Greener Cleanups

United States Environmental Protection Agency

EPA 542-R-12-002

Methodology for Understanding and Reducing a Project's Environmental Footprint

February 2012

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

Office of Superfund Remediation and Technology Innovation

Sponsored by the Technical Support Project
Engineering Forum

www.cluin.org/greenremediation/methodology

Acknowledgements

The U.S. Environmental Protection Agency (EPA) ***Methodology for Understanding and Reducing a Project's Environmental Footprint*** was prepared for the Technical Support Project (TSP) administered by the Office of Superfund Remediation and Technology Innovation (OSRTI). The methodology presented in this document was developed under sponsorship of the Engineering Forum (one of three national TSP forums) to address the need for a uniform EPA methodology that helps regional staff and other members of the cleanup community analyze and take steps toward reducing the environmental footprint of cleanups.

OSRTI and the Engineering Forum gratefully acknowledge key contributions from members of the Agency's Greener Cleanups Methodology Workgroup:

- Carlos Pachon, OSRTI
- Stephanie Vaughn, Region 2
- Dale Carpenter, Region 2
- Deb Goldblum, Region 3
- Hilary Thornton, Region 3
- Brad Bradley, Region 5
- Kendra Morrison, Region 8
- Tim Rehder, Region 8
- Michael Gill, Region 9
- Julie Santiago-Ocasio, Region 9
- Karen Scheuermann, Region 9
- Kira Lynch, Region 10.

Special thanks are expressed to Karen Scheuermann (Region 9) for invaluable assistance in developing the methodology's conceptual design, pilot testing the methodology at three sites, and refining the final methodology.

The Workgroup also recognizes other EPA staff supplying significant feedback during methodology development: Chris Corbett (Region 3), Candice (Jackson) Teichert (Region 4), Raji Josian (Region 6), Jeff Dhont (Region 9), and Beth Sheldrake (Region 10).

Appreciation is extended to other federal or state agencies providing useful input to the methodology, including the U.S. Department of Defense/Naval Facilities Engineering Command and the California Department of Toxic Substances Control.

Development of the methodology described herein was funded by OSRTI under Contract No. EP-W-07-078 to Tetra Tech. Appreciation is extended to Doug Sutton (Tetra Tech GEO) for significant contributions in developing and documenting the methodology.

For additional information about EPA's footprint assessment methodology or strategies for conducting greener cleanups, interested parties may contact Carlos Pachon (OSRTI) at: 703-603-9904 or pachon.carlos@epa.gov. Other technical assistance in implementing greener cleanups is available from EPA's Engineering Forum Greener Cleanup Subcommittee, which can be contacted through: http://www.epa.gov/tio/tsp/engforum/gcs.

An electronic version of this document can be downloaded at:

http://cluin.org/greenremediation/methodology and http://www.epa.gov/oswer/greenercleanups.

Disclaimer

This document presents EPA's methodology to reduce negative environmental effects that might occur during hazardous waste site assessment, site remediation, or non-time critical removal actions and to consequently improve the environmental outcome of cleanup projects. It presents technical information based on EPA's current understanding of the link between cleanup activities and their associated environmental footprint. The document contains information designed to be useful for interested stakeholders including governments, the public, and the regulated community. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This document was subjected to the Agency's administrative and expert review and was approved for release as an EPA document.

This document provides topical introductory information rather than guidance and does not impose legally binding requirements, nor does it confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. EPA recommends that users refer to applicable regulations, policies, and guidance documents regarding selection of cleanup remedies and implementation of cleanup actions; selected references and additional resources are provided herein. The Agency notes that this is a living document that may be revised periodically without public notice. EPA welcomes public comments on this document at any time and will consider those comments in any future revisions of this document.

Abbreviations & Acronyms

AS	air sparging
BSFC	brake-specific fuel capacity
BMP	best management practice
Btu	British thermal unit
ccf	hundred cubic feet
CFC	chlorofluorocarbon
cfm	cubic feet per minute
CO2e	carbon dioxide equivalent of global warming potential
cy	cubic yard
eGRID	Emissions & Generation Resource Integrated Database
EPA	U.S. Environmental Protection Agency
Ft	feet
ft^3	cubic foot
GAC	granular activated carbon
GHG	greenhouse gas
gptm	gallons per ton-mile
GWP	global warming potential
HAP	hazardous air pollutant
HCFC	hydrochlorofluorocarbon
HDPE	high-density polyethylene
HFC	hydrofluorocarbon
HP	horsepower
ISCO	*in situ* chemical oxidation
kW	kilowatts of electric power
kWh	kilowatt-hours of electricity
lbs	pounds
LCA	life cycle assessment
MMBtu	million British thermal units
mpg	miles per gallon
MWh	megawatt-hour
NP	not provided
NOx	nitrogen oxides
N/A	not applicable
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
OSRTI	Office of Superfund Remediation and Technology Innovation
P&T	pump-and-treat
PLF	partial load factor
PM10	particulate matter 10 microns in diameter or smaller
pmpg	passenger miles per gallon
psi	pounds per square inch
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
REC	renewable energy certificate
RMPA	Colorado-Eastern Wyoming eGRID Subregion and Geographic Descriptor
scfm	standard cubic feet per minute
SOx	sulfur oxides
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TBD	to be determined

Ton	short ton (2,000 pounds)
µg/L	micrograms per liter
VFD	variable frequency drive
VOC	volatile organic compound
WRI	World Resources Institute

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1.0 Introduction

1.1 Background

The U.S. Environmental Protection Agency (EPA) defines green remediation as the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprint of cleanup actions. Green remediation strategies can include a detailed analysis in which components of a remedy are closely examined and large contributions to the footprint are identified. More effective steps can then be taken to reduce the footprint while meeting regulatory requirements driving the cleanup.

Use of the methodology can provide quantitative information about the footprint reductions gained by applying EPA's green remediation best management practices (BMPs). Through ongoing efforts, the Agency is identifying BMPs that apply to frequently used remedial technologies such as groundwater pump-and-treat (P&T) systems, distinct project phases such as site investigation, or common sources of contamination such as leaking underground storage tanks. Details about the BMPs are available through the green remediation initiative sponsored by EPA's Office of Superfund Remediation and Technology Innovation (as described on the CLU-IN Green Remediation Focus website at www.cluin.org/greenremediation).

Two concepts are central to analyzing the environmental footprint of a cleanup. The first is to establish those parameters (metrics) that are to be quantified, and the second is to establish a straightforward process (methodology) for quantifying those metrics. The term "footprint" refers to the quantification of a specific metric that has been assigned a particular meaning. For example, the "carbon footprint" is the quantification of carbon dioxide (and other greenhouse gases [GHGs]) emitted into the air by a particular activity, facility, or individual. This common footprint measure has been established in the past because emissions of carbon dioxide and other GHGs have been linked to climate change. The term "environmental footprint" as referenced in the methodology comprehensively includes metrics such as energy use and water use as well as air emissions to fully represent the effects a cleanup project may have on the environment.

In context of the methodology, "metric" refers to a project parameter for which a quantitative value may be:

- Derived mathematically
- Estimated through engineering details, or
- Extracted from past project records with actual data.

This document presents EPA's metrics and methodology for conducting an environmental footprint analysis of site cleanup activities and describes common approaches to reduce that footprint. The document's structure corresponds to EPA's five core elements of green remediation (Figure 1.1). Topics in the document include:

- The methodology's purpose and limitations, the value of footprint analysis, and the level of effort and cost for footprint analysis
- Definitions of metrics aligning with the core elements of green remediation
- A seven-step process to quantify the metrics
    - Step 1 – Set goals and scope of the analysis
    - Step 2 – Gather and organize remedy information
    - Step 3 – Quantify materials and waste metrics

Figure 1.1. Green Remediation Core Elements

- Step 4 – Quantify water metrics
- Step 5 – Quantify energy and air metrics
- Step 6 – Qualitatively describe affected ecosystem services
- Step 7 – Present results

- Considerations for analyzing and utilizing footprint results
- Illustrative approaches to reduce the environmental footprints.

Appendix A of this document provides exhibits containing supporting technical information, Appendix B provides suggested formats for presenting a quantified footprint, and Appendix C provides illustrative footprint reduction scenarios.

The information needed and the process of obtaining the information for this methodology are the same used to develop remedy alternatives, design a remedy, or optimize a remedy. For this reason, the Agency suggests that a footprint analysis be conducted in concert with one or more of these project phases.

> In context of the methodology, "cleanup" or "remedy" generally refers to a remedial project, corrective action, or comparable effort conducted by government or private organizations to address contaminated sites under one or more programs.

1.2 Purpose

EPA recognizes that many factors are involved in quantifying the environmental footprint of a cleanup. The Agency aimed to develop a methodology that is flexible, straightforward, and not overly burdensome to users or the remedial process. The methodology relies on publicly available information and can be implemented through standard spreadsheet software.

The methodology is intended to serve the following purposes:

- Facilitate implementation of EPA's *Principles for Greener Cleanups* (http://www.epa.gov/oswer/greenercleanups/principles.html) by providing a methodology to quantify materials, waste, water, energy, and air metrics that represent the environmental footprint of activities involved with contaminated site cleanup. The metrics are designed to 1) reflect parameters that a remedy project team has a relatively direct ability to change and 2) encourage practices that would result in favorable changes to the metric values.
- Encourage (not require) quantification of these metrics for cleanups. The methodology is a general framework to help site teams understand the remedy components with the greatest influence on the project's environmental footprint. Quantifying the metrics can serve as an initial step in reducing the remedy footprint. The overall process allows those involved in the remedial process to analyze a remedy from another perspective and potentially yields viable and effective improvements that may not have been identified otherwise.
- Provide technical suggestions on approaches to reduce the footprint of a remedy (but not guidance on prioritizing the footprint reduction efforts).
- Expand technology transfer among stakeholders, by conveying EPA's lessons learned about footprint analysis conducted at numerous and varied sites undergoing remediation.
- Provide a process for footprint analyses conducted on behalf of EPA and for use by EPA in evaluating footprint analysis results submitted by other parties under any cleanup program.

- Fulfill action 8.2 of the *Superfund Green Remediation Strategy* to "develop an Agency methodology for evaluating the environmental footprint of a cleanup" (http://www.epa.gov/superfund/greenremediation/sf-gr-strategy.pdf).

1.3 Limitations

The methodology is not intended to be a detailed life cycle assessment (LCA) nor does it discourage the use of LCA by remediation practitioners. Unlike an LCA, the methodology does not attempt to detail all natural resource inputs and all environmental outputs, nor does it include an "impact assessment" that converts emissions and metrics into environmental effects such as acidification, increased incidence of respiratory illness, human toxicity, or ecotoxicity. The methodology uses a suitable number of green remediation metrics to represent each of the green remediation core elements but limits the number of metrics to streamline the footprint analysis process. As a result, EPA recognizes that these metrics may not capture some environmental effects or footprints associated with a cleanup project.

The methodology is not intended for application to non-remediation projects or for submissions to other organizations or programs with established methodologies for footprint analysis, GHG inventories, or similar efforts. The methodology considers the mandates of Executive Order 13514 *Federal Leadership in Environmental, Energy, and Economic Performance* and EPA guidance on resource conservation and waste minimization. It is intended to be applied in a manner consistent with the Agency's *Principles for Greener Cleanups* and *Superfund Green Remediation Strategy*.

The methodology does not constitute an EPA requirement. Use of the methodology is intended to support the remedial process and to help improve the environmental outcome of cleanup efforts but not to disrupt, delay, or otherwise reduce protectiveness of a remedy.

1.4 The Value of Footprint Analysis

Greener cleanups can be implemented by applying BMPs without quantifying a remedy footprint or footprint reductions. EPA's BMPs for green remediation address the most common cleanup activities posing opportunities for footprint reduction (www.cluin.org/greenremediation). Most of the BMPs involve qualitative measures and constitute relatively small modifications to standard operating procedures, such as instituting "no engine idling" policies for vehicles and machinery, substituting potable water with available graywater for onsite needs, and assuring maximum recycling of routine waste. Other BMPs may involve more significant process or equipment changes, such as installing an onsite renewable energy system to meet a portion of, or all of, the energy demand of cleanup equipment.

Footprint analysis brings a number of benefits to a project, including the following:

- Footprint reductions that might be achieved from making project improvements can be quantified.
- Aspects of a cleanup that dominate the footprint can be highlighted, allowing the project team and stakeholders to more specifically target those aspects during remedy design and implementation.
- A cleanup project can be analyzed from a different perspective, which may lead to footprint reduction as well as improvements in remedy effectiveness and efficiency that otherwise may not have been identified by a more traditional evaluation.

A number of other parties recognize these and other benefits of footprint analysis, as evidenced by footprint analysis tools recently developed by other agencies and organizations. Examples include the Sustainable Remediation Tool (SRT), which was developed by the U.S. Air Force, and SiteWise, which was developed by

Battelle in conjunction with the U.S. Army and U.S. Navy. Analytical tools available from non-government organizations include the "Guidance for Performing Footprint Analyses and Life-Cycle Assessments for the Remediation Industry," which was developed by the Sustainable Remediation Forum.

Determining the footprint of a remedy can be a complex process depending on the level of detail and accuracy sought from the analysis. The decision of whether to conduct a footprint analysis, the structure and detail of the analysis, and the level of effort to conduct the analysis depend on several factors, including:

- ***Intended use of the footprint results***: Will the results be used to assist with determining the footprint for an entire organization or a portfolio of sites within the organization? Will the footprint be used to help document or quantify footprint reductions?
- ***Complexity of a site cleanup***: Is the cleanup likely to be dominated by one or two aspects such that footprint analysis is not necessary in order to determine the largest footprint contributors? Without undertaking calculations, is it apparent that the cleanup will have a very small footprint relative to other cleanups within an organization's portfolio? Is the cleanup very complex (with many onsite and offsite components to the footprint) or is it relatively simple?

The methodology does not dictate circumstances in which footprint analysis should be conducted. Users of the methodology are encouraged to practice professional judgment and consult with other environmental professionals to determine the usefulness of footprint analysis in a given set of circumstances.

1.5 Level of Effort and Cost

Application of the methodology is expected to add a negligible amount to the level of effort and cost associated with overall remediation and a fraction of any particular remedial activity, such as a remedy design or an optimization evaluation. For example, footprint analysis is expected to add approximately 10 percent to the level of effort or cost of an optimization evaluation or less than 5 percent to the level of effort or cost of a remedial design. The level of effort and cost will vary depending on the site complexity, experience in conducting footprint analyses, and the level of analytical detail.

The level of effort to conduct a footprint analysis will vary depending on the cleanup project complexity, the availability of information, and prior experience. Most information used in a footprint analysis is generated during typical project phases or activities such as remedy design or remedy optimization and is documented in site reports. Coordinating a footprint analysis with these and other activities can help minimize the level of effort involved in footprint analysis.

The methodology focuses on green remediation metrics and therefore does not include quantification of cleanup cost. The cost of implementing footprint reduction measures is expected to be considered separately by a project team and evaluated on a project-by-project basis. Because cleanup costs often relate to the core elements of greener cleanups (e.g., energy use, materials use, and waste disposal), many footprint reduction strategies can result in cost savings over the life of a cleanup project. The costs and cost savings associated with footprint reductions are project specific; for example, savings attributed to reduced energy use through energy efficiency measures will depend on the unit costs of electricity and fuels, which vary by location and over time.

2.0 Green Remediation Metrics

EPA's green remediation metrics encourage environmentally friendly behaviors that apply to each of the core elements of greener cleanups and emphasize parameters that a remedy project team likely has the ability to change. The metrics identified in this methodology are summarized in Table 2.1 and discussed below. Table 2.1 can be used to present the environmental footprint of a remedy, accompanied by supporting documentation as outlined in this methodology and presented in Appendix B. A more detailed breakdown of the metrics noted in Table 2.1 may be developed based on intermediate calculations in the footprint analysis and may be presented in addition to these metrics.

Table 2.1. Summary of Green Remediation Metrics

Core Element	Metric		Unit of Measure	Metric Value
Materials & Waste	M&W-1	Refined materials used on site	tons	
	M&W-2	Percent of refined materials from recycled or waste material	percent	
	M&W-3	Unrefined materials used on site	tons	
	M&W-4	Percent of unrefined materials from recycled or waste material	percent	
	M&W-5	Onsite hazardous waste generated	tons	
	M&W-6	Onsite non-hazardous waste generated	tons	
	M&W-7	Percent of total potential onsite waste that is recycled or reused	percent	
Water		Onsite water use (by source)		
	W-1	- Source, use, fate combination #1	millions of gals	
	W-2	- Source, use, fate combination #2	millions of gals	
	W-3	- Source, use, fate combination #3	millions of gals	
	W-4	- Source, use, fate combination #4	millions of gals	
Energy	E-1	Total energy use	MMBtu	
	E-2	Total energy voluntarily derived from renewable resources		
	E-2A	- Onsite generation or use and biodiesel use	MMBtu	
	E-2B	- Voluntary purchase of renewable electricity	MWh	
	E-2C	- Voluntary purchase of RECs	MWh	
Air	A-1	Onsite NOx, SOx, and PM10 emissions	lbs	
	A-2	Onsite HAP emissions	lbs	
	A-3	Total NOx, SOx, and PM10 emissions	lbs	
	A-4	Total HAP emissions	lbs	
	A-5	Total GHG emissions	tons CO_2e	
Land & Ecosystems	Qualitative description			

RECs = Renewable energy certificates
NOx = Nitrogen oxides
SOx = Sulfur oxides
PM10 = Particulate matter smaller than 10 microns in size
HAP = Hazardous air pollutants as defined by the Clean Air Act
MWh = megawatt-hour
MMBtu = million British thermal units
CO_2e = carbon dioxide equivalent of global warming potential

2.1 Materials and Waste Metrics

These metrics consider the materials used on site, the recycled content of those materials, the waste generated on site, and the proportion of potential waste generated onsite that is subsequently reused or recycled. Although not included in this footprint methodology, users may wish to add metrics for materials used off site or waste generated off site.

2.1.1 Materials Metrics

The materials metrics consider the total amount of materials used onsite and the percentage of those materials that are produced from recycled material, reused material, or waste material. The following materials metrics are identified for this footprint methodology:

M&W-1. Refined materials used on site – This metric is presented in tons and refers to the mass of manufactured or significantly processed materials that are used onsite and come from offsite sources. Examples include chemicals, nutrients, food grade amendments, metals, plastics, and cement.

> ***Why this Metric?***
> Raw materials are used in the manufacturing of refined materials. In addition, use of refined material or the manufacturing of the material may result in waste generation. Reducing refined materials use helps conserve raw materials and reduce potential waste generation. This metric and the other materials and waste metrics are consistent with EPA's Reduce, Reuse, Recycle concept. (http://www.epa.gov/osw/conserve/rrr).

M&W-2. Percent of refined materials from recycled or waste material – This metric refers to the percentage of the "refined materials" that is produced using recycled or reused materials or is otherwise a waste product of a manufacturing process. Examples include the portion of steel that is from recycled content, off-specification food grade amendments that are otherwise waste and can be used as *in situ* bioremediation reagents, and regenerated (not virgin) granular activated carbon (GAC) or regenerated ion exchange resin.

> ***Why this Metric?***
> Use of materials from recycled products helps reduce the amount of raw materials consumed and the amount of waste generated. Increasing the percentage of refined materials made from recycled or waste materials helps conserve raw materials and reduce potential waste generation.

M&W-3. Unrefined materials used on site – This metric is presented in tons and refers to the mass of materials that are used on site, come from offsite sources, and generally have not undergone significant processing or refinement. Examples include clean fill, sand and gravel, clay, limestone, bentonite, and the aggregate portion of concrete or asphalt. The term "unrefined materials" does not refer to raw materials that are the feedstock of a "refined material" as identified above.

> ***Why this Metric?***
> Unrefined materials use is included as a metric for the same reasons that refined materials use is included as a metric. Unrefined materials are distinguished from refined materials for three reasons: 1) unrefined materials (e.g., clean fill) involve less refinement and processing than refined materials; 2) unrefined materials generally consist of common, more plentiful resources than the raw materials used to manufacture refined materials; and 3) unrefined materials are often used in substantial quantities and may overshadow the use of refined materials.

M&W-4. Percent of unrefined materials from recycled or waste material – This metric refers to the percentage of "unrefined materials" obtained from recycled or reused materials or is otherwise a waste product. An example includes crushed concrete that is brought from offsite sources and used as onsite fill.

> ***Why this Metric?***
> This metric is included for the same reasons as the analogous metric for refined materials. Unrefined materials are distinguished from refined materials for the three reasons described under unrefined materials use.

2.1.2 Onsite Waste Metrics

The waste metrics consider the total amount of waste generated on site and the percentage of total potential onsite waste that is recycled or reused. The following waste metrics are identified for this footprint methodology:

M&W-5. Onsite hazardous waste generated – This metric is presented in tons and refers to the mass of hazardous waste generated on site and disposed of at an offsite hazardous waste facility or in a regulated onsite disposal unit. Examples include excavated soil, treatment plant residuals, and recovered product that are disposed of in this manner.

> ***Why this Metric?***
> Onsite hazardous waste is generated as a direct result of onsite activities and increases the demand for infrastructure needed to treat, store, or dispose of hazardous waste. Reducing onsite hazardous waste generation by reducing the quantity of waste or the toxicity of waste helps conserve hazardous waste treatment, storage, and disposal capacity.

M&W-6. Onsite non-hazardous waste generated – This metric is presented in tons and refers to the mass of non-hazardous waste that is generated on site and disposed of off site or in a regulated onsite disposal unit. Examples include excavated soil, treatment plant residuals, and recovered product that are disposed of in this manner.

> ***Why this Metric?***
> Onsite non-hazardous waste is generated as a direct result of onsite activities and increases the demand for disposal options, including landfill space. Reducing onsite waste generation helps conserve disposal capacity.

M&W-7. Percent of total potential onsite waste that is recycled or reused – This metric reflects the total potential waste (hazardous or non-hazardous) generated on site that is recycled or reused on or off site. Examples of wastes that are considered recycled or reused are as follows:

- Treated soil or crushed concrete from the remedy that is used as fill on or off site
- Cleared vegetation that is chipped, shredded, or composted and used on or off site for mulch or compost
- GAC or ion exchange resin that is sent off site for regeneration instead of disposal
- Recovered product from remedial activities that is recycled or reused.

Consistent with *Clarification on Counting Waste-to-Energy in Waste Diversion Goals As per Executive Order 13423 and Implementing Instructions* (January 14, 2008) waste of high heat content that is used for energy recovery is not considered recycled or reused.

> ***Why this Metric?***
> Reusing and recycling potential waste helps reduce the demand for disposal capacity and conserve raw materials. This metric is included with the other materials and waste metrics to help distinguish between efforts to reduce waste and efforts to recycle and reuse potential waste.

2.1.3 Offsite Waste

A remediation project team may have the ability to reduce waste that is generated as part of onsite activities through BMPs, but does not have much control over the waste generation, reusing, recycling, and disposal practices of material manufacturers or other offsite service providers. As a result, for most project teams, efforts to reduce offsite waste will likely rely on reduced use of materials or reduced use of offsite activities that generate waste. In addition, quantifying waste generated off site and determining the fate of that waste is complex. For these two reasons, an offsite waste metric is not included in this methodology. Although this methodology does not include an offsite waste metric, project teams are not discouraged from evaluating waste that is generated off site in support of a remedy.

2.2 Water Metrics

These metrics consider the water used on site during cleanup and the specific sources and fates of the used water. Although not included in this footprint methodology, users may wish to add metrics for water used off site during supplemental activities.

2.2.1 Onsite Water Metrics

The onsite water metrics consider the source and amount of water used on site, as well as the fate of the water after use. Site-specific factors are discussed further in Section 2.2.2. Onsite water metrics are identified as follows:

W-1, W-2, W-3, W-4. Onsite water use – Onsite water metrics are presented in millions of gallons of each source of water that is used on site, including brief descriptions of the sources, uses, and fates of the various sources of water used. Water sources considered in this metric include but are not limited to the following:

- Water from the public potable water supply
- Extracted groundwater from each local aquifer
- Surface water
- Reclaimed water
- Collected or diverted stormwater.

The use of the water includes but is not limited to the following:

- Equipment decontamination
- Extraction and treatment
- Injection for plume migration control
- Chemical blending.

Potential fates of the used water include but are not limited to the following:

- Reuse in a public or domestic water supply
- Use as industrial process water

- Discharge to groundwater (specify the aquifer)
- Discharge to fresh surface water
- Irrigation
- Discharges to brackish or saline water
- Discharge to the atmosphere (i.e., as water vapor)
- Discharge to the sanitary sewer.

> ***Why this Metric?***
> Water is a natural resource that has beneficial uses that depend on the source and quality of the water. The use of water as part of the remedy and the fate of the water after use can affect water quality and its potential for beneficial reuse. Reducing water use, choosing the appropriate water resources, returning water to the environment with equal or improved quality, or reusing the water all contribute to conserving valuable water resources.

2.2.2 Site-Specific Consideration for the Onsite Water Footprint

Water is typically a local or regional resource that may be plentiful or scarce. In addition, there may be several types of local water resources available, and after use, the water may lose its original quality, retain its original quality, or improve in quality. These concepts are discussed further below.

Water is typically a local or regional resource. The same water footprint calculated for two similar sites in two different parts of the country may be interpreted differently by local site stakeholders. For example, groundwater extraction, treatment, and discharge to surface water in one state may be seen as use of a valuable, potential source of local drinking water. However, groundwater extraction, treatment, and discharge in another state may not be of concern for water use if the groundwater in that particular location is abundant, if groundwater is of relatively low quality, or surface water is the primary source of drinking water for that location.

Various types of water with varying water quality may be used in association with cleanup activities. For example, potable water provided by a water supply utility is a refined water resource that likely involves extraction, treatment, and distribution prior to use. Groundwater and surface water, depending on the aquifer or source, may be of drinking water quality without treatment, may be of drinking water quality with some limited treatment, or may not practicably be used for drinking water or other beneficial purposes. Groundwater and surface water may also be used in industrial processes or for irrigation without prior treatment.

The onsite use of water can affect how it is discharged and how it can be reused. Water use can include groundwater extraction and treatment, which typically improves water quality (in addition to removing contamination). Therefore, extracted and treated groundwater may potentially have more uses than other uncontaminated water from the same aquifer. Water used in single-pass heating or cooling systems (e.g., open-loop water source heat pumps) may cause a change in temperature that does not significantly affect its potential use for other purposes. Public water used for blending chemicals that are injected into an aquifer or added to the process stream in a water treatment plant reduces the quality of the used public water because it is blended with other water of lesser quality and can no longer be used directly for public consumption.

Water may be returned to the environment in the same, improved, or reduced quality as a result of cleanup activities. For example, discharge of treated groundwater from a groundwater P&T system to the subsurface may involve returning that water to its original aquifer and therefore maintain the original groundwater resource. By contrast, the treated groundwater might be discharged to brackish surface water that is not of suitable quality for drinking, irrigation, or industrial uses, and therefore, the extracted groundwater would no longer be available as a fresh water resource.

2.2.3 Offsite Water Use

Offsite water use refers to the quantity of water that is used off site for activities such as electricity generation at a power plant or manufacturing. Unlike onsite water use, offsite water is used for many purposes and may occur in a variety of geographic locations. Information may not be readily available regarding the source of the water, the specific use of the water, the fate of the used water, and the scarcity/availability of water resources in the areas where it is being used. Due to these sources of uncertainty and the level of effort that would be required to better understand offsite water use, an offsite water metric is not included in this methodology. It is noted, however, that offsite water use will generally decrease when other metrics (e.g., energy use and materials use) decrease. Although this methodology does not include an offsite water metric, project teams are not discouraged from evaluating water that is used off site in support of a remedy.

2.3 Energy Metrics

The energy metrics consider the total amount of energy used by the remedy (including onsite and offsite activities), and energy coming from renewable resources. The following energy metrics are identified for this footprint methodology:

E-1. Total energy use – This metric refers to the total amount of energy used by the remedy for onsite and offsite activities including electricity generation, transportation, materials manufacturing, and other offsite activities that support the remedy.

> ***Why this Metric?***
> Energy use involves the use of natural energy resources, which puts strain on the existing energy infrastructure, and can result in waste streams. Therefore, reducing total energy use through energy efficiency measures and efficient cleanup helps conserve natural energy resources, decreases demand on the existing energy infrastructure, and decreases associated waste generation. www.epa.gov/energy

E-2. Total energy voluntarily derived from renewable resources – This metric category refers to renewable energy that a project team voluntarily generates or uses in place of energy derived from other resources. The metric category is comprised of three sub-metrics that distinguish between various forms of renewable energy production and use. Each of the three sub-metrics is described below, and additional information regarding renewable energy as it pertains to this methodology is included in Exhibit 2.1 (see Appendix A).

E-2A. Onsite generation or use and biodiesel use – This sub-metric refers to renewable energy that is generated on site and biodiesel used both on site and off site. Examples include the onsite use of landfill gas in place of natural gas and the use of biodiesel in place of diesel for heavy equipment use or transportation. Other examples include the generation of electricity from onsite renewable energy systems (e.g., photovoltaic modules, wind turbines) or generation of heat from onsite solar thermal systems. Systems that are immediately adjacent to the site and provide the renewable energy directly to the site are also included. The value of this metric can be higher than the value of the total energy use metric if renewable energy generated on site exceeds the energy use by the remedy and is exported off site for use by others. To be counted toward this metric, the rights to the renewable energy generated by the systems described here need to be retained by the cleanup project and not transferred to other parties or facilities.

> ***Why this Metric?***
> Generating and using renewable energy in place of conventional energy helps conserve natural energy resources and reduces waste generation and emissions associated with many conventional sources of energy. In addition, renewable energy generation at the point of use (i.e., on site) helps avoid energy losses due to the transmission of energy from one location to another. Renewable energy in this metric is the most verifiable form of renewable energy production and use for a remedy and therefore is distinguished from the renewable energy in the other sub-metrics.

E-2B. Voluntary purchase of renewable electricity – This sub-metric refers to the voluntary purchase of renewable electricity from an electricity provider in the form of a "green pricing" or "green marketing" product. In regulated electricity markets, renewable electricity may be purchased through the grid from the electric utility by paying a premium for renewable electricity (i.e., buying a "green pricing" product). In competitive electricity markets, the utility distributes the electricity and renewable electricity may be purchased from an electricity generator that offers renewable electricity (i.e., buying a "green marketing" product). This metric does not include the renewable electricity that is purchased by default when purchasing standard grid electricity.

> ***Why this Metric?***
> Purchasing renewable electricity contributes to the development of large-scale renewable electricity projects that are independent of a remedy. For the purpose of this methodology, this form of purchased renewable electricity is considered more verifiable than purchasing RECs because of the substantial variability in the integrity and environmental attributes of RECs. For this reason, purchased renewable electricity from electricity providers is distinguished from purchasing RECs.

E-2C. Voluntary Purchase of RECs – This sub-metric refers to the direct purchase of RECs. Refer to Exhibits 2.1 and 2.2 for more information on RECs.

> ***Why this Metric?***
> Purchasing renewable electricity through the purchase of RECs contributes to the development of large-scale renewable electricity projects that are independent of a remedy. Because of the substantial variability in the integrity and environmental attributes of RECs, they are distinguished from the other forms of renewable electricity.

2.4 Air Metrics

The air metrics consider emissions of GHGs, nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter less than 10 microns in size (PM10), and hazardous air pollutants (HAPs). For the purpose of the methodology, NOx, SOx, and PM10 are combined into a single group at the summary stage to streamline footprint presentation. HAPs refer to the original list of toxic air pollutants defined by the Clean Air Act Amendments of 1990 and subsequent modifications. Additional information related to GHGs can be found on EPA's Climate Change website (www.epa.gov/climatechange). Additional information related to NOx, SOx, and PM10 is available from EPA online at http://www.epa.gov/air/urbanair and additional information about HAPs can be found on EPA's Air Toxics website (http://www.epa.gov/ttn/atw/pollutants/atwsmod.html).

Organizations might purchase emissions off-sets or voluntarily purchase renewable electricity from an electricity provider or through the purchase of RECs (see metrics E-2B and E-2C). For the purpose of this methodology, the air metrics reflect project emissions before any potential reductions from these types of purchases in order to put primary emphasis on improvements that directly reduce emissions associated with the remedy. Although emissions reductions associated with these voluntary purchases of off-sets and renewable electricity are not considered in the air metrics, voluntary purchase of these products are still encouraged (see metrics E-2B and E-

2C). Refer to Exhibit 2.2 (see Appendix A) for more information related to emissions reductions associated voluntary purchases of emissions off-sets, renewable electricity, and RECs.

2.4.1 Onsite Air Metrics

A-1. Onsite NOx, SOx, and PM10 emissions – This metric refers to the sum of the onsite emissions for NOx, SOx, and PM10 measured in pounds before consideration of potential reductions from voluntary purchases of emissions off-sets, renewable electricity, RECs, or similar products.

> ***Why this Metric?***
> NOx, SOx, and PM10 emissions are all examples of criteria pollutants as defined by the Clean Air Act. NOx, SOx, and PM10 each adversely affect local and regional air quality in various ways. Some of the adverse effects are detrimental to the environment (e.g., acid rain caused by NOx and SOx), and some adverse effects are directly detrimental to human health (e.g., increase in incidence of respiratory illness caused by NOx, SOx, and PM10). Fossil fuel combustion is a source for all three of these pollutants. Other sources also exist for each pollutant, including various industrial processes and PM10 emissions associated with dust generation. Reducing on-site air emissions of these pollutants by reducing fossil fuel use on site, using emissions control technologies on onsite equipment, suppressing onsite dust generation, and employing other practices helps reduce adverse effects on a local scale.

A-2. Onsite HAP emissions – This metric refers to onsite combined HAP emissions (i.e., the sum of all listed HAPs) measured in pounds before consideration of potential reductions from voluntary purchases of emissions off-sets, renewable electricity, RECs, or similar products.

> ***Why this Metric?***
> HAP emissions adversely affect air quality by increasing toxicity. Reducing onsite air emissions of HAPs by modifying onsite remedial practices and using emissions control technologies for onsite processes helps reduce the adverse effects of these pollutants on a local scale.

2.4.2 Total Air Metrics

The following three total air metrics described in this subsection refer to combined onsite and offsite emissions. Offsite air emissions include emissions associated with electricity generation, materials manufacturing, transportation, and offsite services used during the cleanup.

A-3. Total NOx, SOx, and PM10 emissions – This metric refers to the total onsite and offsite NOx, SOx, and PM10 emissions measured in pounds before consideration of potential reductions from voluntary purchases of emissions off-sets, renewable electricity, RECs, or similar products.

> ***Why this Metric?***
> As discussed above, NOx, SOx, and PM10 each adversely affect both local and regional air quality in various ways. Therefore, reducing total emissions of these pollutants (i.e., onsite and offsite emissions) can reduce the adverse effects of these pollutants on a regional scale or at the local scale in other regions distant from the cleanup.

A-4. Total HAP emissions – This metric refers to the total onsite and offsite HAP emissions measured in pounds before consideration of potential reductions from voluntary purchases of emissions off-sets, renewable electricity, RECs, or similar products.

> ***Why this Metric?***
> As discussed above, HAPs adversely affect air quality by increasing toxicity. Therefore, reducing total emissions of these pollutants (i.e., onsite and offsite emissions) can improve air quality on a regional scale, particularly for those HAPs that are persistent in the atmosphere such as mercury.

A-5. GHG emissions – This metric refers to the total onsite and offsite GHG emissions associated with the remedy measured in tons of carbon dioxide equivalent (CO_2e) of global warming potential before consideration of potential reductions from voluntary purchases of emissions off-sets, renewable electricity, RECs, or similar products. Onsite emissions are not presented separately from offsite emissions because the effects of GHGs are independent of the location of the emissions. GHGs, global warming potential, and CO_2e are discussed in more detail in Exhibit 2.3 (Appendix A).

> ***Why this Metric?***
> Greenhouse gases contribute to climate change, which can adversely affect climate-sensitive systems such as human health, agriculture, natural ecosystems, coastal areas, and heating or cooling needs (www.epa.gov/climatechange). Reducing greenhouse gas emissions can help reduce the potential for significant changes in climate that might adversely affect climate-sensitive systems.

2.4.3 Further Categorization of Air Metrics

In quantifying the onsite and total air metrics presented above and in Table 2.1, this methodology uses a structure based on three "scopes" for air emissions. The scopes are not individual air metrics for this methodology; rather, they are a suggested means of organizing and calculating the emissions metrics to provide insight in the sources of the emissions and to provide a parallel structure to other forms of emissions tracking. This structure is in general agreement with the approach recommended by the World Resources Institute (WRI) Greenhouse Gas Protocol. The approach based on scopes is also reflected by a number of regulatory, non-profit, and other organizations, such as the former EPA Climate Leaders Program, the Climate Registry, the Chicago Climate Exchange, various GHG inventories, and Executive Order 13514. The specific calculations and backup documentation for air emission metrics used in this methodology are described in Section 3.0; these metrics can be calculated without strictly adhering to the suggested organizational approach for emission scopes.

Onsite (Scope 1) – This scope of air emissions occurs from within the site boundaries. This is generally consistent with the WRI Scope 1 emissions. WRI defines Scope 1 emissions as those derived from equipment "owned" by the facility, even if these emissions occur off-property. However, unlike a manufacturing facility or institution that may participate in a GHG inventory, very few remediation projects actually "own" equipment. Therefore, the definition of Scope 1 emissions has been modified for the purpose of this methodology to include only those emissions from onsite activities. Examples of Scope 1 emissions include emissions associated with fuel combusted on site in heavy equipment.

Electricity generation (Scope 2) – This scope of emissions results from offsite generation of electricity used by the project. Consistent with WRI approach, this scope of air emissions does not include air emissions associated with the transmission of electricity from the power station to the site through the electricity grid.

Offsite (Scope 3) – This scope of air emissions results from remedy-related emissions not covered by the "onsite" or "electricity generation" categories. For this methodology, offsite air emissions are further subdivided as follows:

- *Transportation (Scope 3a)* air emissions are those associated with offsite transportation of personnel, equipment, and materials.

- *Other offsite (Scope 3b)* air emissions are those associated with offsite activities such as materials manufacturing, offsite services (e.g., laboratory analysis), transmission of electricity through the electricity grid, and resource extraction for fuels used in electricity generation.

Because energy and air emissions are closely linked, these categories also apply to calculations and backup documentation for energy use. For example, the electricity used on site (i.e., electricity as measured by the project's utility meter) would be considered "*onsite*" energy use. The waste energy at the offsite electricity power plant would be considered "*electricity generation*" energy use. The energy lost in transmitting the electricity to the site would be considered "*other offsite*" energy use. Similarly, energy use in the form of onsite diesel fuel would be considered "onsite" energy use whereas the energy used to produce the diesel would be considered "other offsite" energy use.

3.0 Footprint Methodology

As illustrated in Figure 3.1, this methodology is a seven-step process that begins with setting goals and scoping the analysis and then gathering and organizing information about the remedy to be footprinted. This information is then used to quantify the onsite materials and waste metrics and the onsite water metrics. The materials, waste, and water information, plus other remedy information, is then used to quantify the energy and air metrics. After the metrics have been calculated, ecosystem services that are affected during remedy implementation are described qualitatively. The process ends with presenting the results in a manner similar to that illustrated in Table 2.1 and described in Appendix B.

After the results are presented, the results can be analyzed to identify large contributors to the metrics and evaluate opportunities for footprint reduction. In general, the methodology utilizes publicly available information and can be implemented using standard spreadsheet software.

Figure 3.1. Overview of Footprint Methodology

Step 1:	**Set Goals and Scope of Analysis**
Step 2:	**Gather Remedy Information**
Step 3:	**Quantify Onsite Materials and Waste Metrics**
Step 4:	**Quantify Onsite Water Metrics**
Step 5:	**Quantify Energy and Air Metrics**
Step 6:	**Qualitatively Describe Affected Ecosystem Services**
Step 7:	**Present Results**

3.1 Step 1: Set Goals and Scope of Analysis

Step 1

The first step of a footprint analysis is to determine the goals and scope of the analysis. Other activities related to this step are establishing the boundaries and functional unit for the analysis.

The goal of the analysis typically varies with the remedial stage and with other site-specific factors. Table 3.1 summarizes likely goals of the footprint quantification based on remedy stage.

Table 3.1. Goals of Footprint Quantification

Remedy Phase	Typical Goal of Footprint Quantification
Development of remedy alternatives*	• Identify components of various remedy alternatives that are large contributors to footprints
Remedial Design and Remedy Optimization	• Identify remedy components that are large contributors to the remedy footprint • View remedy from different perspective to identify opportunities for improvement • Identify: o Design components that are large contributors to footprints during construction or during remedy operation o Refinements or data gaps in the conceptual site model that, if addressed, might help reduce footprints (e.g., improved characterization that refines the known contamination source area) o Potential opportunities for footprint reductions
Other	• Quantify and document emissions

* *Results of a footprint analysis during the development of remedy alternatives may be subject to substantial uncertainty due to limited remedy-specific information available and the absence of actual data or engineering design estimates.*

The scope of the analysis will depend, in part, on the goals of the analysis. For example, the goals of one analysis may be addressed by including only active components of a remedy (e.g., system operation, chemical injections, or excavation) and omitting one or more components of a monitoring program whereas the goals of another analysis may only be adequately addressed by including in the scope all project components affecting the environment, including the remediation monitoring program. Similarly, the goals of one analysis may be addressed by including only the soil component of a remedy and omitting the groundwater component whereas the goals of another study may only be adequately addressed by considering the site-wide remedy for all affected media. The scope of the analysis significantly influences the data to be gathered in Step 2 of the methodology.

The boundary of study is also established at the outset of a footprint analysis. The study boundary is the conceptual boundary around a system or project that determines the processes that are included and the processes that are excluded. One example of a study boundary is the physical boundary of the cleanup site. For example, a footprint analysis that uses the physical site boundary as the study boundary would only include air emissions from onsite sources and would exclude the emissions associated with generating the electricity obtained through the electrical grid. This methodology generally establishes broad study boundaries that include onsite and offsite processes, resource extraction and processing for fuels, resource extraction and processing of manufactured materials, demolition and disposal of wastes, and project infrastructure. Because the methodology establishes these boundaries, it is not necessary for the user of the methodology to independently establish the boundaries.

Another common concept determined early in a footprint analysis is the functional unit, which is the basic unit of the item undergoing the footprint analysis. In the manufacturing sector, the functional unit may be a single manufactured item. In the remediation community, the functional unit is commonly the life cycle of a remedy from the present to the attainment of remedial action objectives and site closure. Alternative functional units could be a year of system operation for a long-term remedy, a cubic yard of soil to be treated, a gallon of water to be treated, or a cubic yard of aquifer to be restored. Although the methodology generally assumes that the most common functional unit is the life of a remedy from the present to the attainment of remedial action objectives and site closure, the user may decide to use an alternative functional unit as appropriate.

3.2 Step 2: Gather Remedy Information

Step 2

This step of the footprint methodology involves collecting information about remedy design, construction, and operation. The information includes design parameters, activities conducted, and types of materials used. Exhibit 3.1 (in Appendix A) provides examples of this type of information for several common remedies.

The quality of the information depends on the stage of the remedy when the footprint analysis is conducted. The information will likely be relatively uncertain during the early design stage but will increase in certainty as the design stage proceeds and as the remedy is implemented. The degree of uncertainty in the remedy information used in the footprint analysis should be documented as the footprint analysis proceeds, along with the likely effects of the uncertainty on the results of the analysis.

The typical outcome of the information gathering step is a bulleted list of remedy information. The footprint reduction scenarios presented in Appendix C illustrate the level of detail that is generally expected for this step of the process. Although the scenarios provide examples for data gathering, professional judgment is used on a site-specific basis to determine the appropriate level of detail to meet the objectives of the footprint analysis.

Some of the information to be gathered in this stage and in the next stages of the footprint analysis process is generally available from existing documents and the site contractor. Moreover, the information needed and the process of obtaining the information is similar to the information and process used while preparing design documents, remedial action progress reports, or conducting remedy optimization evaluations. For this reason, it is highly suggested that the footprint analysis be conducted in concert with one or more of these other activities. Depending on the information available, some technical remediation expertise may be required to translate some aspects of the remedy into useable information. For example, the level of effort and type and size of equipment needed to excavate a given volume of contaminated soil may be estimated to provide information for the footprint analysis, or the amount of GAC to treat process water may be estimated for a specified flow rate and contaminant load. Although the methodology cannot provide all technical details needed to complete this step for all remedies, the exhibits in Appendix A of this document convey examples of fundamental information.

The level of detail achieved in the footprint analysis is heavily dependent on the information gathering step because this step will determine the information that is either included in the analysis or excluded from the analysis. A tradeoff arises between the level of detail achieved in the analysis and the level of effort for conducting the analysis. This methodology suggests setting and documenting the following two types of screening limits to select the activities or materials included in the analysis:

- ***A screening limit based on a specified percentage of the maximum contributor to a particular metric***
- ***A screening limit based on a specified magnitude for a particular metric.***

The limits and the reasoning for selecting them should be clearly documented. Based on professional judgment, an item or activity that is expected to contribute less than either of the limits can be omitted from the analysis with an appropriate level of documentation. Both types of limits should be applied to each of the green remediation metrics or grouping of metrics because an item that is a negligible contributor for one metric (such as GHG emissions) may be a significant contributor for another metric (such as onsite water use). Exhibit 3.2 (Appendix A) presents a screening approach that can be used and an example application of it.

3.3 Step 3: Quantify Onsite Materials and Waste Metrics

Step 3

The methodology involves quantifying materials from off site that are used on site and quantifying waste that is generated on site. This quantification is an accounting of the significant materials used, the recycled content of those materials, various wastes generated, and the portion of that waste that is recycled or reused. The primary challenges associated with this step include 1) converting the various quantities of materials and wastes into common units for each of the metrics; 2) recognizing recycling and reuse when it occurs; and 3) presenting information in a clear and concise manner.

3.3.1 Content of a Materials Footprint Analysis

To assist with identifying materials used on site, Table 3.2 provides materials typically involved in various remedy activities. Where a material is comprised of a known combination of refined and unrefined materials, it is appropriate to distinguish between the refined and unrefined portions. For example, concrete is approximately 15 percent refined materials and 79 percent unrefined material, and the remaining 6 percent is water (see Section 3.3.2 for more information). The use of one ton of concrete therefore is considered 0.15 tons of refined material and 0.79 tons of unrefined material.

Materials that exceed the screening limits discussed in Section 3.2 and Exhibit 3.2 would be included in the calculation of the footprint. Materials that fall below these limits would be excluded from the calculation of the footprint. Materials that are excluded should be described with an appropriate level of documentation and can be addressed through qualitative BMPs for green remediation.

Appendix B includes a sample table format for organizing a materials footprint analysis. Examples of completed tables are presented in the footprint reduction scenarios provided in Appendix C.

Table 3.2. Potential Onsite Use of Materials

The materials listed are "refined" as defined by this methodology unless marked with an asterisk (*).

- Wells
  - Grout
  - Well casing (PVC or steel)
  - Sand/gravel/bentonite*
- Piping
  - Steel
  - Plastic (PVC, HPDE, other)
- Buildings and foundations
  - Concrete**
  - Steel
- Cutoff walls
  - Sheet pile (PVC, steel)
  - Slurry (bentonite, grout, fill)**
- Geomembranes/liners/caps
  - PVC, HDPE
  - Clay*
  - Asphalt**
- Treatment chemicals/materials
  - GAC
  - Oxidants (e.g., hydrogen peroxide)
  - Acids (e.g., sulfuric acid)
  - Bases (e.g., sodium hydroxide)
  - Flocculants (e.g., ferric chloride)
  - Polymer
  - Well rehabilitation chemicals
- Injection reagents
  - Oxidants (e.g., permanganate)
  - Acid (e.g., sulfuric acid)
  - Catalysts (e.g., ferrous sulfate)
  - Zero-valent iron
  - Nutrients, electron donors (e.g., vegetable oil)
- Other
  - Fertilizers
  - Mulch/compost*
  - Process equipment (PVC, HDPE, steel)

** Unrefined material* ***combination of refined and unrefined materials*

PVC = polyvinyl chloride *HDPE = high density polyethylene*

3.3.2 Rules of Thumb and General Assistance for Quantifying Materials Use

Quantifying materials use in tons can be challenging during any phase of a remedy because many materials are ordered or described in different units, such as feet of pipe, square feet of plastic membrane, or gallons of chemical reagents. Some material use can also be difficult to quantify if many small components are used (e.g., treatment system valves, fittings, and piping). In addition, some commonly used construction materials (e.g., steel) include significant recycled content but the recycled content is not necessarily communicated to the purchaser. For this reason, rules of thumb are useful to simplify the materials inventory process when more site-specific information is not readily available. Exhibits 3.3 through 3.8 (Appendix A) provide general information and rules of thumb for this purpose.

- Exhibit 3.3 provides densities of common materials.
- Exhibit 3.4 provides the approximate materials content of commonly used aqueous chemical solutions.
- Exhibit 3.5 provides estimated materials use for piping and wiring runs.
- Exhibit 3.6 provides estimated materials use for well installation.
- Exhibit 3.7 provides estimated materials use for process equipment and building construction.
- Exhibit 3.8 provides reasonable assumptions for recycled content of steel, concrete, and asphalt, which are construction materials with a significant percentage of recycled content.

3.3.3 Content of a Waste Footprint Analysis

The following waste streams are commonly associated with remediation and may significantly contribute to onsite waste generation:

- Drill cuttings and used drilling mud
- Excavated soil for offsite disposal
- Construction debris
- Treatment plant residue
- Spent GAC.

Many of the above potential waste streams can be reused or recycled. Examples include spent GAC, which often can be regenerated and reused rather than sent to a landfill for disposal.

The following waste streams are also commonly associated with remediation but may be too small to merit inclusion in the waste footprint.

- Used packaging
- Used personal-protective equipment that is disposable.

Waste streams that exceed the screening limits discussed in Section 3.2 and Exhibit 3.2 would be included in the calculation of the footprint. Waste streams that fall below these limits would be excluded from the calculation of the footprint. Waste streams that are excluded should be described with an appropriate level of documentation and can be addressed through qualitative BMPs for green remediation.

Quantifying waste generation is generally straightforward during remedy design and remedy implementation because significant waste generation typically results in significant costs that need detailed analysis and documentation. For this reason, general information and rules of thumb for waste generation are not provided as has been done for materials use.

Appendix B includes a sample table format for organizing a waste footprint analysis. Examples of completed tables are presented in the footprint reduction scenarios provided in Appendix C.

3.3.4 Items Not Included in the Materials and Waste Footprint Analysis

The methodology does not include in the materials metric the raw materials used in manufacturing processes or materials used in other offsite activities that support the remedy because the project team often does not have direct control over these materials. Similarly, it does not consider waste generation associated with materials manufacturing or other offsite activities that support the remedy. Emphasis instead is placed on reducing onsite materials use, increasing the recycled content in the materials that are used, reducing onsite waste generation, and recycling or reusing materials that have served their purpose.

Although water is a "material" in a broad sense, this methodology considers water a separate core element of green remediation with its own metrics for footprint analysis. Therefore, water used in a cleanup is not included in the materials metric. Similarly, water discharged to an offsite treatment plant is not considered in the waste metric. The production and treatment of water, however, are considered in the energy and air metrics discussed in Section 3.5 because the production and treatment of water involves energy use and air emissions.

Fuels such as gasoline, diesel, and natural gas are also "materials" in a broad sense, but this methodology does not include fuels in the materials metric because the production and use of fuels are considered thoroughly in the energy and air metrics discussed in Section 3.5.

Equipment that is used only temporarily for a remedy is not considered in the materials metric when it is brought on site and is not considered recycled or reused in the waste metric when it is removed from the site. Examples of equipment that are not included in the materials or waste metrics are contractor equipment used at other sites (e.g., heavy equipment, mixing tanks, and hoses) and rental equipment (e.g., portable generators or air compressors for sampling). Equipment that is dedicated to the cleanup remedy, such as well extraction pumps or tanks for treatment of extracted groundwater, should be included in the materials and waste metrics when they are used and decommissioned, depending on the level of detail desired in the footprint analysis.

3.4 Step 4: Quantify Onsite Water Metrics

Step 4

The methodology involves quantifying onsite water use with emphasis on reducing onsite water use and returning water of high quality to productive use. Activities in this step include:

- Distinguishing among various local and onsite water sources
- Identifying the quality of the water used from each source
- Quantifying the amount of water used from each source
- Identifying the use of the water from each source
- Distinguishing among various fates of the water from each source after use.

The following section discusses each of these items in more detail.

3.4.1 Content of Onsite Water Footprint Analysis

Water Resources – Common sources of water that may be used on site in association with a remedy include potable water from a public water supply system, multiple groundwater resources, multiple surface water resources, captured stormwater, and reclaimed water. Multiple groundwater and surface water resources are possible because there may be different aquifers from which groundwater can be extracted or multiple locations from which surface water is extracted.

Water Quality – The quality of the water used is an important aspect of the water footprint because the potential beneficial uses of the water by the local community, economy, and environment are directly related to the water quality. Indicating the source of water does not necessarily describe the quality of the water. For example, if water is extracted from a shallow aquifer that is classified as a potential source of drinking water by the state but actually has inadequate water quality for this purpose (perhaps due to high levels of naturally occurring dissolved iron or dissolved solids), then the water quality might be described in the footprint analysis as "potential potable water resource that likely requires treatment before use." For water that is contaminated by site-related contamination, the description should pertain to the natural quality of that groundwater and should note the site-related contamination.

Volume Used – The amount of water used from the indicated water resource refers to the volume that is used or diverted from that resource over the life cycle of a remedy. For example, the installation and use of impermeable surfaces as part of the remedy may result in diversion of stormwater to surface water rather than allowing it to infiltrate into the subsurface. The stormwater diversion would be considered a "use" of the water. Exhibit 3.9 in Appendix A provides additional information related to stormwater as it pertains to this methodology.

Potential Water Uses – The uses of the water vary from remedy to remedy. Common uses of water resources associated with remediation include the following:

- Extraction for treatment (e.g., in a groundwater P&T system)
- Extraction for testing (e.g., for long-term pumping tests)
- Injection for plume migration control
- Blending and injecting reagents for *in situ* bioremediation
- Blending and injecting reagents for *in situ* chemical oxidation (ISCO)
- Blending of chemicals for treatment plant operation
- Make-up or backwash water from treatment plant operation
- Mixing grout or slurry
- Evapotranspiration from phytoremediation
- Purge water from sampling
- Equipment decontamination
- Dust control and general construction.

Chemical solutions brought to the site from a chemical vendor can contain a significant amount of water. Absent other information, it is appropriate to consider the water content of the solution to be public water that is used on site. Relevant information for many common aqueous solutions used in remediation is available in Exhibit 3.4. This and other uses of public water are also considered in quantifying the energy and air metrics as described in Section 3.5.

Potential Fates of Used Water – The fate of the used water is an important part of the water footprint because the potential beneficial uses of the "used" water by the local community, economy, and environment directly depend on where the water is discharged and the quality of the water once it is discharged. Common fates of water after water use during remediation include the following:

- Discharge to public water supply
- Discharge for use as industrial process water
- Discharge to groundwater
- Discharge to surface water
- Discharge for use as irrigation

- Discharge to a brackish or saline water body
- Discharge to the atmosphere through evapotranspiration or vaporization.

An onsite water metric is established for each combination of a water source, water use, and water fate that involves significant water use. For example, extracted groundwater from a specified aquifer used for two purposes, each with its own fate, results in two onsite water metrics. Water use from each major water resource that exceeds the screening limits discussed in Section 3.2 and Exhibit 3.2 would be included in the calculation of the water footprint. Water uses from the various sources that fall below these limits would be excluded from the footprint but would be documented; these uses can be addressed through qualitative BMPs for green remediation.

Although water may be used during the remedy, the use and the fate of the used water does not necessarily result in a net effect on the onsite water resource. For example, groundwater may be extracted, treated, and reinjected into the same aquifer, representing no net effect on the onsite water resource. However, if the treated water is of substantially improved quality (e.g., lower total dissolved solids) than the groundwater, then returning the treated water to the aquifer may be a lost opportunity for beneficial reuse. Similarly, groundwater of relatively high quality that is extracted, treated, and discharged to brackish or saline water inherits the brackish or saline quality. In this circumstance, groundwater that was extracted (before or after treatment) now has increased salinity, and its potential uses may now be limited. In addition, discharging the groundwater to naturally brackish water may reduce the salinity of the brackish or saline water in localized areas.

Quantifying onsite water use is generally straightforward during remedy implementation and remedy optimization when actual data is available. It is also generally straightforward during the design process because engineering estimates made at that point can be converted into water use. For example, engineering estimates are typically available for the extraction rate for a P&T system or the amount of water that will be used for injecting nutrients or reagents into the subsurface for an *in situ* remedy. These types of engineering estimates should be used where available. General assistance is provided below to elaborate on some categories of water use and how to quantify that water use.

Appendix B includes a sample table format for organizing a water footprint analysis. Examples of completed tables are presented in the footprint reduction scenarios provided in Appendix C.

Chemical Solutions – Chemical solutions brought to the site from a chemical vendor can contain a significant amount of water. Absent other information, it is appropriate to consider the water content of the solution to be public water that is used on site at the cleanup project. Relevant information for many common aqueous solutions used in remediation is available in Exhibit 3.4. This and other uses of public water are also considered in quantifying the energy and air metrics as described in Section 3.5.

3.5 Step 5: Quantify Energy and Air Metrics

Step 5

The energy and air metrics as calculated by the methodology attempt to account for as much of the life cycle of the material or activity as is practicable. For example, the energy and emissions associated with electricity use includes resource extraction for fuel, use of the fuels, and transmission and distribution losses. In addition, for gasoline and diesel used on site or for transportation, the energy and emissions for extracting crude oil and refining the oil into the gasoline and diesel are included, in addition to combustion of the fuels in equipment and during transportation.

The methodology purposefully does not include energy use and air emissions resulting from the following aspects of the remedy:

- The manufacturing of rental or temporary equipment for the site (e.g., the manufacturing of an excavator that is used for removing contaminated soil) is not included in the footprint because 1) it is assumed that a small fraction of the equipment lifetime operating hours are spent on a single project and 2) the footprint associated with manufacturing the equipment is expected to be small relative to the footprint of operation over the life of the equipment.

- Office-related work and other offsite personnel activities (other than routine transportation between the site and the office) are not included because office-related work is anticipated to have a relatively small footprint relative to site work.

- Items or activities that are non-additional (i.e., would have occurred in the absence of site remediation) are not included because actions taken to reduce the footprint for a remedy would not address the footprint of such items or activities.

- Items or activities external to the remediation process associated with redeveloping a property are not included because they are external to the remediation process.

This methodology recommends including offsite energy use and air emissions because for some sites the offsite energy use and emissions may represent the majority of the remedy footprint and project teams can influence the offsite energy use and air emission by modifying the amounts or types of energy, materials, and offsite services used in the remedy.

Step 5 is divided into the following three parts to facilitate organizing, presenting, and calculating the energy and emission footprints:

Part 1 – Inventory Remedy Transportation, Equipment Use, Materials and Waste, Public Water Use, and Offsite Services
Part 2 – Determine Remedy Energy Use
Part 3 – Convert the Remedy Inventory into Energy and Air Metrics.

Each of these parts is discussed in the following sections.

3.5.1 Part 1 - Inventory Remedy Transportation, Equipment Use, Materials and Waste, Public Water Use, and Offsite Services

The first part of Step 5 is to make an inventory of the transportation, equipment use, materials and waste, public water use, and offsite services required for the remedy. Much of the information required for this inventory is based on the information previously gathered for the materials, waste, and water footprints. Additional information is gathered on transportation, equipment use, and offsite services required for the remedy. As noted earlier for the materials, waste, and water footprints, the quality of the inventory information gathered in this step depends on the phase of the remedy when the footprint methodology is conducted, with greater certainty associated with later phases of the remedial process.

The type of information collected varies by remedy technology and by remedy phase. Exhibits 3.10A and 3.10B provide checklists as suggestions of the types of information to be gathered. Exhibit 3.10A provides a checklist for the remedy construction phase, and Exhibit 3.10B provides a checklist for the remedy operation phase.

In an effort to streamline the footprint analysis process, it is appropriate to screen the information to be included in the analysis. The materials use, waste disposal, and public water use described in Steps 2 and 3 (which have already been screened) can be included directly. The transportation, equipment use, and other offsite services are screened against the limits discussed in Section 3.2 and Exhibit 3.2. Items and activities that exceed the limits would be included, and items and activities that fall below the limits would be excluded. Items and activities that are excluded should be described with an appropriate level of documentation; these aspects can be addressed through qualitative BMPs for green remediation.

The outcome of part 1 of this step is a reference to the previously documented materials, waste, and public water from Steps 3 and 4 along with a bulleted list of types and quantities of transportation, equipment use, and offsite services that are involved in the remedy.

3.5.2 Part 2 – Determine Remedy Energy Use

The second part of Step 5 is to organize and refine the inventory information that was developed in Step 2 and to use that information to determine the amount of energy involved.

This part is divided into the following processes:

- Determining fuel use
  - Converting personnel transportation into fuel use
  - Converting onsite equipment use into fuel use
  - Converting transportation of equipment, materials, and waste into fuel use
  - Gathering information about actual fuel use (when such information is available)
- Determining electricity use
  - Converting electrical equipment and power requirements into electricity use
  - Gathering information about actual electricity use (when such information is available).

Determining Fuel Use

Converting Personnel Transportation into Fuel Use

Fuel use associated with personnel transportation is a function of the type of vehicle, the type of fuel, and the distance traveled. During remedy construction or remedy operation, this information may be readily available, and in some cases, actual fuel use may be tracked. If fuel use has been tracked for some or all of the remedy, it should be used directly and/or used to estimate other fuel use. However, in most cases, particularly during remedy design, it may be necessary to make some assumptions regarding fuel use. Exhibit 3.11A provides information for quantifying fuel use for personnel transportation.

Fuel use associated with relatively routine personnel travel is considered in the footprint calculations. However, it may not be necessary to include fuel use for non-routine or one-time travel because it likely falls below the established screening limits. For example, it is typically appropriate to include daily or weekly travel of a site operator to the site, whereas it may not be necessary to include travel by multiple parties for a kickoff planning meeting. Carpooling can be assumed where appropriate (e.g., two sampling technicians traveling together to conduct a monitoring event). The process of estimating fuel use for personnel transportation is illustrated in the footprint reduction scenarios presented in Appendix C.

Converting Onsite Equipment Use into Fuel Use

Equipment operation typically involves the use of a diesel or gasoline engine that may or may not have been modified to operate on biodiesel or fuel blends. Fuel use associated with equipment operation is a function of the following:

- Horsepower rating of the equipment
- Type of fuel
- Engine efficiency
- Load on the engine
- Hours of operation.

Although the horsepower rating and fuel type may be known, the load on the engine, the engine efficiency (which varies with load), and the hours of operation may not be known. During remedy construction or operation, it may be feasible to track fuel use or contact equipment owners/operators about estimated fuel use. However, during remedy design, this may not be practical and a means of approximating fuel use is needed. Exhibit 3.11B provides assistance with quantifying fuel use for operation of heavy equipment. The process of estimating fuel use associated with heavy equipment operation is illustrated in the footprint reduction scenarios presented in Appendix C.

Converting Transportation of Equipment, Materials, and Waste into Fuel Use

Fuel use associated with transportation of equipment, materials, and waste is a function of the type of vehicle, the type of fuel, the weight of the cargo, the presence of other cargo, the distance traveled, and whether or not the vehicle makes an empty return trip. During remedy construction or remedy operation, this information may be readily available. In some cases, actual fuel use may have been tracked or can be estimated by freight carriers. If fuel use has been tracked for some or all of the remedy, it should be used directly and/or used to estimate other fuel use. In most cases, however, particularly during remedy design, it may be necessary to make some assumptions regarding fuel use. Exhibit 3.11C provides assistance with quantifying fuel use for equipment, materials, and waste transportation. The following additional considerations are noted:

- Empty return trips for trucks should be considered where appropriate (e.g., when items are transported directly to the site from the supplier or when waste is transported to a disposal facility).
- Consideration should be given to how a specific item is transported. For example, large quantities of materials and waste are typically carried in bulk, whereas equipment is typically transported via specialty freight (i.e., with no other cargo on board).
- In general, fuel requirements for transportation from the manufacturer to the vendor and then from the vendor to the site should be considered where practical.
- It is common for heavy equipment such as drill rigs to remain at the site throughout the project, reducing the amount of equipment mobilizations. This can be assumed unless site-specific information suggests otherwise.

The process of estimating fuel use for equipment, materials, and waste transportation is illustrated in the footprint reduction scenarios presented in Appendix C.

Converting Electrical Equipment and Power Requirements into Electricity Use

Electricity use associated with a remedy typically results from one of the following types of equipment:

- Electric motors for pumps, blowers, air compressors, and mixers
- Specialized treatment equipment such as ozone generators or ultraviolet oxidation units
- Subsurface electric resistive heating for *in situ* thermal remedies
- Electric heating, ventilation, and air conditioning for buildings
- Building lighting
- Process controls (typically with negligible electrical use compared to the equipment that is controlled).

Electricity provided by an onsite generator should not be included in quantifying electricity use. Rather, the fuel used to power the generator should be included when converting equipment use into fuel use, as noted above.

Electricity obtained from a utility is easily tracked through past utility bills. When the footprint analysis is conducted on an operating remedy and past electricity use is representative of future electricity use, the electricity use from the electric utility bills should be used in the energy footprint. During the remedy design and remedy construction phases, utility bills are not available and assumptions regarding electricity use are made. In either case, an attempt should be made to document the individual demands for electricity from various pieces of equipment because this information is useful for identifying areas for reducing electricity use during interpretation of the results. Exhibit 3.12 provides equations for estimating equipment power ratings based on remedy information, and Exhibit 3.13 provides equations for estimating electricity use given the equipment power rating. The process of estimating electricity use is illustrated in the footprint reduction scenarios in Appendix C.

Like other forms of energy used on site, electricity generated from onsite renewable energy contributes to the metric of total energy use. Onsite renewable energy is also an important component of the metric for energy voluntarily derived from renewable resources and for avoiding emissions typically associated with conventional energy use. Onsite renewable energy systems that generate electricity commonly include meters tied to the utility grid; data supplied by these meters and associated net metering by the utility can be used to quantify these metrics. Electricity generated from an onsite but off-grid renewable energy system also should be tracked separately so that conversion factors for grid electricity are not applied to the electricity generated from the renewable energy system. During the feasibility study and design stage of a renewable energy system, engineering estimates of electricity generation are often available for footprint analysis. When electricity use is estimated by considering electrical demand of individual pieces of equipment, it is similarly important to subtract from this estimate the amount of electricity generated by the onsite renewable energy system so that the conversion factors for grid electricity are not applied to the electricity generated from the renewable energy system.

3.5.3 Part 3 – Convert the Remedy Inventory into Energy and Air Metrics

The third part of Step 5 is to convert the fuel, electricity, materials, and offsite services involved in the remedy into energy and air metrics. Footprint conversion factors are used for this purpose. Each item noted above (i.e., each type of fuel, each source of electricity, each material, and each offsite service) has its own set of conversion factors related to the production, manufacturing, or provisioning of that item or service. In addition, fuels such as diesel, gasoline, and natural gas each have an additional set of conversion factors related to the combustion of the fuels. For example, for a fuel such as diesel, conversion factors are used to calculate metrics for energy, GHGs, NOx, SOx, PM10, and HAPs associated with the production of the fuel and the combustion. The application of the conversion factors for one of the metrics (GHG emissions measured as CO_2e) is illustrated in the following example for diesel fuel. First, the CO_2e conversion factor for offsite production of a gallon of diesel from the well field through the refinery (which is distinct from using a gallon of diesel) is applied.

Diesel used (gallons)	×	*Footprint conversion factor for converting production of a gallon of diesel to tons of CO_2e*	=	***CO_2e footprint from diesel production (tons of CO_2e)***

Second, the CO_2e conversion factor for diesel use (combustion) is applied.

Diesel used (gallons)	×	*Footprint conversion factor for converting use of a gallon of diesel to tons of CO_2e*	=	***CO_2e footprint from diesel use (tons of CO_2e)***

Footprint conversion factors are applied in a similar manner to calculate the other metrics (energy use and emissions of NOx, SOx, PM10, and HAPs) for production and use of diesel fuel. In addition, unique conversion factors are applied in a similar manner to the production and use of all the other fuels, to the generation and use of electricity, and to the manufacturing or provision of materials and services used for the remedy. The results are then compiled and presented. Example tables for applying the conversion factors, summing the various contributions, and presenting the results are presented in Appendix B and in the footprint reduction scenarios in Appendix C.

One of the challenges of conducting a footprint analysis is establishing accurate conversion factors for the fuels, electricity, materials, and services used in a remedy. Exhibit 3.14 (Appendix A) provides suggested default footprint conversion factors to use in footprint analyses of environmental cleanups. Most of these conversion factors are obtained from publicly available life cycle inventory databases. Others represent reasonable approximations based on analysis of a compilation of conversion factors. The values presented in life cycle inventory databases are generic or industry-wide averages that may not be accurate for specific manufacturing facilities. There is therefore a degree of uncertainty associated with using these values for footprinting specific remedies. These conversion factors are made available in Exhibit 3.14 to provide a means for quantifying green remediation metrics specified in this methodology and are not intended to guide procurement decisions or to suggest that one material should be used in place of another. In some cases, a site team may identify more specific footprint conversion factors that are based on site-specific or vendor-specific information. Site-specific conversion factors can be used for footprint analyses but the source of the conversion factor should be documented as part of the footprint analysis. For example, a site team that uses a vendor who provides "carbon neutral" solid waste disposal (if properly documented by the vendor) would choose a CO_2e conversion factor of zero for solid waste disposal rather than the "default" conversion factor, and documentation for choosing the site-specific conversion factor should be referenced as part of the footprint analysis. Another example is the use of emission control technologies (e.g., particulate filters) on diesel engines, which can reduce emissions of NOx, SOx, or PM. Emissions from diesel engines, in particular, are subject to substantial variation based on idling practices, type of vehicle or engine, model year, retrofits, and emission control technologies. For more thorough analysis of emissions from diesel engines refer to information available from EPA's National Clean Diesel Campaign (http://www.epa.gov/cleandiesel/).

In addition to emissions from fuel combustion on site, other onsite sources of emissions may be identified for cleanup activities, particularly for the GHG and air toxics footprints. For example, air pollutants may be emitted in the off-gas of an air stripper, in the exhaust of a soil vapor extraction (SVE) system, by vaporization from exposed contaminated soil or groundwater, landfill gas emissions, dust generation, or perhaps other site-specific activities. In addition, onsite activities may result in carbon storage or other reductions of the GHG footprint (e.g., combusting landfill gas or carbon storage in tree biomass). Exhibit 3.15 provides a method of calculating air pollutant emissions from treatment processes and a reference for calculating dust and HAP emissions from construction activities. Exhibit 3.16 provides a method of calculating carbon stored in the biomass of trees that have been planted as part of remedial activities.

Conversion factors for energy and air emissions from offsite electricity generation are dependent on the specific grid mix supplied to the site and are determined on a site by site basis. The type of information used to determine the conversion factors is generally available from the individual electricity service providers. Otherwise, related information at the U.S. state level is available online from the U.S. Energy Information Administration (http://www.eia.gov/state/) or can be accessed for U.S. regions defined in the federally sponsored Emissions & Generation Resource Integrated Database (eGRID) (www.epa.gov/egrid). Exhibit 3.17 illustrates how to use the information from these sources to obtain the footprint conversion factors for grid electricity.

The footprint conversion factors suggested in Exhibit 3.14 and calculated as discussed above are not intended for use by site owners or regulatory agencies in submittals of footprint information to other organizations such as climate registries. Rather, they are intended to provide a sufficient level of information to allow a site team to make educated decisions regarding energy use and pollutant emissions associated with the cleanup. It is expected that updates or refinements to these emission factors will be provided as more information becomes available.

Appendix B provides example tables for applying conversion factors and presenting results, and the footprint reduction scenarios in Appendix C provide examples of calculating and presenting the energy and air metrics.

3.6 Step 6: Qualitatively Describe Affected Ecosystem Services

Step 6

In its current form, the methodology suggests the use of qualitative descriptions of the effects of a remedy on land and ecosystem services such as nutrient uptake and erosion control. Concepts related to ecosystem services are available online from EPA's Ecosystem Services Research Program at http://www.epa.gov/ecology.

3.7 Step 7: Present Results

Step 7

A suggested format for presenting results of each step is presented in Appendix B. In addition to the information gained through each step, documentation in a footprint analysis should be provided for:

- The screening process
- Analytical assumptions
- Possible areas of uncertainty
- Specific ideas of how to reduce the footprint.

> Project teams may wish to supplement the methodology with additional metrics meeting project or organization needs and to tailor the presentation of footprint analysis results accordingly.

4.0 Considerations for Interpreting Footprint Results

Interpreting the results of a footprint analysis is influenced by a number of considerations, including the quality of the data used in the analysis, trade-offs among footprint metrics, and the magnitude of the footprint. The following sections discuss each of these considerations, and the footprint reduction scenarios provided in Appendix C demonstrate how they are considered.

4.1 Data Quality

There are three main factors that influence data quality:

- The first influence is the **quality of the remedy information input** into the footprint analysis. Variations in remedy information, such as the volume of soil to be treated or the groundwater extraction rate, can result in significant variations in the footprint results. This influence affects all green remediation metrics. The quality of the data input is generally lowest during the development of remedy alternatives when design studies have not been conducted and design-level engineering estimates have not been made. By contrast, the quality of data input is generally highest during remedy operation when actual data is available and the site has been thoroughly studied. The data quality during the design stage generally has benefited from several design studies and engineering estimates but does not have the benefit of actual data for input into the footprint analysis.

- The second influence is the **accuracy or appropriateness of the formulas** for quantifying use of electricity, fuel, water, materials, and offsite services involved in a specific remedy. Although formulas are provided in this methodology to help provide reasonable estimates of these quantities, they do not necessarily apply accurately to each site or scenario. This influence primarily affects the energy and air metrics but can also affect the other metrics to some degree. Example #1 (at the end of this section) demonstrates how assumptions regarding materials transport can greatly affect the footprint results.

- The third influence is the **accuracy of the conversion factors** used to convert the remedy inventory into green remediation parameters. Although the methodology includes conversion factors to use for this purpose, the conversion factors are general in nature and cannot account for differences that might occur from one manufacturing facility to another. Even the footprint conversion factors associated with converting electricity generation to emissions can impart significant variation in the footprint results. Example #2 (at the end of this section) provides an example of this influence and demonstrates that footprint conversion factors could vary by as much as one order of magnitude. This third influence also predominantly affects the energy and air metrics.

Based on the above discussion, it is apparent that the energy and air metrics may have the largest amount of uncertainty relative to the other metrics because the energy and air metrics are affected by all three data quality influences and the other metrics are primarily affected by the first data quality influence.

Project teams are encouraged to perform sensitivity analyses on the results by varying key input parameter values within reasonable ranges and evaluating the resulting changes in the metric values. Large changes in the metrics from relatively minor variations in a particular input parameter value suggests that the metric calculations are highly sensitive to that parameter and that uncertainty in that input parameter translates to a similar level of uncertainty in the metric calculation. Sensitivity analyses are helpful tools for project teams to understand the implications of variations in data quality and better understand the quality of the footprint analysis results.

4.2 Tradeoffs between Metrics

The methodology helps quantify metrics for more than 15 different parameters in four different green remediation core elements. Some of the parameters are local in nature (e.g., onsite HAP emissions or local water use), and others are more regional (e.g., NOx/SOx/PM10 emissions) or global in nature (e.g., total GHG emissions). A potential modification to an existing remedy may increase the values for some metrics and decrease the values for others.

For example, a bioremediation remedy using water from the public supply results in significant use of public water but relatively minimal onsite emissions of NOx, SOx, and PM10 because a generator or other equipment is not needed to provided power for extracting groundwater. Potentially modifying the remedy to use extracted groundwater will decrease or eliminate the use of public water but may increase the onsite NOx, SOx, and PM10 emissions from a generator that provides the power for groundwater extraction. Different site teams and different stakeholders may favor one option over another depending on their prioritization of green remediation parameters, cost, and other factors. When such tradeoffs exist, it is helpful to know the metrics or parameters that are more important to site stakeholders as well as the influence of parameters relative to regulatory requirements.

4.3 Footprint Magnitude

Two main questions regarding the magnitude of a footprint may arise when interpreting the results of a footprint analysis:

- *"What is considered a large footprint or footprint reduction?"* When seeking to reduce a footprint, it is helpful to understand the significance of the magnitude of the potential reduction and the appropriate level of resources (e.g., time, materials, and money) that could be reasonably invested to achieve the reduction. A small percentage decrease in a footprint of a remedy with a large footprint may be greater in magnitude and more cost-effective to achieve than a large percentage decrease in the footprint of another remedy with a relatively small footprint.

- *"What is considered a significant difference between footprints of two or more potential modifications that are under consideration?"* The data quality influences noted above are crucial elements in determining if there is a significant difference between the footprints of two potential modifications to a remedial system, and comparisons of footprints should be interpreted with a degree of caution that is commensurate with the degree of uncertainty in the input data.

Example 1. Data Quality - Transportation

Consider the example of transporting 1.5 tons of emulsified vegetable oil (equivalent to approximately 400 gallons) 500 miles via specialty freight and common freight. The fuel economies used are from Exhibit 3.11C and assume that the weight of the freight negligibly affects fuel economy relative to other factors that affect fuel economy.

Specialty freight (includes empty return trip)

Delivery trip:	500 miles	÷	6 miles per gallon	=	83 gallons
Empty return trip:	500 miles	÷	6 miles per gallon	=	83 gallons
				Total:	166 gallons

Specialty freight (excludes empty return trip)

500 miles	÷	6 miles per gallon	=	83 gallons

Common freight "heavy load" (i.e., truck is fully loaded, including freight not related to the site)

1.5 tons	×	500 miles	×	0.029 gallons per ton-mile	=	22 gallons

The fuel use differs by 750 percent depending on the mode of transportation assumed. This example also assumes that the distance transported is known and correct. In many cases, especially during the remedy design stages, the transport distance or mode of transportation may not be known, introducing additional data quality concerns.

Example 2. Data Quality – Electricity Generation

Consider the following example of estimating the GHG emissions (measured in CO_2e) from a P&T system in Tacoma, WA, where electricity use is 100,000 kilowatt-hours (kWh) per year and represents the large majority of the GHG footprint for the remedy. Various sources of information on the fuel blend or generation mix for grid electricity supplied to the site may be found on the internet or may be obtained from electricity providers. The sources include the 2007 generation mix for the eGRID (www.epa.gov/egrid) Northwest Power Pool (NWPP) subregion (where Washington is located), the 2009 generation mix for the NWPP from the Washington State Department of Commerce ("Commerce"), the 2007 Washington state generation mix from eGRID, the 2009 Washington state generation mix from Commerce, and the 2009 generation mix for Tacoma Power (local utility) provided by Commerce.

	NWPP (eGRID 2007)	NWPP (Commerce 2009)	WA (eGRID 2007)	WA (Commerce 2009)	Tacoma Power (Commerce 2009)
Generation Mix					
Coal	31.96	44.29	8.00	17	3.83
Hydropower	48.37	34.76	73.72	64	87.64
Natural Gas	12.78	17.46	6.81	13	1.51
Nuclear	3.0	1.41	7.58	4	6.68
Other	3.89	2.08	3.89	2	0.34
Total	100%	100%	100%	100%	100%
CO_2e emissions generation (lbs/kWh)	0.87	1.20	0.26	0.54	0.10
CO_2e footprint (lbs) for 100,000 kWh of electricity use	87,000	120,000	26,000	54,000	10,000

Notes:

- *"Commerce" = Washington State Dept. of Commerce http://www.commerce.wa.gov/site/539/default.aspx)*
- *Coal, natural gas, and nuclear CO_2e emissions for "Commerce" generation mixes are based on data from the National Renewable Energy Laboratory Lifecycle Inventory (NREL, www.nrel.gov/lci). Hydropower CO_2e emissions are assumed to be 0 lbs/kWh. "Other" fuels are assigned CO_2e emissions of 0 lbs/kWh in calculating conversion factors for each fuel blend, which may slightly underestimate emission factors for these generation mixes. The footprint for extracting and transporting fuels is not included.*

This analysis demonstrates that the generation mixes vary considerably among the various sources of information. For example, the percentage of electricity generated from coal varies from 8 percent to 44 percent. The variation in the generation mix results in a variation in the footprint from 10,000 to 120,000 pounds of CO_2e per year, which is more than one order of magnitude. The conversion factor even varies by over 35 percent for the NWPP sub-region depending on the year, the entity compiling the data, or both. The method for calculating the conversion factors for electricity generation therefore has a significant influence on the footprint results. The conversion factors for electricity are relatively straightforward to calculate compared to the conversion factors for other items associated with a remedy, and it is reasonable to expect that the conversion factors for manufactured goods also vary significantly based on factory location and several other factors.

5.0 Approaches to Reducing Footprints

The process of conducting a footprint analysis and the results from analysis can help project teams identify the largest contributions and develop potential approaches to reducing those contributions and achieving a greener cleanup. The largest footprint reductions for any one metric typically result from modifying certain processes or project components. For example, if electricity use is the largest contributor to the energy footprint, the largest footprint reduction will likely come from reducing overall electricity use. In many cases, the electricity use can be reduced by modifying specific remedy components that use the most electricity.

Each approach should be tailored to a site's unique conditions and the expected operating parameters of a particular cleanup remedy. Some contributions to a metric may appear to be small relative to other contributions from the same project but are large when compared to comparable remedies implemented at other sites. For example, the energy footprint associated with materials used for a large P&T remedy may be small relative to the energy footprint associated with electricity use at the same site. However, the energy footprint associated with materials at that site may be large when compared to the energy footprint of a comparable P&T remedy at a different site. Appendix B includes figures that can be used to illustrate the magnitudes of various footprint contributions relative to each other or a threshold value to help identify those that merit the most attention for footprint reduction.

Experience and documentation gained through EPA's green remediation initiative, including illustrative profiles of green remediation strategies (available online at http://www.cluin.org/greenremediation/tab_d.cfm), suggests that the greatest opportunities for footprint reduction often relate to renewable energy or remedy optimization. Example #3 (in Section 5.3) illustrates footprint reductions that could result from applying both strategies. Renewable energy can be incorporated through onsite systems that generate direct power for cleanup equipment or through purchases from the local utility or a competitive provider. Optimization could involve changes in the conceptual site model, data interpretation, or specific system components that result in more cost-effectiveness and higher project efficiencies. Planning and implementation of either strategy can benefit from the additional perspective provided by a footprint analysis.

Footprint reduction approaches can be linked to specific or general categories of EPA's green remediation BMPs. The Agency has compiled a series of quick-reference fact sheets describing BMPs for specific remedial technologies, project phases, and issues common to many sites. These documents (available at http://www.cluin.org/greenremediation/docs/GR_factsheet_topics_update.pdf) include:

- Excavation and Surface Restoration (EPA 542-F-08-012, December 2008)
- Site Investigation (EPA 542-F-09-004, December 2009)
- Pump and Treat Technologies (EPA 542-F-09-005, December 2009)
- Bioremediation (EPA 542-F-10-006, March 2010)
- Soil Vapor Extraction & Air Sparging (EPA 542-F-10-007, March 2010)
- Clean Fuel & Emission Technologies for Site Cleanup (EPA 542-F-10-008, August 2010)
- Integrating Renewable Energy into Site Cleanup (EPA 542-F-11-006, April 2011)
- Sites with Leaking Underground Storage Tank Systems (EPA 542-F-11-008, June 2011)
- Landfill Cover Systems & Energy Production (EPA 542-F-11-024).

Sections 5.1 through 5.3 describe overall approaches and specific BMPs that could be used to reduce the environmental footprint posed by types of remedies that are commonly implemented for site cleanup. Results of a footprint analysis can help project teams target the BMPs that most effectively reduce the footprint and track associated improvements to a project's environmental outcome.

5.1 Approaches to Reducing Materials and Waste Footprints

P&T remedies: The largest contributors to the materials and waste footprints for a P&T remedy are typically system construction, chemicals use, and waste disposal. All of these items are directly tied to the extraction rate and water quality, so the optimal extraction program would be a key focus for footprint reduction of P&T systems. Consider the GCL Tie & Treating Superfund Site in Sydney, NY. Potassium permanganate use and waste generation associated with removal of manganese (a nuisance parameter for treatment at this site, but not a contaminant of concern) is directly tied to manganese loading (flow rate multiplied by influent concentration). Optimizing the extraction network can reduce the flow rate and manganese loading, resulting in a reduction of both potassium permanganate use and waste generation. Another key focus for footprint reduction of P&T systems is the beneficial reuse of the treated water. Also consider the P&T system at the 10th Street Superfund Site in Columbus, NE. A dispersant is added to the water to reduce fouling of the air stripper. However, the treated water is distributed for public consumption, and the dispersant addition is required by the water provider to prevent scaling in distribution piping and piping in residential and commercial buildings. Because the dispersant is required for public distribution of the water, the dispersant use is not an "additional" item contributed by the remedy and need not be considered part of the materials footprint for the remedy. Therefore, the beneficial reuse of water not only reduces the water footprint but the materials footprint associated with dispersant production.

ISCO and *in situ* bioremediation: The largest contributors to the materials footprint associated with these *in situ* remedies is the amount of reagents used/injected and the construction of permanent injection locations. Optimizing the number of injection locations and the reagent demand could lead to significant footprint reductions. In some cases, using existing wells as injection points can reduce the number of additional wells needed. Optimizing the area to be treated (perhaps with more characterization) could reduce both the number of injection locations and the demand for reagents. Creating recirculation cells by using extracted groundwater for reagent blending and injection could help distribute the reagents in the subsurface, potentially reducing the number of injection points. The use of direct-push technology to deliver reagents instead of permanent injection wells may reduce materials use but increase energy use, presenting a potential tradeoff for site stakeholders.

Excavation remedies: The largest contributions to materials use and waste generation for excavation remedies are the disposal of excavated material in a landfill and the use of clean fill for backfill. Consideration could be given to conducting onsite treatment of impacted soils followed by reuse of the treated soil on site, using clean soil from the excavation to partially backfill the excavation, and locating crushed concrete or other reusable materials for fill. Consideration could also be given to *in situ* remediation via contaminant removal/destruction or soil stabilization. These alternative approaches may reduce waste generation but might also affect the materials use or energy and air footprints, presenting a potential tradeoff for the site team.

5.2 Approaches to Reducing Water Footprints

P&T remedies: The most important factor in quantifying the water footprints for many P&T remedies is the change in water quality through the extraction, treatment, and discharge process. Extracted and treated groundwater may be a valuable resource, but if the treated water is discharged to relatively low quality surface water (e.g., water with high dissolved or suspended solids), the higher quality of the treated water is degraded and its direct usefulness as a resource is lost. Finding beneficial use of the treated water (e.g., potable water, industrial process water, or irrigation) is preferred if an appropriate use can be identified and the water has been thoroughly tested. This is because using the treated water displaces demand on other water supplies and offsets the energy and footprint of obtaining that other water resource. If a beneficial use is not available, discharging the water to an aquifer or surface water body of equal quality and availability is another means of reducing the water footprint. Focus should also be placed on optimizing the groundwater extraction rate.

ISCO and *in situ* bioremediation: The largest contributors to the water footprint associated with these *in situ* remedies are reagent dilution, injection, and dispersal. Optimizing the number of injection locations, reagent demand, and delivery concentration could help reduce overall water use. In addition, the source of water used can be a factor. Using extracted groundwater in place of water from the public supply would be favorable because extracted groundwater is a less-refined water resource than public supply water. In addition, use of extracted groundwater may help disperse the reagents in the subsurface.

Excavation remedies: Large contributions to the water footprint for excavation and other earth moving remedies could include water used for dust control or water from dewatering. Water used for dust control could be reduced by planning work for the appropriate season or weather condition. Water use could also be reduced through use of chemicals, but this would result in an increase in the materials footprint. With respect to dewatering, excavations below the water table can result in substantial dewatering efforts to lower the water table below the planned extent of the excavation. Cutoff walls or other engineering controls could help reduce the extraction rates for dewatering. Polymers or bentonite slurry may also help prevent trenches beneath the water table from collapsing and help avoid or reduce the need for dewatering.

5.3 Approaches to Reducing Energy and Air Footprints

P&T remedies: The largest contributors to the energy and air footprints are typically electricity, chemicals use, process sampling, and waste disposal. Electricity, chemical use, and waste disposal are directly tied to the extraction rate, so establishing the optimal extraction rate would be a key focus for footprint reduction of P&T systems. The intensive electricity use of P&T systems also makes them excellent candidates for the application of renewable energy. The renewable energy may be generated on site (e.g., by a photovoltaic system, wind turbine, or system for converting landfill gas to energy), purchased from the utility provider, or purchased as RECs. Significant energy is used to lift groundwater from the water table to the surface and to treat it. As a result, substantial footprint reduction can be achieved if the treated water can be put to an appropriate beneficial use (after appropriate testing), effectively eliminating the energy and emissions associated with the water supply that has been displaced. Process sampling can also be a large contributor to the energy and air footprints. For that reason, optimizing the process sampling program and utilizing surrogate parameters such as pressure drop, oxidation-reduction potential, pH, turbidity, and other parameters that help streamline the process sampling program can help reduce the energy and air footprints.

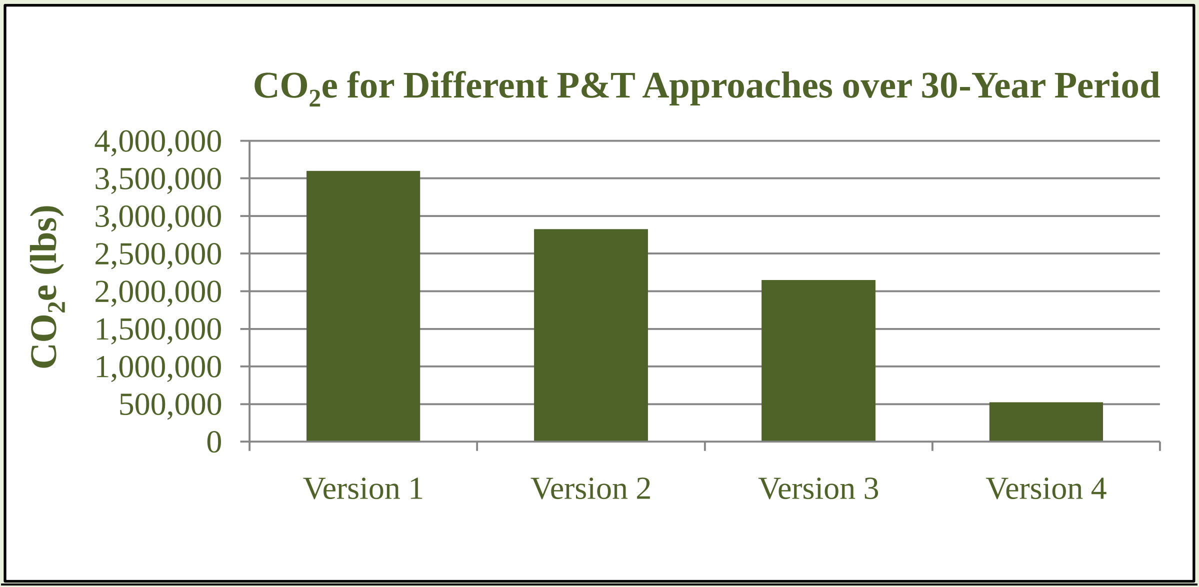
ISCO and *in situ* bioremediation: The largest contributors to energy and air footprints are typically the production and transport of the reagents to be injected. Therefore, optimizing the amount of reagent to be added would be a key focus for footprint reduction for *in situ* remedies that involve reagent injection. It may be appropriate to work in phases, beginning with the best estimate of reagent use and modifying or increasing reagent doses for future injection events rather than injecting too much reagent in the first event. Increased characterization of the treatment area may also help reduce the treatment volume and the reagent use. Selection of the reagent type can be a factor. Although most reagents for chemical oxidation are refined chemicals that are unlikely to be a manufacturing waste or byproduct, the reagents for *in situ* bioremediation may be food or agricultural waste products. Mulch, off-specification soft-drink syrup, low-grade molasses, and other waste products may be appropriate reagents for *in situ* bioremediation of chlorinated solvents. Because these items are waste products, the footprint for producing them would not be attributed to the remedy. Attention could also be given to the provider's location. Preference could be given to local providers to avoid long transport distances. Where multiple injections are required or the subsurface formations are relatively tight, it may be preferable to use permanent injection wells to avoid the repeated mobilization of heavy equipment (e.g., direct-push rigs) that would operate throughout the injection events.

Excavation remedies: The largest contributions to energy and air footprints for excavation remedies are the transport of the excavated material or backfill material from one location to another. The transport may be from one portion of the site to another portion via dump truck, loader, or dozer. It may also be from the site to an offsite location for disposal or reuse. As a result, minimizing this horizontal transport distance and choosing the optimal mode of transportation would be key areas of focus in reducing the footprints of excavation remedies. In some circumstances, transportation by train or barge over long distances may have a lower footprint than transportation by truck. Consideration could be given to using onsite treatment of impacted soils followed by reuse of the treated soil on site, using clean soil from the excavation to partially backfill the excavation, locating local sources for fill, and minimizing the distance to disposal locations. If soil or material requires substantial transport on site, footprint reductions may be best achieved by loading dump trucks rather than carrying loads long distances in front loader buckets or transporting long distances with a dozer. The use of renewable fuels (e.g., biodiesel) could increase the percentage of energy from renewable resources. It could also reduce the GHG footprint for the remedy. Although there may be a GHG footprint for onsite soil treatment, there is also a footprint associated with landfill activities that could partially or completely offset the footprint of the onsite treatment.

It is noted that many footprint reduction approaches also result in cost reductions. For example, materials use and waste disposal can be significant contributors to the costs of a cleanup project. As a result, decreasing the materials and waste footprints often results in a cost savings. Similarly, energy use, materials use, and laboratory analysis also can be significant contributors to the costs of a cleanup project and significant contributors to the energy and air footprints. As a result, decreases in the energy and air footprints by decreasing these items can often result in cost savings. Actual costs and cost savings associated with these reductions will depend on the changes made and a variety of site-specific factors.

Example 3. Footprint Reductions from Optimization and Application of Renewable Energy

The chart below presents the greenhouse gas emissions for several alternative versions of a P&T system that treats approximately 50 gpm of extracted water with a trichloroethene (TCE) concentration of approximately 500 µg/L. The chart illustrates the footprint reductions associated with optimized versions of the P&T system plus the effect of using renewable energy. Although other parameters of are of importance, the greenhouse gas (CO_2e) footprint is used as an example parameter.



***Version 1** – Treatment provided by air stripping with treatment of air stripper off-gas*
***Version 2** – Air stripping with off-gas treatment – but use of variable frequency drives on motors*
***Version 3** – Treatment provided by liquid phase GAC instead of air stripping*
***Version 4** – Version 1 with all electricity use provided by renewable electricity generated on-site*

The example illustrates that the footprint can be reduced by energy efficiency efforts (e.g., variable frequency drives), potential changes to the treatment system components (e.g., GAC instead of air stripping), and application of renewable energy.

6.0 References

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http://www.cluin.org/greenremediation

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http://www.epa.gov/cleandiesel/tools/

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U.S. Environmental Protection Agency, Wastes – Resource Conservation – Reduce, Reuse, Recycle
http://www.epa.gov/osw/conserve/rrr/

U.S. Environmental Protection Agency, Greening EPA - Water Conservation
http://www.epa.gov/oaintrnt/water/

Appendix A:
Exhibits

EXHIBIT 2.1 – ACCOUNTING FOR RENEWABLE ENERGY

There are four main ways in which renewable energy can be applied to site remediation on a voluntary basis:

- Onsite systems that generate electricity, mechanical power, direct heat, or landfill gas
- Use of biodiesel in equipment and vehicles
- Renewable-sourced electricity purchased from the local utility or a competitive provider
- Direct purchase of renewable energy certificates (RECs)

A portion of standard grid electricity provided to the site may also include electricity that was generated from renewable resources. This form of renewable energy, which is provided by default to the site as part of a utility's basic electricity generation mix, is not considered "voluntary" in this methodology. This form of renewable energy is included in the total energy metric (metric E-1) of this methodology, but is not considered in the renewable energy metrics (metrics E-2A – E-2C) because project teams have little or no control over the sources of energy in the basic generation mix. The emission factors used for estimating emissions from electricity generation, however, do include the renewable energy component of the basic generation mix such that grid electricity with a relatively high percentage electricity from renewable resources will likely have lower emissions factors than grid electricity that has a relatively low percentage of electricity from renewable resources.

Each of the four voluntary ways of applying renewable energy to site remediation is discussed below in more detail.

Onsite Systems that Generate Electricity, Mechanical Power, Direct Heat, or Landfill Gas

The following table presents the forms of onsite energy use and the renewable resources that can be used to generate the energy.

Form of Energy	Renewable Resource for Generating Energy
Electricity	Solar Wind Hydroelectric Geothermal Biomass*
Mechanical energy	Wind Hydropower
Heat	Solar thermal Geothermal** Biomass*

** Biomass refers to woody waste, agricultural crops or waste, animal and other organic waste, energy crops, landfill gas, and methane generated from waste water that is used to generate usable energy.*
*** Geothermal refers to heat extracted from the subsurface for direct use and does not refer to heat exchange with water source heat pumps or air heat pumps.*

Use of Biodiesel in Equipment and Vehicles

Biodiesel can be used on site to generate electricity, used on site to power heavy equipment, and used on site and off site for transportation. Biodiesel may be used alone or blended with regular diesel (e.g., B20 is 20 percent biodiesel and 80 percent petroleum-derived diesel). For biodiesel blends, only the percentage of the blend that is biodiesel counts as biodiesel use. Bio-ethanol is not considered a renewable energy source in this methodology.

EXHIBIT 2.1 – ACCOUNTING FOR RENEWABLE ENERGY (continued)

Renewable-Sourced Electricity Purchased from the Local Utility or a Competitive Provider

The EPA Green Power Purchasing Program *Guide to Purchasing Green Power* (Office of Air (6202J), EPA430-K-04-015, March 2010) describes renewable electricity products that project teams may have the ability to purchase directly from the electricity provider. In regulated electricity markets, a *green pricing* product could be voluntarily purchased from the local utility. Green pricing allows customers to voluntarily purchase renewable electricity by paying a premium that supports a greater level of utility investment in renewable energy. In competitive electricity markets, an electricity service provider can be selected that offers renewable electricity. In this type of market, a *green marketing* product can be voluntarily purchased (and delivered through the electric grid) from a provider other than the local utility. Similar to a green pricing product, a green marketing product involves paying a premium in exchange for electricity generated from renewable resources. For this methodology, the definition of renewable electricity as it applies to purchased electricity from renewable resources meets the definition of "green power" used by the *U.S. EPA Green Power Partnership, Partnership Requirements, Appendix A* as follows:

- Solar photovoltaic
- Wind
- Geothermal (not to be confused with the use of geothermal heat pumps)
- Eligible biomass
- Eligible hydropower

The reader is directed to the above reference for definitions of "eligible" biomass and hydropower. More information about purchasing renewable electricity is provided online by EPA's Green Power Partnership at www.epa.gov/greenpower. The effects of voluntary purchases of renewable electricity on air emissions are discussed in Exhibit 2.2.

For the purpose of this methodology, potential emissions reductions from the voluntary purchase of renewable electricity are not applied to the emissions metrics (Metrics A-1 through A-5). See Exhibit 2.2 for more information.

Direct Purchase of Renewable Energy Certificates (RECs)

Where green pricing and green marketing products are not available, project teams can purchase renewable electricity in form of RECs. The EPA Green Power Purchasing Program *Guide to Purchasing Green Power* defines a REC as follows:

> *A REC is a certificate that represents the generation of one megawatt-hour (MWh) of electricity from an eligible source of renewable energy. Each REC denotes the underlying generation energy source, location of the generation, and year of generation (a.k.a. "vintage"), environmental emissions, and other characteristics associated with the generator.*

RECs can be purchased and "bundled" with electricity purchased from the grid, resulting in renewable electricity. Once RECs are sold, the seller can no longer claim that the electricity it produces from its facility is renewable because those rights have been transferred to another party.

More information about RECs is provided at www.epa.gov/greenpower. The effects of purchasing RECs on air emissions are discussed in Exhibit 2.2.
For the purpose of this methodology, potential emissions reductions from the voluntary purchase of RECs are not applied to the emissions metrics (Metrics A-1 through A-5). See Exhibit 2.2 for more information.

EXHIBIT 2.2 – EFFECTS OF VOLUNTARY PURCHASES OF RENEWABLE ELECTRICITY AND RECS ON AIR EMISSONS

Many federal and non-federal programs support emission reductions from the voluntary purchase of renewable electricity from green pricing products, green marketing products, or RECs. One example is the EPA Green Power Purchasing Program (www.epa.gov/greenpower). The White House Council on Environmental Quality document titled *Federal Greenhouse Gas Accounting and Reporting Guidance*, October 6, 2010 and the associated document titled *Federal Greenhouse Gas Accounting and Reporting Guidance Technical Support Document* both provide similar guidance on reducing emissions through the purchase of renewable electricity in the form of RECs.

Selecting the appropriate renewable electricity products to purchase and appropriately accounting for potential reductions in air emissions can be complex. Further guidance on purchasing renewable electricity (including RECs) and quantifying air emission reductions from those purchases can be found in the above-noted resources.

The methodology encourages reduction of air emissions through onsite generation or use of energy from renewable resources and use of biodiesel (E-2A) prior to considering air emission reductions through voluntary purchase of renewable electricity or RECs (E-2B and E-2C).

This prioritization is intended to establish a primary focus on practices that directly reduce emissions associated with a remedy, including energy efficiency measures, engine retrofits, and emissions control technologies.

EXHIBIT 2.3 – DEFINING GLOBAL WARMING POTENTIAL

Different GHGs have different residence times and different effectiveness in absorbing and emitting back to Earth the infrared radiation that results in temperature increases. The concept of global warming potential (GWP) accounts for these differences and quantifies the contribution of a particular GHG to global warming in terms of a reference gas. Carbon dioxide is typically chosen as the reference gas, and GWP is measured in carbon dioxide equivalents (CO_2e). The GWP of common GHGs used for this methodology are as follows:

GHG	**GWP (CO_2e)**
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Carbon tetrachloride (CCl_4)	1,400
1,1,1-Trichloroethane (CH_3CCl_3, methyl chloroform)	146
Bromomethane (CH_3Br)	5
Chloromethane (CH_3Cl)	13
Methylene chloride (CH_2Cl_2)	8.7
CFC-11 (CCl_3F, Freon-11)	3,800

Intergovernmental Panel on Climate Change Assessment Report 4, Chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing (www.ipcc.ch), which is referenced by U.S. EPA at www.epa.gov/climatechange.

Example: the emission of 1 pound of methane has an equivalent warming effectiveness as the emission of 21 pounds of carbon dioxide.

Many other compounds, particularly chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and other perfluorinated compounds, are strong GHGs but are not typically associated with environmental cleanups. If these compounds are identified in the soil, groundwater, or sediments of a site, it may be important to include air emissions of the compounds in the GHG metric. Information pertaining to their global warming potential can be found in the Intergovernmental Panel on Climate Change Assessment Report 4, Chapter 2, *Changes in Atmospheric Constituents and in Radiative Forcing* (www.ipcc.ch).

EXHIBIT 3.1 – EXAMPLE REMEDY INFORMATION TO GATHER FOR STEP 2

Excavation and Disposal
- Volume of soil to be excavated
- Percentages disposed of as hazardous waste and non-hazardous waste
- Methods of transportation available
- Facilities for disposal
- Associated sampling and analysis
- Material used for backfill
- Need for dewatering and discharge point for water

Pump and Treat (P&T) and Soil Vapor Extraction (SVE)
- Number of wells, trenches, etc. and distance to process area
- Extraction rates
- Expected influent concentrations
- Treatment processes
- Discharge location (for P&T)
- Frequency of operator visits

In situ Remedies Involving Nutrient or Reagent Injections
- Method of injection (direct-push, injection wells, delivery trenches)
- Aquifer volume to be treated
- Number of injection points
- Number of injections
- Nutrient demand for calculating mass of injected materials

Phytoremediation
- Number and types of trees
- Method of planting
- Fertilizer, pesticide, watering, and fencing needs

In situ Thermal Remediation
- Method of heating
- Volume of treatment area
- Type of contaminant and required heating temperature
- Size of vapor control system
- Method of treating off-gas
- Pounds of contaminants to be removed

Soil Amendments
- Amendment material
- Volume of soil to be treated
- Method of adding amendment
- Amendment demand

Monitoring for Various Remedy Types
- Process monitoring
- Long-term monitoring
- Performance monitoring

EXHIBIT 3.2 – SCREENING APPROACH

The screening approach uses user-specified limits, two streamlined comparison approaches, and professional judgment to determine items and activities that are included in the footprint analysis. Two types of user-specified limits are as follows:

- Limit based on a specified percentage of the maximum contributor to a particular metric
- Limit based on a specified magnitude for a particular metric

Based on professional judgment, an item or activity that is expected to contribute less than either of the limits can be excluded from the analysis with an appropriate level of documentation. These limits are applied to the following categories:

- Refined materials
- Unrefined materials
- Non-hazardous waste
- Hazardous waste
- Each onsite water resource
- Onsite NOx, SOx, PM10 emissions
- Onsite HAP emissions
- Total energy use*

** The total energy use category is assumed to be generally representative of the total emissions for CO_2e and other air pollutants.*

Comparing items for the materials, waste, and water metrics to the two limits noted above is reasonably straightforward. Comparison of emissions and energy use is more complicated. Streamlined approaches are provided below for comparing 1) various onsite sources of NOx, SOx, and PM10 emissions and 2) various contributions to total energy use. An example is provided for developing the two screening limits noted above. The screening approach is also demonstrated in the footprint reduction scenarios in Appendix C.

Streamlined Comparison of Onsite NOx, SOx, and PM10 Emissions

The onsite NOx, SOx, and PM10 emissions are generally linked to onsite fuel combustion; therefore, determining the largest contributor and gauging other contributions relative to the set limits is based on use of various fuels. The table to the right shows the approximate amounts of fuel that will result in generally equivalent NOx, SOx, and PM10 emissions. For purposes of this screening process, assume that combustion of the volumes of fuel noted in the table to the right results in emissions of 0.2 pounds (lbs) of NOx + SOx + PM10. However, do not use this assumption for final footprint presentation.

Approximate Equivalencies for NOx, SOx, and PM10 from On-Site Fuel Combustion	
Diesel combustion	1 gallon (gal)
Gasoline combustion	1 gal
Natural gas combustion	10 ccf

ccf = 100 cubic feet, which contains a similar amount of energy as 1 therm
Note: The sum of the NOx, SOx, and PM10 emissions from the combustion of the indicated amounts of the fuels are generally comparable. This table is not intended to suggest that they are equal. This table is based on the information provided elsewhere in this document.

FOR SCREENING COMPARISON PURPOSES ONLY
DO NOT USE THESE APPROXIMATE EQUIVALENCIES FOR FINAL FOOTPRINT PRESENTATION

EXHIBIT 3.2 – SCREENING APPROACH (continued)

Streamlined Comparison for Total Energy Use

Contributions to the total energy use metric are based on a variety of factors, including electricity use, fuel combustion, and materials manufacturing. The following table provides approximate amounts of energy-related items, materials, or services that result in generally equivalent amounts of energy use. The table also defines an "energy screening unit". As shown in the example below, the energy screening units and values in this table can be used to compare the magnitudes of various contributors to the total energy footprint to determine those contributors that exceed screening limits and will be included in the footprint analysis.

Item	Physical Unit	# of Physical Units in One Screening Unit	# of Screening Units in One Physical Unit
Electricity use	kWh	1	1
Continuous electric motor operation	Horsepower (HP)-hr	1	1
Natural gas use	ccf or therm	0.1	10
Diesel or gasoline use	Gal	0.1	10
Onsite heavy equipment use	HP-hr	2	0.5
Excavation	Cubic yard	5	0.2
Trenching and pipe installation	Linear foot	10	0.1
Well installation (including drill rig)	Vertical foot	0.02	50
Personnel transport	Mile	2	0.5
Materials or waste transportation	Mile	0.5	2
Materials or waste transportation	Ton-mile	3	0.33
Refined materials use	lb	1	1
Unrefined materials use	Ton	1	1
Water discharged to the sanitary sewer	1,000 Gal	1	1
Waste disposal (drums)	Drum	10	0.1
Waste disposal (bulk)	Ton	0.1	10
Laboratory analysis	$	1	1

Note: The total energy uses associated with a screening unit is generally between 0.01 and 0.02 MMbtus (with some exceptions) based on information provided elsewhere in this document. The values are only intended to be used to assist with screening, not for final footprint presentation.

Example: A remedy involves the following:

Item	Number of Screening Units
10,000 lbs of refined materials	10,000 × **1** = 10,000
5,000 ton-miles of materials transport	5,000 × **0.33** = 1,650
250,000 kWh of electricity	250,000 × **1** = 250,000

The numbers in bold in the table to the left are taken from the far right-hand column of the above table. The use of a screening unit facilitates comparison between various items that involve energy use. For example, 1,650 is a small fraction of 250,000 (<1%), indicating that materials transport can be omitted from the footprint analysis.

EXHIBIT 3.2 – SCREENING APPROACH (continued)

Example Development of Screening Limits

The table below demonstrates the development of screening limits for the screening categories presented at the beginning of this exhibit. The user identifies the "largest contributor" and the magnitude of the contribution ("largest contribution") for each of the 10 categories (rows). Based on the level of detail and accuracy sought in the footprint analysis, the user also specifies for each category 1) the "selected % of largest contributor" to calculate the "percent-based limit" and 2) the "selected magnitude-based limit". The "applicable screening limit" is the larger of the "percent-based limit" and the "selected magnitude-based limit". A simplified *in situ* bioremediation remedy is used for example purposes in this table.

Once the "applicable screening limits" are determined, various items in each screening category would then be compared to "applicable screening limit" for that category (comparison not shown in this example). Items in each category that are expected to be less than the limit by professional judgment are excluded from the footprint analysis. Refer to the footprint reduction scenarios in Appendix C for detailed application of the screening approach.

Category	Unit	Largest Contributor	Largest Contribution	Selected % of Largest Contributor	Percent-based Limit	Selected Magnitude-based Limit	Applicable Screening Limit
Refined Materials	tons	Vegetable oil	150	1%	1.5	0.5	**1.5**
Unrefined Materials	tons	Sand for sand pack	1.5	1%	0.015	0.5	**0.5**
Non-hazardous Waste	tons	Drill cuttings	6	1%	0.06	0.5	**0.5**
Hazardous Waste	tons	None	0	1%	0	0.5	**0.5**
Public water	gals	Water for drilling	500	1%	0.05	1,000	**1,000**
Shallow groundwater (offsite disposal)	gals	Pump test	1,000,000	1%	10,000	1,000	**10,000**
Shallow groundwater (reinjection)	gals	Nutrient blending and injection	3,000,000	1%	30,000	1,000	**30,000**
Onsite NOx, SOx, PM10 emissions	lbs	Drilling	120	1%	1.2	1	**1.2**
Onsite HAP emissions	lbs	Drilling	<1	1%	0.01	1	**1**
Total Energy use	Screening Units*	Vegetable oil	300,000	1%	3,000	1	**3,000**

** Energy screening units defined above.*

EXHIBIT 3.3 – DENSITIES OF COMMON MATERIALS

The following table provides approximate densities of common materials that can be used to convert a known volume of a material into a mass of that material for documenting material use by mass. This information has been provided to help streamline the process of gathering information for the materials metric.

Material	Density
Refined	
Cement	94 lbs/ft^3
GAC	30 lbs/ft^3
HDPE	59.6 lbs/ft^3
Lime (hydrated)	30 lbs/ft^3
PVC	87.36 lbs/ft^3
Steel	490 lbs/ft^3
Unrefined	
Asphalt	1.95 tons/cy
Concrete	1.95 tons/cy
Compacted clay	1.5 tons/cy
Mulch/compost	0.4 tons/cy
Sand, gravel, soil	1.5 tons/cy

ft^3 = cubic foot
tons = short tons (2,000 pounds)
cy = cubic yard

REFERENCES:
Cement – Portland Cement Association (www.cement.org)
GAC – consistent with various GAC vendor specifications
HDPE – consistent with HDPE pipe made to ASTM International standards
Lime – consistent with National Lime Association fact sheet values for hydrated lime
PVC – consistent with PVC pipe made to ASTM International standards
Steel – various materials handbooks (specific gravity of 7.8)
Asphalt – Nation Asphalt Pavement Association
Concrete – Portland Cement Association (www.cement.org)
Compacted clay, sand, gravel and soil – generally accepted engineering assumption
Mulch/compost – generally consistent with purchased bagged mulch

Example conversion from volume to mass

10 *cubic yards of concrete* × 1.95 *tons per cubic yard* = 19.5 *tons of concrete*

EXHIBIT 3.4 – APPROXIMATE MATERIAL AND WATER CONTENT OF AQUEOUS CHEMICAL SOLUTIONS

Environmental remedies commonly involve the use of chemical solutions, and in some cases a substantial portion of the solution may be water. For the purpose of this methodology, the water use in chemical solution preparation is considered to be of equal quality to public water. Public water is not considered part of the materials metrics but is part of the water metrics and is also used in the calculation of the energy and air footprints. In general, for chemical solutions, the mass of the chemical itself (not the full solution) is used for determining the mass of the refined material. The following table lists common chemical solutions, the specific gravity of the solution, the solution density, and the mass of the chemical per gallon of solution. The table is intended to help determine the mass of a chemical present in the solution for the purpose of calculating the materials metrics and to help determine the amount of water present in the solution for the further purpose of calculating the water, energy, and air metrics.

Chemical Solution	Specific Gravity	Density of Solution (lbs/gal)	Mass of Chemical per Gallon of Solution (lbs/gal)	Volume of Water per Gallon of Solution (gal/gal)
Hydrochloric acid (37%)	1.19	9.92	3.67	0.75
Sulfuric acid (98%)	1.84	15.3	15.0	0.04
Sodium hydroxide (20%)	1.22	10.2	2.03	0.98
Sodium hydroxide (50%)	1.53	12.8	6.40	0.77
Hydrogen peroxide (30%)	1.11	9.26	2.78	0.78
Hydrogen peroxide (50%)	1.19	9.92	4.96	0.59
Ferric chloride (37%)	1.4	11.7	4.33	0.88
Sequestering agent (assume 40% solution)	1.2	10.0	4.00	0.72

Information obtained from Material Data Safety Sheets for these chemical solutions

Example conversion from gallons of solution to pounds of chemical

4,000 *gallons of* 20% *NaOH solution* × 2.03 *pounds per gallon* = ~800 *pounds of NaOH*

NaOH = sodium hydroxide

Equation for determining water content of an aqueous solution

$$\text{Water content (gallons)} = \text{Volume of solution (gallons)} \times \text{Specific gravity (unitless)} \times \text{(100 - \% concentration) (\%)}$$

Example: 10,000 gallons of 20 percent Sodium Hydroxide (Specific gravity = 1.22)

$$9{,}760 \text{ gallons} = 10{,}000 \text{ gallons} \times 1.22 \times 80\%$$

EXHIBIT 3.5 – APPROXIMATE MATERIALS USE FOR PIPING AND WIRING RUNS

Some remedies include long runs of piping and wiring to connect extraction wells to a treatment system. The following table can be used to estimate the mass of refined materials involved in long runs of plastic piping and wiring/conduit based on an approximate flow rate carried in the pipes. Values for PVC or HDPE pipe are provided. This information has been provided to help streamline the process of gathering information for the materials metric.

Pipe Diameter	Approx. Flow (gpm)	SDR 11 HDPE Pipe (lbs/foot)	SCH 80 PVC Pipe (lbs/foot)	Estimated Wire and Conduit (lbs/foot)
1-inch	5	0.196	0.405	N/A
2-inch	25	0.639	0.936	1
3-inch	50	1.387	1.911	1.5
4-inch	90	2.294	2.793	2
6-inch	200	4.971	5.327	2.5
8-inch	350	8.425	8.089	3

REFERENCES/METHODOLOGY:
Pipe size is based on approximate flow velocity of 2 to 2.5 feet per second. Pipe weight is based on pipe made to ASTM International standards. Conduit values are general estimates based on one PVC or HDPE power cable conduit and one PVC or HDPE control cable conduit that are sized appropriately for the necessary cable/wire conductors. Wire values are general estimates based on four conductors (including a ground) appropriately sized to provide power to a submersible pump providing the specified flow and the associated control cables.

Example Application

1,000 *feet of* 6-*inch HDPE pipe* × 4.971 *pounds per foot* = ~5,000 *pounds of HDPE*

EXHIBIT 3.6 – APPROXIMATE MATERIALS USE FOR WELL INSTALLATION

Wells are a common element of groundwater remedies and can be complex from a materials inventory perspective. The following table lists approximate materials use for well construction on a per foot basis of well depth that may be helpful in quantifying materials use for the materials metrics.

Well Diameter	Pounds per Foot of Well Depth						
	SCH 40 PVC Casing	**Steel Casing**	**Stainless Steel Screen**	**Grout for Annulus**	**Grout to Abandon Well**	**Sand for Annulus***	**Drill Cuttings for Disposal**
2-inch	0.681	3.65	1.5	13	2	19	22
4-inch	2.012	10.79	2.9	19	6	29	39
6-inch	3.537	18.97	4.8	25	14	39	61
8-inch	5.323	28.55	7.0	32	25	48	87
10-inch	7.547	40.48	8.9	38	40	58	119
12-inch	9.979	49.56	13.6	45	57	68	155

REFERENCES/METHODOLOGY: *Grout and sand use assumes annulus around casing has a diameter that is 4 inches larger than the casing. Grout values are for neat cement assuming 6 gallons of water is mixed with 94 pounds of neat cement with a blended density of 15 pounds per gallon (generally typical of engineering specifications). Pipe values based on typical of pipe specifications made to ASTM International standards. Screen values are typical of manufacturer specifications for a 250-foot deep well. Actual values may vary depending on the specific application. Drill cutting volume does not include drilling mud for mud rotary drilling*

EXHIBIT 3.7 – APPROXIMATE MATERIALS USE FOR PROCESS EQUIPMENT AND BUILDING CONSTRUCTION

The following approximate rules of thumb have been established to assist in estimating materials use for complex items in an attempt to streamline the level of effort to conduct a footprint analysis. Actual materials use will vary, and use of site-specific values for these items is encouraged when these items are believed to be significant contributors to the footprint.

Process Equipment and Controls

Permanent process equipment, piping, valves, and controls at a site can be comprised of many different types of materials, and therefore can be complex from a materials inventory perspective. For simplicity, this methodology suggests using the weight of the primary components (for example, the weight of steel in an air stripper) and adding 25 percent to this weight as a general rule of thumb to obtain a reasonable approximation of the refined materials associated with the piping, pumps, and controls for an overall system. The weight of process equipment is typically readily available from a vendor web site.

Building Construction

Building construction is another type of materials use that can be difficult to inventory, especially during the design stage if building vendors have not been contacted. Absent other information, the following general rules of thumb can be used for estimating materials use associated with steel building construction.

- Approximately 1 pound of steel per cubic foot of building space
- Approximately 1.3 pounds of steel per square foot of 6-inch slab
- Approximately 72.5 pounds of concrete per square foot of 6-inch slab

EXHIBIT 3.8 – APPROXIMATE CONTENT OF CONCRETE, ASPHALT, AND STEEL

Concrete, asphalt, and steel are construction materials that are commonly used in environmental cleanups and can represent a substantial portion of the materials used. General information about these materials that is relevant to the footprint methodology, such as the typical proportions of the components in concrete and asphalt, and the typical recycled content in steel, is provided in the following table and discussed below. *Note that if specific information is available from the manufacturer on the content of the material used, the specific information should be used instead of the information provided below.*

Material	Density (lbs/ft^3)	Pounds per Cubic Foot of Material			
		Refined Material		Unrefined Material	
		Total	Recycled/Reused Content	Total	Recycled/Reused Content
Concrete	145	22	0	115	0
Fly ash concrete	145	22	4	115	0
Asphalt	145	7	1.4	138	28
Steel	490	490	270	0	0

Concrete – Mixed concrete (by volume) is typically 0.5 parts water, 1 part cement (a refined material), and 4.5 parts aggregate (an unrefined material). Water is covered separately under the water footprint and is not considered a material in this methodology. Using the densities in Exhibit 3.3, concrete is 15 percent refined material and 79 percent unrefined material by weight, with the remaining 6percent attributed to the water. The density of concrete is approximately 145 pounds per cubic feet. Therefore, for every cubic foot of concrete, approximately 22 pounds is refined material, 115 pounds is unrefined material, and the remainder is water. For many applications, fly ash can be used as an admixture to replace up to 20 percent of the cement component. Therefore, for fly ash concrete, 20 percent of the refined material (4 pounds) can be considered recycled/reused.

REFERENCES: Values for proportions by volume obtained from Portland Cement Association (www.cement.org) and converted to mass using densities provided from same source. Information on fly ash from the Federal Highways Administration Materials Group: http://www.fhwa.dot.gov/infrastructure/materialsgrp/flyash.htm.

Asphalt – Asphalt is approximately 5 percent asphalt cement (a refined material) and 95 percent aggregate (unrefined) by weight. Therefore, for the purpose of this methodology, asphalt is assumed to be 5 percent refined material and 95 percent unrefined material. Asphalt has an approximate compacted density of 145 pounds per cubic foot. Therefore, for every cubic foot of asphalt, approximately 7 pounds is refined material and 138 pounds is unrefined material. Asphalt pavement typically contains up to as much as 20 percent recycled material. For the purpose of this methodology, this recycled content is assumed to be evenly distributed among the refined and unrefined portions. Therefore, for one cubic foot of compacted asphalt, approximately 1.4 pounds of the refined material is from recycled material and approximately 28 pounds of the unrefined material is from recycled material.

REFERENCES: National Asphalt Pavement Association (www.hotmix.org).

Steel – Recycling is an inherent part of the steel industry, and the recycled content of steel varies depending on the furnace technology, which is somewhat specific to the type of product produced. The recycled content for steel produced from a blast oxygen furnace is approximately 30 percent and the recycled content for steel produced from an electric arc furnace is approximately 80 percent. For the purpose of this methodology, the recycled content of steel is assumed to be the average (approximately 55 percent).

REFERENCES: Steel Takes LEED® with Recycled Content, American Iron and Steel Institute, November 2009

EXHIBIT 3.9 – STORMWATER DIVERSION

Significant diversions of stormwater can be considered a “use” because it results in transferring (using) water from one resource and adding (discharging) it to another. For example, a large cap might divert stormwater to a local surface water body rather than allowing it to recharge an aquifer. This diversion has two effects. First, it reduces the recharge to the aquifer. The significance of this effect will vary from site to site. If the site is in the recharge area of a drinking water aquifer, then diversion of precipitation would affect replenishment of a potential drinking water resource. By contrast, a site might be located along a creek such that infiltrating water would migrate only a short distance in the subsurface before discharging to the creek. Preventing the water from recharging the aquifer in this latter case will not significantly affect the local groundwater resource. Second, diversion of stormwater results in higher peak flows in the receiving stream. This may have an effect on soil erosion or local ecosystems, potentially affecting one of the other core elements of green remediation. It could also increase loading to a storm sewer or combined sewer infrastructure. The significance of stormwater diversion can be conveyed by describing the quantity and quality of the water diverted and the fate of the water. The quality of the water diverted is considered the same quality as if it had naturally infiltrated and recharged the aquifer.

Diverted stormwater does not necessarily need to be discharged to surface water. Depending on the facility, the surrounding environment, and the local land uses, the diverted stormwater may be collected and used for beneficial purposes such as irrigation. The use of collected stormwater could then displace the need to use other potentially valuable local water resources for these purposes. The collected stormwater could also be diverted to facilitate infiltration into a different area of the same aquifer.

Calculating the amount of stormwater diverted depends on the percentage of precipitation water that typically infiltrates. This is dependent on the surface soil, vegetation, slope, and other factors. Unless site-specific calculations have been made to estimate changes in infiltration, the maximum amount of water diverted can be used. This conservative approach assumes that all water naturally infiltrates into the subsurface and the cap or remedy involves diversion of all of this water. Using these conditions, the amount of water diverted annually is the average precipitation multiplied by the area of water diverted according to the following equation:

Annual water diverted (gallons/year)	=	Annual precipitation (inches/year)	×	Area (acres)	×	27,157 (gallons/acre-inches)

Total water diverted as a result of the remedy would be the annual water diverted multiplied by the number of years diversion would occur.

EXHIBIT 3.10A – GENERAL CHECKLIST FOR TYPICAL ITEMS TO CONSIDER IN A FOOTPRINT ASSOCIATED WITH CONSTRUCTION OF A REMEDY

This exhibit applies to the construction of remedies such as P&T, SVE, multi-phase extraction, or other remedies that involve installing wells, laying pipe, erecting a building, and site grading (e.g., *in situ* bioremediation remedies that involve permanent water supply wells and/or injection wells). This checklist is intended to serve as an aid in identifying relevant components and is not necessarily an exhaustive list. Other items related to the remedy, but not included below, should also be included if they are believed to contribute significantly to the remedy footprint.

Transportation	Equipment Use	Quantities of Materials and Offsite Services
• Distance between site and - Office of primary consultant - Offices of primary contractors - Manufacturers of various construction materials - Non-hazardous waste landfill - Hazardous waste landfill • Types of vehicles or modes of transportation for personnel, equipment, material, and waste transport • Quantity of material or waste transported per trip • Type of fuel used in vehicles • Material or waste transport that requires an empty return trip after delivery	• Equipment type, horsepower rating, and total hours of operation for - Drilling wells - Laying extraction and injection network piping - Trenching - Clearing and grubbing - Excavation and backfilling - Grading - Dredging - Erecting buildings - Dewatering - Onsite electricity generation - Providing compressed air • Major electrical equipment not running off of generators - Pumps - Blowers - Mixers	• Materials* • Services - Waste disposal* - Offsite water treatment** - Laboratory analysis ** SEE MATERIALS AND WASTE SECTION* *** SEE WATER SECTION*

EXHIBIT 3.10B – GENERAL CHECKLIST FOR TYPICAL ITEMS TO CONSIDER IN A FOOTPRINT ASSOCIATED WITH REMEDY OPERATION

This exhibit applies to the operation of remedies such as P&T, air sparging (AS)/SVE, multi-phase extraction, or other remedies that involve long-term operation (e.g., *in situ* bioremediation or monitored natural attenuation). This checklist is intended to serve as an aid in identifying relevant components and is not necessarily an exhaustive list. Other items related to the remedy, but not specified below, should also be included if they are believed to contribute significantly to the remedy footprint.

Transportation	Equipment Type, Power Rating, Hours of Operation	Quantities of Materials and Services
• Distance between site and - Office of primary consultant - Office of primary contractors - Manufacturers of various construction materials - Non-hazardous waste landfill - Hazardous waste landfill • Types of vehicles or modes of transportation for personnel, equipment, material, and waste transport • Quantity of material or waste transported per trip • Type of fuel used in vehicles • Material or waste transport that requires an empty return trip after delivery	• Electrical equipment - Extraction pumps - Transfer pumps - Chemical feed pumps - Blowers - Air compressors for pneumatic equipment and air sparging - GAC pre-heaters - Mixers - Ozone generators - Subsurface electric heating - Electric building heat - Building lighting - Building ventilation - Catalytic oxidizers • Gasoline, diesel, and biofuel equipment - Direct-push rigs for chemical injection - Other heavy equipment - Generators - Fuel-powered pumps and compressors - Subsurface heating - Major landscaping - Vehicles for onsite transportation • Natural gas equipment - Building heat - Process heaters - Generators - Thermal oxidizers - Subsurface steam heating - Boilers	• Materials* • Services - Waste disposal* - Offsite water treatment** - Laboratory analysis ** SEE MATERIALS AND WASTE SECTION* *** SEE WATER SECTION* **Onsite Emissions and Reductions** • Landfill gas emissions • Air stripper or SVE off-gas • Emissions from large open excavations • Planted trees and biomass

EXHIBIT 3.11A – QUANTIFYING FUEL USE FOR PERSONNEL TRANSPORTATION

The following table can be used to organize and calculate fuel use for personnel transportation. Two different calculation options are provided in decreasing order of known information. It is preferable to use the calculation Option 1 where possible. Option 2 can be used if the information is not available for Option 1.

Activity	Input #1		Input #2		Fuel Use
Option 1 – Known Number of Events and Known Fuel Use per Trip					
	# of events	×	**Fuel use per event**	=	**Fuel Use (gals)**
Option 2 – Known Distance and Vehicle Type					
	Distance traveled	÷	**Fuel efficiency (mpg or pmpg)**	=	**Fuel Use (gals)**

Notes:
"Event" can refer to a specific trip, time period, or broader activity for which fuel use is known.
"mpg" = miles per gallon *"pmpg" = passenger miles per gallon*

If the distance of travel is not known, it should be estimated based on professional judgment (e.g., the approximate distance to the nearest suburban or metropolitan area where a consultant or contractor may be located). If the vehicle type is not known, it can be assumed based on professional judgment and applying the fuel efficiencies from the following table.

Vehicle Type	Fuel Efficiency (mpg or pmpg)	
	Gasoline	**Diesel or B20**
Airplane (pmpg)	N/A	45
Bus (pmpg)	N/A	96
Passenger car (mpg)	24	28
Light-duty truck (mpg)	17	20
Light-duty truck with trailer or heavy load (mpg)	N/A	6
Train (pmpg)	N/A	59

- *Airplane/jet fuel calculated as diesel for simplicity and due to similarities between kerosene and diesel*
- *Gasoline car and truck efficiencies and diesel car, truck, airplane, bus, and train efficiencies from converting average CO2 emissions for each mode of transportation using values of 22.3 pounds of CO2 per gallon of diesel and 19.4 pounds of CO2 per gallon of gasoline. Average CO2 emissions are from Climate Leaders from Commuting, Business Travel and Product Transport to diesel use assuming Climate Leaders. CO2 emissions per gallon of fuel are from Climate Leaders Direct Emissions from Mobile Combustion Sources.*

EXHIBIT 3.11B – QUANTIFYING FUEL USE FOR HEAVY EQUIPMENT USE

The following table can be used to organize and calculate fuel use associated with heavy equipment use. Two different calculation options are provided in decreasing order of known information. It is preferable to use the calculation Option 1 where possible. Option 2 can be used if the information is not available for Option 1.

Activity	Input #1				Input #2				Fuel Use
Option 1 – Known Fuel Use or Equipment Owner Estimated Fuel Use									
	Event			×	**Fuel use per event**			=	**Fuel Use (gals)**
Option 2 – Known or Estimated Horsepower Rating, Fuel Type, and Hours of Operation									
	HP	×	**Hours**	×	**BSFC**	×	**PLF**	=	**Fuel Use (gals)**

Notes:
Option 1 – "Event" can refer to a specific task, time period, or entire scope of work. Fuel use per event is assumed to be a reasonable estimate by the equipment owner based on fuel use for a similar, but previously executed event.
Option 2 – "HP" = horsepower rating of equipment "Hours" = hours of operation
"BSFC" brake-specific fuel capacity "PLF"= partial load factor

The assumed BSFC for diesel and biodiesel is 0.050 gallons per HP-hr.
The assumed BSFC for gasoline is 0.056 gallons per HP-hr.

BSFC values are consistent with 7,000 British thermal units (Btu)/HP-hr (as used by EPA AP-42, Compilation of Air Pollutant Emission Factors, Chapter 3) and fuel higher heating values of 139,000 Btus for diesel and 124,000 Btus for gasoline (as used by Climate Leaders).

The following table provides HP and PLF values for common types of equipment.

Equipment Type	HP	PLF	Production Rate
Medium/large excavator (2 CY bucket)	175	0.75	720 cy/day
Medium loader (3 CY bucket)	200	0.75	1200 cy/day
Medium dozer, 100+ foot haul	200	0.75	500 cy/day
Direct-push rig for soil sampling	60	0.75	250 ft/day
Hollow-stem auger for well installation	150	0.75	100 ft/day
Air or mud rotary for well installation	500	0.75	200 ft/day

Production rates and equipment sizes are generally consistent with production rates reported RS Means Building Construction Cost Data and are representative averages. Actual production rates may vary due to a number of factors including site conditions and operator experience. Site teams are encouraged to use more site-specific production rates if they can be documented. Absent other information a PLF of 0.75 is a reasonable estimate for heavy equipment. The PLF may decrease if work is inefficient for a variety of reasons. Many of the same inefficiencies would also reduce the production rate. Therefore, if the assumed production rate is lower, it is appropriate for the PLF to be lowered by a commensurate amount resulting in no net change in fuel use.

EXHIBIT 3.11C – QUANTIFYING FUEL USE FOR EQUIPMENT, MATERIALS, AND WASTE TRANSPORTATION

The following table can be used to organize and calculate fuel use for equipment, materials, and waste transportation. Two different calculation options are provided in decreasing order of known information. It is preferable to use Option 1. Option 2 can be used if information is not available for Option 1.

Activity	Input #1				Input #2		Fuel Use
Option 1 – Known Number of Events and Known Fuel Use per Trip							
	# of events			×	**Fuel use per event**	=	**Fuel Use (gals)**
Option 2a – Common Freight - Known Distance, Cargo Weight, and Vehicle Type							
	Distance traveled	×	**Weight (tons)**	×	**Fuel efficiency (gptm)**	=	**Fuel Use (gals)**
Option 2b – Specialty Freight Load or Empty Load by Truck – Known Distance							
	Distance			×	**Fuel efficiency (mpg)**	=	**Fuel Use (gals)**

Notes:
"Event" can refer to a specific trip, time period, or broader activity for which fuel use is known.
"gptm" = gallons per ton-mile *"mpg" = miles per gallon*

The distance for materials transport should be from the manufacturer, not just from the local distributor. If the distance of travel is not known, it should be estimated based on professional judgment considering the following examples: 1,000 miles for specialty items and hazardous waste transport, 500 miles for most materials, and 25 miles for borrow, fill, sand/gravel, asphalt, concrete, and non-hazardous waste transport. Empty return trips should be considered as appropriate. Fuel efficiencies reported in gallons per ton-mile (gptm) are assumed to include the empty return trip:

Vehicle Type	Fuel Efficiency	
	Units	**Value**
Truck (include separate empty return trip as appropriate)	mpg	6
Truck Common Freight (empty return trips included)	gptm	0.029
Train (empty return trips included)	gptm	0.0025
Barge (empty return trips included)	gptm	0.0047
Aircraft (empty return trips included)	gptm	0.15

- *Airplane/jet fuel calculated as diesel for simplicity and due to similarities between kerosene and diesel.*
- *Fuel efficiencies are obtained by from converting average CO_2 emissions reported in Climate Leaders: Commuting, Business Travel and Product Transport (EPA430-R-08-006) to diesel use.*
- *Provided fuel efficiencies are representative averages. Actual efficiencies may vary due to a number of factors. Site teams are encouraged to use more site-specific fuel efficiencies if those efficiencies can be documented.*

EXHIBIT 3.12 – ESTIMATING SIZES OF ELECTRICAL EQUIPMENT

Estimating Pump Size Based on Expected Flow Parameters

$$HP = \frac{QH}{3956} \times \frac{1}{\eta}$$

HP = horsepower
Q= flowrate (gpm)
H=total dynamic head (feet of water)
η=pump efficiency (absent other information, assume (70%)
3956 = conversion factor from ft-gpm to HP

Round HP to the next highest value of (0.5, 0.75, 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 30, 40, 50,…) to determine motor size

Estimating Blower Size Based on Expected Air Flow Requirements

$$HP = \frac{QH}{527} \times \frac{1}{\eta}$$

HP = horsepower
Q= flowrate (cfm)
H=total dynamic head (inches of water)
η=blower efficiency (absent other information, assume (55%)
527 = conversion factor from cfm-inches of water to HP

Round HP to the next highest value of (0.5, 0.75, 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 30, 40, 50,…) to determine motor size

Estimating Compressor Size Based on Compressed Air Requirements

Absent more specific information, based on a general rule of thumb, at 100 pounds per square inch (psi), assume approximately 3.6 standard cubic feet per minute (scfm) per HP.

$$HP = \frac{scfm}{3.6}$$

Off-gas Preheating

Absent more specific information, based on a general rule of thumb, assume approximately 0.003 kW of electricity demand per scfm of air flow.

$$kW = 0.003 \times scfm$$

Note: The above formulas are intended to provide approximate values for the purpose of estimating an energy footprint and are not intended to provide estimates for design purposes or financial forecasting. If more specific information is available, it should be used in place of these formulas.

EXHIBIT 3.13 – ESTIMATING ELECTRICITY USE FOR TYPICAL REMEDIATION COMPONENTS

During operation, electricity use can typically be determined by referring to electrical bills; however, during the early remedy design stages, estimating electrical use is not as straightforward. In addition, even if electrical bills are available during operation, it is helpful to estimate electricity use from all major remedial components. This exhibit provides general rules of thumb for estimating electricity power requirements.

Item	Calculation for Estimating Electricity Use
Small motors (< 1 HP) (e.g., for pumps, blowers, mixers)	$kWh = \frac{HP \times L_M}{\eta_m} \times 0.746 \times hours$ (η_m = 0.65, L = 80%)
Large motors (≥ 1HP) (e.g., for pumps, blowers, mixers)	$kWh = \frac{HP \times L_M}{\eta_m} \times 0.746 \times hours$ (η_m = 0.75, L = 80%)
Items with known electrical ratings (e.g., kW)	$kWh = kW \times hours$
Interpreting VFD settings	$kWh = \frac{HP \times L_V^{3}}{\eta_m \times \eta_v} \times 0.746 \times hours$

kW = kilowatts of electric power
kWh = kilowatt-hours of electricity
HP = horsepower
L_M = percent of motor full load
L_V = percent of VFD full load (or speed in Hertz divided by 60 Hertz)
η_m = motor efficiency (typically 60% for less than 1 HP to 85% for 15 HP or greater)
η_v = VFD efficiency (typically 75% for less 50% load to 93% for more than 90% load)
hours = hours of operation over time frame of project
0.746 = conversion of HP to kW
VFD = variable frequency drive

Note: The above formulas are intended to provide approximate values for the purpose of energy footprinting and are not intended to provide estimates for design purposes or financial forecasting. If more specific information is available, it should be used in place of these formulas.

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS

Suggested conversion factor values are provided to help convert various forms of fuel use, materials manufacturing, and offsite services into energy use and air pollution emissions. The conversion factors presented here are from a variety of sources, most of which are publicly available life cycle inventory databases, and there is an inherent degree of uncertainty in the values. First, the life cycle inventory data may not be able to accurately represent complex processes involved in manufacturing materials or providing offsite services. Second, the life cycle inventory data represent overall averages of a particular industry rather than the specific processes or resources used at a particular facility that may produce the majority of a particular material used in a project. Actual conversion factors may vary substantially due to a variety of factors including variations in manufacturing practices and in sources of energy used in the manufacturing process. Third, there are many materials or services that may be used in a remedy that are not included in the publicly available databases. More robust proprietary life cycle inventory databases exist and were consulted as part of developing this methodology, but proprietary conversion factors are not presented in the tables below due to restrictions in database licensing agreements. Project teams are encouraged to identify more specific conversion factors and to follow green procurement practices when practicable. The data quality and the sources of alternative conversion factors, whether obtained from life cycle inventory databases or developed independently by the project team, should be well documented as part of the footprint analysis.

			Suggested Conversion Factors						
			Parameters Used, Extracted, Emitted, or Generated						
Item or Service			**Energy**	**CO_2e**	**NOx**	**SOx**	**PM**	**HAPs**	**Reference**
			Used	**Emitted**	**Emitted**	**Emitted**	**Emitted**	**Emitted**	
		Unit	**MMBtu**	**lbs**	**lbs**	**lbs**	**lbs**	**lbs**	
Fuel Combustion									
Biodiesel use		gal	0.127	22.3	0.20	0	0.00099	NP	1
Diesel use		gal	0.139	22.5	0.17	0.0054	0.0034	0.0000052	2
Gasoline use		gal	0.124	19.6	0.11	0.0045	0.00054	0.000039	3
Landfill gas use		ccf CH_4	0.103	13.1	0.01	0.0000063	0.00076	0.0000084	4
Natural gas use		ccf	0.103	13.1	0.01	0.0000063	0.00076	0.0000084	4

See notes on last page of this exhibit for references.

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS (continued)

Item or Service Used			Suggested Conversion Factors – Parameters Used, Extracted, Emitted, or Generated: Energy	CO_2e	NOx	SOx	PM	HAPs	Reference
			Used	Emitted	Emitted	Emitted	Emitted	Emitted	
		Unit	MMBtu	lbs	lbs	lbs	lbs	lbs	
Construction Materials									
Cement		Dry-lb	0.0021	0.9	0.0018	0.00105	0.0000032	0.000029	5
Concrete		lb	0.00041	0.171	0.00035	0.00021	0.00001	0.00001	6
Gravel/sand/clay		lb	0.000028	0.0034	0.000017	0.000015	0.0000020	2.1E-10	7
HDPE		lb	0.031	1.9	0.0032	0.0041	0.00064	0.0000034	8
Photovoltaic system (installed)		Watt	0.034	4.5	0.015	0.032	0.00063	0.0000029	9
PVC		lb	0.022	2.6	0.0048	0.0076	0.0012	0.00047	10
Stainless Steel		lb	0.012	3.4	0.0075	0.012	0.0044	0.00014	11
Steel		lb	0.0044	1.1	0.0014	0.0017	0.00056	0.000067	12
Other refined construction materials		lb	0.014	1.98	0.0037	0.0053	0.0014	0.00014	13
Other unrefined construction materials		lb	0.000028	0.00335	0.000017	0.000015	0.000002	2.1E-10	14

See notes on last page of this exhibit for references.

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS (continued)

Item or Service Used			Suggested Conversion Factors						Reference
			Parameters Used, Extracted, Emitted, or Generated						
			Energy	CO_2e	NO x	SO x	PM	HAPs	
			Used	Emitted	Emitted	Emitted	Emitted	Emitted	
		Unit	MMBtu	lbs	lbs	lbs	lbs	lbs	
Treatment Materials and Chemicals									
Cheese Whey		lb	0.0025	0.031	0.000062	0.000033	0.000002	NP	15
Emulsified vegetable oil		lb	0.0077	3.44	0.0066	0.0019	0.000033	NP	16
Molasses		lb	0.0044	0.48	0.0011	0.00024	0.0000041	NP	17
Treatment materials and chemicals		lb	0.015	1.7	0.003	0.0065	0.00061	0.000016	18
Virgin GAC (coal based)		lb	0.015	8.5	0.014	0.034	0.00078	0.0012	19
Fuel Processing									
Biodiesel Produced		gal	0.029	-16.8	0.018	0.033	0.00082	NP	1
Diesel Produced		gal	0.019	2.7	0.0064	0.013	0.00034	0.00012	20
Gasoline Produced		gal	0.021	4.4	0.008	0.019	0.00052	0.00016	21
Natural Gas Produced		ccf	0.0052	2.2	0.0037	0.0046	0.000072	0.0000061	22
Public water		gal x 1000	0.0092	5	0.0097	0.0059	0.016	0.0000150	23

See notes on last page of this exhibit for references.

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS (continued)

Item or Service Used		Suggested Conversion Factors: Parameters Used, Extracted, Emitted, or Generated						Reference
		Energy	CO_2e	NOx	SOx	PM	HAPs	
		Used	Emitted	Emitted	Emitted	Emitted	Emitted	
	Unit	MMBtu	lbs	lbs	lbs	lbs	lbs	
Offsite Services								
Offsite waste water treatment	gal x 1000	0.015	4.4	0.016	0.015	NP	NP	24
Offsite Solid Waste Disposal	ton	0.16	25	0.14	0.075	0.4	0.0014	25
Offsite Haz. Waste Disposal	ton	0.18	27.5	0.154	0.0825	0.44	0.0015	26
Offsite Laboratory Analysis	$	0.0065	1	0.0048	0.0036	0.0004	0.00013	27
Electricity Generation	See Exhibit 3.17							
Resource Extraction for Electricity								
Coal extraction and processing	MWh	3.1	180	0.77	0.15	0.018	NP	28
Natural gas extraction and processing	MWh	1.6	270	0.18	13	0.0071	NP	29
Nuclear fuel extraction and processing	MWh	0.16	250	0.15	0.5	0.0015	NP	30
Oil extraction and processing	MWh	2.3	270	1.7	0.069	0.042	NP	31
Electricity Transmission	10 percent of electricity generation footprint for each parameter							32

MMBtu = millions of British thermal units
lbs = pounds
NP = not provided
gal = gallon
ccf = hundred cubic feet
MWh = megawatt-hour
ton = short ton (2,000 pounds)
See notes on last page of this exhibit for references.

EXHIBIT 3.14– SUGGESTED CONVERSION FACTORS (continued)

REFERENCES:

1. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus, NREL/SR-580-24089 UC Category 1503, U.S. Department of Agriculture and U.S. Department of Energy, May 1998. The CO2e emissions for "biodiesel produced" are negative because of the uptake of CO2 in the crops used to produce the fuels. This CO2 is emitted during fuel combustion and is reflected in the CO2e emissions for "biodiesel use".*
2. *Multiple sources*
    a. *Energy and CO_2e emissions from Direct Emissions from Mobile Combustion Sources, EPA430-K-08-004, U.S. EPA, May 2008.*
    b. *NOx, SOx, PM, and HAPs from NREL: SS_Transport, single unit truck, diesel powered.xls*
3. *Multiple sources*
    a. *Energy and CO_2e emissions from Direct Emissions from Mobile Combustion Sources, EPA430-K-08-004, U.S. EPA, May 2008.*
    b. *NOx, SOx, PM, and HAPs from NREL: SS_Transport, single unit truck, gasoline powered.xls*
4. *Multiple sources and simplifying assumption that emissions of natural gas reasonably represent combustion of methane component of landfill gas*
    a. *Energy and CO_2e emissions for compressed natural gas in heavy vehicles from Direct Emissions from Mobile Combustion Sources, EPA430-K-08-004, U.S. EPA, May 2008.*
    b. *NOx, SOx, PM, and HAPs from NREL: SS_Natural gas, combusted in industrial boiler.xls*
5. *EUROPA – Portland cement*
6. *Calculated from presented emission factors for public water, cement, and gravel/sand/clay by assuming typical concrete proportions by weight of 0.45:1:4 of water, cement, and sand/gravel*
7. *EUROPA – Gravel 2/32*
8. *EUROPA – Polyethylene high density granulate (PE-HD)*
9. *Life-Cycle Assessment of the 33 kW Photovoltaic System on the Dana Building at the University of Michigan Thin Film Laminates, Multi-Crystalline Modules, and Balance of System Components Sergio Pacca, Deepak Sivaraman and Gregory A. Keoleian Center for Sustainable Systems, University of Michigan Report No. CSS05-09, June 1, 2006*
10. *EUROPA - Suspension Polymerisation PVC*
11. *EUROPA – Stainless steel*
12. *EUROPA – Average of Steel hot rolled section, Steel hot rolled coil, Steel rebar*
13. *Averages of conversion factors for cement, HDPE, PVC, stainless steel, and steel*
14. *Same as conversion factors for gravel/sand/clay*
15. *Offset values for cheese whey obtained from the module for yellow cheese from Nielsen PH, Nielsen AM, Weidema BP, Dalgaard R and Halberg N (2003). LCA food data base. www.lcafood.dk, Andersen M and Jensen JD (2003). Marginale producenter af udvalgte basislevnedsmidler (in Danish) Udkast d. 5. februar 2003.*
16. *Values for rapeseed oil from Nielsen PH, Nielsen AM, Weidema BP, Dalgaard R and Halberg N (2003). LCA food data base. www.lcafood.dk. Landbrugets rådgivningscenter (2000). Tal fra Fodermiddeltabellen, Raport nr. 91. In Danish. Weidema BP (1999). System expansions to handle co-products of renewable materials. Presentation Summaries of the 7th LCA Scenarios Symposium SETAC-Europe, 1999. Pp. 45-48. pdf. Weidema B (2003). Market information in life cycle assessments. Technical report, Danish Environmental Protection Agency (Environmental Project no. 863).*
17. *Offset values for molasses obtained from the module for sugar from Nielsen PH, Nielsen AM, Weidema BP, Dalgaard R and Halberg N (2003). LCA food data base. www.lcafood.dk, Sugar Production based on Danisco Sugar Author: Per H. Nielsen July 2003*

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS (continued)

18. *Intended for any common treatment chemical in pure form including chemical oxidants and regenerated granular activated carbon. For chemical solutions, use only the mass of the chemical portion of the solution. Conversion factor is based on average value of conversion factors for the following seven common treatment chemicals as reported by Ecoinvent v2.1 from the Ecoinvent Centre for Life-Cycle Inventories, http://www.ecoinvent.ch/*
    - *Hydrochloric Acid (30 percent) – normalized to pure hydrochloric acid by dividing by database results by 0.3.*
    - *Sodium hydroxide (50 percent) – normalized to pure sodium hydroxide by dividing database results by 0.5.*
    - *Ferric chloride (iron III chloride)*
    - *Potassium permanganate*
    - *Sodium persulfate*
    - *Chlorine gas*
    - *Hydrogen peroxide (50 percent) – normalized to pure hydrogen peroxide by dividing database result by 0.5.*

    This averaging approach adds an additional layer of uncertainty to the conversion factors provided. For example, the range for energy is approximately 0.007 MMBtu to 0.025 MMBtu. The average (0.015 MMBtu) may overestimate the energy use value for some of the chemicals below by more than 100 percent and underestimate the energy us value for other chemicals by 40 percent. Additionally, some common treatment chemicals (e.g., sulfuric acid and ferrous sulfate) have energy footprints that are substantially outside the presented range and would not be accurately represented by these values. If an additional level of accuracy is preferred, readers of this methodology are encouraged to seek and document well referenced conversion factors as part of footprint analysis submittals.
19. *Based on "treatment materials and chemicals" above plus the result of combusting 1.86 pounds of bituminous coal. The additional coal combustion represents the coal that is combusted in the activation process. The 1.86 pounds of bituminous coal assumes that the activated carbon yield is approximately 35 percent of the coal used as a feedstock (e.g., 2.86 pounds of coal yields 1 pound of granular activated carbon), which is consistent with values reported in Pore Develop of Activated Carbon Prepared by Steam Activate Process, Kim SC and Hong, IK, Journal of Industrial and Engineering Chemistry, Vol. 4, No. 3, September 1998, 177-184.*
20. *EUROPA – diesel at refinery*
21. *EUROPA – gasoline at refinery*
22. *EUROPA – natural gas at consumer*
23. *EUROPA - Drinking water from surface water and drinking water from groundwater*
24. *Calculated based on Life-Cycle Energy and Emissions for Municipal Water and Wastewater Services: Case-Studies of Treatment Plants in US Malavika Tripathi, Center for Sustainable Systems, University of Michigan Report No. CSS07-06, April 17, 2007*
25. *EUROPA – Inert waste disposal*
26. *Values from EUROPA inert waste disposal plus an arbitrary additional 10 percent to account additional practices required of a hazardous waste disposal facility*
27. *Based on U.S. CARBON DIOXIDE EMISSIONS AND INTENSITIES OVER TIME: A DETAILED ACCOUNTING OF INDUSTRIES, GOVERNMENT AND HOUSEHOLDS, APRIL 2010. Approximately 1 lb of CO2 is emitted per dollar of gross domestic product. In the absence of other information, it is assumed that the laboratory also has an emission profile of approximately 1 lb of CO2 emitted per dollar of sample cost. Conversion factor estimates assume that 50 percent of this 1 lb of CO2 per dollar of sample cost results from electricity use (U.S. average fuel blend) and 50 percent is due to diesel use. A dollar of sample cost can then be converted into electricity and diesel use. The conversion factors result from this electricity and diesel use using the average electricity fuel blend for the United States and the diesel conversion factors provided here.*

EXHIBIT 3.14 – SUGGESTED CONVERSION FACTORS (continued)

28. *NREL – life cycle of electricity from bituminous coal minus the emissions from combusting coal*
29. *NREL – life cycle of electricity from natural gas minus the emissions from combusting natural gas*
30. *NREL – life cycle of electricity from nuclear*
31. *NREL – life cycle of electricity from residual oil minus the emissions from combusting residua oil*
32. *U.S. Dept. of Energy (GridWorks: Overview of the Electric Grid http://sites.energetics.com/gridworks/grid.html).*

NREL = National Renewable Energy Laboratory, Life Cycle Inventory, provided by the National Renewable Energy Laboratory and operated by Alliance for Sustainable Energy, LLC under contract to the U.S. Department of Energy. www.nrel.gov/lci

EUROPA = European Reference Life Cycle Database (ELCD core database), version II compiled under contract on behalf of the European Commission - DG Joint Research Centre - Institute for Environment and Sustainability with technical and scientific support by JRC-IES from early 2008 to early 2009. (http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm)

EXHIBIT 3.15 – ESTIMATING AIR POLLUTANT EMISSIONS FROM ONSITE SOURCES

Some treatment processes (such as air strippers used in P&T systems) and some remedies (such as SVE systems) involve discharge of process air to the atmosphere. It is common to include off-gas treatment to mitigate discharge of pollutants to the atmosphere, but in some cases off-gas treatment is not provided. The following equations provide assistance in calculating the emission rate in pounds per year from air strippers and SVE systems.

Estimating Air Emissions from Air Stripper Off-Gas

$$E = \frac{Q \times C \times 3.785 \times 1440 \times 365 \times 2.2 \times \eta_s \times (1-\eta_t)}{10^9}$$

E = Emission rate (pounds per year)
Q = process water flow rate (gpm)
C = concentration (µg/L)
η_s = air stripper efficiency (assume 100%)
η_t = off-gas treatment efficiency (varies)
3.785 = liters per gallon
1440 = minutes per day
365 = days per year
2.2 = pounds per kilogram

Estimating Air Emissions from SVE Systems

$$E = \frac{Q \times C \times 0.0283 \times 1440 \times 365 \times 2.2 \times (1-\eta_t)}{10^9}$$

E = Emission rate (pounds per year)
Q = process water flow rate (cfm)
C = concentration (µg/m^3)
0.0283 = cubic meters per cubic feet
1440 = minutes per day
365 = days per year
2.2 = pounds per kilogram
η_t = off-gas treatment efficiency (varies)

Estimating Air Emissions from Soil during Construction Activities

The 2002 EPA guidance document titled *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (OSWER 9355.4-24) provides a number of equations that can be used to estimate pollutant emissions from soil and dust generation from construction activities. Dust generation can be a significant source of PM10 emissions.

EXHIBIT 3.16 – ESTIMATING CARBON STORED IN PLANTED TREES

<u>*Carbon Stored in Planted Trees*</u>

$$C_S = e^{-2.2+2.4\ln(bhd)} \times (1 + e^{(-1.63+.0.74/bhd)}) \times 0.46 \times 1.69$$

C_s = carbon dioxide stored

bhd = breast-height diameter of tree in (cm), assume 1 cm/yr growth rate for up to 40 years and a slower rate thereafter

Values represent average parameters for willow, poplar, oak, birch, and cypress trees

REFERENCES:

Biomass calculated based on equations from Jenkins, Jennifer C.; Chojnacky, David C.; Heath, Linda S.; Birdsey, Richard A., National scale biomass estimators for United States tree species, Forest Science. 49: 12-35, 2003

Willow - http://na.fs.fed.us/pubs/silvics_manual/volume_2/salix/nigra.htm
species group (aa) according to Jenkins 2003

Bald Cypress - http://na.fs.fed.us/pubs/silvics_manual/Volume_1/taxodium/distichum.htm
species group (cl) according to Jenkins 2003

Poplar - http://na.fs.fed.us/pubs/silvics_manual/volume_2/liriodendron/tulipifera.htm
species group (aa) according to Jenkins 2003

River Birch - http://na.fs.fed.us/pubs/silvics_manual/volume_2/betula/nigra.htm
species group (mb) according to Jenkins 2003

Water Oak - http://na.fs.fed.us/pubs/silvics_manual/volume_2/quercus/nigra.htm
species group (mo) according to Jenkins 2003

EXHIBIT 3.17 – USING DATA FROM ELECTRIC SERVICE PROVIDERS TO DETERMINE FOOTPRINT CONVERSION FACTORS

The methodology involves the use of footprint conversion factors to convert electricity use into energy use and CO_2e, NOx, SOx, PM, and HAP emissions. When possible, the fuel blend from the electric service provider should be used to determine this information because it is likely more specific to the site and has likely been updated more recently than eGRID. This fuel blend may be referred to as a "generation mix" or provided on a "Power Content Label". If this information is not available, then the data for the state where the site is located can be obtained from the most recent year indicated in Table 5 of the state electricity profile obtained from www.eia.gov. Note that information for electricity service providers is available through eGRID (www.epa.gov/egrid) but should not be used for this methodology unless the information is consistent with that obtained directly from the electric service provider. Note that although renewable components of grid electricity are considered when establishing conversion factors for the electricity, the renewable components are not included in the renewable energy metrics (E-2). This is because renewables in the basic grid electricity is not considered a "voluntary" renewable. See Section 2.3 of the methodology for additional information.

Example Power Content from Electric Service Provider

Energy Source	**Percentage of Power Mix Delivered to Customers**
Natural gas	39%
Nuclear	22%
Renewable (30% total)	
- Geothermal (16%)	4.8%
- Biomass/waste (15%)	4.5%
- Hydroelectric (63%)	18.9%
- Wind (6%)	1.8%
- Solar (<1%)	<1%
Coal	8%
Other	1%

Converting Resource Mix to Footprint Conversion Factors and Portion of Energy Derived from Renewable Resources

Type	**% of Total Used**	**Energy (MMbtu/MWh)**		**CO_2e (lbs/MWh)**		**NOx (lbs/MWh)**		**SOx (lbs/MWh)**		**PM (lbs/MWh)**		**HAPs (lbs/MWh)**	
		Full Load	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**
Conventional Energy													
Coal		6.9		2200		6		15		.092		0.66	
Natural Gas		6.9		1300		1.1		0.0066		0.08		0.025	
Oil		6.9		1800		2.2		2.8		0.13		0.066	
Nuclear		6.9		0		0		0		0		0	
Renewable Energy													
Biomass		6.9		0	0	1.4		0.65		0.084		5.3E-6	0
Geothermal		6.9		0	0	0	0	0	0	0	0	0	0
Hydro		6.9		0	0	0	0	0	0	0	0	0	0
Solar		6.9		0	0	0	0	0	0	0	0	0	0
Wind		6.9		0	0	0	0	0	0	0	0	0	0
Total													

Full load emission values for each fuel type obtained from www.nrel.gov/lci.

All values do not include energy and emissions for resource extraction or for transmission losses, which are counted in Scope 3b.

Energy conversion factors exclude the energy contained in the MWh of electricity used by the remedy to avoid double counting of Scope 1 energy use.

For simplicity, energy conversion factors are assumed to be 6.9 MMBtu per MWh (equivalent to 33% efficiency) for all energy sources, which is typical for thermoelectric facilities but may under or over estimate the energy footprint from other sources.

Appendix B:
Suggested Formats for Presenting the Results of the Footprint Analysis

FLOW OF INFORMATION FOR TABLES B-1 THROUGH B-6

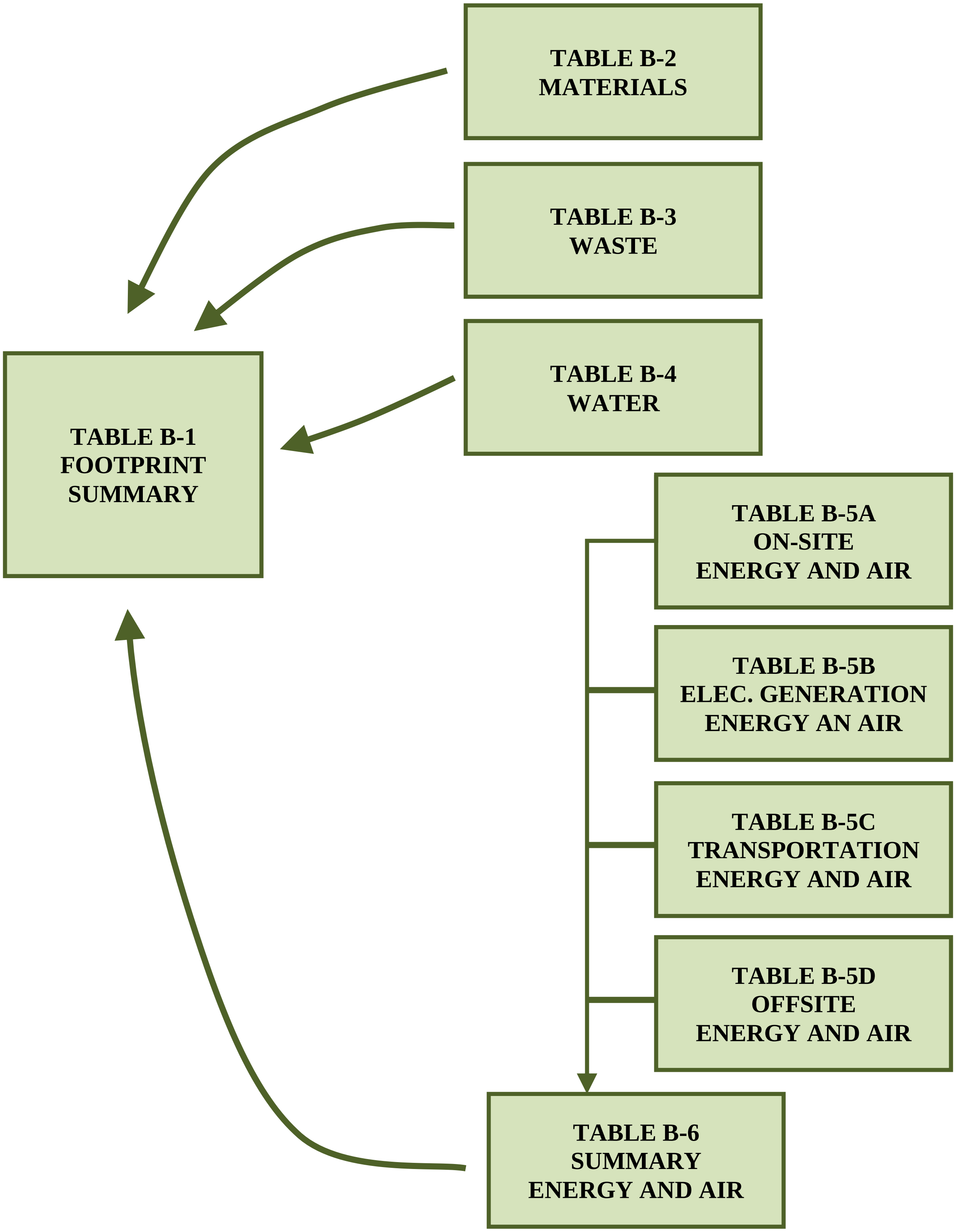


TABLE B-1. SUGGESTED FORMAT FOR PRESENTING THE ENVIRONMENTAL FOOTPRINT ANALYSIS RESULTS

Core Element	Metric		Unit of Measure	Value
Materials & Waste	M&W-1	Refined materials used on site	tons	Obtain value from Table B-2, Item D
	M&W-2	percent of refined materials from recycled or waste material	percent	Obtain value from Table B-2, Item E
	M&W-3	Unrefined materials used on site	tons	Obtain value from Table B-2, Item H
	M&W-4	percent of unrefined materials from recycled or waste material	percent	Obtain value from Table B-2, Item I
	M&W-5	Onsite hazardous waste generated	tons	Obtain value from Table B-3, Item E
	M&W-6	Onsite non-hazardous waste generated	tons	Obtain value from Table B-3, Item F
	M&W-7	percent of total potential onsite waste that is recycled or reused	percent	Obtain value from Table B-3, Item D
Water		Onsite water use (by source)		
	W-1	- Source, use, fate combination #1	millions of gals	Obtain value from Table B-4, Column 3
	W-2	- Source, use, fate combination #2	millions of gals	Obtain value from Table B-4, Column 3
	W-3	- Source, use, fate combination #3	millions of gals	Obtain value from Table B-4, Column 3
	W-4	- Source, use, fate combination #4	millions of gals	Obtain value from Table B-4, Column 3
Energy	E-1	Total energy use	MMBtu	Obtain value from Table B-6, Item A
	E-2	Total energy voluntarily derived from renewable resources		
	E-2A	- Onsite generation or use and biodiesel use	MMBtu	Obtain value from Table B-6, Item K
	E-2B	- Voluntary purchase of renewable electricity	MWh	Obtain value from Table B-6, Item L
	E-2C	- Voluntary purchase of RECs	MWh	Obtain value from Table B-6, Item M
Air	A-1	Onsite NOx, SOx, and PM emissions	lbs	Obtain value from Table B-6, Item D
	A-2	Onsite HAP emissions	lbs	Obtain value from Table B-6, Item E
	A-3	Total NOx, SOx, and PM emissions	lbs	Obtain value from Table B-6, Item F
	A-4	Total HAP emissions	lbs	Obtain value from Table B-6, Item G
	A-5	Total GHG emissions	tons CO_2e	Obtain value from Table B-6, Item C
Land & Ecosystems		Qualitative description.		

The above table presents the results for the footprint analysis metrics. The following tables are support tables that present the information and calculations used to obtain the metrics.

TABLE B-2. SUGGESTED FORMAT FOR PRESENTING MATERIALS METRICS

Material and Use	Units	Quantity	Conversion Factor to lbs	% Recycled or Reused Content	Quantity	
					Virgin	Recycled
Refined Materials (lbs)						
Refined materials Total (lbs):					(A)	(B)
Refined materials Total (lbs):					(C)	
Refined Materials Total (tons = lbs/2000):					(D)	
Percent of Refined Materials that is Recycled or Reused Content					(E)	
Unrefined Materials (tons)						
Unrefined Materials Total (tons):					(F)	(G)
Unrefined Materials Total (tons):					(H)	
Percent of Unrefined Materials that is Recycled or Reused Content					(I)	

(D) Values calculated in highlighted cells are transferred to the summary table (Table B-1).

Items in parentheses are for explanatory purposes only.

C=A+B C=D/2000 E=B/C

H=F+G I=G/H

TABLE B-3. SUGGESTED FORMAT FOR PRESENTING WASTE METRICS

Waste or Spent Material	Quantity	% of Total Potential Waste
Recycled/Reused Waste (tons)		
Used On Site		
Used On Site Subtotal:	(A)	
Recycled or Reused Off Site		
Recycled/Reused Off Site Subtotal:	(B)	
Recycled/Reused Waste Total:	(C)	(D)
Waste Disposal (tons)		
Hazardous Waste		
Hazardous Waste Subtotal:	(E)	
Non-Hazardous Waste		
Non-Hazardous Waste Subtotal:	(F)	
Waste Disposal Total:	(G)	
Total Potential Waste*:	(H)	**100%**

** Includes waste that is recycled or reused as well as waste that is disposed of in landfills, incinerators, or other forms of disposal that do not allow for recycling or reuse.*

(D) Values calculated in highlighted cells are transferred to the summary table (Table B-1).

Items in parentheses are for explanatory purposes only.

C=A+B D=C/H G=E+F H=C+G

TABLE B-4. SUGGESTED FORMAT FOR PRESENTING ONSITE WATER METRICS

Water Resource	Description of Quality of Water Used	Volume Used (Millions of gals)	Uses	Fate of Used Water
Public water supply				
Extracted groundwater #1 Location: Aquifer:				
Extracted groundwater #2 Location: Aquifer:				
Extracted groundwater #3 Location: Aquifer:				
Surface water #1 Intake Location:				
Surface water #2 Intake Location:				
Reclaimed water Source:				
Collected/diverted stormwater				
Other resource #1				
Other resource #2				

Column 1	Column 2	Column 3	Column 4	Column 5

Descriptions from Columns 1, 4, and 5 are used to define the water metric in Table B-1.
Values from Column 3 are the values of those metrics.

TABLE B-5A. SUGGESTED FORMAT FOR CALCULATING AND PRESENTING ONSITE (SCOPE 1) ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Contributors to Footprints	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2e**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Onsite Renewable Energy														
Electricity generated on site by renewable resources	MWh		10.3											
Landfill gas combusted on site	ccf CH_4		0.103		13.1		0.01		0.0000063		0.00076		8.4E-06	
Biodiesel used on site	gal		0.127		22.3		0.20		0		0.00099		NP	
Other onsite renewable energy use #1	TBD		TBD		TBD		TBD		TBD		TBD		TBD	
Other onsite renewable energy use #2	TBD		TBD		TBD		TBD		TBD		TBD		TBD	
Onsite Renewable Energy Subtotals				(A)										
Other Onsite Energy														
Grid electricity	MWh		3.413											
Onsite diesel use	gal		0.139		22.5		0.17		0.0054		0.0034		0.0003	
Onsite gasoline use	gal		0.124		19.6		0.11		0.0045		0.00054		0.0003	
Onsite natural gas use	ccf		0.103		13.1		0.01		0.0000063		0.00076		8.4E-06	
Other forms of onsite energy use #1	TBD		TBD		TBD		TBD		TBD		TBD		TBD	
Other forms of onsite energy use #2	TBD		TBD		TBD		TBD		TBD		TBD		TBD	
Other Onsite Energy Subtotals														
Other Onsite Emissions Contributions														
Onsite HAP process emissions	lb												1	
Onsite GHG emissions	lb				1									
Onsite carbon storage	lb				(1)									
GHG reductions by combusting onsite landfill methane	lb				(20)									
Other onsite contributions	TBD				TBD		TBD		TBD		TBD		TBD	
Other Onsite Subtotals														
Onsite Totals				(B1)		(B2)		(B3)		(B4)		(B5)		(B6)

TBD = to be determined. Values in parentheses are negative values. Energy for electricity is only that energy of that electricity and not the energy required to generate the electricity.
ccf CH_4 = 100 cubic feet of methane. Obtained by multiplying total volume of landfill gas in ccf by the percentage of the gas that is methane.
Energy associated with onsite generation of electricity is assumed to be 10.3 MMBtu/MWh (3.413 MMBtu/MWh for usable electricity plus 6.9 MMBtu/MWh for energy loss due to an assumed 33 percent efficiency). 33 percent efficiency is consistent with Exhibit 3.17.
Energy associated with onsite use of grid electricity is 3.413 MMBtu/MWh of electricity because the energy loss associated with 33 percent efficiency is counted in Scope 2 energy calculations
If fuel is a blend of conventional fuel and renewable resource fuel, enter the amount of fuel from conventional sources into appropriate conventional fuel categories and enter amount of fuel from renewable resources into appropriate renewable fuel categories (e.g., for 100 gallons of B20 biodiesel blend, 20 gallons would be entered under biodiesel and 80 gallons would be entered under diesel).

Use × Conversion factor = Footprint

1. *Enter use into blue cells in "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.*
3. *Sum Onsite Renewable Energy results for each parameter and enter in green "Onsite Renewable Energy Subtotals" cells.*
4. *Sum Other Onsite Energy results for each parameter and enter in green "Other Onsite Energy Subtotals" cells.*
5. *Sum Other Onsite Contributions results for each parameter and enter in green "Other Onsite Subtotals" cells.*
6. *Sum green cells for each parameter and enter result in green "Onsite Totals" cells.*

This table is for calculation purposes only.
Items (A) and (B1) through (B6) are transferred to Table B-6.

TABLE B-5B. SUGGESTED FORMAT FOR CALCULATING AND PRESENTING ELECTRICITY GENERATION (SCOPE 2) ENERGY AND AIR METRICS

Contributors to Footprints	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2e	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Grid electricity use	MWh		TBD	(A1)	TBD	(A2)	TBD	(A3)	TBD	(A4)	TBD	(A5)	TBD	(A6)
Green pricing or green marketing product purchases	MWh	(B)												
REC purchase	MWh	(C)												

See Exhibit 3.17 for how to determine the conversion factors for grid electricity.

Use × Conversion factor = Footprint

1. Enter grid electricity use in MWh into blue cell in "Use" column.
2. Convert MWh use into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.
3. Enter quantity of voluntary purchased renewable electricity in the form of green pricing and green marketing products into the associated blue cell, and document information regarding that product in the table below.
4. Enter quantity of voluntary purchased renewable electricity in the form of RECs into the associated blue cell, and document information regarding that product in the table below.

Description of purchased green pricing or green marketing product	Provider:
	Type of product:
	Type of renewable energy source:
	Date of renewable system installation:
Description of purchased RECs	Provider:
	Type of renewable energy source:
	Date of renewable system installation:

This table is for calculation purposes only.
Items (A1) through (A6), (B), and (C) are transferred to Table B-6.

TABLE B-5C. SUGGESTED FORMAT FOR CALCULATING AND PRESENTING TRANSPORTATION (SCOPE 3A) ENERGY AND AIR METRICS

Category	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Conventional Energy														
Diesel use	gal		0.139		22.5		0.17		0.0054		0.0034		0.000005	
Gasoline use	gal		0.124		19.6		0.11		0.0045		0.00054		0.000039	
Natural gas use	ccf		0.103		13.1		0.01		0.0000063		0.00076		0.0000084	
Conventional Energy Subtotals														
Renewable Energy														
Biodiesel use	gal		0.127	(A)	22.3		0.20		0		0.00099		NP	
Transportation Totals				(B1)		(B2)		(B3)		(B4)		(B5)		(B6)

1. *Enter uses of each material or service into "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factor. Enter result into blue cells in parameter columns.*
3. *Sum Conventional Energy results for each parameter and enter in green "Conventional Energy Subtotals" cells.*
4. *Sum Conventional Energy Subtotals and biodiesel use results for each parameter and enter in green "Transportation" cells.*

Use × Conversion factor = Footprint

This table is for calculation purposes only.
Items (A) and (B1 through (B6) are transferred to Table B-6.

TABLE B-5D. SUGGESTED FORMAT FOR CALCULATING AND PRESENTING OFFSITE (SCOPE 3B) ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Construction Materials														
Cement	dry-lb		0.0021		0.9		0.0018		0.00105		0.0000032		0.000029	
Concrete	lb		0.00041		0.171		0.00035		0.00021		0.00001		0.00001	
Gravel/sand/clay	lb		0.000028		0.0034		0.000017		0.000015		0.0000020		2.1E-10	
HDPE	lb		0.031		1.9		0.0032		0.0041		0.00064		0.0000034	
Photovoltaic system (installed)	W		0.034		4.5		0.015		0.032		0.00063		0.0000029	
PVC	lb		0.022		2.6		0.0048		0.0076		0.0012		0.00047	
Stainless Steel	lb		0.012		3.4		0.0075		0.012		0.0044		0.00014	
Steel	lb		0.0044		1.1		0.0014		0.0017		0.00056		0.000067	
Other refined construction materials	lb		0.014		1.98		0.0037		0.0053		0.0014		0.00014	
Other unrefined construction materials	lb		0.000028		0.00335		0.000017		0.000015		0.000002		2.1E-10	
Treatment Materials and Chemicals														
Cheese Whey	lb		0.0025		0.031		0.000062		0.000033		0.000002		NP	
Emulsified vegetable oil	lb		0.0077		3.44		0.0066		0.0019		0.000033		NP	
Molasses	lb		0.0044		0.48		0.0011		0.00024		0.0000041		NP	
Treatment materials and chemicals*	lb		0.015		1.7		0.003		0.0065		0.00061		0.000016	
Virgin GAC (coal based)	lb		0.015		5.8		0.014		0.034		0.00078		0.0012	
Fuel Processing														
Biodiesel Produced	gal		0.029		-16.8		0.018		0.033		0.00082		NP	
Diesel Produced	gal		0.019		2.7		0.0064		0.013		0.00034		0.00012	
Gasoline Produced	gal		0.021		4.4		0.008		0.019		0.00052		0.00016	
Natural Gas Produced	ccf		0.0052		2.2		0.0037		0.0046		0.000072		0.0000061	
Public water	gal x 1000		0.0092		5		0.0097		0.0059		0.016		0.000015	
Offsite Services														
Offsite waste water treatment	gal x 1000		0.015		4.4		0.016		0.015		NP		NP	
Offsite Solid Waste Disposal	ton		0.16		25		0.14		0.075		0.4		0.0014	
Offsite Haz. Waste Disposal	ton		0.176		27.5		0.154		0.0825		0.44		0.00154	
Offsite Laboratory Analysis	$		0.0065		1		0.0048		0.0036		0.0004		0.00013	

TABLE B-5D. SUGGESTED FORMAT FOR CALCULATING AND PRESENTING OFFSITE (SCOPE 3B) ENERGY AND AIR METRICS (continued)

Category	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Resource Extraction for Electricity														
Coal extraction and processing	MWh		3.1		180		0.77		0.15		0.018		NP	
Natural gas extraction and processing	MWh		1.6		270		0.18		13		0.0071		NP	
Nuclear fuel extraction and processing	MWh		0.16		25		0.15		0.5		0.0015		NP	
Oil extraction and processing	MWh		2.3		270		1.7		0.069		0.042		NP	
Electricity Transmission														
Transmission and distribution losses	MWh		10.3											
Offsite Totals				(A1)		(A2)		(A3)		(A4)		(A5)		(A6)

NP = not provided

Use × Conversion factor = Footprint

1. *Enter uses of each material or service into "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factor. Enter result into blue cells in parameter columns.*
3. *Fuel processing refers to all fuel used, including that for onsite equipment use and transportation.*
4. *Electricity from various resources is obtained from generation mix that is used in Exhibit 3.17 and the resource extraction conversion factors from Exhibit 3.14.*
5. *For electricity transmission, enter 10 percent of the grid electricity used for calculating energy and emissions from electricity generation. The conversion factors are the same as those used for electricity generation, but the energy conversion factor is 10.3 MMBtu/MWh (3.413 MMBtu/MWh for usable electricity plus 6.9 MMBtu/MWh for energy loss due to an assumed 33 percent efficiency at the power plant).*
6. *Resource extraction conversion factors are calculated using values in Exhibit 3.14 and the specified fuel blend for electricity generation.*

This table is for calculation purposes only.
Items (A1) through (A6) are transferred to Table B-6.

TABLE B-6. SUGGESTED FORMAT FOR SUMMARZING ENERGY AND AIR METRICS

Category	Total Energy MMbtus	GHGs lbs CO_2e	NOx lbs	SOx lbs	PM lbs	NOx+SOx+PM10 lbs	HAPs lbs
Onsite (Scope 1)						(D)	(E)
Electricity Generation (Scope 2)							
Transportation (Scope 3a)							
Other Offsite (Scope 3b)							
Remedy Totals	(A)	(B)				(F)	(G)
GHG Footprint in Tons (1 ton = 2,000 lbs)		(C)					

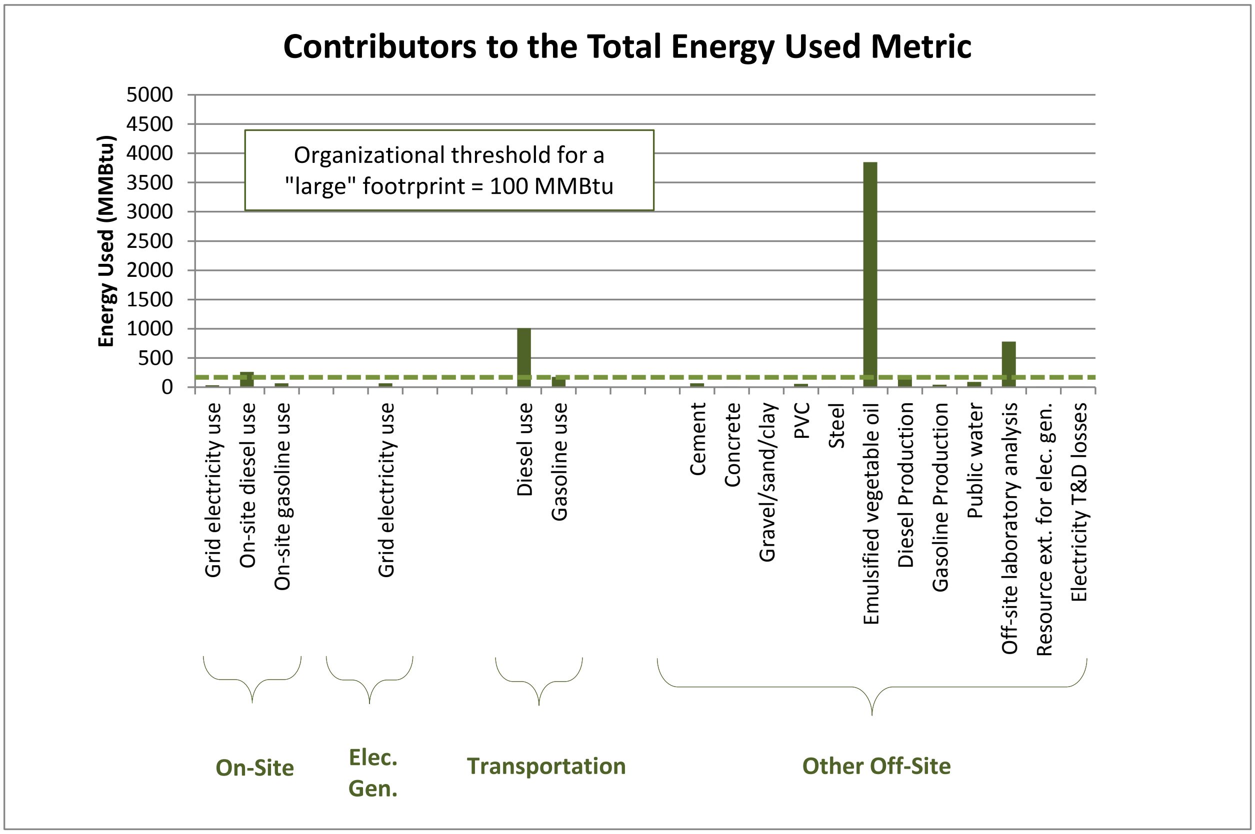
1. *Values for "On Site (Scope 1)" are items B1 through B6 from Table B-5A.*
2. *Values for "Electricity Generation (Scope 2)" are items A1 through A6 from Table B-5B.*
3. *Values for "Transportation (Scope 3a)" are items B1 through B6 from Table B-5C.*
4. *Values for "Other Offsite (Scope 3b)" are items A1 through A6 from Table B-5D*
5. *Sum Scope 1 through Scope 3b values in each column to obtain "Remedy Totals"*
6. *Divide item B by 2000 to obtain GHG metric in tons*
7. *Sum NOx, SOx, and PM10 values in each row to obtain "NOx+SOx+PM10"*

Voluntary Renewable Energy Use	Unit	Quantity
Onsite generation or use	MMBtu	(H)
Onsite biodiesel use	MMBtu	(I)
Biodiesel use for transportation	MMbtu	(J)
Onsite generation or use and biodiesel use	MMBtu	(K)
Renewable electricity purchase	MWh	(L)
REC purchases	MWh	(M)

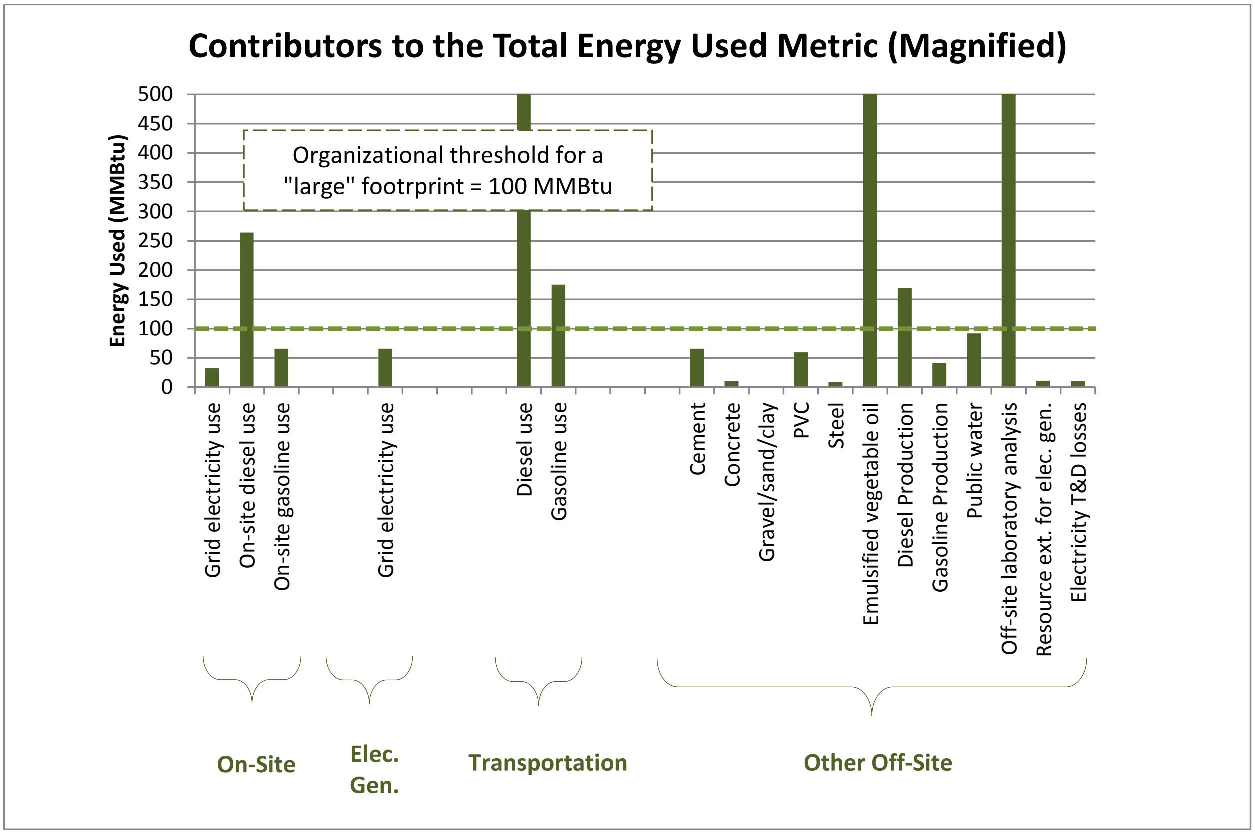
1. *Value for "Onsite energy generation or use" is item A from Table B-5A.*
2. *Value for "Onsite biodiesel use" is from Table B-5A.*
3. *Value for "Biodiesel use for transportation" is item A from Table B-5C*
4. *Value for "Onsite generation or use and biodiesel use" (K) is calculated as follows: K = H +I+J.*
5. *Value for "Renewable electricity purchase" is item B from Table B-5B.*
6. *Value for "REC purchases" is item C from Table B-5B.*

SUGGESTED FORMAT FOR ILLUSTRATING CONTRIBUTIONS TO A METRIC

Project teams may find it helpful to graph the contributions to each metric to identify the values of the contributions next to each other or next to some guide or threshold value. The following example figure depicts the contributions to the *total energy used* metric from Energy and Air Scenario #1. The *total energy used* metric was chosen as an example. Figures might be generated for other metrics as well. The organization operating the remedy has determined that any activity that uses more than 100 MMBtu should be targeted for potential footprint reduction. The figure illustrates this 100 MMBtu guide.



Some contributions (e.g., diesel for transportation, emulsified vegetable oil, and laboratory analysis) are significantly higher than this 100 MMBtu target. These contributions are clear targets for applying footprint reduction practices or BMPs. The figure is also regenerated on the following page with a different vertical axis to visualize some of the smaller footprint contributions relative to the 100 MMBtu guide.



This figure shows that onsite diesel use, gasoline use for transportation, diesel production (e.g., at a refinery), and public water use are all contributions that are close to or larger than the 100 MMBtu guide. The project team might consider use of biodiesel blends, carpooling, and use of alternate water supplies as potential practices for reducing these footprints.

Appendix C:
Footprint Reduction Scenarios

Eight hypothetical cleanup scenarios are presented in this appendix to illustrate how the results of methodology application could be screened to find potential strategies for reducing the project's environmental footprint. The footprint reduction scenarios are categorized as follows:

- **Materials and Waste**
- **Water**
- **Energy and Air**

These scenarios are categorized for illustrative purposes and are independent of one another. As such, the site conditions or other influential factors in each scenario are not necessarily common among the three categories.

Scenarios in this appendix are provided for illustrative purposes only and do not constitute a recommendation by EPA.

Footprint Reduction Scenarios: Materials and Waste

MATERIALS AND WASTE SCENARIO #1

MATERIALS AND WASTE SCENARIO #2

MATERIALS AND WASTE SCENARIO #3

MATERIALS AND WASTE FOOTPRINT REDUCTION SCENARIO #1

Background:

A P&T system is under design to treat arsenic through co-precipitation. The 50 percent design extraction rate is 700 gpm, and the system is anticipated to operate for 30 years. The process water is oxidized with hydrogen peroxide. Ferric chloride is added to provide iron to adsorb the arsenic, and sodium hydroxide is added to neutralize the water. Polymer is added to assist with flocculation. Precipitated metals are dewatered and disposed of off site as listed hazardous waste. No other significant waste streams are associated with the site.

The following items will be constructed:

- Ten 6-inch extraction wells, each to 60 feet deep with 20-foot screens
- 3,000 feet of 6-inch HDPE piping with electrical conduit and wiring
- 80-foot x100-foot building that is 30 feet high
- 200-foot x 200-foot reinforced fly-ash concrete pad and containment area (20,000 ft^3 of concrete)
- 50,000 pounds of primary treatment equipment

Screening:

The largest contributor to refined materials is expected to be the sodium hydroxide (over 6,000,000 lbs of pure sodium hydroxide) over a 30-year period. The largest contributor for unrefined materials is expected to be the aggregate in the concrete for the building foundation (about 1,200 tons). No specific appreciable non-hazardous waste streams have been identified. The dewatered sludge from metals removal is expected to be 2,600 tons. The project team has chosen a percent-based screening limit of 1 percent for refined and unrefined materials and magnitude based limits of 1,000 lbs for refined materials and 1 ton for unrefined materials and wastes. The limits are therefore as follows:

Category	Largest Contributor	Largest Contribution	Selected % of Largest Contributor	Percent-based Limit	Magnitude-based Limit	Applicable Limit
Refined materials	Sodium hydroxide	6,000,000 lbs	1%	60,000 lbs	1,000 lbs	**60,000 lbs**
Unrefined materials	Concrete aggregate	1,200 tons	1%	12 tons	1 tons	**12 tons**
Non-hazardous Waste	General waste	Unknown	1%	Unknown	1 ton	**1 ton**
Hazardous Waste	Dewatered sludge	2,600 tons	1%	26 tons	1 ton	**26 tons**

The data quality for the remedy information is considered poor to moderate. The extraction rate is subject to change due to additional modeling and capture zone evaluation during startup. The chemical dosing is highly dependent on actual influent chemical loading, and the remedy duration was loosely estimated for cost estimating purposes. The footprint results are expected to be highly sensitive to these relatively uncertain parameters. Because the metrics are direct presentation of expected materials use and waste, there is little or no added uncertainty associated with converting remedy information and engineering estimates into the metrics as there would be for energy and air metrics.

MATERIALS AND WASTE SCENARIO #1 *(continued)*

Estimated Materials Footprint over 30-Year Operation Period

Material and Use	Units	Quantity	Conversion Factor to lbs	% Recycled or Reused Content	Quantity: Virgin	Quantity: Recycled
Refined Materials (lbs)						
Wells – PVC casing and grout		Expected to be less than screening limit				
Wells – screen		Expected to be less than screening limit				
Piping and conduit	ft	3,000	7.5 lbs/ft		22,500*	
Building steel	ft^3	240,000	1 lbs/ft^3	55%	108,000	132,000
Concrete reinforcing steel	ft^2	40,000	1.3 lbs/ft^2	55%	23,400*	28,600*
Cement portion of concrete	ft^3	20,000	22 lbs/ft^3	20%	352,000	88,000
Process equipment		Expected to be less than screening limit				
Process controls		Expected to be less than screening limit				
Hydrogen peroxide (50%)	gal	295,650	4.96 lbs/gal	0%	1,467,000	0
Ferric chloride (37%)	gal	1,368,750	4.33 lbs/gal	0%	5,928,000	0
Sodium hydroxide (20%)	gal	3,011,250	2.04 lbs/gal	0%	6,144,000	0
Polymer (specific gravity = 1.04)	gal	120,450	8.7 lbs/gal	0%	1,047,000	0
				Refined materials Total (lbs):	**15,091,900**	**248,600**
				Refined materials Total (lbs):	**15,340,500**	
				Refined Materials Total (tons = lbs / 2000):	**7,670**	
				Percent of Refined Materials that is Recycled or Reused Content	**<2%**	
Unrefined Materials (tons)						
Wells –sand pack		Expected to be less than screening limit				
Aggregate for concrete	ft^3	20,000	115 lbs/ft^3		1,150	
			2000 lbs/ton			
				Unrefined Materials Total (tons):	**1,150**	**0**
				Unrefined Materials Total (tons):	**1,150**	
				Percent of Unrefined Materials that is Recycled or Reused Content:	**0%**	

NOTE: polymer quantity includes unknown water content of aqueous solution

** Values for piping/conduit and concrete reinforcing steel are shown in the above table because the project team determined that professional judgment alone was not sufficient to assume they were below the screening limit. Because the project team invested the time and resources to estimate the values for the screening process, the contributions from these items are retained in the analysis.*

Values provided in the "Quantity" Column are obtained from engineering estimates during design.

Conversion factors in above tables obtained from Exhibit 3.3 through Exhibit 3.8.

MATERIALS AND WASTE SCENARIO #1 (continued)

Estimated Waste Footprint

Waste or Used Material	Quantity	% of Total Potential Waste
Recycled/Reused Waste (tons)		
Used On Site		
None.		
Used On Site Subtotal:	**0**	**0%**
Recycled or Reused Off Site		
None.		
Recycled/Reused Off Site Subtotal:	**0**	**0%**
Recycled/Reused Waste Total:	**0**	**0%**
Waste Disposal (tons)		
Hazardous Waste		
2,600 tons of dewatered precipitated metals sludge	2,600	100%
Hazardous Waste Subtotal:	**2,600**	**100%**
Non-Hazardous Waste		
None.		
Non-Hazardous Waste Subtotal:	**0**	**0%**
Waste Disposal Total:	**2,600**	**100%**
Total Potential Waste*:	**2,600**	**100%**

** Includes waste that is recycled or reused as well as waste that is disposed of in landfills, incinerators, or other forms of disposal that do not allow for recycling or reuse.*

Findings:

Overall materials use is dominated by the treatment chemicals. Efforts for footprint reduction can be focused on identifying a potential waste stream of iron hydroxides that may help reduce some of the sodium hydroxide and ferric chloride use. Use of this waste stream would also increase the percentage of materials from recycling/reuse. The waste footprint is dominated by the precipitated sludge. The waste is not characteristically hazardous. Delisting the waste may allow for non-hazardous waste disposal, which would lower the hazardous waste footprint and increase the non-hazardous waste footprint. Effort will also be placed on optimizing the extraction rate because the extraction rate directly influences treatment chemical use and waste disposal.

MATERIALS AND WASTE SCENARIO #2

Background:

A biobarrier that involves routine injections of emulsified vegetable oil is designed to control groundwater plume migration. A total of 20 permanent injection wells each with 20-foot screen intervals will be used. Of the 20 wells, 10 will be 60 feet deep and 10 will be 40 feet deep. The wells will be constructed with 2-inch PVC casing. A total of 400,000 lbs of emulsified vegetable oil will be injected over events spanning 10 years. Drill cuttings (approximately 9 tons) are disposed of off site at a landfill as non-hazardous waste.

Screening:

The largest contributor to refined materials is expected to be the emulsified vegetable oil. The largest contributor for unrefined materials is expected to be the sand (about 4 tons) for the sand packs of the injection wells. The drill cuttings are the only anticipated waste stream. The project team has chosen a percent-based screening limit of 1 percent for refined and unrefined materials and magnitude based limits of 1,000 lbs for refined materials and 1 ton for unrefined materials and wastes. The limits are therefore as follows:

Category	Largest Contributor	Largest Contribution	Selected % of Largest Contributor	% - based Limit	Magnitude-based Limit	Applicable Limit
Refined materials	Emulsified vegetable oil	400,000 lbs	1%	4,000 lbs	1,000 lbs	**4,000 lbs**
Unrefined materials	Sand	4 tons	1%	0.04 tons	1 ton	**1 ton**
Non-hazardous Waste	Drill cuttings	9 tons	1%	0.09 tons	1 ton	**1 ton**
Hazardous Waste	None expected					

The data quality for the remedy information is considered moderate. The design for the injection well network is finalized and is conservative. No additional wells are expected. The amount of emulsified vegetable oil to be added in the first event has also been determined, but the frequency of maintenance injections and the amount of oil to be injected in each maintenance injection event are estimates to be refined during remedy implementation. The footprint results are expected to be highly sensitive to parameters of the reinjection events. Because the metrics are direct presentation of expected materials use and waste, there is little or no added uncertainty associated with converting remedy information and engineering estimates into the metrics as there would be for energy and air metrics.

MATERIALS AND WASTE SCENARIO #2 *(continued)*

Estimated Materials Footprint

Material and Use	Units	Quantity	Conversion Factor to lbs	% Recycled or Reused Content	Quantity	
					Virgin	Recycled
Refined Materials						
Injection well PVC casing/screen		Expected to be less than screening limit				
Injection well grout	ft	800	13 lbs/ft	0%	10,400	0
Emulsified vegetable oil	lbs	400,000	1	0%	400,000	0
Other items		Expected to be less than screening limit				
Refined materials Total (lbs):					410,400	0
Refined materials Total (lbs):					410,400	
Refined Materials Total (tons = lbs/2000):					**205**	
Percent of Refined Materials that is Recycled or Reused Content					**0%**	
Unrefined Materials						
Injection wells – sand pack	ft	400	0.01 tons/ft	0%	4	0
Unrefined Materials Total (tons):					4	0
Unrefined Materials Total (tons):					**4**	
Percent of Unrefined Materials that is Recycled or Reused Content:					**0%**	

Values provided in the "Quantity" Column are obtained from engineering estimates during design.

Conversion factors in above tables obtained from Exhibit 3.3 through Exhibit 3.8.

Estimated Waste Footprint

Waste or Used Material	Quantity	Percent of Total Potential Waste
Recycled/Reused Waste (tons)		
Used On Site		
None.		
Used On Site Subtotal:	**0**	**0%**
Recycled or Reused Off Site		
None.		
Recycled/Reused Off Site Subtotal:	**0**	**0%**
Recycled/Reused Waste Total:	**0**	**0%**
Waste Disposal (tons)		
Hazardous Waste		
None.	0	0%
Hazardous Waste Subtotal:	**0**	0%
Non-Hazardous Waste		
Drill cuttings	9	100%
Non-Hazardous Waste Subtotal:	**9**	**100%**
Waste Disposal Total:	**9**	**100%**
Total Potential Waste*:	**9**	**100%**

** Includes waste that is recycled or reused as well as waste that is disposed of in landfills, incinerators, or other forms of disposal that do not allow for recycling or reuse.*

MATERIALS AND WASTE SCENARIO #2 (continued)

Findings:

Overall materials use is dominated by the emulsified vegetable oil. Efforts for footprint reduction can be focused on identifying a potential off-spec food grade amendment that will otherwise be considered a waste product. This may modify the total amount of materials used but will also increase the percentage of materials from recycled/reused material. Performance monitoring data will be reviewed closely to evaluate quantity and frequency of maintenance injections so that remedy protectiveness is maintained without using much more vegetable oil than expected. The drill cuttings are not hazardous, and it may be possible to use them as fill elsewhere on site to reduce the quantity of waste for offsite disposal and increase the total potential waste that is recycled or reused.

MATERIALS AND WASTE SCENARIO #3

Background:

Contaminated soil is being consolidated on site and covered with a Resource Conservation and Recovery Act (RCRA) Subtitle C cap. The total cap surface area is approximately 100,000 square feet. No waste is being transported off site for disposal, so there is no waste footprint. The cap components are as follows:

- 24 inches of earthen material (200,000 ft^3 or 7,400 cy = 9,000 tons)
- 12 inches of sand (100,000 ft^3 or 3,700 cy = 5,600 tons)
- 40-mil HDPE membrane (40 mils = 0.040 inches, total volume = 333 ft^3 =19,900 lbs)
- 24 inches of compacted clay (200,000 ft^3 or 7,400 cy = 11,100 tons)
- 12 inches of native soil/sand as a foundation for the cap (100,000 ft^3 or 3,700 cy = 5,600 tons)

The 12 inches of native soil/sand are used from an onsite borrow pit that will be converted to a required stormwater retention basin. The 24-inch thick layer of earthen material will be a combination of onsite soil (75 percent) and mulch/compost (25 percent) generated from onsite vegetation. The 12-inches of sand for the drainage layer, the 24-inches of clay, and the HDPE are brought from offsite sources. The design has been finalized, and little change is expected in these parameters.

Screening:

The largest contributor to refined materials is expected to be the HDPE liner. The largest contributor for unrefined materials is the clay. The native soil is considered a reused product because the excavated area will be converted to a stormwater retention basin. The mulch/compost is also considered a reused or recycled material because it is generated from cleared vegetation that would otherwise need to be hauled off site. No waste streams have been identified. The project team has chosen a percent-based screening limit of 1 percent for refined and unrefined materials and magnitude based limits of 1,000 lbs for refined materials and 1 ton for unrefined materials and wastes. The limits are therefore as follows:

Category	Largest Contributor	Largest Contribution	Selected % of Largest Contributor	Percent-based Limit	Magnitude-based Limit	Applicable Limit
Refined materials	HDPE	19,900 lbs	1%	190 lbs	1,000 lbs	**1,000 lbs**
Unrefined materials	Clay	11,100 tons	1%	110 tons	1 ton	**110 tons**
Non-hazardous Waste		None expected				
Hazardous Waste		None expected				

The data quality for the remedy information is considered good. The design has been completed and construction is underway. No significant changes in materials use are anticipated. Because the metrics are direct presentation of expected materials use and waste, there is little or no added uncertainty associated with converting remedy information and engineering estimates into the metrics as there would be for energy and air metrics.

MATERIALS AND WASTE SCENARIO #3 *(continued)*

Estimated Materials Footprint

Material and Use	Units	Quantity	Conversion Factor	% Recycled or Reused Content	Quantity	
					Virgin	Recycled
Refined Materials (lbs)						
HDPE – 40 mil thickness (40 mil = 0.040 inches)	ft^3	333	59.6 lbs/ft^3	0%	19,900	0
Refined materials Total (lbs):					19,900	0
Refined materials Total (lbs):					19,900	
Refined Materials Total (tons = lbs/2000):					**9.95**	
Percent of Refined Materials that is Recycled or Reused Content					**0%**	
Unrefined Materials (tons)						
Clay	cy	7,400	1.5 tons/cy	0%	11,100	0
Soil for 12-inch layer	cy	3,700	1.5 tons/cy	100%	0	5,600
Soil for 75% of 24-inch layer	cy	5,550	1.5 tons/cy	100%	0	8,300
Mulch/compost for 25% of 24-inch layer	cy	1,850	0.4 tons/cy	100%	0	700
Sand	cy	3,700	1.5 tons/cy	0%	5,600	0
Unrefined Materials Total (tons):					16,700	14,600
Unrefined Materials Total (tons):					**31,300**	
Percent of Unrefined Materials that is Recycled or Reused Content					**47%**	

Values provided in the "Quantity" Column are obtained from engineering estimates during design.

Conversion factors in above tables obtained from Exhibit 3.3 through Exhibit 3.8.

Waste Footprint
NONE

Findings:

The materials metrics and waste metrics are the result of careful planning during design to use materials for multiple purposes (e.g., excavated areas for retention basins and cleared vegetation for mulch). No other materials and waste footprint reduction opportunities are expected to be identified for this remedy.

Footprint Reduction Scenarios: Water

WATER SCENARIO #1

WATER SCENARIO #2

WATER SCENARIO #3

WATER SCENARIO #1

Background:

A P&T system at a site in the Eastern United States with non-aqueous phase liquid extracts 50 gpm from a shallow aquifer to contain a continuing source of groundwater contamination and prevent the contamination from discharging to a local creek. The aquifer from which water is extracted is considered a potential source of drinking water by the State, but given the water quality, treatment would be required prior to use. Treatment would include removal of dissolved iron and potentially other forms of treatment. There are no current local users of the aquifer. Public water supply source in the area is either surface water or groundwater from deeper, uncontaminated wells. Water treated by the P&T system is discharged to the creek that is protected by the remedy. The P&T system is expected to operate for more than 30 years.

An optimization evaluation team suggested constructing a slurry wall and impermeable cap around the contaminant source to reduce the required pumping rate to 10 gpm from 50 gpm. The slurry wall would be 3,000 feet long, with an average depth of 30 feet, and a minimum width of 3 feet. Construction of the slurry wall requires approximately 2 million gallons of extracted groundwater to prepare the slurry. Treated water would be discharged to the same creek. The stormwater diverted by the cap (approximately 1 million gallons per year) eventually discharges to the creek.

Screening:

Given the extraction rates and remedy duration for the existing and optimized remedy configurations, extracted groundwater for treatment is expected to range between 157 and 800 million gallons. The amount of extracted groundwater required for slurry wall construction (2 million gallons) is considered negligible by comparison. No appreciable public water is used for the remedy.

Estimated Onsite Water Footprint:

See tables on following pages.

Findings:

The existing remedy configuration has the largest total water footprint, but the majority of the water use is from the extraction and treatment of shallow groundwater that would otherwise discharge to a local creek. The extracted water is treated and discharged to the same creek such that local water resources are not significantly affected. The existing remedy and optimization configurations both have marginal effects on local water resources, but other green remediation metrics may be substantially affected. The diverted stormwater could be used to help construct wetlands to increase ecosystem services in the area.

WATER SCENARIO #1 – Existing Remedy Configuration - Onsite Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Public water supply				
Extracted groundwater #1 Location: **within 100 feet of creek** Aquifer: **shallow**	Shallow groundwater that discharges to creek in relatively short distance. Groundwater classified as drinking water by State. Requires treatment prior to use. Other water resources available	790	Extracted for treatment	Discharged to creek
Surface water #1 Intake Location: **not applicable**				
Collected/diverted stormwater				

WATER SCENARIO #1 – Optimization Consideration (Slurry Wall) Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gallons)	Uses	Fate of Used Water
Public water supply				
Extracted groundwater #1 Location: **within 100 feet of creek** Aquifer: **shallow**	Shallow groundwater that discharges to creek in relatively short distance. Groundwater classified as drinking water by State. Requires treatment prior to use. Other water resources available	160	Extracted for treatment	Discharged to creek
Surface water #1 Intake Location: **not applicable**				
Collected/diverted stormwater	Rain water quality	30	Prevented from recharging shallow groundwater near creek	Eventually discharged to nearby creek.

For the above tables, orange shading indicates areas of potential improvement in the water footprint. Yellow shading indicates no net or significant effect on the water footprint. Green shading indicates examples of water best management practices.

WATER SCENARIO #2

Background:

Note that this scenario purposely includes similar features to Scenario #1, with the exception of the quality and local use of groundwater that is extracted and treated as part of the remedy. The water footprint differs significantly from that of Scenario #1 based on the quality of the water and its local use.

A P&T system in the Midwestern United States with non-aqueous phase liquid extracts 200 gpm from an aquifer used as a local potable water supply. Water treated by the P&T system is discharged to surface water. The P&T system is expected to operate for more than 30 years.

An optimization team has suggested two potential modifications to the existing remedy that are not mutually exclusive:

Slurry wall and impermeable cap – A slurry wall and impermeable cap could be constructed around the contaminant source to reduce the required pumping rate to 40 gpm from 200 gpm. The slurry wall would be 3,000 feet long, with an average depth of 30 feet, and a minimum width of 3 feet. Construction of the slurry wall will require approximately 2 million gallons of water to prepare the slurry. Water treated by the P&T system is discharged to surface water. The P&T system is expected to operate for more than 30 years. The stormwater diverted by the cap (approximately 1 million gallons per year) is directed to a nearby infiltration basin.

Beneficial reuse – The treated water can be used for irrigation during the growing season. Approximately 40 percent of the extracted water could therefore be used beneficially.

Screening:

Given the extraction rates and remedy duration for the existing and optimized remedy configurations, extracted groundwater for treatment is expected to range between 630 million gallons and more than 3 billion gallons. The amount of extracted groundwater for slurry wall construction (2 million gallons) is considered negligible by comparison. No appreciable public water is used for the remedy.

Estimated Onsite Water Footprint:

See tables on following pages.

Findings:

The existing remedy configuration has the largest total onsite water footprint. The two optimization suggestions both improve the onsite water footprint, and the two suggestions implemented together improve the footprint further. The substantial volume of extracted water may also serve a beneficial purpose if it can be used for heat transfer in a geothermal heat pump application. Water that is not used for a beneficial purpose can be reinjected to maintain the water resource.

WATER SCENARIO #2 – Existing Remedy Configuration – Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	3,200	Extracted for treatment	Discharged to surface water (not reusable)
Collected/diverted stormwater				

WATER SCENARIO #2 – Optimization Suggestion (Slurry Wall) – Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	630	Extracted for treatment	Discharged to surface water (not reusable)
Collected/diverted stormwater	Rain water quality	30	Diverted from source area	Allowed to recharge aquifer in unimpacted area.

WATER SCENARIO #2 – Optimization Suggestion (Beneficial Reuse) – Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	1,920	Extracted for treatment	Discharged to surface water (not reusable)
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	1,280	Extracted for treatment	Used beneficially. No net loss of water resource due to groundwater extraction and treatment.
Collected/diverted stormwater				

WATER SCENARIO #2 – Optimization Suggestion (Slurry Wall and Beneficial Reuse) – Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	378	Extracted for treatment	Discharged to surface water (not reusable)
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply. Limited alternative potable water resources available	252	Extracted for treatment	Used beneficially. No net loss of water resource due to groundwater extraction and treatment.
Collected/diverted stormwater	Rain water quality	30	Diverted from source area	Allowed to recharge aquifer in unimpacted area.

For the above tables, orange shading indicates areas of potential improvement in the water footprint. Yellow shading indicates no net or significant effect on the water footprint. Green shading indicates examples of water best management practices.

WATER SCENARIO #3

Background:

This scenario compares two similar remedies considered at two different sites to illustrate how location and local water resources affect the onsite water footprint.

Example #1 - A soil remedy for a site in the arid Western United States involves the excavation, land farming, and backfill of treated soil. Up to 40 acres is expected to be disturbed by heavy equipment. The underlying aquifer is a crucial local water resource for potable water and irrigation. No other viable sources of potable water are available in the area. Over 2 million gallons of extracted groundwater is anticipated to be used for dust control over the duration of the remedy. Over 4 million gallons of extracted groundwater is anticipated to be used to foster degradation of contaminants during landfarming over the duration of the remedy.

Example #2 - A soil remedy for a site in the Northern Central United States involves the excavation, land farming, and backfill of treated soil. Up to 40 acres is expected to be disturbed by heavy equipment. The underlying aquifer is not used for potable water or irrigation. Surface water resources are the predominant sources of water in the area. No water is anticipated to be needed for dust control over the duration of the remedy. Approximately 750,000 gallons of extracted groundwater and 250,000 gallons of collected stormwater, which would otherwise discharge to surface water downgradient of the local reservoir, are anticipated to be used to foster degradation of contaminants during landfarming over the duration of the remedy.

Screening:

There are no other appreciable water resource uses other than those specified.

Estimated Onsite Water Footprint:

See tables on following pages.

Findings:

Water use for a the same soil remedy is substantially higher in the arid Western United States than it is the Northern Central United States due to the need for dust control and the high evaporation potential in west. In addition, the water resource in the Western United States is of greater local value due to its use and the absence of other potential sources of water. Timing some of the work associated for Example #1 with or following precipitation events may help reduce the amount of water that needs to be extracted for dust control. However, this could adversely affect schedule. Groundwater use for Example #2 is lower for the same remedy as Example #1. In addition, groundwater is the not the primary water resource used in the area and stormwater is an available resource.

WATER SCENARIO #3 – Example #1 (Arid Western United States) - Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Public water supply				
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply and irrigation. Limited alternative potable water resources available	2	Dust control	Evaporated to atmosphere
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater used for local potable water supply and irrigation. Limited alternative potable water resources available	4	Landfarming	Evaporated to atmosphere or microbial metabolism
Surface water #1 Intake Location: **not applicable**				
Collected/diverted stormwater				

WATER Scenario #3 – Example #2 (Northern Central United States) - Water Footprint Analysis

Water Resource	Description of Quality of Water Used	Volume Used (million gals)	Uses	Fate of Used Water
Public water supply				
Extracted groundwater #1 Location: **on site** Aquifer: **water supply aquifer**	Groundwater not used for local potable water supply or irrigation.	0.75	Landfarming	Evaporated to atmosphere or microbial metabolism
Surface water #1 Intake Location: **not applicable**				
Collected/diverted stormwater	Stormwater that would otherwise discharge to local creek	0.25	Landfarming	Evaporated to atmosphere or microbial metabolism

For the above tables, orange shading indicates areas of potential improvement in the water footprint. Yellow shading indicates no net or significant effect on the water footprint. Green shading indicates examples of water best management practices.

Footprint Reduction Scenarios: Energy and Air

ENERGY AND AIR SCENARIO #1

ENERGY AND AIR SCENARIO #2

ENERGY AND AIR SCENARIO #1

Background:

Design of an *in situ* bioremediation remedy for chlorinated volatile organic compounds (VOCs) is underway.

Remedy information is as follows:

- Restoration of 200-foot x 200-foot area of shallow aquifer (25 feet to 50 feet deep)
- Construction of 80 permanent 2-inch PVC wells, 50 feet deep with 20-foot screen intervals
- Drill cuttings left at well locations
- Injection of 500,000 pounds of emulsified vegetable oil (5 percent solution) over three injection rounds
- Extracted groundwater used for chemical blending and injection
- Quarterly sampling at 30 points for 5 years, semi-annual sampling at 30 points for additional 5 years, annual sampling at 30 points for 10 additional years
- All samples analyzed for VOCs only
- Purge water disposed to ground surface

Screening:

This step identifies the largest contributors to the energy and onsite air metrics and develops screening limits for use in identifying important potential contributors to the footprint and providing the rationale for excluding minor contributors.

Onsite NOx+SOx+PM Emission Screening

The only sources of onsite emissions are expected to be the drill rig operation and the low-flow sampling equipment. Both are expected to be above the screening limits.

Onsite HAP Emission Screening

No additional sources beyond those counted in the NOx+SOx+PM screening.

Total Energy Screening

The screening limit is based on the higher of a magnitude based limit of 100 screening units or a percentage-based limit equal to 1 percent of the largest contributor to the total energy footprint. Because no appreciable renewable energy is used, it is assumed that the total energy screening process reasonably screens items/activities for the total air emissions metrics. Based on professional judgment, the two most likely candidates for the largest total energy contributor are the 500,000 pounds of emulsified vegetable oil and the well installation. Based on Exhibit 3.2, the 500,000 pounds of emulsified vegetable oil equates to 500,000 screening units (500,000 × 1), and the well installation equates to 200,000 screening units (4,000 × 50). The emulsified vegetable oil is the largest contributor. Therefore, the percentage based screening unit is 5,000 (500,000 × 1 percent). Items or activities associated with the remedy that would equate to less than 5,000 screening units will be omitted.

ENERGY AND AIR CASE STUDY #1 *(continued)*

The following table presents the primary items/activities associated with the remedy and preliminary engineering estimates regarding the quantities of those items/activities. Screening unit conversions from Exhibit 3.2 are applied to calculate the number of screening units, and a decision to include or exclude each item/activity is stated. Items exceeding the screening limit of 5,000 will be quantified more accurately during footprint calculation. As noted, some items that are available from the materials or waste footprint or for the onsite emissions footprint are included even if the values are below the screening limit because the information is already available.

Item	Quantity	Screening Units	Limit = 5,000 Decision
Vegetable oil	500,000 lbs	500,000	Include
Drill rig operation	Used for onsite NOx+SOx+PM footprint		Include
PVC, Grout, and Steel for wells	Available from materials footprint		Include
Sand for wells	Available from materials footprint		Include
Concrete for wells	Available from materials footprint		Include
Drill rig transport	<1,000 miles	<2,000	Exclude
Oversight transport	<1,000 miles	<500	Exclude
Well materials transport	<10,000 ton-miles	<3,300	Exclude
Vegetable oil transport	>100,000 ton-miles	>33,000	Include
Laboratory analysis	>$100,000	>100,000	Include
Electricity	>5,000 kWh	>5,000	Include
Injection team travel	>10,000 miles	>5,000	Include
Sampling travel	~5,000 miles	<5,000	Exclude
Sampling equipment	Used for onsite NOx+SOx+PM footprint		Include
Sampling materials	<5,000 lbs	<5,000	Exclude

Footprint Calculation:

This part of the footprint calculation follows Step 5: Quantify Energy and Air Metrics. Step 5 is comprised of 3 parts.

Part 1: Inventory Remedy Travel, Equipment Use, Materials, and Offsite Services

The following construction materials are available from the materials footprint (not shown)

- 2,700 pounds of PVC (estimated as noted in Exhibit 3.6)
- 30,400 lbs of sand/gravel (estimated as noted in Exhibit 3.6)
- 31,200 lbs of cement for grout (estimated as noted in Exhibit 3.6)
- Bentonite negligible relative to other materials
- 2,000 lbs of steel for well covers (estimated)
- 12 tons of concrete for surface finish (estimated)

Based on Exhibit 3.11B, drilling of 4,000 vertical feet might involve 40 days with a 150 HP rig operating a 75 percent load.

The following are items associated with system operation that passed the screening process:

- 500,000 pounds (250 tons) of emulsified vegetable oil injected over three events, shipped from approximately 1,000 miles away, empty return trip not required
- 10,000,000 gallons of water extracted, blended, and reinjected
- Average injection rate (multiple wells simultaneously) is 100 gpm
- Consultants and contractors visit site 200 times over three years
  - Travel in three light-duty trucks
  - Roundtrip daily commute is 40 miles
  - Total is 3 x 40 x 200 = 24,000 miles
- Mixers and pumps powered by onsite electricity for 1,800 hours total
  - Four 0.75 HP extraction pumps
  - Two 0.5 HP mixers
  - Two 1 HP transfer pumps
- Local fuel blend for electricity generation is as follows:
  - 40 percent natural gas
  - 15 percent coal
  - 20 percent hydro
  - 20 percent nuclear
  - 2 percent biomass
  - 3 percent wind

The following are items associated with monitoring that passed the screening process:

- 1,200 samples collected and analyzed for VOCs at $100/sample is $120,000
- Sampling requires a total of 2,500 hours of two 2.5 HP gasoline compressors (12,500 HP-hrs)

Part 2: Energy Inventory

This step converts the above transportation and equipment use into fuel use and converts electrical equipment use into electricity use. For scenario expediency, energy inventory for three tasks are combined. A formal analysis might split the inventory into three tasks: construction, operations and maintenance (O&M), and long-term monitoring.

Fuel Use for Personnel Transportation

Personnel or Equipment	Trips	Roundtrip Distance (miles)	Total Distance (miles)	Vehicle Type	Fuel Efficiency	Fuel Use (gals)
Gasoline						
Injection contractor #1	200	40	8,000	Truck	17 mpg	470
Injection contractor #2	200	40	8,000	Truck	17 mpg	470
Injection consultant	200	40	8,000	Truck	17 mpg	470
					Total Gasoline	1,410

**Driller and drill rig transport, drilling oversight, and sampling technician transportation to site excluded based on screening.*

Fuel Use for Equipment Use

Equipment Type	HP	Hours	BFSC	PLF	Fuel Use (gals)
Diesel					
Drill rig	150	320	0.052	0.75	1,900
Gasoline					
Sampling compressors	2 x 2.5	2,500	0.057	0.75	530

Fuel Use for Equipment, Materials, and Waste Transport

Equipment	Tons	Travel Distance (miles)	Vehicle Type	Fuel Efficiency	Fuel Use (gals)
Diesel (transport)					
Drill rig	Excluded				
Well PVC and Steel					
Sand, cement, concrete					
Sand, cement, concrete					
Vegetable Oil	250	1,000	Truck	0.029 gptm	7,250
				Total	7,250

gptm = gallons per ton-mile

Onsite Electricity Use

Equipment	HP	% Full Load	Motor Efficiency	kW	Hours	kWh
Two 0.5 HP mixers	1	80%	65%	0.92	1,800	1,660
Four 0.75 HP extraction pumps	3	80%	65%	2.75	1,800	4,950
Two 1 HP transfer pumps	2	80%	75%	1.6	1,800	2,880
					Total	**~9,500**

1 HP = 0.746 kW, See Exhibit 3.13 for calculations and assumptions.

Part 3: Convert to Energy and Air Metrics

See accompanying tables

Findings:

The largest contributor to the energy and air metrics is the production of the emulsified vegetable oil, but the following items and activities are also significant contributors that merit additional focus when attempting to reduce the energy and air metrics:

ENERGY AND AIR CASE STUDY #1 *(continued)*

- Transportation of the emulsified vegetable oil
- Laboratory analysis
- Drill rig operation
- Generators for low-flow sampling

The conversion factor to estimate energy use and emissions from laboratory analysis is generic and derived without specific consideration of what occurs within a laboratory. This additional uncertainty in the laboratory footprint should be considered when interpreting the footprint results. The materials for well installation were generally insignificant with respect to the calculated energy and air metrics.

ENERGY AND AIR SCENARIO #1 – DETERMINING FOOTPRINT CONVERSION FACTORS FOR GRID ELECTRICITY BASED ON UTILITY OR LOCATION

Power Content from Electric Service Provider

Energy Source	Percentage of Power Mix Delivered to Customers
Coal	15%
Natural gas	40%
Oil	0%
Nuclear	20%
Hydroelectric	20%
Biomass	2%
Geothermal	0%
Wind	3%
Solar	<1%

Converting Resource Mix to Footprint Conversion Factors

Type	% of Total Used	Energy (MMbtu/MWh)		CO_2e (lbs/MWh)		NOx (lbs/MWh)		SOx (lbs/MWh)		PM (lbs/MWh)		HAPs (lbs/MWh)	
		Full Load	Adj. by %	Full Load	Adj. by %	Full Load	Adj. by %	Full Load	Adj. by %	Full Load	Adj. by %	Full Load	Adj. by %
Conventional Energy													
Coal	15%	6.9	1.035	2200	330	6	0.9	15	2.3	0.092	0.014	0.66	0.099
Natural Gas	40%	6.9	2.76	1300	520	1.1	0.44	0.0066	0.0026	0.08	0.032	0.025	0.01
Oil	0%	6.9	0	1800	0	2.2	0	2.8	0	0.13	0	0.066	0
Nuclear	20%	6.9	1.38	0	0	0	0	0	0	0	0	0	0
Renewable Energy													
Biomass	2%	6.9	0.138	0	0	1.4	0.028	0.65	0.013	0.084	0.0017	5.3E-6	1.1E-7
Geothermal	0%	6.9		0	0	0	0	0	0	0	0	0	0
Hydroelectric	20%	6.9	1.38	0	0	0	0	0	0	0	0	0	0
Solar	0%	6.9		0	0	0	0	0	0	0	0	0	0
Wind	3%	6.9	0.207	0	0	0	0	0	0	0	0	0	0
Total	**100%**		**6.9**		**850**		**1.4**		**2.4**		**0.048**		**0.1**

Full load emission values for each fuel type obtained from www.nrel.gov/lci.
All values do not include energy and emissions for resource extraction or for transmission losses, which are counted in offsite (Scope 3b).
Energy conversion factors exclude the energy contained in the MWh of electricity used by the remedy to avoid double counting of onsite energy use.
For simplicity, energy conversion factors are assumed to be 6.9 MMBtu per MWh (equivalent to 33 percent efficiency) for all energy sources.

ENERGY AND AIR SCENARIO #1 – CALCULATING AND PRESENTING ONSITE (SCOPE 1) ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Contributors to Footprints	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2e**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Onsite Renewable Energy														
Electricity generated on site by renewable resources	MWh	0	10.3	0										
Landfill gas combusted on site	ccf CH_4	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	8.4E-06	0
Biodiesel used on site	gal	0	0.127	0	22.3	0	0.20	0	0	0	0.00099	0	NP	
Other onsite renewable energy use #1		0		0		0		0		0		0		0
Other onsite renewable energy use #2		0		0		0		0		0		0		0
Onsite Renewable Energy Subtotals				**0**		**0**		**0**		**0**		**0**		**0**
Other Onsite Energy														
Grid electricity	MWh	9.5	3.413	32.4										
Onsite diesel use	gal	1,900	0.139	264.1	22.5	42,750	0.17	323	0.0054	10.26	0.0034	6.46	0.0003	0.57
Onsite gasoline use	gal	530	0.124	65.72	19.6	10,388	0.11	58.3	0.0045	2.385	0.00054	0.2862	0.0003	0.159
Onsite natural gas use	ccf	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	8.4E-06	0
Other forms of onsite energy use #1		0		0		0		0		0		0		0
Other forms of onsite energy use #2		0		0		0		0		0		0		0
Other Onsite Energy Subtotals				**362**		**53,138**		**381.3**		**12.645**		**6.7462**		**0.729**
Other Onsite Emissions Contributions														
Onsite HAP process emissions	lb	0											1	0
Onsite GHG emissions	lb	0			1	0								
Onsite carbon storage	lb	0			(1)	0								
GHG reductions by combusting onsite landfill methane	lb	0			(20)	0								
Other onsite contributions		0				0		0		0		0		0
Other Onsite Subtotals						**0**		**0**		**0**				**0**
Onsite Totals				**362**		**53,138**		**381.3**		**12.645**		**6.7462**		**0.729**

TBD = to be determined. Values in parentheses are negative values. Energy for electricity is only that energy of that electricity and not the energy required to generate the electricity.
ccf CH_4 = 100 cubic feet of methane. Obtained by multiplying total volume of landfill gas in ccf by the percentage of the gas that is methane.
Energy associated with onsite generation of electricity is assumed to be 10.3 MMBtu/MWh (3.413 MMBtu/MWh for usable electricity plus 6.9 MMBtu/MWh for energy loss due to an assumed 33 percent efficiency). 33 percent efficiency is consistent with Exhibit 3.17.
Energy associated with onsite use of grid electricity is 3.413 MMBtu/MWh of electricity because the energy loss associated with 33 percent efficiency is counted in Scope 2 energy calculations
If fuel is a blend of conventional fuel and renewable resource fuel, enter the amount of fuel from conventional sources into appropriate conventional fuel categories and enter amount of fuel from renewable resources into appropriate renewable fuel categories (e.g., for 100 gallons of B20 biodiesel blend, 20 gallons would be entered under biodiesel and 80 gallons would be entered under diesel).

Use × Conversion factor = Footprint

1. *Enter use into blue cells in "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.*
3. *Sum Onsite Renewable Energy results for each parameter and enter in green "Onsite Renewable Energy Subtotals" cells.*
4. *Sum Other Onsite Energy results for each parameter and enter in green "Other Onsite Energy Subtotals" cells.*
5. *Sum Other Onsite Contributions results for each parameter and enter in green "Other Onsite Subtotals" cells.*
6. *Sum green cells for each parameter and enter result in green "Onsite Totals" cells.*

ENERGY AND AIR SCENARIO #1 – CALCULATING AND PRESENTING ELECTRICITY GENERATION (SCOPE 2) ENERGY AND AIR METRICS

Contributors to Footprints	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2e	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Grid electricity use	MWh	9.5	6.9	65.6	850	8,075	1.4	13.3	2.4	22.8	0.048	0.456	0.1	0.99
Green pricing or green marketing product purchases	MWh	0												
REC purchase	MWh	0												

See Exhibit 3.17 for how to determine the conversion factors for grid electricity.

Use × Conversion factor = Footprint

1. Enter grid electricity use in MWh into blue cell in "Use" column.
2. Convert MWh use into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.
3. Enter quantity of voluntary purchased renewable electricity in the form of green pricing and green marketing products into the associated blue cell, and document information regarding that product in the table below.
4. Enter quantity of voluntary purchased renewable electricity in the form of RECs into the associated blue cell, and document information regarding that product in the table below.

Description of purchased green pricing or green marketing product	Provider:
	Type of product:
	Type of renewable energy source:
	Date of renewable system installation:
Description of purchased RECs	Provider:
	Type of renewable energy source:
	Date of renewable system installation:

ENERGY AND AIR SCENARIO #1 –CALCULATING AND PRESENTING TRANSPORTATION (SCOPE 3A) ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Conventional Energy														
Diesel use	gal	7,250	0.139	1008	22.5	163125	0.17	1233	0.0054	39	0.0034	25	0.000005	0.038
Gasoline use	gal	1,410	0.124	175	19.6	27636	0.11	155	0.0045	6	0.00054	1	0.000039	0.055
Natural gas use	ccf	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	0.0000084	0.000
Conventional Energy Subtotals				**1,183**		**190,761**		**1,388**		**45**		**25**		**0.093**
Renewable Energy														
Biodiesel use	gal	0	0.127	0	22.3	0	0.20	0	0	0	0.00099	0	NP	
Transportation Totals				**1,183**		**190,761**		**1,388**		**45**		**25**		**0.093**

1. *Enter uses of each material or service into "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factor. Enter result into blue cells in parameter columns.*
3. *Sum Conventional Energy results for each parameter and enter in green "Conventional Energy Subtotals" cells.*
4. *Sum Conventional Energy Subtotals and biodiesel use results for each parameter and enter in green "Transportation" cells.*

Use × Conversion factor = Footprint

ENERGY AND AIR SCENARIO #1 – CALCULATING AND PRESENTING OFFSITE (SCOPE 3B) ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Construction Materials														
Cement	dry-lb	31,200	0.0021	65.52	0.9	28080	0.0018	56.16	0.00105	32.76	0.0000032	0.09828	0.000029	0.9048
Concrete	lb	24,000	0.00041	9.84	0.171	4104	0.00035	8.4	0.00021	5.04	0.00001	0.24	0.00001	0.24
Gravel/sand/clay	lb	30,400	0.000028	0.8512	0.0034	101.84	0.000017	0.5016	0.000015	0.456	0.0000020	0.0608	2.1E-10	6.232E-06
HDPE	lb	0	0.031	0	1.9	0	0.0032	0	0.0041	0	0.00064	0	0.0000034	0
Photovoltaic system (installed)	W	0	0.034	0	4.5	0	0.015	0	0.032	0	0.00063	0	0.0000029	0
PVC	lb	2,700	0.022	59.4	2.6	7020	0.0048	12.96	0.0076	20.52	0.0012	3.24	0.00047	1.269
Stainless Steel	lb	0	0.012	0	3.4	0	0.0075	0	0.012	0	0.0044	0	0.00014	0
Steel	lb	2,000	0.0044	8.8	1.1	2200	0.0014	2.8	0.0017	3.4	0.00056	1.12	0.000067	0.134
Other refined construction materials	lb	0	0.014	0	1.98	0	0.0037	0	0.0053	0	0.0014	0	0.00014	0
Other unrefined construction materials	lb	0	0.000028	0	0.00335	0	0.000017	0	0.000015	0	0.000002	0	2.1E-10	0
Treatment Materials and Chemicals														
Cheese Whey	lb	0	0.0025	0	0.031	0	0.000062	0	0.000033	0	0.000002	0	NP	
Emulsified vegetable oil	lb	500,000	0.0077	3850	3.44	1720000	0.0066	3300	0.0019	950	0.000033	16.5	NP	
Molasses	lb	0	0.0044	0	0.48	0	0.0011	0	0.00024	0	0.0000041	0	NP	
Treatment materials and chemicals	lb	0	0.015	0	1.7	0	0.003	0	0.0065	0	0.00061	0	0.000016	0
Virgin GAC (coal based)	lb	0	0.015	0	5.8	0	0.014	0	0.034	0	0.00078	0	0.0012	0
Fuel Processing														
Biodiesel Produced	gal	0	0.029	0	-16.8	0	0.018	0	0.033	0	0.00082	0	NP	
Diesel Produced	gal	9,150	0.019	169.275	2.7	24705	0.0064	58.56	0.013	118.95	0.00034	3.111	0.00012	1.098
Gasoline Produced	gal	1,940	0.021	40.74	4.4	8536	0.008	15.52	0.019	36.86	0.00052	1.0088	0.00016	0.3104
Natural Gas Produced	ccf	0	0.0052	0	2.2	0	0.0037	0	0.0046	0	0.000072	0	0.0000061	0
Public water	gal x 1000	10,000	0.0092	92	5	50000	0.0097	97	0.0059	59	0.016	160	0.000015	0.15
Offsite Services														
Offsite waste water treatment	gal x 1000	0	0.015	0	4.4	0	0.016	0	0.015	0	NP		NP	
Offsite Solid Waste Disposal	ton	0	0.16	0	25	0	0.14	0	0.075	0	0.4	0	0.0014	0
Offsite Hazardous Waste Disposal	ton	0	0.176	0	27.5	0	0.154	0	0.0825	0	0.44	0	0.00154	0
Offsite Laboratory Analysis	$	120,000	0.0065	780	1	120000	0.0048	576	0.0036	432	0.0004	48	0.00013	15.6

ENERGY AND AIR SCENARIO #1 – CALCULATING AND PRESENTING OFFSITE (SCOPE 3B) ENERGY AND AIR METRICS (continued)

Category	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Resource Extraction for Electricity														
Coal extraction and processing	MWh	1.425	3.1	4.35	180	256.5	0.77	1.09725	0.15	0.21375	0.018	0.02565	NP	
Natural gas extraction and processing	MWh	3.8	1.6	6.20	270	1026	0.18	0.684	13	49.4	0.0071	0.02698	NP	
Nuclear fuel extraction and processing	MWh	1.9	0.16	0.30	25	47.5	0.15	0.285	0.5	0.95	0.0015	0.00285	NP	
Oil extraction and processing	MWh	0	2.3	0	270	0	1.7	0	0.069	0	0.042	0	NP	
Electricity Transmission	MWh													
Transmission and distribution losses	MWh	0.95	10.3	9.785	850	807.5	1.4	1.33	2.4	2.28	0.048	0.0456	0.1	0.095
Off Site Totals				**5,097**		**1,966,884**		**4,131**		**1,712**		**233**		**20**

NP = not provided

Use × Conversion factor = Footprint

1. *Enter uses of each material or service into "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factor. Enter result into blue cells in parameter columns.*
3. *Fuel processing refers to all fuel used, including that for onsite equipment use and transportation.*
4. *Electricity from various resources is obtained from generation mix that is used in Exhibit 3.17 and the resource extraction conversion factors from Exhibit 3.14.*
5. *For electricity transmission, enter 10 percent of the grid electricity used for calculating energy and emissions from electricity generation. The conversion factors are the same as those used for electricity generation, but the energy conversion factor is 10.3 MMBtu/MWh (3.413 MMBtu/MWh for usable electricity plus 6.9 MMBtu/MWh for energy loss due to an assumed 33 percent efficiency at the power plant).*
6. *Resource extraction conversion factors are calculated using values in Exhibit 3.14 and the specified fuel blend for electricity generation.*

ENERGY AND AIR SCENARIO #1 – SUMMARY OF METRICS

Category	Total Energy MMbtus	GHGs lbs CO_2e	NOx lbs	SOx lbs	PM lbs	NOx+SOx+PM lbs	HAPs lbs
Onsite (Scope 1)	**362**	**53,138**	**381**	**12.6**	**6.7**	**400.5**	**0.73**
Electricity Generation (Scope 2)	**65.6**	**8,075**	**13.3**	**22.8**	**0.46**	**36.56**	**0.99**
Transportation (Scope 3a)	**1,183**	**190,761**	**1,388**	**45**	**25**	**1,459**	**0.093**
Other Offsite (Scope 3b)	**5,097**	**1,966,844**	**4,131**	**1,712**	**233**	**6,076**	**20**
Remedy Totals	**6,708**	**2,218,818**	**5,913**	**1,792**	**265**	**7,971**	**22**
GHG Footprint in Tons (1 ton = 2,000 lbs)		**1,109**					

Voluntary Renewable Energy Use	**Unit**	**Quantity**
Onsite energy generation or use	MMBtu	**1,229**
Onsite biodiesel use	MMBtu	**0**
Biodiesel use for transportation	MMBtu	0
Onsite generation or use and biodiesel use	MMBtu	**0**
Renewable electricity purchase	MWh	**0**
REC purchases	MWh	**0**

ENERGY AND AIR SCENARIO #2

Background:

This scenario involves quantifying the energy and air metrics over a 30-year period for an operating P&T system (i.e., construction of the system is not included in the footprint analysis):

- O&M of P&T system that is containing VOC and semi-volatile organic compound (SVOC) plume
- VOC influent is 1,000 micrograms per liter (µg/L), SVOC influent is 600 µg/L
- Combined extraction rate of 200 gpm from three extraction wells
- Onsite photovoltaic system generates 12,000 kWh per year (360,000 kWh over 30 years) of renewable energy that is used on site
- 50 feet to water table
- Treatment with air stripping, GAC treatment of air stripper off-gas, and GAC treatment of air stripper effluent
- GAC is 95 percent efficient for VOC removal and untreated VOCs are HAPs (according to Exhibit 3.15, approximately 26,000 pounds of HAPs are emitted on site over 30 years)
- Treated water is reinjected
- Semi-annual sampling at 50 points for 30 years
- All samples analyzed for VOCs and SVOCs
- Estimated remedy duration of 30 years

Screening:

The step identifies the largest contributors to the energy and onsite air metrics and develops screening limits for use in identifying important potential contributors to the footprint and providing the rationale for excluding minor contributors.

Onsite NOx+SOx+PM Emission Screening

The only source of onsite emissions is expected to be the low-flow sampling equipment.

Onsite HAP Emission Screening

No additional sources beyond those counted in the NOx+SOx+PM screening.

Total Energy Screening

The screening limit is based on the higher of a magnitude based limit of 100 screening units or a percentage-based limit equal to 1 percent of the largest contributor to the total energy footprint. Because no appreciable renewable energy is used, it is assumed that the total energy screening process reasonably screens items/activities for the total air emissions metrics. Based on professional judgment, the largest total energy contributor is the electricity (204,000 kWh per year for 30 years, which translates to 6,120,000 kWh). Accounting for the electricity generated from the onsite photovoltaic system, this translates to (6,120,000 kWh – 360,000 kWh = 5,760,000 kWh). According to Exhibit 3.2, this translates to 5,760,000 screening units. Therefore, the percentage based screening unit is 57,600 (57,600,000 × 1 percent). Items or activities associated with the remedy that would equate to less than 61,200 screening units will be omitted.

The following table presents the primary items/activities associated with the remedy and preliminary engineering estimates regarding the quantities of those items/activities. Screening unit conversions from Exhibit 3.2 are applied to calculate the number of screening units, and a decision to include or exclude each item/activity is stated. Items exceeding the screening limit of 57,600 will be quantified more accurately during footprint calculation. As noted below, some items that are available from the materials or waste footprint or for the onsite emissions footprint are included even if the values are below the screening limit because the information is already available.

Item	Quantity	Screening Units	Limit = 57,600 Decision
Electricity	5,760,000 kWh	5,760,000	Include
Laboratory analysis (GW monitoring)	>$100,000	>100,000	Include
Laboratory analysis (process)	>$100,000	>100,000	Include
GAC	>100,000 lbs	>100,000	Include
GAC transport	>100,000 ton-miles	>33,000	Include
Operator and sampling tech. transport	>100,000 miles	>50,000	Include
Sampling equip.	Used for onsite NOx+SOx+PM footprint		Include
Sampling materials	<1,000 lbs	<1,000	Exclude

The engineering estimates for GAC transport and personnel transport were not sufficiently detailed to confirm they would be below the screening limit. Therefore, they are included in the footprint calculation step, and will be included in the footprint analysis.

Footprint Calculation:

This part of the footprint calculation follows Step 5: Quantify Energy and Air Metrics. Step 5 is comprised of 3 parts.

Part 1: Inventory Remedy Travel, Equipment Use, Materials, and Offsite Services

The following are items associated with remedy operation that passed the screening process:

- 7,000 pounds of GAC per year for 30 years (210,000 pounds or 105 tons)
  - 1,000 miles round-trip distance from regeneration facility to local warehouse
  - 100 miles round-trip distance from warehouse to site, two trips per year (60 trips total)

- Estimated 2000 operator/technician/oversight visits over next 30 years
  - Travel in light-duty trucks
  - Roundtrip daily commute is 40 miles

- Pumps and blowers powered by onsite electricity for 250,000 hours over next 30 years
  - Typical electrical bill is 204,000 kWh per year
    - Three 3 HP extraction pumps with VFDs
    - One 3 HP transfer pump with VFD
    - One 3 HP effluent pump with VFD
    - One 10 HP blower with VFD

- Site located in Colorado, generation mix not available from utility, use eGRID Subregion RMPA fuel blend for electricity generation is as follows:
  - 71.7 percent coal
  - 19.5 percent natural gas
  - 7.4 percent hydro
  - 1.4 percent wind

- Renewable Energy Certificates each year to offset all grid electricity use
  - RECs purchased from wind facility located in RMPA (Colorado – Eastern Wyoming) Subregion constructed in 2005

- Process sampling, 3 samples for VOCs ($100 /sample) and SVOCs ($200/sample) each month for 30 years

The following are items associated with long-term monitoring that passed the screening process:

- 500 trips to site by sampling team in one light-duty truck (100 miles round trip)
- 3,000 samples collected and analyzed for VOCs at $100 per sample and SVOCs at $200 per sample (includes cost of QA samples)
- Sampling requires a total of 6,000 hours of 2.5 HP gasoline compressors
- Purge water disposed of in treatment plant

Part 2: Energy Inventory

This step converts the above transportation and equipment use into fuel use and converts electrical equipment use into electricity use. For scenario expediency, energy inventory for three tasks are combined. A formal analysis might split the inventory into three tasks: construction, O&M, and long-term monitoring.

Fuel Use for Personnel Transportation

Personnel	Trips	Roundtrip Distance (miles)	Total Distance (miles)	Vehicle Type	Fuel Efficiency	Fuel Use (gals)
Diesel						
None						
Gasoline						
Operator	2000	40	80,000	Truck	17 mpg	4,706
Sampling techs	500	100	50,000	Truck	17 mpg	2,941
					Total Gasoline	7,647

Fuel Use for Equipment Use

Equipment Type	Hours	Fuel Consumption Rate (gal/hr)	Fuel Use (gals)
Diesel			
None			
Gasoline			
Sampling compressors	6000	0.14	840

Fuel Use for Materials, Equipment, and Waste Transport

Equipment	Tons	Travel Distance (miles)	Vehicle Type	Fuel Efficiency	Fuel Use (gals)
Diesel					
GAC facility to warehouse	105	1,000	Truck	0.029 gptm	3,045
GAC warehouse to site	105	60 x 100	Truck	6 mpg	1,000
				Total	4,045

gptm = gallons per ton-mile

Onsite Electricity Use

Equipment	HP	% Full Load	Motor Efficiency	kW	Hours	kWh
Extraction pumps	9	80%	75%	9.6	250,000	2,160
Two process pumps	6	80%	75%	6.4	250,000	5,760
One air stripper blower	10	80%	75%	10.7	250,000	3,780
				Calculated Total		**6,675,000**
			Total from Electric Bills			**6,120,000**

Calculated and actual values are close. Use actual value from electric bills and use calculated values to help understand breakdown of electricity use.

Part 3: Convert to Energy and Air Metrics

See accompanying tables

Findings:

Electricity generation accounts for approximately 40 percent of the total energy use but approximately 70 percent of the GHG emissions because a large percentage of the electricity is generated from the combustion of coal. Resource extraction for electricity generation and electricity transmission losses are also large contributors to energy use and air emissions. The onsite generation and use of renewable energy provides a favorable metric related to the voluntary use of renewable energy and avoids some of the emissions associated with the electricity generation. The purchase of RECs provides another favorable metric related to voluntary use of renewable energy. Although this methodology focuses on air emissions before potential reductions from REC purchases, some EPA programs and federal guidance supports air emission reductions associated with a REC purchase.

Other significant contributors to the energy and air emissions metrics are laboratory analysis, GAC manufacturing, and various aspects of transportation. Footprint reduction would likely focus on reducing electricity use, potentially identifying an alternative source of electricity, optimization of GAC use, and GAC transportation.

ENERGY AND AIR SCENARIO #2 – DETERMINING FOOTPRINT CONVERSION FACTORS FOR GRID ELECTRICITY BASED ON UTILITY OR LOCATION

Power Content from eGRID RPMA Subregion

Energy Source	**Percentage of Power Mix Delivered to Customers**
Coal	71.7%
Natural gas	19.5%
Oil	0%
Nuclear	0%
Hydroelectric	7.4%
Biomass	0%
Geothermal	0%
Wind	1.4%
Solar	0%

Converting Utility Resource Mix to Footprint Conversion Factors

Type	**% of Total Used**	**Energy (MMbtu/MWh)**		**CO_2e (lbs/MWh)**		**NOx (lbs/MWh)**		**SOx (lbs/MWh)**		**PM (lbs/MWh)**		**HAPs (lbs/MWh)**	
		Full Load	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**	**Full Load**	**Adj. by %**
Conventional Energy													
Coal	71.7%	6.9	4.947	2200	1577	6	4.3	15	10.8	0.092	0.06596	0.66	0.47322
Natural Gas	19.5%	6.9	1.346	1300	254	1.1	0.21	0.0066	0.014	0.08	0.0156	0.025	0.00488
Oil	0%	6.9	0	1800	0	2.2	0	2.8	0	0.13	0	0.066	0
Nuclear	0%	6.9	0	0	0	0	0	0	0	0	0	0	0
Renewable Energy													
Biomass	0%	6.9	0	0	0	1.4	0	0.65	0	0.084	0	5.3E-6	0
Geothermal	0%	6.9	0	0	0	0	0	0	0	0	0	0	0
Hydroelectric	7.4%	6.9	0.511	0	0	0	0	0	0	0	0	0	0
Solar	0%	6.9	0	0	0	0	0	0	0	0	0	0	0
Wind	1.4%	6.9	0.0966	0	0	0	0	0	0	0	0	0	0
Total	**100%**		**6.9**		**1831**		**4.5**		**10.8**		**0.081**		**0.47**

Full load emission values for each fuel type obtained from www.nrel.gov/lci.
All values do not include energy and emissions for resource extraction or for transmission losses, which are counted in Scope 3.
Energy conversion factors exclude the energy contained in the MWh of electricity used by the remedy to avoid double counting of Scope 1 energy use.
For simplicity, energy conversion factors are assumed to be 6.9 MMBtu per MWh (equivalent to 33 percent efficiency) for all energy sources.

ENERGY AND AIR SCENARIO #2 – CALCULATING AND PRESENTING ONSITE ENERGY AND AIR METRICS

Contributors to Footprints	Units	Use	Energy		GHGs		NOx		SOx		PM		HAPs	
			Conv. Factor	MMBtus	Conv. Factor	lbs CO_2e	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs	Conv. Factor	lbs
Onsite Renewable Energy														
Electricity generated on site by renewable resources	MWh	360	3.413	1,229										
Landfill gas combusted on site	ccf CH_4	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	8.4E-06	0
Biodiesel used on site	gal	0	0.127	0	22.3	0	0.20	0	0	0	0.00099	0	NP	
Other onsite renewable energy use #1		0		0		0		0		0		0		0
Other onsite renewable energy use #2		0		0		0		0		0		0		0
Onsite Renewable Energy Subtotals				**1,229**		**0**		**0**		**0**		**0**		**0**
Other Onsite Energy														
Grid electricity	MWh	5,760	3.413	19,659										
Onsite diesel use	gal	0	0.139	0	22.5	0	0.17	0	0.0054	0	0.0034	0	0.0003	0
Onsite gasoline use	gal	840	0.124	104.16	19.6	16464	0.11	92.4	0.0045	3.78	0.00054	0.4536	0.0003	0.252
Onsite natural gas use	ccf	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	8.4E-06	0
Other forms of onsite energy use #1		0		0		0		0		0		0		0
Other forms of onsite energy use #2		0		0		0		0		0		0		0
Other Onsite Energy Subtotals				**19,763**		**16464**		**92.4**		**3.78**		**0.4536**		**0.252**
Other Onsite Emissions Contributions														
Onsite HAP process emissions	lb	26,000											1	26,000
Onsite GHG emissions	lb	0			1	0								
Onsite carbon storage	lb	0			-1	0								
GHG reductions by combusting onsite landfill methane	lb	0			-20	0								
Other onsite contributions		0				0		0		0		0		0
Other Onsite Subtotals				**0**		**0**		**0**		**0**		**0**		**0**
Onsite Totals				**20,992**		**16,464**		**92**		**3.8**		**0.45**		**26,000**

TBD = to be determined. Values in parentheses are negative values. Energy for electricity is only that energy of that electricity and not the energy required to generate the electricity.

ccf CH_4 = 100 cubic feet of methane. Obtained by multiplying total volume of landfill gas in ccf by the percentage of the gas that is methane.

Energy associated with onsite generation of electricity is assumed to be 10.3 MMBtu/MWh (3.413 MMBtu/MWh for usable electricity plus 6.9 MMBtu/MWh for energy loss due to an assumed 33 percent efficiency). 33 percent efficiency is consistent with Exhibit 3.17.

Energy associated with onsite use of grid electricity is 3.413 MMBtu/MWh of electricity because the energy loss associated with 33 percent efficiency is counted in Scope 2 energy calculations

If fuel is a blend of conventional fuel and renewable resource fuel, enter the amount of fuel from conventional sources into appropriate conventional fuel categories and enter amount of fuel from renewable resources into appropriate renewable fuel categories (e.g., for 100 gallons of B20 biodiesel blend, 20 gallons would be entered under biodiesel and 80 gallons would be entered under diesel).

Use × Conversion factor = Footprint

1. *Enter use into blue cells in "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.*
3. *Sum Onsite Renewable Energy results for each parameter and enter in green "Onsite Renewable Energy Subtotals" cells.*
4. *Sum Other Onsite Energy results for each parameter and enter in green "Other Onsite Energy Subtotals" cells.*
5. *Sum Other Onsite Contributions results for each parameter and enter in green "Other Onsite Subtotals" cells.*
6. *Sum green cells for each parameter and enter result in green "Onsite Totals" cells.*

ENERGY AND AIR SCENARIO #2 – CALCULATING AND PRESENTING ELECTRICITY GENERATION ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Contributors to Footprints	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2e**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Grid electricity use	MWh	5,760	6.9	39,744	1831	10,546,560	4.5	25,920	10.8	62,208	0.081	467	0.47	2,707
Green pricing or green marketing product purchases	MWh	0												
REC purchase	MWh	5,760												

See Exhibit 3.17 for how to determine the conversion factors for grid electricity.

Use × Conversion factor = Footprint

1. Enter grid electricity use in MWh into blue cell in "Use" column.
2. Convert MWh use into indicated units of each parameter by multiplying use by the indicated conversion factors. Enter result into blue cells in parameter columns.
3. Enter quantity of voluntary purchased renewable electricity in the form of green pricing and green marketing products into the associated blue cell, and document information regarding that product in the table below.
4. Enter quantity of voluntary purchased renewable electricity in the form of RECs into the associated blue cell, and document information regarding that product in the table below.

Description of purchased green pricing or green marketing product	Provider:
	Type of product:
	Type of renewable energy source:
	Date of renewable system installation:
Description of purchased RECs	Provider: **REC Seller, LLP**
	Type of renewable energy source: **Wind**
	Date of renewable system installation: **2005**

ENERGY AND AIR SCENARIO #2 –CALCULATING AND PRESENTING TRANSPORTATION ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Conventional Energy														
Diesel use	gal	4,045	0.139	562	22.5	91013	0.17	688	0.0054	22	0.0034	14	0.000005	0.021
Gasoline use	gal	7,647	0.124	948	19.6	149881	0.11	841	0.0045	34	0.00054	4	0.000039	0.298
Natural gas use	ccf	0	0.103	0	13.1	0	0.01	0	0.0000063	0	0.00076	0	0.0000084	0.000
Conventional Energy Subtotals				**1,510**		**240,894**		**1,529**		**56**		**18**		**0.319**
Renewable Energy														
Biodiesel use	gal	0	0.127	0	22.3	0	0.20	0	0	0	0.00099	0	NP	
Transportation Totals				**1,510**		**240,894**		**1,529**		**56**		**18**		**0.319**

1. *Enter uses of each material or service into "Use" column in indicated units.*
2. *Convert uses into indicated units of each parameter by multiplying use by the indicated conversion factor. Enter result into blue cells in parameter columns.*
3. *Sum Conventional Energy results for each parameter and enter in green "Conventional Energy Subtotals" cells.*
4. *Sum Conventional Energy Subtotals and biodiesel use results for each parameter and enter in green "Transportation" cells.*

Use × Conversion factor = Footprint

ENERGY AND AIR SCENARIO #2 –CALCULATING AND PRESENTING OFFSITE ENERGY AND AIR METRICS

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Construction Materials														
Cement	dry-lb	0	0.0021	0	0.9	0	0.0018	0	0.00105	0	0.0000032	0	0.000029	0
Concrete	lb	0	0.00041	0	0.171	0	0.00035	0	0.00021	0	0.00001	0	0.00001	0
Gravel/sand/clay	lb	0	0.000028	0	0.0034	0	0.000017	0	0.000015	0	0.0000020	0	2.1E-10	0
HDPE	lb	0	0.031	0	1.9	0	0.0032	0	0.0041	0	0.00064	0	0.0000034	0
Photovoltaic system (installed)	W	0	0.034	0	4.5	0	0.015	0	0.032	0	0.00063	0	0.0000029	0
PVC	lb	0	0.022	0	2.6	0	0.0048	0	0.0076	0	0.0012	0	0.00047	0
Stainless Steel	lb	0	0.012	0	3.4	0	0.0075	0	0.012	0	0.0044	0	0.00014	0
Steel	lb	0	0.0044	0	1.1	0	0.0014	0	0.0017	0	0.00056	0	0.000067	0
Other refined construction materials	lb	0	0.014	0	1.98	0	0.0037	0	0.0053	0	0.0014	0	0.00014	0
Other unrefined construction materials	lb	0	0.000028	0	0.00335	0	0.000017	0	0.000015	0	0.000002	0	2.1E-10	0
Treatment Materials and Chemicals														
Cheese Whey	lb	0	0.0025	0	0.031	0	0.000062	0	0.000033	0	0.000002	0	NP	
Emulsified vegetable oil	lb	0	0.0077	0	3.44	0	0.0066	0	0.0019	0	0.000033	0	NP	
Molasses	lb	0	0.0044	0	0.48	0	0.0011	0	0.00024	0	0.0000041	0	NP	
Treatment materials and chemicals	lb	210000	0.015	3150	1.7	350700	0.003	630	0.0065	1365	0.00061	128.1	0.000016	3.36
Virgin GAC (coal based)	lb	0	0.015	0	5.8	0	0.014	0	0.034	0	0.00078	0	0.0012	0
Fuel Processing														
Biodiesel Produced	gal	0	0.029	0	-16.8	0	0.018	0	0.033	0	0.00082	0	NP	
Diesel Produced	gal	4,045	0.019	74.8325	2.7	10921.5	0.0064	25.888	0.013	52.585	0.00034	1.3753	0.00012	0.4854
Gasoline Produced	gal	8,487	0.021	178.227	4.4	37342.8	0.008	67.896	0.019	161.253	0.00052	4.41324	0.00016	1.35792
Natural Gas Produced	ccf	0	0.0052	0	2.2	0	0.0037	0	0.0046	0	0.000072	0	0.0000061	0
Public water	gal x 1000	0	0.0092	0	5	0	0.0097	0	0.0059	0	0.016	0	0.000015	0
Offsite Services														
Offsite waste water treatment	gal x 1000	0	0.015	0	4.4	0	0.016	0	0.015	0	NP		NP	
Offsite Solid Waste Disposal	ton	0	0.16	0	25	0	0.14	0	0.075	0	0.4	0	0.0014	0
Offsite Haz. Waste Disposal	ton	0	0.176	0	27.5	0	0.154	0	0.0825	0	0.44	0	0.00154	0
Offsite Laboratory Analysis	$	1,100,000	0.0065	7150	1	1100000	0.0048	5280	0.0036	3960	0.0004	440	0.00013	143

ENERGY AND AIR SCENARIO #2 –CALCULATING AND PRESENTING OFFSITE ENERGY AND AIR METRICS (continued)

			Energy		GHGs		NOx		SOx		PM		HAPs	
Category	**Units**	**Use**	**Conv. Factor**	**MMBtus**	**Conv. Factor**	**lbs CO_2**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**	**Conv. Factor**	**lbs**
Resource Extraction for Electricity														
Coal extraction and processing	MWh	4,130	3.1	12,803	180	743,386	0.77	3,180	0.15	619	0.018	74	NP	
Natural gas extraction and processing	MWh	1,123	1.6	1,797	270	303,264	0.18	202	13	14,602	0.0071	8	NP	
Nuclear fuel extraction and processing	MWh	0	0.16	0	25	0	0.15	0	0.5	0	0.0015	0	NP	
Oil extraction and processing	MWh	0	2.3	0	270	0	1.7	0	0.069	0	0.042	0	NP	
Electricity Transmission	MWh													
Transmission and distribution losses	MWh	576	10.3	5,933	1831	1,054,656	4.5	2,592	10.8	6,221	0.081	47	0.47	271
Off Site Totals				**31,086**		**3,619,224**		**11,978**		**26,981**		**703**		**419**

ENERGY AND AIR SCENARIO #2 – SUMMARY OF METRICS

Category	Total Energy MMbtus	GHGs lbs CO_2e	NOx lbs	SOx lbs	PM lbs	NOx+SOx+PM lbs	HAPs lbs
Onsite (Scope 1)	**20,992**	**16,464**	**92**	**3.8**	**0.45**	**96**	**26,000**
Electricity Generation (Scope 2)	**39,744**	**10,546,560**	**25,920**	**62,208**	**467**	**88,595**	**2,707**
Transportation (Scope 3)	**1,510**	**240,894**	**1,529**	**56**	**18**	**1,603**	**0.319**
Other Offsite (Scope 3)	**31,086**	**3,619,224**	**11,978**	**26,981**	**703**	**39,662**	**419**
Remedy Totals	**93,332**	**14,423,142**	**39,519**	**89,249**	**1,188**	**129,956**	**29,126**
GHG Footprint in Tons (1 ton = 2,000 lbs)		**7,212**					

Voluntary Renewable Energy Use	**Unit**	**Quantity**
Onsite energy generation or use	MMBtu	**1,229**
Onsite biodiesel use	MMBtu	**0**
Biodiesel use for transportation	MMBtu	0
Onsite generation or use and biodiesel use	MMBtu	**1,229**
Renewable electricity purchase	MWh	**0**
REC purchases	MWh	**5,760**