PARCMAN

NATIONAL ***PAR***KS ***C***ARBON ***MAN***AGEMENT TOOL

Background, Guidelines and Methodology

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Abstract

National parks have a responsibility to determine and reduce their carbon footprint, given the growing threat of climate change and their unique role as custodians of US natural and cultural resources. However, conducting a carbon footprint analysis can be an overwhelming task due to resource constraints and an information overload. Multiple established protocols exist to assist with greenhouse gas (GHG) accounting initiatives. However, no discussion or comparison of these protocols exists in the literature. Therefore, I conducted an analysis of four prominent GHG inventory protocols to determine the most appropriate for use in national parks. I examined the comprehensiveness, usability, transparency and applicability of the IPCC 2006 Guidelines, GHG Protocol Initiative Corporate Standard, EPA Climate Leaders Guidelines, and Climate Friendly Parks program relative to GHG management in national parks. All four protocols offer detailed guidance for developing carbon footprint analyses in national parks with the Climate Friendly Parks program proving to be the most appropriate. The analysis highlighted four characteristics that are necessary for a user-friendly, high quality GHG inventory protocol: explicit source data, a calculation tool, flexibility, and a discussion of uncertainty. The results of this assessment were used to develop a new calculation tool, referred to by the acronym PARCMAN, to facilitate carbon footprint analyses in national parks. This report provides an overview of the inventory protocol assessment, and PARCMAN tool, guidelines and methodology.

Part A. BACKGROUND

A.1 Climate Change Basics

Naturally occurring atmospheric gases help to keep the earth warm by absorbing heat reflected from the earth's surface and trapping some of it in the atmosphere, a phenomenon known as the "greenhouse effect[1]." Since the industrial revolution, human-induced activities such as the burning of fossil fuels (including coal, oil and natural gas), land use changes (including deforestation), and industrial processes have increased the amount of gases in the atmosphere[2]. This increasing accumulation of greenhouse gases (GHG), particularly carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), has intensified the warming effect[2].

The consequences of global warming, including sea-level rise, temperature changes, and altered precipitation patterns, may be profound if allowed to continue unabated[2]. However, current technological tools and continued advances in scientific research will allow us to mitigate some of these threats[2]. With the reality of human-induced global warming now widely accepted in the international community[3], the reduction of greenhouse gas emissions is at the fore of mitigation efforts[4,5]. In order to achieve emissions reductions objectives and assess mitigation options, it is necessary to attain an accurate knowledge of emissions trends by conducting a *carbon footprint* analysis based on a reliable GHG inventory[6].

A.2 National Parks and Climate Change

National parks serve as custodians of the United States' natural and cultural resources. Unfortunately, climate change poses a particular threat to national parks given its predicted impact on environmental protection and management[7]. Everglades and Point Reyes National

Parks, for example, are areas particularly vulnerable to sea level rise[8,9]. Additionally, National parks are in a position to serve as role models and educational resources in GHG mitigation efforts. Therefore, national parks have a responsibility to determine their carbon footprint and actively seek ways to reduce GHG emissions.

To facilitate climate change awareness and reduction efforts, the National Park Service (NPS) established the Climate Friendly Parks Program (CFP)[10]. Parks that enroll in CFP are eligible for training and assistance in GHG accounting methods and management. Additionally, the new Presidential Executive Order *Strengthening Federal Environmental, Energy, and Transportation Management* (EO 13423) mandates that all federal agencies, including national parks, to address their GHG emissions[11]. EO 13423 requires federal agencies to "improve energy efficiency and reduce greenhouse gas emissions…by 3 percent annually through the end of FY 2015, or 30 percent by the end of FY 2015 relative to the baselines of the agency's energy use in FY 2003"[11].

National parks' emissions sources are similar to those of smaller corporate entities and industrial organizations with some exceptions. National parks generally have no process emissions from physical or chemical processes (e.g. cement manufacturing) but may include emissions from agricultural practices (e.g. livestock, land management), heavy equipment, and off-road vehicles (e.g. watercraft, snowmobiles). Additionally, whereas corporations theoretically have more resources to dedicate towards GHG management, national parks are consistently challenged by a lack of funding and limited resources. However, recognizing emissions reduction opportunities and managing risks provides advantages for both businesses and national parks. Figure 1 provides a graphical overview of emissions sources in national parks.

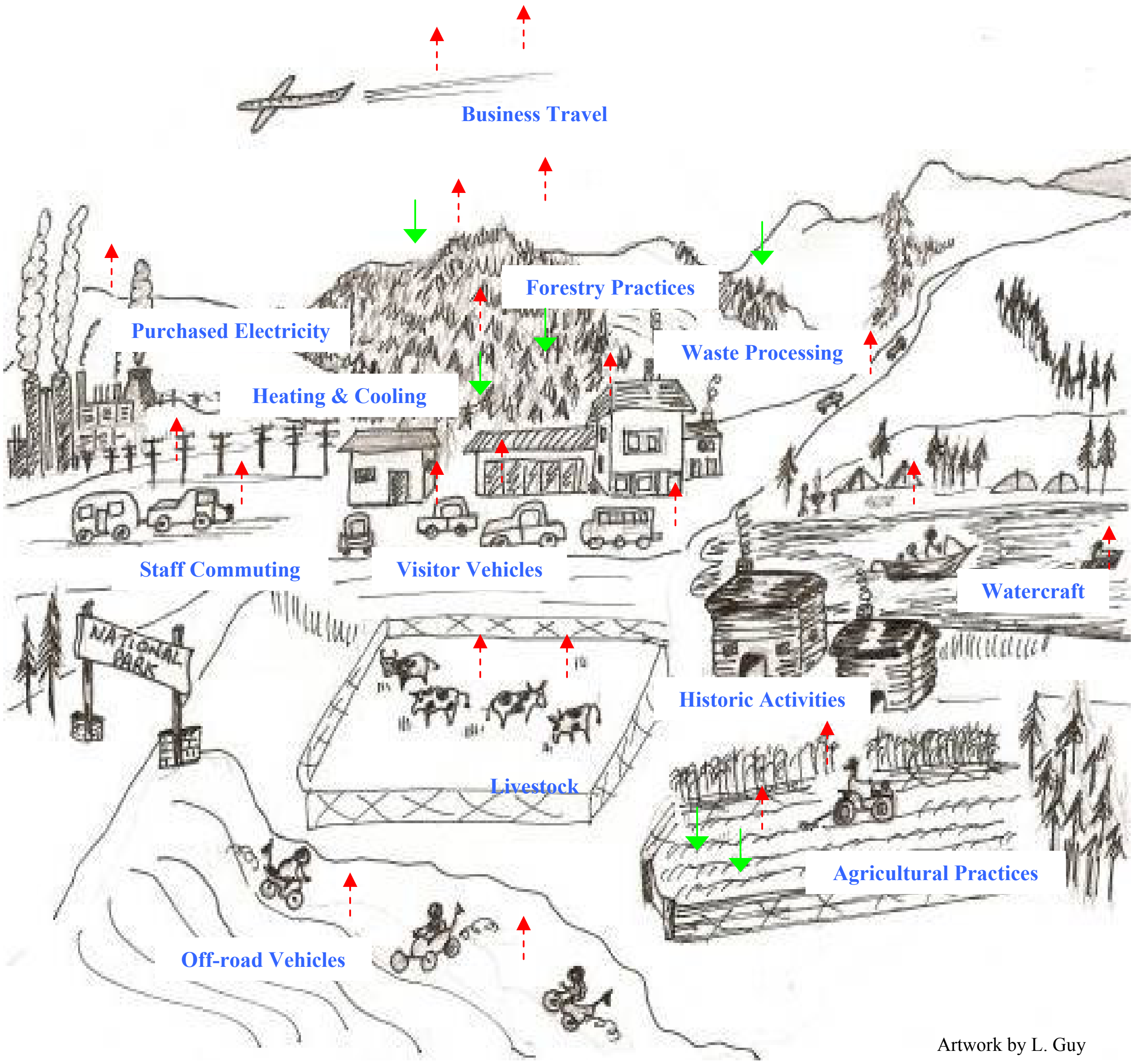

Figure 1. Greenhouse gas emissions and sequestration in national parks. Red arrows represent emissions sources and green arrows represent opportunities for sequestration.

The Climate Friendly Parks Program and EO 13423 both reinforce that national parks should take steps to reduce their GHG emissions. However, in order to achieve GHG reductions, it is first necessary to estimate the carbon footprint at the park level.

A.3 Estimating a *Carbon Footprint*: GHG Accounting Protocols

The term *carbon footprint* refers to the quantitative estimate of an entity's total greenhouse gas output, minus an estimate of the amount of carbon sequestered, for a given time period. A carbon footprint analysis typically entails conducting an emissions inventory of the six primary greenhouse gases:

- Carbon dioxide (CO_2)
- Methane (CH_4)Nitrous oxide (N_2O)
- Sulfur hexafluoride (SF_6)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)

The overall carbon footprint of an entity is determined by totaling the weight of greenhouse gas emissions and converting it into the equivalent heat-trapping ability in metric tons (1,000 kg) of carbon dioxide equivalent ($MTCO_2e$). It may also be expressed in terms of metric tons of carbon equivalent (MTCe). CO_2e is determined by multiplying the weight of the gas in metric tons by its global warming potential (GWP):

$$CO_2e = (\text{weight in metric tons}) \times (\text{GWP})$$

GWP is a measure of a greenhouse gas' potential to contribute to global warming based on a comparison of that gas' heat-absorbing ability to that of an equivalent mass of carbon dioxide. For a 100-year time horizon, the GWPs of carbon dioxide, methane, and nitrous oxide are 1, 21 and 310 respectively[12].

Creating an inventory of greenhouse gas emissions to estimate a carbon footprint can be a challenging or even overwhelming task due to resource constraints and information overload[13]. However, utilizing a thorough protocol consisting of clear guidelines, explicit methodologies and calculation tools can greatly diminish the burden. While multiple protocols currently exist for GHG accounting inventories at the national, business and organizational level, it can be confusing to determine the most appropriate and user-friendly. Furthermore, without close scrutiny, the comprehensiveness of each protocol is unclear. Since no discussion or comparison of GHG inventory protocols currently exists in the literature, I conducted an analysis of prominent protocol guidelines to determine the most appropriate GHG accounting methods for national parks.

Following the analysis, I developed GHG inventory guidelines and a calculation tool for national parks since the most fitting protocol is one tailored specifically for the entity being measured. The tool, referred to by the acronym PARCMAN from the name National *Par*ks *C*arbon *Man*agement tool, is an Excel-based calculation tool created to facilitate the process of estimating a national park's carbon footprint. The Climate Friendly Parks Program's Climate Leadership in Parks (CLIP) tool serves as the foundation for PARCMAN. A discussion of the GHG inventory assessment and introduction to PARCMAN follows.

A.4 Overview and Analysis of GHG Inventory Guidelines

I examined inventory guidelines and accompanying calculation tools from the IPCC, GHG Protocol, Environmental Protection Agency's (EPA) Climate Leaders, and Climate Friendly Parks programs. These programs were selected for analysis based on their prominence and potential relevance to GHG management in national parks. The IPCC National GHG Inventory Guidelines, the first guidelines to be developed, are intended for GHG accounting at the national level. The GHG Protocol targets organization-level inventories and is based on the IPCC Guidelines. The EPA Climate Leaders and Climate Friendly Parks protocols follow from the GHG Protocol and are designed for corporate entities and national parks respectively. Figure 2 demonstrates the relationship between these inventory protocols and the flow of information that led to the development of PARCMAN.

A.4.i Analysis Criteria

The inventory guidelines were examined according to the following criteria:

- *Comprehensiveness* – does the inventory address all relevant GHG emissions sources?
- *Usability* – are the inventory guidelines user-friendly and the methodologies clear?
- *Applicability* – how appropriate is the inventory for national parks in particular?
- *Transparency* – are the origins of source data and calculations clear and accessible?

Based on prior experience conducting a carbon footprint analysis in a national park, these four criteria were determined to have the most significant impact on the quality of a GHG inventory and its appropriateness to national parks. The results from this study are discussed below.

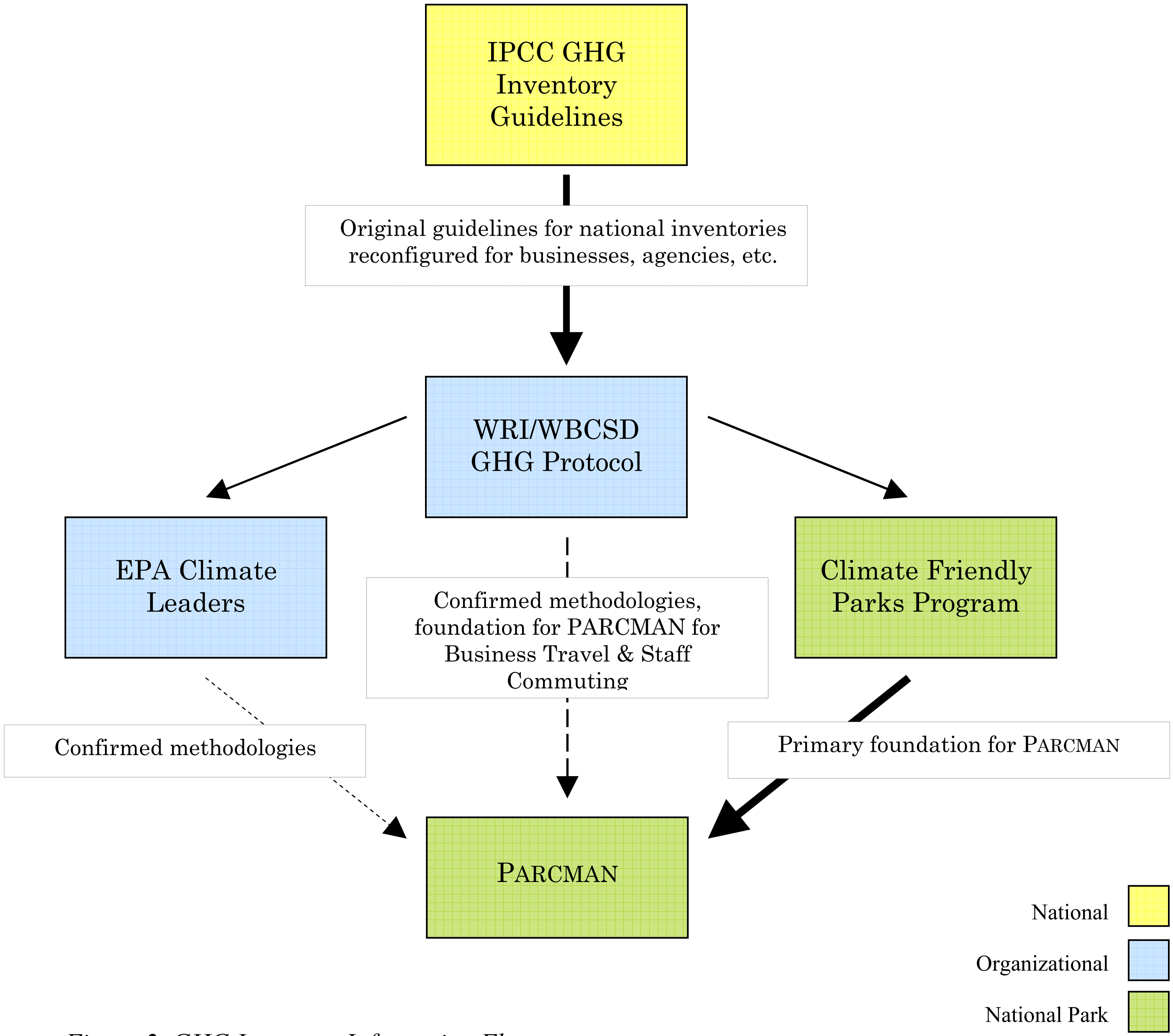

Figure 2. GHG Inventory Information Flow

<u>A.4.ii National - IPCC 2006 National Inventory Guidelines</u>

Overview

In 1988, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) initiated the first international efforts to address climate change. This collaboration led to the establishment of the Intergovernmental Panel on Climate Change

(IPCC), a body of hundreds of international scientists, to provide an "objective source of information about climate change" [14]. The findings of the IPCC's 1990 Assessment Report resulted in the United Nations Framework Convention on Climate Change (UNFCCC), which "provides the overall policy framework for addressing climate change" [14]. The UNFCCC produces the IPCC greenhouse gas inventory guidelines for signatories to the Kyoto Protocol and the UNFCCC. Countries are required to conduct and submit these inventories, which undergo a technical review process annually, to the secretariat[15].

The IPCC guidelines are internationally accepted and serve as the basis for all greenhouse gas inventories, "ensuring that they are comparable and understandable" [16]. First published in 1995 and revised in 1996, the most recent IPCC guidelines were published in 2006[17].

The IPCC guidelines' basic methodological approach multiplies *activity data* (AD), such as the amount of fuel combusted, for a particular calendar year with *emissions factors* (EF), coefficients that quantify the emissions or removals per unit activity, giving the simple equation[17]:

$$Emissions = AD \times EF$$

Comprehensiveness

The IPCC Guidelines are applicable for the following greenhouse gases for which global warming potential values are given in the IPCC Third Assessment Report (TAR):

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

- Hydrofluorocarbons (HFC's: e.g. HFC-23, HFC-143a, HFC-152a)
- Perfluorocarbons (PFC's: CF_4, C_2F_6, C_3F_8, C_4F_{10}, c-C_4F_8, C_5F_{12}, C_6F_{14})
- Sulfur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3)
- Trifluoromethyl sulfur pentafluoride (SF_5CF_3)
- Halogenated ethers
- Other hydrocarbons not covered by the Montreal Protocol
- Other halogenated GHGs not covered by the Montreal Protocol

Additionally, the IPCC Guidelines group emissions into five main sectors:

- Energy
- Industrial Processes and Product Use
- Agriculture, Forestry and Other Land Use
- Waste
- Other

These guidelines provide general rules for determining key emissions categories, defined as those that have a "significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend…or uncertainty in emissions or removals [17]." This allows for the prioritization of limited resources. The guidelines also provide methodologies for three levels, or *tiers*, of complexity. The level of methodological complexity increases with tier level – Tier 1 refers to the least complex and Tier 3 refers to the most complex[17].

Thus, the IPCC guidelines, created to address national GHG inventories, are extremely comprehensive. However, they are comprehensive on a very *broad* scale. While they provide guidance for estimating emissions for more GHGs and source categories than are necessary for national parks' purposes, their broad nature renders them largely only *indirectly* useful for the creation of the PARCMAN tool.

Usability

In creating the revised 2006 guidelines, the IPCC sought to improve usability and methodologies based on experiences with inventory compilation and technical developments[18]. Inventory developers have attempted to make the guidelines and methodologies as clear and understandable as possible. They provide worksheets, reporting tables, software and manuals to aid the user. Currently, the IPCC has called for proposals for new software to be developed that "both increases the educational nature of the software and [it] increases understanding and ability to check the calculations[19]."

However, given the convoluted nature of the entire undertaking, instructions on how to conduct a greenhouse gas inventory at the national level are innately complicated and the guidelines are difficult to navigate. The level of clarity experienced by users will largely depend on their prior knowledge and understanding of the process and underlying science.

Applicability

The IPCC Guidelines cover greenhouse gas emissions and removals occurring within national and offshore territories over which the country has jurisdiction[17]. Since they are intended for national-level inventories, they are not directly applicable to emissions accounting for a national park. However, for their intended purposes, they allow for "flexibility to use a range of methods and data, reflecting the diversity of national circumstances around the world" [16].

For the purposes of creating PARCMAN, the IPCC Guidelines proved useful for understanding the importance of organizational GHG inventories in a broader, international context and laying the foundation for the conducting the inventory process itself.

Transparency

The IPCC Guidelines go through an extensive, multi-level review process before adoption. All source data are clearly cited and detailed methodologies are provided.

<u>A.4.iii Organizational – GHG Protocol</u>

Overview

The World Resource Institute (WRI), an independent nonprofit environmental "think tank," and the World Business Council for Sustainable Development (WBCSD), a coalition of international companies focused on business and sustainable development, jointly established the Greenhouse Gas Protocol Initiative (GHG Protocol) in 1998[20]. The partnership's mission is to "develop internationally accepted greenhouse gas accounting and reporting standards for business and to promote their broad adoption"[20].

The GHG Protocol consists of two standards: private and public organization GHG accounting and reporting standards (Corporate Protocol), and project accounting protocol and guidelines. This analysis focuses on the Corporate Protocol in particular. The GHG Protocol's IPCC-compatible accounting methods are "the most widely used" internationally and provide the basis for "nearly every GHG standard and program in the world"[20].

Comprehensiveness

The GHG Protocol provides guidance for cross-sector and sector specific GHG accounting. It provides assistance for calculating emissions from mobile and stationary combustion sources, fuel use in facilities, purchased electricity, business travel, staff commutes, refrigeration, and waste management, and other sources. Sector specific calculation tools are provided for emissions from the production of cement, iron and steel, lime, pulp and paper mills, aluminum, and more. It also provides guidance for determining organizational boundaries, accounting for emissions from leased assets, and making base year adjustments. The GHG Protocol provides Excel spreadsheets to complement the Protocol and assist with calculations[21].

Additionally, the GHG Protocol offers guidance for determining uncertainty estimates and methods for quality control. The guidelines encourage auditing and third-party verification.

Usability

The strength of the GHG Protocol lies in its detailed guidelines, thorough methodologies, and user-friendly Excel-based calculation tools, all available from the GHG Protocol website. During

development, the Protocol was test-run by 30 high-profile companies, including BP, Ford Motor Company, Nike and Dupont Company, in nine countries. The GHG Protocol Initiative seeks on-going input from users to improve usability. Additionally, the Greenhouse Gas Management Institute, a nonprofit created by the GHG Experts Network and WRI offers courses and certification in GHG management and the GHG Protocol[22].

Transparency

GHG Protocol sources and calculations are described in detail. Because the Protocol is applicable to businesses wishing to participate in the carbon market, a high level of verifiable accuracy and transparency is expected.

Applicability

The GHG Protocol guidelines were created primarily for business inventories, but can easily apply to other organizations such as government agencies. Since they are geared at the organizational level, they are more applicable than the IPCC Guidelines to conducting a carbon footprint analysis of a national park. The Protocol offers sector-specific calculation tools, such as for cement manufacturers that go beyond the needs of national parks. Additionally, the GHG Protocol guidelines discuss the use of GHG offsets and credits. However, calculation tools for forest and soil sequestration that *are* applicable to national parks are omitted.

A.4.iv Organizational – EPA Climate Leaders

Overview

In 2002, the US Federal government introduced a strategy to lower the GHG intensity of the national economy by 18 percent by 2012[23]. The Environmental Protection Agency has developed multiple initiatives including Climate Leaders that promote voluntary reductions in order to meet this goal. Climate Leaders is a partnership between the EPA and industry created to help companies address their impact on climate change and reduce greenhouse gas emissions. Currently, over 150 companies have joined the Climate Leaders program[24].

The Climate Leaders GHG guidelines are based on the WRI/WBCSD GHG Protocol. With EPA assistance, Climate Leaders partner companies complete a GHG inventory according to EPA guidance documents, set approved emissions reduction targets to be met within five to ten years, and report to the EPA annually[25]. Reduction goals can be met through absolute GHG reductions or through a reduction in GHG intensity.

Climate Leaders supports the development of an Inventory Management Plan (IMP) which institutionalizes a company's particular planned procedures for conducting the GHG inventory[25]. The purpose of IMP development is to ensure consistency and facilitate more accurate data gathering and documentation.

Comprehensiveness

The Climate Leaders GHG inventory guidelines consist of three parts:

- Design Principles: help to identify emissions sources and define inventory boundaries.

- Core Modules: provide guidance on estimating emissions from stationary and mobile combustion, process emissions, refrigeration, and purchased electricity. Separate guidance documents are available for core cross-sector and sector-specific emissions.
- Optional Modules: provide guidance on incorporating GHG offsets, renewable energy, business travel, employee commuting, product transport, and international operations.

Company partners are required to report on the six primary greenhouse gases: CO_2, CH_4, N_2O, SF_6, PFCs, and HFCs. Climate Leaders discourages exclusion of *de minimis* emissions and encourages incorporating an uncertainty assessment, although these are not mandatory.

Usability

Climate Leaders offers clear guidance documents and technical support to partner companies. While calculation tools are not provided, Climate Leaders does offer an Excel-based tool to facilitate reporting. The EPA provides 80 hours of technical support towards completion of the base year inventory and development of an IMP and 10 hours of support for subsequent years. It also conducts inventory reviews to advise on improving efficiency and accuracy.

To ensure continual improvement in accuracy and usability, the program holds panel discussion sessions for partners to share knowledge and experience conducting GHG inventories.

Transparency

The methodology Climate Leaders employs is based on is discussed in depth and sources are cited. The program encourages a “good faith effort” towards transparent documentation and independent verification.

Applicability

Since the Climate Leaders inventory protocol is based on the GHG Protocol, it is geared at the organizational lever and can also apply to national parks.

A.4.v National Parks – Climate Friendly Parks Program

Overview

The Climate Friendly Parks (CFP) program was jointly established by the National Park Service (NPS) and the U.S. Environmental Protection Agency (EPA) in 2003 to provide guidance on GHG accounting and management in national parks[26,27]. To become members of the CFP, parks submit an application and then conduct a GHG inventory to determine baseline emissions. The CFP bases its methodologies on the IPCC and EPA guidelines and provides an Excel-based calculation tool called the Climate Leadership in Parks, or CLIP, tool. Guidelines regarding the compilation of the inventory are incorporated in the CLIP tool itself and not provided in a separate document.

Member parks complete and implement an action plan for GHG reductions and report results annually. The CFP works closely with member parks, offering guidance and workshops and facilitating stakeholder involvement at each step in the process[27]. Currently, 34 national parks, including Everglades, Yellowstone, Yosemite, Glacier and Mount Ranier, are enrolled in the program[28].

Comprehensiveness

The CLIP tool provides assistance for calculating both emissions of the six major greenhouse gases and EPA regulated criteria air pollutants (CAP). It allows for analysis of emissions from park activities, concessionaires, and other partners. Some emissions from park visitors are included, although the methodology used to calculate these emissions is not immediately apparent to the independent user.

The CLIP tool is very comprehensive since it includes emissions from stationary and mobile combustion sources, purchased electricity, fertilizer use, refrigeration, forestry and waste. However, the tool does not include emissions from park staff business travel, staff daily commutes, or agricultural practices. Moreover, the CLIP tool does not include a measure or discussion of uncertainty, which is necessary for assessing the validity of the final result and strongly suggested for inclusion by the IPPC Guidelines and GHG Protocol.

Usability

The user inputs greenhouse gas emissions data into the CLIP tool. CLIP then computes the park's total emissions in metric tons of carbon equivalent (MTCe). It also provides a graphical break-down of the emissions sources. The consulting firm that developed the CLIP tool provides technical support for CFP member parks. Without this support, the CLIP tool is fairly easy to use and understand but difficult to tailor or alter as needed. A separate guidance document would be helpful.

Transparency

The main weakness of the CLIP tool is that its methodologies are unclear. While a description of most of the calculations *is* provided, some appear to be incomplete. For example, it is not apparent how annual visitor population data is used to determine total emissions from visitor travel and waste. The IPCC recommends that calculation tools are not "black boxes," but that calculations and sources are clearly apparent within them[Error! Reference source not found.].

Applicability

Since the Climate Friendly Parks program was created specifically for national parks, its inventory is the most appropriate for GHG accounting in national parks. A weakness emerges regarding applicability in the forest activities worksheet: it appears the source data cannot be tailored by region.

A.4.vi Conclusions

Multiple well-established guidelines for conducting greenhouse gas inventories at all levels are currently available. Although these guidelines are continually being improved upon, the methodologies are widely validated and considered reliable. The four inventory protocols reviewed here present sufficient guidance to conduct a high quality GHG inventory and create a new calculation tool specifically for national parks. Table 1 presents a comparison of these GHG accounting programs.

Table 1. Summary of GHG Inventory Programs

GHG Inventory Program	Intended Use	Assistance Tools	Shortcomings (in relation to NP)	Footprint Unit
IPCC GHG Inventory	Kyoto signatory countries	Extensive Excel-based tool and manual	Too broad for National Parks	$MTCO_2e$
GHG Protocol Initiative	Corporate entities, government agencies, other organizations	Multiple Excel-based calculation tools & guidance documents	On-going forest and agricultural management omitted	$MTCO_2e$
EPA Climate Leaders	Corporate entities	Excel-based tool to assist reporting	Calculation tools lacking, some sources omitted	$MTCO_2e$
Climate Friendly Parks Program	US National Parks	Excel-based calculation tool with guidelines embedded	Some sources omitted & unclear, difficult to tailor	MTCe

Additionally, the results of this analysis have brought to light important conclusions regarding the characteristics that contribute to GHG inventory quality. These characteristics are discussed below and were incorporated into the development of PARCMAN.

Source Data

Source data refers to predetermined numerical values, such as emissions factors and global warming potentials, necessary for certain calculations. These data play a significant role in determining inventory accuracy and quality. Since GHG accounting methodologies continue to be refined, it is important to understand when and where the source data provided in inventory guidelines originates. The IPCC states,

> "…all the calculations and emission estimation methods should be open and transparent to the user, not hidden away in the software. This is important as it both increases the educational nature of the software and it increases understanding and ability to check the calculations[19]."

The GHG Protocol Corporate Standard recommends that inventory compilers "obtain source/supplier specific emission factors for the electricity purchased" if possible, in order to

achieve the most accurate calculations. At the national level, the IPCC states that it is "…preferable to use national data since national data sources are typically more up to date and provide better links to the originators of the data.[17]" Accurate source data is necessary for compiling a reliable inventory, and reliable inventories are essential for addressing global warming in a meaningful way[29].

Calculation Tools

When compiling a GHG inventory, "difficulties arise due to information overload and disconnects.[13]" Therefore, including calculation software to facilitate the process can greatly benefit the user. Guidance documents alone may be sufficient for experienced users. However, wading through dense guidelines and methodologies can be overwhelming. Well-designed calculation tools that can be tailored make the accounting process more efficient and ultimately more accurate[31].

Flexibility

Ideally, calculation tools should be flexible. The IPCC recommends that the system be "designed so that it can be updated and extended in the future"[19]. Flexibility allows for the tool to be tailored to the entity being measured and for inclusion of the most up-to-date source data, again yielding gains in both efficiency and accuracy.

Uncertainty

The IPCC, GHG Protocol and Climate Leaders stress the importance of including uncertainty estimates in the GHG accounting process. The IPCC offers guidance on assessing uncertainty in

the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*[33], as does Climate Leaders in EPA's *Emissions Inventory Improvement Program on Quality Assurance/Quality Control*[32]. The GHG Protocol provides guidance and an uncertainty calculation tool. Climate Leaders describes two types of uncertainties associated with GHG inventories[25]:

- Scientific – results from a misunderstanding of the science of emissions and sequestration processes
- Estimation – results from incorrect mathematical modeling or inappropriate data input, and parameter uncertainty

Uncertainty assessments promote feedback and quality improvement[25]. Since a quantitative estimate of uncertainty of the final carbon footprint can be extremely difficult to calculate[25,34], a qualitative discussion should be provided at a minimum[34].

These "lessons learned" from the assessment of inventories were integrated into the development of PARCMAN.

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34. GHG Protocol Initiative. A Corporate Accounting and Reporting Standard, Revised Edition. Guidelines. Ch 7, pg 56. http://www.ghgprotocol.org/files/ghg-protocol-revised.pdf Accessed July 2007.

Part B. PARCMAN GUIDELINES

Introduction

The objective of this project was to create a carbon footprint calculation tool and accompanying guidelines to facilitate GHG accounting in national parks. The tool and guidelines, referred to by the acronym PARCMAN (National *Par*ks *C*arbon *Man*agement), resulted from an assessment of multiple prominent GHG accounting protocols. Based on their comprehensiveness, usability, applicability to national parks, and transparency, the Climate Friendly Parks' CLIP tool, not surprisingly, proved to offer the most appropriate protocol on which to base the new tool. However, while CLIP provides the foundation, the WRI/WSBC tools, GHG Protocol guidelines, EPA Climate Leaders and IPCC guidance documents all contribute to the final product. In theory, an inventory compiler could calculate a national park's carbon footprint by using selected elements from each GHG accounting program. However, one system for measurement "yields significant efficiency and accuracy gains[1]". PARCMAN is an attempt to create this one system.

PARCMAN, a Microsoft Excel-based tool, is intended to be a user-friendly, flexible alternative to CLIP. It differs from CLIP in that it includes emissions from livestock, staff commuting and business travel, and excludes forest processes. However, the purpose of conducting a carbon footprint analysis of a national park is primarily to identify opportunities for reductions. Since forests in national parks sequester more carbon than they emit, excluding forests does not detract from this goal. Additionally, the decision to exclude forest sequestration and forestry activities also resulted from the level of difficulty required for accurate GHG modeling of forest processes.

[1] GHG Protocol Initiative. A Corporate Accounting and Reporting Standard. Guidelines. Ch. 6, pg 43. Online. Available at: http://pdf.wri.org/ghg_protocol_2004_chp006.pdf Accessed January 2008.

Since flexibility was determined to be a significant characteristic of a user-friendly inventory, PARCMAN allows for the compiler to update, tailor and improve upon the tool as needed. Additionally, since PARCMAN is intended for use in US national parks, English units are given where possible.

PARCMAN gives the final carbon footprint in both metric tons of carbon dioxide equivalent ($MTCO_2e$), utilized by IPCC, GHG Protocol and Climate Leaders, and metric tons of carbon equivalent (MTCe), used by Climate Friendly Parks. It is useful to be able to compare parks' carbon footprints that were determined using the different tools.

These guidelines are intended for use by a national park's GHG inventory compiler and PARCMAN user. The guidelines outline the steps of the carbon footprint analysis process and provide general guidance for using the PARCMAN tool. See *Appendix A* for screenshots of two PARCMAN worksheets.

B.1. What to Include in the Footprint

The first step in the carbon footprint analysis process is to determine the park's operational boundaries to define the scope of its carbon footprint. The compiler must decide which operations the park is directly responsible for by reviewing the park's organizational and financial authority. Determining park boundaries can be complicated when considering whether or not to include indirect source emissions, such as non-park related groups that make use of park facilities, and emissions throughout the entire value chain. The definitions of direct and indirect emissions are discussed in greater detail in the next section.

Since the main goal of conducting a carbon footprint analysis is to become better informed about park emissions in general and to determine opportunities to reduce these emissions, the inventory compiler should attempt to include as many emissions sources as is feasible. However, it is crucial that all sources are clearly and individually documented and that double counting is avoided. For example, it is recommended that indirect emissions from concessionaires, partners, and contractors are included in the overall analysis to the extent that this is possible, but data from these sources should be entered separately. One-time projects such as the construction of a new facility should also be accounted for separately.

B.2. How to Identify GHG Emissions Sources

Greenhouse gas emissions are categorized as either “direct” or “indirect" emissions. Direct emissions originate from sources owned and operated by the entity being measured at the time of emission[2]. Indirect emissions occur as a result of activities of the entity being measured but originate from sources owned by a second entity[3]. For national parks, direct emissions include those resulting from mobile combustion of fossil fuels such as motor gasoline and diesel, and stationary combustion of propane and number 2 fuel oil, as well as emissions from fertilizer applications and refrigeration. Indirect emissions come from purchased electricity and staff air travel.

PARCMAN calculates emissions from the following sources:

- Mobile combustion
    - Park activities

[2] EPA Climate Leaders EPA. Climate Leaders. Design Principles. Online. Available at: http://www.epa.gov/climateleaders/resources/design-principles.html. Accessed November 2007.

[3] Energy Information Administration. Voluntary Reporting of Greenhouse Gases. 1605(b). General Guidelines. Online. Available at: http://www.eia.doe.gov/oiaf/1605/1605b.html Accessed July 2007.

        - Staff commutes
        - Business travel
        - Visitor travel
    - Stationary combustion
        - Natural gas
        - Distillate fuel
        - Liquefied petroleum gas (LPG)
        - Propane
        - Kerosene
        - Wood
        - Coal
    - Purchased electricity
    - Fertilizer application
        - Synthetic
        - Organic
    - Wastewater treatment
    - Agricultural activities
        - Livestock

B.3. How to Conduct the Inventory

Data Gathering: The most time-consuming part of the carbon footprint analysis process is the GHG inventory compilation. Once the inventory compiler has identified all possible emissions sources, he or she then gathers the necessary activity data on these emissions sources, as stipulated in the PARCMAN tool, for the calendar year being measured. The majority of the data can be obtained from park purchasing receipts and use records such as electricity bills. Since carbon footprint analyses are typically conducted on a calendar year basis, the compiler will need to account for data provided on a fiscal year basis. The compiler may also need to convert data to the appropriate unit for entry into the PARCMAN tool.

Documentation: To maintain the quality of the inventory, the importance of documenting the steps taken and identifying the data sources used cannot be overemphasized. The inventory compiler should keep detailed records of decisions and data conversions made during the inventory compilation process. Record-keeping will help ensure credibility and consistency from year to year and allows for verification.

Accuracy and Uncertainty: The carbon footprint analysis process has inherent uncertainties. Uncertainties are associated with the mathematical models and parameters in the PARCMAN tool and with the data itself. It is recommended that the park establishes a team of people to review the analysis process in its entirety and to check the data conversions and input. Additionally, the park should define and document procedures to maintain and update the GHG inventory. The lead inventory compiler should familiarize himself or herself with GHG inventory literature and periodically review credible sources such as the EPA for calculation and emissions factors updates.

B.4. How to Input the Data

PARCMAN is organized by worksheets in Microsoft Excel: different emissions sources appear on individual worksheets. A sentence in italics at the top of each worksheet's data table describes which data to input. The user enters this data into the green-colored cells. PARCMAN calculates the emissions output immediately, given in the bright yellow cells in the bottom right corner of each worksheet. The user can save the program and return to update the data at any time.

Cells with a red arrow in the corner have an associated comment box. Comments provide additional information such as the source of the value in the cell, definitions, or more detailed instructions. To see the comment, the user moves the cursor over the cell. Cells containing formulas have been protected in order to avoid unintentional changes and to maintain the integrity of the inputted calculations. However, these can be unprotected if alterations to the formulas are deemed necessary by the lead inventory compiler. To unprotect the worksheet, click on *Tools – Protection - Unprotect Worksheet* – enter the password “parcman.”

B.5. How to Interpret the Results

PARCMAN has been formulated to give the overall carbon footprint in tabular and graphical form in the worksheet labeled *Results*. The table gives emissions values in $MTCO_2e$ by source while the pie chart and bar graph show the percentage of emissions by source.

By their very nature, emissions are difficult to track and quantify with a high degree of accuracy. Therefore, the final results should not be interpreted as the exact quantity of the greenhouse gases emitted by the park, but rather as representative of relative quantities of emissions by source. However, the purpose of conducting a carbon footprint analysis is to establish a baseline value and to examine opportunities for emissions reductions. By determining where and in what proportion the emissions are coming from, the park is able to concentrate its reduction efforts.

It can be very difficult to determine a quantitative estimate of uncertainty using statistical methods. Therefore, when reporting the park’s carbon footprint analysis, the inventory compiler

should, at a minimum, discuss the analysis' uncertainty in qualitative terms. This will elucidate opportunities to improve the quality of the inventory in the future.

Part C. PARCMAN METHODOLOGY

C.1. Mobile Sources

i. Mobile - Park Activities

To calculate CO_2 emissions from mobile sources associated with regular park activities:

- The User enters the vehicle miles traveled (VMT) by vehicle type in the green cells
- Default miles per gallons (MPG) values from the CLIP tool are already entered in the PARCMAN tool. The User can obtain a more accurate estimate by un-protecting the worksheet [Tools – Protection – Unprotect – pwd: parcman] and replacing the given values with values from the sources in the comment box.
- Fuel Consumed (gal) = VMT x MPG
- The carbon factor is the amount of carbon in kilograms per gallon of fuel: kg C/gal. Source: EPA. Climate Change. Unit Conversions, Emissions Factors and Other Reference Data. November 2004. Online. Available at: www.epa.gov/appdstar/pdf/brochure.pdf
- Total Carbon = Fuel Consumed (gal) x Carbon Factor (kg C/gal). This gives the total amount of carbon produced by combustion in kilograms.
- CO_2 Emissions = Total Carbon (kg) x Percent Oxidized x Molecular Weight Ratio (weight ratio of CO_2 (44) to C (12))
- $MTCO_2e$ = convert to metric tons and multiply by the global warming potential of CO_2, 1 = (CO_2 / 1000)*1
- MTCe = $MTCO_2e$ x (12/44)

To calculate N_2O emissions from mobile sources:

- N_2O emissions factor (EF), the amount of N_2O in grams per mile of fuel, is given in the tool. Source: EPA. Climate Leaders. Greenhouse Gas Inventory Protocol Core Module Guidance. Direct Emissions from Mobile Combustion Sources. Online. Available at: www.epa.gov/stateply/documents/resources/mobilesource_guidance.pdf
- N_2O emissions (kg) = (EF x VMT)/1000

- $MTCO_2e$ = convert to metric tons and multiply by the GWP of N_2O, 21 = (N_2O/1000)*21
- MTCe = $MTCO_2e$ x (12/44)

To calculate CH_4 emissions from mobile sources:

- CH_4 emissions factor (EF), the amount of CH_4 in grams per mile of fuel, is given in the tool. Source: EPA. Climate Leaders. Greenhouse Gas Inventory Protocol Core Module Guidance. Direct Emissions from Mobile Combustion Sources. Online. Available at: www.epa.gov/stateply/documents/resources/mobilesource_guidance.pdf
- CH_4 emissions (kg) = (EF x VMT)/1000
- $MTCO_2e$ = convert to metric tons and multiply by the GWP of CH_4, 310 = (CH_4/1000) x 310
- MTCe = $MTCO_2e$ x (12/44)

To calculate total emissions from mobile sources from park activities:

- Sum $MTCO_2e$ and MTCe from CO_2, N_2O and CH_4

ii. Mobile – Business Travel

See *Appendix A* for a screenshot of the Business Travel worksheet.

To calculate emissions from Staff Business Travel using Distance Traveled:

- User enters distance traveled in miles, by vehicle type and fuel or trip type in the green cells. See Comment boxes for further explanation.
- CO_2 Emissions (lbs) = Distance Traveled x CO_2 (lbs) per Passenger Mile. Source: Energy Information Administration. Voluntary Reporting of Greenhouse Gases Program (1605(b)). Fuel and Energy Source Codes and Coefficients. Online. Available at: http://www.eia.doe.gov/oiaf/1605/coefficients.html
- CO_2 Emissions (kg) = CO_2 Emissions (lbs) x 0.4536
- $MTCO_2e$ = CO_2 Emissions (kg) / 1000
- MTCe = $MTCO_2e$ x (12/44)

To calculate emissions from Staff Business Travel using Amount of Fuel Used:

- User enters fuel used by fuel type in the green cells.
- CO_2 Emissions (lbs) = Amount of Fuel x CO_2 (lbs) per Unit. Source: Energy Information Administration. Voluntary Reporting of Greenhouse Gases Program (1605(b)). Fuel and Energy Source Codes and Coefficients. Online. Available at: http://www.eia.doe.gov/oiaf/1605/coefficients.html
- CO_2 Emissions (kg) = CO_2 Emissions (lbs) x 0.4536
- $MTCO_2e$ = CO_2 Emissions (kg) / 1000
- MTCe = $MTCO_2e$ x (12/44)

iii. Mobile – Staff Commuting

To calculate emissions from Staff Commuting:

- User enters vehicle miles traveled (VMT) per person per year according to fuel and vehicle type in the green cells.
- Average miles per gallon (MPG) default values given by CLIP tool. User can follow links in the Comment box to find vehicle specific values.
- Fuel Consumed (gal) = VMT x MPG
- Total Carbon (kg) = Fuel Consumed (gal) x Carbon Factor (kg C/gal). Source: EPA. Climate Change. Unit Conversions, Emissions Factors and Other Reference Data. November 2004. Online. Available at: www.epa.gov/appdstar/pdf/brochure.pdf
- CO_2 Emissions (kg) = Total Carbon (kg) x Oxidation Factor (% oxidized) x Molecular Weight Ratio (CO_2/C, 44/12)
- CO_2 Emissions (lbs) = CO_2 Emissions (kg) x 0.002204
- $MTCO_2e$ = CO_2 Emissions (kg)/1000
- MTCe = $MTCO_2e$ x (12/44)

iv. Mobile – Visitor Travel

To calculate emissions from visitor vehicles in the park:

- User enters the average number of visitor vehicles traveling in the park per day

- User enters the average miles traveled per vehicle per day
- Vehicle miles traveled per year = Average number of vehicles per day x Average miles traveled per vehicle per day
- Average miles per gallon (MPG) calculated as follows:
  Average MPG for cars is 22.13, average MPG for trucks is 17.69. Overall average determined by averaging these two values: 22.15/17.69 = 19.92.
- Fuel consumed (gal) = Av. Miles traveled per year / MPG per year
- Total Carbon Content (kg) = Fuel Consumed (gal) x Carbon Factor (kg C/gal). Source: EPA. Climate Change. Unit Conversions, Emissions Factors and Other Reference Data. November 2004. Online. Available at: www.epa.gov/appdstar/pdf/brochure.pdf
- CO2 Emissions (kg) Total Carbon (kg) x Oxidation Factor (% oxidized) x Molecular Weight Ratio (CO_2/C, 44/12)
  - CO_2 Emissions (lbs) = CO_2 Emissions (kg) x 0.002204
  - $MTCO_2e$ = CO_2 Emissions (kg)/1000
  - MTCe = $MTCO_2e$ x (12/44)

C.2. Stationary Sources

See *Appendix A* for a screenshot of the Stationary Combustion worksheet.

To calculate emissions from Stationary Combustion:

- User inputs the amount of fuel used by fuel type in the green cells
- CO_2 emissions (lbs) = Amount Used x Emissions Coefficient (lbs of CO_2 per Unit). Source: Energy Information Administration. Voluntary Reporting of Greenhouse Gases Program (1605(b)). Fuel and Energy Source Codes and Coefficients. Online. Available at: http://www.eia.doe.gov/oiaf/1605/coefficients.html
- CO_2 Emissions (kg) = CO_2 Emissions (lbs) x 0.4536
- $MTCO_2e$ = CO_2 Emissions (kg) /1000
- MTCe = $MTCO_2e$ x (12/44)

C.3. Purchased Electricity

To calculate emissions from Purchased Electricity:

- User inputs the amount of electricity used per year in kWh
- User inputs Emissions Factor directly from electricity provider or from eGRID: EPA, Clean Energy. The Emissions and Generation Resource Integrated Database (eGRID). Online. Available at: www.epa.gov/cleanenergy/egrid/index.htm
- CO_2 emissions (lbs) = Electricity used (kWh) x Emissions factor (lbs CO_2/kWh)
- CO_2 Emissions (kg) = CO_2 Emissions (lbs) x 0.4536
- $MTCO_2e$ = CO_2 Emissions (kg) /1000
- MTCe = $MTCO_2e$ x (12/44)

C.4. Fertilizer

To calculate emissions from Fertilizer use, PARCMAN takes N lost to fertilization and leading into account based on the following:

- User inputs the amount of synthetic or organic fertilizer used in pounds per year in the green cells
- User inputs the average percentage of nitrogen in the fertilizer as a fraction of 1. E.g. If the fertilizer is 20% N, enter 0.20 in the cell
- Total Nitrogen = Amount of fertilizer used (lbs) x Percent N
- Amount lost to volatilization (lbs) = Total N x Percent Volatilized. Source: IPCC 2006 Guidelines, Chapter 11, Table 11.3. Online. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf
- Direct emissions (lbs) = Total N x (1-Percent volatilized) x Emissions Factor for Applied N. Source: IPCC 2006 Guidelines, Chapter 11, Table 11.1
- Indirect emissions from volatilization = Amount volatilized (lbs) x Volatilization emissions factor. Source: IPCC 2006 Guidelines, Chapter 11, Table 11.3. Online. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf
- Amount lost to leaching and runoff (lbs) = Total N x (1-Percent volatilized) x Percent leached

- Indirect emissions from leaching and runoff (lbs) = Amount leached (lbs) x Leached emissions factor. Source: IPCC 2006 Guidelines, Chapter 11, Table 11.3. Online. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf
- Total N_2O emissions = Direct emissions + Indirect volatilized + Indirect leached
- $MTCO_2e$ = Total N_2O emissions (kg) /1000) x 310, the GWP of N_2O
- MTCe = $MTCO_2e$ x (12/44)

C.5. Wastewater Treatment

To calculate emissions from Wastewater Treatment:

- User inputs the number of gallons of wastewater sent to the treatment plant and the percent treated aerobically, as fraction of 1, in the green cells
- CH_4 emissions (kg) = (Wastewater (gal) x % Treated anaerobically x BOD_5 factor (mg/gal) x CH_4 factor/BOD_5) x 0.000001. [BOD_5 (biological oxygen demand) measures oxygen uptake by microorganisms over a 5 day period] Source: directly from Climate Friendly Parks Program CLIP tool
- N_2O Emissions (kg) = (Wastewater (gal) x Protein (kg/gal) x Protein N content x Conversion factors). Given in tool. Source: NPS. Climate Friendly Parks Program. CLIP tool. Emissions Inventory Module. Online. Available at: http://www.nps.gov/climatefriendlyparks/CLIPtool/emissioninventory.html
- $MTCO_2e$ from CH_4 = (CH_4 emissions x 0.001 x GWP21)
- $MTCO_2e$ from N_2O = (N_2O emissions x 0.001 x GWP310)
- Total $MTCO_2e$ = $MTCO_2e$ from CH_4 + $MTCO_2e$ from N_2O
- MTCe = $MTCO_2e$ x (12/44)

C.6. Refrigerants

To calculate emissions from Refrigerants:

- User inputs the number of refrigerator or air conditioning units by type and refrigerant in the green cells

- Total Emissions (kg) = Number of units x Charge size (kg) x (Leak percent/100).
  Source: taken directly from the Climate Friendly Parks Program CLIP tool
- $MTCO_2e$ = Number of units x Charge size (kg) x (Leak percent/100)
- MTCOe = $MTCO_2e$ x (12/44)

C.7. Agricultural Activities - Livestock

To calculate emissions from Livestock:

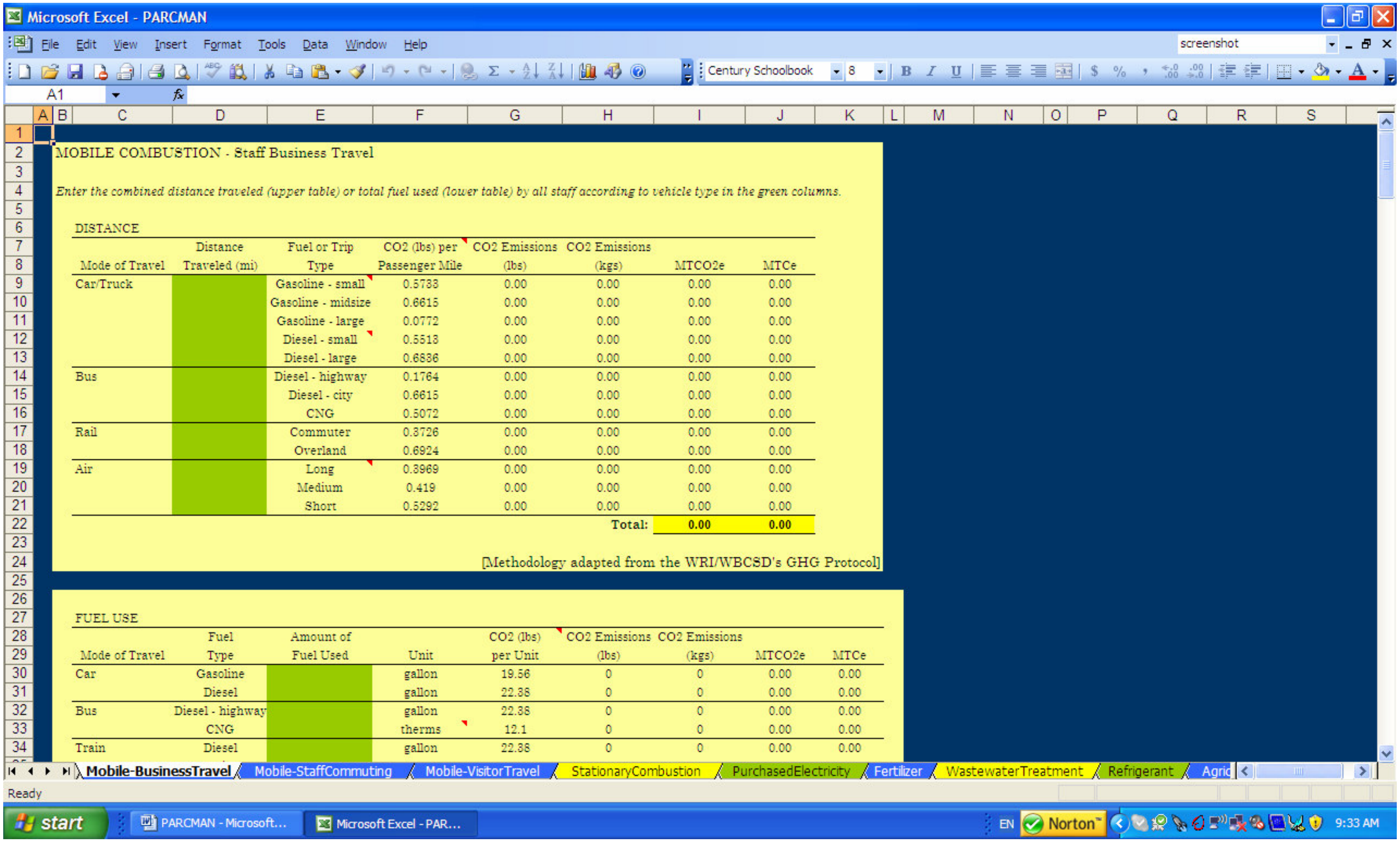
- User inputs the average population of animals per year
- CH_4 Emissions (kg) = Animal population x EF.
  For cattle, User inputs EF according to type from the table. Source: Energy Information Administration. Voluntary Reporting of Greenhouse Gases, 1605(b) Program, Technical Guidelines, Table 1.4.H, pg.185 March 2006.
- $MTCO_2e$ = (CH_4 emissions / 1000) x GWP21
- MTCe = $MTCO_2e$ x (12/44)

C.8. Results

The Results worksheet automatically provides a summary of the data in table and graphic form by Emissions Source category.

Appendix A. PARCMAN Tool Example Worksheets

1. Mobile – Business Travel Worksheet



MOBILE COMBUSTION - Staff Business Travel

Enter the combined distance traveled (upper table) or total fuel used (lower table) by all staff according to vehicle type in the green columns.

DISTANCE

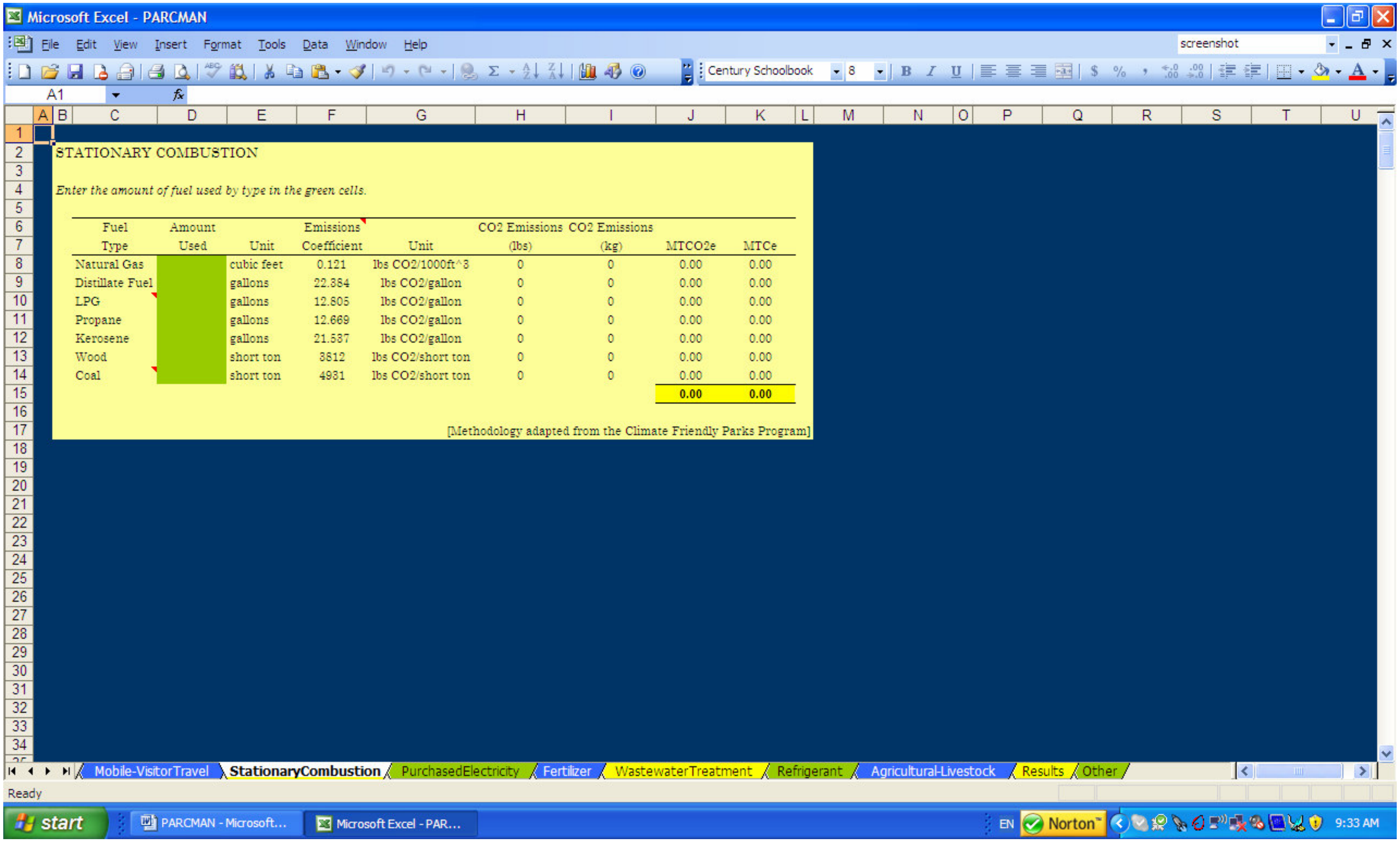
Mode of Travel	Distance Traveled (mi)	Fuel or Trip Type	CO2 (lbs) per Passenger Mile	CO2 Emissions (lbs)	CO2 Emissions (kgs)	MTCO2e	MTCe
Car/Truck		Gasoline - small	0.5733	0.00	0.00	0.00	0.00
		Gasoline - midsize	0.6615	0.00	0.00	0.00	0.00
		Gasoline - large	0.0772	0.00	0.00	0.00	0.00
		Diesel - small	0.5513	0.00	0.00	0.00	0.00
		Diesel - large	0.6836	0.00	0.00	0.00	0.00
Bus		Diesel - highway	0.1764	0.00	0.00	0.00	0.00
		Diesel - city	0.6615	0.00	0.00	0.00	0.00
		CNG	0.5072	0.00	0.00	0.00	0.00
Rail		Commuter	0.3726	0.00	0.00	0.00	0.00
		Overland	0.6924	0.00	0.00	0.00	0.00
Air		Long	0.3969	0.00	0.00	0.00	0.00
		Medium	0.419	0.00	0.00	0.00	0.00
		Short	0.5292	0.00	0.00	0.00	0.00
					Total:	**0.00**	**0.00**

[Methodology adapted from the WRI/WBCSD's GHG Protocol]

FUEL USE

Mode of Travel	Fuel Type	Amount of Fuel Used	Unit	CO2 (lbs) per Unit	CO2 Emissions (lbs)	CO2 Emissions (kgs)	MTCO2e	MTCe
Car	Gasoline		gallon	19.56	0	0	0.00	0.00
	Diesel		gallon	22.38	0	0	0.00	0.00
Bus	Diesel - highway		gallon	22.38	0	0	0.00	0.00
	CNG		therms	12.1	0	0	0.00	0.00
Train	Diesel		gallon	22.38	0	0	0.00	0.00

2. Stationary Combustion Worksheet



STATIONARY COMBUSTION

Enter the amount of fuel used by type in the green cells.

Fuel Type	Amount Used	Unit	Emissions Coefficient	Unit	CO2 Emissions (lbs)	CO2 Emissions (kg)	MTCO2e	MTCe
Natural Gas		cubic feet	0.121	lbs CO2/1000ft^3	0	0	0.00	0.00
Distillate Fuel		gallons	22.384	lbs CO2/gallon	0	0	0.00	0.00
LPG		gallons	12.805	lbs CO2/gallon	0	0	0.00	0.00
Propane		gallons	12.669	lbs CO2/gallon	0	0	0.00	0.00
Kerosene		gallons	21.537	lbs CO2/gallon	0	0	0.00	0.00
Wood		short ton	3812	lbs CO2/short ton	0	0	0.00	0.00
Coal		short ton	4931	lbs CO2/short ton	0	0	0.00	0.00
							0.00	**0.00**

[Methodology adapted from the Climate Friendly Parks Program]