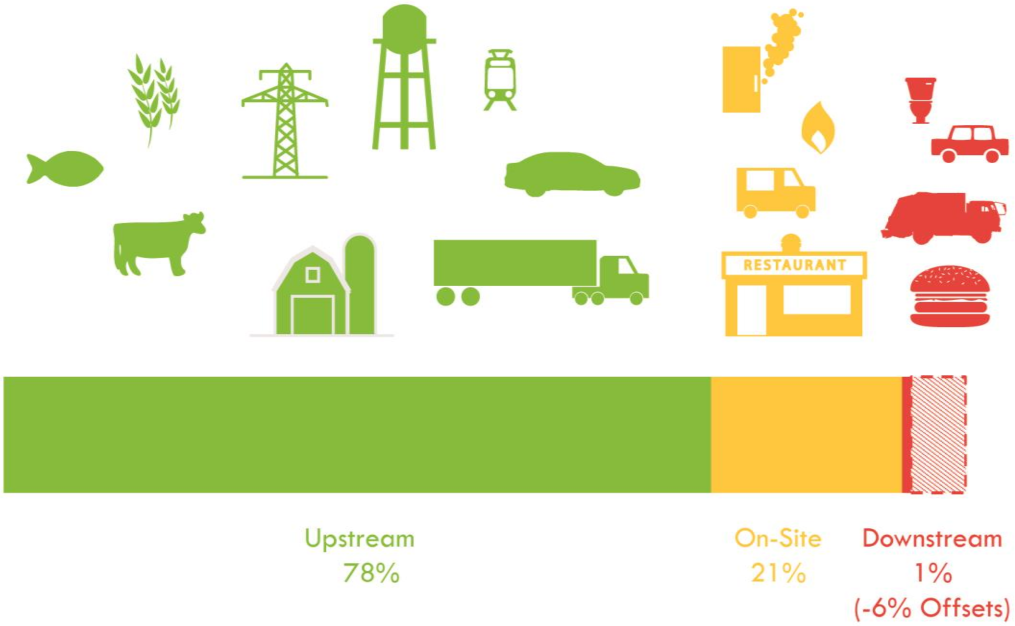
Sources

TESTING THE RESTAURANT GHG GUIDELINE: TEST CASE RESTAURANT

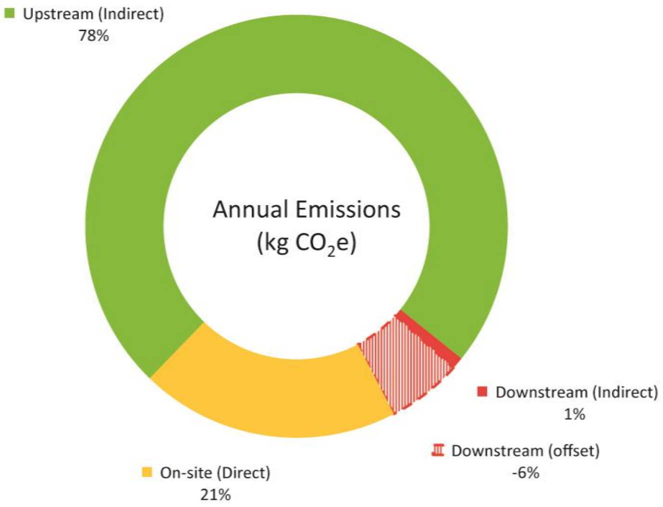
Historic operational data from a Minneapolis restaurant is used to test the guideline.
Characteristics of this Test Case Restaurant include:

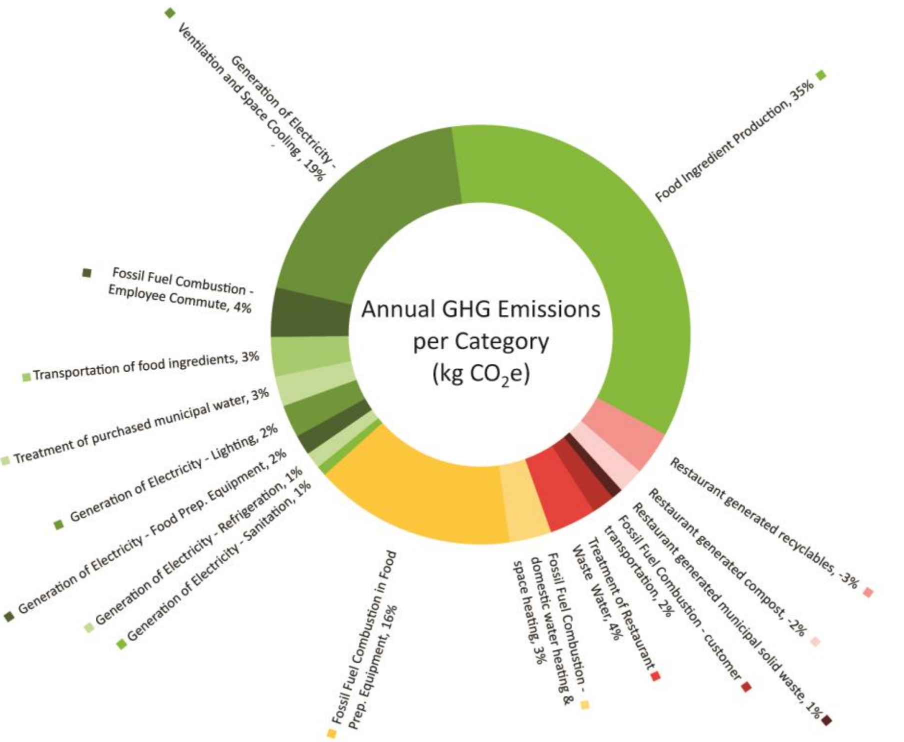
Building size:	4000 ft2 (2500 ft2 Dining area / 1500 ft2 Back of house)
Menu type:	American (includes meat, seafood, and vegetarian options)
Operation type:	Dine in only (no take-out or delivery service)
Average # meals served per day:	148
Days of operation per year:	360
Peak day operational hours:	17 (Kitchen operates 15.5 hours)
Non- Peak day operational hours:	15 (Kitchen operates 14 hours)
Energy types consumed:	Electricity, natural gas
Waste streams utilized:	Organic composting, plastic, paper, metal recycling, municipal solid waste
Date of operation data:	March 2008 - February 2009

TESTING THE RESTAURANT GHG GUIDELINE: RESULTS

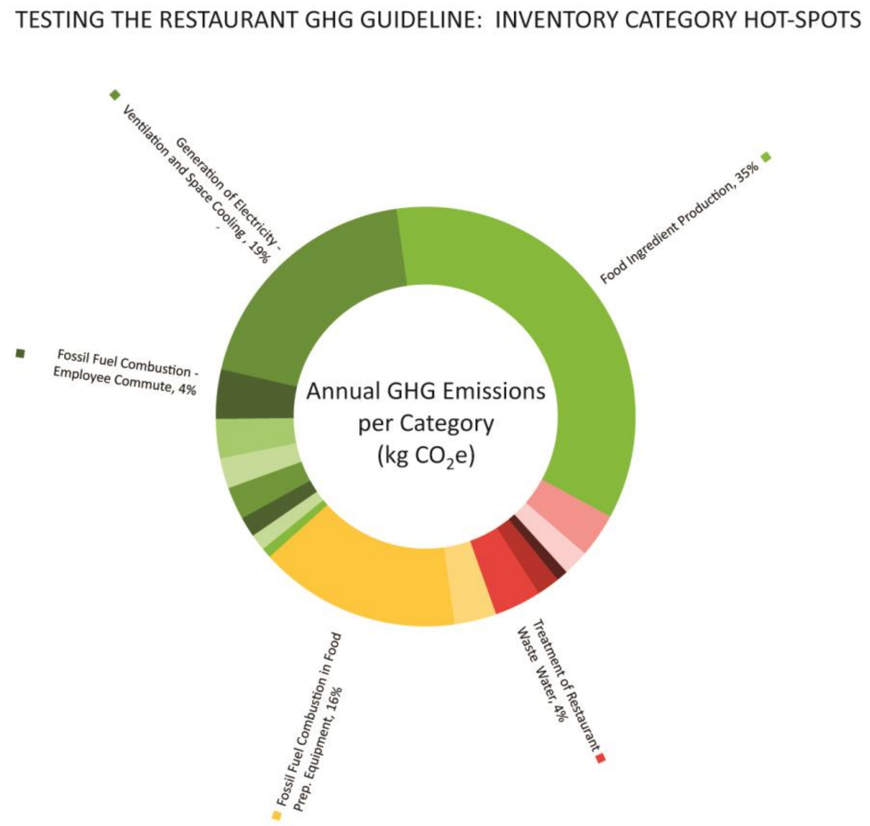


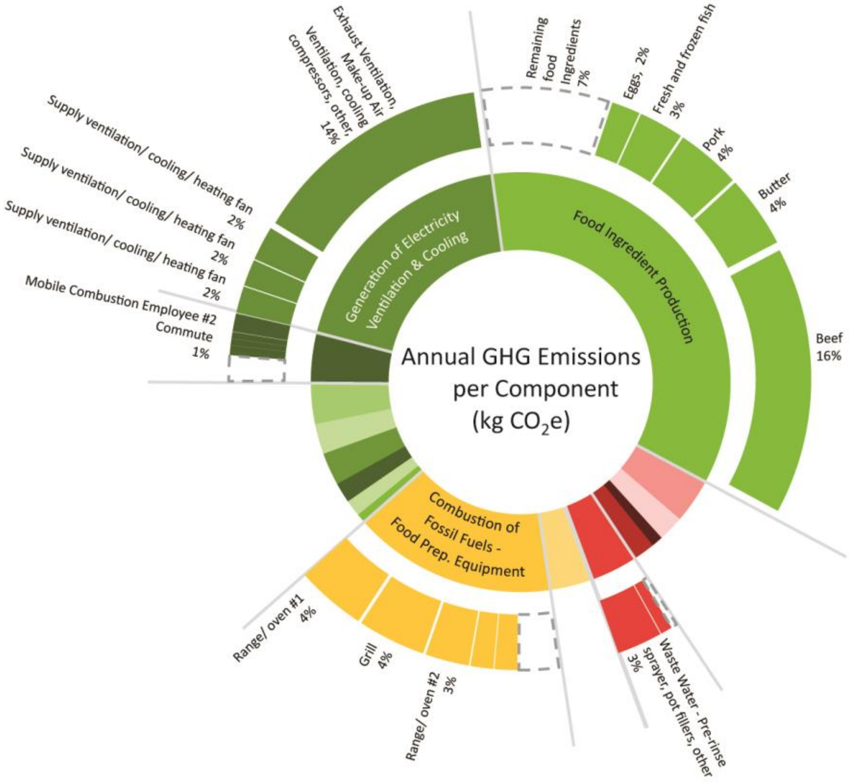
TESTING THE RESTAURANT GHG GUIDELINE: EMISSIONS ACROSS SUPPLY CHAIN



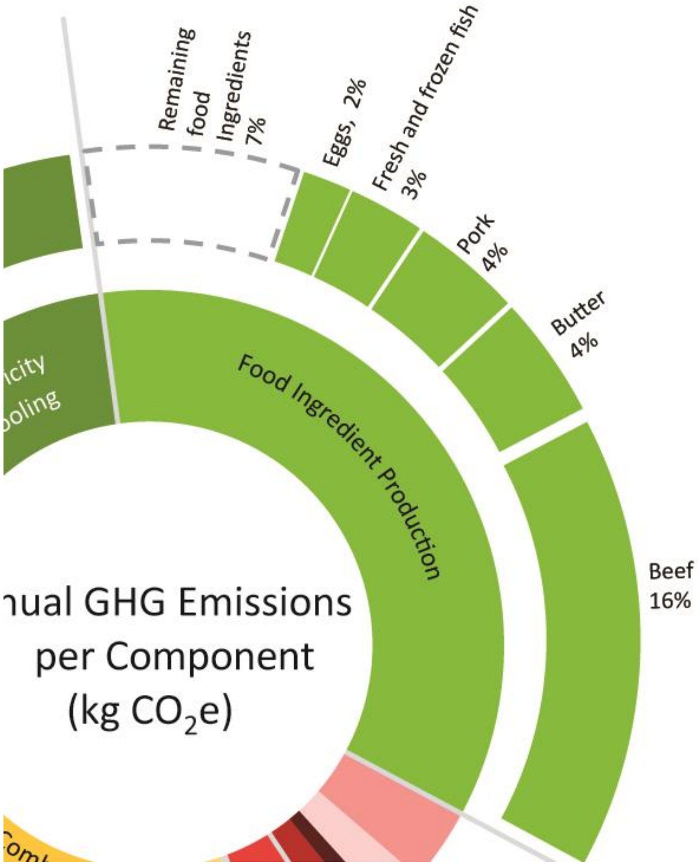


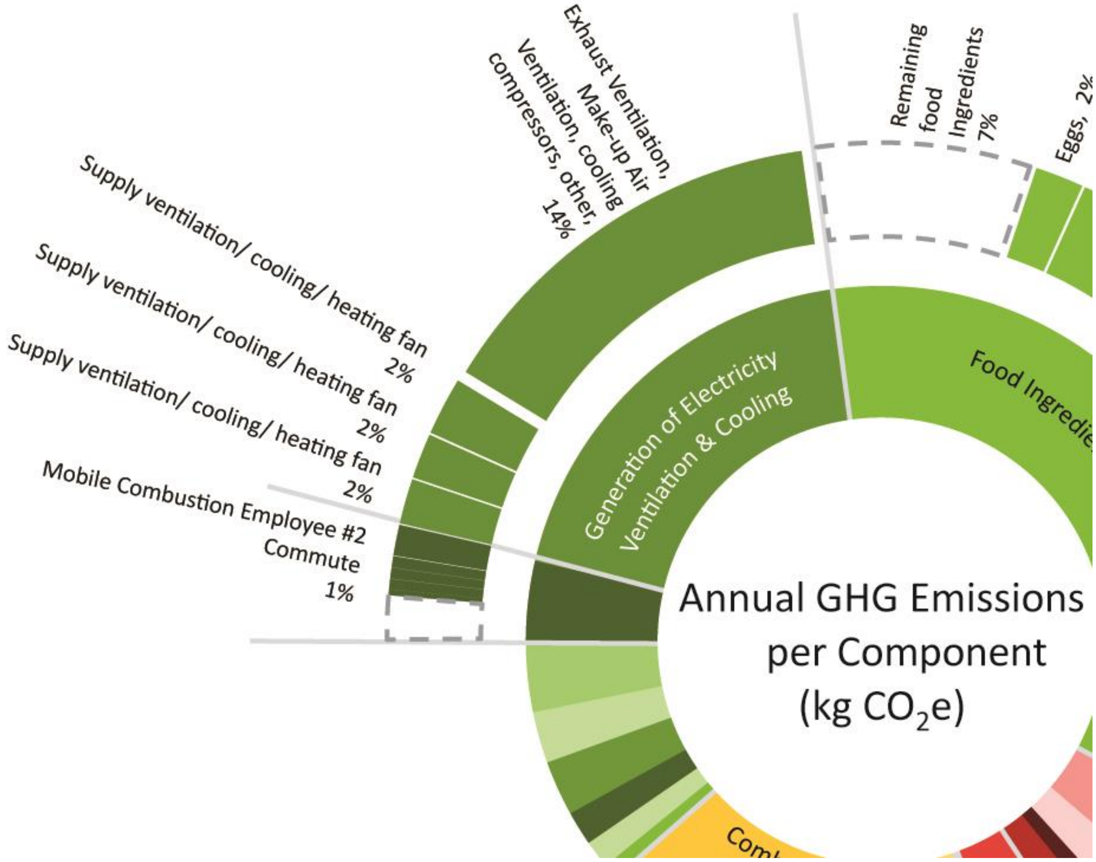
TESTING THE RESTAURANT GHG GUIDELINE: EMISSIONS PER INVENTORY CATEGORY

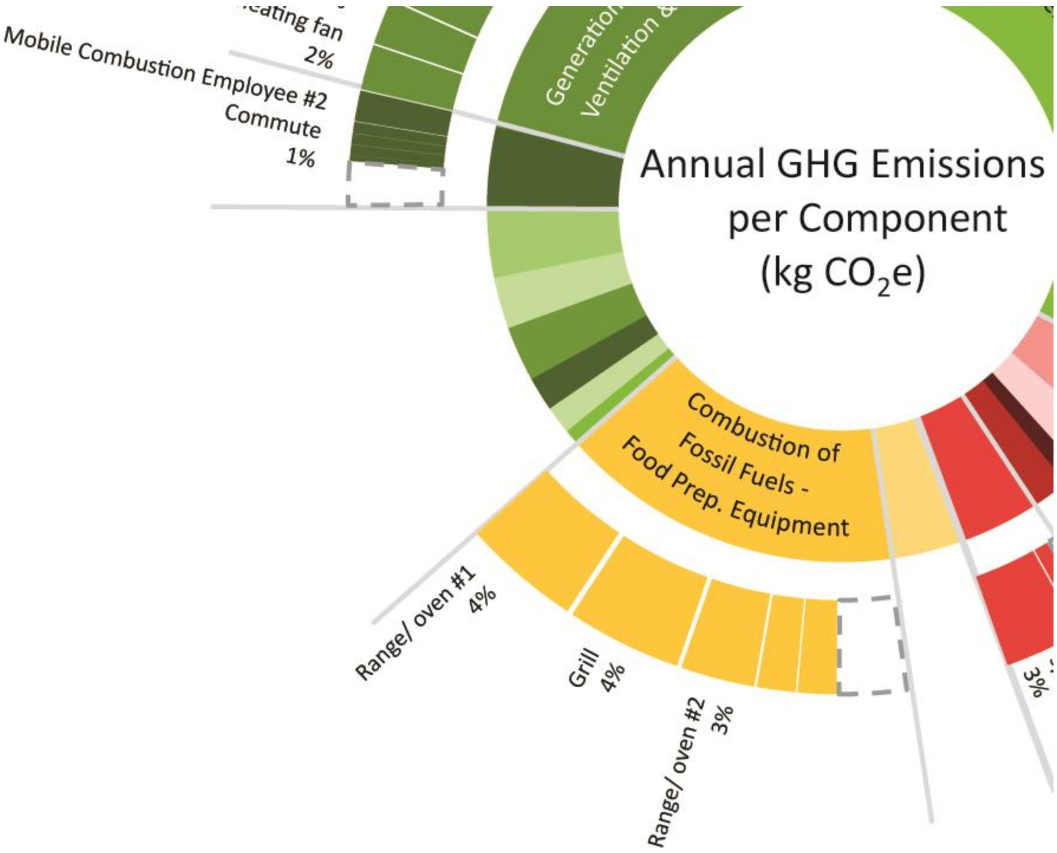

TESTING THE RESTAURANT GHG GUIDELINE: INVENTORY CATEGORY HOT-SPOTS



TESTING THE RESTAURANT GHG GUIDELINE: INVENTORY COMPONENT HOT-SPOTS


Remaining food Ingredients 7%
Eggs, 2%
Fresh and frozen fish 3%
Pork 4%
Butter 4%
Beef 16%
Food Ingredient Production
icity
ooling
nual GHG Emissions per Component (kg CO2e)
Com


Exhaust Ventilation, Make-up Air Ventilation, cooling compressors, other, 14%
Remaining food Ingredients 7%
Eggs, 2%
Supply ventilation/ cooling/ heating fan 2%
Supply ventilation/ cooling/ heating fan 2%
Supply ventilation/ cooling/ heating fan 2%
Mobile Combustion Employee #2 Commute 1%
Generation of Electricity Ventilation & Cooling
Food Ingredie
Annual GHG Emissions per Component (kg CO_2e)
Com


eating fan
2%
Mobile Combustion Employee #2
Commute
1%
Generation
Ventilation &
Annual GHG Emissions
per Component
(kg CO$_2$e)
Combustion of
Fossil Fuels -
Food Prep. Equipment
Range/ oven #1
4%
Grill
4%
Range/ oven #2
3%
3%

“WHAT’S NEXT?”

RESTAURANT GHG GUIDELINE: FUTURE IMPROVEMENTS

- Apply tool to pilot restaurants to set benchmarks for various restaurant types
- Establish a metric for (GHG emissions/functional unit) for comparing restaurant GHG emissions inventories. GHG emissions/meal could be effective for communicating
- Continue to update emissions factors as more LCA studies are published
- Engage chefs and restaurant operators to share findings and develop input methods that could integrate with existing data tracking

QUESTIONS?