


Greenhouse Gas Emissions Inventory Methodology Review

King County

Department of Natural Resources and Parks

2016

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Acronyms

ACR	American Carbon Registry
AFOLU	Agriculture, Forestry, and Other Land Use
ARB	California Air Resources Board
CAR	Climate Action Reserve
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CH_4	methane
CO_2	carbon dioxide
GHG	greenhouse gas
HDPE	high density polyethylene
LDPE	low density polyethylene
N_2O	nitrous oxide
PET	polyethylene terephthalate
PP	polypropylene
TCR	The Climate Registry
TDR	Transfer of Development Rights
VCS	Verified Carbon Standard
WBCSD	World Business Council for Sustainable Development

Executive Summary

In 2013, King County Department of Natural Resources and Parks (DNRP) made a commitment to go *Beyond Carbon Neutral*. The department already carefully calculates and manages its greenhouse gas (GHG) emissions activities—and in many cases, does so in a manner that exceeds traditional inventory guidance or best practices. For example, DNRP quantifies GHG emissions associated department purchasing of goods and services, which if often excluded from traditional inventories. Furthermore, DNRP has a long track record of GHG emission reduction activities, such as practicing responsible forest management and protection, applying biosolids instead of synthetic fertilizers, and incentivizing non-vehicular transportation through the Eastside Rail Corridor. These activities exemplify King County's longtime commitment to curbing harmful climate pollution.

The *Beyond Carbon Neutral* commitment will require that DNRP's sources of GHG emissions—including electricity used for buildings and wastewater treatment; fuel use in vehicles; methane emissions from wastewater treatment and landfills; and emissions from purchase of services, supplies, and equipment—are offset either externally through purchased offsets or internally through greenhouse gas removals, such as renewable energy production, forest protection, and sustainable solid waste management practices.

This report summarizes outcomes of an independent third party review of greenhouse gas emissions calculation methodologies specific to DNRP operations, with a particular emphasis on emissions associated with DNRP landfill management and purchasing. The review included consideration of the most up-to-date tools, publications, and protocols, including those from the Greenhouse Gas Protocol, The Climate Registry, The Climate Action Reserve, and the Verified Carbon Standard. Two primary elements of DNRP's GHG inventory were examined: 1) the inventory boundaries (i.e., what is included and what is excluded) and 2) the inventory methodologies (e.g., emissions factors, baseline assumptions, and other variables). For each of these aspects, we compared the current DNRP approach to industry best practices and, if warranted, provided recommended adjustments and rationales.

Regarding DNRP's overarching inventory approach and boundary, we recommend that DNRP implement the following:

- Seek to achieve carbon neutrality first through internal GHG reduction and removal projects and second, as needed, through the purchase of offsets.
- Include all relevant emissions sources and removals in its inventory, so as long as removals are quantified using an accepted and verifiable offset methodology or supported by the GHG Protocol for Project Accounting (Project Protocol). Any removals that do not fall under the above criteria should not be counted toward the DNRP carbon neutrality goal but should still be tracked.
- Use the operational control approach for delineating DNRP's inventory boundary.
- Include, to the extent possible, all three scopes in the DNRP inventory, including sources that may be very small (also known as "*de minimis*" sources).

To ensure consistency with the above guiding principles, we recommend that DNR include the following general categories of emissions sources and removals in its inventory:

Include in Inventory		Exclude from Inventory**	
Sources	**Removals***	**Sources**	**Removals**
▪ Facility energy use ▪ Landfill gas processing and delivery ▪ Vehicle fleet use ▪ Employee commuting ▪ Business travel ▪ Refrigerants and Fire protection*** ▪ Purchased goods and services ▪ Wastewater treatment and conveyance	▪ South Plant biogas fossil gas displacement ▪ Loop biosolids ▪ Transfer center recycling ▪ Recycling and composting in unincorporated King County ▪ Carbon sequestered by growth of DNRP-owned forests ▪ Protection of privately owned forests ▪ Tree planting ▪ Regional trail system	▪ Flared landfill gas ▪ Landfill gas and South Plant biogas end use	▪ Landfill carbon sink ▪ County-wide diversion programs ▪ Carbon stored in existing DNRP-owned forests ▪ Brokering of TDR transactions

**subject to defendable computation using an accepted third party methodology*
***in some cases, we recommend reporting of sources that are excluded from the inventory*
****De minimis sources can calculated using a simplified estimation methodology or alternate methodology*

We recommend several adjustments to individual methodologies, summarized below:

Inventory Component	Recommendation
Electricity Use	▪ Use gross energy consumption. ▪ Report emissions by sector. ▪ Use utility-specific emission factors that are verified and/or meet Scope 2 Quality Criteria; otherwise, use eGRID subregion default emission factors.
Combined Heat and Power	▪ Use either efficiency or energy content method to allocate emissions based on available data.
Natural Gas, Propane, and Diesel	▪ Use updated TCR default emissions factors and adjust other variables as known. ▪ Report emissions by sector.
Fuel Supplied to Regional Pipelines	▪ Quantify removals based on Project-Specific Protocol.
Vehicle Fleets	▪ Use up-to-date default emissions factors from The Local Government Operations (LGO) Protocol specific to vehicle year and type.
Employee Commuting	▪ Use Commute Trip Reduction survey and mode-specific emissions factors.
Refrigerants and Fire Protection	▪ Use mass balance approach.
Wastewater Treatment	▪ Use measurement-based calculations recommended by LGO Protocol and using published sampling protocols. ▪ If variability due to plant conditions is high, support this assertion through sensitivity testing.
Loop biosolids	▪ Include all emissions related to transporting biosolids. ▪ Follow and/or develop offset methodology, including a full assessment of baseline scenarios.
Forest growth and protection	▪ As resources allow, follow voluntary or compliance offset protocol for avoided conversion, reforestation, and improved forest management related removals for projects that meet eligibility requirements and can likely demonstrate additionality. ▪ Use CAR's Urban Tree Planting Protocol for urban tree planting projects.
Regional trail system	▪ Calculate using GHG Project Accounting Protocol along with APTA mode shift guidance.
Transfer Center Recycling and Diversion	▪ If level of effort is deemed worthwhile, follow CDM methodology for claiming removals related to recycling plastics and other materials.
Purchasing	▪ Use the CY2009 CBEI output as a foundation. ▪ Identify and measure reduction projects. ▪ Set a schedule for emissions intensity updates. ▪ Compare CBEI/IMPLAN with REMI for future updates to sector emissions intensities.

A more thorough assessment of landfill emissions revealed the following recommendations for emissions attributed to all landfills:

- Include any GHG emissions generated by stationary sources located at any of the landfills. The emissions are generated by combustion of fossil fuels (e.g. No. 2 fuel oil, waste oil, propane fuels, etc.) to power emergency generators, lighting plants, comfort heaters, or water heaters located at the landfills.
- Determine if CO_2 pass-through (uncombusted CO_2 from the LFG going through destruction devices) is included in the inventory boundaries.
- Confirm the flow meters at landfills with a GCCS that are subject to the federal MRR or Ecology GHG reporting rule(s) are calibrated in accordance with the conditions required in the rule.
- Landfill GHG emissions may be reported in four different categories to distinguish the type of emissions: non-fugitive biogenic CO_2, non-fugitive anthropogenic CH4 and N2O, fugitive biogenic CO_2, and fugitive anthropogenic CH_4.
- Carbon sequestration should not be included as an offset when determining landfill inventories.
- Confirm stationary combustion, mobile, and fugitive sources (e.g. landfill equipment and fleet vehicles) GHG emissions are being accounted for in the inventory.

We also recommend the following considerations regarding active and closed landfills with an active GCCS and destruction device(s):

- Clarify BEW Plant reporting boundaries verse the CHRL reporting boundaries.
- Utilize the federal GHG MRR guidance and methodology for preparation of annual GHG inventories for the active and closed landfills regardless if they are required for reporting to EPA or Ecology.
- Utilize the federal GHG MRR landfill cover area-based calculations to determine site specific GCCS collection efficiencies for landfills that employ a GCCS.
- Utilize the federal GHG MRR recommended landfill methane soil oxidation fractions.
- Inventories for landfills with a GCCS should include the CO_2 and CH_4 emissions that pass through the destruction devices (e.g. flares).
- Inventories for landfills with active GCCS should include the CH_4 and N_2O emissions generated during combustion of LFG within the destruction devices (e.g. flares).
- Utilize the official source tested methane destruction efficiency for all landfill flares where applicable.
- Utilize the default CH_4 destruction efficiency for open flares if site-specific data is not available.

In summary, this assessment revealed specific methodology alterations that could be implemented to improve inventory robustness and alignment with accepted protocols and best practices. Some recommended emissions calculation methodologies may be rigorous and resource-intensive to complete—in those cases, we recommend using best practices and best available data to the extent feasible. For calculating removals, we recommend beginning with projects in sectors and areas 1) that will most likely demonstrate additionality against the baseline scenario, 2) for which there is adequate data available, and/or 3) have an established and straightforward calculation methodology. Until resources allow identified removals to be fully quantified using accepted protocols, the purchase of verified offsets could be pursued to achieve carbon neutrality.

Overview

King County is a national and regional leader in addressing climate change through ambitious greenhouse gas (GHG) emissions reduction plans and goals. In support of King County's carbon neutral goals and per the requirements of Council Ordinance #17971, this report summarizes outcomes of an independent third party review of greenhouse gas emissions calculation methodologies specific to the Department of Natural Resources and Parks (DNRP).

Cascadia Consulting Group, Inc., with support from SCS Engineers and Hammerschlag & Co., provided a holistic, yet focused review of inventory approaches and methodologies to-date relevant to the following DNRP activities:

- Energy use, including from facilities and transportation
- Energy production from landfill management and wastewater treatment
- Water use
- Tree and forest growth, management, and conservation
- Wastewater treatment, including application of loop biosolids
- Solid waste management and processing, including landfill and recycling center management and countywide diversion policies and programs
- Purchasing
- Regional trail system development

The review included consideration of the most up-to-date tools, publications, and protocols from around the world, including those from the Greenhouse Gas Protocol, The Climate Registry, The Climate Action Reserve, and the Verified Carbon Standard. (See References section for a full list of examined resources and the next section for a discussion of these protocols.) We examined two primary aspects of the inventory:

1. **Inventory boundaries:** what is included and what is excluded
2. **Inventory methodologies:** how emissions are calculated, including emissions factors, baseline assumptions, and other variables

For each of the above aspects and DNRP activities, we examine how it compares to available best guidance and, if warranted, recommend adjustments and rationale for that adjustment. We begin with an examination of inventory boundaries—including guiding principles, reporting considerations, and individual delineations—and follow with examinations of individual methodologies for inventory component identified as within the recommended boundary. We conclude with an in-depth examination of two emissions sources of particular interest to DNRP: purchasing and landfill emissions.

The recommendations in this report present suggested adjustments for maximizing alignment with industry best practices and guidance. In some cases, achieving this optimal level can be challenging due to resource or data constraints. In these cases, we provide two tiers of recommendations:

- **Tier 1** recommendations represent the "gold standard," or adjustments that would optimize alignment with industry best practices
- **Tier 2** recommendations represent alternative approaches that may be acceptable within DNRP's voluntary GHG accounting context given resource and/or data constraints

Greenhouse Gas Accounting Protocols

This review prioritized comparison of DNRP methodologies and approaches to the following accepted protocols:

- World Resource Institute and LMI's ***GHG U.S. Public Sector Protocol*** provides guidance based on the widely accepted *GHG Protocol Corporate Accounting and Reporting Standard* and is tailored for public sector entities. These standards form the basis for various other GHG reporting programs and protocols, including the American College and University President's Climate Commitment, The Climate Registry, Global Reporting Initiative, EIA 1605b, ICLEI, ISO 14064, and sector-specific protocols for the International Council of Forest and Paper Associations. [1, p. 3]
- The Climate Registry's ***Local Government Operations Protocol*** provides general guidance to local governments and is program neutral. The protocol was developed through a collaborative, consensus-based process with the California Climate Action Registry, the California Air Resources Board, and ICLEI Local Governments for Sustainability. Each participating program has additionally developed supplemental guidance. [2]
- World Resources Institute and World Business Council for Sustainable Development's (WBCSD) ***GHG Protocol for Project Accounting*** (Project Protocol) provides principles, concepts, and methods for quantifying and reporting GHG reductions from climate change mitigation projects. The protocol's development included involvement and testing from over twenty developers of GHG projects from ten counties and review from over 100 experts. [3, p. 5]

Our in-depth, sector-specific methodology review also consulted various sector-specific protocols, including the following:

- The Verified Carbon Standard's (VCS) ***Methodology for Avoided Ecosystem Conversion*** provides guidance for quantifying GHG emission reductions and removals from project activities that prevent conversion of forest to non-forest land use. [4] It addresses components required by the VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities and uses available Clean Development Mechanism (CDM) tools for testing significant GHG project emissions. [4]
- The GHG Protocol's ***Scope 2 Guidance*** amends the GHG Protocol Corporate Accounting and Reporting Standard to answer specific questions and measurement concerns related to Scope 2 emissions resulting from acquired and consumed electricity, steam, heat, or cooling. [5]
- The GHG Protocol's ***Corporate Value Chain (Scope 3) Accounting and Reporting Standard*** supplements the GHG Protocol Corporate Accounting and Reporting Standard to provide requirements and guidance for companies and other organizations on preparation and public reporting of a GHG emissions inventory that includes indirect emissions resulting from value chain activities (i.e., Scope 3 emissions). [6, p. 4]
- The GHG Protocol's ***Technical Guidance for Calculating Scope 3 Emissions*** supplements the Corporate Value Chain standard and provides methods for calculating Scope 3 GHG emissions. [7, p. 5]
- The GHG Protocol's ***Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects*** provides conceptual considerations for developing emission factors for quantifying the reductions and removals related to grid-connected electricity projects. [8]
- The GHG's Protocol's ***Global Protocol for Community-Scale Green Gas Emission Inventories*** provides guidance on wastewater treatment and other activities that occur at the community scale. [9]

- The GHG Protocol's ***Calculation Tool for Direct Emissions from Stationary Combustion*** provides specific guidance on the selection and implementation of emission estimation methodologies, data collection, documentation, and quality management of stationary combustion sources. [10]
- The GHG Protocol's ***Product Life Cycle Accounting and Reporting Standard*** provides the rationale and general principles and processes for lifecycle accounting. [11]
- The American Carbon Registry's (ACR) ***Improved Forest Management Methodology for Quantifying GHG Removals and Emission Reductions through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands*** provides step-by-step guidance for quantifying GHG emission reductions resulting from carbon projects that exceed baseline forest management practices. [12, p. 4]
- The United States Environmental Protection Agency's (EPA) ***eGRID Emission Estimation Methods*** provides guidance about emissions attributable to electric power generation sources, including combined heat and power, in the United States. [13]
- EPA's ***Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Direct Emissions from Stationary Sources*** provides guidance on stationary combustion sources, including biofuels, waste fuels, and non-combustion emission sources. It is based on GHG Protocol and provides more precise guidance for Climate Leaders. [14]
- US Department of Energy's (DOE) ***Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program, Forestry Appendix*** provides methods for calculating forest ecosystem and harvested carbon and standard estimates for forest types of the United States.
- Clean Development Mechanism's (CDM) ***Small-scale Methodology: Recovery and recycling of materials from solid wastes*** provides guidance on claiming emissions reductions related to waste recovery and recycling. Included reductions are related to recycling plastic materials into intermediate or finished products and avoiding CH_4 emissions from the anaerobic decay of paper or cardboard. CDM is under the United Nations Framework Convention on Climate Change. [15]
- The American Public Transit Association's (APTA) ***Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit*** provides guidance for quantifying generation of GHG emissions and the potential reduction of emissions through efficiency and displacement.

Inventory Boundaries

Greenhouse Gas Emissions, Removals, and Neutrality

This assessment uses the following greenhouse gas accounting nomenclature, consistent with The Greenhouse Gas Protocol: [3]

- **Emissions** refer to the release of greenhouse gases into the atmosphere.
- **Greenhouse gas (GHG) reductions** refer to either decreases in GHG emissions or increases in removals and/or storage, typically from climate change mitigation projects (GHG projects). [3, p. 5]
- **Emissions reductions** refer to actions that decrease the production of GHG emissions, such through increased use of renewable energy or commute mode shifts.
- **Removals** refer to actions that take existing greenhouse gases out of the atmosphere, such as through avoided deforestation or improved forest management.
- **Offsets** refer to credits issued for verified GHG projects that occur at sources not covered by the program, often to achieve a net zero increase in emissions.

GHG reductions can be quantified for a number of reasons, including:

- to generate officially recognized GHG reduction credits to meet mandatory emission targets,
- to obtain recognition for GHG reductions under voluntary programs, or
- to offset GHG emissions to meet internal organization targets for public recognition or other internal strategies. [3, p. 5]

In the case of DNRP, GHG reductions are sought to achieve the agency's goal of carbon neutrality. Because DNRP will always have some emissions, even with strong GHG emissions reductions projects and initiatives, achieving carbon neutrality will require both emissions reductions *and* removals. This can be done either externally, by offsetting emissions through purchase of credits from verified emission reduction projects, or internally, through DNRP GHG reduction and removal projects.

Because DNRP activities readily lend themselves to GHG reductions and removals, we recommend that DNRP first seek to achieve carbon neutrality through internal GHG reduction and removal projects. If internally-driven GHG reductions are not sufficient to achieve neutrality, then the agency should purchase external, verified offsets to make up the difference.[i]

We recommend that DNRP seek to achieve carbon neutrality first through internal GHG reduction and removal projects and second, as needed, through purchase of offsets.

[i] A more detailed discussion of protocols and requirements for internal reduction projects are discussed in later sections of the report.

Overarching Principles

For both emission and removal accounting, protocols agree in their recommendation of the following three guiding principles: [3, p. 23]

Relevance	"Use data, methods, criteria, and assumptions that are appropriate for the intended use of reported information."
Consistency	"Use data, methods, criteria, and assumptions that allow for meaningful and valid comparisons."
Transparency	"Provide clear and sufficient information for reviewers to assess the credibility and reliability of GHG reduction claims."

A fourth principle, **Completeness**, is applied differently across protocols. Some protocols allow for *de minimis* thresholds or "simplified estimation methodolog[ies]" for *de minimis* sources.[ii] Alternatively, the U.S. Public Sector Protocol recommends including estimates for even very small emissions sources to avoid bias and ensure completeness. [1, p. 10]

The fifth principle, **Accuracy,** is defined consistently among protocols but applied differently to emissions and offsets. Generally, protocols advocate for the complete and accurate quantification of emission sources and the selective and conservative inclusion of removal projects:

Emissions	"The quantification of greenhouse gas emissions should not be systematically over or under the actual emissions. Accuracy should be sufficient to enable users to make decisions with reasonable assurance as to the integrity of the reported information." [2, p. 10]
Offsets	"Reduce uncertainties as much as is practical…where accuracy is sacrificed, data and estimates used to quantify GHG reductions should be *conservative* (emphasis added). [2, p. 25]

[ii] According to 1605(b) Program for GHG reporting, *de minimis* emissions are "emissions from one or more sources and of one or more greenhouse gases that, in aggregate, are less than or equal to 3 percent of the total annual CO_2 equivalent emissions of a reporting entity." http://www.eia.gov/oiaf/1605/FAQ_deMinimisA.htm#what

To ensure conservativeness, offset accounting protocols require support of **additionality** to ensure that the action is above and beyond business as usual:

- Additionality is embedded in the verified offset methodologies, such as those provided by Verified Carbon Standard (VCS), American Carbon Registry (ACR), Climate Action Reserve (CAR), and Clean Development Mechanism (CDM).
- The Greenhouse Gas Protocol for Project Accounting (Project Protocol) also embeds the requirement of additionality by quantifying removals "against a forward-looking, counter-factual baseline scenario." [3, p. 13]
- If a project results in a greater level of removals than the baseline scenario, the incremental removals are additional.

We recommend that DNRP include all relevant emissions sources and removals in its inventory, so as long as removals are quantified using an accepted and verifiable offset methodology or supported by the Project Protocol. Any removals that do not fall under the above criteria should not be counted toward the DNRP carbon neutrality goal but should still be tracked.

In lieu of purchasing offsets, DNRP must account for internal reductions and removals in a way that would be accepted and verifiable on the offset market. **We recommend that DNRP include all relevant emissions sources and removals, so as long as removals are quantified following an accepted and verifiable offset methodology or supported by the Project Protocol.**

The U.S. Public Sector Protocol encourages tracking all Scope 3 sources regardless of their accuracy or verifiability for purposes of goal and priority setting. **Any removals that do not fall under the above criteria should not be counted toward the DNRP carbon neutrality goal but should still be tracked.**

Recommendations specific to various DNRP activities are included the "Inventory Methodologies" section of this report.

Accounting

Accounting for greenhouse gas emissions requires selecting a method for consolidation of, or claiming responsibility for, emission sources. Once selected, a chosen consolidation approach helps define the inventory boundary and must be applied consistently to all levels of the organization to avoid double counting or omitting emissions.

There are three primary consolidation approaches, defined by the U.S. Public Sector Protocol as follows:

- **Operational control:** the authority to introduce and implement operating policies; generally demonstrated if an organization holds an operating license for a facility.
- **Financial control:** the authority to direct the policies of the operation with a view to gaining economic or other benefits.
- **Equity share:** the share of economic risks and rewards in an operation; usually aligned with the organization's percentage ownership of that operation.

We recommend the operational control approach for consolidating DNRP emissions. The rationale for this recommendation is as follows:

- DNRP is in the business of generating public benefit through specific operations, such as waste disposal and water treatment, and it is most able to influence emissions sources under its operational control.
- DNRP's purpose is not to generate value from assets such as real estate.
- DNRP does not buy or trade equity.

This recommendation is supported by the U.S. Public Sector Protocol and The Climate Registry's Local Government Operations (LGO) Protocol. [1, p. 17] The U.S. Public Sector Protocol states, "This…Protocol recommends the operational control approach as the most appropriate boundary for government organizations, as their primary activities most often consist of providing public services through specific operations." [1, p. 17] The LGO Protocol further states, "Operational control most accurately represents the emissions sources that local governments can influence. Operational control is also the consolidation approach required under [California's] mandatory reporting program and is consistent with the requirements of many other types of environmental and air quality reporting." [2, p. 14]

We recommend the operational control approach for delineating DNRP's inventory boundary.

Unlike emissions, removals are not subject to the traditional inventory boundary. Removal projects may influence behaviors or systems outside of its project boundaries—as noted by the U.S. Public Sector Protocol, "a GHG target can be met entirely from internal reductions at sources included in the target boundary *or* through using offsets generated from GHG reduction projects that reduce emissions at sources (or enhance sinks) *external to the target boundary* (emphasis added)." [1, p. 84]

Reporting

The U.S. Public Sector Protocol and the LGO Protocol, among others, recommend reporting emissions and removals by scope. Scopes indicate the relationship between the organization's actions and the resulting greenhouse gas emissions or removals. [2]

- **Scope 1** includes emissions directly caused by an organization's actions (except direct carbon dioxide emissions from biogenic sources).[iii]
- **Scope 2** includes emissions indirectly associated with purchased electricity, steam, heating, or cooling.
- **Scope 3** includes all other indirect emissions not covered in Scope 2 and all removals associated with claimed projects.

Reporting Scope 1 and Scope 2 emissions is required by all researched protocols, while reporting Scope 3 emissions are optional.[iv] While optional, protocols encourage organizations to "identify and measure all Scope 3 emissions sources to the extent possible," [2, p. 25] especially in cases where Scope 3 emissions could be significant relative to Scope 1 and 2 emissions or organizations could undertake or influence potential emissions reductions. [1, p. 31] As stated in the GHG Protocol Scope 3 Standard, including Scope 3 emissions "enables [entities] to understand their full emissions impacts across the value chain and focus efforts where they can have the greatest impact." [6, p. 5]

Because DNRP has considerable influence over its Scope 3 emissions sources and removals, we recommend including, to the extent possible, all three Scopes in the DNRP inventory.

It is important to note that Scope 3 emissions are unique in that they necessarily represent the Scope 1 and Scope 2 emissions of *other* organizations. Therefore, if pertinent emissions sources are controlled by an organization, those emissions are included under Scope 1 instead of Scope 3. [1, p. 30] For example, DNRP operates the facility that processes the waste it generates, so the emissions associated with DNRP waste generation should be included under Scope 1 instead of Scope 3. [2, p. 124]

To compile a comprehensive and meaningful inventory, all relevant emission sources within the chosen boundary must be included. According to the U.S. Public Sector Protocol, some established GHG programs define a minimum (i.e., *de minimis*) emissions accounting threshold for small sources or a group of sources not exceeding a certain size. These programs note that a lack of data or the cost of data gathering may be a limiting factor, thus allowing the *de minimis* sources to be omitted from the inventory. However, excluding emissions under the *de minimis* threshold is not compatible with the completeness principle. Furthermore, using the *de minimis* threshold requires quantifying the source to ensure that it is under the threshold, which nullifies the benefits of having the threshold in the first place. [1, p. 10]

[iii] As noted on page 24 of the LGO Protocol, "Carbon dioxide emissions from biomass combustion are tracked separately because the carbon in biomass is of a biogenic origin—meaning that is was recently contained in living organic matter—while the carbon in fossil fuels has been trapped in geologic formations for millennia…the Protocol is designed to account primarily for the anthropogenic sources of GHG emissions."

[iv] Researched protocols that cover Scope 1 and Scope 2 emissions include the U.S. Public Sector Protocol, the TGO Protocol, The Climate Registry's General Reporting Protocol, and the Greenhouse Gas Protocol's Scope 2 Guidance document.

Many GHG reporting programs, such as The Climate Registry, have modified the *de minimis* concept from one of exclusion to one of simplification; for sources that fall beneath a defined threshold, reporting organizations may use a "simplified estimation methodology" or "alternate methodology" to calculate emissions from these source. This approach minimizes the reporting burden while still achieving the requirement of a complete inventory. [1, p. 10]

We recommend that simplified estimation methodologies are only employed when data availability limits the use of recommended methodologies for *de minimis* sources.

Finally, we recommend excluding, but reporting biogenic CO_2 emissions within the inventory. Although the majority of similar inventories do not include biogenic CO_2, we recommend reporting on this amount to the extent possible due to proposed reporting requirements under the upcoming Washington Clean Air Rule (WAC 173-441-050 (3)(d)).

We recommend including, to the extent possible, all three scopes in the DNRP inventory, including sources that may be very small (also known as "de minimis" sources), with the exception for biogenic CO_2 emissions.

Individual Inventory Components

With protocol guidance and overarching principles in mind, the following table summarizes our recommended boundary delineations and supporting rationale.

Table 1. Individual inventory components

Category	Specific Sources	Recommended Scope	Type	Additional Rationale
Energy use at facilities	Gross electricity consumption	2	**Emission**	WRI's Scope 2 Guidance document states that "for accurate Scope 2 GHG accounting, companies shall use the total—or gross—electricity purchases from the grid rather than grid purchases 'net' of generation." [5, p. 38]
	Energy associated with water use	2	**Emission**	
	Anthropogenic emissions from natural gas, propane, and diesel	1	**Emission**	
	Biogenic CO_2 emissions (Cedar Hills, South Plant)	Exclude, but report	**Emission**	Reporting of biogenic CO_2 emissions is required in the Washington Clean Air Rule (WAC 173-441-050 (3)(d)), but is typically not included in these types of inventories.

Category	Specific Sources	Recommended Scope	Type	Additional Rationale
Energy (sold)	Biogas (South Plant)	Exclude, but report	**Emission** (end use)	Reporting of biogenic CO_2 emissions is required in the Washington Clean Air Rule (WAC 173-441-050 (3)(d)), but is typically not included in these types of inventories.
		3 (conditional*)	**Removal** (displacement of fossil gas)	* To be included in Scope 3, removal due to displacement of fossil gas must be computed following third-party methodology.
	Electricity (West Point Wastewater Cogeneration)	Exclude	**Removal** (displacement of grid electricity)	All electricity and environmental attributes are sold to SCL.
	Landfill gas (Cedar Hills)	Exclude, but report	**Emission** (end use)	Reporting of biogenic CO_2 emissions is required in the Washington Clean Air Rule (WAC 173-441-050 (3)(d)), but is typically not included in these types of inventories.
		3	**Emission** (processing and delivery)	PSE purchases the environmental attributes of gas received from BEW only. If BEW or others release some of the untreated gas, these releases should be reported by King County as Scope 3 fugitive emissions.
		Exclude, but report	**Removal** (displacement of fossil gas)	Environmental attributes are sold to PSE.
Vehicle fleet fuels	Diesel, gasoline, CNG	1	**Emission**	
Employee commute	Diesel, gasoline, CNG	3	**Emission**	Often included in other jurisdictions' inventories.
Business travel	Air and road travel (private vehicles)	3	**Emission**	Often included in other jurisdictions' inventories.
Refrigerants	Refrigerants from HVAC and AC in buildings and cars	1	**Emission**	Often included in other jurisdictions' inventories.
Fire protection	Vehicles, fire suppression systems	1	**Emission**	Explicitly noted in public sector example in U.S. Public Sector Protocol
Purchasing	Purchased goods and services	3	**Emission**	Corporate Value Chain Protocol recommends including, some jurisdictions include paper purchasing.
Wastewater treatment	Methane and nitrous oxide emissions from conveyance system and onsite	1	**Emission**	

Category	Specific Sources	Recommended Scope	Type	Additional Rationale
	Loop biosolids	3 (conditional*)	**Removal**	To be included in Scope 3, removals due to increased soil carbon, increased biomass, or synthetic fertilizer displacement must be computed following a third-party methodology.
Solid waste	Fugitive methane and nitrous oxide emissions	1	**Emission**	
	Flared landfill gas	Exclude, but report	**Emission**	Reporting of biogenic CO_2 emissions is required in the Washington Clean Air Rule (WAC 173-441-050 (3)(d)), but is typically not included in these types of inventories.
	DNRP generation of waste	NA	**Emission**	Would double count emissions already included in Scope 1.
			Removal (carbon sink)	Not additional; disposing compostables and recyclable is not a specific policy pursued by DNRP.
	Landfill carbon sink	Exclude	**Removal**	Not additional; not a specific policy pursued by DNRP because the sink is based on the actions of the individual waste generators.
	Transfer center recycling	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to increased transfer center recycling should be computed following a third-party methodology.
	Recycling and composting in unincorporated King County	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to recycling and composting should be computed following a third-party methodology.
	County-wide diversion programs	Exclude	**Removal**	Additional, but burdensome to estimate.
Forests	Carbon stored in existing DNRP-owned forests	Exclude	**Removal**	No precedent for counting existing carbon stocks.
	Carbon sequestered by growth of DNRP-owned forests	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to forest growth should be computed following a third-party methodology.
	Protection of privately-owned forests	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to forest protections should be computed following a third-party methodology.
	Tree planting	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to afforestation or reforestation should be computed following a third-party methodology.
Transfer of development rights	King County's brokering of TDR transactions	Exclude	**Removal**	Unclear that King County contributes directly to additionality.
Regional trail system	Avoided emissions from adding 175 miles of paved trail	3 (conditional*)	**Removal**	* To be included in Scope 3, removals due to avoided transportation emissions should be computed following a third-party methodology.

Inventory Methodologies

The following sections discuss current DNRP approaches, supporting and/or dissenting documentation from available protocols and case studies, and our recommendation and rationale for each emissions inventory component.

Energy Use and Production

Emissions and removals related to electricity are complicated by the engineering realities of the electricity grid, which aggregates electricity from multiple generating resources—each with different emission factors—where the mix of resources varies by utility and time of day. Emissions and removals for fuel use are relatively straightforward as each fuel type is known at the time of use. However, the emissions of fuels are complicated by the technologies used to burn the fuels, which may result in different levels of remaining CO_2 after the fuel is combusted.

Electricity Use

Current Methodology

DNRP calculates utility-specific emission factors using the Washington State Department of Commerce's annual Fuel Mix Disclosure reports. The report contains 1) the total CO_2 emissions associated with each fuel source (in metric tons or MT), 2) the total generation by fuel source (in megawatt hours or MWhs), and 3) the percent of fuel used in each utility's fuel mix.

To calculate the utility-specific emission factors, DNRP first divides the total statewide emissions associated with a fuel by the total statewide generation associated with that fuel and 1.102 to convert the emissions from short tons to metric tons. [v] DNRP then multiples the resulting emission factor ($MTCO_2$/MWh) by the percent of that fuel in a specific utility's fuel mix. This step is repeated for all fuels associated with anthropogenic emissions, listed below:

- Coal
- Cogeneration
- Landfill Gases
- Natural Gas
- Petroleum
- Waste

[v] Note that in the workbook provided by DNRP (Utility Emissions Coefficients_2007_3_18_15.xls), landfill gas emissions are divided by nuclear generation and petroleum emissions are divided by wind generation, assumed to be in error. Furthermore, cogeneration emissions are assumed to be equal to natural gas emissions as 98 percent of cogeneration was associated with natural gas in 2008 before the reporting process made denoting cogeneration optional. While this assumption is reasonable given limited data availability, it does not account for the efficiencies of cogeneration over natural gas generation, resulting in overestimated emissions for cogeneration.

The following fuel sources are not associated with anthropogenic emissions within the utility's fuel mix:

- Biomass
- Geothermal
- Hydro
- Nuclear
- Window
- Solar
- Other

Next, DNRP adds together the emissions per megawatt hour for each fuel to get a weighted average emission factor ($MTCO_2$/MWh). Finally, DNRP multiples this weighted average emissions factor by the net amount of energy consumed by DNRP in that inventory period (net of on-site energy production such as solar energy).

DNRP also includes the emissions associated with water use-related electricity based on the quantity of water used. The emission factor is based on EPA's Pollution Prevention Calculator, which in turn is based on non-baseload emission factors. EPA's tool allows users to select either national or state-specific non-baseload emission factors. DNRP uses the state-specific emission factors.

Other Methodologies

We reference two primary protocols relevant to energy use and production accounting:

- The GHG Protocol's *Scope 2 Guidance*
- The Climate Registry's *Local Government Operations (LGO) Protocol*

These protocols are similar in their approach and guidance for energy use and production. The Scope 2 Guidance is more recent and amends the GHG Protocol *Corporate Accounting and Reporting Standard* by introducing more detailed guidance around employing location- and market-based emission factors.

LGO Protocol

For all energy sources, the LGO Protocol recommends reporting energy emissions by the following sectors as it "facilitates a more useful comparison of a local government's emissions over time, and a more accurate comparison between local governments that may not provide these other services:" [2, p. 30]

1. Water delivery services
2. Power generation facilities
3. Solid waste facilities
4. Wastewater facilities
5. Port facilities
6. Airport facilities
7. All other buildings and facilities not included in the sectors above

The LGO Protocol also recommends using one of two emission factors for electricity consumption:

1. **Verified utility-specific emission factors, which must be third-party verified to the standard of CCAR Power/Utility Protocol or The Climate Registry (TCR) Electric Power Sector Protocol.** According to The Climate Registry's website, only Seattle City Light has TRC-verified emission rates and only for 2013. [16]

Seattle City Light submitted more updated emission rates in 2016 and expects to have updated verified rates by 2017.

2. **Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database's (eGRID) subregion default emissions factors.** Emissions reductions related to RECs are not allowed if using this factor, as the renewable energy attributes are already calculated in the region's eGRID emissions factor.

GHG Protocol

GHG Protocol *Scope 2 Guidance* also offers two approaches to emission factors. If differentiated energy products in the form of contractual instruments (including direct contracts, certificates, or supplier-specific information) are *not* available in an organization's energy market, then the organization should only report emissions based on location-based emission factors. Organizations with access to differentiated energy products should have *dual* reporting of emissions using both location- and market-based emission factors:

3. **Location-based emission factors**, which are based on average grid emission factors.
4. **Market-based emission factors**, which first take into account any contracts, such as renewable energy certificates (RECs) that meet Scope 2 Quality Criteria and then apply a supplier-specific emission factor to the remaining energy demand. [5, p. 25]

If market-based emissions factors are used, they must meet Scope 2 Quality Criteria. Scope 2 Quality Criteria include specifications around the contractual instruments, such as that they convey a direct GHG emission rate, are the only instruments that carry the emission rate attribute claim, and can be tracked and redeemed, retired, or canceled by or on behalf of the reporting entity. For example, the Quality Criteria outline that RECs may only be considered in Scope 2 emission calculations if the supplier-specific emissions factors reflect the purchase and sale of RECs and RECs are retired through a tracking system, contract audit, third-party certification, or other disclosure mechanism. [5, p. 64]

If the required data for adjusting emission factors to account for RECs is not available, organizations must disclose that emissions have not been adjusted to reflect voluntary purchases, and must state that it may result in double counting. Reporters may also provide the information about the relative magnitude of this error, if available and appropriate. [5, p. 64]

The *Scope 2 Guidance* also clarifies how to account for on-site energy production. The guidance recommends that "for accurate Scope 2 GHG accounting, companies shall use the total—or gross—electricity purchases from the grid rather than grid purchases 'net' of generation." [5, p. 38]

Recommendations

Given the guidance and methodologies set forth in the *LGO Protocol* and *Scope 2 Guidance*, we recommend that DNRP review its emissions factors and activity data to ensure consistency with accepted protocols. Specifically, we recommend evaluating current energy consumption data to ensure inclusion of all consumed energy—including that offset by on-site production. Additionally, we recommend that DNRP explore the emission factors of its energy utilities to ensure that they comply with either the *LGO Protocol's* verification requirements or *Scope 2 Guidance's* Scope 2 Quality Criteria. Table 2 below summarizes DNRP and other identified methodologies for calculating emissions associated with electricity, and our consequent recommendations and rationale.

Table 2. Methodology recommendations for electricity

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Activity data	Net energy consumption	▪ **GHG Protocol Scope 2 Guidance**: gross energy consumption	▪ Use gross energy consumption. ▪ Report emissions by sector.	Gross energy consumption is consistent with the GHG Protocol's Scope 2 guidance.
Electricity emission factors	Utility-specific emission factors calculated by DNPR using Dept. of Commerce's Fuel Disclosures (SCL; PSE; SnoPUD)	▪ **GHG Protocol Scope 2 Guidance**: location- and market-based emission factors ▪ **LGO Protocol**: verified utility-specific emission factors or eGRID's subregion default emission factor are recommended option, while non-verified utility-specific emission factors are considered an "alternative" option. ▪ **Hermosa Beach**: verified utility-specific emission factors ▪ **Sound Transit:** utility-specific emission factors ▪ **Seattle**: utility-specific emission factors (subject to verification)	▪ Use utility emission factors that are verified and/or meet Scope 2 Quality Criteria. ▪ If utility-specific emission factors do not meet required criteria, use eGRID subregion default emission factors (i.e., standard emission factors) and/or most recently published verified utility-specific emission factors. ▪ Continue quantifying water use-related emissions using eGRID factors for Washington.	▪ Both the GHG Protocol and LGO Protocol stipulate quality/verification requirements for utility-specific emission factors. ▪ Location-based emissions are required in all cases by the GHG Protocol, though organizations may also report market-based emissions. ▪ The Department of Commerce Fuel Disclosures do not meet the Quality Criteria outlined in the Scope 2 Guidance. ▪ Ideally, the water use-related emissions would be based on the same (standard) emission factors rather than state-specific, non-baseload emission factors.

Electricity Supply and Reduced Consumption

Supplying electricity to the grid that has fewer emissions than the grid can result in GHG removals and reduced consumption of grid-provided electricity through energy efficiency. Onsite renewable energy generation can also reduce emissions. The exact amount of the removals and reductions depends on the methodology used.

Current Methodology

DNRP currently produces its own electricity through a large solar array at the Weyerhauser King County Aquatic Center, as well as at the West Point wastewater treatment plant. For the West Point plant, DNRP sells all environmental attributes associated with the energy production, and therefore does not include this energy in its GHG emissions and removals inventory.

DNRP is currently using a non-baseload emissions rate, also known as a marginal emissions coefficient, for estimating the GHG impact of all energy conservation projects and efficiency measures and for other planning purposes. The non-baseload emissions rate is provided by eGRID. Currently, King County does not provide any electricity to the grid for which is retains the environmental attributes required to claim the removal.

Other Methodologies

GHG Protocol

The Greenhouse Gas Protocol's *Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects* (Electricity Project Protocol) provides specific guidance regarding projects that either supply electricity to the grid or reduce the consumption of grid-supplied electricity. As noted in the guidance document, "different types of projects will have different impacts on the grid, [therefore]…standard baseline emission rates should be specified for types of project activities that share the same operating characteristics, and therefore have approximately the same effects on grid emissions." [17, p. 7]

The process for developing standard baseline emissions rates requires the following:

- Defining the GHG assessment boundary and identifying any secondary effects that may result from the project.
- Estimating the relative effects a project activity will have on new plant construction (i.e., build margin) and the dispatch of electricity from existing power plants (i.e., operating margin).

EPA

In addition to standard emission factors, eGRID provides non-baseload emissions rates as "an estimate of emission reduction benefits from energy efficiency and clean energy projects." [18, p. 11] This separate estimate was developed in recognition that non-baseload power can have a very different emissions profile than baseload power. Non-baseload refers to power that is generated to meet peak demand rather than constant, or baseload, demand. Peak demand is often associated with higher emissions rates as peak resources must be able to turn on quickly. For example, natural gas plants can generate energy much more quickly than hydropower plants. However, the timing of peak demand changes over the course of the day and the year. Therefore, the guidance provided by EPA states that non-baseload values "may be less appropriate when attempting to determine the emission benefits of resources that operate fairly constantly or operate mostly during off peak times." [18, p. 11] Additionally, EPA notes that, in some locations, the timing of intermittent renewable resources, such as wind power, may affect the appropriateness of this factor as well. [18, p. 11]

Use of the non-baseload emission factor for estimating project benefits creates an inherent disconnect with the overall treatment of energy-related emissions. For example, estimating a project's benefits using the non-baseload emission factor will result in a higher level of estimated reductions than the incremental difference between energy use before and after the project was implemented reflected in an annual inventory. This is because the annual inventory process does not differentiate emissions based on the timing on energy consumption. Therefore, the EPA recommends that the standard emission factor is used when an inventory has been prepared or is the driving force behand the project. [18, p. 15]

Recommendations

For consistency with the treatment of electricity in other sections of the inventory, we recommend using the same emission factor to calculate removals associated with the production of electricity as used for consumption (see Table 2). Table 3 below summarizes DNRP and other identified methodologies for calculating emissions associated with electricity supply and reduced consumption, and our consequent recommendations and rationale.

Table 3. Methodology recommendations for electricity supply and reduced consumption

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Marginal efficiencies	eGRID non-baseload emission factor	▪ **Electricity Project Protocol**: methodology for calculating project-specific emission factors ▪ **EPA**: guidance regarding use of non-baseload emission factor vs. standard emission factor	Use the same emission factor as for energy consumption (may be specific to the utility that serves the facility; see Table 2).	This approach is consistent with the treatment of the other electricity sources (i.e., default rather than non-baseload) in DNRP's inventory.
Electricity sold to the grid	N/A as DNRP sells the RECs to SCL	N/A	N/A	N/A

Combined Heat and Power

Combined heat and power (CHP), also known as cogeneration, simultaneously generates electricity and useful heating. When fuels are used in CHP processes, the emission factors are generally lower due to the thermodynamically efficient use of the fuel.

Current Methodology

DNRP currently calculates the anthropogenic emissions associated with its CHP plant by multiplying estimated diesel quantities and known natural gas and propane quantities by their associated standard TCR emission factors.

Other Methodologies

LGO Protocol

The LGO Protocol states that there are two primary approaches for estimating emissions from CHP facilities. The recommended methodology accounts for the increased efficiency of CHP plants and is called the product steam method. In this method, the reporting organization determines the "share" of total emissions associated with electricity and heat by using a ratio based on the Btu content of each relative to the plant's total output. This methodology is described in detail starting on page 51 of the LGO Protocol. [2, p. 51]

The second approach outlined by the LGO Protocol separately calculates the emissions from steam and electricity. In this approach, the emission factors assume the standard efficiencies of conventional boilers and grid electricity, respectively. Accordingly, this approach overestimates the emissions of the steam since CHP processes are always more efficient than conventional boilers. Additionally, this approach likely overestimates the emissions from electricity as grid-supplied electricity may be produced less efficiently than at the CHP plant. [2 p. 54]

GHG Protocol

The GHG Protocol also states the importance of allocating emissions between the electricity and heat (usually steam), especially when the electricity and heat are not sold together to the same organization. [19, p. 3] The GHG Protocol also notes that there are many different ratios that could be used to allocate emissions from the CHP plant. The three most common methods are based on efficiency, energy content, and work potential. While the LGO Protocol effectively recommends the energy content method, the GHG Protocol recommends the efficiency method. In the efficiency method, emissions are allocated based on the energy inputs used to produce the separate steam and electricity products. [2, p. 4] The efficiency method therefore inherently accounts for the efficient conversion of fuel to steam. [2, p. 6]

EPA

EPA's methodology for allocating emissions to develop eGRID emission factors assumes an equal ratio between heat and electricity for CHP facilities. [13, p. 5]

Recommendations

Table 4 below summarizes DNRP and other identified methodologies for calculating emissions associated with combined heat and power, and our consequent recommendations and rationale.

Table 4. Methodology recommendations for combined heat and power

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Emissions split between electricity and heat	Emission factors associated with conventional boilers and grid-supplied electricity (consistent with LGO's alternative approach)	▪ **LGO approach:** product steam method (i.e., energy content method) ▪ **LGO alternative approach:** separate emission factors for heat and electricity ▪ **GHG Protocol**: efficiency method ▪ **EPA:** equal split between heat and electricity	**Tier 1** Use a method of allocating emissions (either the efficiency method or energy content method) based on available data. **Tier 2** Continue current methodology.	**Tier 1** For accuracy, CHP emissions should reflect higher process efficiency. Also, the steam and electricity are not sold together, so it's important to separately account for the emissions. **Tier 2** The current approach is consistent with LGO's alternative approach.

Natural Gas, Propane, and Diesel

Natural gas, heating oil, and propane are most commonly used in stationary combustion to produce electricity, heat, or motive power. Stationary combustion is a Scope 1 emission source that is based on fuel use by fuel type. Emissions from stationary combustion can vary based on the carbon content and heat content of the fuels. In addition to fuel characteristics, technology type, combustion characteristics, use of pollution control equipment, and maintenance and operational practices can influence CH_4 and N_2O emissions.

Current Methodology

For stationary combustion sources, DNRP uses the 2008 emission factors published by The Climate Registry, activity data based on estimates for diesel, and actual data for natural gas and propane.

Other Methodologies

LGO Protocol

According to the LGO Protocol, measured fuel characteristics should be used over default values whenever possible. The carbon content and heat content of the fuels can be determined through fuel sampling and analysis or from data provided by suppliers. If using the fuel sampling and analysis approach, do so according to the applicable industry--approved, national, or international technical standards.

According to the LGO Protocol, "For most local government operations, you will use the "commercial/institutional" sector emission factors to determine CH_4 and N_2O emissions. However, because local government services are so diverse, the Protocol includes other sectors that may be more appropriate, depending on the facility in question." [2, p. 32]

GHG Protocol

The GHG Protocol confirms the appropriateness of using a calculation-based methodology that involves monitoring the fuel consumption rates and fuel composition and adjusting for the oxidization fraction. The GHG Protocol also states that direct measurement is also acceptable. Specifically, direct measurement may involve continuous emissions monitoring systems or discontinuous measurements made for verification or calibration purposes. [20, p. 13]

Recommendations

Table 5 below summarizes DNRP and other identified methodologies for calculating emissions associated with natural gas, heating oil, propane, and diesel, and our consequent recommendations and rationale.

Table 5. Methodology recommendations for natural gas, heating oil, propane, and diesel

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Emissions factors	TCR default emissions factors	▪ **LGO Protocol:** update factors for carbon content, heat content, and oxidization rate based on sampling data ▪ **GHG Protocol:** Sampling method or direct measurement of emission factors ▪ **Hermosa Beach:** LGO Protocol	Use 2015 TCR's default emission factors and adjust carbon content (MMBTU), heat content, and oxidization rate, if known.	Use the most contemporaneous emission factors and reflect differences, where known, to ensure accuracy.

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Reporting	Total emissions	▪ **LGO Protocol:** report by sector	Report emissions by sector.	Reporting by sector helps identify opportunities for reductions and makes the inventory results comparable to those of other jurisdictions.

Fuel Supplied to Regional Pipelines

Supplying low emission fuels to the regional pipeline can result in removals if doing so results in lower emissions than the counter-factual, or baseline, scenario.

Current Methodology

King County does not currently claim the removals associated with selling biomethane purified and sold from South Plant, though they are proposing it as a removal moving forward. DNRP is proposing to calculate the removal assuming that the biomethane will directly displace fossil fuel gas usage. Therefore, DNRP is intending to use the emission factor for natural gas to calculate the amount of the removal.

Other Methodologies

CAR

There are currently no approved protocols regarding biomethane generated from wastewater treatment plants. However, the Climate Action Reserve's U.S. Landfill Project Protocol has the following requirements for selling biogas from landfills that may prove useful when considering the additionality requirements embedded in the Project Protocol:

- The facility must not be required to capture biogas.
- The technology used to capture biogas must not be common in the market place.
- The return from capturing and selling the biogas must not be economic without the consideration of environmental attributes.

Furthermore, when generating the baseline scenario per the Project Protocol, it is important to understand the counter-factual scenario. Specifically, it is important to understand the fuel mix within the regional pipelines.

Recommendations

Since there are no verified protocols governing the supply of biofuels to a regional pipeline, we recommend following the Project Protocol described in Appendix B. Table 6 below summarizes DNRP and other identified methodologies for calculating emissions associated with fuel supply, and our consequent recommendations and rationale.

Table 6. Methodology recommendations for removals related to fuel supplied to regional pipeline

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Emissions factors	Use the emission factor for natural gas to calculate removal.	No verified protocols, though CAR's U.S. Landfill Project Protocol and the Project Protocol provide useful guidance	Quantify removals based on Project Protocol described in Appendix B.	Removals must be based on a baseline that establishes the counter-factual scenario, including what percent of fossil fuel use is avoided.

Fleets, Travel, and Commuting

Vehicle Fleets

Emissions from vehicle fleets include mobile combustion of traditional and biofuel vehicles, alternative fuel vehicles, and electric vehicles (EV). Typically, a local government's vehicle fleet is reported as two sectors: 1) transit fleet and 2) all other fleet vehicles. [2, p. 64]

Standard Vehicles

Combustion from mobile sources include both on- and off-road vehicles such as automobiles, trucks, buses, trains, ships and other marine vessels, airplanes, tractors, and construction equipment. These sources combust fossil fuels that emit CO_2, CH_4, and N_2O. [2, p. 64]

Current Methodology

Current emission factors used by DNRP are based on TCR emission factors published in 2008. Some fuel oil consumed by fleet vehicles is derived from heating oil that was initially used in tractor-trailer engines. Actual volumes burned are indirect and assumed to be the total volume delivered for the vehicle engines. [21] Most of the fuel use data for fleet vehicles is obtained through fleet staff and directly from the wastewater biosolids fleet. Fleet division data is organized by division and work unit.

Other Methodologies

The LGO Protocol states that CO_2 emissions account for the majority of emissions from mobile sources and can be calculated using fuel consumption data (known fuel use). [2, p. 64] CH_4 and N_2O emissions calculations require information on vehicle characteristics (e.g., emissions control technologies) and vehicle miles traveled. As a result, CO_2 guidance is provided separately from CH_4 and N_2O guidance. [2, p. 64] The GHG Protocol offers a fuel-based methodology for mobile combustion emissions that is similar to the LGO Protocol, so it is not included in this section to avoid redundancy.

LGO Recommended Approach

CO_2 Emissions from Mobile Combustion Sources

The LGO Protocol recommends using known fuel use to calculate CO_2 emissions from mobile combustion sources. This requires obtaining data on actual fuel consumption by fuel type and using the national default emission factors for each fuel type. This calculation involves three steps: (1) identify total annual fuel consumption by fuel type; (2) determine the appropriate emission factor (use national default for the given fuel type); and (3) calculate total CO_2 emissions. [2 p. 65]

CH_4 and N_2O Emissions from Mobile Combustion

The LGO Protocol's recommended approach is to estimate emissions based on fuel use by vehicle type, model year, and fuel type. This requires identifying all vehicles owned and operated by the agency and associated mileage. The agency can then select the appropriate emission factor for each vehicle type using the LGO Protocol default emission factors for highway and non-highway vehicles (organized by model year). [2, pp. 70-71]

LGO Alternative Approach

CO_2 Emissions from Mobile Combustion (Alternative)

The LGO Protocol provides an alternative methodology for local governments that lack fuel use data but have detailed information on fleet and annual mileage by vehicle. In this case, fuel consumption can be estimated based on vehicle characteristics (make, model, and year) and fuel type once annual mileage traveled by each vehicle is identified. local governments can determine vehicle fuel economy using EPA's fuel economy website (www.fueleconomy.gov), which assumes 45 percent of vehicle miles traveled (VMT) is highway driving and 55 percent is city driving. In the case of heavy duty truck, fuel economy should be available from vehicle suppliers or manufacturers.

CH_4 and N_2O Emissions from Mobile Combustion (Alternative)

The LGO Protocol provides an alternative methodology that can be used if mileage data cannot be obtained, but fuel consumption data is available. The methodology involves estimating annual mileage for each vehicle type based on an assumed proportion of city and highway driving and associated fuel use efficiencies.

Recommendations

Both of the LGO Protocol approaches are based on known fuel use or mileage data. We recommend that King County follow the standard/recommended LGO Protocol methodology along with the most up-to-date emissions factors and assumptions from TCR to calculate vehicle emissions. Table 7 below summarizes these recommendations, along with DNRP and other identified methodologies for calculating emissions associated with mobile combustion from standard vehicles.

Table 7. Methodology recommendations for standard vehicle combustion

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Activity data	Fuel use data obtained from fleet staff and fuel vendors	▪ **LGO recommended:** emissions based on known fuel use and mileage data ▪ **LGO alternative**: emissions based on estimated fuel use and mileage data	▪ Use TCR's recommended approach. ▪ If activity data is currently estimated using assumptions, begin compiling data from actual records.	Using accurate activity data will optimize accuracy.
Emission Factors	LGO emission factors from 2008 publication	▪ **LGO recommended:** national defaults for fuel type and vehicle characteristics ▪ **LGO alternative:** national defaults for fuel type and vehicle characteristics	Use updated LGO protocol to apply emission factors that correspond with vehicle year (for CH_4 and N_2O).	Calculations should be based on most current published list of emissions factors, by vehicle age and type for CH_4 and N_2O.

**This procedure applies only to highway vehicles and alternative fuel vehicles. For non-highway vehicles (e.g., ships, aircraft, non-road vehicles), use the known fuel use CO_2 methodology described above.*

Vehicles Combusting Biofuels

Current Methodology

DNRP currently accounts for biofuel combustion emissions based on the biogenic and anthropogenic sources. Specifically, DNRP's methodology separates out the fuel components and then apply emission factors to quantities determined from fuel bills from fuel provides. For example, if DNRP uses 100 gallons of 20% biodiesel (B20), they calculate the biogenic emissions for 20 gallons of 100% biodiesel and 80 gallons of fossil fuel diesel.

Each biogenic source has a prescribed emission factor based on the California Air Resources Board's Low Carbon Fuel Standard Program (CA-LCFS) carbon intensity lookup tables, which are based on the CA-GREET model. For biogenic sources that are unknown or averaged, a generic emission factor is applied based on EPA regulations for the National Renewable Fuel Standard for 2010 and beyond. Anthropogenic sources are based on TCR emission factors published in 2008.

Other Methodologies

LGO Recommended Approach

CO_2 Emissions from Biofuels

For vehicles that run on pure biofuels, the recommended LGO Protocol approach is equivalent to that for other standard fuel vehicles (see "Standard Vehicles" section above), save for the application of a biofuel-specific emission factor. However, since biofuel blends create emissions of both fossil CO_2 and biogenic CO_2, they must be separately reported for each fuel. [2, p. 69] Biofuel emissions are therefore calculated based on the blend being used, annual combustion, and the appropriate emissions factor for both anthropogenic and biogenic sources.

CH_4 and N_2O Emissions from Biofuels

The LGO Protocol recommends that CH_4 and N_2O emissions are calculated based on activity data such as annual mileage by vehicle type, model year, and fuel type for highway vehicles only. For non-highway vehicles, the LGO Protocol recommends to use the same fuel consumption data used to estimate CO_2 emissions in the previous section, with the appropriate emission factor applied for each vehicle type. [2, pp. 70-71]

LGO Alternative Approach

If the local government does not have mileage data, the LGO Protocol recommends using fuel consumption data by vehicle type and estimated VMT using vehicle type-specific fuel economy factors. Then, the methodology described above in the section titled "CO_2 Emissions from Mobile Combustion (Alternative)" is applied. Calculations for each type of vehicle must be done separately; if only bulk fuel purchase data is available, consumption should be allocated across vehicle types and model year in proportion to the fuel consumption distribution among vehicle type and model years, based on the agency's usage data.

Recommendations

The LGO Protocol's recommended approach for biofuel emissions requires calculations based on both biogenic and fossil fuel sources. We recommend that DNRP continue its current use of emission factors for biogenic sources and anthropogenic sources. Table 8 below summarizes these recommendations and DNRP and other identified methodologies for calculating emissions associated with biofuel combustion.

Table 8. Methodology recommendations for vehicles combusting biofuels

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Activity data	Fuel use data obtained from fuel vendor bills	▪ **LGO recommended:** emissions based on known fuel use and mileage data ▪ **LGO alternative:** emissions based on estimated fuel use and mileage data	Use the LGO Protocol's recommended approach.	Using accurate activity data helps avoid miscalculations or generalizations.
Emission factors	Emission factors based on biogenic source/generic factor if source is unknown based on EPA (2010).	Use default emission factors for transport fuels (LGO Protocol)	▪ Use current emission factors for specific sources. ▪ Use LGO Protocol's default emissions factors for transport fuels for other sources.	Using specific emission factors for specific sources is above and beyond protocols but is already the practice of DNRP.

Electric Vehicles

Current Methodology

DNRP's emissions from EVs are captured through building energy use, so the methodology described in the "Electricity Use" section is applied to calculate electric vehicle emissions.

Other Methodologies

LGO Protocol

The LGO Protocol recommends calculating EV emissions using their recommended electricity consumption methodology (eGRID default emission factors). A detailed discussion on calculating electricity emissions can be found in the section titled "Electricity Use"." [2, p. 75]

GHG Protocol

The GHG Protocol also recommends reporting EV emissions as indirect emissions under Scope 2 in GHG Protocol's "Stationary Combustion Tool." Like for the LGO Protocol, the tool requires use of a region-specific emission factor found in the eGRID database (GHG Protocol, GHG emissions from purchased electricity (Excel worksheet), 2006).

Recommendations

It is unclear if DNRP accounts for EV emissions related to charging stations not owned or operated by King County. We recommend that these emissions should be calculated as well using appropriate activity data and eGRID emission factors. These recommendations and supporting rationale are summarized in Table 9 below.

Table 9. Methodology recommendations for electric and alternative fuel vehicles

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Emissions factor	Utility-specific emission factors calculated by DNPR using Dept. of Commerce Fuel Disclosures (SCL; PSE; SnoPUD)	▪ **LGO:** recommends subregion default eGRID emission factors ▪ **GHG Protocol's Stationary Combustion Tool**: subregion default eGRID emission factors	▪ Report emissions by sector. ▪ Use eGRID subregion default emission factors.	TCR and GHG agree on using activity data and eGRID emission factors.

Employee Commuting

According to the LGO Protocol, emissions associated with employee travel to and from work in vehicles not owned and operated by the agency are considered Scope 3 emissions.

Current Methodology

King County does not currently account for emissions related to employee commuting.

Other Methodologies

LGO Protocol

Local governments can influence these emissions through various programs (e.g., carpools or telecommuting). The LGO Protocol recommends calculating energy use and emissions associated with employee travel to and from work by first conducting a survey of all employees' commuting habits. This survey should include commute distance, mode, and frequency. Once accurate commuting information has been obtained, it is possible to use the same accounting methodology as described in the LGO Protocol's recommended approach for standard vehicles/mobile combustion found above. [2, p. 123] For commuters using other forms of transportation, such as transit, the LGO Protocol provides mode-specific emission factors based on statistics from the Federal Administration Highway. [22, p. 4]

GHG Protocol

The GHG Protocol lists three methods for accounting for employee commuting: fuel-based, distance-based, and average-data methods. The fuel-based method is similar to the LGO Protocol's method for known fuel use, wherein the amount of fuel consumed during commutes needs to be identified and the appropriate emission factor for the fuel type should be applied. The distance-based method relies on commuting habits and the emission factors for the transportation modes used. The average-data method is based on estimates of employee commuting derived from national averages regarding commuting patterns.

This protocol recommends that governments collect data on employee commuting using a survey to obtain data on distance travelled, mode of transit, number of commuting days, and energy used from telecommuting. [7, pp. 87-92]

Commute Trip Reduction Survey

The Commute Trip Reduction Survey (CTR) is organized through the Washington State Department of Transportation (WSDOT). The CTR can be used by localities to assess commuting habits of their employees. Additional “drive alone” trips are added if survey response rates are less than 70 percent based on the assumption that non-responding employees drive alone five days a week. Survey results are broken down by transit mode, employee zip code, and work schedules.

Recommendations

Each of the above methodologies recommends the use of a survey taken by all employees to gather needed activity data and commuting habits. The GHG Protocol may offer more flexibility in how this data is calculated based on the quality of data obtained from the survey. Table 10 below summarizes DNRP and other identified methodologies for calculating emissions associated with employee commuting and our consequent recommendations and rationale.

Table 10. Methodology recommendations for employee commuting

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Activity data	N/A	▪ **LGO Protocol**: survey results that include distance, mode, and frequency. ▪ **GHG Protocol**: fuel-based, distance-based, or average-data method, Agencies can extrapolate data from a representative sample if survey responses from every employee cannot be obtained. ▪ **Hermosa Beach**: uses activity data from a self-administered survey.[vi] Fill in non-answers with average response. ▪ **Sound Transit**: commute trip reduction (CTR) survey results. Fill in non-answers with average if over 70% response rate. Otherwise, fill in with drive alone assumption.	▪ Survey employees for activity data.	Survey is best way to obtain activity data. GHG Protocol offers alternative approaches based on activity data availability.

[vi] Respondents who drove city vehicles and also walked, bicycled, or used another form of transportation were excluded from the emissions inventory. Included employees were assumed to solely drive gasoline-fueled passenger vehicles. Commuting habits of employees that did not respond to the survey were estimated based on survey responses. Respondents who were not employed by the City in the years surveyed were also excluded from the emissions inventory. 29, p. 30

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Emission factors/ assumptions	N/A	▪ **LGO Protocol:** national defaults based on fuel type and vehicle characteristics. ▪ **GHG Protocol:** emission factors based on transportation mode. ▪ **Hermosa Beach:** assumed drive alone, gasoline passenger vehicle. ▪ **Sound Transit:** emissions calculated by WA State as part of the CTR survey.	▪ Use mode specific emission factors.	Mode-specific emissions factors are the most accurate.

Business Travel

Current DNRP Methodology

DNRP employee business travel is accounted for through fleet vehicle usage. The use of personal vehicles for business travel is considered too small to consider accounting for those emissions. For air travel, King County utilizes the "Myclimate Flight Calculator" to determine CO_2 emissions for passenger flights. These calculations are based on average consumption data for typical short-haul and long-haul aircraft based on the most recent international statistics on passenger aircraft type usage. Calculations account for total CO_2 emissions per flight and CO_2e emissions per individual passenger based on cargo weight and cabin class. [23, pp. 1-2]

Other Methodologies

LGO Protocol

The LGO Protocol recommends that local governments account for emissions and energy use associated with employee business travel with an established mechanism for tracking travel distances and modes for all business-related travel. Once this information is obtained, the same accounting methodology can be used as described in the LGO Protocol's recommended approach for standard vehicles/mobile combustion. [2, p. 123]

GHG Protocol

GHG Protocol lists three options for calculating emissions associated with business travel: (1) fuel-based method, (2) distance-based method, and (3) spend-based method. For information on calculating options 1 and 2, see the GHG Protocol section under "Employee Commuting" found above. Spend-based method requires determining the amount of money spent on each mode of business travel transport and applying a secondary (EEIO) emission factor. According to the GHG Protocol, this method should only be used if business travel does not significantly contribute to Scope 3 emissions or if engagement with travel providers is not relevant to business goals. [7, pp. 65, 86]

Climate Leaders GHG Inventory Protocol

For air travel, the 2008 Climate Leaders GHG Inventory Protocol divides emissions by flight distance (long, medium, and short haul). Estimations are based on emission factors determined by flight distance and type of emissions (CO_2, CH_4, or N_2O). If distance cannot be determined, calculations can be based on the use of a single passenger-mile emission factor for all airline travel based on passenger miles of domestic and international commercial flights.

Recommendations

DNRP's current methodology of excluding personal vehicle emissions is not consistent with other accounting principles. As a result, we recommend that DNRP account for personal vehicle use for business travel using the GHG Protocol approach, given its flexibility based on available data. Myclimate and Climate Leaders are similar in approach, so we recommend continued use of the Myclimate Flight Calculator. Table 11 below summarizes DNRP and other identified methodologies for calculating emissions associated with electricity supply and reduced consumption and our consequent recommendations and rationale.

Table 11. Methodology recommendations for business travel

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Flight emission factors	Air travel using myclimate flight calculator	▪ **LGO**: standard emission factors applied to actual activity data ▪ **GHG Protocol**: estimates based on dollar spent for each mode of travel	Continue using Myclimate flight calculator for air travel.	GHG Protocol offers alternative approaches based on activity data availability (more flexibility).
Vehicle use emission factors	Does not calculate emissions from personal vehicle	▪ **LGO**: standard emission factors applied to actual activity data ▪ **GHG Protocol**: estimates based on dollar spent for each mode of travel ▪ **Climate Leaders GHG Inventory Protocol**: emission factors for long-, medium-, and short-haul flights ▪ **Sound Transit**: Climate Leaders GHG Inventory Protocol	Follow the GHG Protocol for personal vehicles.	Myclimate and Climate Leaders are similar in approach.

Refrigerants and Fire Protection

Refrigerants

Buildings and facilities commonly contain refrigeration systems that consist of HFC compounds. Through the installation, use, and disposal of these systems, refrigerant leaks are likely to occur and are considered Scope 1 fugitive emissions.

On-road vehicles with air conditioning systems also use refrigerants that contain or consist of HFC compounds that should be reported. Some of these compounds have high global warming potentials (GWP) that can translate into significant GHG emissions. [2, p. 56] Air conditioning and refrigeration systems likely use refrigerants that have high GWPs that can translate into significant greenhouse gas emissions. Refrigerants that include HFCs are the primary GHG concern.

Current DNRP Methodology

DNRP does not currently include refrigerant use emissions in its inventory.

Other Methodologies

LGO Protocol

The LGO Protocol recommends the mass balance method to account for HFC emissions, especially if the agency services their own equipment. This relies on determining a base inventory of each HFC in use at each facility by recording the quantity in storage at the beginning of the year and at the end of the year. Governments can then calculate changes to the base inventory (e.g., purchases, disbursements, or changes in capacity). To determine annual emissions, the LGO Protocol recommends using the appropriate GWP to convert to CO2e and then summing across each type of HFC. [2, pp. 56-59]

GHG Protocol

GHG Protocol recommends a sales-based approach for users that maintain their own equipment. This is similar to LGO Protocol's mass balance method described above and can be accomplished based on the same process.

Recommendations

Table 12 below summarizes DNRP and other identified methodologies for calculating emissions associated with electricity supply and reduced consumption, and our consequent recommendations and rationale.

Table 12. Methodology recommendations for refrigerant use

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Approach to quantification	N/A	▪ **LGO**: mass balance method ▪ **GHG Protocol**: sales-based approach (i.e. mass balance method)	Use LGO/GHG mass balance method.	Mass balance method is most accurate for determining HFC emissions and is recommended for governments who service their own equipment. [2, p. 57]

Fire Protection

HFCs are commonly found in fire suppression equipment, including fire extinguishers. These HFCs are released when the equipment used and should be calculated if the owners of this equipment have ever tested or deployed these systems.

Current DNRP Methodology

DNRP does not currently incorporate fire protection-related emissions in its inventory.

Other Methodologies

LGO Protocol

The LGO Protocol's recommended approach is the mass balance method, described in the "Refrigerants" section above. [2, p. 56]

If an organization does not have the necessary data to use the mass balance approach, the LGO Protocol offers a simplified mass balance method as an alternative methodology. This methodology involves determining the types and quantities of HFC used at each facility and calculating annual emissions of each type by converting to units of CO_2e using the appropriate GWP for each HFC and summing across all HFCs used. This approach differs from the mass balance method in that it does not require establishing a base inventory for each HFC in use at each facility.

Recommendations

Although the LGO Protocol offers two approaches, they both rely on the mass balance method. This method is the most accurate for determining HFC emissions for governments that service their own equipment. Table 13 below summarizes DNRP and other identified methodologies for calculating emissions associated with electricity supply and reduced consumption, and our consequent recommendations and rationale.

Table 13. Methodology recommendations for fire protection equipment.

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Approach to quantification	N/A	▪ **LGO recommended:** mass balance method ▪ **LGO alternative:** simplified mass balance method	Use mass balance method.	Mass balance method is most accurate for determining HFC emissions and is recommended for governments who service their own equipment. [2, p. 57]

Wastewater Treatment

Conveyance and Onsite Systems

Wastewater treatment generates emissions associated with removing soluble organic matter, suspended solids, pathogenic organisms, and chemical contaminants. Specifically, microorganisms produce CH_4 emissions when biodegrading soluble organic material in wastewater under anaerobic conditions. The resulting biosolids may also further biodegrade under aerobic or anaerobic conditions. Additionally, the treatment of domestic wastewater during both nitrification and denitrification can generate N_2O emissions. N_2O can be an intermediate product of both processes, but—according to the LGO Protocol—it is more often associated with denitrification. [2 p. 106]

Current Methodology

DNRP estimates emissions associated with the fugitive emission activities using the methods described in Table 14.

Table 14. Fugitive emission activities associated with wastewater treatment

Activity	Associated Emissions	Rationale
Methane slippage related to pressurized water used to clean biogas scrubber	Assumes 4,350 $MTCO_2e$ per year based on calculated CH_4 sip of 2.5 percent in 2012.	Bases estimate on calculated methane slip of 2.5 percent in 2012. Still seeking means to verify extent of slippage.
Wastewater treatment process	Assumes 3.2 gm of N_2O production per capita per year based on IPCC estimate for plants without "intentional nitrification/denitrification."	Assumes minimal CH_4 production in anoxic or anaerobic zones due to low residence time and sub-optimal temperature for methanogen growth.
Supplemental and backup fuel use	Uses TRC default emission factors applied to amounts of diesel, natural gas, and propane used.	N/A
Uncombusted CH_4 in biogas	Assumes 1 percent of gas is uncombusted based on EPA estimates.	Assumes combustion systems in engines, turbines, and boilers are designed, operated and maintained such that no or negligible CH_4 is released.

Additionally, DNRP provides justification for assuming that emissions from the fugitive emission activities in Table 15 are negligible.

Table 15. Negligible fugitive emission activities associated with wastewater treatment

Activity	Rationale
Conveyance system activities	1. NW climate, hydraulics/relative sewage strength, and ventilation/oxygenation activities provide justification for negligible impact until more information is known. 2. Sampling program would need to be comprehensive and long-term to adequately assess annual CH4 production. 3. CO_2 emissions from monthly testing of diesel-powered emergency generators are included in the "Supplemental and backup fuel use" section.
Onsite biogas release	Open surface area along outside edge of floating cover amounts to only 1 percent of total digester surface area. The pressure of the biogas in the digester is very low, helping to minimize release. In addition, modeling conducted in 2008 shows hydraulic circulation in the digesters (downdraft from circulating solids along sidewall) would impede upflow of gas towards annular space.

Other Methodologies

LGO Protocol

The LGO Protocol estimates emissions associated with stationary, fugitive, and process emissions based on the data needs described in Table 16. This methodology requires data collection processes conforming to local, state, or federal regulations or permits or published industry-standardized sampling and testing methodologies.

As noted in the LGO Protocol, the IPCC, EPA, and others have been working to estimate GHG emissions from wastewater on a gross regional basis. However, there are not widely accepted, standardized guidelines to estimate emissions from wastewater treatment at a facility level. Therefore, the LGO Protocol provides guidance on estimating the process and fugitive emissions from wastewater treatment based on "top-down" methodologies used by ARB, EPA and others to estimate emissions for an entire state or county. [2 p. 107]

Table 16. LGO Protocol's recommendations regarding wastewater treatment emissions

GHG Type	GHG Source	Data Needed
Stationary CH_4 emissions	Incomplete combustion of digester gas at a centralized WWTP with anaerobic digestion of biosolids	▪ Digester gas (ft^3/day) ▪ Fraction of CH_4 in biogas
Process CH_4 emissions	Anaerobic and facultative treatment of lagoons	▪ BOD_5 load (kg BOD_5/day) ▪ Fraction of overall BOD_5 removal performance
Fugitive CH_4 emissions	Septic systems	▪ BOD_5 load (kg BOD_5/person/day)
Process N_2O emissions	Centralized WWTP w/ and w/o nitrification/ denitrification	▪ Population served, separated into industrial (including commercial) population and non-industrial population
Process N_2O emissions	Effluent discharge to receiving aquatic environments	▪ N load (kg N/day)

GHG Protocol

Separate methodologies are published by the GHG Protocol's for Community-Scale Greenhous Gas Emission Inventories. These methodologies are focused less on measurement and more on community-specific estimates, such as per capita consumption of protein. [9 p.103]

Recommendations

Table 17 below summarizes DNRP and other identified methodologies for calculating emissions associated with wastewater treatment, and our consequent recommendations and rationale.

Table 17. Methodology recommendations for wastewater treatment

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Approach to quantification	Combination of measurements from previous years and estimates from EPA and IPCC.	▪ **LGO Protocol**: data collection using published sampling protocols ▪ **GHG Protocol**: calculations are based on assumptions and values of community	▪ Use measurement-based calculations recommended by the LGO Protocol. ▪ Use published sampling protocols. ▪ If variability due to plant conditions is high, support this assertion through sensitivity testing.	There is no widely-accepted, standardized methodology for estimating emissions from individual wastewater facilities, but measurement-based emissions are most accurate.

Loop Biosolids

Biosolids can be applied to lands as a soil amendment or fertilizer. Recent research indicates that using biosolids in these ways can sequester carbon in the soil and displace emissions associated with the use of synthetic fertilizer. Research by the University of Washington and Washington State University has shown that using biosolids reduces emissions through three pathways:

1. Some portion of the carbon in biosolids will stay in the soil.

2. Biosolids increase plant growth, which increases both aboveground sequestration and adds to soil carbon through root growth and detritus. (This pathway is only relevant when biosolids are not displacing another equally effective fertilizer.)
3. Where biosolids displace synthetic fertilizers, GHG emissions associated with manufacturing the synthetic fertilizers are avoided.

Current Methodology

DNRP's current methodology calculated the removal related to the accumulation of carbon in the soil and the replacement of synthetic fertilizer.

The accumulation of carbon in soil calculation is based on data from field tests conducted by the University of Washington and Washington State University where Loop biosolids have been applied for the last 7 and 14 years. The results of the field tests vary by geography and use. Specific values are used for agricultural application in eastern Washington, compost use in western Washington, and application of soil amendments to forests in Western Washington.

The removal related to replacement of synthetic fertilizers is based on the avoided emissions associated with manufacturing nitrogen and phosphorus fertilizers. The emission factor is based on a weighted average of emissions related to nitrogen and phosphorus fertilizers, respectively, in a ratio approximately equal to the profile of biosolids produced at DNRP's applicable plants; the sources of biosolids vary depending on the end use.

The emission removals associated with the Loop biosolids are offset by emissions related to 1) burning fuel used by tractors and other equipment at the application site (unless equipment is owned by DNRP, in which case emissions are already included in Scope 1 emissions) and 2) N_2O emissions from the microbial degradation of nitrogen in the biosolids. Fuel-related emissions are based on the average fuel needed to apply one metric ton of biosolids. Data from the field studies shows no increase in N_2O emissions at biosolids application sites.

Other Methodologies

We are unaware of any approved offset-quantification methodologies that govern all three GHG reduction mechanisms listed above. However, a number of methodologies treat one or two of them as components of GHG reduction pathways different from King County's biosolids processes. For example, VCS treats soil carbon generally in VM0021 *Soil Carbon Quantification Methodology v1.0,* albeit primarily in grasslands. CDM AMS-III.A *Offsetting of Synthetic Nitrogen Fertilizers by Inoculant Application in Legumes-Grass Rotations on Acidic Soils on Existing Cropland v3.0* treats displacement of synthetic fertilizers, but again only in the highly specific context described in the title.

These and several other existing methodologies can offer components of an eventual offset standard relevant to Loop biosolids, but none describe GHG reduction mechanisms sufficiently similar to King County's program that they can be applied to quantify GHG removals against the County's inventory. However, any specific emissions-reduction activity could be quantified guidance offered from the *GHG Protocol for Project Accounting*, which includes specifications around accounting for baseline emissions, demonstrating additionality, and ongoing monitoring and quantification.

Recommendations

There are few available protocols to guide accounting for DRNP's application of Loop biosolids. Given this scarcity, we provide two recommendations: 1) for the time being, account for Loop biosolids removals by following guidance provided by the *GHG Protocol for Project Accounting*, and 2) in the meantime, work with an offset methodology steward like VCS or the ACR to collaboratively develop a new methodology specific to the Loop biosolid application process. At a minimum, we recommend that DNRP fully reflect and account for removals *net* of an established baseline scenario. For example, DNRP should ensure that when comparing to application of synthetic fertilizers, all differences are taken into account, including any differences in required quantities and any associated transportation and storage emissions. Table 18 below summarizes DNRP and other identified methodologies for calculating emissions associated with wastewater treatment, and our consequent recommendations and rationale.

Table 18. Methodology recommendations for Loop biosolids

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Loop biosolids emissions	Emission factors for applying biosolids onsite are multiplied by biosolids tons applied at the three location types and debited against removals.	N/A	▪ Include all emissions related to transporting biosolids, not just those related to DNRP vehicles or applying biosolids on site.	Accounting for all known and quantifiable emissions is more accurate and consistent with other DNRP approaches (e.g., measuring purchasing emissions).
Loop biosolids removals	Avoided emission factors are multiplied by biosolids tons applied at the three location types.	N/A	**Tier 1** ▪ Develop an appropriate offset methodology with American Carbon Registry or Verified Carbon Standard. **Tier 2** ▪ Ensure that approach is consistent with GHG Protocol for Project Accounting (e.g., take into account full baseline scenario to estimate net removals).	Removals must be treated conservatively and included only if additional to a baseline. **Tier 1** Approved methodologies ensure that removals are additional. **Tier 2** Quantified removals are calculated to reflect additional removals without the administrative burden of the approval process.

Forests

Carbon Sequestered by Growth of DNRP-Owned Forests

Current DNRP Methodology

DNRP does not currently include carbon sequestration from its 21,849 acres of DNRP-owned lands classified as multi-use, working forest, and resource (omits recreation parks). DNRP lands are managed both passively and actively; actively managed lands undertake active forest stewardship practices, including thinning and invasive species removal, that result in enhanced sequestration as compared to passively managed forests.

Other Methodologies

DNRP activities on DNRP-owned land could fall under two primary types of offset methodologies, discussed in detail below:

- For **improvement forest management** practices that maintain or increase carbon stocks on forested land relative to baseline levels of carbon stocks
- For **avoided conversion** projects that prevent the conversion of forestland to a non-forest land use by dedicated the land to continuous forest cover through a conservation easement or transfer to public ownership

Duke University examined CAR and ACR protocols in their assessment of university-owned forest carbon removals. [24] These protocols were chosen because they address the carbon accounting guiding principles, explicitly provide project-based protocols, are scientifically rigorous in their carbon quantification methods, and have industry support for their quality standards.

In this assessment, we examine the following protocols:

- Climate Action Reserve's *Forest Project Protocol*
- California Air Resources Board's (ARB) *Compliance Offset Protocol for U.S. Forest Projects*
- Verified Carbon Standard's methodologies, including *Methodology for Avoided Ecosystem Conversion* and methodologies for improved forest management
- American Carbon Registry's *Improved Forest Management Methodology for Quantifying GHG Removals and Emissions Reductions through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands*

All these protocols are similar, with some technical differences. In general, DNRP could pursue use of any of these protocols, depending on the particular application and context, as they are produced by widely accepted registries and organizations. If DNRP were to choose, we recommend considering the ARB protocol because it has been recently used in the region for a similar purpose (namely toward reaching Microsoft 's carbon neutrality goal) and was released most recently (2015). However, CAR, VCS, and ACR protocols are also suitable for DNRP's forestry applications, and may be more applicable, as the ARB protocol eligibility requirements can be more limiting in some cases.

Avoided Conversion

Several accepted protocols provide guidance for quantifying removals associated with avoided conversion, including the following described in more detail below:

- Climate Action Reserve's *Forest Project Protocol*
- California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects*
- Verified Carbon Standard's *Methodology for Avoided Ecosystem Conversion*

Climate Action Reserve's Forest Project Protocol

The California Air Resources Board's (ARB) *Compliance Offset Protocol for U.S. Forest Projects* was originally developed based on the CAR *Forest Project Protocol* Version 3.2. In 2012, CAR released Version 3.3, which involved minor editorial changes and clarifications as well as improved guidance based on recommendations from soil carbon, lying dead wood, and sustainable forestry certification white papers and stakeholder comment processes.

Differences between the CAR *Forest Project Protocol* and ARB *Compliance Offset Protocol* include the following:[vii]

- ARB will accept projects that began as early as 2007, whereas CAR will only accept new projects.
- ARB limits quantification of carbon stocks to the use of approved allometric equations, based on an annual measurement of all project trees or a representative sample, whereas CAR provides for other options.
- Remote sampling of project trees is not allowed under the ARB compliance protocol.
- ARB requires more detailed documentation of inputs for project quantification, and a greater number of parameters must be tracked and reported.

Because the ARB *Compliance Offset Protocol* was originally built from the CAR *Forest Project Protocol*, we considered an in-depth examination of the ARB protocol as a suitable proxy for the CAR *Forest Project Protocol*. However, we recommend that DNRP explore the CAR *Forest Project Protocol* should any of the differences between the two protocols (see bullet list above) warrant further investigation.

California Air Resources Board's Compliance Offset Protocol

The *Compliance Offset Protocol for U.S. Forest Projects* provides the following information:

- offset project eligibility rules;
- methods to calculate an offset project's net effects on greenhouse gas (GHG) emissions and removals of CO_2 from the atmosphere (removals);
- procedures for assessing the risk that carbon sequestered by a project may be reversed (i.e. released back to the atmosphere); and
- approaches for long-term project monitoring and reporting.

The protocol, which is built off The Climate Action Reserve's *Forest Project Protocol Version 3.2.1*, includes guidance for reforestation, improved forest management, and avoided conversion. (Avoided conversion may involve tree planting and harvesting.)

[vii] Source: file:///C:/Users/andream/Downloads/Comparison_of_Reserve_UFPP_to_ARB_COP_UF_Projects.pdf

Avoided conversion projects under the *Compliance Offset Protocol for U.S. Forest Projects* must satisfy the following requirements:

- Demonstrated significant threat of conversion of project land to non-forest land use by following the requirements for establishing the project's baseline (see more detailed discussion of baseline in Appendix A).
- Not on lands that were part of a previously listed and verified Forest Project.
- On lands that are privately owned prior to offset project commencement.
- Ability to achieve GHG reductions or removal enhancements above and beyond any which would result from compliance with federal, state, or local law, regulation, or ordinance. This can be assessed using a "Performance Test," which includes a real estate appraisal for the project area that indicates that the area is both suitable for conversion and that the alternative land use has a higher market value than forestland.

Eligible projects are baselined using models based on initial field inventory measurements and expected land-use conversion rates and are evaluated using field measurements and updated forest carbon inventories. Each year, the project's actual onsite carbon stocks must be determined and compared to baseline carbon stocks to arrive at the project annual removal estimate (see Appendix A for a more detailed methodology).

VCS Protocol

The VCS *Methodology for Avoided Ecosystem Conversion* provides voluntary guidance on quantifying removals associated with prevented conversion of forest to non-forest land. The methodology requires choosing among eight baselines based on the identified proximate agent of conversion, drivers of conversion, and progression of conversion. When the agents of conversion are not known, they can be identified using expert knowledge or a participatory rural appraisal (a type of community survey). Each baseline type is characterized by baseline emissions models that are applied to a project accounting area. These models, including the Biomass Emissions Model and Soil Emissions Model, have fairly straightforward parameterization and implementation requirements—depending on the baseline type, model parameters can be selected from defaults or estimated from data. Leakage must be quantified using activity-shifting leakage, market leakage, and reference areas, and the methodology requires monitoring of carbon stocks using a sample of fixed area plots in the project accounting and proxy areas.

Improved Forest Management

Several accepted protocols provide guidance for quantifying removals associated with improved forest management, including the following described in more detail below:

- California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects*
- American Carbon Registry's *Improved Forest Management Methodology*
- Verified Carbon Standard's *Methodology for Improved Forest Management Through Extension of Rotation Age (IFM ERA)*
- U.S. Department of Energy's *Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program, Forestry Appendix*

ARB's Compliance Offset Protocol

In fall 2015, Microsoft purchased roughly 35,000 in carbon credits from the Nisqually Carbon Project as part of its own initiative to be carbon-neutral in its data centers, offices, software development labs, and employee air travel. The project includes protection of 520 acres of Douglas fir and western hemlocks so the trees can store carbon dioxide for an additional 100 years. Offsets were verified to standards set forth by the California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects*.

The *Compliance Offset Protocol for U.S. Forest Projects* also provides a methodology for improved forest management projects. The following types of management activities are included:

- Increasing the overall age of the forest by increasing rotation ages.
- Increasing the forest productivity by thinning, diseased, and suppressed trees.
- Managing competing brush and short-lived forest species.
- Increasing the stocking of trees on understocked areas.
- Maintaining stocks at a high level.

Projects on both private and public lands are eligible. Other eligibility requirements are similar to those for avoided conversion projects, including:

- Project must take place on land with greater than 10 percent tree canopy cover.
- Project must employ natural forest management practices.
- Project must not employ broadcast fertilization.
- Project must not take place on land previously listed as a verified or voluntary offset project.

Like for avoided conversion projects, improved forest management projects must satisfy additionality and monitoring requirements. Projects must undertake particular management practices, including natural forest management and sustainable harvesting practices. Examples of required practices include restricting harvesting to stands no greater than 40 acres and establishing/maintaining forest types that are native to the project area. Projects must also model and track standing live carbon, standing dead carbon, carbon in in-use forest products, and biological emissions from site preparation activities. The project baseline is established similarly to avoided conversion but uses a different method for projecting future changes to project area forest carbon stocks (extrapolating from historical trends instead of modeling conversion rates).

Paula Swedeen, technical lead on the Microsoft offset project, summarized their process for calculating the baseline as follows: [25]

1. "Establishing where projects carbon stocks at beginning of the project are in relation to a regional average stocking, based on Forest Inventory and Analysis (FIA) plots on non-federal lands by eco-region.
2. If a project is above the regional average, one then calculates a 100-year average carbon stocking based on a legally permissible and financially feasible harvest regime. For our project, this was a 40-45 year rotation and taking into account all relevant State Forest Practices rule and ESA requirements. (Projects that start below the regional average are eligible, but they don't pencil out financially for project developers).
3. Calculate carbon stored in harvested wood products under the baseline scenario compared to project harvest for the years getting verified.

4. Available credits for the first issuance are the delta between starting stocks and the 100-year average baseline, minus some calculation factors for harvested wood products and potentially a deduction if inventory data had error rates above +/- 5% at the 90% confidence interval. There is a mandatory buffer pool (insurance risk pool) contribution of about 19% of issued credits.
5. Credits for subsequent years are based on net carbon accumulation compared to the last verification, calculated on an annual basis."

ACR Protocol

The American Carbon Registry's *Improved Forest Management Methodology for Quantifying GHG Removals and Emissions Reductions through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands* provides a similar methodology for quantifying removals associated with improved forest management. Baseline determination under this methodology is defined as the harvesting scenario that would maximize net present value of perpetual wood products harvests, using discount rates specific to land ownership classes. (For non-federal public lands, this value is 4%.) Projects must also demonstrate no activity-shifting leakage above a 3% *de minimis* threshold (i.e., 3% of the final calculation of emissions reductions or removals). Similar to the California protocol, public non-federal ownerships must either be certified by FSC, SFI, or ATFS OR to have its forest management plan sanctioned by elected government officials within a state or federal agency. Projects proponents must also demonstrate ownership or control of timber rights for 12 or more months prior to the project start date.

Under the ACR methodology, if the project start date is more than one year before submission of the GHG plan, the project proponent must provide evidence that GHG mitigation was seriously considered in the decision to proceed with the project activity. Evidence is based on official and/or legal documentation. Early actors undertaking voluntary activities to increase forest carbon sequestration prior to the release of this requirement may submit as evidence recorded conservation easements or other deed restrictions that affect onsite carbon stocks.

VCS Protocols

The Verified Carbon Standard provides several approved protocols and tools for various types of improved forest management practices, including the following:

- *VSC Tool for Demonstration and Assessment of Additionality in VCS Agriculture, Forestry, and Other Land Use (AFOLU) Project Activities* provides a step-wise approach to demonstrate and assess additionality for AFOLU project activities
- *Methodology for Improved Forest Management Through Extension of Rotation Age (IFM ERA)* quantifies the GHG emissions reductions and removals generated from improving forest management practices to increase the carbon stock on land by extending the rotation age of a forest or patch of forest before harvesting.
- *Methodology for Conversion of Low-productive Forest to High-productive Forest (IFM-LtHF)* quantifies the GHG emissions reductions and removals generated by avoiding re-logging and/or the rehabilitation of previously logged forest, applicable to logged or degraded natural evergreen tropical forest.
- *Methodology for Improved Forest Management: Conversion from Logged to Protected Forest (IFM-LtPF)* is applicable where the baseline scenario includes planned timber harvest, and under the project

scenario, forest use is limited to activities that do not result in commercial timber harvest or forest degradation.

In general, these methods follow similar best practices as indicated in other protocols, including satisfaction of eligibility requirements, delineation of project baseline, demonstration of additionality, and accounting for possible leakage. Baseline definitions require consideration of legal rights and requirements and intended management regimes. Use of the *VCS Tool for Demonstration and Assessment of Additionality* is often required for demonstrating project additionality.

U.S. DOE Technical Guidelines

The U.S. Department of Energy's *Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program, Forestry Appendix* provides "look-up" tables that allow users to identify average regional carbon values for different forest types. The guidelines cautioned that the values provided are "average estimates," meaning that they should be used when it is impractical to use more resource-intensive methods to characterize forest carbon (e.g., when more specific information is not available). The tables and guidance in this document form the basis for other accepted protocols, such as the California Air Resources Board's Compliance Offset Protocol's guidance for estimating carbon in wood products. [26, p. 95]

Recommendations

The extent to which DNRP-owned forest and resource lands could contribute GHG removals is dependent upon the projected land use and management that would have resulted had DNRP not purchased the land.

If DNRP believes that newly purchased land would have been converted to non-forestland without DNRP ownership, then quantification of these avoided emissions could be pursued using either a compliance (e.g., *Compliance Offset Protocol for U.S. Forest Projects*) or voluntary (VCS *Methodology for Avoided Ecosystem Conversion*) protocol. Note that under a compliance protocol, only newly acquired land could be included, as projects must be implemented on private land, unless the land was transferred to public ownership as part of the project. Also note that the process for calculating these removals would require more in-depth modeling and field monitoring than has been completed to-date.

For land eligible for improved forest management removals, several protocols, guidance documents, and tools are available. Many of the widely accepted protocols—such as from ARB, VCS, and ACR—share similar approaches and assumptions. While the ARB protocol is the most recent and was recently used for Microsoft's offsets in Washington State, the ACR protocol has fewer requirements for carbon pool calculations and a straightforward baseline calculation formula. All methodologies recommend the use of sample plots to estimate each category of carbon stocks (e.g., aboveground live, standing dead, wood products, etc.).

Table 19 below summarizes DNRP and other identified methodologies for calculating emissions associated with forest carbon sequestration and our consequent recommendations and rationale. **In summary, we recommend that DNRP consult VCS, ACR, and/or ARB protocols to pursue calculation of improved forest management removals on currently managed lands and, as time and resources allow, calculate avoided conversion removals on newly acquired lands that are large enough to justify calculation and are perceived by DNRP to have been under considerable threat of conversion.** Specific components of these recommendations are detailed below. While each methodology varies slightly among these components, DNRP should choose one methodology that best suits its needs and consistently apply that methodology across eligible lands. **We recommend the ARB methodology, as it has a regional precedent and is the most up-to-date and rigorous.**

Table 19. Methodology recommendations for DNRP-owned forest carbon sequestration

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Avoided Conversion (for newly-acquired lands)				
Eligibility	N/A	**VCS/ARB:** ▪ Cannot be legally required ▪ Must be suitable for conversion **ARB:** cannot be previously publically owned	▪ Follow chosen methodology for newly acquired DNRP lands that meet all requirements.	Although VCS does not explicitly require private ownership prior to project, should only apply methodology to newly acquired lands to be conservative.
Baseline	N/A	▪ **ARB:** Dependent on identified conversion types ▪ **VCS:** Dependent upon identified baseline types ▪ **VCS/ARB**: Identify drivers/effects; apply model for each *inventoried* carbon pool	▪ Follow chosen methodology (ARB may be better suited for more urban areas). ▪ Use sampling plots to determine initial carbon stocks.	Methodologies are similar, but ARB provides default conversion factors for different conversion land uses (e.g., residential, commercial, golf course, etc.).
Included Carbon Pools	N/A	**VCS/ARB** require: ▪ Aboveground tree ▪ Aboveground non-tree (Optional) ▪ Belowground (Optional) ▪ Dead wood ▪ Long-lived wood products	▪ Include all required carbon pools identified by protocols.	All methodologies require calculation of removals by carbon pool.
Leakage	N/A	▪ **ARB:** not explicitly addressed ▪ **VCS:** must estimate market and activity-shifting leakage	▪ Follow chosen methodology (ARB is less onerous for this component).	Leakage should be accounted for consistently with the chosen methodology.

Improved Forest Management (for new and/or currently managed lands)				
Eligibility	N/A	▪ **ARB/ACR:** Both private/public lands ▪ **ARB:** Certain size/management requirements ▪ **ACR:** year threshold (if not, must demonstrate that GHG was considered in activity)	▪ Ensure project meets size, management, and temporal requirements of chosen methodology before calculating removals.	Not all DNRP-owned lands may meet qualifications for improved forest management.
Baseline	N/A	▪ **ACR/ARB:** baseline carbon stock from sampling plots ▪ **ARB:** Extrapolate from historical trends ▪ **ACR:** NPV maximization with discount rate by ownership class	▪ Chose methodology based on available data. ▪ Calculate baseline using sampling plots and pool-specific formulas. ▪ If ARB methodology is chosen, pursue parallel methodology to that completed for Microsoft.	Because methodology approaches differ for this component, methodology should be chosen based on available data to determine baseline.
Included Carbon Pools	N/A	**ACR/ARB** require: ▪ Aboveground tree ▪ Dead wood (Optional for ACR) ▪ Long-lived wood products ▪ Belowground (Optional for ARB) ▪ **ACR only:** Aboveground non-tree	▪ At a minimum, include required carbon pools by chosen methodology.	
Leakage	N/A	▪ **ACR:** must demonstrate no leakage above *de minimis* threshold ▪ **ARB:** default 20% leakage factor	Follow chosen methodology.	

Protection of Privately Owned Forests

Current DNRP Methodology

Over the last few decades, King County has paid for the permanent protection of more than 140,000 acres of privately owned forest lands, which store significant quantities of carbon and help to limit sprawl and associated transportation emissions. In at least some of the contracts, King County has retained any carbon credit/rights associated with these lands. However, a majority are working forests that are periodically harvested (although some of the lands are not actively harvested).

Other Methodologies

The California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects* provides guidance for avoided conversion via "qualified conservation easements," which are required for any avoided conservation projects on private land. To qualify, conservation easements must be granted by the owner of the fee to a qualified owner in accordance with the enabling statute of the state, be perpetual in duration, and be recorded no earlier than one year before the offset project's commencement date. If a Qualified Conservation Easement was recorded more than one year prior to the offset project commencement date, the limits imposed by the easement on forest management activities must be considered a legal mandate for the purpose of satisfying the legal requirement test for additionality and in determining the forest project's baseline.

Recommendations

Table 20 below summarizes DNRP and other identified methodologies for calculating emissions associated with conservation and removal of development rights of privately-owned forests and our consequent recommendations and rationale. In summary, we recommend DNRP employ available avoided conversion methodologies to calculate removals associated with easements recorded after DNRP's initial greenhouse gas emissions inventory year, as measured by annual increments against a calculated baseline.

Table 20. Methodology recommendations for conservation and removal of development rights of privately-owned forests

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Qualifying lands	N/A	**ARB:** All easements recorded no earlier than one year before project commencement date	Incorporate all easements recorded after the first inventory year.	To comply with project additionality requirement, cannot receive credit for past easements.
Net removal calculation	N/A	**ARB:** Based on avoided conversion methodology	Use avoided conversion methodology.	Consistent with offset protocols.

Tree Planting

Urban forests provide a variety of GHG benefits. In addition to absorbing carbon dioxide and storing carbon in their biomass and soils, urban trees can reduce summertime air temperatures and building energy use for air-conditioning.

Current DNRP Methodology

DNRP accounts for removals associated with each year's tree plantings on restoration sites. Removals are calculated by multiplying the total trees planted that year by the carbon stored by a single tree at age 100, minus a mortality "survival factor." The method assumes that planted trees will remain in forest indefinitely and that 100 years is an appropriate age at which to measure carbon storage because sequestration rates drop considerably after that. These methods and underlying assumptions are based on available research and modeling on forest composition and growth, including from Lippke et al. 2011, the USDA Forest Service, and Smith et al. 2006.

Other Methodologies

The most relevant available methodology for calculating removals associated with urban tree planting is Climate Action Reserve's (CAR) *Urban Forest Protocol*, which has two project specific protocols: Urban Tree Planting and Urban Forest Management.

CAR's Urban Tree Planting Protocol

Under the CAR *Urban Tree Planting (UTP) Project Protocol*, an urban tree planting project is a planned set of activities designed to increase removals of carbon dioxide from the atmosphere or reduce carbon dioxide emissions through increasing and/or conserving urban forest carbon stocks. New trees must be planted in areas where trees have not been harvested with a commercial interest during ten years prior to project commencement. Only planted trees and trees that regenerate from planted trees are eligible. The area on which urban trees are planted must be controlled by DNRP—meaning that DNRP has legal authority to effect changes to urban forest carbon quantities (e.g., right to plant or remove). Other requirements include the following:

- Project must be entirely within Urban Area boundaries defined under the U.S. Census.
- Project must meet additionality tests, including the legal requirement test (activities are beyond that which are legally required) and performance test (activities are beyond business as usual activities, which for counties is defined as average trees per capita between the 50th and 100th percentiles).
- Project must monitor, report, and undergo verification activities for 100 years following the last credit issued to the project.
- Project must include provisions for social and environmental co-benefits.
- Typically, six percent of reductions are set aside as a buffer pool to address permanence concerns.

UTP projects must quantify the following sources, sinks, and reservoirs:

- Standing live carbon
- Standing dead carbon

Quantifying net GHG reductions and removals generally follows the below methodology, which is similar to other forest offset methodologies:

1. **Estimate baseline carbon stocks** for a 100-year period by applying the appropriate performance test. This exercise is done once at the beginning of the project and, for county governments, is the average trees per capita between the 50th and 100th percentiles over the past five years from entities similar to the project entity. This performance standard statistic will soon be available on the Reserve's Urban Forest Project Protocol webpage.
2. **Determine actual onsite carbon stocks** (each year for which removals are quantified) using protocol tools and guidance documents.
3. **Calculate the projects primary effect and net GHG reductions and removals** (each year for which removals are quantified) by calculating the difference between current and last year carbon stocks and subtracting from the difference between the two years under the baseline scenario.

The protocol provides the following tools and guidance documents for urban tree planting projects:

- Biomass equations for managed trees and unmanaged trees (not yet published on Reserve website)
- Quantification Guidance for Urban Tree Planting Projects

The Urban Tree Planting Protocol specifies the following in their methodology:

- All trees must be 100% inventoried (no sampling allowed). (Note: the Reserve will consider alternative methodologies, including sampling methodologies, as they are developed and reviewed.)
- The following must be inventoried for each tree: 1) date of tree visit, 2) latitude of tree center, 3) longitude of tree center, 4) navigational features to help locate the tree, 5) tree number, 6) inventory personnel, 7) species, 8) DBH, 9) total height, 10) growth condition (in natural or non-natural setting), 11) vigor, 12) defects, and 13) decay class (for standing dead wood).
- Each tree must be re-measured in the field at least every ten years. Incremental biomass changes must be determined by both DBH and height. Height can be estimated through regression analysis.

ARB's Reforestation Protocol

In instances in which tree plantings are applied with the intent of reforesting a more rural area, DNRP could consider applying a compliance or voluntary reforestation offset protocol. The California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects* provides guidance for reforestation projects, defined as a project that involves "restoring tree cover that is not at optimal stocking levels and has minimal short-term (30-years) commercial opportunities." The project can be on private or public land. To qualify under the protocol, reforestation projects must satisfy the following requirements:

- The land must have had less than 10 percent tree canopy cover for a minimum of 10 years or been subject to "significant disturbance" that has removed at least 20 percent of the land's above-ground live biomass in trees.
- Project activities cannot be legally required at the time of project commencement.
- The project must occur on a type of land for which the forest owner has not historically engaged in or allowed timber harvesting (examples include municipal or state parks).

Calculation of reforestation removals includes quantification of both baseline and project-related removals/emissions associated with:

- standing live carbon,
- shrubs and herbaceous understory carbon,
- standing dead carbon, and
- carbon in in-use forest products.

These calculations require the development of an onsite forest carbon inventory. Standard inventories require the establishment of sample plots and estimation of cubic or board foot volumes based on the species, trunk/bole diameter, form, and height of the tree. Other requirements of these inventories are described in Appendix A.

Defining the baseline also requires qualitative characterization of vegetative conditions and activities that would have occurred without the project, taking into consideration any laws, statutes, regulations, or other legal mandates that would encourage or require reforestation in the project area. This qualitative piece must include an assessment of the commercial value of trees within the project area over the next 30 years. Secondary effects emissions, including emissions associated with site preparation and shifting of cropland or grazing activities to forestland outside the project area, must also be considered.

Recommendations

Table 21 below summarizes DNRP and other identified methodologies for calculating emissions associated with tree planting and our consequent recommendations and rationale. Our recommendations vary depending on the context of tree planting. For urban tree planting projects, we recommend following the Climate Action Reserve's Urban Tree Planting Protocol. For reforestation projects outside urban areas, we recommend that DNRP employ one of the accepted reforestation offset methodologies to quantify net annual removals associated with tree planting activities during or following its initial inventory year.

Table 21. Methodology recommendations for tree planting

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Urban Tree Planting				
Timeframe	Receive credit for each newly planted tree as if it were 100 years old.	Receive credit each year as reflected by estimated net carbon removals as compared to a baseline (CAR UTP).	Calculate net removals each year as compared to an established baseline.	Consistent with most relevant methodology.
Project Lifespan	Assume 100-year project lifespan.	Project must monitor, report, and undergo verification activities for 100 years following the last credit issued to the project (CAR UTP).	Define project lifespan as 100 years.	Consistent with DNRP and other methodologies.

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Carbon stock calculations	Area- or individual tree-based "Lookup" tables from Forest Service, Smith et al. (2006), or USDOE that distinguish between growth rates and types.	▪ Apply biomass equations based on individual DBH and height measurements (CAR UTP). ▪ Update inventories annually through a combination of projecting existing inventory data and/or re-measuring inventory data. ▪ Conduct field measurements in the first year and at least every ten years thereafter. Estimate interim biomass using regression analysis.	▪ Apply biomass equations based on individual tree DBH and height measurements and estimations. ▪ Use models to project out estimated net CO_2e and ground-truth using field measurements as needed.	Consistent with most relevant methodology.
"Survival rate" adjustment	Apply a flat survival rate of 20%.	Model net removals each year based on individual tree dimensions and ground-truth in field, if needed. Contribute at least 6% of removals to a "buffer pool" to offset reversals due to natural disasters, etc. (CAR UTP).	Estimate net CO_2e removals annually and contribute a proportion to a "buffer pool" in case of reversal. Estimate "survival" annually and integrate into biomass equations and projection models.	Consistent with most relevant methodology.
Reforestation				
Timeframe	Receive credit for each newly planted tree as if it were 100 years old.	Receive credit each year as reflected by actual carbon storage accumulated that year (ARB).	Calculate net removals each year.	More conservative to account for net removals as they occur, rather than assume 100-year value.
Project Lifespan	Assume 100-year project lifespan.	Forest Projects must continue to monitor, verify, and report offset project data for a period of 100 years following any ARB or registry offset credit issuance (ARB).	Define project lifespan as 100 years.	Consistent with DNRP and other methodologies.
Carbon stock calculations	Area- or individual tree-based "Lookup" tables from Forest Service, Smith et al. (2006), or USDOE.	Use accepted list of models, supported by sampling plots (ARB).	Develop and monitor sampling plots; explore using ARB-accepted growth model.	Consistent with standard methodologies.
"Survival rate" adjustment	Apply a flat survival rate of 20%.	Identify and quantify the specific types of risks that may lead to a reversal based on project-specific factor, including financial, management, social, and natural disturbances (ARB). Translate to risk ratings that affect contributions to Forest Buffer Account.	Apply a risk rating (e.g., using ARB's risk table) to inventory and deduct from inventory annually.	Because DNRP cannot contribute to the buffer account, reduce inventory values accordingly.

Other

Regional Trail System

Current DNRP Methodology

DNRP is leading redevelopment the Eastside Rail Corridor, which offsets an estimated 20 million trips, including five mission trips along five key corridors. Currently, DNRP does not account for removals associated with this mode shift in its GHG inventory.

Other Methodologies

We identified two primary guidance documents that could address removals associated with mode shifts:

- American Public Transportation Association's (APTA) *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit*
- The GHG Protocol's *GHG Protocol for Project Accounting*

The GHG Protocol for Project Accounting provides an overview of essential steps and calculations that should be undertaken in calculating removals from a "custom" GHG project such as DRNP's regional trail system. See Appendix C for a more detailed discussion of the project accounting protocol.

The APTA guidance specifies three methodological approaches for calculating mode shift benefits: [27]

1. Use of regional travel demand models
2. Evidence from "natural experiments"
3. Applying a mode shift factor to transit passenger mileage data

In all three approaches, mode shift benefits are calculated by 1) determining how and if transit passengers would have traveled in the absence of transit and 2) multiplying those changes by the mode's applicable GHG emission factor. The approaches vary in how they estimate passenger behavior.

APTA recommends using the third approach (applying a mode shift factor) due to the limitations of the first two approaches. The considerations for the other two approaches are summarized in Table 22, where the crucial limitation(s) of the approach is underlined.

Table 22. Approaches for mode shift calculations

Approach	Considerations
Travel demand models	<u>Models must be calibrated to address fundamental changes in transit availability.</u> Modeling staff may not have the resources to conduct this modeling. <u>Transit models may not reflect trip suppression resulting from eliminating transit service.</u>
Natural experiments	<u>Requires cessation of the transit system to acquire data.</u> Short-term travel adaptations may not be representative of long-term travel adaptations.

Recommendations

Table 23 below summarizes DNRP and other identified methodologies for calculating emissions associated with the regional trail system, and our consequent recommendations and rationale. In summary, we recommend using the GHG Protocol project accounting protocol along with the APTA mode shift guidance to estimate removals associated with the DNRP regional trail system.

Table 23. Methodology recommendations for the regional trail system

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Mode shift GHG removals	N/A	**APTA:** Calculate mode shift benefits through one of three identified approaches.	Apply mode shift factor to transit passenger mileage data.	Recommended by APTA guidance due to limitations of other approaches.

Transfer Center Recycling and Diversion in Unincorporated King County

Recycling materials can reduce emissions related to production of virgin products, and composting materials can reduce CH_4 emissions associated with anaerobic decay.

Current Methodology

DNRP does not currently claim the removals associated with transfer center recycling or diversion in unincorporated King County. However, DNRP currently uses MEBCalc to estimate reductions in GHG and other pollutants related to changes in disposal practices and changes in recycling and waste prevention polices. The model includes both biogenic and anthropogenic emissions.

MEBCalc includes a 100-year lifecycle analysis of operational changes or changes in policies, including induced upstream changes. The model specifically includes benefits of the following operational and technological characteristics:

1. Wet and dry anaerobic digestion, including updated estimates related to food scrap digestion.
2. Deposit-return collection systems for multi-family/commercial, construction and demolition, and self-haul.
3. Biweekly collection for residential collection of garbage, organics, and recyclables.
4. Compressed natural gas collection trucks.
5. Diversion of approximately 75 percent of the waste types disposed in the SWD service area, including carpet, copper, household batteries, gypsum wallboard, paint, and used oil.

The MEBCalc model also calculates the benefits of energy “offsets” in cases where landfill byproducts—such as anaerobic digestion, collected landfill gas, and waste-to-energy incineration—are used to displace other energy sources. The model assumes these energy sources displace natural gas-fired electricity generation.

Regarding upstream emissions, MEBCalc includes emissions reductions related to resource extraction, refining, production, and packaging. Emissions reductions are based on the recycled-content product manufactured from the diverted material.

Finally, MEBCalc includes removals related to carbon sequestering that results from grass, plant, or tree growth over the 100 years following the managements of biogenic materials in the municipal solid waste system. MEBCalc cautions users to only include these “offsets” if not included in other parts of the GHG inventory. [28, pp. 1-3]

Other Methodologies

CDM's *Small-scale Methodology: Recovery and recycling of materials from solid wastes* provides guidance on 1) claiming emissions reductions related to recycling plastic materials into intermediate or finished products and 2) avoiding CH_4 emissions from the anaerobic decay of paper or cardboard. The methodology states that:

"Other materials such as glass and metals found in solid wastes that are manufactured in industrial processes can be recycled, however the emissions associated with the production of virgin materials of these categories are not available in the present version. Project proponents are encouraged to submit a revision of this methodology to include additional materials proposing conservative default values for specific energy consumption for the production from virgin raw materials." [15, p. 3]

In CDM's methodology, existing public-sector facilities must meet the following criteria to claim removals:

1. The facility must have average, pre-activity recycling data by material from the previous three years of operation to use as the estimated baseline activity level.
2. The facility must demonstrate that the project activities are not diverted from other existing public-sector facilities or, alternatively, that the project is not a common practice in the region.
3. The facility must demonstrate that materials are from the municipal waste stream.
4. The final output of the recycling facility and the input to a final processing/manufacturing facility must be directly measured and recorded by dry weight separately for LDPE, HDPE, PET, PP, paper, and cardboard.
5. The recycled materials must be sold directly to a process/manufacturing facility or intermediary retailers that transfer materials to a final, identifiable processing/manufacturing facility.
6. Procedures, such as contractual agreements, must be implemented to eliminate double counting of emission reductions with other involved organizations.
7. Procedures must also provide credible proof that provided materials are used for processing/manufacturing and no other purposes, such as providing a fuel source.

When calculating the emissions reduction related to plastic recycling, the facility must verify that PET and PP replace virgin inputs by demonstrating the chemical equivalence of the recycled PET and PP to that of PET and PP made from virgin inputs by comparing the intrinsic viscosities of the two sources. Furthermore, emissions reductions can only be claimed for the difference in energy use for the production of plastic products from virgin inputs compared to recycled inputs. For paper or cardboard emissions reductions, credit may only be claimed if 1) the project avoids methane emissions from anaerobic decay and 2) the baseline scenario is waste disposal at a site without methane recovery. [15, pp. 4-5]

Recommendations

While the process for verifying removals under CMD's approach is very cumbersome, DNRP would need to comply with the methodology to any removal claims related to recycling activities. Additionally, since paper and cardboard would have otherwise gone to a disposal site with methane capture, removals associated with diverting these materials are not eligible for inclusion in the inventory. While removals require a conservative approach within the formal inventory, King County may continue to calculate and report estimated benefits from their recycling-related activities as additional information.

Table 24 below summarizes DNRP and other identified methodologies for calculating emissions associated with transfer center recycling and diversion in unincorporated King County, and our consequent recommendations and rationale.

Table 24. Methodology recommendations for transfer center recycling and diversion in unincorporated King County

Methodology Component	King County Methodology	Other Protocols/ Jurisdictions	Recommendation	Rationale
Claiming removals	Currently not included in the inventory, but MEBCalc is used for quantifying emissions reductions of similar activities	▪ **CDM:** emissions reductions based on energy savings from using recycled plastics where additional and verifiable	**Tier 1** If the level of effort is deemed worthwhile, follow the CDM methodology for claiming removals related to recycling plastics. **Tier 2** Calculate avoided emissions for other materials following the themes within the CDM methodology for additional materials.	▪ CDM's methodology is consistent with the principles guiding the inventory as it is conservative regarding the inclusion of removals. ▪ Removals related to paper and cardboard are not included as the baseline disposal site has methane capture.
Baseline	N/A	▪ **CDM:** Three years of data prior to project initiation	Use three years of data prior to project initiation to establish baseline.	While the three years' worth of data does not correct for other possible influences on recycling levels, it is allowed and required in an approved methodology.

Purchasing Emissions

Typically, Scope 3 emissions sources are not a required component of an organization's GHG emissions inventory. However, in an effort to be as comprehensive as possible, DNRP has chosen to include GHG emissions associated with department purchasing within its GHG inventory and carbon neutrality goal.

Based on DNRP's capital and operating expenditure information, known industry best practices, and available tools and methodologies, we present in this section a recommended approach to quantify GHG emissions associated with DNRP's purchases, including construction-related sources and contracts. We begin with a discussion of available options and their relative merits, proceed with a description of our recommended approach, and conclude with an introduction to our pilot tool and its preliminary findings.

Economic Input-Output Methodologies

Economic input-output strengths & limitations

Economic input-output (I/O) methodologies for GHG emissions estimation are based on I/O matrices compiled by the federal government, state government, or private entities. An I/O matrix represents an entire economy, classified into a set of complete and mutually exclusive economic sectors. Each row of the matrix represents one of the sectors, and the matrix elements in that row represent the relative spending in all the *other* sectors when money is spent in the sector represented by that row.[viii] I/O matrices are intrinsically an economic tool and do not, alone, have any meaning for GHG emissions or other environmental impacts.

I/O methodologies for GHG emissions estimation build on the economic tool, by assigning an *emissions intensity* to each sector. Each emissions intensity states the quantity of GHG emissions induced, on average, by one standard amount of final spending in the sector. Typical units are tons of carbon dioxide equivalent per million dollars, for example. Once emissions intensities are assigned, an entity can estimate the emissions induced throughout the economy when the entity purchases a given quantity of goods or services from a given sector.

I/O methodologies for emissions estimation have these strengths:

- **Completeness:** Because the I/O matrix covers the entire economy, I/O methodologies capture emissions regardless of the number of degrees removed from the original purchaser. There is not a chance of "missing" something. I/O methodologies can be good at uncovering surprising, upstream contributors to emissions.
- **Ease of use:** Though the I/O matrices and emissions intensities are very laborious to compile, once the matrix is compiled application of the tool is almost trivially simple, requiring no more than spending allocated into the modeled set of sectors.

[viii] It is simplest to imagine that each matrix element shows how many pennies of a consumer dollar spent in the primary sector represented by the row, are then passed on by that sector in business-to-business transactions with each secondary sector represented by the columns. This is not technically correct because the matrix actually captures *all* induced spending further down each value chain, but it is a good conceptual approximation.

But suffer from these weaknesses:

- **Low precision:** The methodology relies on economic allocations assigned to an entire economy, and on average emissions intensities across the same economy. It accounts poorly for emissions induced by spending in regions outside the modeled economy. Due to data collection lags as well as the labor intensive process of updating an I/O-based tool, such tools are typically operated using four- to ten-year-old data.
- **Low resolution:** Spending in a given economic sector is treated the same regardless of the particular entity contracted, or of any conditions placed on the purchases. There is no way to distinguish between competing vendors within a given sector, nor is there any way to distinguish the effects of environmentally preferred purchasing practices.

King County CBEI/IMPLAN

During calendar year 2011 Stockholm Environment Institute (SEI) developed a consumption-based emissions inventory (CBEI) calculator applicable to King County, and used it to generate a calendar year 2008 consumption-based GHG inventory for the community published in February 2012, and an estimate of calendar year 2009 GHG emissions ascribable to King County government purchases published in April 2012. The King County CBEI is based on a regional I/O matrix developed by MIG, Inc. using its proprietary IMPLAN software. CBEI augments the I/O methodology developed by IMPLAN to account for the specific emission rates known for local electric utilities, traffic patterns in the Puget Sound area, and local waste management practices. The IMPLAN I/O matrix divides the economy into 440 sectors.

CBEI is fairly complex, but could in principle be operated by King County on an annual basis. However, update of the model with new IMPLAN data is time-consuming and requires payment of additional licensing fees to MIG, Inc. A simpler approach would be to apply the sector emissions intensities computed by SEI to DNRP spending each year, and retain SEI or another contractor to update those emissions intensities on an infrequent (e.g. every six to ten years) basis.

Carnegie Mellon EIOLCA

Carnegie Mellon University's Economic Input-Output Life Cycle Assessment (EIOLCA) models are maintained for research use through collaboration with its authors, and for public use through a Web interface. The most current model available is based on 2002, national-level economic data in 428 sectors. Carnegie-Mellon University does offer a program for non-commercial entities like King County to gain direct access to the models and underlying files without going through the web interface.

The tool's owners do not have any plans or schedule for future updates to the underlying economic data.

REMI

Regional Economic Models, Inc. (REMI) stewards a number of I/O models. REMI sells licenses to these models and offers customization to meet their customers' needs, and can also furnish turnkey analyses to meet customers' specifications. As an example of typical costs, the 70-sector PI+ model can be licensed for $19,000 for one six-month period, or licensed continuously for a $45,000 initiation fee plus $10,500 annually. An upcoming expansion to the PI+ model, expected to be released before mid-year 2016, will incorporate emissions rates and allow I/O-based environmental assessment with fairly little customization of the model. License fees for the expanded PI+ model are expected to be 10% to 20% above those for the basic model.

REMI is holding a technical informational seminar in Olympia, WA on February 1, 2015. We recommend that County staff attend the seminar if they wish to become more familiar with the capabilities of this particular tool. See http://www.remi.com/events/olympia-washington-3.

Using I/O Methodologies for Secondary Analysis

Since each row of the I/O matrix breaks out a primary sector's induced spending (emissions) in secondary sectors, the matrix elements in the row indicate where the primary sector has the greatest potential to reduce emissions through behavioral changes, by reducing spending on GHG-intensive secondary sectors. SEI conducted such a secondary analysis for a construction sector in its April 2012 report on King County government purchases, and discovered that 47% of emissions are direct fuel use by construction contractors; 10% are associated with cement purchases; and another 11% with shipping of materials. These outcomes point to obvious and useful policy initiatives King County can take toward reducing emissions induced by construction spending.

Being fluent with I/O methodologies will give DNRP the institutional knowledge to leverage this capacity for secondary analysis toward meaningful GHG reduction actions through purchasing.

Process Analysis

Process analysis strengths & limitations

Process analysis for GHG inventories is typically done under International Standards Organization (ISO) technical specification ISO/TS 14067:2013, *Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication*. ISO/TS 14067 encourages a full accounting of GHG emissions from materials extraction through product delivery that follows the process steps constituting the actual manufacturing (or service delivery) process.

When compared to I/O-based methodologies, process analysis has advantages:

- **High precision:** Because the process analyzed is the specific one from which King County is purchasing output, the resulting emission factors will be highly relevant and precise.
- **High resolution:** Process analyses can differentiate finely between different vendors or even different options from a single vendor.

But carry significant disadvantages:

- **Onerous cost:** Process analyses are very expensive, typically tens of thousands of dollars per process (per product).
- **Access limitations:** An accurate and complete process analysis requires complete access to a given vendor's process data. Very few vendors would be comfortable giving this level of access to an actor working on behalf of another party's interests.

Process Analysis Databases

The architectural community was an early adherent to life-cycle thinking, and over the years architects have made numerous attempts at compiling life-cycle assessments of building materials, including “embodied energy” and “embodied carbon”, meaning the total energy or CO_2 emissions induced during raw materials extraction and manufacture of a given material.

Circular Ecology’s ICE database[ix] is a publicly-accessible (with registration) database of embodied energy and carbon for building materials. The National Renewable Energy Laboratory (NREL) stewards the U.S. Life Cycle Inventory Database,[x] which includes detailed, process-based life cycle inventories of various inputs and emissions for a number of industrial processes, including several that manufacture building materials.

The Taiwan Environment and Development Foundation maintains a library of “Product Category Rules,”[xi] which include some emission factors and other parameters used to compute carbon footprints of products under ISO/TS 14067:2013. U.S. analysts have not been active in creating Product Category Rules, and the database primarily contains rules describing processes in Asia and Europe.

Each process analysis database contains a somewhat arbitrary selection of materials, products or processes, depending on what has been evaluated and published by academic or industry sources. These databases cannot be a comprehensive resource underlying DNRP’s purchasing emissions inventory, but might offer occasional insight. By their nature, process analyses are complex and can be time-consuming to understand, so DNRP would benefit most from these resources if they are used to support special projects, perhaps in conjunction with I/O secondary analysis.

Hybrid Approach: I/O-Based Gross Adjusted by Reduction Projects

Any annual inventory of emissions associated with County purchases should have sufficient resolution to justify its cost. The resolution required to differentiate between product or vendor choices requires process analysis, at (presumably) unaffordable costs. For a much lower cost, the county can show the fluctuation of gross emissions from purchasing as it fluctuates with expenditures, using annual application of an I/O-based model. This method reveals large-scale reductions in consumption but is unlikely to show progress from the targeted purchasing policies typical of EPP.

A compromise is possible by continuing with I/O-based analysis, augmented with purchasing emissions reduction projects. For example, if DNRP requires vendors of construction services to utilize a minimum proportion of cement substitutes, DNRP can compute an emissions baseline associated with ordinary cement use and a reduction associated with the cement substitution.

Ideally, each such reduction project would be accounted following a sanctioned, third-party offset methodology as we recommend for the line-item Scope 3 removals. Since these reduction projects are all secondary to a line-item Scope 3 emissions source (purchasing), there is an argument to be made for streamlined methodologies to keep the level of effort reasonable. We recommend setting a materiality

[ix] http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html
[x] http://www.nrel.gov/lci/
[xi] http://pcr-library.edf.org.tw/index.asp

threshold for requiring adherence to a third-party methodology for these secondary reduction projects, for example projects claiming reductions greater than 0.5% of the gross DNRP inventory (all three scopes included) must follow a third-party methodology.

Recommendation and Pilot Tool

Recommendations

1. **Begin by using CY2009 CBEI output** as the foundation for purchasing-related DNRP emissions. Use a very simple intensity-based multiplier tool similar to the Pilot Tool offered below.
2. **Identify and measure reduction projects**. Identify reduction projects available in sectors with significant purchasing by DNRP. Compute baselines and reductions for each; recalculate following third-party methodologies for those that promise reductions above an established materiality threshold (*e.g.* 0.5% of gross inventory).
3. **Set a schedule for emissions intensity updates**. Sector emission intensities should be updated together with the underlying I/O matrix on a slow, regular basis that guarantees reasonably accurate multipliers in the simple tool. We recommend an interval between six and ten years for these updates.
4. **Compare CBEI/IPLAN with REMI** for future updates to the sector emissions intensities.[xii] Both models and their vendors have high integrity so DNRP should probably make the choice based primarily on cost and on accessibility to (transparency of) the results.

Pilot DNRP Purchasing Emissions Calculation Tool

As an attachment to this report we offer the Pilot DNRP Purchasing Emissions Calculation Tool (Pilot Tool). The Pilot Tool requires DNRP staff to compile spending figures in 58 sectors chosen for relevance to King County operations. The tool multiplies each of these spending figures by the overall emission intensity for the respective sector that was computed by SEI for the government purchasing analysis reported in April 2012, based on calendar year 2009 spending.

DNRP supplied Cascadia with records of approximately $217 million in calendar year 2014 spending, for analysis in the pilot tool. The spending did not include employee salaries, energy purchases or waste management. Cascadia computed approximately 85,500 tCO_2e of emissions outside the DNRP inventory boundary ascribable to the reported spending.

A final DNRP purchasing emissions calculations tool derived from this Pilot Tool can be re-used each year until the intensity-based multipliers are updated per recommendation #3, at which point the final tool would be repopulated with new multipliers (in columns main!F:G of the Pilot Tool, as delivered).

Though the Pilot Tool offers a shortcut to I/O based analysis, it does not allow secondary I/O analysis in the way described above; secondary analysis needs to be performed with a fully enabled I/O tool such as CBEI or EIOLCA.

[xii] Carnegie Mellon promises no future updates to its underlying I/O matrices, so may soon become a deprecated model. For this reason we recommend the focus on either CBEI/IMPLAN or REMI.

Improvements to the Pilot Tool

The following enhancements will make the Pilot Tool ready for deployment to serve DNRP's needs for estimating GHG emissions ascribable to purchasing:

- Review and confirm all sectoral emission intensities computed from SEI's 2012 report.
- Add spending categories for intragovernmental ("55000-series") transfers from DNRP to other King County departments. Amend the Pilot Tool to compute emissions ascribable to intragovernmental transfers as follows:
    1. Subtract gross DNRP GHG emissions from gross County government GHG emissions to create net government GHG emissions;
    2. Subtract DNRP's budget from King County's budget to create a net county budget;
    3. Divide the net government GHG emissions by the net county budget to create a non-DNRP government emissions intensity; and
    4. Multiply the non-DNRP government emissions intensity by DNRP's total intragovernmental transfers outside DNRP to estimate emissions.

    Many variants of this are possible to increase precision, including disaggregation by non-DNRP department, or exclusion of large, unrelated emissions sources (e.g. the bus fleet).
- Harden the Excel spreadsheet to avoid accidental miscalculations. This should be accomplished by adding relevant checksums and by turning on worksheet protection features offered in Microsoft Excel.
- Establish administrative processes inside King County to ensure proper archiving of each year's results and reliable, consistent release of the "clean" tool for each new year.
- (Optional) Provide sector subgroupings under the three primary sector groups Supplies, Services and Capital Outlay.
- (Optional) Allow input for certain sectors in more than one of the primary sector groups. In SEI's 2012 analysis, the following four IMPLAN sectors appeared in the Capital Outlay group, and also in either Supplies or Services:
    - 299 Institutional furniture
    - 345 Software
    - 365 Commercial and industrial machinery and equipment rental and leasing services
    - 417 Commercial and industrial machinery and equipment repairs and maintenance

    King County divided CY2009 financial data provided to SEI for these four sectors, between capital and expenses. This allows precise segregation of capital from expenses, but has no bearing on the gross GHG inventory. The practice should be carried over to DNRP's tool only if DNRP finds precise segregation of capital and expenses to be important; we do not recommend it due to the increased labor and increased probability of errors.

References

1. World Resources Institute and LMI, *The Greenhouse Gas Protocol for the U.S. Public Sector: Interpreting the Corporate Standard for U.S. Public Sector Organizations* (2013).

2. The Climate Registry, *Local Government Operations Protocol* (2010).

3. Greenhouse Gas Protocol, *The GHG Protocol for Project Accounting*.

4. Verified Carbon Standard, *Approved VCS Methdology VM0009: Methdology for Avoided Ecosystem Conversion* (2014).

5. World Resources Institute, *Scope 2 Guidance*.

6. World Resources Institute and WBCSD, *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*.

7. Greenhouse Gas Protocol, *Technical Guidance for Calculating Scope 3 Emissions: Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard*.

8. Greenhouse Gas Protocol, *Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects* (2005).

9. Greenhouse Gas Protocol, *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*.

10. Gillenwater, M., *Calcaulation Tool for Direct Emissions from Stationary Combustion* (2005).

11. Greenhouse Gas Protocol, *Product Life Cycle Accounting and Reporting Standard*.

12. American Carbon Registry, *Improved Forest Management Methodology for Quantifying Removals and Emission Reduction Through Increased Forest Carbon Sequestration on Non-Federal U.S. Forestlands* (2014).

13. EPA, *eGRID Emission Estimation Methods*.

14. EPA, *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance: Direct Emissions from Stationary Combustion Sources*.

15. Clean Development Mechanism, *Small-scale Methodology: Recovery and recycling of materials from solid wastes*.

16. The Climate Registry, *General Reporting Protocol*.

17. World Resources Institute, *Guidance for Quantifying GHG Reductions from Grid-Connected Electricity Projects*.

18. Diem, A. & Quiroz, C., *How to use eGRID for Carbon Footprinting Electricity Purchases in Greenhouse Gas Emission Inventories* (2012).

19. WRI and WBCSD, *Alocation of GHG Emissions from a Combined Heat and Power (CHP) Plant* (2006).

20. Greenhouse Gas Protocol, *GHG Protocol Guidance: Direct Emissions from Stationary Combustion*.

21. Broustis, D., *email exchange* (December 29, 2015).

22. The Climate Registry, *Emission Factors for Greenhouse Gas Inventories* (April 4, 2014).

23. myclimate - The Climate Protection Partnership, *The myclimate flight emission calculator* (Zurich, Switzerland, March 9, 2015).

24. Duke Forest Carbon Assessment, *Why Forest Offsets?* (Duke University).

25. Swedeen, P. (2016).

26. California Air Resources Board, *Compliance Offset Protocol for U.S. Forest Projects* (2014).

27. American Public Transportation Association, *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit* (2009).

28. DNRP, *Life Cycle MEBCalc Analysis*.

29. South Bay Cities Council of Governments, *City of Hermosa Beach Municipal Greenhouse Gas Emissions Inventory Report* (2009).

Appendix A.
Calculating GHG Removals for Forest Projects

Although calculating GHG removals associated with forest projects can be a daunting task, it represents a significant opportunity for DNRP to reach its carbon neutrality goals. This appendix provides guidance provided by the California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects* for avoided conversion, improvement forest management, and reforestation projects and their corresponding steps, assumptions, and considerations. For more information, see the California Air Resources Board website.[xiii]

The basic process for quantifying GHG removals under the *Compliance Offset Protocol for U.S. Forest Projects* is as follows (also see Figure 1):

1. **Estimating baseline onsite carbon stocks.** The baseline is an estimate of what would have occurred in the absence of a Forest Project. To establish baseline onsite carbon stocks, the carbon stock changes in each of the Forest Project's required onsite carbon pools must be modeled over 100 years. Modeling must be based on inventoried carbon stocks at the time of the Forest Project's offset project commencement (or when first inventoried as is allowed for Reforestation Projects), following the applicable requirements in this section. Onsite carbon stocks are inventoried following the requirements in Appendix A; modeling of onsite carbon stocks over time must be conducted. Baseline onsite carbon stocks are estimated over 100 years at the time of the Forest Project's commencement.
2. **Estimating baseline carbon in harvested wood products.** In conjunction with modeling baseline onsite carbon stocks, a forecast of any harvesting that would have occurred in the baseline must be developed and converted to an average annual harvesting volume. From this, the amount of carbon that would have been transferred each year (on average) to long-term storage in wood products can be determined.
3. **Determining actual onsite carbon stocks.** Each year, the Forest Project's actual onsite carbon stocks must be determined. This must be done by updating the Forest Project's forest carbon inventory for the current year. The estimate of actual onsite carbon stocks must be adjusted by an appropriate confidence deduction.
4. **Determining actual carbon in harvested wood products.** Each year, any harvesting in the Project Area must be reported and from this, the amount of carbon transferred to long-term storage in wood products must be calculated.
5. **Calculating the offset project's Primary Effect.** Each year, the actual change in GHG emissions or GHG removal enhancements associated with the Forest Project's intended ("Primary") effect must be quantified. For any given year, the Primary Effect is calculated by:
    a. Taking the difference between actual onsite carbon stocks for the current year and actual onsite carbon stocks for the prior year
    b. Subtracting from (a) the difference between baseline onsite carbon stocks for the current year and baseline onsite carbon stocks for the prior year
    c. Adding to (b) the calculated difference between actual and baseline carbon in harvested wood products for the current year

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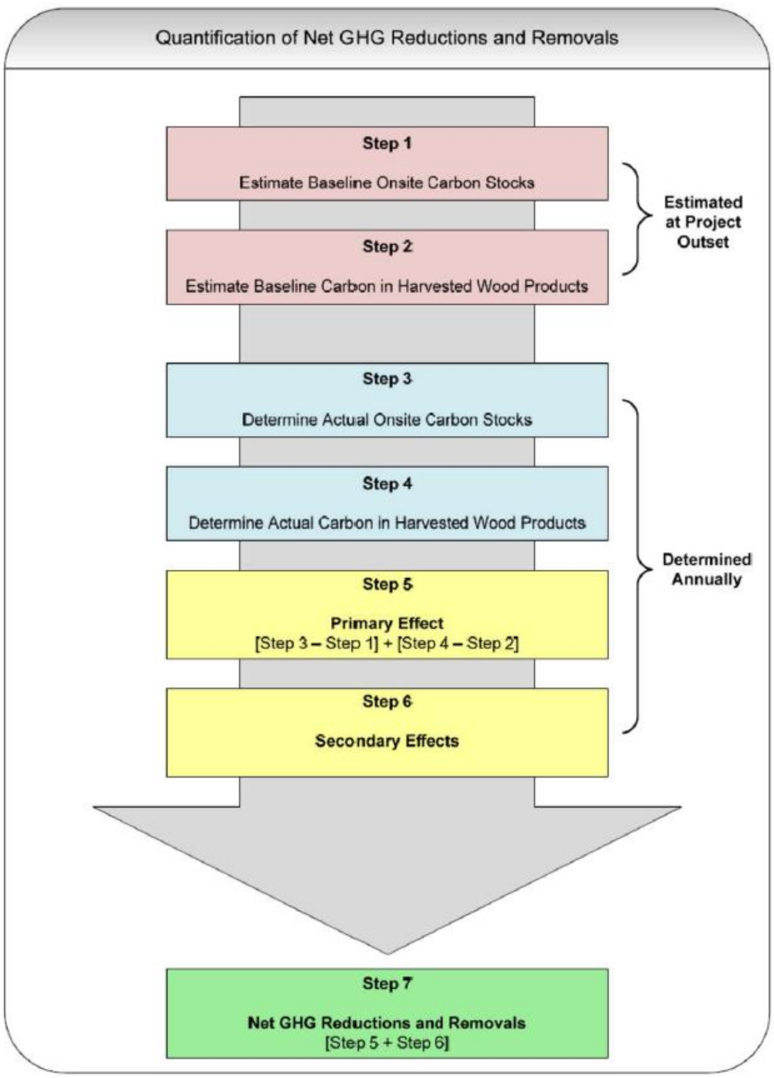
[xiii] http://www.arb.ca.gov/cc/capandtrade/protocols/usforest/usforestprojects_2014.htm

6. **Quantifying the offset project's Secondary Effects.** Each year, the actual change in GHG emissions or GHG removal enhancements associated with the Forest Project's unintended ("Secondary") effects must be quantified. Requirements and methods for quantifying Secondary Effects are provided below for each type of Forest Project. Secondary Effects will almost always be negative (i.e. they will reflect an increase in GHG emissions caused by the offset project).
7. **Calculating total net GHG reductions and GHG removal enhancements.** For each year, total net GHG reductions and GHG removal enhancements are calculated by summing a Forest Project's Primary and Secondary Effects. If the result is positive, then the Forest Project has generated GHG reductions and/or GHG removal enhancements in the current year. If the result is negative, this indicates a reversal has occurred except as specified below.

Figure 1. Process for quantifying GHG removals under the California Air Resources Board's *Compliance Offset Protocol for U.S. Forest Projects*



Avoided Conversion

The California Air Resources Board's Compliance Offset Protocol for U.S. Forest Projects lays out the following methodology for **calculating net GHG removals due to avoided conversion on public lands**:

1. **Estimating Baseline Onsite Carbon Stocks**

   The baseline for Avoided Conversion Projects is a projection of onsite forest carbon stock losses that would have occurred over time due to the conversion of the Project Area to a nonforest land use. Estimating the baseline for Avoided Conversion Projects involves two steps:

   a. Characterizing and projecting the baseline; and
   b. Discount for the uncertainty of conversion probability.

   Step 1 - Characterizing and Projecting the Baseline

   The project baseline must be characterized by:

   c. Clearly specifying an alternative highest-value land use for the Project Area, as identified by an appraisal.
   d. Estimating the rate of conversion and removal of onsite carbon stocks, taking into consideration any laws, statutes, regulations, or other legal mandates that affect land use conversion or removal of onsite carbon stocks. The rate of conversion and removal of onsite carbon stocks must be estimated by either:

      i. Referencing planning documentation for the Project Area (e.g. construction documents or plans) that specifies the timeframe of the conversion and intended removal of forest cover on the Project Area; or
      ii. In the absence of specific documentation, identifying default Total Conversion Impact and Annual Conversion values.

   e. Using a model to project changes in onsite carbon stocks over 100 years, reflecting the

      i. rate of conversion estimated in (2). The simulation must model changes in onsite carbon
      ii. stocks for all required carbon pools.

Table 25. Default Avoided Conversion

Type of Conversion Identified in Appraisal	***Total Conversion Impact***	***Annual Conversion***
	This is the assumed total effect over time of the conversion activity. (The total conversion impact is amortized over a 10-year period to determine the annual conversion in the next column.	*This is the assumed annual conversion activity. The percentages below are multiplied by the initial onsite carbon stocks for the project on an annual basis for the first 10 years of the project.*
Residential	*Estimate using the following formula:* *TC = min(100, (P*3 / PA)*100)* *Where:* *TC = % total conversion (TC cannot exceed 100%)* *PA = the Project Area (acres) identified in the appraisal* *P = the number of unique parcels that would be formed on the project area as identified in the appraisal* **Each parcel is assumed to deforest 3 acres of forest vegetation.*	*Estimate using the following formula:* *AC = TC / 10* *Where:* *AC = % annualized conversion* *TC = % total conversion*
Mining and agricultural conversion, including pasture or crops	*90%*	*9.0%*
Golf course	*80%*	*8.0%*
Commercial and Industrial buildings	*95%*	*9.5%*

The baseline modeling must apply the identified rate of conversion over time to estimate changes in onsite carbon stocks, beginning with the Project Area's initial onsite carbon stocks at the time of offset project commencement.

If the projected conversion rate does not result in a complete removal of onsite forest carbon stocks, the baseline projection should account for any residual forest carbon value as a steady condition for the balance of a 100-year projection.

Step 2 - Discount for Uncertainty of Conversion Probability

If the fair market value of the anticipated alternative land use for the Project Area (as determined by the appraisal required in Section 3.1.2.3) is not more than 80 percent greater than the value of the current forested land use, then a discount must be applied each year to the offset project's quantified GHG reductions and GHG removal enhancements. If quantified GHG reductions and GHG removal enhancements for the year are positive (i.e. $[(\Delta AC_{onsite} - \Delta BC_{onsite}) + (AC_{wp}, y - BC_{wp}, y) * 0.80 + SE_y] > 0$ *within Equation 6.1) then use the following formula (Equation 6.11) to calculate the appropriate Avoided Conversion Discount factor, ACD. If quantified GHG reductions and removals for the year are negative, then ACD must equal zero.*

Equation 6.11. *Avoided Conversion Discount Factor*

If 0.4 < ((VA / VP) – 1) < 0.8, then ACD = [0.80 – ((VA / VP) – 1)] x 2.5

If ((VA / VP) – 1) ≥ 0.8, then ACD = 0

If ((VA / VP) – 1) ≤ 0.4, then ACD = 1

Where,

ACD = The Avoided Conversion Project discount factor (used in Equation 6.1).

VA = The appraised fair market value of the anticipated alternative land use for the Project Area

VP = The appraised fair market value of the current forested land use for the Project Area

2. **Estimating Baseline Carbon in Harvested Wood Products**

   Harvesting is assumed to occur in the baseline over time as the Project Area is converted to another land use. To estimate the baseline carbon transferred to long-term storage in harvested wood products each year:

   a. *Determine the amount of carbon in standing live carbon stocks (prior to delivery to a mill) that would have been harvested in each year of the baseline, consistent with the rate of reduction in baseline standing live carbon stocks determined in Section 6.3.1. This projection is determined at offset project commencement, using the same volume models and biomass equations used to calculate biomass in live trees and estimate baseline onsite carbon stocks; this will not change over the course of the offset project life.*
   b. *On an annual basis, determine the amount of harvested carbon that would have remained stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.*

3. **Determining Actual Onsite Carbon Stocks**

   Actual carbon stocks for Avoided Conversion Projects must be determined by updating the Project Area's forest carbon inventory. This is done by:

   1. *Incorporating any new forest inventory data obtained during the previous year into the inventory estimate. Any plots sampled during the previous year must be incorporated into the inventory estimate.*
   2. *Using an approved model to "grow" (project forward) prior-year data from existing forest inventory plots to the current reporting year. Approved growth models are identified in Appendix B. Methods for projecting forest inventory plot data using models is also provided in Appendix B.*
   3. *Updating the forest inventory estimate for harvests and/or disturbances that have occurred during the previous year.*
   4. *Applying an appropriate confidence deduction for the inventory based on its statistical uncertainty, following the provided requirements and methods.*

4. Determining Actual Onsite Carbon Stocks

Perform the following steps to determine actual carbon in harvested wood products:

1. *Determine the actual amount of carbon in standing live carbon stocks (prior to delivery to a mill) harvested in the current year (based on harvest volumes).*
2. *Determine the amount of actual harvested carbon that will remain stored in wood products, averaged over 100 years, following the provided requirements and methods.*

5. Quantifying Secondary Effects

Significant Secondary Effects for Avoided Conversion projects can arise if the type of land use conversion that would have happened on the Project Area is shifted to other forest land.

To quantify Secondary Effects for Avoided Conversion projects, use Equation 6.12.

The value for Secondary Effect emissions will always be negative or zero.

Equation 6.12. Secondary Effects Emissions

$SE_y = MIN[(-0.036 \times (\Delta AC_{onsite} - \Delta BC_{onsite}), 0]$

Where,

SE_y = *Secondary Effect GHG emissions caused by the project activity in year y (Equation 6.1)*
MIN = The lowest value in the set of values being evaluated.
-0.036 = Conversion displacement risk value, assumed to be 3.6% for all forest lands
ΔAC_{onsite} = *Annual difference in actual onsite carbon (CO2e) as defined in Equation 6.1*
ΔBC_{onsite} = *Annual difference in baseline onsite carbon (CO2e) as defined in Equation 6.1*

Improved Forest Management

The California Air Resources Board's Compliance Offset Protocol for U.S. Forest Projects lays out the following methodology for **calculating net GHG removals due to improved forest management on public lands**:

1. **Estimating Baseline Carbon**

   For Improved Forest Management Projects on lands owned or controlled by public agencies, the baseline must be estimated by:

   - *Conducting an initial forest carbon inventory for the Project Area*
   - *Projecting future changes to Project Area forest carbon stocks by:*
     - *Extrapolating from historical trends*
     - *Anticipating how current public policy will affect onsite carbon stocks*

   The method that results in the highest estimated carbon stock levels must be used to determine the baseline.

   To extrapolate from historical trends:

   - *For Project Areas that have a ten-year history of declining carbon stocks, the baseline must be defined by the average of the carbon stocks over the past ten years and considered static for the project life (i.e. the same level of carbon stocks is assumed in every year).*
   - *For Project Areas that demonstrate an increasing inventory of carbon stocks over the past ten years, the growth trajectory of the baseline shall continue until the forest (under the baseline stocks) achieves a stand composition consistent with comparable forested areas that have been relatively free of harvest over the past 60 years.*

   To anticipate how current public policy will affect onsite carbon stocks, the baseline must be modeled over 100 years following the requirements and methods in Appendix B incorporating constraints imposed by all applicable statutes, regulations, policies, plans and Activity-Based Funding.

2. **Estimating Baseline Carbon in Harvested Wood Products**

   To estimate the amount of baseline carbon transferred to long-term storage in wood products each year, the following steps must be performed:

   a. *Determine the average amount of carbon in standing live carbon stocks (prior to delivery to a mill) that would have been harvested in each year of the baseline over 100 years. The result will be a uniform estimate of harvested carbon in each year of the baseline. This estimate is determined at offset project commencement, using the same volume models and biomass equations used to calculate biomass in live trees and estimate baseline onsite carbon stocks; this will not change over the course of the project life.*

      i. *For offset projects on private lands, the amount of harvested carbon must be derived from the growth and harvesting regime used to develop the baseline for onsite carbon stocks in Section 6.2.1.*

      ii. *For offset projects on public lands, the amount of harvested carbon must be derived from the growth and harvesting regime assumed in the baseline for onsite carbon stocks derived in Section 6.2.2.*

b. *On an annual basis, determine the amount of harvested carbon that would have remained stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.*

3. **Determining Actual Onsite Carbon Stocks**

Actual carbon stocks for Improved Forest Management projects must be determined by updating the Project Area's forest carbon inventory. This is done by:

a. *Incorporating any new forest inventory data obtained during the previous year into the inventory estimate. Any plots sampled during the previous year must be incorporated into the inventory estimate.*
b. *Using an approved model to "grow" (project forward) prior-year data from existing forest inventory plots to the current reporting year. Approved growth models and requirements and methods for projecting forest inventory plot data using models are provided in Appendix B.*
c. *Updating the forest inventory estimate for harvests and/or disturbances that have occurred during the previous year.*
d. *Applying an appropriate confidence deduction for the inventory based on its statistical uncertainty, following the requirements and methods in Appendix A, Section A.4.*

4. **Determining Actual Carbon in Harvested Wood Products**

Perform the following steps to determine actual carbon in harvested wood products:

a. *Determine the actual amount of carbon in standing live carbon stocks (prior to delivery to a mill) harvested in the current year (based on harvest volumes determined in Section 6.2.4).*
b. *Determine the amount of actual harvested carbon that will remain stored in wood products, averaged over 100 years, following the requirements and methods in Appendix C.*

5. **Quantifying Secondary Effects**

For Improved Forest Management Projects, significant Secondary Effects can occur if a project reduces harvesting in the Project Area, resulting in an increase in harvesting on other properties. Equation 6.10 must be used to estimate Secondary Effects for Improved Forest Management projects:

Equation 6.10. Secondary Effects Emissions

$$If \sum_{n=1}^{y}(AC_{hv,n} - BC_{hv,n}) \geq 0, then\ SE_y = 0$$

$$If \sum_{n=1}^{y}(AC_{hv,n} - BC_{hv,n}) < 0, then\ SE_y = (AC_{hv,y} - BC_{hv,y}) \times 20\%$$

Where,

SE_y	=	Estimated annual Secondary Effects (used in Equation 6.1.)
$AC_{hv,n}$	=	Actual amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons
$BC_{hv,n}$	=	Estimated average baseline amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tons, as determined in Step 1 of Section 6.2.3
Y	=	The current year or reporting period

Ensuring the Permanence of Credited GHG Reductions and GHG Removal Enhancements

The Regulation requires that credited GHG reductions and GHG removal enhancements be "permanent." Permanence of Forest project GHG reductions and removals is addressed through three mechanisms:

a. *The requirement for all offset projects to monitor onsite carbon stocks, submit annual Offset Project Data Reports, and undergo third-party verification of those reports with site visits at least every six years for the duration of the Project Life.*
b. *The regulatory obligation for all intentional reversals of GHG reductions and GHG removal enhancements to be compensated for through retirement of other Compliance Instruments.*
c. *The maintenance of a Forest Buffer Account by ARB to provide insurance against reversals of GHG reductions and GHG removal enhancements due to unintentional causes (including natural disturbances such a fires, pest infestations, or disease outbreaks).*

GHG reductions and GHG removal enhancements can be "reversed" if the stored carbon associated with them is released (back) to the atmosphere. Many biological and non-biological agents, both natural and human-induced, can cause reversals. Some of these agents cannot completely be controlled and may therefore result in an unintentional reversal, such as natural agents like fire, insects, and wind. Other agents can be controlled such as the human activities like land conversion and over-harvesting. Under this protocol, reversals due to controllable agents are considered intentional as defined in the Regulation. The Offset Project Operator or Authorized Project Designee is required to identify and quantify the risk of reversals from different agents based on offset project-specific circumstances. The resulting risk rating determines the quantity of ARB offset credits that the project must contribute to the Forest Buffer Account to insure against unintentional reversals.

Identifying a Reversal

The Offset Project Operator or Authorized Project Designee must demonstrate, through annual reporting and periodic verification, that stocks associated with credited GHG reductions and GHG removal enhancements are maintained for a period of time considered to be permanent.

For purposes of this protocol 100 years is considered permanent. If the quantified GHG reductions and GHG removal enhancements (i.e. QRy in Equation 6.1) in a given year are negative, and ARB offset credits were issued to the Forest Project in any previous year, it is considered a reversal, regardless of the cause of the decrease. Planned thinning or harvesting activities, for example, may cause a reversal if they result in a negative value for QRy.

Insuring Against Reversals

Unintentional reversals are insured against by contributing a percentage of ARB offset credits to a Forest Buffer Account. The amount of the contribution is based on a project-specific risk evaluation.

About the Forest Buffer Account

A Forest Buffer Account is a holding account for ARB offset credits issued to Forest Project, which is administered by ARB. All Forest Projects must contribute a percentage of ARB offset credits to the Forest Buffer Account any time ARB offset credits are issued by ARB for verified GHG reductions and GHG removal enhancements. Each Forest Project's contribution is determined by a project-specific risk rating, as described in Section 7.2.2. If a Forest Project experiences an unintentional reversal of credited GHG reductions and GHG removal enhancements (as defined in Section 7.3), ARB offset credits from the Forest Buffer Account will be retired in an amount equal to the total amount of carbon that was reversed (measured in metric tons of CO2-equivalent) according to the process identified in the Regulation. A Forest Buffer Account therefore acts as a general insurance mechanism against unintentional reversals for ARB offset credits issued to Forest Projects.

Reforestation

The California Air Resources Board's Compliance Offset Protocol for U.S. Forest Projects lays out the following requirements for **developing a forest inventory to calculate net GHG removals due to reforestation on public lands**:

Step 1 – Developing Inventory Methodology and Sample Plots

- *Stratification is not required, but it may simplify verification.*
- *The requirements of Table A.2 below must be satisfied:*

Table A.2. Minimum required sampling criteria for estimated pools

Carbon Pool	Name of Requirement	Description of Requirement
Standing Live Carbon Stocks (above-ground portion)	Diameter (breast height) Measurements	The minimum diameter (at breast height) must be stated in the methodology, and this minimum diameter must not be greater than 5 inches (inventory must include all trees 5 inches and greater in diameter).
	Height Measurements	Height must be measured as per the inputs required by the volume models and/or biomass equations for each species and/or for subsequent updates to the inventory upon re-measurement. If the project's growth and yield model imputes heights utilizing the model's own data points (but accepts measured height) height measurements collected in the field or derived from field inventory must be used in the model. In interim years when inventory data is modeled, DBH and height estimate outputs from the model may be used as the basis for carbon calculations. A portion of heights may be estimated as long as the height estimate methodology and overall inventory method employed results in an inventory that is capable of being quantified at the plot level to a high degree of accuracy, designed such that any qualified forester would be able to accurately repeat the previous measurements, whereby the verifier reviews the inventory sampling methodology and agrees that all sampling methodology and measurement standards are statistically sound. All height and field measurements within a project area are subject to passing sequential sampling and verification.
	Deductions for Missing Biomass	Standing live trees may have cavities, broken tops, or other deformities that reduce biomass in the trees. Inventory methodology must include a standardized approach and description of how deductions are estimated to account for missing biomass.
	Measurement Tools	Description of tools used for height measurement, diameter measurement, and plot measurement.
	Measurement Standards	The methodology shall include a set of standards for tree and plot size measurements.
	Plot Layout	A description of plot layout.
	Merchantability of Trees	The methodology shall include all trees regardless of current merchantability to be included in the sampling design.
	Allometric Equation used for Estimating Biomass	The methodology must include a description of the allometric equation used to estimate the whole tree biomass (bole, branches, and leaves) from bole diameter measurements. The use of functions other than those provided in the protocol will need to be approved by ARB and the verification body.
Standing Live Carbon Stocks (below-ground portion)	Plot-level Allometric Equation used for Estimating Biomass	Apply model (Cairns, Brown, Helmer, & Baumgardner, 1997) to estimate below-ground biomass density for projects located in California, Oregon, and Washington. This model equation is based on above-ground biomass density in tons per hectare. For projects in the other 45 states apply the component ration methods. The use of a function other than that provided in the protocol will need to be approved by ARB and the verification body.

Herbaceous Understory	Sampling Methodology	The sampling methodology prepared by Brown, Shoch, Pearson, & Delaney (2004). Alternative methodologies need to be reviewed and approved by ARB and the verification body.
Standing Dead Tree Carbon Stocks (above-ground)	Diameter (breast height) and top Diameter Measurements	The minimum diameter (at breast height) must be stated in the methodology, and this diameter must not be greater than 5 inches. The minimum height of standing dead trees is 15'. The method must include how volume is derived where a total height does not exist (i.e. where the tree is broken).
	Deductions for Missing Biomass	Standing dead trees may have cavities, broken tops, or other deformities that reduce biomass in the trees. Inventory methodology must include a standardized approach and description of how deductions are estimated to account for missing biomass. For projects in California, Oregon, and Washington, adjustments for decay and structural loss must be incorporated in the sampling design and reflected in the project inventory accounting methodology, using Harmon et al. (2011) density factors by decay class. For projects in the other 45 states, adjustments for decay and structural loss must be incorporated in the sampling design and reflected in the project inventory accounting methodology using Domke et al (2011) decay and structural loss adjustment factors.
	Measurement Standards	The methodology shall include a set of standards for height and diameter measurements.
	Plot Layout	A description of plot layout (may be the same layout as for live tree biomass).
	Merchantability of Trees	The methodology shall include all trees regardless of current merchantability to be included in the sampling design.
Standing Dead Tree Carbon Stocks (below-ground portion)	Plot-level Allometric Equation used for Estimating Biomass	Apply model (Cairns, Brown, Helmer, & Baumgardner, 1997) to estimate below-ground biomass density for projects located in California, Oregon, and Washington. This model equation is based on above-ground biomass density in tons per hectare. For projects in the other 45 states apply the component ration methods. The use of a function other than that provided in the protocol will need to be approved by ARB and the verification body.

Step 2 – Estimating Carbon in Live Trees from Sample Plots

- *Includes carbon in all portions of the tree*
- *Estimate of aboveground live tree biomass combined with other carbon pools to estimate volume/mass, with a summary that describes the statistical confidence of the estimate.*

Step 3 – Estimating Carbon Standing Dead Tree Carbon from Sample Plots

- *Estimate for standing dead tree carbon for highly decayed trees must be calculated first volumetrically and subsequently converted to biomass and carbon tons.*
- *Volumes will need to be converted to biomass density by applying conversion factors based on decay class.*
- *For projects in California, Oregon and Washington, estimates of trees in advanced stages of decay are obtained by estimating gross volume using the required volume models on the ARB Forest Offset Protocol Resources section of ARB's webpage, converting to sound volume, and then applying density factors by decay class from Harmon el al. (2011) to estimate density in standing dead trees.*

Step 4 – Estimate Carbon in Shrubs and Herbaceous Understory from Sample Plots

- *Most applicable estimation methods may be used, including photo series, estimation functions from published papers, direct sampling, or combinations of approaches.*

Step 5 – Estimate of Carbon Tons in Soil

- *Use the soil sampling methodology prepared by Brown, Shoch, Pearson, & Delaney (2004).*

Step 6 – Sum Carbon Pools

- *All numbers must be converted to metric tons of CO_2-equivalent.*

Applying a Confidence Deduction

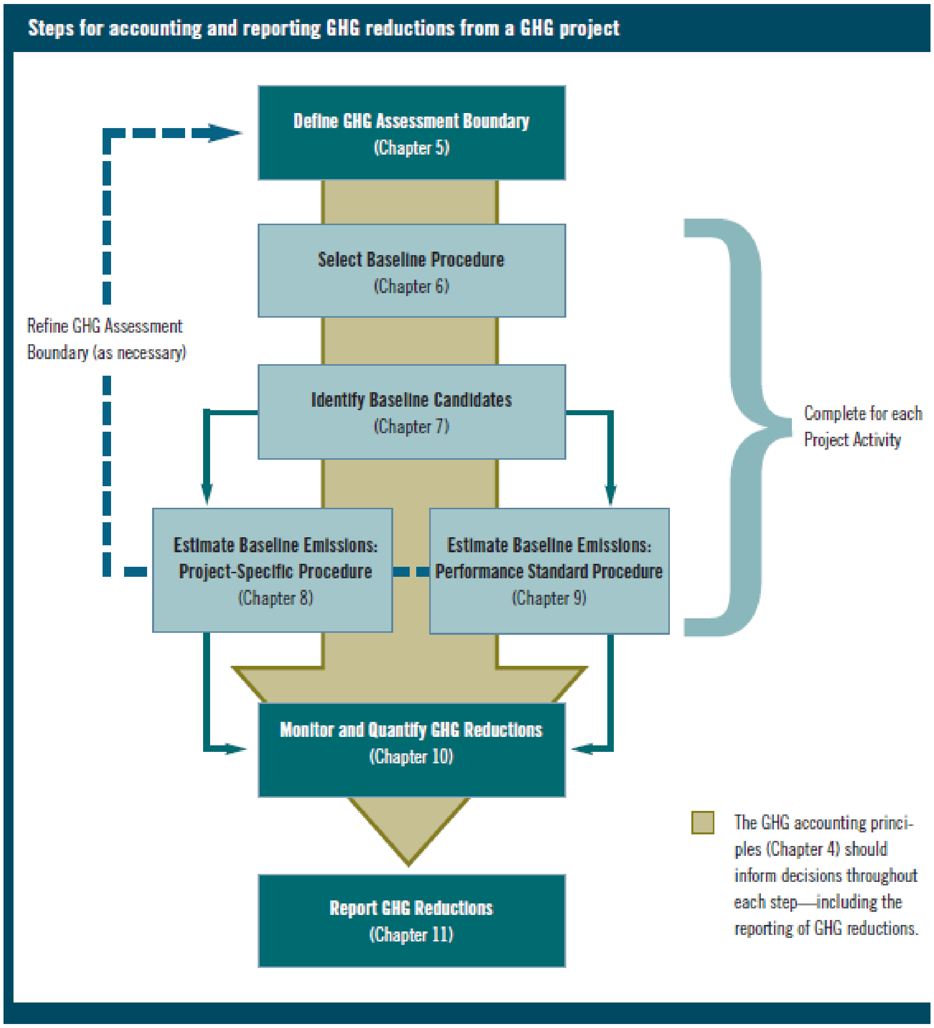
- *To help ensure that estimates of GHG reductions and GHG removal enhancements are conservative, a confidence deduction must be applied each year to the inventory of actual onsite carbon stocks. A confidence deduction is not applied to the forest carbon inventory when it is used to model baseline carbon stocks.*
- *Calculate sampling error using provided methodology, and deduct from inventory as needed.*

Using Models to Forecast Carbon Stocks

- *The use of simulation models is required for estimating a Forest Project's baseline carbon stocks.*
- *Models may also be required to forecast actual carbon stocks expected under the Forest Project (e.g. in conjunction with determining expected harvesting volumes or in updating forest carbon inventories).*
- *A modeling plan must be prepared that addresses all required forecasting or updating of baseline and actual carbon stocks for the Forest Project.* ***The modeling plan shall contain the following elements:***
    - *A description of all silviculture methods modeled. The description of each silviculture method will include:*
        - *A description of the trees retained (by species groups if appropriate) at harvest.*
        - *The harvest frequency (years between harvests).*
        - *Regeneration assumptions.*
    - *A list of all legal constraints that affect management activities on the Project Area. This list must identify and describe the constraint and discuss the silviculture methods that will be modeled to ensure the constraint is respected.*
    - *A description of the site indexes used for each species and an explanation of the source of the site index values used.*
    - *A description of the model used and an explanation of how the model was calibrated for local use, if applicable.*
- *Modeling outputs must include:*
    - *Periodic harvest, inventory, and growth estimates for the entire Project Area presented as total carbon tons and carbon tons per acre.*
    - *Harvest yield streams on modeled stands, averaged by silviculture method and constraints, which must include the period over which the harvest occurred and the estimated volume of wood removed.*

Appendix B.
Project-Specific Protocol Overview

This appendix provides an overview of the GHG Protocol's *GHG Protocol for Project Accounting*.



1. Defining the GHG Assessment Boundary

For complete, accurate, and transparent quantification of project-based GHG reductions, the GHG assessment boundary shall be clearly defined and reported. The GHG assessment boundary shall include the primary and significant secondary effects of all project activities. The following steps are required for defining the GHG assessment boundary:

1. Identify each project activity associated with the GHG project.
2. Identify all primary effects related to each project activity.
3. Consider all secondary effects related to each project activity.
4. Estimate the relative magnitude of all secondary effects.
5. Assess the significance of all secondary effects.

Exclude insignificant secondary effects from the GHG assessment boundary. Justify any exclusions.

2. Selecting a Baseline Procedure

For each primary effect associated with a project activity the project developer shall select and justify the choice of baseline procedure used to estimate baseline emissions.

The performance standard procedure may be preferred when:

- **A number of similar project activities are being implemented.** Where a number of similar project activities in the same geographic area are being undertaken, developing a performance standard may be the most cost-effective route. If a GHG program approves a performance standard for one project activity, it may be used for numerous similar project activities in the same area (assuming they are all developed within the time period for which the performance standard is valid).

- **Obtaining verifiable data on project activity alternatives is difficult.** The project-specific procedure requires a structured analysis of the barriers and possibly the benefits associated with the project activity and its alternatives. This requires access to verifiable data on the barriers faced by these alternatives, as well as the expected benefits of these alternatives, including in some cases economic or financial performance data. While identifying barriers and expected benefits for the project activity may be relatively straightforward, undertaking the same analysis for its alternatives may be more challenging and time consuming. The performance standard procedure requires verifiable data on the GHG emission rates of individual alternatives, but not on their potential barriers or benefits. Thus, when access to information on the barriers and benefits for alternatives is limited, the performance standard procedure may be preferred.

- **Confidentiality concerns arise with respect to the project activity.** Under the project-specific procedure, any data relating to barriers and possibly net benefits should be reported. In some cases, these data may include financial or other information that project developers wish to keep confidential. If the credible identification of the baseline scenario under the project-specific procedure is not possible without the use of confidential data, project developers may prefer to use the performance standard procedure. However, in some cases gathering sufficient data from competitors to determine a performance standard may also be complicated due to confidentiality issues.

The project-specific procedure may be preferred when:

- **The number of baseline candidates is limited, or GHG emission rate data for baseline candidates are difficult to obtain.** The performance standard procedure requires verifiable GHG emission rate data on each individual facility or site within a given geographic area and temporal range, or a large enough sample of data to represent each facility or site statistically. The project-specific procedure, on the other hand, requires verifiable information relating to each representative type of technology or practice in the chosen geographic area and temporal range. In cases where the data set of facilities or sites may be too small—or access to GHG emission rate data is too limited—developing a robust performance standard may be difficult. In these situations, the project-specific procedure may be more appropriate.

Using a combination of baseline procedures

In some cases, it may be possible to combine the project specific and performance standard procedures to estimate baseline emissions. This would involve using a performance standard to characterize one of the alternatives (e.g., the continuation of current activities) in the project-specific procedure. Using a combination of the baseline procedures may be useful when the baseline scenario could be represented by a blend of alternative technologies, management or production practices, or delivery systems (e.g., grid-connected electricity generation). If a combination of baseline procedures is used, both procedures should be performed in their entirety.

3. Identifying the Baseline Candidates

For each project activity, the project developer shall develop a complete list of baseline candidates that will be used in the baseline procedures to represent possible alternatives to the project activity. The following steps are required:

1. Define the product or service provided by the project activity.
2. Identify possible types of baseline candidates.
3. Define and justify the geographic area and the temporal range used to identify baseline candidates.
4. Define and justify any other criteria used to identify baseline candidates.
5. Identify a final list of baseline candidates.
6. Identify baseline candidates that are representative of common practice (for the project-specific baseline procedure).

4. Estimating Baseline Emissions – Project-specific Procedure

For each project activity, the following steps shall be performed to identify the baseline scenario and estimate baseline emissions:

1. Perform a comparative assessment of barriers.
    a. Identify all barriers that would affect decisions to implement the project activity or any of the baseline candidates.
    b. Identify barriers to the continuation of current activities.
    c. Assess the relative importance of the identified barriers for each alternative.
2. Identify and justify the baseline scenario.
    a. Explain the significance of any barriers that affect the project activity and how these barriers will be overcome.
    b. Identify the baseline scenario using the results of the comparative assessment of barriers. Where it is not possible to identify the baseline scenario using the results of the comparative assessment of barriers, either:
        i. identify the baseline scenario as the most conservative viable alternative, which will have the lowest GHG emissions or the highest GHG removals compared to other viable alternatives; or
        ii. identify the baseline scenario using a net benefits assessment. The baseline scenario will be the alternative with the greatest net benefits— excluding any benefits resulting from GHG reductions—relative to assessed barriers.
    c. Justify the identified baseline scenario.

3. Estimate baseline emissions.
    a. Use assumptions, calculations, and emission factors specific to the identified baseline scenario.

5. Estimating Baseline Emissions – Performance Standard Procedure

The steps outlined below shall be followed to derive a performance standard relevant to the type and location of the GHG project being proposed.

5.1 Specify appropriate performance metrics for all baseline candidates.

Select and report an appropriate performance metric(s), depending on the type of project activity and the number of relevant inputs used by the baseline candidates.

Production-based performance standards

For energy efficiency, energy generation, and industrial process project activities, a performance metric shall be identified for each set of baseline candidates that uses the same type of relevant input.

$$\text{Performance Metric} = \frac{I_c}{P}$$

Where:

• Ic = Units of a relevant input common to all baseline candidates of type c

• P = Units of a product or service, common to all baseline candidates, that depends on input Ic

Justify the choice of input, and product or service, for each identified performance metric. The product or service (denominator) shall be the same as that identified in Chapter 7, section 7.1.

Where a baseline candidate does not use any inputs related to the project activity's primary effect, a separate performance metric does not need to be identified and the GHG emission rate for the baseline candidate is zero.

Time-based performance standards

For project activities involving storage and removals of CO_2 by biological processes, fugitive emissions, or waste emissions, a single performance metric shall be identified that relates GHG emissions to a specific length of time for each baseline candidate:

$$\text{Performance Metric} = \frac{E}{S \cdot t}$$

• E = Units of GHG emissions or removals

• S = Units of baseline candidate size or capacity

• t = Units of time

Justify why the type of units chosen for S and t are the most appropriate for developing a performance metric. Both the type of GHG emissions in the numerator and the type of units for the denominator shall be common to all baseline candidates.

5.2 Calculate the GHG emission rate for each baseline candidate

For each baseline candidate, calculate and report a GHG emission rate using the performance metric(s) selected above. Perform the following steps, depending on the type of performance standard being derived:

Production-based performance standards

For each baseline candidate:

- Obtain the quantity of the relevant input required by the baseline candidate over a specified time period (in units of Ic). The time period used to gather the data shall be reported and justified and shall be comparable for all baseline candidates. Report and justify any discrepancies between the time periods used for different baseline candidates (e.g., different lengths or different periods of time).
- Obtain the quantity of product or service produced by the baseline candidate (in units of P) over the same time period that was used to measure the quantity of relevant input used.
- Convert the quantity of the relevant input to GHG emissions using an appropriate emission factor. Any and all emission factors shall be reported and justified. Each baseline candidate shall have a GHG emission rate of the form:

$$\frac{\text{Quantity of GHG emissions}}{\text{P}}$$

Time-based performance standards

For each baseline candidate:

- Identify the size or capacity of the baseline candidate (in units of S).
- Obtain the quantity of the relevant GHG emissions (in units of E) produced by the baseline candidate over a specified time period (in units of t). Report and justify the time period and its length. Where GHG emissions data for a baseline candidate were collected during a period of time significantly different from other baseline candidates (e.g., during a different year), report and justify this discrepancy. Each baseline candidate shall have a GHG emission rate in the form:

$$\frac{\text{Quantity of GHG emissions}}{\text{S} \cdot t}$$

5.3 Calculate GHG emission rates for different stringency levels

Numerically analyze the GHG emission rates of all baseline candidates to calculate the GHG emission rates corresponding to the following stringency levels:

- Most stringent: The best-performing baseline candidate (i.e., the baseline candidate with the lowest GHG emission rate or highest GHG storage/removal rate).
- The weighted mean GHG emission rate.

- The median GHG emission rate (i.e., the 50^{th} percentile, calculated in the same manner as other percentile calculations).
- At least two better-than-average GHG emission rates (e.g., the 25th and 10th percentiles). The mean, median, and percentile GHG emission rates shall be calculated to reflect the relative contribution of each baseline candidate to total production (production- based performance standards) or to the aggregate size or capacity of all baseline candidates (time-based performance standards).

5.4 Select an appropriate stringency level for the performance standard

Choose the stringency level that is most appropriate for approximating baseline emissions. The GHG emission rate associated with this stringency level shall be the performance standard. Report the selected stringency level and associated performance standard and justify why it was chosen.

5.5 Estimate baseline emissions

For production-based performance standards, calculate baseline emissions by multiplying the level of production of the project activity (i.e., total units of product or service produced) by the performance standard emission rate. For time-based performance standards, calculate baseline emissions by multiplying the relevant time period (e.g., one year) and the project activity size or capacity by the performance standard emission rate.

6. Monitoring and Quantifying GHG Reductions

6.1 Create a plan for monitoring GHG emissions and baseline parameters related to each project activity's GHG effects.

The monitoring plan shall contain provisions for:

- monitoring GHG emissions from all GHG sources and sinks related to primary and significant secondary effects within the GHG assessment boundary;
- monitoring any data related to assumptions underlying baseline emission estimates (i.e, baseline parameters); and
- describing data storage and quality assurance/quality control (QA/QC) measures.

Monitor Project Activity Emissions

For each GHG source or sink related to a primary or significant secondary effect, the following shall be described in the monitoring plan:

- The data that will be monitored relating to GHG emissions.
- Whether the data are measured, modelled, calculated, or estimated; the level of uncertainty in any measurements or estimates; and how this uncertainty will be accounted for.
- Where relevant, the project activity operating conditions during periods when data are monitored.
- All measurement or other data collection methods used. Include all relevant assumptions, constants, mathematical relationships, and formulas.
- Technical information related to the collection of measurement data.
- For technology-based projects this includes such information as the location and specifications of meters; procedures for meter reading, calibration, and maintenance; the length of measurement periods, etc.
- For practice-based projects, this includes a description of equipment and methods used to gather data, control sites (if any), procedures for calibrating and maintaining equipment, etc.
- The frequency of monitoring activities.

- All sources of data and information.

Justify any instances where GHG emissions associated with a secondary effect are too costly to monitor and must therefore be estimated.

Monitor Baseline Parameters

All baseline parameters shall be described in the monitoring plan, including:

- What data will be monitored and how they relate to baseline emission estimates for the primary and secondary effects.
- Whether the data are measured, modelled, calculated, or estimated; the level of uncertainty in any measurements or estimates; and how this uncertainty will be accounted for.
- All measurement or other data collection methods used. Include all relevant assumptions, constants, mathematical relationships, and formulas.
- Technical information related to the collection of measurement data.
- The frequency of monitoring activities.
- All sources of data and information.

Describe QA/QC Measures

How the GHG project data will be maintained and how QA/QC measures will be implemented shall be described in the monitoring plan and include the following information:

- Entity(ies) or person(s) responsible for measurement and data collection procedures.
- Length of time the data will be archived.
- Data transmission, storage, and backup procedures and strategies for identifying and managing lost or poor-quality data.
- All QA/QC procedures for measurement, calculation, and data collection procedures.

6.2 Quantify GHG reductions for the GHG project.

GHG reductions shall be quantified using the following steps.

- Identify the time period over which the GHG reductions will be quantified:
    - For each project activity and primary effect, identify and justify the valid time length for the corresponding baseline scenario or performance standard.
    - Quantify GHG reductions for a period of time no longer than the shortest valid time length identified.
- Using monitored data, quantify the GHG reductions for the GHG on a periodic basis, e.g., annually
    - Quantify the project's GHG reductions as the sum of all primary effects and significant secondary effects for all project activities.
    - Document the calculation methods used to quantify GHG reductions and any uncertainties associated with estimates of each project activity's GHG emissions.

Appendix C.
Landfill Emissions Assessment

SCS ENGINEERS

King County Landfill Greenhouse Gas (GHG) Methodology Review

Presented to:

Cascadia Consulting Group

CASCADIA
CONSULTING GROUP

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November 4, 2016
File No. 04215055.00

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Section **Page**

1 INTRODUCTION

The following serves as SCS Engineers (SCS) draft report regarding the review of the King County (County) Department of Natural Resources and Parks (DNRP) greenhouse gas (GHG) emission inventory and offset calculations methodology for the County landfills (Project). A brief background, summary of our review, and recommendations are provided below. SCS's methodology review was completed based on provided documentation and subsequent discussions with the DNRP. This work was completed under contract to Cascadia Consulting Group (Cascadia).

2 BACKGROUND

SCS' goal for this project was to review the DNRP's GHG calculation methodology and emissions inventory for County landfills, specifically related to landfill and landfill gas (LFG) emissions. The calculation methodology was compared with industry literature, best practices, and protocols used within the solid waste industry for calculating and reporting GHG emissions from landfills at the state and federal levels. SCS has provided recommended changes to the GHG emissions and offset inventory and methodologies for DNRP's closed and active landfill GHG inventory.

DNRP provided the following documents for review in regards to the landfill GHG emission calculations methodology:

- Draft Solid Waste Division (SWD) Green House Gas (GHG) Emissions Report for King County 2014 Annual Climate Report and Appendices A through C
- Greenhouse Monitoring Plan, Cedar Hills Regional Landfill, Revised May 18, 2011
- 2013 Flare Source Test Report at Cedar Hills Regional Landfill, May 24, 2013

2.1 KING COUNTY SOLID WASTE DIVISION

- Number of Facilities – 7
  - Active Landfills – 1 facility
    - Cedar Hills Regional Landfill (CHRL)
  - Closed Landfills – 6 facilities
    - Cedar Falls Landfill
    - Enumclaw Landfill
    - Hobart Landfill
    - Vashon Landfill
    - Puyallup Landfill
    - Houghton Landfill
- GHG Included in the Landfill Inventory
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous oxide (N_2O)

- Excluded GHGs from landfill Inventory, but included in Cascadia scope
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur hexafluoride (SF_6)
- Project Emissions
  - Stationary Sources
    - Flares (open and closed)
    - LFG to BioEnergy Washington (BEW) Plant
  - Fugitive Sources
    - Vented methane (CH_4) from landfills
    - Vented CH_4 from flares
- Project Offsets
  - Carbon Sequestration at the CHRL

Note, based on the scope of work and previous conversations with Cascadia, it is assumed that indirect emissions from electricity usage, direct emissions from mobile sources (e.g. landfill vehicles, landfill mobile equipment, landfill working face mobile equipment, etc.) and stationary combustion (e.g. emergency generators, light plants, comfort heating for onsite buildings, etc.), and fugitive emissions from refrigerants (e.g. air conditioning, refrigerator, etc.) will be covered under Cascadia's scope of work. As such, SCS did not review these items during our landfill methodology review. SCS also did not review the transfer station emissions or any other solid waste facility emissions outside of landfill emissions in regards to the DNRP's emission inventory and methodology review.

3 PROJECT APPROACH AND METHODOLOGY

Per DNRP's project approach and methodology for the solid waste division's landfills, DNRP followed the United States (U.S.) Environmental Protection Agency (EPA) standard methods for estimating and screening emissions. SCS only reviewed information pertinent to the County's landfill and the associated emissions stated above in the background section. Per the landfill GHG emissions inventory, DNRP relied upon the EPA Landfill Gas Emissions Model (LandGEM), Version 3.02, which is a first-order decay model for municipal solid waste landfills. For sites with an active gas system, DNRP collects and records the emissions associated with destruction or venting of LFG emissions by each system/device. In regards to carbon sequestration, DNRP used the EPA's Waste Reduction Model (WARM).

4 REVIEW SUMMARY AND FINDINGS

The purpose of the draft SWD GHG Emissions Report for King County 2014 Annual Climate Report was to compile the GHG emissions inventory for 2014 at the active and closed landfills within the DNRP's control. Another purpose of the report was to project GHG emissions from those landfills until 2020 for inclusion in the 2014 King County Climate Action Report.

The GHG inventory included emissions calculations and methodology for the following sources:

- CHRL – Active
- Cedar Falls Landfill – Closed
- Enumclaw Landfill – Closed
- Hobart Landfill – Closed
- Vashon Landfill – Closed
- Puyallup Landfill – Closed
- Houghton Landfill – Closed
- LFG Fueled Stationary Combustion Sources (flares)
- Carbon Sequestration at the CHRL

4.1 LANDFILL GAS EMISSIONS MODEL (LANDGEM)

LFG emission generation rates were estimated by utilizing the EPA LandGEM for the active and closed landfills, except the Puyallup and Houghton landfills. These two facilities were included in the report but historical waste disposal records were not available, therefore, a LandGEM model was not performed.

The LandGEM models for the remaining landfills incorporated waste quantities specific to each landfill's disposal history. Several modeling variables were assigned the default LandGEM values, which included:

- Degrading organic compound (DOC),
- Methane correction factor,
- Degrading organic compound fraction, and
- Methane content.

The following modeling variables were assigned site specific or industry specific values which are shown in ***Table 1*** below.

Table 1 – DNRP Modeling Variables

Modeling Variable	DNRP Value	Unit	Comments
Potential methane generation capacity (L_o)	100	cubic meters per tonne (m^3/tonne)	Used in all models was based on the default Inventory Conventional value
Methane generation rate (k)	0.057	per year	Used in all models was a non-default value
Non-methane organic compound (NMOC) concentration	350	parts per million by volume (ppmv) as hexane	Used in all models was a non-default value, but was based on the NMOC concentrations measured during the 2013 flare source testing conducted at the CHRL

The LandGEM model for the CHRL included waste tonnage projections through the year 2040. However, according to the draft SWD GHG Emissions Report, the current landfill life for the

CHRL is assumed to be 2027 per the 2010 Site Development Plan. The DNRP's GHG emission inventory included estimated emissions through 2020. Emissions may vary depending on the lifespan of CHRL as well as the project annual future disposal tonnages.

4.2 ACTIVE GCCS DATA COLLECTION METHODS

LFG composition data for all sites with an active LFG collection and control system (GCCS) were collected at the inlet points of the individual facilities flare station or carbon canister system. The inlet point of the flare station at the CHRL is collected once every morning using a GEM 2000, or GEM 5000 portable gas analyzer. At the Enumclaw and Hobart closed landfills, LFG composition data is also collected at the flare inlet point, and at Vashon Island landfill, LFG composition is collected at the carbon canister system inlet point using a GEM 2000 or GEM 5000 portable gas analyzer.

LFG flow rates at CHRL are measured with flow meters installed at the flare inlets at the CHRL. The flow rates are recorded at 15 minute intervals and are retrievable through an electronic supervisory control and data acquisition (SCADA) system at the CHRL. It is unclear how the flow rates are recorded at the closed landfills, which have operating GCCSs.

4.3 DATA VALIDATION METHODS

CHRL data is collected from the field measurements or obtain by the SCADA system is proposed to be validated through the following process parameter metrics:

- Total Flow rate - <12,000 standard cubic feet per minute (scfm)
- Methane concentration – between 35 and 60 percent by volume for the active landfill and less than 45 percent by volume for the closed landfills.
- Oxygen concentration – less than 21 percent by volume
- Carbon dioxide concentration – less than 40 percent by volume
- Temperature – less than 131 degrees Fahrenheit (°F)
- Flow rate to BioEnergy Washington facility – less than 10,000 scfm
- Flow rate through flares – less than 3,000 scfm
- LFG collection efficiency – less than or equal to 100 percent

Data validation methods were not provided for the closed landfill emissions.

4.4 DATA ANALYSIS METHODS

The CHRL data is collected from the field measurements or obtain by the SCADA system is proposed to be analyzed using MS Excel software utilizing the following steps:

- Raw LFG data are organized based on date and time

- Methane concentration and flow rate data expressed as a percent volume and in scfm, respectively.
- Methane quantity in the LFG is determined by multiplying the LFG flow rate by the measured methane concentration and converted into metric tons using the approximate density of 0.68 kilograms per cubic meter and other unit conversion factors.
- A methane oxidation factor for the landfill cover system based on the EPA's oxidation factor table.
- Net methane emissions are calculated by multiplying the gross methane amount by (1-0.35) to account for oxidation.
- The net methane gas quantity is multiplied by 25 (methane global warming potential) to convert the GHG emissions to metric tons of carbon dioxide equivalent ($MTCO_2e$)

Data analysis methods were not provided for the closed landfill emissions.

4.5 MISSING DATA ANALYSIS

The CHRL missing data analysis is based on the federal GHG Mandatory Reporting Rule (MRR) requirements contained in 40 Code of Federal Regulations (CFR) Part 98.354. For each missing value of methane content and/or gas flow rate, the substitute data value is obtained by calculating the arithmetic average of the quality-assured values immediately preceding and immediately following the missing data set. If the "after" value is not obtained by the end of the reporting year, the "before" value is used for the missing data substitution. If, for a particulate parameter, no quality-assured data is available prior to the missing data, the first quality-assured value obtained after the missing data period is used as the substitute data value.

For missing daily waste disposal quantity data, the substitute data value used is the average daily waste disposal quantity for that day of the week as measured on the week before and the week after the missing daily data.

Missing data analysis methods were not provided for the closed landfill emissions.

4.6 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

The following QA/QC procedures have been selected for collecting, recording, analyzing, and reporting of GHG emissions data at the CHRL in accordance with 40 CFR 98.364.

- Calibration of Instruments – GEM 2000 and GEM 5000. The GEM instrument(s) are calibrated against a gas of known concentration before taking any readings in the field.
- The working condition of sensors are checked during regular maintenance shutdowns
- Recorded data is stored in a database that is routinely backed up.
- For any abnormal gas composition of flow rate reading, the data is re-measured. For outlying data, the monitoring is repeated.

- Data field names, units, locations, dates and times of measurements are properly recorded for verification purposes.

QA/QC methods were not provided for the closed landfill emissions.

4.7 REGULATORY REQUIREMENT AND CONSISTENCY CHECK

According to the report, the main requirements of the Title V air operating permit for the CHRL are to construct and contain the environmental control systems of the landfill; create the proper anaerobic conditions of the landfill; monitor, measure, record, report the LFG emissions (including GHG emissions), fugitive emissions, gas collection and system utilization; measure, record, and report gas combustion systems startup, shutdown, and malfunction (SSMs) of the treatment system.

The Title V permit contains conditions that require monthly, quarterly, bi-annual, and annual reporting. The GHG emission inventory performed for Title V compliance is consistent with the EPA reporting requirements.

Starting on January 1, 2010, the EPA required landfill site owners to monitor and report GHG emissions under 40 CFR Part 98, Subpart HH if their facilities meets the reporting criteria of 40 CFR §98.2 (a) (1). The two criteria that can trigger reporting requirements are:

1. Municipal Solid Waste (MSW) landfills which have accepted waste on or after January 1, 1980. This source does not include hazardous waste landfills, construction and demolition landfills, or industrial landfills. This source category consists of the following at MSW landfills: the landfill itself, LFG collection systems, and LFG destruction devices (including flares).

2. MSW landfills that generate methane in amounts equivalent to 25,000 metric tons of carbon dioxide equivalent (MT CO_2e) or more per year, as determined according to Subpart HH of this part.

Furthermore, if the MSW landfill facility has a GCCS, additional data must be reported and additional calculations must be completed for reporting. A list of the specific data reporting and recordkeeping requirements is contained in 40 CFR Part 98, Subpart HH.

The Washington Department of Ecology (Ecology) also requires reporting of GHG emissions. The specific requirements are found under the Washington Administrative Code (WAC) Chapter 173-441. WAC 173-441-120 incorporates calculation methodologies by reference from 40 CFR Part 98 for specific facilities. MSW landfills are included on Table 120-1 adopting the federal methodology (Subpart HH) in whole, except that carbon dioxide (CO_2) emissions from combustion of LFG must also be included in calculating emissions for reporting and applicability determination.

Regulatory requirement and consistency checks were not provided for the closed landfill emissions.

5 RECOMMENDATIONS

Based on a review of the documents and discussions with DNRP, the GHG emission calculations appear to be a mix of the federal GHG MRR and the EPA LandGEM methodologies. The mix of methodologies was likely performed in an attempt to meet the dual purpose of the emissions report (prepare a GHG emissions inventory for 2014 and to project GHG emissions until 2020 for inclusion in the Climate Action Report). However, by mixing the methodologies, it creates an emissions inventory that does adhere to the state or federal GHG reporting requirements and their respective methodologies.

Although there are numerous GHG protocols and for calculating or projecting emissions, the best practices used within the industry for calculating and reporting a GHG emissions inventory from a landfill is the federal MRR methodology. The LandGEM methodology is typically used as a screening tool to determine state and federal reporting requirements. For consistency with reporting requirements as well as inventory reporting, SCS would recommend the use of a single methodology for each of the following categories instead of using a combine approach for all sites:

- Active and Closed Landfills with Active GCCS and Destruction Devices (flares)
    - CHRL
    - Enumclaw Landfill
    - Hobart Landfill
- Closed Landfills with Active GCCS and Passive Systems with Active Data Collection
    - Cedar Falls Landfill
    - Vashon Island Landfill
- Closed Landfills with Passive/Removed GCCS with No Data Collection
    - Puyallup Landfill
    - Houghton Landfill

For all landfills currently required to report GHG emissions to the EPA and Ecology using the federal MRR as well as those with destruction devices, SCS would recommend using the federal MRR reporting methodology, as this methodology is required by the EPA and Ecology for emissions inventory calculation and reporting for landfills throughout the state and country. SCS believes that it is appropriate to use for the DNRP inventory and will reduce confusion of reporting different GHG emission estimates for these landfills to different public agencies. Also, the federal MRR gives landfills with active GCCSs two options for GHG emission estimates, which DNRP SWD staff could select from.

SCS provides the following specific recommendations for consideration in developing a GHG inventory for the DNRP in regards to those emissions attributed specifically to **active and closed landfills with an active GCCS and destruction device(s)**:

- Clarify BEW Plant reporting boundaries verse the CHRL reporting boundaries.

- Utilize the federal GHG MRR guidance and methodology for preparation of annual GHG emission inventories for the active and closed landfills regardless if they are required to report emissions to EPA or Ecology.
- Utilize the federal GHG MRR landfill cover area-based calculations to determine site specific GCCS collection efficiencies for landfills that employ a GCCS. Table HH-3 to Subpart HH of the GHG MRR provides collection efficiency percentages based on the different types of areas (A2 – areas without active gas collection [0%]; A3 – areas with daily soil cover and active gas collection [60%]; A4 – areas with an intermediate soil cover and active gas collection [75%]; A5 – areas with a final soil and geomembrane cover system and active gas collection [95%]). The overall collection efficiency for a landfill is calculated by determining the area weighted average collection efficiency.
- Utilize the federal GHG MRR recommended landfill methane soil oxidation fractions. The highest oxidation fraction percent (35) should be used only for landfills that have a soil cover of at least 24 inches for a majority of the landfill area containing waste and for which the methane flux rate is less than 10 grams per square meter per day ($g/m^2/d$). For landfills that do not have a geomembrane (synthetic) cover with less than 12 inches of cover soil for the majority of the landfill area containing waste and for which a methane flux rate has not been determined a landfill methane soil oxidation fraction of 10 percent should be used.
- Inventories for landfills with a GCCS should include the CO_2 and CH_4 emissions that pass through the destruction devices (e.g. flares)
- Inventories for landfills with active GCCS should include the CH_4 and N_2O emissions generated during combustion of LFG within the destruction devices (e.g. flares)
- Utilize the official source tested methane destruction efficiency for all landfill flares where applicable. Device-specific source testing shall include at least three test runs, with the accepted final value being the average destruction efficiency. For CHRL the average destruction efficiency of 99.65 percent, obtained for the four flares included in the 2013 flare source testing, may be used.
- Utilize the default CH_4 destruction efficiency for open flares if site specific destruction data is not available. SCS recommends using either Ecology or local air district default destruction efficiency's for the landfills flares, if available. If not, the federal GHG MRR, 40 CFR Part 98, Subpart HH, combustion devices destruction efficiency of 99 percent may be used as a default or the manufactures recommended value.

For **closed landfills with an active GCCS and passive gas systems with active data collection**, SCS would also recommend the use of either EPA MRR methodology or LandGEM for reporting purposes. SCS recommends the use of a single methodology at each site to ensure consistency.

SCS provides the following specific recommendations for consideration in developing a GHG inventory for the DNRP in regards to those emissions attributed specifically to **closed landfills with passive gas systems**:

- Use site specific and regional factors for each landfill. For closed landfills without active GCCS, it is inaccurate to use site specific factors from CHRL. If using the LandGEM model, use methane generation rates (k), potential methane generation capacity (L_o), and methane content (% by volume) based on site specific factors from actual site conditions (e.g. inventory wet k (e.g. 0.7 per year) and L_o (e.g. 97 m^3/tonne) values and site specific methane content).
- NMOC for CHRL was used in the LandGEM model for all other sites. Note that the NMOC value will not have a direct effect on the GHG emissions but it can be deceiving for others reviewing the documents. SCS would recommend removing it from the LandGEM model and inserting actual Tier 2 NMOC data or the default model value.
- Projected collection efficiency for Enumclaw and Hobart Landfills escalate extremely fast between current/historical collection efficiency data to projected 2020 data. SCS would recommend reevaluating the projected collection efficiency for future years based on actual projected GCCS expansions or cover system improvements planned in the next five years.

For **closed landfills with passive/removed GCCS with no data collection**, SCS would recommend the use of either the EPA MRR methodology or LandGEM for reporting purposes. SCS recommends use of a single methodology at each site to ensure consistency.

- Calculate emissions for all landfills, even if accurate waste tonnage is not available. Per inventory conventions it is better to include an estimate of emissions instead of omitting them. The EPA MRR, 40 CFR 98.343(a)(3) provides three methods for estimating waste disposal quantities for years when waste disposal quantities are not available. For Puyallup Landfill and Houghton Landfill, SCS would recommend using the population served by the landfill (equation HH-2) or estimated landfill capacity method (equation HH-3).

SCS provides the following specific recommendations for consideration in developing a GHG inventory for the DNRP in regards to those emissions attributed specifically to **all landfills**:

- Include any GHG emissions generated by stationary sources located at any of the landfills. The emissions are generated by combustion of fossil fuels (e.g. No. 2 fuel oil, waste oil, propane fuels, etc.) to power emergency generators, lighting plants, comfort heaters, or water heaters located at the landfills.
- Determine if CO_2 pass-through (uncombusted CO_2 from the LFG going through destruction devices) is included in the inventory boundaries.
- Confirm the flow meters at landfills with a GCCS that are subject to the federal MRR or Ecology GHG reporting rule(s) are calibrated in accordance with the conditions required in the rule. Alternatively, the calculations should be adjusted to correct for the specific flow meter calibration conditions state in the rule (e.g. 60 degrees Fahrenheit [°F] and 1 atmosphere [atm]).

- Landfill GHG emissions may be reported in four different categories to distinguish the type of emissions: non-fugitive biogenic CO_2, non-fugitive anthropogenic CH_4 and N_2O, fugitive biogenic CO_2, and fugitive anthropogenic CH_4.
- Carbon sequestration should not be included as an off-set when determining landfill inventories.
- Confirm stationary combustion, mobile, and fugitive sources (e.g. landfill equipment and fleet vehicles) GHG emissions are being accounted for in the inventory.

6 CLOSING

SCS appreciates supporting you on this important project and we trust that you will find this information of value. If you have any questions or desire any additional information, please contact Mr. Sonsthagen at (425) 289-5441, or Ms. Drotman at (562) 426-9544.

Sincerely,

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