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Top-Down and Bottom-Up Approaches to Greenhouse Gas Inventory Methods

A Comparison Between National- and Forest-Scale Reporting Methods

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Abstract

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Federal agencies are mandated to measure, manage, and reduce greenhouse gas (GHG) emissions. The General Services Administration (GSA) Carbon Footprint Tool (CFT) is an online tool built to utilize measured GHG inventories to help Forest Service units streamline reporting and make informed decisions about operational efficiency. In fiscal year 2013, the Forest Service Sustainable Operations GHG Tracking Team completed GHG inventories of three Forest Service units to compare top-down (national) and bottom-up (local) inventory reporting approaches.

In this report, the Track to Zero Team (formerly the GHG Tracking Team) and Sustainability Science Team summarize the top-down and bottom-up approaches to GHG inventories collected and data input into the GSA CFT for the three pilot units: the Northern Research Station Institute for Applied Ecosystem Studies, (Rhinelander, Wisconsin, location), the Stevensville Ranger District (Bitterroot National Forest, Stevensville, Montana), and the Tongass National Forest (Alaska).

Because both top-down and bottom-up reporting methods and the scale of the three pilot units differ significantly enough to preclude quantitative analysis, this report will use qualitative analysis to compare (1) sources and methods of obtaining information, (2) ease of data access to GHG inventories, (3) level of accuracy of data within the inventories, (4) confidence in data accuracy, and (5) level of data aggregation. By conducting these pilots and comparing the top-down results from the national GHG inventory with the bottom-up or local results, we will identify methods to improve the accuracy of local GHG inventorying and tracking, strengthen the connection between local and national GHG inventories, and promote information sharing.

Keywords: Carbon footprint, top-down analysis, bottom-up analysis, sustainable operations, greenhouse gas inventory, CO_2 emissions.

Contents

Introduction

Greenhouse gases (GHGs) are produced by a number of common global activities, such as heating and cooling, use of fossil-fuel-powered vehicles, business travel and employee commuting, and others (fig. 1). Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, requires all federal agencies to set goals for the reduction of GHG emissions. As specified in EO 13514, all goals should be met by fiscal year (FY) 2020. Each year annual progress must be measured, and reported in accordance with of annual progress toward GHG reduction goals attainable by FY 2020. Estimated U.S. Department of Agriculture (USDA) Forest Service emissions are close to 360,000 metric tons of carbon dioxide (CO_2) per year when considering heat, power, and motor vehicle use (Trapani, n.d.) (table 1), and these emissions decreased between 2010 and 2012 (fig. 2) (Parker and Polansky 2013).

The linkage between operations at the USDA Forest Service national level and those at the forest level is important. This report explores the potential for the Tongass National Forest, encompassing close to 17 million ac in southeast Alaska, to serve as an example in GHG inventories, as well as methodologies for assessing and reducing GHGs. The objective of this research is to qualitatively evaluate GHG inventories using both a top-down (national) and a bottom-up (local) approach.

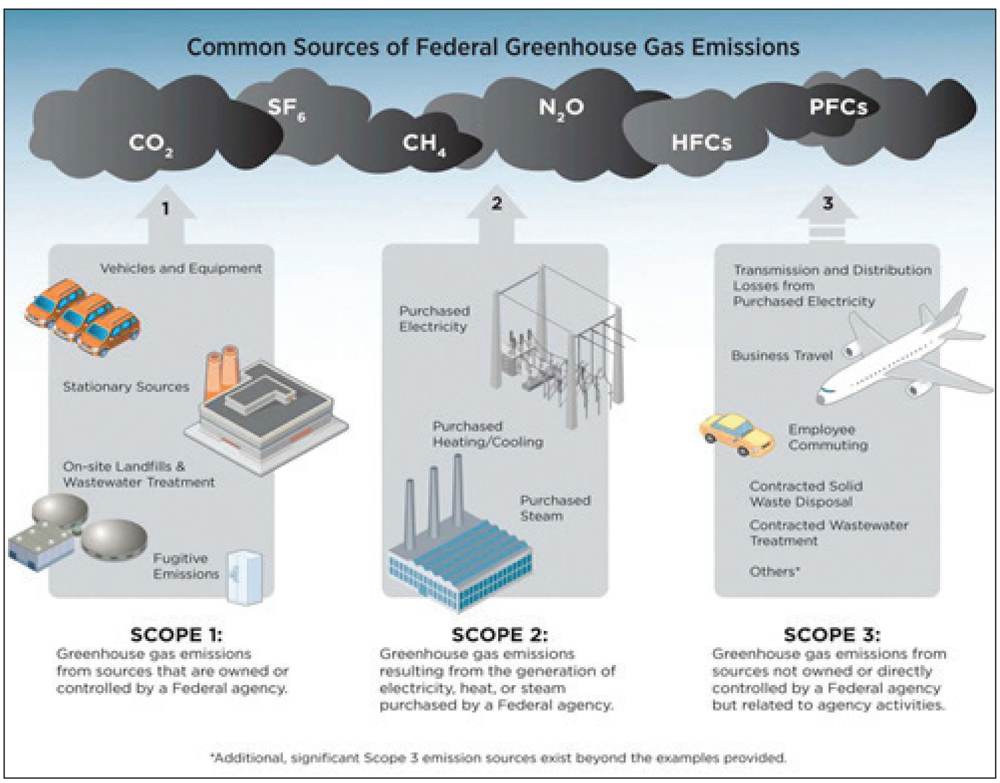

Figure 1—Common sources of federal greenhouse gas emissions. Source: “Sustainability Across Boundaries: The Greater Yellowstone Area Climate Action Plan,” June 2011.

Table 1—Total estimated U.S. Department of Agriculture Forest Service carbon footprint from heat, power, and motor vehicles

Source	Amount	Fiscal year of reporting
	Metric tons carbon dioxide per year)	
Electricity	202,000	2003
Natural gas	22,000	2003
Propane	36,000	2003
Fuel oil	14,000	2003
Coal	2,500	2003
Motor vehicles	86,500	2005 and 2006 (average of)
Total	360,000	

Source: Trapani, n.d.

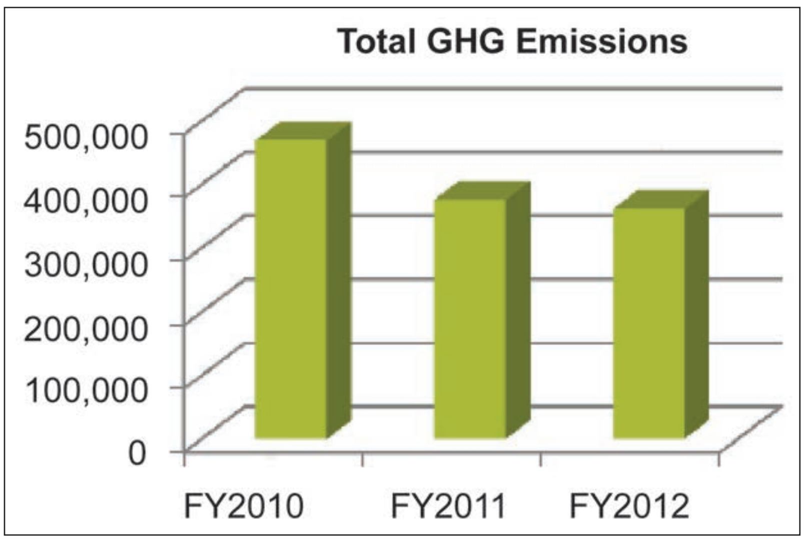

Figure 2—Total USDA Forest Service greenhouse gas emissions by fiscal year (metric tons carbon dioxide equivalent). Source: Parker and Polansky 2013.

What Is a Top-Down Approach?

A top-down approach to GHG inventories is one that originates from "the top," and is often directed based on decisionmaking from "the top." Within the USDA Forest Service, top-down data are aggregated and analyzed, entered, and calculated at the headquarters level (Washington office). The Forest Service agencywide emissions inventory is then reported to the USDA, where it is aggregated with other USDA agencies and reported to the White House's Council on Environmental Quality. Under the top-down approach, there is little interaction between managers at the headquarter level and those in the field. Although this system may result in efficiency gains, it can also lead to errors in which aggregated data do not accurately reflect local conditions.

What Is a Bottom-Up Approach?

A bottom-up approach describes data collected and processed at the local level, often the same as an individual Forest Service facility. For this report, the bottom-up approach accounts only for emissions resulting from business operations and employee activities at the "pilot" site location. Greenhouse gas emissions accounting at a given location does not extend to the activities of vendors, visitors, or other partners. Data-gathering efforts for the GHG inventories are consistently a challenge because data requirements do not always reflect the data historically tracked for a given location. This illustrates one of the disadvantages of bottom-up GHG accounting: Data collection and accounting procedures can differ from site to site, from person to person, and over time. Thus, managers using bottom-up results to assess GHG emissions must assess the overall quality of data whether evaluating short timeframes or longer term trends.

The smallest local site (such as a district office or laboratory) using the bottom-up approach may collect emissions data at a finer resolution than the national level. This might lead one to believe that the bottom-up approach would be more accurate. However, top-down reporting accounts for all emissions-producing activities throughout the entire agency and is aggregated from all Forest Service sites, even if the local site had conducted a full GHG inventory.

Top-Down Versus Bottom-Up Approach

Top-down and bottom-up modelling approaches can sometimes lead to different results, given that they were "conceived and designed through different disciplines and for different purposes" (Wilson and Swisher 1993). Whether top-down or bottom-up techniques are being used, a few questions often remain central to the analysis: What quantity of GHG emissions are being emitted? How much energy

By quantifying environmental footprints, units can better prioritize efforts to become more efficient, resulting in actions that can save money and decrease GHG emissions.

can be saved, and at what cost? (Hoogwijk et al., n.d.). In either approach, a GHG inventory can help an organization identify its "environmental footprint in this case, a measure of the demands of the Forest Service on the natural system in terms of consumption of renewable and nonrenewable resources" (Parker 2008).

By quantifying environmental footprints, units can better prioritize efforts to become more efficient, resulting in actions that can save money and decrease GHG emissions. However, conducting meaningful GHG inventories can take several dedicated staff (i.e., "project champions") to complete, which must be balanced against other uses of staff time. A national, top-down approach uses less on-the-ground resources for reporting, so may be less costly to perform. Conversely, the bottom-up approach requires more local resources and, hence, may be more costly to perform. The bottom-up approach may bring to light certain strategies or incentives to reduce GHG emissions by having control of information, including input data, charts, and reports that can be immediately conveyed to local managers.

Ultimately, if standardized measurements are used, improved bottom-up reporting will diffuse meaningful information to national managers. This will result in a more accurate report of GHG emissions, and the mainstream use of GHG inventories and tools will help point to areas where agency environmental footprints can most easily be reduced.

Literature Review

Much research has been completed on both top-down and bottom-up analyses. The scale of these studies is broad and can produce meaningful results on scales as small as a university faculty (Aroonsrimorakot et al. 2013). Other studies have been conducted on a given ecosystem (Carpenter et al. 2012) or a national forest scale (Parker 2008). Footprinting studies are often conducted at the national scale, for example Denmark (Jacobsen 1998), Nepal (Khadka and Vacik 2012), Ireland (Kenny and Gray 2009), and the United States (Lutsey and Sperling 2008, Tuladhar et al. 2009). This scale can be expanded to include multiple nations, such as the European Union (Radu et al. 2013). Similar methods can be used to evaluate GHGs even at the global scale (Creutzig et al. 2012, Hoogwijk et al. 2010, van Vuuren et al. 2009).

In some cases, details from a bottom-up approach for a given energy system can be combined with a top-down analysis (often done for an overall economy) (Bohringer and Rutherford 2008). This approach is often referred to as a hybrid model and can include a "general equilibrium" approach in which both elements are included (Frei et al. 2003). Hybrid models have been used successfully to evaluate technology choices, for example industrial steam generation in Canada (Rivers and Jaccard 2005).

Greenhouse Gas Inventory Background

Forest Service involvement—

The USDA Forest Service is a large land management agency within the federal government, managing approximately 193 million ac of public land. It is also the largest forestry research organization in the world, providing technical assistance to state, private, and international forestry agencies. Forest scientists have characterized healthy forests as net “carbon sinks,” and U.S. forests play a significant role—when considering all forest growth and removals—by absorbing up to 20 percent of U.S. carbon emissions annually (USDA FS 2014). On a much smaller scale, Forest Service operations are a net contributor to GHG emissions, potentially equivalent to the annual electricity usage of 45,000 U.S. households (Trapani, n.d.).

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In 2007, the Forest Service was one of the first federal agencies to join the Environmental Protection Agency (EPA) Climate Leaders Program. Members of Climate Leaders commit to completing an inventory of their GHG emissions, setting reduction goals, and reporting annually to the EPA (Parker 2008). Since FY 2010, the Forest Service has reported its national-level GHG inventories using a top-down approach. The Forest Service’s GHG emissions level has decreased from 470,000 $MTCO_2e$ (metric tons of carbon dioxide equivalent) in FY 2010 to 360,000 $MTCO_2e$ in FY 2012 (fig. 2) (Parker and Polansky 2013).

Emission units—

The conventionally accepted approach to reporting GHG emissions is to convert non-CO_2 GHGs, such as methane and nitrous oxide, to a CO_2 equivalent. This approach allows all GHG emissions to be compared on an “apples-to-apples” basis. To convert emissions of non-CO_2 gases into their CO_2 equivalent, the emissions are multiplied by the gas’s Global Warming Potential (GWP) factor. The GWP is a relative measure of how much heat a GHG traps in the atmosphere relative to the amount of heat trapped by a similar mass of CO_2. Emission results are shown in $MTCO_2e$.

The Pilot Units

Tongass National Forest—

The Tongass National Forest is the largest forest in the National Forest System, with over 17 million ac of land area. It contains the world’s largest temperate rain forest and hundreds of miles of shoreline, islands, and wetlands. The headquarters of the Tongass National Forest are in Ketchikan, Alaska, with other supervisory offices in Sitka and Petersburg, Alaska. The forest includes 10 ranger districts (fig. 3) and

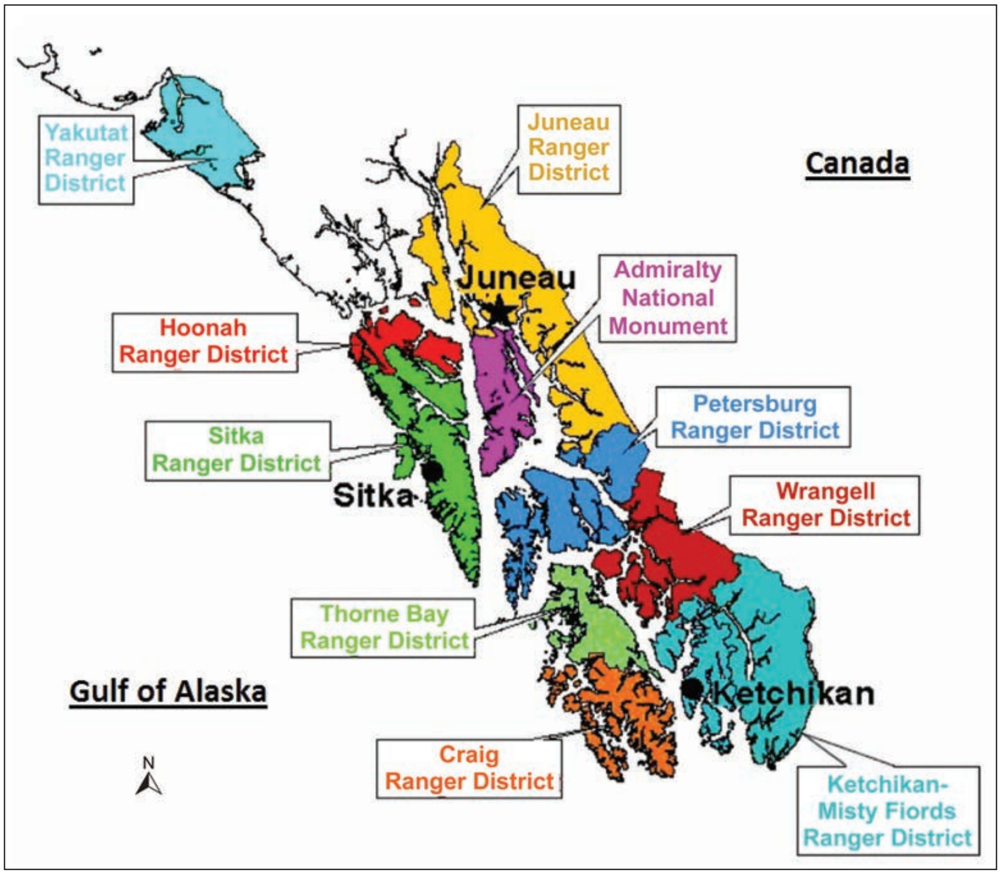

Figure 3—Southeast Alaska, showing ranger districts on the Tongass National Forest.

Not only is the Tongass spread across nearly 700 mi, but many locations are accessible only by boat or plane, resulting in potentially greater GHG emissions than on forests in the continental United States that have well-defined road systems.

is a good example of multiple, complex facilities spread out over a large land area. During FY 2008, Forest Service motor vehicle use on the Tongass National Forest accounted for 655,895 mi driven, requiring more than 47,000 gal of fuel (table 2).

Not only is the Tongass spread across nearly 700 mi, but many locations are accessible only by boat or plane, resulting in potentially greater GHG emissions than on forests in the continental United States that have well-defined road systems. And, given the remoteness of southeast Alaska, most goods are shipped in rather than being produced locally, which also has implications for the region's GHG emissions.

Table 2—Tongass National Forest miles driven and fuel use during fiscal year 2008 (gasoline)

Ranger district	Heavy-duty trucks	Light-duty trucks	Passenger cars	Miles driven	Gallons	Average miles per gallon
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Craig	5	9		83,411	5,513	15.1
Hoonah	6	2		19,353	1,402	13.8
Juneau	10	9	3	79,086	5,520	14.3
Ketchikan	21	9	11	90,431	6,194	14.6
Petersburg	21	9	11	90,431	6,194	14.6
Sitka	6	4		14,981	1,066	14.1
Thorne Bay	28	9		217,664	17,407	12.5
Wrangell	11	5		46,035	3,259	14.1
Yakatat	7	1		22,810	1,614	14.1
Total	115	59	4	655,895	47,032	13.9

Source: Parker 2008.

The Tongass National Forest has been a leader in GHG inventories for several years. Following the Climate Leaders Program's established protocols, the Tongass National Forest conducted its first bottom-up GHG inventory in FY 2007. Additional GHG inventories have been conducted annually since then (except for FY 2009).

Stevensville Ranger District—

The 1.6-million-ac Bitterroot National Forest, in west-central Montana and east-central Idaho, is part of the Northern Rocky Mountains. The district encompasses about 250,000 ac of public land, including about 100,000 ac within the scenic and majestic Selway-Bitterroot Wilderness Area. About 2,600 mi of Forest Service roads are open to motorized vehicles on the Bitterroot National Forest. The Stevensville Ranger District Office is located in the historic town of Stevensville, Montana.

There is no public transportation in the Bitterroot Valley, so employees commute to work an average of 17 mi daily. Some of the field-going employees are "zoned," working across more than one ranger district. Because they may travel across the entire forest as part of their work duties, employees may require large fleets of motorized vehicles. Stevensville Ranger District inventory sites included a residential building, fire warehouse, office and old warehouse, hazardous material building, Charles Waters Host and Handicap Site, Larry Creek Campground, and the Kootenai Creek Trailhead. The Stevensville Ranger District had already been collecting utility data but was new to reporting and calculating GHG emissions.

Northern Research Station—

The Northern Research Station (NRS) laboratory Institute for Applied Ecosystem Studies, located in Rhinelander, Wisconsin, represents the smallest physical area of the three pilot units. This NRS facility reported energy data for one building covering about 38,000 ft^2, and three fleet vehicles. The institute's main goal in participating with the GHG inventory was to have a clear sense of energy use and costs both before and after a planned changeover from old, inefficient boilers to new, more efficient condensing boilers in its main building. The boiler replacement was completed in mid-2013, during the time that energy data were being regularly inventoried.

The pilot inventory and local weather records have proved that the institute used fewer British thermal units this winter (winter of 2013 to 2014) versus the same period last winter, even though this was a much colder winter overall. The cost of heating the building has increased owing to higher fuel costs this year. If the boilers had not been replaced in summer 2013, heating costs would have likely been higher owing to higher fuel prices coupled with the use of less efficient equipment. Like the Stevensville Ranger District, the Rhinelander NRS facility had already been collecting utility data but was new to reporting and calculating GHG emissions.

Research Objectives and Scope

This report compares the top-down and bottom-up approaches to GHG data collection and reporting. By identifying gaps and barriers, and by bringing them to light, we expect to improve the accuracy of local GHG inventorying and tracking, find ways to streamline the process at the unit level, and present options for future implementation of GHG inventory data collection.

We hope this publication will generate discussions between the Forest Service and practitioners who have been engaged in grassroots GHG inventories and are willing to offer their expertise to improve future reporting efforts. We also hope that unit managers will recognize the "new normal" condition of knowing their unit's GHG emissions sources, and will seize opportunities to reduce GHG emissions. Local green team leaders, energy managers, unit climate change and sustainable operation coordinators, volunteers, and unit staff will play a crucial role in continuing local GHG data collection and input and open discussions.

This report does not attempt to compare GHG emissions results quantitatively among the national and pilot units; however, it is hoped that it will shed light on where the national GHG emission numbers are aligned (as well as where they are not). Some of the national GHG inventory numbers are estimated based on the number of full-time equivalents employed by the Forest Service and not on measured emissions. Also, there are different levels of completeness for some emissions categories because of issues with data availability. The same is true with the pilot units.

The comparisons conducted in this research will highlight the different approaches for characterizing GHG emissions and are expected to help local units collect, enter, and display their GHG emissions data, while learning ways to reduce them. A comparison of unit data in a quantitative manner is not made on account of inherent differences in the geographic size of the units, the number of facilities, and the number of employees at each location.

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Methods

The methods we used to compare bottom-up and top-down approaches included soliciting experts in GHG emissions methods as well as interviewing Forest Service staff members. To accomplish this, we contacted agency staff involved in the GHG Tracking Team and program managers at the national level to obtain first-hand information. We relied heavily on experts outside of the Forest Service, including feedback from partners at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).

One of the first steps in conducting a GHG inventory is determining which tool to use. The Forest Service and NREL evaluated three tools and selected the General Services Administration (GSA) Carbon Footprint Tool (CFT) as being the most appropriate. Establishing data collection processes simplifies subsequent GHG data collection and reporting. A data reporting structure was then established within the GSA CFT, so all pilot units could be considered on the same basis. The initial focus for the pilot units was to get raw data into the GSA CFT. As part of this program, all the technical calculations required for GHG reporting were done automatically once the data were entered. It was not necessary for support staff at the pilot locations to be energy experts or engineers, just conscientious about reporting and recording data accurately.

The pilot units differed significantly in geographic location, site size, number of employees, seasonal staff and housing, number and age of buildings or facilities, miles of roads, and management priorities and activities. Although variability of location and size exists among the different units, the process these units followed to input GHG inventory data into the GSA CFT was essentially the same.

Top-Down Approach

At the national level, the GHG inventory tracking team used the Microsoft Excel® workbook developed by the U.S. Department of Energy's Federal Energy Management Program (FEMP) (FEMP 2011). This workbook is used by all federal agencies to conduct their GHG emissions inventories annually. The FEMP tool uses internationally accepted formulas and equations that aggregate the populated data fields to estimate GHG emissions in multiple categories and scopes. Thus, there was a certain degree of automation to this approach.

The top-down example used for comparison is the national-level FY 2011 report obtained from the Washington office Sustainable Operations group. Here, emissions are broken down into 11 categories, with "mobile emissions" and "purchased electricity" accounting for more than 75 percent of the total (fig. 4). When comparing a national data collection effort to a local or site-specific data collection effort, some discrepancies are expected. This report identifies these discrepancies, as well as areas where the two methodologies are most appropriate.

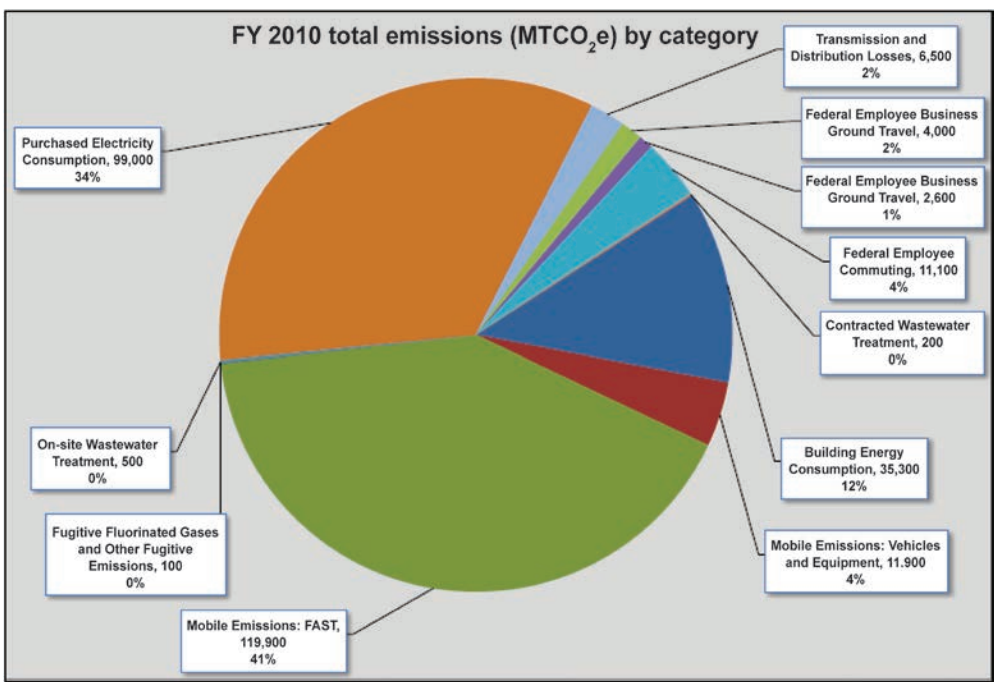

Figure 4—U.S. Department of Agriculture Forest Service total emissions during fiscal year 2010, by category. $MTCO_2e$ = metric tons of carbon dioxide equivalent. Source: USDA FS 2011.

National Data Sources Used

The following data sources and coding protocols from the national top-down approach are summarized:

National Finance Center (NFC)—
This center serves all of USDA in managing administrative, financial, personnel, security, and workforce data (https://www.nfc.usda.gov/).

GSA FAST—
General Services Administration Federal Automotive Statistical Tool (FAST) is used by all federal agencies to report their on-highway vehicle fuel consumption. Data are analyzed and reported by the Forest Service national fleet manager (http://drivethru.fas.gsa.gov/drivethru/drivethru/).

GSA TravelTrax®—
TravelTrax(sm) is used by all federal agencies to report air and business travel information. Data are automatically uploaded from each agency's Travel Management Information System (https://gsa.traveltrax.com).

FAMWeb—
The Fire and Aviation Management Web applications (FAMWeb 2013) site brings together a variety of applications, tools, and services related to interagency fire and aviation management managed by the National Wildfire Coordinating Group and participating agencies. The website provides detailed information, data access, and application entry points for system users, interagency partners, providers, and the public.

Budget Object Classification Codes—
Budget Object Classification Codes are used by USDA agencies and departments serviced by the office of the Chief Financial Officer. These codes are used when obligations are first incurred to record financial transactions according to the nature of services provided or received (https://cod.nfc.usda.gov/documents/docs/boc.pdf).

Bottom-Up Approach

The online GSA CFT was used to report the forest-level (bottom-up) data. This includes data input for stationary combustion (heating oil, propane, natural gas), mobile combustion (vehicle, aircraft, and watercraft fuel use), purchased electricity (kilowatt hours), solid waste disposal, employee commuting, and business travel data. These categories were used by the GSA CFT to calculate the GHG emissions from the facilities and activities of the three pilot units.

Local Data Sources Used

For the Tongass National Forest, some of the data was available online from scanned invoices that were recorded and paid at NFC. The data were given a higher confidence rating owing to their presumed accuracy. Local payment data had to be collected by reviewing the paper files and contacting utility providers in all of the Tongass National Forest districts. This resulted in the data being given a lower confidence rating. These data were then entered into an Excel spreadsheet to make them readily accessible to the engineers responsible for energy management and in a format compatible with the GSA CFT. For the other two pilot locations, the data were collected locally.

All three pilots used a custom Employee/Business Commuter Survey rather than the national- or GSA-supplied one for more relevant results in the bottom-up approach. The custom survey was developed to align with GSA input fields to elicit more accurate results. The Stevensville Ranger District pilot unit was new to the GHG inventory process. Because they had no experience with reporting GHG emissions, they were provided the template spreadsheet used on the Tongass National Forest, and they entered their data into that spreadsheet. The NRS laboratory in Rhinelander used their own spreadsheet design. Although local data collecting is a multistep process that can involve numerous people and introduce opportunities for error, it also has the ability to capture local operating conditions very well when properly conducted.

Results

We found that having complete and accurate data available is essential to the GHG reporting process. A Utility Bill Cleanup Project is the recommended first step, and units that have completed this phase are usually well on their way to having accurate data available. The goal of the utility bill clean-up is to:

> …provide the tools necessary to understand the cost and consumption associated with a unit’s energy use, water use, and solid waste disposal and to identify places where efficiencies in billing and consumption can be made. (USDA 2011).

Some units have previously been tracking utility usage on their own, in which case the Utility Bill Cleanup Project may not be necessary. The GSA CFT will accept monthly data in most categories, but annual data can also be used. Smaller units should enter their data manually site by site while larger, more complex units can use batch uploads to enter multiple sites. Thus, a finding of this research is that bottom-up procedures can vary, depending on the size of the local unit, level of support available, and other factors.

The results of our qualitative analysis between pilot locations are summarized in tables 3 through 7. Each table addresses one aspect of data completeness and integrity. We discuss the following data quality characteristics among the three pilot areas:

- Sources or methods in which the GHG data were obtained
- Level of aggregation of data within the inventories
- Ease of access to GHG inventories, and
- Confidence in data accuracy of each category

In tables 3 through 7, an item is not applicable (N/A) if the pilot unit has no operative category that would contribute to GHG emissions (e.g., aviation or watercraft), and an item is “Not reported” if a unit may have an operative category that would contribute to GHG emissions, but for whatever reason the pilot did not provide data. An inherent limitation of these results is that not all scopes and categories of emissions were reported by each location.

Analysis Area 1: Data Source

Sources of data between the top-down and bottom-up approach are compared, with differences shown between categories (table 3). Most of the national-level data came from the Washington office. The primary sources are the Washington office Engineering “data call”—an annual call to forest energy managers requesting information on a subset of emissions categories not captured in the Forest Service systems of record (e.g., renewable energy generation and refrigerant use, among other categories). Last year, the data call was issued by the Forest Service Sustainable Operations group, in close cooperation with Forest Service engineers.

A second source of information is the “system of record”—corporate databases that track data connected with Forest Service hard targets. These databases are used to capture statistics that represent critical Forest Service goals as defined in the agency’s Program and Budget Advice. For example, fleet managers reported fuel consumption for both the Tongass National Forest and Stevensville Ranger District. Only the Tongass National Forest reported both aviation and watercraft data, and the Stevensville Ranger District alone reported all-terrain-vehicle and snowmobile fuel consumption. In both pilot units, fuel consumption in these vehicles was estimated through hands-on, labor-intensive data conversion methods that may not

Table 3—Sources of data used for greenhouse gas emissions analyses

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 1: Goal subject Buildings energy	Budget Object Codes	NFC/ECM database plus utility company records	Tracked internally	ACE spreadsheet prepared for forest fleet manager
Scope 1: FAST Mobile (vehicle fleet) energy	GSA FAST	Data sheets from forest fleet manager	Not reported	Data sheets from forest fleet manager
Scope 1: Aviation	FAMWeb	Calculated from dispatch flight records	N/A	N/A
Scope 1: Watercraft	Included in vehicles and equipment (below)	Engine hours—dispatch records and Budget and Finance purchases	N/A	N/A
Scope 1: Vehicles and equipment energy	Estimate from national fleet manager	Not reported	Not reported	All terrain vehicle and snowmobile estimated
Scope 1: Mixed refrigerants and fugitive F-gases	WO engineering data call	N/A	N/A	N/A
Scope 1: Agency-operated wastewater treatment facilities	WO engineering data call	N/A	N/A	N/A
Scope 1: Fugitive landfill gases	WO engineering data call	N/A	N/A	N/A
Scope 2: Electricity	NFC	NFC/ECM database plus utility company records	Tracked internally	ACE
Scope 2: Steam and hot water	WO engineering data call	N/A	N/A	N/A
Scope 2: Chilled water	WO engineering data call	N/A	N/A	N/A
Scope 3: Transmission and distribution losses	Automatically calculated	Automatically calculated by GSA Tool	Automatically calculated by GSA tool	Automatically calculated by GSA tool
Scope 3: Business travel (air and ground)	GSA Travel Trax	Employee survey (Survey Monkey)	Employee survey (Survey Monkey)	Employee survey (Survey Monkey)

Table 3—Sources of data used for greenhouse gas emissions analyses (continued)

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 3: Commuter travel	Employee survey	Employee survey (Survey Monkey)	Employee survey (Survey Monkey)	Employee survey (Survey Monkey)
Scope 3: Contracted wastewater treatment	WO engineering data call	NFC/ECM, city records	Not reported	Not reported
Scope 3: Contracted waste disposal	U.S. Department of Agriculture reported	NFC/ECM, city records	Not reported	Ace provided cost, then tonnage was estimated from cost
Renewable energy	WO engineering data call	N/A	N/A	N/A

N/A = not applicable.

NFC = National Finance Center.

ACE = Administrative Center of Excellence.

ECM = Enterprise content management.

FAST = Federal Automotive Statistical Tool.

GSA = General Services Administration.

WO = Washington office.

Table 4—Greenhouse gas emission analysis scopes, categories, and sources used to quantify emissions

Scope	Categories	Sources
Scope 1	Direct emissions	Emissions from fossil fuels burned on site, emissions from entity-owned or entity-leased vehicles, and other direct sources.
Scope 2	Indirect emissions	Emissions resulting from the generation of electricity, heating and cooling, or steam-generated off site but purchased by the entity and the transmission and distribution losses associated with some purchased utilities (e.g., chilled water, steam, and high-temperature hot water).
Scope 3	Emissions related to goods or services purchased by the agency	Transmission and distribution losses associated with purchased electricity, employee travel and commuting, contracted solid waste disposal, and contracted wastewater treatment.

Table 5—Level of data aggregation

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 1: Goal subject Buildings energy	District	Site level	Site level	Site level
Scope 1: FAST Mobile (vehicle fleet) energy	State or GSA region	District	Not reported	District level
Scope 1: Aviation	Unit	District level	N/A	N/A
Scope 1: Watercraft	Included in estimate for non-FAST vehicles and equipment	District level	N/A	N/A
Scope 1: Vehicles and equipment energy	Forest Service	Not reported	Not reported	District
Scope 1: Mixed refrigerants and fugitive F-gases	Unit	N/A	N/A	N/A
Scope 1: Agency-operated waste-water treatment facilities	Unit	N/A	N/A	N/A
Scope 1: Fugitive landfill gases	Unit	N/A	N/A	N/A
Scope 2: Electricity	ZIP Code	Site level	Site level	Site level
Scope 2: Steam and hot water	Unit	N/A	N/A	N/A
Scope 2: Chilled water	Unit	N/A	N/A	N/A
Scope 3: Transmission and distribution losses	Zip Code	District level	Station level	District level
Scope 3: Business travel (air and ground)	Forest Service	District level	Station level	District level
Scope 3: Commuter travel	Unit	District level	Station level	District level
Scope 3: Contracted wastewater treatment	Unit	Site level	Not reported	N/A
Scope 3: Contracted waste disposal	Forest Service	Site level	Not reported	Site level
Renewable energy	Unit	N/A	N/A	N/A

N/A = not applicable.

FAST = Federal Automated Statistical Tool.

GSA = General Services Administration.

Table 6—Ease of data access

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 1: Goal subject buildings energy	Moderately difficult to get access but easy once you have it	Moderately difficult for FY 2011. Moderately easy for future years because heating oil payments are now made through NFC.	N/A	Easy—ACE had spreadsheet
Scope 1: FAST Mobile (vehicle fleet) energy	Moderately difficult	Moderate. Dependent on fleet manager's cooperation for data.	Not reported	Easy—Fleet manager provided vehicle miles
Scope 1: Aviation	Difficult	Moderate. Dependent on dispatch data detail availability	N/A	N/A
Scope 1: Watercraft	Not tracked separately	Moderate. Dependent on dispatch data detail availability	N/A	N/A
Scope 1: Vehicles and equipment energy	Data availability is dependent upon national fleet manager completing estimate	Not reported	Not reported	Difficult—Had to estimate ATV and snowmobile usage
Scope 1: Mixed refrigerants and fugitive F-gases	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A
Scope 1: Agency operated wastewater treatment facilities	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A
Scope 1: Fugitive landfill gases	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A
Scope 2: Electricity	Moderately difficult to get access but easy once you have it	Easy. From NFC and established utility company contact for billing histories	N/A	Easy—ACE
Scope 2: Steam and hot water	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A
Scope 2: Chilled water	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A

Table 6—Ease of data access (continued)

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 3: Transmission and distribution losses	Automatically calculated by FEMP tool	Automatically calculated by GSA GHG Tool	Automatic. calculated by GSA GHG Tool	N/A
Scope 3: Business travel (air and ground)	Moderately difficult to get access but easy once you have it.	Moderate. Requires local survey	Moderate. Requires local survey	Moderate. Requires local survey
Scope 3: Commuter travel	Difficult. Employee survey	Moderate. Requires local survey	Moderate. Requires local survey	Moderate. Requires local survey
Scope 3: Contracted wastewater treatment	Data availability is dependent upon WO engineering data call to field units	Difficult. Most facilities do not have meters, some bill in 1,000- to 5,000-gal increments.	N/A	N/A
Scope 3: Contracted waste disposal	Data availability is dependent upon USDA providing estimate. Estimate is done at USDA level, so an FS estimate is not available	Difficult—most utilities provide only rough data that requires calculations to arrive at tonnage.	Not reported	N/A
Renewable energy	Data availability is dependent upon WO engineering data call to field units	N/A	N/A	N/A

N/A = not applicable.

ACE = Administrative Center of Excellence.

NFC = National Finance Center.

GHG = Greenhouse gas.

WO = Washington office.

GSA = General Services Administration.

FEMP = Federal Energy Management Program.

Table 7—Confidence in data accuracy comparison

Category	National	Tongass National Forest	Northern Research Station	Stevensville Ranger District
Scope 1: Goal subject Buildings energy	C because many Budget Object Codes are coded improperly	C for FY 2011, B+ for future years		A
Scope 1: FAST Mobile (vehicle fleet) energy	B-	D for older data, B for newer data (estimated from mileage reports)		A
Scope 1: Aviation	C	D for older data, B for newer data	N/A	N/A
Scope 1: Watercraft	N/A	D for older data, B for newer data	N/A	N/A
Scope 1: Vehicles and equipment energy	C+	Not reported	Not reported	D
Scope 1: Mixed refrigerants and fugitive F-gases	C	N/A	N/A	N/A
Scope 1: Agency-operated wastewater treatment facilities	C	N/A	N/A	N/A
Scope 1: Fugitive landfill gases	A because the Forest Service no longer uses landfills	N/A	N/A	N/A
Scope 2: Electricity	A-	A	N/A	A
Scope 2: Steam and hot water	C because we are not sure if we are getting a complete set of data	N/A	N/A	
Scope 2: Chilled water	C because we are not sure if we are getting a complete set of data	N/A	N/A	N/A
Scope 3: Transmission and distribution losses	A	C—GSA CFT method of calculation probably not relevant to SE Alaska	A	A
Scope 3: Business travel (air and ground)	A for air travel, D for ground travel	C	C	N/A
Scope 3: Commuter travel	D in FY 2011	A	A	
Scope 3: Contracted wastewater treatment	C	C—No data entered in GSA CFT for FY 2011 (by Prizim)	N/A	Not reported
Scope 3: Contracted waste disposal	D	C	Not reported	D
Renewable energy	B-	N/A	N/A	N/A

N/A = not applicable.

FAST = Federal Automative Statistical Tool.

GSA CGT = General Services Administration Carbon Footprint Tool.

be truly accurate. The subcategory in which the national and local inventories used the same data source is utility/electricity from NFC. Separate employee commuter surveys were completed on the national level and at each local unit. When comparing the Tongass National Forest data to the Stevensville Ranger District data, it becomes clear that the equipment underlying the data source (i.e., passenger vehicles versus snowmobiles versus aircraft) can also influence GHG results.

This first comparison is a good example of the significant differences between top-down and bottom-up approaches. National data collected through the Washington office Engineering Data Call provide virtually all information in scope 1 (mixed refrigerants, wastewater, and landfill gases), scope 2 (steam, hot water, and chilled water), and scope 3 (renewable energy) (table 4). None of the local units in the pilot contributed any information about these GHG producers. Without the top-down approach, no information about these classes of GHGs would be available.

Analysis Area 2: Data Aggregation Level

Differences are noted between the national approach (top-down) and the local approach (bottom-up) in terms of the level of aggregation of GHG emissions data (table 5). At the national level, aggregation varies depending on the system used to collect and report data. Pilot unit data are aggregated at the site level. The site-level aggregation will not be easy for a national top-down approach owing to the large number of individual sites that the Forest Service operates. Site-level data will be meaningful for a national data collection effort if all of the sites conduct the inventory consistently. However, that is a major challenge of aggregating at such a fine scale.

Analysis Area 3: Ease of Data Access

The ease of access of collecting GHG data is a subjective measure in which data managers were asked to use the words “Easy,” “Moderate,” or “Difficult” to best describe their experience in each category. However many respondents chose to refine their responses over a spectrum of ratings based on their unique experiences (table 6). Owing to this subjective nature, we expect the value of qualitative interpretations to be relatively low, and they therefore should be used in combination with other reported results.

More data sources are available at the national level than the unit level (table 6), providing another example of how the top-down approach has the potential to be more successful than the bottom-up approach. For example, if local units do not collect their own local data, the national database may be used as a proxy for the missing data. The data manager at the national level states that most of the data are moderately difficult to access, but relatively easy to use once access is obtained.

It is possible that if one inexperienced data manager were given two different units from which to collect and enter data, their assignments of subjective terms for the different units might be disparate simply based on the scale (geographic size) between units. For instance, the NRS data manager did not have to supply answers to 13 out of 17 questions, because NRS was not contributing data in those areas. Thus, the perception of the NRS data manager that it was “Easy” to collect and enter data could be because there were so few data. Conversely, the Tongass National Forest data manager found it “Moderately difficult” or “Difficult” on just under half (9 of 17) of the questions, possibly owing to the volume of data alone for the size of the Tongass National Forest, and the number of additional data providers that the data manager had to contact.

The Stevensville Ranger District benefitted from its Administrative Center of Excellence (ACE), a centralized business organization serving Northern Region (Region 1) forests since 2006. The ACE reviews all Region 1 utility accounts (paid through NFC) to validate that the meters and accounts are current, correct, and belong to the Forest Service. The ACE staff record and track Forest Service utility usage monthly by reviewing data directly from online vendor accounts or copies of utility bills (Johnson and Bowles, n.d.). Of the questions that the Stevensville data manager answered, “ease of access” responses differed greatly, depending on whether the district had data already compiled for utility records and vehicle use, or whether specific estimates of hours or miles of use had to be calculated by hand.

Analysis Area 4: Data Accuracy

Comparisons are made in confidence of data accuracy based on FY 2012 results (table 7). A subjective grading scale was provided, similar to American educational grading standards, in which the letter “A” represents a high level of confidence in the accuracy, and the letter “D” represents very little confidence (with “B” and “C” corresponding to “Good” and “Satisfactory,” respectively). Rather than a numerical or measured grading system (such as a percentage of “correct” answers), this grading scale is designed to be more subjective.

Although this rating system comes from program managers as first-hand information input, it is nonetheless subjective in nature owing to responses being obtained from four data managers. At first glance, managers are more confident about accuracy at the national level than at the forest level. In the Tongass National Forest, the manager gives "C" and "D" ratings for most of the confidence-level categories for FY 2011, but an improved outlook for future years.

This is of interest in terms of the relation between ease of access and level of data accuracy. We observed that at the national level, managers initially found it difficult to access data systems, but once access was obtained, the level of accuracy was considered moderately high. At the national level, reporting systems are assumed to be consistent because effective control systems are in place, whereas these control systems may not be present at the local level.

On the Tongass National Forest, the data manager rated the level of accuracy quite low, even though these data were relatively easy to access. Here, the data manager was more confident with newer data. For the Stevensville Ranger District, half of the categories reviewed (four out of eight) were graded "A," and the other half graded "C" or "D."

Data managers at the local level are more directly involved in the data collection, than those at that national level so it should be more apparent to them when the data are inaccurate or incomplete. For scope 1 data (table 4), the Tongass National Forest manager estimated emissions using units of miles per gallon (car and truck fleet) and units of gallons per hour (aircraft), despite the possibility of sacrificing some accuracy with these methods. One of the major purposes of conducting an inventory is to refine methodologies and improve processes so as to acquire more accurate data with higher levels of confidence over time.

The contracted waste disposal category had the lower quality of data owing to the scale of estimating required. Unit waste generated is required to be reported in short tons. In most cases, the monthly charge incurred was the only number available from the utility providers for the bottom-up data. This dollar amount was then backed down into an estimate of the number and size of waste containers, multiplied by the number of pickups per month for each. Even after estimating these numbers, another estimate was made based on the average weight of each size container, which varied widely among utility providers and also has no standard available for federal agencies to use. Even if there were standard weights available, another variable to consider is whether containers were full when picked up. The units that reported contracted waste used "100 percent full" in their calculations, so the emissions from this category are knowingly overstated.

Because this is a nationwide requirement for GHG data, waste disposal companies can be encouraged to provide waste tonnage information on regular billing documents or statements. At the top-down level, data availability is dependent upon USDA providing an estimate, and because this estimate is done at the USDA level, no Forest Service estimate is available.

Although successful in terms of complying with the requirement from the USDA and the White House mandate, national reporting systems have the potential to differ widely in accuracy.

Discussion

A top-down approach can be used to evaluate GHG emissions within the USDA Forest Service as well as contribute to national policies for other agencies. The top-down approach helps the agency to establish a baseline estimate of CO_2 emissions, identifying opportunities to reduce emissions, and allocating resources in priority areas. In some cases, top-down data are dependent on national-level queries of field units. In others, these data are calculated directly from existing tools, for example, the FEMP tool. In still other cases, the data are provided from an even more aggregated source, for example, at the USDA level. Other factors that could influence differences include the scale of aggregation of data (i.e., whether the data originate from the site, district, or forest level). Clearly, there is no single formula for conducting top-down analyses, and the specific procedures used can influence overall results.

Although successful in terms of complying with the requirement from the USDA and the White House mandate, national reporting systems have the potential to differ widely in accuracy. Owing to large discrepancies of different forest units, capacity, and regional climate, a national strategy might be more effective by targeting a few early adopters, rather than attempting to characterize local facilities.

A bottom-up approach can be more accurate and closer to quantifying actual emissions at a given location. The benefit of a bottom-up approach is that data are more immediate: The shortcoming is data from local units are in different forms, and may be nonstandardized. Aggregation at the national level from a bottom-up approach might not be feasible in all cases. However, it is still important for units to compile and analyze GHG data, so that progress can be tracked locally.

The manner in which GHG data are collected raises several questions about data quality, including completeness, confidence in accuracy, and timeliness. With limited time and resources, perhaps managers can discuss where to focus their energy in order to improve data collection. For instance, if scope 1 GHG emissions (table 4) are the largest but the level of data confidence is the lowest, then the data collection and recording improvements should become an area of focus for the next round of GHG emission inventory data improvement. In comparison, if business air travel is a small portion of the total GHG emissions, an estimate based on an employee survey may be sufficient.

The NFC will soon begin using the Ameresco AXIS Invoice Management Service for managing utility bills. This service provides a streamlined process for compiling utility bill invoices, and analyzing them to find opportunities for energy and cost savings. The advanced technology behind the service replaces time-intensive manual accounting with fast and accurate data access with multiple analysis functions designed to show inefficiencies in current utility use. By significantly improving the availability and accuracy of utility data, the Ameresco AXIS system may serve a critical role in helping reduce agency utility costs and personnel requirements while meeting sustainable operations goals for energy reduction (Ameresco 2014).

Conclusions

This report has provided a qualitative comparison of top-down versus bottom-up approaches to GHG data collection and reporting within the USDA Forest Service. The decision of whether to use top-down or bottom-up methods can have an important influence on results, with numerous pros and cons for each method. Top-down methods offer advantages of efficiency and economies of scale, while bottom-up methods offer potential gains in accuracy owing to more immediate data collection reporting. Other important considerations include the level of aggregation of data, the confidence level in data accuracy, the ease of access in data collection, and which specific data sources are used.

We hope that this report will stimulate discussion among all those involved in carbon reporting within the USDA Forest Service, including Local Green Team leaders, energy managers, unit climate change and sustainable operation coordinators, volunteers, and other interested staff at all levels. The lessons learned and observations from managers articulated here should have broader implications for other national forests that may soon be embarking on a GHG monitoring program, and help them develop efficient and accurate data reporting systems. Likewise, these lessons may encourage renewable energy generation as a means of reducing GHG emissions, as has been done on the Tongass National Forest with wood energy (fig. 5) and solar energy (fig. 6).

Last, we point out that the Forest Service is in a unique position to evaluate both its emissions from ongoing operations as well as the carbon sequestered by the forests on its 193 million ac under management. Thus, an important area of future work could be to compare emissions and sequestration to determine the climate change benefits and impacts of the agency as a whole.

Figure 5—Wood energy system at Discovery Center, Ketchikan, Alaska.

Figure 6—Solar panels in use, southeast Alaska.

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Metric Equivalents

When you know:	Multiply by:	To find:
Feet (ft)	0.305	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Gallons (gal)	3.78	Liters
Tons (ton)	.907	Tonnes or megagrams
Kilowatt-hour (kW-hr)	3.6	Megajoules

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