USER GUIDE

UG-NAVFAC EXWC-EV-1502

SiteWise™ Version 3.1
User Guide

September 2015

Distribution Statement A: Approved for public release; distribution is unlimited.

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14. ABSTRACT

SiteWise™ is designed to calculate the environmental footprint of remedial alternatives generally used by the industry. The tool is a series of Excel sheets and currently provides a detailed baseline assessment of several quantifiable sustainability metrics including: greenhouse gases (GHGs); energy usage; criteria air pollutants that include sulfur oxides (SOx), oxides of nitrogen (NOx), and particulate matter (PM); Water Usage; resource consumption; and accident risk. The tool has been updated to include incremental cost due to footprint reduction activities. SiteWise™ has been developed by Battelle, US Navy and US Army Corps jointly. SiteWise™ has also been updated to include life cycle impacts for all global impacts of all remedial activities included in the tool. SiteWise™ tool can be applied at remedy selection, design, or implementation stage.

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EXECUTIVE SUMMARY

SiteWise™ is designed to calculate the environmental footprint of remedial alternatives generally used by the industry. The tool is a series of Excel sheets and provides a detailed baseline assessment of several quantifiable sustainability metrics including: greenhouse gases (GHGs); energy usage; electricity usage from renewable and non-renewable sources; criteria air pollutants that include sulfur oxides (SOx), oxides of nitrogen (NOx), and particulate matter (PM); water usage; resource consumption; and accident risk. The tool has been updated to include incremental cost due to footprint reduction activities. SiteWise™ has been jointly developed by Battelle, U.S. Navy and U.S. Army Corps of Engineers (USACE) and is available on the Green and Sustainable Remediation (GSR) Web page located on the NAVFAC Environmental Restoration and Base Realignment and Closure (BRAC) (ERB) Web site. SiteWise™ Version 3.1 has been modified to address sediments remediation specific activities.

The assessment is carried out using a building block approach where every remedial alternative is first broken down into modules that can represent generic components of an alternative or mimic the remedial phases in most remedial actions, including remedial investigations (RIs), remedial action constructions (RACs), remedial action operation (RAO), and long-term monitoring (LTM). Once broken down into various modules, the footprint of each module is calculated individually. The different footprints are then combined to estimate the overall footprint of the remedial alternative. This building block approach reduces redundancy in the sustainability evaluation and facilitates the identification of specific activities that have the greatest environmental footprint.

SiteWise™ can be applied at the remedy selection, design, or implementation stage. The building block approach of the tool makes it flexible enough to be used at the remedy optimization stage as well.

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ACRONYMS AND ABBREVIATIONS

BRAC	base realignment and closure
CH_4	methane
CMS	corrective measures study
CO_2	carbon dioxide
ESTCP	Environmental Security Technology Certification Program
FS	feasibility study
GHG	greenhouse gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GSR	green and sustainable remediation
ICE	internal combustion engine
LTM	long-term monitoring
N_2O	nitrous oxide
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NOx	nitrogen oxide
NREL	National Renewable Energy Laboratory
PM	particulate matter
PV	photovoltaic
PVC	polyvinyl chloride
RAC	remedial action construction
RA-O	remedial action operation
RI	remedial investigation
SOx	sulfur oxide
USACE	U.S. Army Corps of Engineers
U.S. EPA	U.S. Environmental Protection Agency
VFD	variable frequency drive

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 General Description of the SiteWise™ Tool

SiteWise™ is a stand-alone tool developed jointly by the U.S. Navy, the U.S. Army, the U.S. Army Corps of Engineers (USACE), and Battelle that assesses the remedy footprint of a remedial alternative/technology in terms of a consistent set of metrics, including: (1) greenhouse gas (GHG) emissions; (2) energy use (total energy use and electricity from renewable and non-renewable sources); (3) air emissions of criteria pollutants (total emissions and onsite emissions) including nitrogen oxide (NOx), sulfur oxide (SOx), and particulate matter (PM); (4) water consumption; (5) resource consumption (landfill space and top soil consumption); and (6) worker safety (risk of fatality, injury and lost hours). The assessment is carried out using a building block approach where every remedial alternative is first broken down into modules that can represent generic components of an alternative or mimic the remedial phases in most remedial actions, including remedial investigations (RIs), feasibility studies (FS), corrective measures studies (CMS), remedial action constructions (RACs), remedial action operations (RA-Os), and long-term monitoring (LTM). Once broken down into various modules, the footprint of each module is individually calculated. The different footprints are then combined to estimate the overall footprint of the remedial alternative. This building block approach reduces redundancy in the sustainability evaluation and facilitates the identification of specific activities that have the greatest remedy footprint.

The inputs that need to be considered include: (1) production of material required by the activity; (2) transportation of the required materials, equipment and personnel to and from the site; (3) all on-site activities to be performed (e.g., equipment operation); and (4) management of the waste produced by the activity. Materials usage is considered only for materials that are completely consumed (referred to hereafter as consumables) and cannot be reused during the application of the alternative. For example, the footprint of polyvinyl chloride (PVC) for well casing or piping is considered because it is a consumable used for well installation or transfer pipe. However, the complete remedy footprint for production of equipment used, or production of the vehicles used for transportation, is not considered.

SiteWise™ can be downloaded from the Green and Sustainable Remediation (GSR) Web page on the NAVFAC Environmental Restoration and Base Realignment and Closure (BRAC) Web site:

http://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/gsr.html

1.2 SiteWise™ Application

SiteWise™ conducts a comparative analysis of several different remedial alternatives, making it well suited for use during the remedy selection phase. The tool can also be used to conduct an analysis of a planned remedy during the design phase or the operation and/or LTM of an existing remedy, making it useful as part of optimization studies. The tool can be applied during the development of the RI work plan to determine the footprint of the RI. In addition, SiteWise™ can be applied to any part of a remedy as a way to aid in decision making.

The objectives of using SiteWise™ are to allow GSR metrics to be considered during remedy selection and to identify the aspects of a particular remedy that cause the greatest footprint for each metric. This information allows remediation professionals to focus footprint reduction methods on those aspects of the remedy that can have the greatest impact.

1.3 SiteWise™ Architecture

SiteWise™ is based on the 2007 Microsoft® Excel platform. The tool includes eight different Excel files as shown in Figure 1-1. The tool can be downloaded from the NAVFAC GSR web page as a zip file.[1] Once downloaded, the SiteWise™ files should be extracted into a folder specifically dedicated to the tool. The folder will contain seven worksheet files, which together make up the SiteWise™ tool. The user should never change the file names of the seven files (Figure 1-1) that constitute the SiteWise™ tool.

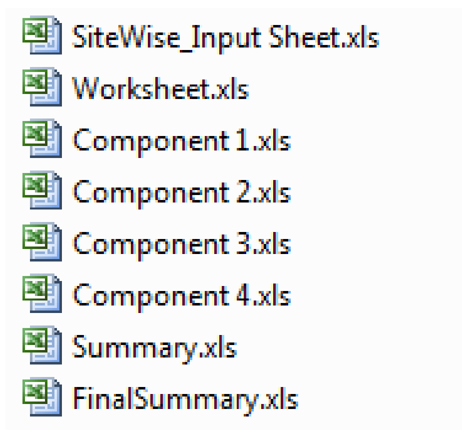


Figure 1-1. SiteWise™ Files

These files are described below.

Input Sheet: The input sheet is what is opened first and is the location where all data are entered. The input sheet has a tab for each of the four components of a remedy, which may be renamed to typical remedial phases: RI, FS, CMS, RAC, RA-O, and LTM. It also includes the look-up table as a tab. The lookup table contains referenced data that are used as the basis for calculating the GSR metrics. The Input Sheet also includes a Calculations tab, where emissions resulting from custom electricity profiles and material requirements for groundwater monitoring wells may be calculated. Lastly, it includes a Footprint Reduction tab, where emissions reduction technologies can be applied to the calculation of the remedy footprint.

[1] Some U.S. Department of Defense users have had problems with Microsoft® Excel crashing when opening and/or closing the program, with the program getting stuck in an endless loop of closing and reopening. The ApproveIt Desktop software, which is an add-on used to digitally sign electronic documents, has been found to be the main cause. This issue is specific to a user profile on the computer, meaning that a particular user can have problems while another does not. Uninstalling ApproveIt, clearing the residual directories and files associated with ApproveIt, and reinstalling ApproveIt has proven to successfully resolve this issue.

Worksheet: The Worksheet includes calculations tabs, where emissions resulting from custom electricity profiles and material requirements for groundwater monitoring wells can be calculated. These can be used interchangeably with the Calculations tab of the Input Sheet, although the Worksheet allows for a vast number of electricity profiles or well types to be calculated and documented.

Calculation Sheets: The worksheets representing Component 1, Component 2, Component 3, and Component 4 are referred to hereafter as calculation sheets. These are linked to the input sheet such that they receive the data that were entered by the user into the input sheet. The calculation sheets contain activities related to material production, transportation of personnel and materials, equipment use (pumps, electrical equipment, earthwork, and other miscellaneous equipment), sediment remedy activities, and residual handling. All activities are set up as different tabs of a worksheet. The calculation sheets are not for data entry and are available to provide the user with an option to go into the backend of the tool to see how calculations are being done by SiteWise™ (discussed further in Section 5.6). In addition, reviewing the calculation sheets allows the user to obtain detailed information about what specific aspects of the remedy are contributing the most to the remedy footprint. For example, the user can see the footprint associated with each consumable and each piece of equipment.

Summary: The summary sheet can be used to review outputs from the different calculation sheets. The summary sheet also has an extra tab that compares the components of the remedial alternative and helps identify the activities that result in the greatest footprint. Summary sheets of the different remedial alternatives are linked to the final summary sheet that compares the different remedial alternatives.

Final Summary: The final summary file in the tool is for comparative analysis of multiple alternatives inputted into the tool.

1.4 Summary of Changes from SiteWise™ Version 3 to Version 3.1

SiteWise™ Version 3.1 has been modified to address sediment-specific remediation activities, including the following specific additions:

Under the heading of "Material Production" in the input sheet for each component:

- Impacts from silt curtain materials are now accounted for in a separate calculations module. Table 1d has been added to the Look-up Table tab that includes information on the assumed types and quantities of materials used in silt curtain construction. The user is required to enter the length and the depth of the silt curtain.

Under the heading of "Equipment Use" in the input sheet for each component:

- Impacts from sediment dredging and related ancillary activities are now accounted for in a separate calculations module. Table 3f has been added to the Look-up Table tab that includes information on the assumed production rate, specifications, and operational impacts of a variety of typical dredges.

- Impacts from the management of sediment, including staging and drying processes, are accounted for in a separate calculations module. Table 3b in the Look-up Table tab has been extended to include impacts from the operation of a variety of typical crawler cranes.
- Impacts from the capping of sediment and related ancillary activities are accounted for in a separate calculations module. Table 3f has been added to the Look-up Table tab that includes information on the assumed production rate, specifications, and operational impacts of a variety of typical dredges and hopper barges. The impact from the production of the capping material must be accounted for separately under the "Bulk Material Quantities" module under the "Material Production" header. This header has not been modified, but the user can use this module to input the amount of mass (either as a volume or mass) and select the material type for the drop-down menu. The user could either select a representative material from the drop-down menu such as sand or a custom material. If a custom material is selected, the user would then be required to input the footprint factors for that custom material into Table 1c in the lookup table.
- Impacts from the operation of watercraft are accounted for in a separate calculations module. Table 3e has been added to the Look-up Table tab that includes information on the assumed specifications and operational impacts of typical watercraft.

In addition to adding features related to sediments remediation, the following modifications have been made:

- SiteWise™ Version 3.1 has been designed for backwards-compatibility with Version 2 and Version 3 input sheets.
- Dialogue during the generation of an alternative using the Input Sheet has been adjusted for clarity. The dialogue box will now indicate that the tool is ready to generate a new alternative if the user has edited an input since the last alternative was run.
- Figures in the Summary and Final Summary sheets were formatted for improved presentation and printing.
- Under the heading of "Equipment Use" in the input sheet for each component, the impacts from the operation of diesel equipment can now be accounted for in a per-operational hour basis in a separate calculations module.

2.0 GETTING STARTED

SiteWise™ was developed using Microsoft® Excel 2007. To conduct an assessment, data need to be entered into the input sheet. Therefore, the **first step in using SiteWise™** is to **copy the tool into a new project folder** to reduce the chances of changing the original version of the tool. Once copied into the new project folder, the user can start entering data into an input sheet for one of the remedial alternatives. As soon as an input sheet is opened, all macros should be enabled before the data are entered (Figures 2-1 and 2-2) to allow for all functionalities of the tool to work. Macros should be enabled in all files of the tool and not just the input sheet. The user can also choose to open the Trust Center (Figure 2-2) and select to add a new location in the Trusted Locations tab of the prompt. By adding the parent directory that includes the SiteWise™ project folder to trusted locations, all macros should be enabled automatically. If macros are still not automatically enabled after following these steps, the user should review the Trust Center settings and finally consult an information technology specialist if this issue is not resolved. As soon as the macros are enabled in the tool, the user will also see a welcome screen window with a disclaimer (Figure 2-3).

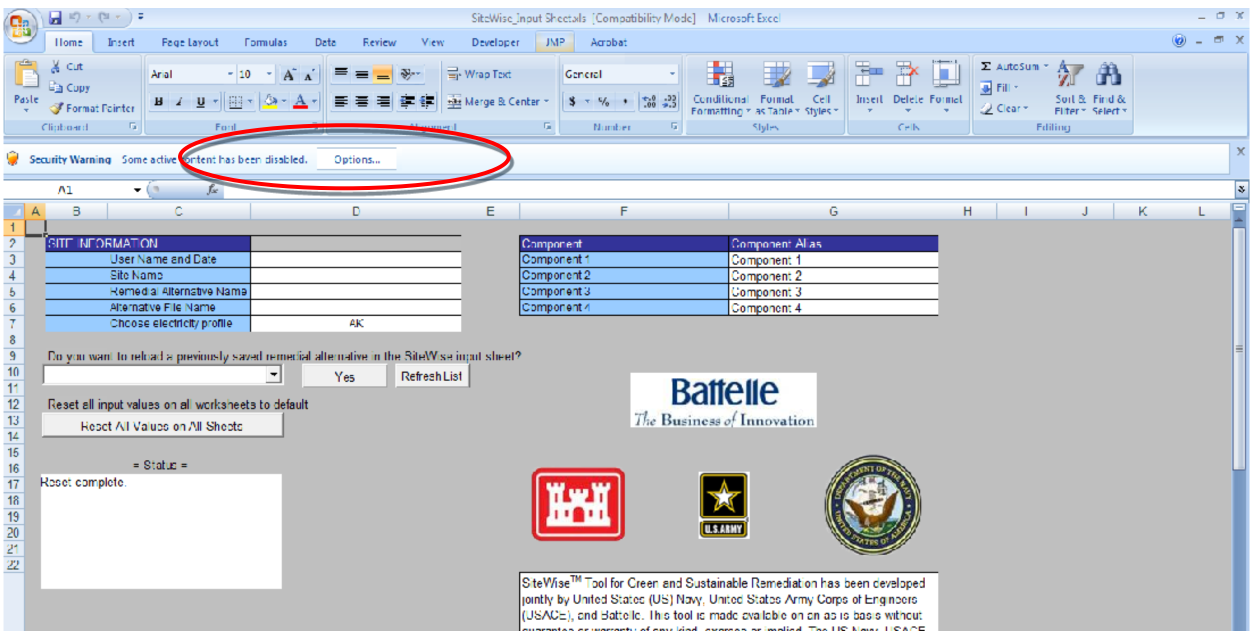
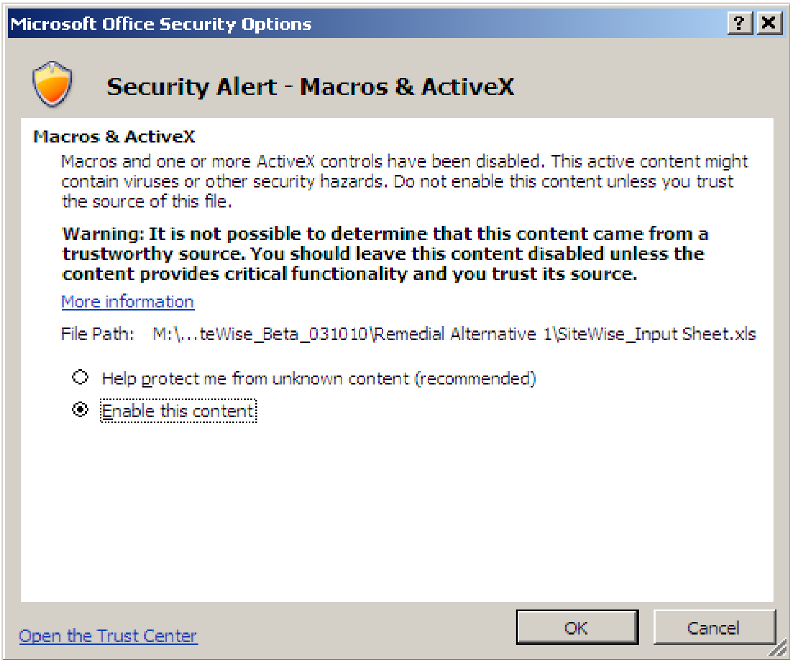


Figure 2-1. Enable the Macros in the Input Sheet



Please click on 'Enable this content' for the tool to be functioning properly whenever a security alert/warning appears while running SiteWise™. Alternatively, select to "Open the Trust Center" to add the project folder location to trusted locations.

Figure 2-2. The Security Alert that Pops Up for Enabling Macros in the Tool

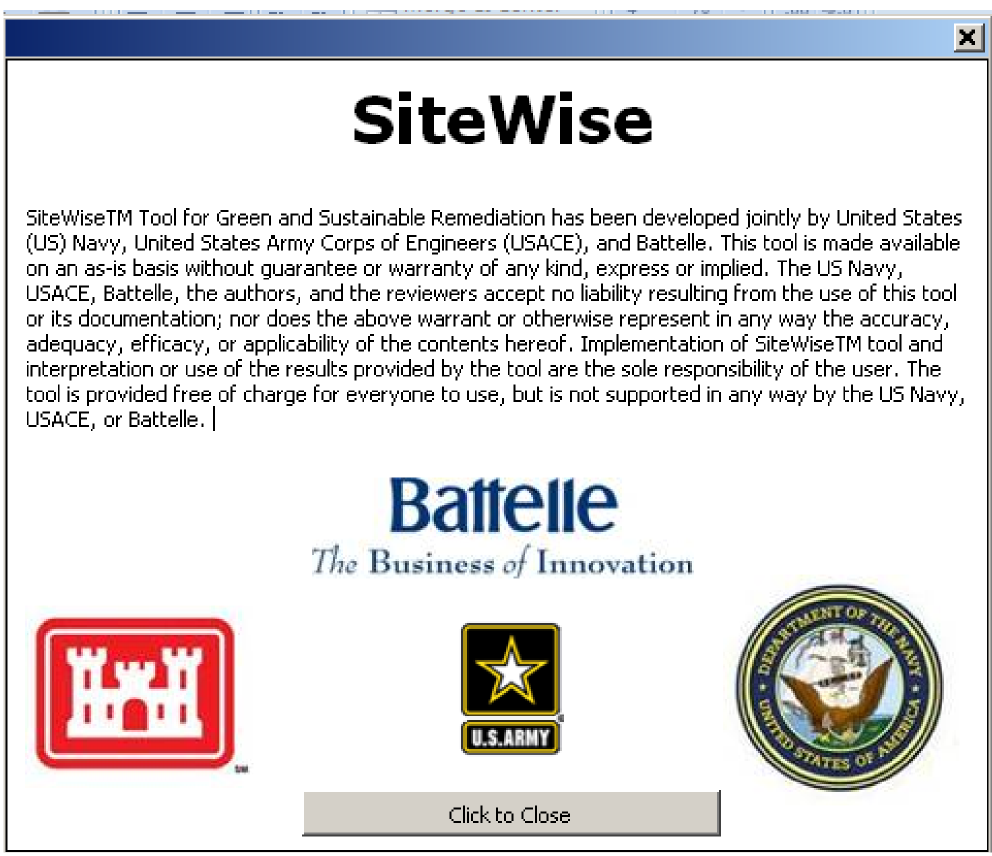


Figure 2-3. SiteWise™ Welcome Screen

2.1 Data Input

SiteWise™ requires information for activities pertaining to material production, transportation of personnel and equipment/materials, equipment use entailing electrical equipment, drilling equipment, earthwork equipment, pumps, and other equipment such as equipment used for mixing, agricultural, and paving activities, and residual handling. Appendix A lists all of the inputs and assumptions required to calculate the environmental footprint of a remedial alternative. Input sheets are the same for all components of a remedial action.

The first sheet that the user should fill out in SiteWise™ is found by clicking on the Site Info tab (Figure 2-4). The site info sheet contains all of the important information about the site where GSR evaluation has to be conducted. This is also the point where the user is given a choice to reset all of the values on each sheet of the tool prior to inputting new data.

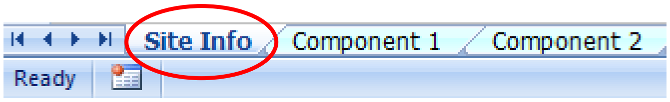


Figure 2-4. SiteWise™ Input Sheet Tabs

The Site Info sheet (Figure 2-5) requires the user to input the user name, date, site name, the remedial alternative name, and alternative file name. The remedial alternative name is provided for the user's book-keeping and archiving. SiteWise™ uses the alternative file name as file names for use. The alternative file name that the tool asks the user to enter is important because that is the name the tool uses for creating output folders and files. Since this name will be incorporated into folder and file names, it is important to keep this brief and avoid using special characters (e.g., # and %). The user also must select the electricity profile (i.e., the State in which the remedy is implemented), which the tool uses at other locations where electric energy consumed and emissions assosciated with electric consumption are calculated. The user also has the option of renaming remedy components from generic titles to the typical phases of a remedial alternative or another custom scheme; these titles are carried through the calculations and summary sheets and in the results presentation. For example, if the analysis is being done during the FS, the user may choose to name the components for the subsequent phases of the remedy, such as RA-C, RA-O, and Long-Term Monitoring. It is not necessary to use all four of the tabs. As another example, the user may choose to generate a remedial alternative that includes only RA-Os, but divides operations into components such as "Extraction Well Pump Operation," "Normal Treatment System Operation," "Process Control Sampling," and "Treatment System Cleaning Operations" to compare the footprints of different components of a pump-and-treat system for an optimization study. In the Site Info tab, the tool also asks the user to load a previously saved and generated remedial alternative input sheet on the main SiteWise™ input sheet for changes or additions. It is allowable to load a Version 2 or 3 input sheet but if this is done, pop-up notes direct the user within the tool on how to properly update the Version 2 or 3 inputs for Version 3.1 output generation. This is necessary because some key calculation infrastructure has changed between the versions (e.g., the user must now specify electricity resource mix by state rather than by region).

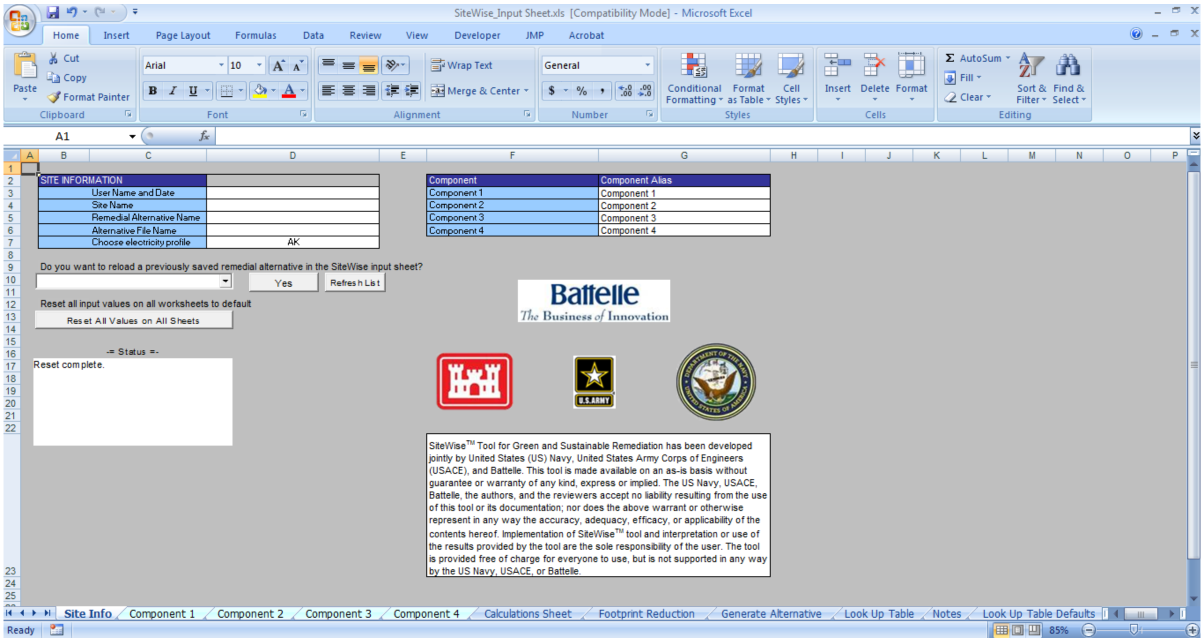


Figure 2-5. Site Info Sheet

Before beginning a GSR assessment, the user has a choice to reset the values from previous evaluations to zero to use the tool for a new study. Resetting the values to zero removes data present in the input sheet from previous assessments and is a recommended initial step to avoid mistakes. It should be noted that although the reset function will remove all notes, it will only reset entries in selected areas of the spreadsheets (e.g., entries in Columns D through O in the component tabs will be automatically reset, but not entries in Columns A through C). This task can be accomplished by either resetting all of the input sheets to zero from the site info sheet (Figure 2-6) or from individual component sheets (Figure 2-7).

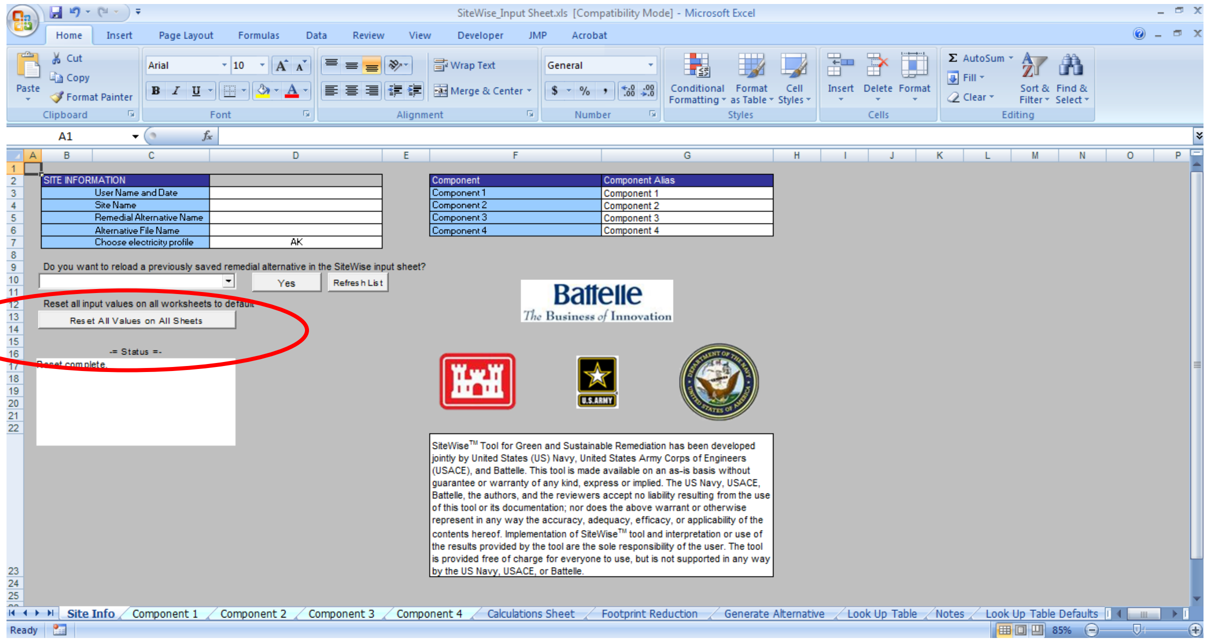


Figure 2-6. Layout of a Site Info Sheet with the Capability to Reset Input Values to Zero

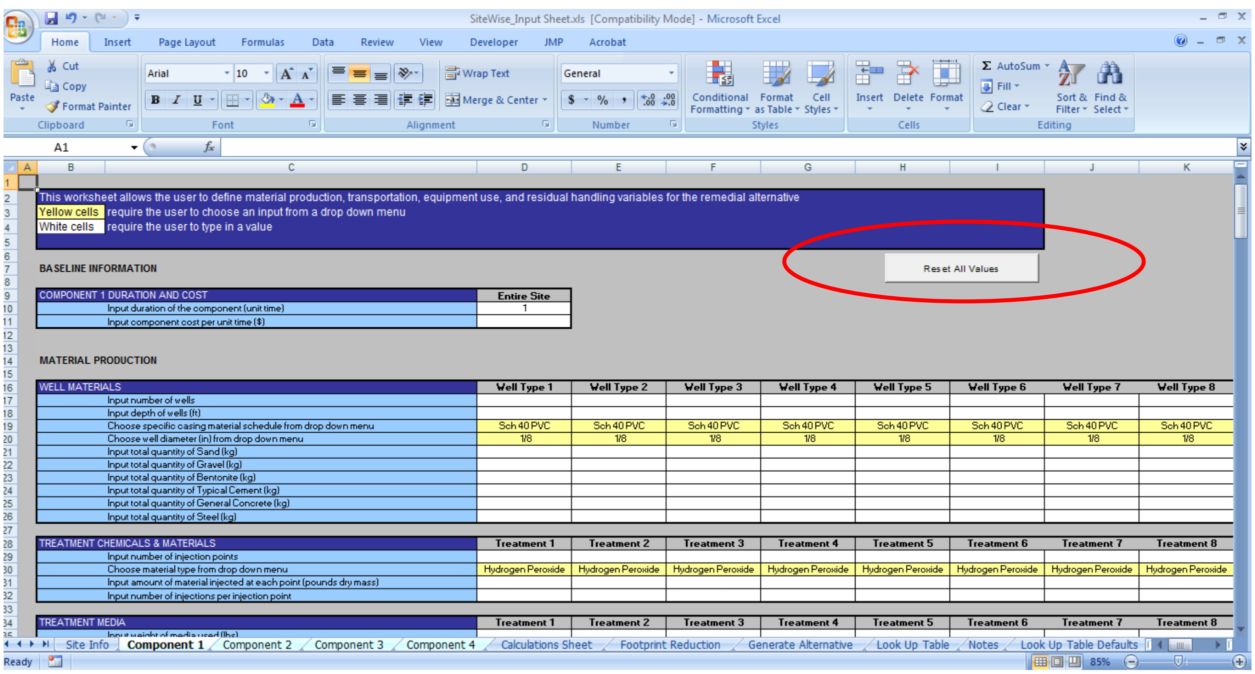


Figure 2-7. Layout of an Input Sheet with the Capability to Reset Input Values to Zero

The tool is designed to include 12 inputs at one time for a remedial activity. However, there can be instances when more than 12 inputs are required to be made. In such cases, another input file with an alternative name that is in numeric order of the previous file can be started. The user is essentially breaking down the alternative into two or more alternatives for the tool. At the final summary level, the user has to be cautious that rather than performing a comparative analysis between the two files that represent the same alternative, the footprints should be added together. The addition will have to be done by the user manually or at a different location in the file. The summed footprints can be manually entered into a blank generated Summary sheet for graphical comparison to other alternatives.

The tool contains some default values (e.g., motor efficiency for electrical equipment such as pump, blowers, and compressors). The defaults set in the tool are explained in Appendix A. All defaults in the tool can be overridden by the user. The user may also choose to rename column headings (e.g., "MW-21" in place of "Well Type 1"), or to insert notes using the "New Comment" function in Microsoft® Excel. These changes are preserved in the Input Sheet when an alternative is generated. Finally, the user may choose to input formulas in place of numerical entries; these formulas are also preserved when an alternative is generated. For example, if the user would like to input the area of a circular pad of concrete in the Construction Materials section, the user can choose to input "=pi()*3^2" for a pad with a radius of 3 ft rather than "28.274." This formula is preserved in the Input Sheet after an alternative is generated and the user's calculation is documented directly in the tool.

3.0 INPUT SHEET TABS

3.1 Input Sheets

The input sheets in the tool for all components are identical. In each input sheet, the white cells denote a cell for user input and yellow cells denote an input that features a drop-down menu listing options to choose from, and the blue cells denote a user default embedded in the tool, which can be overridden by the user. The inputs have been geared towards:

- **Material Production and Use** (Figures 3-1 and 3-2): The inputs in the material production phase are designed to calculate the amount of material used at the site for well installation, injection, treatment, silt curtain deployment, or well abandonment. The user also receives a choice of inputting data for materials that are not embedded into SiteWise™ by selecting generic materials with very low, low, medium, high, or very high impact, or materials A through F in case of injection or treatment chemicals in the look-up table where material impacts are listed.

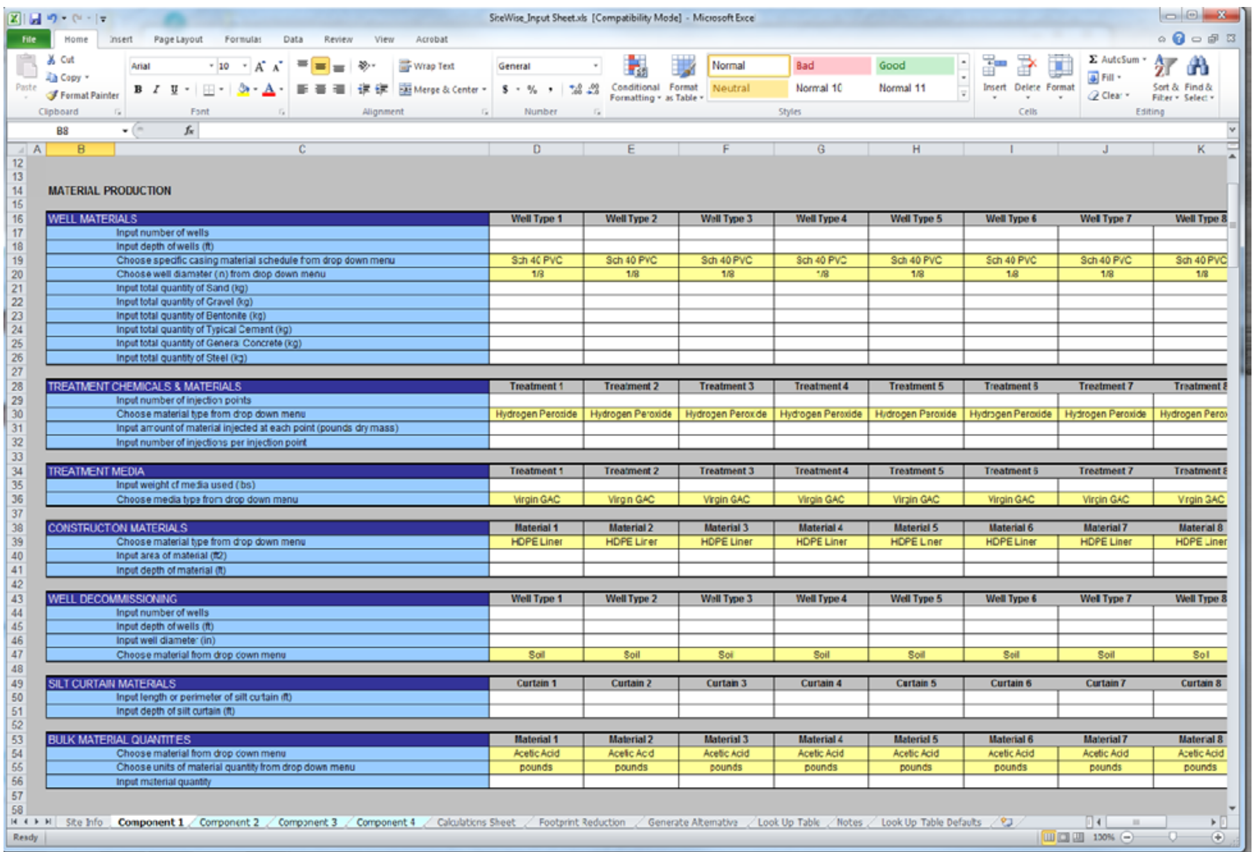


Figure 3-1. Material Production Use Screen Shot of SiteWise™ Input Sheet

Table 1c: Impact per kg of material									
Material	**kg CO2 e / kg**	**g NOx / kg**	**g SOx / kg**	**g PM10 / kg**	**MJ /kg**	**MWH /kg**	**Density (g /gal)**	**Density (kg /m3)**	**References**
Material A									
Material B									
Material C									
Material D									
Material E									
Material F									
Very Low Impact Material (Generic)	1.00E+01	2.00E+01	2.00E+01	1.00E+00	1.00E+02	2.78E-02	3.79E+03	1.00E+03	
Low Impact Material (Generic)	3.00E+00	6.00E+00	8.00E+00	1.00E+00	6.00E+01	1.67E-02	3.79E+03	1.00E+03	
Medium Impact Material (Generic)	1.00E+00	3.00E+00	5.00E+00	1.00E+00	3.00E+01	8.33E-03	3.79E+03	1.00E+03	
High Impact Material (Generic)	5.00E-01	1.00E+00	2.00E+00	4.00E-01	1.00E+01	2.78E-03	3.79E+03	1.00E+03	
Very High Impact Material (Generic)	1.00E-02	4.00E-02	5.00E-02	2.00E-02	2.00E-01	5.56E-05	3.79E+03	1.00E+03	

Figure 3-2. User Inputs for Material Emission Factors in the Look-up Table

- **Transportation** (Figure 3-3): The transportation inputs are designed to calculate the amount of fuel used due to transportation activities. The tool requires the user to input information about the type of fuel used, mode of transportation, distance traveled, and number of travelers. In case of equipment or material transportation, the tool requires the user to input amount of material or weight of equipment transported.

TRANSPORTATION						
PERSONNEL TRANSPORTATION - ROAD	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Will DIESEL-run vehicles be retrofitted with a particulate reduction technology?	No	No	No	No	No	No
Choose vehicle type from drop down menu*	Cars	Cars	Cars	Cars	Cars	Cars
Choose fuel used from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasolin
Input distance traveled per trip (miles)						
Input number of trips taken						
Input number of travelers						
Input estimated vehicular fuel economy (mi/gal) (Input only if known for the vehicle selected, otherwise a default will be used by the tool)						
*For vehicle type 'Other' please enter values in Table 2b in the Look Up Table tab.						
PERSONNEL TRANSPORTATION - AIR	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Input distance traveled (miles)						
Input number of travelers						
Input number of flights taken						
PERSONNEL TRANSPORTATION - RAIL	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Choose vehicle type from drop down menu	Intercity rail	Intercity rail	Intercity rail	Intercity rail	Intercity rail	Intercity
Input distance traveled (miles)						
Input number of trips taken						
Input number of travelers						
EQUIPMENT TRANSPORTATION - DEDICATED LOAD ROAD	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Will DIESEL-run vehicles be retrofitted with a particulate reduction technology?	No	No	No	No	No	No
Choose fuel used from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasolin
Account for an empty return trip?	No	No	No	No	No	No
Input one-way distance traveled (miles) with a given load. If applicable, impact for an empty return trip will be accounted for (no additional input is						
Input weight of equipment transported per truck load (tons)						
EQUIPMENT TRANSPORTATION - SHARED LOAD ROAD	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Input distance traveled (miles)						
Input weight of equipment transported (tons)						
EQUIPMENT TRANSPORTATION - AIR	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Input distance traveled (miles)						
Input weight of equipment transported (tons)						
EQUIPMENT TRANSPORTATION - RAIL	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Input distance traveled (miles)						
Input weight of load (tons)						
EQUIPMENT TRANSPORTATION - WATER	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip**
Input distance traveled (mile)						
Input weight of load (tons)						

Figure 3-3. Transportation Screen Shot of SiteWise™ Input Sheet

- **Equipment Use** (Figures 3-4 and 3-5): In the equipment use input sheets, the inputs are designed to calculate the amount of fuel used or electricity used to run the equipment.

EQUIPMENT USE

EARTHWORK	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipment 6	Equipment 7
Choose earthwork equipment type from drop down menu	Dozer	Dozer	Dozer	Dozer	Dozer	Dozer	Dozer
Choose fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input volume of material to be removed (yd3)							
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No	No	No	No	No

DRILLING	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7
Input number of drilling locations							
Choose drilling method from drop down menu	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push
Input time spent drilling at each location (hr)							
Choose fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel

TRENCHING	Trencher 1	Trencher 2	Trencher 3	Trencher 4	Trencher 5	Trencher 6	Trencher 7
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Choose horsepower range from drop down menu	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3
Input operating hours (hr)							

SEDIMENT DREDGING	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipment 6	Equipment 7
Choose dredge equipment type from drop down menu	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical
Choose dredge fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input volume of material to be dredged (yd3)							
Choose dredge equipment size	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1	awler Crane, 25 ton, 1
Suggested dredge equipment size	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1	wler Crane, 25 ton, 1
Input number of dredge tenders (default already present, user override possible)	1	1	1	1	1	1	1
Choose dredge tender fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input operating time for dredge tenders (hr) (default calculated value, user override pos	0	0	0	0	0	0	0
Input number of scow tenders (default already present, user override possible)	2	2	2	2	2	2	2
Choose scow tender fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input operating time for scow tenders (hr) (default calculated value, user override possi	0	0	0	0	0	0	0
Choose size of research vessel from drop down menu	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large
Choose research vessel fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input number of research vessels (default already present, user override possible)	1	1	1	1	1	1	1
Input operating time for research vessels (hr) (default calculated value, user override po	0	0	0	0	0	0	0
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No	No	No	No	No

SEDIMENT MANAGEMENT (STAGING AND DRYING)	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipment 6	Equipment 7
Choose earthwork equipment type from drop down menu	Crawler Crane	Crawler Crane	Crawler Crane	Crawler Crane	Crawler Crane	Crawler Crane	Crawler Crane
Choose fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input volume of material to be removed (yd3)							
Is volume input that of saturated sediment?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Will the sediment be dry when this work is performed?	No	No	No	No	No	No	No
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No	No	No	No	No

SEDIMENT CAPPING	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipment 6	Equipment 7
Choose capping method from drop down menu	Surface Release	Surface Release	Surface Release	Surface Release	Surface Release	Surface Release	Surface Release
Choose capping equipment fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input volume of capping material to be placed (yd3)							
Choose capping equipment size/type	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge
Suggested capping equipment size/type	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge	Hopper Barge
Input number of dredge tenders (hr) (default already present, user override possible)	1	1	1	1	1	1	1
Choose tender fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input operating time for dredge tenders (hr) (default calculated value, user override pos	0	0	0	0	0	0	0
Input number of scow tenders (default already present, user override possible)	0	0	0	0	0	0	0
Choose scow tender fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input operating time for scow tenders (hr) (default calculated value, user override possi	0	0	0	0	0	0	0
Choose size of research vessel from drop down menu	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large
Choose research vessel fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input number of research vessels (default already present, user override possible)	1	1	1	1	1	1	1
Input operating time for research vessels (hr) (default calculated value, user override po	0	0	0	0	0	0	0
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No	No	No	No	No

WATERCRAFT OPERATION	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipment 6	Equipment 7
Choose size of research vessel from drop down menu	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large	esearch Vessel (large
Choose research vessel fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Input number of vessels							
Input operating time (hours)							
Will DIESEL-run equipment be retrofitted with a particulate reduction technology?	No	No	No	No	No	No	No

For each pump, select only one of the three methods to calculate energy and GHG emissions
Enter "0" for all user input values for unused pump columns or unused methods

PUMP OPERATION	Pump 1	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7
Choose method from drop down	Method 1	Method 1	Method 1	Method 1	Method 1	Method 1	Method 1
Method 1 - ELECTRICAL USAGE IS KNOWN							
Input pump electrical usage (KWh)	0	0	0	0	0	0	0
Method 2 - PUMP HEAD IS KNOWN							
Input flow rate (gpm)	0	0	0	0	0	0	0
Input total head (ft)	0	0	0	0	0	0	0
Input number of pumps operating	0	0	0	0	0	0	0
Input operating time for each pump (hrs)	0	0	0	0	0	0	0
Pump efficiency (default already present, user override possible)	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Pump motor efficiency (default already present, user override possible)	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Input specific gravity (default already present, user override possible)	1	1	1	1	1	1	1
Method 3 - NAME PLATE SPECIFICATIONS ARE KNOWN							
Input pump horsepower (hp)	0	0	0	0	0	0	0
Input number of pumps operating	0	0	0	0	0	0	0
Input operating time for each pump (hrs)	0	0	0	0	0	0	0
Percent of max speed for pump motor (Optional input for variable speed motor)	100%	100%	100%	100%	100%	100%	100%
Pump load if max motor speed draws full nameplate horsepower	1	1	1	1	1	1	1
Input pump load (default already present, user override possible, consider above value)	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Pump motor efficiency (default already present, user override possible)	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Region							
Electricity Region	AK	AK	AK	AK	AK	AK	AK

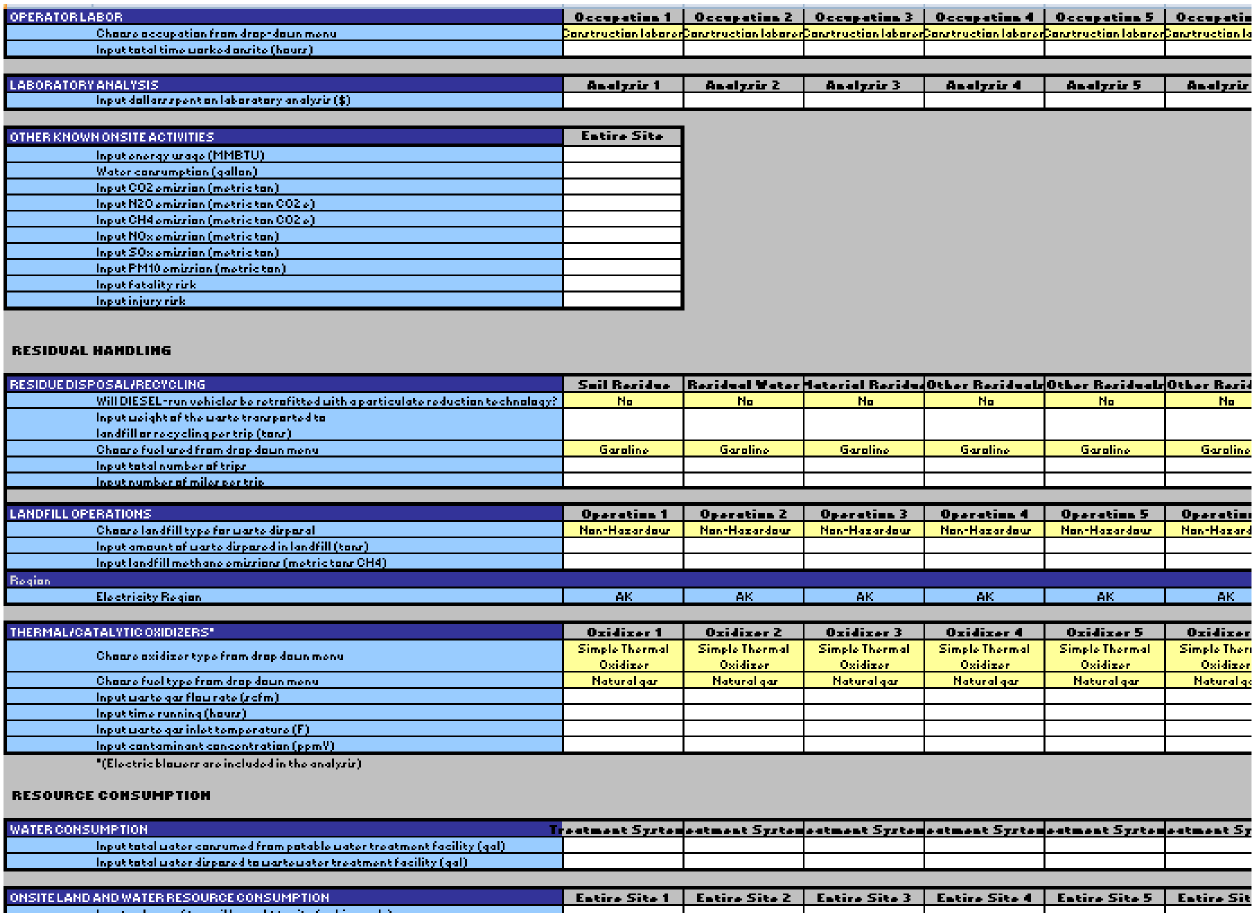
DIESEL AND GASOLINE PUMPS	Pump 1	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Choose horsepower range from drop down menu	2-Stroke: 0 to 1	2-Stroke: 0 to 1	2-Stroke: 0 to 1	2-Stroke: 0 to 1	2-Stroke: 0 to 1	2-Stroke: 0 to 1	2-Stroke: 0 to 1
Equipment operating hours (hrs)							
Input estimated fuel consumption rate (gal/hr) (Input only if known for the pump selected, otherwise a default will be used by the tool)							

Figure 3-4. Earthwork and Pump Operations Screen Shot of SiteWise™ Input Sheet

For each type of equipment, select only one of the methods to calculate energy and GHG emissions Enter "0" for all user input values for unused equipment columns or unused methods						
BLOWER, COMPRESSOR, MIXER, AND OTHER EQUIPMENT	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipm
Choose type of equipment from drop down	Blower	Blower	Blower	Blower	Blower	Blow
Choose method from drop down	Method 1	Method 1	Method 1	Method 1	Method 1	Metho
Method 1 - NAME PLATE SPECIFICATIONS ARE KNOWN						
Input equipment horsepower (hp)	0	0	0	0	0	0
Input number of equipments operating	0	0	0	0	0	0
Input operating time for each equipment (hrs)	0	0	0	0	0	0
Percent of max speed for motor (Optional input for variable speed motor)	100%	100%	100%	100%	100%	100%
Equipment load if max motor speed draws full nameplate horsepower	1	1	1	1	1	1
Input equipment load (default already present, user override possible, consider al	0.85	0.85	0.85	0.85	0.85	0.85
Equipment motor efficiency (default already present, user override possible)	0.85	0.85	0.85	0.85	0.85	0.85
Method 2 - ELECTRICAL USAGE IS KNOWN						
Input equipment electrical usage, if known (kWh)	0	0	0	0	0	0
Region						
Electricity Region	AK	AK	AK	AK	AK	AK
GENERATORS	Generator 1	Generator 2	Generator 3	Generator 4	Generator 5	Genera
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoli
Choose horsepower range from drop down menu	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to
Input operating hours (hr)						
AGRICULTURAL EQUIPMENT	Tillage Tractor	Tillage Tractor	Tillage Tractor	Tillage Tractor	Tillage Tractor	Tillage Tr
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoli
Input area to till (acre)						
Choose soil condition from drop down menu	Firm untilled soil	Firm untilled soil	Firm untilled soil	Firm untilled soil	Firm untilled soil	Firm until
Choose soil type from drop down menu	Clay Soil	Clay Soil	Clay Soil	Clay Soil	Clay Soil	Clay S
Input time available (work days)						
Input depth of tillage (in)						
CAPPING EQUIPMENT	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5	Equipm
Choose stabilization equipment type from drop down menu	Roller	Roller	Roller	Roller	Roller	Rolle
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoli
Input area (ft2)						
Input time available (work days)						
MIXING EQUIPMENT	Mixer 1	Mixer 2	Mixer 3	Mixer 4	Mixer 5	Mixe
Choose fuel type from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoli
Choose horsepower range from drop down menu	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3
Input volume (yd3)						
Input production rate (yd3/hr)						
Input estimated fuel consumption rate (gal/hr) (Input only if known for the mixer selected, otherwise a default will be used by the tool)						
INTERNAL COMBUSTION ENGINES	Engine 1	Engine 2	Engine 3	Engine 4	Engine 5	Engin
Choose fuel type from drop down menu	Diesel	Diesel	Diesel	Diesel	Diesel	Diese
Input fuel consumption rate (gal/hr or scf/hr)						
Input operating hours (hr)						
OTHER FUELED EQUIPMENT	Fuel 1	Fuel 2	Fuel 3	Fuel 4	Fuel 5	Fuel

Figure 3-5. Equipment Use Screen Shot of SiteWise™ Input Sheet

- **Residual Handling and Site Data** (Figure 3-6): SiteWise™ allows the user to enter site-specific data in the module Other Known Site Activities. The tool requires the user to input data for site workers to calculate the risk to workers due to remedial activities.



OPERATOR LABOR	Occupation 1	Occupation 2	Occupation 3	Occupation 4	Occupation 5	Occupatio
Choose occupation from drop-down menu	Construction laborer	Construction laborer	Construction laborer	Construction laborer	Construction laborer	Construction la
Input total time worked onsite (hours)						
LABORATORY ANALYSIS	Analysis 1	Analysis 2	Analysis 3	Analysis 4	Analysis 5	Analysis
Input dollars spent on laboratory analysis ($)						
OTHER KNOWN ONSITE ACTIVITIES	Entire Site					
Input energy usage (MMBTU)						
Water consumption (gallon)						
Input CO2 emission (metric ton)						
Input N2O emission (metric ton CO2 e)						
Input CH4 emission (metric ton CO2 e)						
Input NOx emission (metric ton)						
Input SOx emission (metric ton)						
Input PM10 emission (metric ton)						
Input fatality risk						
Input injury risk						
RESIDUAL HANDLING						
RESIDUE DISPOSAL/RECYCLING	Soil Residue	Residual Water	Material Residue	Other Residuals	Other Residuals	Other Resid
Will DIESEL-run vehicles be retrofitted with a particulate reduction technology?	No	No	No	No	No	No
Input weight of the waste transported to landfill or recycling per trip (tons)						
Choose fuel used from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline	Gasoline
Input total number of trips						
Input number of miles per trip						
LANDFILL OPERATIONS	Operation 1	Operation 2	Operation 3	Operation 4	Operation 5	Operation
Choose landfill type for waste disposal	Non-Hazardous	Non-Hazardous	Non-Hazardous	Non-Hazardous	Non-Hazardous	Non-Hazard
Input amount of waste disposed in landfill (tons)						
Input landfill methane emissions (metric tons CH4)						
Region						
Electricity Region	AK	AK	AK	AK	AK	AK
THERMAL/CATALYTIC OXIDIZERS*	Oxidizer 1	Oxidizer 2	Oxidizer 3	Oxidizer 4	Oxidizer 5	Oxidizer
Choose oxidizer type from drop down menu	Simple Thermal Oxidizer	Simple Thermal Oxidizer	Simple Thermal Oxidizer	Simple Thermal Oxidizer	Simple Thermal Oxidizer	Simple Therm Oxidizer
Choose fuel type from drop down menu	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas	Natural ga
Input waste gas flow rate (scfm)						
Input time running (hours)						
Input waste gas inlet temperature (F)						
Input contaminant concentration (ppmV)						
*(Electric blowers are included in the analysis)						
RESOURCE CONSUMPTION						
WATER CONSUMPTION	Treatment System	eatment System	eatment System	eatment System	eatment System	eatment Sy
Input total water consumed from potable water treatment facility (gal)						
Input total water disposed to wastewater treatment facility (gal)						
ONSITE LAND AND WATER RESOURCE CONSUMPTION	Entire Site 1	Entire Site 2	Entire Site 3	Entire Site 4	Entire Site 5	Entire Sit

Figure 3-6. Other Activities, Residual Handling, and Resource Consumption Screen Shot of SiteWise™ Input Sheet

Certain activities associated with remediation occur at different stages during the life of a project. Furthermore, many common remedial activities such as pouring pavement require that the user inputs data in multiple areas of the SiteWise™ tool. Table 3-1 provides some of the commonly used remedial technologies on the different phases of the remediation process and also certain activities that are commonly part of a remedial action. The activities can be further broken down into certain inputs that are part of the tool (Table 3-2). The inputs required by some of the activities include:

- **Well Installation:** The inputs required in the tool for well installation are geared towards calculating the amount of material used for well construction, fuel used for drilling the wells and monitoring well installation, and labor hours. Therefore, the inputs in the tool will be for materials (well materials such as PVC, steel or high density polyethylene; construction materials such as cement, steel, or concrete; well decommissioning materials such as sand, clay; and bulk materials such as bentonite), drilling equipment and operation, personnel and equipment transportation, on-site labor, and groundwater use. In addition, the user has the option to calculate material requirements for wells, such as steel, concrete, bentonite, sand, gravel, and cement, using the Worksheet or the Calculations tab on the User Input file.

- **Sampling and Analysis:** The inputs required by the tool for sampling and analysis are mostly related to calculating the fuel use by transportation and on-site equipment. The inputs to the tool are equipment and personnel transportation, earthwork or drilling if needed, operational inputs for pumps (electric or diesel) and generators (if required), watercraft operation (if required), on-site labor, laboratory analysis, and water consumption.

- **Chemical Injection:** The inputs in the tool are such to calculate the amount of material injected in situ and also the fuel and energy required to conduct the injection. The inputs include treatment chemicals and materials used, personnel and equipment travel, drilling equipment, electric equipment for injection, on-site labor hours, and water consumption.

- **Construction Activities:** The inputs in the tool calculate the amount of fuel or electricity used to run the equipment needed for construction activities and the labor hours that go into it. The inputs in the tool are mostly related to construction materials and equipment. The equipment used in the tool can be mixers, pumps, generators, capping equipment, and any electrical equipment for which the user knows the specifications. Furthermore, if equipment used at the site is not included in the tool, then internal combustion engine (ICE) inputs can be used to model that equipment because most equipment has ICE-related engines to run them.

- **Earthwork Activities:** The inputs in the tool calculate the amount of fuel used during earthwork activities. These activities are related to drilling, trenching, and excavation. The user is required to enter information related to the equipment used or the amount of soil excavated to calculate the emissions related to using this equipment onsite.

- **Sediment Dredging:** The inputs in the tool calculate the amount of fuel used during dredging activities. These activities are related to dredging, dredge and scow tender operation, research vessel operation, and sediment management activities. The user is required to enter information related to the equipment used or the amount of sediment dredged to calculate the emissions related to using this equipment onsite. The user should use separate modules for accounting for personnel and equipment travel, on-site labor, sediment management activities, laboratory analysis, and electricity and water consumption.

- **Sediment Capping:** The inputs in the tool calculate the amount of fuel used during sediment capping activities. These activities are related to capping, dredge and scow tender operation, research vessel operation, and cap management activities. The user is required to enter information related to the equipment used or the amount of cap placed to calculate the emissions related to using this equipment onsite. The user should use separate modules for accounting for personnel and equipment travel, material production, on-site labor, cap management activities, laboratory analysis, and electricity and water consumption.

- **Groundwater Extraction:** The activities and inputs required for groundwater extraction calculate the amount of electricity and fuel used to pump the groundwater as well as the amount of water that is removed from the aquifer and not reinjected.

- **Waste Removal:** The inputs required for waste removal are to calculate the amount of fuel used to haul waste from the site to a waste receiving facility such as a landfill. The tool also lets the user enter the landfill space used as resource consumption. The inputs for calculating the emissions of transporting waste are generally the amount of waste in tons transported and the distance to the receiving facility from the site.
- **Contamination Treatment:** The inputs required for the treatment can include consumption of treatment chemicals (e.g., acids and bases), treatment media (e.g., granular activated carbon and ion exchange), operation of electrical equipment (e.g., pumps and blowers), operation of fuel burning equipment (e.g., oxidizers), transportation of personnel and equipment, use of potable water and discharge of treated water.

Table 3-1. Technology Mapping onto Remediation Phases and Activities

	Phase				Activity Category									
Technology Category	**RI**	**RAC**	**RA-O**	**Long-Term Monitoring**	**Well Installation**	**Sampling and Analysis**	**Chemical Injection**	**Groundwater Extraction**	**Earthwork Activities**	**Sediment Dredging**	**Sediment Capping**	**Construction Activities**	**Waste Removal**	**Contamination Treatment**
Site Characterization	X				X	X		X	X				X	
Injection Technologies (i.e., enhanced bio, in situ chemical oxidation, zero-valent iron)		X			X	X	X	X					X	X
In Situ Thermal Construction		X			X							X		
In Situ Thermal Operation			X			X		X					X	X
Monitored Natural Attenuation			X	X	X	X							X	
Air Sparging/Biosparging Construction		X			X							X	X	
Air Sparging/Biosparging Operation			X			X	X							
Permeable Reactive Barrier Construction		X			X		X	X	X			X	X	
Permeable Reactive Barrier Maintenance			X			X	X							
Phytoremediation Construction		X			X				X					
Phytoremediation Maintenance			X			X	X							
Multiphase Extraction Construction		X			X							X	X	
Multiphase Extraction Operation			X			X		X					X	X
Constructed Wetlands Construction		X			X				X	X	X		X	X
Constructed Wetlands Maintenance			X			X	X			X	X			
Pump and Treat Construction		X			X				X			X	X	X
Pump and Treat Operation (includes operation of stripper, oxidizers, filter units, reactors)			X			X		X					X	X
Soil Flushing Construction		X			X				X			X	X	
Soil Flushing Operation			X			X	X	X					X	X
Soil Washing		X				X			X			X	X	X
Excavation		X				X			X				X	
Capping		X							X				X	
Land Farming		X				X			X				X	
Land Tilling		X				X			X			X	X	
Biopiles/Composting Construction		X							X			X	X	
Biopiles/Composting Operation			X			X								X

Table 3-1. Technology Mapping onto Remediation Phases and Activities (Continued)

	Phase				Activity Category									
Technology Category	**RI**	**RAC**	**RA-O**	**Long-Term Monitoring**	**Well Installation**	**Sampling and Analysis**	**Chemical Injection**	**Groundwater Extraction**	**Earthwork Activities**	**Sediment Dredging**	**Sediment Capping**	**Construction Activities**	**Waste Removal**	**Contamination Treatment**
Soil Vapor Extraction /Bioventing Construction		X			X				X			X	X	
Soil Vapor Extraction/Bioventing Operation			X			X		X						X
Sediment Dredging		X				X				X		X	X	
Sediment Capping		X				X					X	X	X	
Enhanced Monitored Natural Recovery			X	X		X					X		X	
In Situ Sediment Amendments		X												
Monitoring				X	X	X							X	

Table 3-2. Activity Phases Mapped Onto SiteWise™ Inputs

Activity Category	Well Material	Treatment Chemicals	Treatment Media	Construction Materials	Well Decommissioning	Material Bulk Quantities	Personnel Travel	Equipment Transportation	Earthwork	Drilling	Sediment Dredging	Sediment Management	Sediment Capping	Watercraft Operation	Electric Pump Operation	Diesel Pump Operation	Other Electric Equipment	Generators	Agricultural Equipment	Capping Equipment	Mixing Equipment	Internal Combustion Engines	Other Fueled Equipment	On Site Labor Hours	Laboratory Analysis	Residue Disposal/Recycling	Landfill Operations	Thermal/Catalytic Oxidizers	Water Consumption	Top Soil Consumption	Groundwater/Surface Water Use
Well Installation	X			X	X	X	X	X		X														X							X
Sampling and Analysis							X	X	X	X	X	X	X		X	X	X	X					X	X	X						X
Chemical Injection		X				X	X	X		X					X	X	X	X						X					X		
Groundwater Extraction							X	X							X	X	X	X					X	X		X					X
Earthwork Activities							X	X	X			X					X	X	X	X		X	X	X					X	X	
Sediment Dredging						X	X	X			X	X		X	X	X	X	X			X		X	X	X	X	X		X		X
Sediment Capping						X	X	X				X	X	X									X	X	X				X		X
Construction Activities				X		X	X	X	X								X	X		X	X	X	X	X					X	X	
Waste Removal								X																		X	X				
Contamination Treatment		X	X			X	X	X			X	X	X	X	X	X	X	X				X	X	X				X	X		X

3.2 Duration and Cost of Activity

Each component tab has a cell in which the user can enter the duration of remedial action. All of the values entered in the component sheets are multiplied by the value entered in this cell. This cell should be used when the data for a component are entered on a time basis (i.e., quarterly, semi-annually, or annually). By entering a value for the duration of remedial action, the user is specifying the length of time over which the action will take place. For example, if data for RA-O are entered on an annual basis and the user wants to see the impact of operating for 20 years, the duration of remedial action should be set at 20.

It is important to note that this approach only works when the inputs remain the same for the entire time period of analysis. If the inputs vary from year to year, the user can either 1) calculate an average for the entire operating or monitoring period; or 2) calculate the total for the entire operating or monitoring period and then enter 1 for duration. If the user does not wish to enter data on a basis of time, the procedure of calculating the totals for the entire action and entering 1 for the duration can be used.

SiteWise™ also allows the user to enter the cost associated with each component of remediation in a cell at the top of each activity sheet. The cost entered in the component sheets is NOT multiplied by the duration of analysis value so the cost entered must represent the entire time period of the activity and not the cost per year or quarter, etc.

4.0 BASIS OF CALCULATIONS

The remedy footprint is calculated in SiteWise™ by multiplying the impact factors (e.g., emissions per usage rate) with the usage rate (consumption) of a material, electricity, or fuels during a remedial action. SiteWise™ performs all of the calculations based on emissions factors that have been obtained from credible governmental or non-governmental research sources. Table 4-1 lists all of the data sources for the emissions factors used in SiteWise™.

Table 4-1. Data Sources for Metrics in SiteWise™

GHG Emission Footprint Calculation: The United State Environmental Protection Agency (U.S. EPA) Climate Leaders Program (U.S. EPA, 2009b) provides a GHG Inventory Guidance that is used by industry to document emissions of GHGs including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The U.S. EPA Climate Leaders GHG Inventory Guidance is a modification of the GHG protocol developed by the World Resources Institute and the World Business Council for Sustainable Development. SiteWise™ also uses emissions factors developed by Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, U.S. EPA's Mobile 6 model, and U.S. EPA's Non-road model. Emissions factors for consumables are life-cycle based and obtained from sources that provide life-cycle inventories (e.g., the life cycle inventory provided by National Renewable Energy Laboratory [NREL]). Emissions factors for watercraft operation are taken from U.S. EPA's Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (U.S. EPA, 2009a).

Energy Usage Calculation Methodology: Electricity used onsite can be determined through meter readings for existing systems and/or by performing engineering calculations for each piece of equipment. The energy embodied in fuels is obtained from Argonne National Laboratory's GREET model that provides life-cycle energy consumption.

Water Usage: Similar to electric use, information regarding water consumed at the site can generally be obtained from the site. In the case of cooling water for electric production, a factor of 510 gallons/MWh is used by the tool, which was obtained from a study conducted by Arizona Water Institute.

Air Emission Inventories Development: Mobile 6 and Non-road are two computer programs developed by the U.S. EPA's Office of Transportation and Air Quality that calculate NO_x, SO_x, CO, volatile organic compounds, and PM_{10} emissions factors for mobile and non-road equipment, respectively. Other inventories such as AP-42 (U.S. EPA, 1995) are available for obtaining emissions factors for various activities. Emissions factors for watercraft operation are taken from U.S. EPA's Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (U.S. EPA, 2009a).

Accident Risk Calculation Methodology: Several organizations (including Automobile Transport Statistics, Airplane Transport Statistics, Railroad Transport Statistics, and Labor Statistics) provide statistics of both fatalities and injuries that occur during various activities including transportation by automobile, airplane, and rail.

Note:
U.S. EPA. 2009. Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories. April.
U.S. EPA. 2009. Center for Corporate Climate Leadership. Available at: http://www.epa.gov/climateleadership/.
U.S. EPA. 1995. Compilation of Air Pollutant Emission Factors; Volume I: Stationary Point and Area Sources. Fifth Edition. January.

All of the emissions factors used by the tool are housed in a tab in the input sheet called Look-up Tables. The emission factors in the Look-up Tables are all referenced. There are provisions in the look-up table to enter user-specific data. However, if the user decides to abandon previously entered user-specific data, or if values in the data tables are accidentally changed or deleted, then the values in the look-up table can be reset by selecting the Reset Sheet to Default Values button as shown in Figure 4-1. To let the user compare initial data in the tool, a copy of the look-up table tab titled "Look-Up Table Defaults" is also provided in all input sheets in the tool. Some of the inputs in the look-up table such as electric regions or the materials table also have a custom option to let the user enter the emission factors for the electric mix used at a specific site, in case the user has such site-specific data. Information such as water consumed, any site-specific emissions, and risk can be entered by the user. When a user inputs factors into the Look-Up Tables, the inputted value will be automatically highlighted in yellow to allow reviewers to easily see what has been added or modified.

Table 1a: Global warming potentials for GHG other than CO_2

Reset Tables to Default Values

100-Year Global Warming Potential (GWP)		
N_2O GWP	310	CO_2 e
CH_4 GWP	21	CO_2 e

U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008", EPA 430-R-10-006, page 1-7, Table 1-2 (April 15, 2010)

Table 1b: Pipe weight per unit length for PVC, Steel, Stainless Steel, and HDPE

Nominal Pipe Size	Pipe Outside Diameter [a]	Schedule 40 PVC [b]	Schedule 80 PVC [b]	Schedule 120 PVC [c]	Schedule 40 Steel [a]	Schedule 80 Steel [d]
(inches)	(inches)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)
1/8	0.410	0.051	0.063	-	0.24	0.31
1/4	0.540	0.086	0.105	-	0.42	0.54
3/8	0.680	0.115	0.146	-	0.57	0.74
1/2	0.840	0.17	0.213	0.236	0.85	1
3/4	1.050	0.226	0.289	0.311	1.13	1.47
1	1.320	0.333	0.424	0.464	1.68	2.17
1 1/4	1.660	0.45	0.586	0.649	2.27	3
1 1/2	1.900	0.537	0.711	0.787	2.72	3.65
2	2.380	0.72	0.984	1.111	3.65	5.02
2 1/2	2.880	1.136	1.5	1.615	5.79	7.66
3	3.500	1.488	2.01	2.306	7.58	10.3
4	4.500	2.118	2.938	3.713	10.79	14.9
5	5.560	2.874	4.078	-	14.61	20.8
6	6.630	3.733	5.61	7.132	18.97	28.6
8	8.630	5.619	8.522	11.277	28.55	43.4
10	10.750	7.966	12.635	-	40.48	64.4
12	12.750	10.534	17.384	-	53.6	88.6
14	14.000	12.462	20.852	-	63	107
16	16.000	16.286	26.81	-	78	137
18	18.000	20.587	33.544	-	105	171
20	20.000	24.183	41.047	-	123	209

Figure 4-1. Layout of the Look-Up Table with the Reset Button

In SiteWise™, emissions factors for GHGs and energy used for consumables such as materials, fuel, and electricity are based on life-cycle analysis. The boundary condition that is drawn for calculating the life-cycle-based emission factors is around the entire life cycle or 'cradle-to-gate' of the consumables. This means that complete life-cycle emissions for material production are taken into account. The analysis includes all energy used and emissions due to manufacturing of consumables, production of the electricity and manufacturing, and production and transportation of raw materials for manufacturing the consumable. Appendix A lists the different activities being considered by SiteWise™ and the formulas used to calculate emissions due to those activities. Appendix B is the listing of the different emission factors used in the tool.

4.1 Footprint Reduction

SiteWise™ includes an evaluation of footprint reduction methods, mostly related to reduction in energy consumption. The tool asks the user whether the user wants to consider footprint reduction for the alternative in consideration. The user can select "yes" for footprint reduction and "no" if no footprint reduction needs to be considered. The tool has a default "no" for this question (Figure 4-2). To compare the overall effect of footprint reduction, it is recommended that the user first considers evaluating the alternative without any footprint reduction; then once a baseline has been established, footprint reduction could be considered to see the overall impact of the reduction.

Do you wish to use footprint reduction methods for this remedial alternative?	No

Figure 4-2. Footprint Reduction Inclusion in the Evaluation

SiteWise™ requires the user to enter some baseline electric information (Figure 4-3) for calculating energy savings by renewable energy application.

BASELINE INFORMATION

ELECTRICITY RATE	
Choose state for electricity rate calculation	AL
Choose state for emission reduction calculations	AL
Average electricity rate (2007) ($/kWh)	0.08
Input electricity rate to override default ($/kWh) (if known, otherwise enter "0")	0.00
Final electricity rate to be used ($/kWh)	0.08

Figure 4-3. Basic Electric Consumption Information in the Input Sheet in Footprint Reduction Tab in SiteWise™

SiteWise™ includes calculation modules for landfill gas microturbines, photovoltaic (PV) solar energy systems, wind turbines, and use of renewable energy certificates as part of its renewable energy application. The tool requires the user to establish in which component the renewable energy application would be applied. After the user selects the component, the tool calculates the amount of electricity being used for that component. The user has the option to base the renewable energy analysis on that calculated amount of energy by selecting Method 1 or overriding this by selecting Method 2 and inputting the amount of energy to be used for the analysis. Figure 4-4 shows a screen shot where the user would make this selection. Since the user enters the baseline electric consumption in Method 2, there is a possibility of an error by inputting a higher value for electric consumption than the actual electric consumption at the site. Inputting a higher baseline value can lead to discrepancies in the GSR analysis. For example, GHG emissions can be negative in the final summary. To avoid such errors, the inputted footprint reduction data should be checked for accuracy.

Once the amount of electric consumption has been determined, the tool requires the user to enter the duration of the renewable energy application to be applied and the amount of electricity that the renewable energy application is desired to produce over the lifetime of the renewable energy application. This number is expressed as a percent of the total electrical consumption from the site. Once the data are entered, SiteWise™ calculates the specific renewable energy design and cost of installation based on available literature.

The tool also calculates the simple payback period for the capital used for the renewable energy application. If the calculation of the payback period determines it to be negative for any of the applications, then the renewable energy application in consideration is a liability and the return on investment will never be achieved. Therefore, this particular observation, if presented, should prompt the user to change the design of the application to achieve an optimal return on investment (Figure 4-4).

SOLAR POWER	Remedial Investigation	Remedial Action Construction	Remedial Action Operations	Longterm Monitoring
Choose "yes" or "no" to indicate if the footprint reduction technology will be implemented for each phase of the remedial alternative	No	Yes	Yes	No
Method 1 Total from electrical equipment use and other known site activities (MWh)	5.0E-01	1.1E+01	2.5E+00	3.0E-01
Method 2 Override the electric consumption entered previously (MWh)	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Choose method to calculate electricity use	Method 1	Method 1 represents the total from input sheet and method 2 represents the user override		
Enter duration of PV system operation (years)	3.0			
Electricity amount to be used in footprint reduction calculations (MWh)	1.4E+01			
Enter percent electric supply desired from PV systems (%)	50			
Desired installed capacity (kWh/year)	2,250			
Energy available for system operation (hours/year)	912.5			
Recommended system size (kW)	2 – 5			
Installation cost ($/W)	8.20			
Capital cost of photovoltaic installation ($)	20,219			
O&M cost of installing PV cells ($)	240			
Total cost of the system ($)	20,459			
Electricity cost avoidance ($)	896			
Simple payback period (years)	92.4			

Figure 4-4. Example of Renewable Energy Application

The tool calculates the footprint reduction, cost of application, and cost of electric avoidance due to renewable energy application (Figure 4-5). The cost of footprint reduction activities is added to this cost while the cost accrued due to energy savings because of footprint reduction activities is subtracted from the final cost. The costs calculated by SiteWise™ for footprint reduction do not include federal, state, and local incentives or tax rebates that are available for new renewable energy projects.

COST OF ELECTRIC CONSUMPTION REDUCTION	
Total cost of the remedial alternative ($)	735,000
Total cost of electricity consumption reduction methods ($)	21,134
Cost of landfill gas microturbines ($)	0
Cost of wind power system ($)	0
Cost of solar power system ($)	20,459
Cost of renewable energy certificates ($)	675
Total electricity cost avoidance ($)	896
Total cost of the remedial alternative with electric consumption reduction methods and cost avoidance ($)	755,238

Figure 4-5. Results of Footprint Reduction

The tool also requires the user to enter any incremental cost due to use of alternative fuels (i.e., biofuels can be selected from the fuel selection input menu), use of diesel oxidation catalysts (a drop-down menu option each time diesel equipment is used) for emissions reduction, and variable frequency drives (VFDs) (which can be modeled into the tool as discussed later in the report in Appendix A-Equipment Use). The energy and other footprint avoidance achieved due to application of these footprint reduction devices can be observed by comparing two alternatives with and without these devices; by inputting the cost factors associated with them, the total cost impact can be observed. It should be noted, however, that in the case of VFDs, the reduction in energy cost would need to be calculated by the user and factored into the total remedy cost. The tool also considers water footprint reduction by recycling or reinjection of extracted groundwater (Figure 4-6).

FOOTPRINT REDUCTION - EMISSION REDUCTION TECHNOLOGIES

BIODIESEL 20	Component 1	Component 2	Component 3	Component 4
Incremental cost of using Biodiesel 20 ($/gal)	0.00	0.00	0.00	0.00

DIESEL OXIDATION CATALYSTS	Component 1	Component 2	Component 3	Component 4
Average cost of DOC installation ($/unit)	540.00	540.00	540.00	540.00
Enter cost of DOC installation to override default ($/unit) (if known, otherwise enter "0")	0.00	0.00	0.00	0.00
Total cost of DOCs ($)	0			

VARIABLE FREQUENCY DRIVES	Component 1	Component 2	Component 3	Component 4
Enter cost of variable frequency drives ($)	0	0	0	0

FOOTPRINT REDUCTION - WATER RECYCLING

WATER RECYCLING	Component 1	Component 2	Component 3	Component 4
Enter amount of water recycled (gal)	0.0	0.0	0.0	0.0
Amount of water recycled (gal)	0	0	0	0

Figure 4-6. Emission, Energy, and Water Footprint Reduction

5.0 DATA OUTPUT

5.1 Generating Remedial Alternative

The Generate Remedial Alternative tab of the input sheets directs the user to click on the Generate Remedial Alternative button to generate a sub-folder with the file name provided by the user in the same folder that contains SiteWise™ (Figure 5-1).

Figure 5-1. Remedial Alternative Generation Tab in Input Sheet

The generated folder contains the input sheet that has the data entered by the user for the remedial alternative GSR evaluation, all calculation sheets without calculation links, and the summary sheet that has the evaluation results for the alternative. The tool allows the user to save the input file to work on later. If the user intends to change some information and replace the existing alternative with the new changes, the button "Click to Replace an Existing Alternative with the Same Name" can be used. By clicking this button the user will replace an existing alternative that has the same alternative file name with the one currently being worked on. The "Click to Generate Alternative Using Previously Entered Alternative Name" button cannot be used for this function because that will create a new folder in ascending numerical order rather than replacing an existing folder.

5.2 File Name Structure

SiteWise™ generates two types of folders when a user clicks on the "Generate Remedial Alternative" button. One is RA_file name_FR _(number) and the other is RA_file name_NoFR _(number). The folders contain an input and summary file with a similar file name structure. RA stands for remedial alternative, which is followed by the file name that the user specifies in the site info sheet followed by either 1) FR (for footprint reduction) if the user clicked "yes" for footprint reduction in the footprint reduction sheet as shown on Figure 5-2, or 2) NoFR (for no footprint reduction) if the user clicked "no" for no footprint reduction in the footprint reduction sheet shown on Figure 5-2.

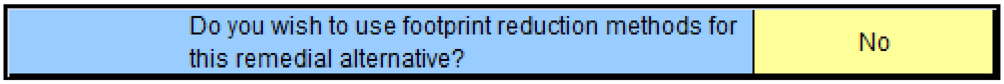


Figure 5-2. Footprint Reduction Input

This file name structure is followed throughout the tool. The input sheet in the folder that is generated can be reloaded on the main SiteWise™ input sheet (Figure 5-3) and the summary sheets can be loaded in the final summary sheet for comparative analysis (Figure 5-4). Previously saved input sheets can be loaded back on the SiteWise™ input sheet to view, change, or add new information to existing remedial alternatives.

Figure 5-3. Input for Re-loading a Previously Saved Remedial Alternative Generated Input File

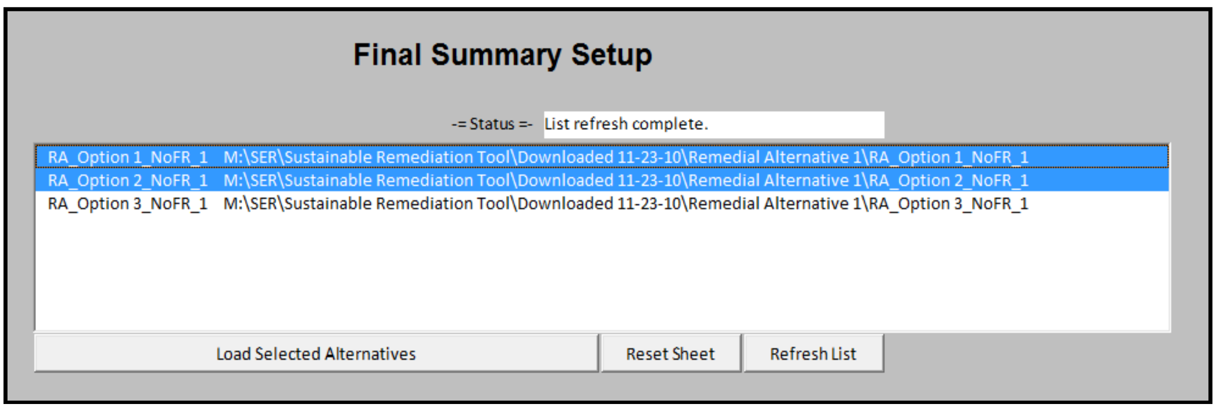


Figure 5-4. Reloading Previously Generated Input File

5.3 Summary Sheets

Summary sheets contain the output for each alternative and are provided in all of the folders generated by the user for a remedial alternative to see the remedy footprint of that remedy. Every remedial alternative folder also has an input sheet corresponding to the summary sheet. The information included in the summary sheets is presented in Section 5.4.

The final summary sheet performs a comparative analysis among all of the remedial alternatives generated by uploading the summary sheets that are stored with the remedial alternative folders generated by the tool. Any alternative folder can be moved into or out of the project folder, thus allowing greater options for performing the comparative analysis.

5.4 SiteWise™ Graphical Outputs

SiteWise™ compares different remedial alternatives on a set of consistent metrics (Figure 5-5) and drills down to the level of activity in every component of every remedial alternative (Figure 5-6) to determine the activities with the highest footprint for each metric.

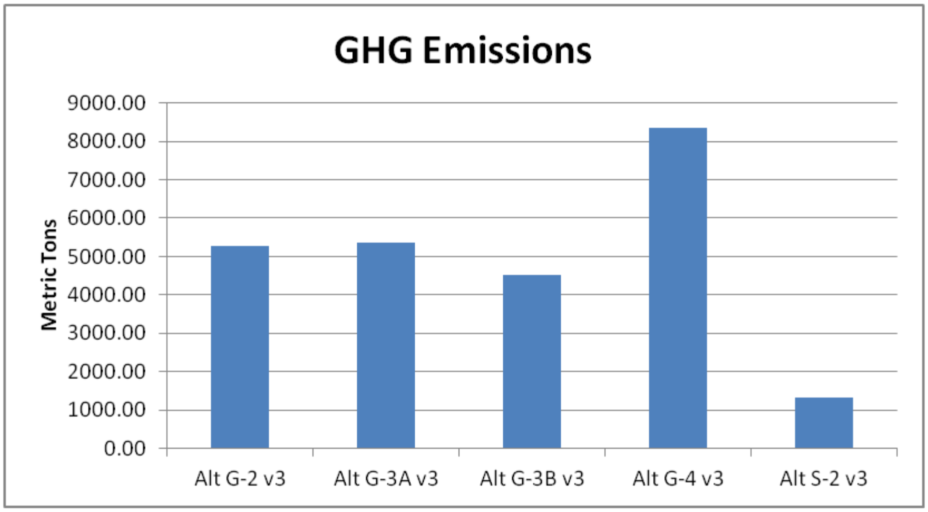


Figure 5-5. Example Output from SiteWise™: Comparative Analysis for Remedial Alternatives for GHG Emissions (Generated within the Final Summary Sheet)

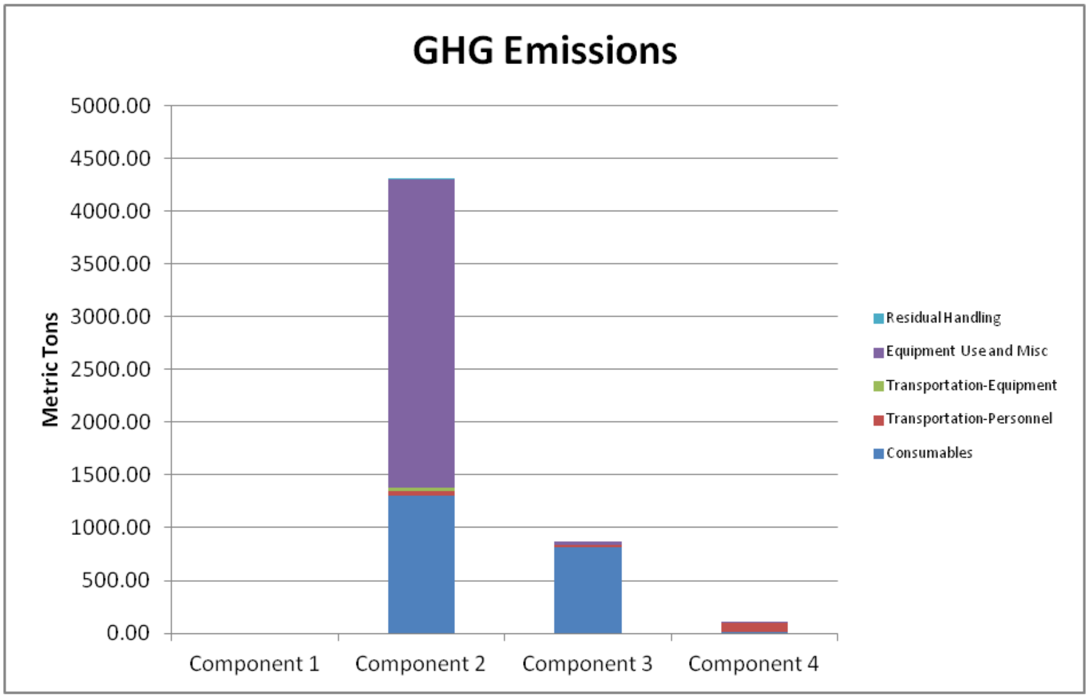


Figure 5-6. Example Output from SiteWise™: Detailed Analysis for One Remedial Alternative for GHG Emissions (Generated within the Summary Sheet for each Alternative)

5.5 Impact Category Table and Normalized Impacts

The tool's final summary file also has an impact table that lists all of the Navy GSR metrics. The tool assigns an impact category such as high, medium, and low to different alternatives relative to each other for a respective metric based on the quantified value. The tool assigns high to the first alternative then adjusts the rating based on the other alternatives and the difference in the data between the alternatives for all the GSR metrics. The tool is based on a 30% difference. Therefore, if the two data points are within the 30% difference then both the alternatives are assigned the same high, medium, or low relative to the other alternatives for that particular GSR metric. The metrics that are not currently quantified by the tool such as community impacts and ecological impacts are evaluated manually by the user. To enhance flexibility the tool also has a copy of the impact table for the user to manually select the impact category in cases where there is a disagreement between what the user believes is appropriate versus what was assigned by the tool (Figure 5-7).

Additionally, the tool final summary file contains a normalized impacts chart, which graphically compares alternatives by various metrics; all metrics are shown on the same chart for ease of comparison (Figure 5-8). For each metric, the alternative with the highest impact is assigned a value of 1.0 and impacts for the other alternatives are presented as ratios to that alternative for that metric. It should be noted that the same alternative is not always assigned a value of 1.0 for all metrics. Also, impacts are not normalized between metrics (e.g., there is no comparison in the tool between GHG emissions and water consumption); therefore, the chart does not offer comparison between metrics. Similarly to the impact category table, this chart offers an overview of which alternatives generally have high impacts across all metrics and which alternatives generally have low impacts across all metrics in a quantified form.

Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	Electricity Usage	Onsite NOx Emissions	Onsite SOx Emissions	Onsite PM10 Emissions	Total NOx emissions	Total SOx Emissions	Total PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resourc es Lost
Alt G-2 v3	Medium	Medium	Medium	Medium	High	High	High	Medium	High	Medium	Low	Low	user select	user
Alt G-3A v3	Medium	Medium	Medium	Medium	High	High	High	High	High	Medium	Low	Low	user select	user
Alt G-3B v3	Medium	Medium	Medium	Medium	High	High	High	Medium	Medium	Medium	Low	Low	user select	user
Alt G-4 v3	High	High	High	High	High	High	High	High	High	High	Low	Low	user select	user
Alt S-2 v3	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Low	High	Medium	Low	user select	user

Relative Impact (User Override)

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	Electricity Usage	Onsite NOx Emissions	Onsite SOx Emissions	Onsite PM10 Emissions	Total NOx Emissions	Total SOx Emissions	Total PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury	Community Impacts	Resourc es Lost
Alt G-2 v3	Medium	Medium	Medium	Medium	High	High	High	Medium	High	Medium	Low	Low	user select	user
Alt G-3A v3	Medium	Medium	Medium	Medium	High	High	High	High	High	Medium	Low	Low	user select	user
Alt G-3B v3	Medium	Medium	Medium	Medium	High	High	High	Medium	Medium	Medium	Low	Low	user select	user
Alt G-4 v3	High	High	High	High	High	High	High	High	High	High	Low	Low	user select	user
Alt S-2 v3	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Low	High	Medium	Low	user select	user

*Accident Risk is an estimate of how many accidents may occur. This risk is not the same as Cancer Risk, which is the probablity (for a single person) of getting cancer. Accident risk is not comparable to Cancer Risk due to inherent fundamental differences.

Figure 5-7. Impact Category Table Generated in the Final Summary Sheet of the Tool

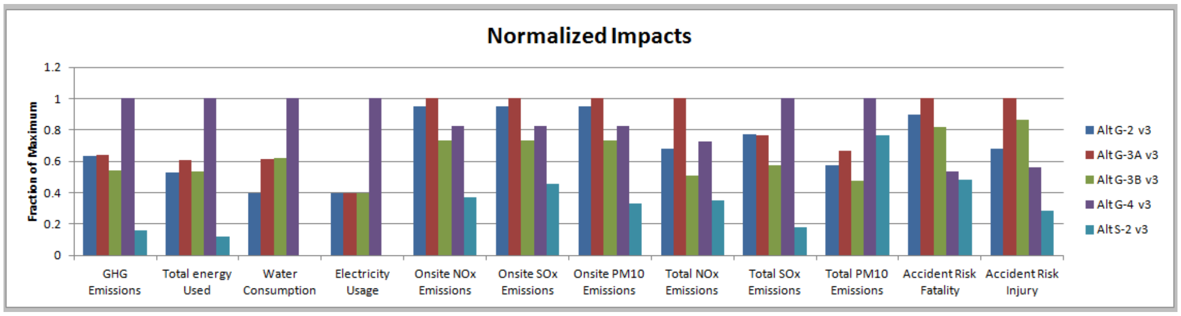


Figure 5-8. Impact Category Table Generated in the Final Summary Sheet of the Tool

5.6 Analysis of Calculation and Summary Sheets

The user can view all of the different calculation sheets to conduct a more detailed analysis of the footprint to determine what activity, material, or equipment contributes the most to the remedy footprint and validate how calculations are being done in the tool. This feature makes the tool more flexible and transparent. The user must be cautious of not opening or keeping any calculation sheet open during the time the tool generates the remedial alternative.

The summary file contains graphs and data tables that can be exported to any other presentation or report. However, before exporting the files, the user has the ability to make any custom changes to the graphs. The axes, fonts, and colors of the graphs can be changed according to user preference.

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APPENDIX A
BASIS OF CALCULATION

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The formulas used in calculating the environmental footprint due to remedial activities are provided in Table A-1. Appendix B provides the emission factors used in the tool.

Assumptions and Inputs

The section below describes the inputs required by the tool for the different remedial activities and assumptions made for those activities. The emission factors for these activities are provided in the SiteWise™ lookup tables which are also included in Appendix B.

Material Production

Within SiteWise™, consumables are separated into six categories: well materials, treatment chemicals, granular activated carbon (GAC), construction materials, silt curtain materials, and well decommissioning materials. For all consumables considered in the tool, GHG emissions, energy usage, and criteria air pollutants are considered and calculated based on the weight of the material. The emission factors (Appendix B, Tables 1a through 1d) for GHG and criteria air pollutants are based on the life cycle of the material and are provided in kg/kg material. However, criteria air pollutants emissions for consumables only contribute to total (global) impacts calculated by the tool and not on site impacts. Certain materials such as glass, tubing, or plastic bottles are not taken into consideration because the footprint associated with these materials is not appreciable enough to be accounted for. Currently, the tool also doesn't go into the manufacturing footprint of equipment used at the site for remedial action.

<u>Assumption:</u> *For materials, water usage and accident risk are not calculated. These criteria are included in the tool to account for the local and regional impacts due to site activities. However, the manufacturing of the materials in almost all cases happens outside the local and regional boundary of the site and in many cases outside the U.S. Therefore, for material production, only global impacts such as energy consumed, total (global) criteria air pollutants emissions, and GHG emissions are considered.*

- **Well materials –** The environmental footprint for using PVC, steel, and high density polyethylene (HDPE; both schedule 5S and 10S, schedule 40 and schedule 80 and some Standard Dimension Ratio [SDR] specifications in case of high density polyethylene) to install wells is calculated by SiteWise™. The user is required to input the number of wells being installed and the depth of each well. From a drop-down menu the user can select the diameter of the well and the material of the well casing. The diameter choices range from 0.5 to 16 inches. In addition, the user has the option to calculate material requirements for wells, such as steel, concrete, bentonite, sand, gravel, and cement, using the Worksheet or the Calculations tab on the User Input file. Along with the dimensions listed above, the user is required to input the well finish type and filter pack material. The user can edit a vast number of dimensions to create a custom well construction or rely on estimations provided by the tool based on design guidelines (U.S. EPA Region 4, 2008).

<u>Assumption:</u> *The tool provides estimates for well materials based on design guidelines for flush mount and above ground riser type monitoring wells. If the user requires entering materials for specialized well types, dimensions can be edited in the Worksheet or Calculations tab of the Input sheet or dimensions can be calculated manually by the user and then input into the tool in*

the Bulk Quantities Materials table that has steel, concrete, and other construction materials among the choices. The Bulk Quantities Materials also provide the flexibility to select user designed materials. For such materials, the choice can be from material A to F and the emission factor will have to be manually input in the look-up table.

- **Treatment chemicals –** The materials included in the tool are in situ chemical oxidation (ISCO) chemicals (i.e., hydrogen peroxide, hydrochloric acid, biostimulant [vegetable oil], emulsified zero valent iron (EZVI), urea, fertilizer, acetic acid, sodium hydroxide, sodium hypochlorite, mulch, lime, phosphate fertilizer, soda ash, and iron exchange resin). Once the chemical used is selected, the user is required to input the number of injection points, the amount of material per injection and the number of injections. These inputs are considered to calculate the amount of material used, and this value determines the environmental impact of using these chemicals. SiteWise™ contains a list of commonly used materials, but in instances where materials are required but not included in the tool, five generic impact materials (very low, low, medium, high, and very high) are included in the tool. Table A-2 provides a list of example materials that fall within the generic materials categories. If a material is required but not included in this list, it is suggested that the user determine the GHG emissions for the material per kg outside of the tool and use the category ranges provided in this table to determine the appropriate generic impact material category to use. If the user has site-specific data, the emission factors in the look-up table can be overridden.

- **GAC (virgin and regenerated)** – To calculate the GHG emissions from GAC, the user is required to input the mass of either virgin or regenerated GAC used.

- **Construction materials –** The materials included in this category are HDPE, general concrete, gravel, and cement. After selecting the construction material, the user is required to input the total volume of the material used by entering both the area and depth required to be filled by the material in square feet and feet, respectively. The user should note that mils—a common method for specifying thickness of sheeting from materials such as HDPE—is not the unit specified. The user must convert the thickness from mils to feet for calculation in the tool.

<u>Assumption:</u> *The construction materials provided in the tool and used in remediation activities are primarily for capping and backfill after excavation.*

- **Well decommissioning materials –** The materials included in the tool in this category are soil, sand, general concrete, gravel, and typical cement. The amount of the material is calculated by entering the number, depth of wells, diameter of the well, and the material that would be used to backfill the wells.

- **Silt curtain materials –** The materials included in this category are all the different materials used in the construction of silt curtains, including steel, PVC, and a generic high impact material to account for polystyrene and nylon. The user inputs the total depth and area of the curtain and the tool calculates the quantities of each material required based on typical silt curtain design parameters.

- **Bulk Quantities materials –** The materials included in this category are all the different materials that are included in the other categories such as treatment, GAC, construction, sediment capping materials, and well decommissioning materials. The user also has the option to select generic impact materials or user defined materials (titled Materials A-F in the drop-down menus), for which the user will have to input the emission factor manually in the look-up table.

Transportation

SiteWise™ considers both personnel and material/equipment transportation to calculate the environmental footprint of a remedial action. The emission factors used by the tool for calculating the environmental footprint due to transportation-related activities are provided in Tables 2a to 2h and 6b of Appendix B.

Transportation - Personnel

The means of personnel transportation considered by SiteWise™ are road, air, and rail. For personnel transportation, the emission factors for air emissions are provided in mass per passenger mile based on the specific fuel used. Life cycle emission factors considered in the tool for the fuels were obtained from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory. The emission factors are termed "well to wheel" and therefore provide the impact of each fuel from the feedstock, manufacturer of the fuel, and the vehicle operation. Impacts for environmental criteria air pollutants emissions for personnel transportation contribute only to total (global) impacts and not on site impacts calculated by the tool.

- **Personnel Transportation Road –** To calculate the environmental footprint of road travel, SiteWise™ requires the user to input the distance travelled in miles, the number of travelers, the number of trips taken, the type of vehicle, and type of fuel. The choices for vehicles of personnel transport in the tool are car, hybrid car, sports utility vehicle (SUV), hybrid SUV, light truck, hybrid trucks, heavy duty trucks, and user specified types. The choices for fuel types in the tool for road transportation are gasoline, diesel, biodiesel 20, and e-diesel. The tool accounts for the fuel used and the emissions associated by producing and using that fuel by the distance traveled per trip (miles) and the number of trips taken. SiteWise™ also requires the user to input the number of travelers to calculate the accident risk associated with the travel. SiteWise™ estimates the vehicle fuel economy based on the vehicle selected, however the user has the option of over-riding the default fuel economy value with a known fuel miles per gallon (mpg). The default fuel economy values in the tool were obtained from www.fueleconomy.gov. If diesel fuel is selected, SiteWise™ calculates the decrease in PM emissions due to retrofitting the diesel run vehicles. The tool decreases the PM emissions by a general 50% (average for such retrofits, [U.S. EPA, 2009]) if the user selects to retrofit vehicles.

- **Personnel Transportation Air –** To calculate the environmental footprint of air travel, SiteWise™ requires the user to input the distance travelled in miles, the number of travelers, and the number of flights taken.

Assumption: *SiteWise™ assumes that the footprint of each traveler on a plane is not equal to the environmental impact of the entire plane's travel but the impact is shared or divided between all passengers on the plane*.

- **Personnel Transportation Rail –** SiteWise™ calculates the environmental impact for three types of rail travel: intercity, commuter, and transit. The user first selects the type of rail from a drop-down menu, then inputs the distance travelled in miles, the number of trips, and the number of travelers. Using this information, the tool can then determine the environmental footprint per passenger mile of rail travel.

Assumption: *Similar to air travel the environmental footprint is calculated per passenger mile assuming the environmental footprint of rail travel is per passenger and not for the entire rail.*

Transportation – Equipment

For transportation of equipment, SiteWise™ considers transportation by road, air, rail and water. For each mode of transportation, the environmental footprint is calculated based on the mass of material or equipment transported.

- **Equipment Transportation Dedicated Load Road –** For transporting equipment and supplies by dedicated load road, SiteWise™ considers transportation using an on-road truck. The inputs to calculate the emissions due to transporting the load are similar to road transport in personnel transportation except that the user is required to input the weight of the material or equipment transported. A default fuel economy of 7.2 mpg is used for the on-road truck; the user cannot override this fuel economy value because this fuel economy is of regular on-road truck with no mass to transport. The user can enter the weight of the material to be transported as zero when accounting for empty trucks for return trips to or from the site, or the user can select the option for the tool to automatically account for empty return trips. This fuel economy is used to calculate the change in fuel economy as the weight of transporting the material increases. The change is based on a linear extrapolation of carrying 0 to 40 tons of weight with the fuel economy being 7.2 mpg for 0 tons to carry and 3.6 mpg to carry 40 tons of weight. Trucks in the U.S. can carry a maximum of 40 tons (Federal Highway Administration [FHA], 2009). The emission factors for transportation of equipment by dedicated load road are provided in mass per gallon of fuel used.

- **Equipment Transportation Shared Load Road –** For transporting equipment and supplies by shared load road, SiteWise™ considers transportation using on-road trucks. The inputs to calculate the emissions due to transporting the mass in this case are distance traveled and weight of equipment transported. A default fuel economy of 42.5 ton-miles per gallon for equipment transported is used (U.S. EPA, 2008). This is based on national averages for diesel combination trucks. It should be noted that taking into account the fuel economies assumed in the tool for dedicated load and shared load equipment transportation, dedicated load equipment transportation is preferred with loads greater than 12.7 tons. The emission factors for transportation of equipment by road are provided in mass per gallon of fuel used.

- **Equipment Transportation Air –** To determine the environmental footprint of transporting equipment by air, the user simply needs to input the distance travelled and the mass of equipment being transported. Several references were used to calculate life cycle emission factors for air travel.

- **Equipment Transport Rail –** Similar to equipment transport by air the user is required to input the distance travelled and the mass of equipment being transported. Several references were used to calculate life cycle emission factors for rail cargo travel.

- **Equipment Transport Water –** As was done for rail and air equipment transport, the user needs to input the distance travelled and the mass of equipment transported by the waterborne craft. Emission factors in mass per ton-mile are provided by U.S. EPA Climate Leaders for a waterborne craft. If this mode is selected, the user is required to input the emission factors for criteria pollutants into the look-up table.

Equipment Use

SiteWise™ has the ability to calculate the environmental footprint associated with using pumps (electrical and run by fuel), earthwork equipment, sediment dredging and capping equipment, sediment management equipment, watercraft, blowers, compressors, generators, agricultural equipment, mixers, and stabilization equipment. The emission factors used by the tool for calculating the environmental footprint due to equipment use are provided in Tables 3a to 3f, 4b, 5a, 6c to 6k and 7b, and 7c of Appendix B.

Equipment Use Earthwork

Equipment use earthwork is separated into earthwork equipment, well drilling equipment, and trenching. Air emissions are based on mass per gallon of fuel used. Environmental criteria air pollutants emissions for fueled equipment are divided between on site (for fuel combustion) and off site (for fuel production). The tool estimates the life cycle emissions of CO_2e by assuming that the emissions are similar to heavy duty trucks in the GREET model. The other emission factors were taken from U.S. EPA's non-road model. SiteWise™ uses default horsepower, production rate, and fuel consumption rate based on the values provided in the look-up tables (Table 3b of Appendix B). These defaults can be over-ridden by the user in the look-up tables. The maximum horsepower of the equipment required is calculated by the tool based on the defaults listed in Table 3b. The emissions are all based on the horsepower of the equipment used. The tool calculates the risk to the operator for this equipment. This is only the risk of the equipment operator and not for other personnel working at the construction site. To determine the risk for other workers at the site, the user must input labor hours for these workers under the Operator Labor portion of the input sheet. For earthwork equipment such as dozers and scrapers, SiteWise™ determines the specification of the equipment according to the user input of volume of earth to be moved.

Equipment Use Sediment Remedy

Equipment use sediment remedy is separated into sediment dredging, sediment management, sediment capping, and watercraft operation. Air emissions are based on mass per gallon of fuel used. Environmental criteria air pollutants emissions for fueled equipment are divided between on site (for fuel combustion) and off site (for fuel production). For non-watercraft equipment, the tool estimates the life cycle emissions of CO_2e by assuming that the emissions are similar to heavy duty trucks in the GREET model. The other emission factors were taken from U.S. EPA's non-road model. For watercraft, emissions are estimated by using those methodologies outlined in Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories (U.S. EPA, 2009a). SiteWise™ assigns default horsepower, production rate, and fuel consumption rate based on the values provided in the look-up tables (Tables 3e and 3f of Appendix B). These defaults can be over-ridden by the user in the look-up tables. The maximum horsepower of the equipment required is calculated by the tool based on the defaults listed in Tables 3e and 3f. The emissions are all based on the horsepower of the equipment used. The tool calculates the risk to the operator for sediment management equipment only. This is only the risk of the sediment management equipment operator and not for other personnel working in landside operations. The tool does not automatically account for risk to operators of the dredging or capping equipment or operators of watercraft. To determine the risk for other workers at the site, the user must input labor hours for these workers under the Operator Labor portion of the input sheet. For sediment dredging, management, and capping equipment, SiteWise™ determines the specification of the equipment according to the user input of volume of sediment or cap material to be managed.

Equipment Use Pumps

SiteWise™ provides the user with several different options to calculate the air emissions impact of pumps used during remediation activities. Impacts can be calculated for general pumps using either electricity or fossil fuels. The user should ensure that only one method of calculating pump use is selected when inputting operational data, or else the tool may not correctly calculate the impact.

- **Electrical Pumps –** There are three different ways to calculate the electric consumption by pumps in the tool. The environmental footprint due to this equipment is based on the electric consumption. The first method to compute electric consumption is simple and is a manual entry by the user of the known total amount of electricity that the pump uses in total kilowatt- hour for the duration of the project or period being evaluated. The second method requires several more inputs. The user needs to enter the flowrate of the pump, total head, number of pumps operating, and total time each pump is operating. Default values are provided for the pump efficiency (0.6) and specific gravity (SG = 1.0) for the pump but these values can be overridden by the user, if necessary. The tool multiplies the pump motor efficiency (0.85) with the pump efficiency (0.6) to calculate the overall efficiency of the pump ($\eta = 0.85*0.6 = 0.51$). The user has the ability to override these values with other known values. This information is used to calculate the energy use of the pump:

$$Energy\ Use = \frac{Q \cdot H \cdot \rho \cdot SG}{\eta} \cdot N \cdot T \cdot Conversion\ Factor$$

where:
Q = flowrate [gpm]
H = total head [feet]
P = density of water [lb/cu.ft.]
N = number of pumps
T = time operating [hr]

The third method requires the user to input the horsepower of the pump, the number of pumps operating and the operating time of each pump. Default values are provided for pump load (0.8) and pump motor efficiency (0.85) but the user can override these values with other known values. The tool also provides the option for the user to input percent of maximum speed for VFD equipped motors, providing an estimate for pump load. The tool then calculates the electric consumption, which is used to calculate the environmental footprint.

$$Energy\ Use = Pump \cdot N \cdot T \cdot Conversion\ Factor$$

where:
Pump = pump specifications
N = number of pumps
T = time operating [hr]

The first method would be the most accurate, but it is not available for systems that are not yet operating and sometimes not known for operating systems. For existing systems, the total electric usage may be available for the entire system and, if so, then that value can be inputted. In that case, no other inputs should be used for any other electrical device. Method 2 is preferred for pumps with VFDs because the power output would be automatically adjusted based on pumping requirements. For pumps with single speed motors, Method 3 is preferred if the pump flow is to be controlled by throttling a flow control valve, but it can still be used for VFD equipped pumps by adjusting the pump load as indicated above. If the pump cycles, the user should input the number of hours that the pump is running.

Since VFDs tend to be more efficient and use less energy than single speed motors, VFDs can be considered to be a footprint reduction method. In order to evaluate the benefit and cost impact of using a VFD compared to a single speed motor, the user must run two scenarios where in one case Method 3 is used to model a single speed motor and then in the footprint reduction scenario Method 2 would be used. In the scenario where Method 2 is used and data for a VFD are entered at this input location, then the cost of the VFD should also be included in the Footprint Reduction tab. The comparative analysis would determine the energy savings by using a VFD, but the user will need to then determine the cost savings for this energy reduction and make sure that the inputting operating cost reflects this savings. Once this is done, the comparative analysis will show the impacts of using the VFD on all metrics including cost.

The emission factors for air emissions are based on those provided by State in the look-up table (Table 4a of Appendix B). The user chooses the State where the site is located in the Site Info tab. For sites where the user has site-specific information on electric emission factors, there is a provision in the tool called CUST in the drop-down menu to allow custom local emission factors to be used where the state emission factors do not apply. Emission factors for custom electricity profiles can be calculated within a given State using the calculator in the Worksheet or Calculations tab in the User Input file. In this case, the user is required to enter the electrical resource mix as percentages of electricity produced and the State where the site is located. Environmental criteria air pollutants emissions for electrical equipment are applied only to total (global) impacts.

- **Fuel Pumps –** For fuel pumps the user is required to first select the fuel used by the pump from the drop-down menu (gasoline, diesel, biodiesel 20 and e-diesel). The tool then allows the user to select the stroke of the pump. Either two or four stroke pumps can be selected with ranges from 0 to 74 horsepower for two stroke pumps and 0 to 175 horsepower for four stroke pumps. Emission factors are provided in mass per gallon. Environmental criteria air pollutants emissions for fueled pumps are divided between on site (for fuel combustion) and off site (for fuel production).

Assumption: *The equipment specification and horsepower range in the tool are according to U.S. EPA Non Road Model (U.S. EPA, 2005). The emissions are based on the horsepower ranges provided in the U.S. EPA model. If the user has different horsepower range equipment, then the best way to include such equipment is by using Other Fueled Equipment tab, which will require calculating the fuel consumption of the equipment outside the realm of the tool.*

Equipment Use Electrical

The electrical usage section of SiteWise™ is separated into two categories — general electrical equipment and generators. The user should ensure that only one method of calculating electrical equipment use is selected when inputting equipment use data, or else the tool may not correctly calculate the impact.

- **General Electrical Equipment –** Similar to electrical pumps, SiteWise™ provides different methods to determine the environmental footprint of using electrical equipment. The electrical equipment included in the tool is blowers, compressors, mixers, and other. After selecting the method of input and equipment type, the user should input the specific information required for the input method selected. In method 1, the user is asked to input the equipment horsepower, the number of pieces of equipment used, and the operating time for each piece of equipment. The tool provides default values for the equipment load and motor efficiency, but the user can override these values. The tool also provides the option for the user to input percent of maximum speed for VFD equipped motors, providing an estimate for pump load. The second method allows the user to input the total amount of electricity used by the equipment in use. Environmental criteria air pollutants emissions for electrical equipment are applied only to total (global) impacts.

- **Generators –** Three inputs are required to calculate the impact of air emissions by using generators during remediation. The user must choose the fuel type (gasoline, diesel, biodiesel 20, or e-diesel) from a drop-down menu. The horsepower range must then be selected. The tool can calculate emissions for generators with horsepower ratings ranging from 3 to 175. The user is also required to input the number of operating hours for the generator. Environmental criteria air pollutants emissions for generators are divided between on site (for fuel combustion) and off site (for fuel production).

Assumption: *The equipment specification and horsepower range in the tool are according to the U.S. EPA Non Road Model (U.S. EPA, 2005). The emissions are based on the horsepower ranges provided in the U.S. EPA model. If the user has different horsepower range equipment, then the best way to include such equipment is by using Other Fueled Equipment tab, which will require calculating the fuel consumption of the equipment outside the realm of the tool.*

Equipment Use Other

The other equipment sheet of SiteWise™ calculates the air emissions impact for agricultural, stabilization, and mixing equipment, as well as impacts from operation of diesel equipment on a per-hour basis. For each type of equipment the emission factors are provided in mass per gallon. The tool calculates the risk to the operator for this equipment. This is only the risk of the equipment operator and not for other personnel working at the construction site. To determine the risk for other workers at the site, the user must input labor hours for these workers under the Operator Labor portion of the input sheet. The inputs required by the tool are set up such that the total amount of fuel used by the equipment can be calculated. Environmental criteria air pollutants emissions for other equipment are divided between on site (for fuel combustion) and off site (for fuel production).

- **Agricultural Equipment –** The user must select from a drop-down menu the fuel used by the equipment (gasoline, diesel, biodiesel 20, or e-diesel). The other drop-down menus that the user must select from are the soil condition (firm untilled soil, previously tilled soil, and soft or sandy soil) and the soil type (clay, loam, or sand). The user should input the area that should be tilled (acres), the time taken to till (in work days), and the depth of area to till (inches). Using the inputs provided, SiteWise™ determines the minimum horsepower required by the equipment and selects the next higher horsepower as the horsepower of the tractor used. The tool calculates the fuel consumption rate of the equipment based on the horsepower determined, thus calculating the total amount of fuel used by the agricultural equipment. The defaults included in the tool pertaining to draft ratio and soil condition ratio are provided in Tables 6c and 6d of Appendix B. The tool assumes a speed of 5 miles/hour for the equipment and also assumes that the actual power is the same as the rated power of the equipment. The horsepower of the equipment is calculated using the formula (Sumner and Williams, 2007):

$$Horsepower = \frac{Area\ to\ till \cdot \text{factor for theoretical capacity} \cdot \text{Depth of Tillage} \cdot \text{Draft Ratio} \cdot \text{Speed} \cdot \text{Soil Condition ratio}}{\text{Time Available} \cdot \text{8 hours/day} \cdot \text{Speed}}$$

- **Internal Combustion Engine –** The tool has an ICE modeled so that the user can use this feature to model equipment that are not currently a part of SiteWise™ due to the fact that ICE (or a modified version of ICE) are part of the working mechanism of several equipment that are used. The user must input the operating hours and fuel consumption rate for the ICE and select the type of fuel used for the tool to calculate the emissions from the ICE.

- **Stabilization Equipment –** The user can calculate the environmental impact of a roller or paver. The stabilization equipment type should be selected from the drop-down menu as well as the fuel type. The same fuel options are available for all equipment in this category. The area to be stabilized (ft^2) and the estimated time to complete are inputs required to determine the environmental impact of stabilization equipment. The tool calculates the horsepower of the stabilization equipment based on best fit equations from a selection of documented rollers and pavers with rated gross power and specified operating widths (i.e., specified width for rollers and one-half the specified maximum width for pavers). Operating width, and therefore the rate of area coverage, is plotted against rated horsepower to estimate the relationship between area/time and calculated minimum required horsepower for each stabilization equipment type. Production rates for specific equipment types and horsepower ratings for plant mix asphalt paving are reported by RSMeans Building Construction Cost Data (RSMeans); these rates were used to calibrate the best fit equations used in the tool. The specific equations used are listed in the look-up table (Table 6f to 6h of Appendix B).

- **Mixers –** The impact of mixers are calculated in the same manner as agricultural and stabilization equipment. The inputs are required to determine the total amount of fuel and time required for use of the mixer to accomplish the task to determine its environmental footprint. The fuel type and horsepower should be selected from the drop-down menu. SiteWise™ can calculate the impact of mixers with horsepowers ranging from 1 to 750. The user is also required to input the volume of soil to be mixed (yd^3), the production rate (yd^3/hr), and the consumption rate (gal/hr).

- **Other Fueled Equipment –** The tool provides the user flexibility in terms of equipment use by providing the user with an option to add the amount of various fuels used to calculate the emissions. Since all equipment used onsite are not part of SiteWise™, the user can use this flexibility to calculate the emissions by the equipment if the amount of fuel used by the equipment is calculated manually by the user outside the realm of the tool. The emission factors for energy consumed and CO_2e emissions for the fuel used are life cycle based, while the criteria air pollutant emissions are based on emissions due to combustion of the fuel and do not take the entire life cycle of the fuel into consideration. This input location can also be used to input equipment that is not included specifically in the tool but the user has specifications for or knows the electric usage of it.

- **Other Fueled Equipment –** The tool also provides the user flexibility in terms of equipment use by providing the user with an option to input equipment use by selecting specific equipment on site and inputting the number of operational hours and fuel type. The impact of operating this equipment is then calculated as in the other tabs, but without the automatic selection of default equipment.

Assumption: *The equipment specification and horsepower range in the tool are according to the U.S. EPA Non Road Model (U.S. EPA, 2005). The emissions are based on the horsepower ranges provided in the U.S. EPA model. If the user has different horsepower range equipment, then the best way to include such equipment is by using Other Fueled Equipment tab, which will require calculating the fuel consumption of the equipment outside the realm of the tool.*

Residual Handling

The residual handling section of the input sheet allows the user to calculate the air emissions footprint from transporting residual waste (similar to transporting material by on-road truck), incinerating waste, and using a thermal oxidizer to oxidize contaminant waste.

- **Thermal/catalytic oxidizer –** SiteWise™ allows the user to calculate the environmental footprint of several different types of thermal oxidizers (Table 7b of Appendix B). From a drop-down menu the user must choose among the thermal oxidizer that will be used at the site: simple, recuperative, regenerative, flameless, recuperative flameless, fixed bed catalytic, and recuperative catalytic oxidizer. The user should also choose between natural gas and propane from the fuel type drop-down menu. Additional information the user is required to input is the waste gas flowrate (scfm) of the oxidizer, the running time (hr), waste gas inlet temperature (^{o}F), and the contaminant concentration. Electric blowers that are sometimes used in conjunction with the oxidizers can be modeled separately into SiteWise™ using electric equipment input box. Environmental criteria air pollutants emissions for thermal oxidizers are divided between on site (for fuel combustion) and off site (for fuel production).

Laboratory Analysis – SiteWise™ provides the user with inputting the cost of laboratory analysis to calculate the footprint associated with the laboratory analysis. The emission factors for this analysis were obtained from a U.S. EPA study.

On-site Labor Hours and Activities – On-site labor hours and activities are added into the tool to increase flexibility of the tool and allow the user to input labor hours for several categories of activities. Emission factors are based on data from the Department of Labor.

Table A-1. List of Formulas in SiteWise™ Tool

Equipment Use – Table of Outputs: Energy, Pollutants, Risks

Metric	Formula	Earthmoving	Well Drilling	Electric Pumps	Sediment Dredging	Sediment Management	Sediment Capping	Watercraft Operation	Fuel Pumps	General Electrical	Electric Generators	Agricultural	Stabilization	Mixing
BTU	Hours* gallons/hour * BTU/gallon = BTU	X	X		X	X	X	X	X		X	X	X	X
	MWh * conversion = BTU			X						X				
CO_2	Hours * gallons/hour * grams/gallon * conversion = metric tons	X			X	X	X	X	X		X	X	X	X
	MWh * pounds/MWh * conversion = metric tons			X						X				
	Hours * gallons/hour * kilograms/gallon * conversion = metric tons		X											
N_2O	Hours * gallons/hour * grams/gallon * GWP * conversion = metric tons	X	X		X	X	X	X	X		X	X	X	X
	MWh * pounds/MWh * GWP * conversion = metric tons			X						X				
CH_4	Hours * gallons/hour * grams/gallon * GWP * conversion = metric tons	X	X		X	X	X	X	X		X	X	X	X
	MWh * pounds/MWh * GWP * conversion = metric tons			X						X				
NO_x	Hours * gallons/hour * grams/gallon * conversion = metric tons	X	X		X	X	X	X	X		X	X	X	X
	MWh * pounds/MWh * conversion = metric tons			X						X				
SO_x	Hours * gallons/hour * grams/gallon * conversion = metric tons	X	X		X	X	X	X	X		X	X	X	X
	MWh * pounds/MWh * conversion = metric tons			X						X				
PM_{10}	Hours * gallons/hour * grams/gallon * conversion = metric tons	X	X		X	X	X	X	X		X	X	X	X
Risk	Hours * risk/hour = risk	X	X			X			X		X	X	X	X

Table A-1. List of Formulas in SiteWise™ Tool (Continued)

Transportation – Table of Outputs: Energy, Pollutants, Risks

Metric	Formula	Personnel - Road	Personnel - Air	Personnel - Rail	Equipment – Dedicated Load Road	Equipment – Shared Load Road	Equipment - Air	Equipment - Rail	Equipment - Water
BTU	Miles * gallons/mile * BTU/gallon = BTU	X			X				
	Passenger miles * BTU/passenger mile = BTU		X	X					
	Miles * tons * BTU/ton mile = BTU						X	X	X
	Ton miles * Gallons/ton mile * BTU/gallon = BTU					X			
CO_2	Miles * gallons/mile * kilograms/gallon * conversion = metric tons	X			X				
	Passenger miles * kilograms/passenger mile * conversion = metric tons		X	X					
	Ton miles * kilograms/ton mile * conversion = metric tons						X	X	X
	Ton miles * Gallons/ton mile * kilograms/gallon * conversion = metric tons					X			
N_2O, CH_4	Miles * gallons/mile * grams/mile gallon * GWP * conversion = metric tons	X			X				
	Passenger miles * grams/passenger mile * GWP * conversion = metric tons		X	X					
	Ton miles * grams/ton mile * GWP * conversion = metric tons						X	X	X
	Ton miles * Gallons/ton mile * grams/gallon * GWP * conversion = metric tons					X			
NO_x, SO_x, PM_{10}	Miles * gallons/mile * grams/gallon * conversion = metric tons	X			X				
	Passenger miles * grams/passenger mile * conversion = metric tons		X	X					
	Ton miles * grams/ton mile * conversion = metric tons						X	X	X
	Ton miles * gallons/ton mile * grams/gallon * conversion = metric tons					X			
Risk	Number of travelers * miles * risk/traveler mile = risk	X							
	Passenger miles * risk/passenger mile = risk		X	X					
	Miles * risk/mile = risk				X				

Table A-1. List of Formulas in SiteWise™ Tool (Continued)

Residual Handling – Table of Outputs: Energy, Pollutants, Risks

Metric	Formula	Waste Disposal	Thermal Oxidizer
BTU	Miles * gallons/mile * BTU/gallon = BTU	X	
	Fuel heating value * fuel consumed * conversion = MMBTU		X
CO_2	Miles * gallons/mile * kilograms/gallon * conversion = metric tons	X	
	MMBTU * pounds/MMBTU * conversion = metric tons		X
N_2O, CH_4	Miles * gallons/mile * grams/gallon * conversion = metric tons	X	
	MMBTU * pounds/MMBTU * GWP * conversion = metric tons		X
NO_x, SO_x, PM_{10}	Miles * gallons/mile * grams/gallon * conversion = metric tons	X	
	MMBTU * pounds/MMBTU * conversion = metric tons		X

Table A-1. List of Formulas in SiteWise™ Tool (Continued)

Materials – Table of Outputs: Energy, Pollutants, Risks

Metric	Formula	Well Materials	Treatment	GAC	Construction	Silt Curtain Materials	Decommissioning
BTU	Kilograms required * MJ/kilogram * conversion = BTU	X	X	X	X	X	X
CO_2	Kilograms required * kilograms/kilogram * conversion = metric tons	X	X	X	X	X	X
N_2O, CH_4	Kilograms required * grams/kilogram * GWP * conversion = metric tons	X	X	X	X	X	X
NO_x, SO_x, PM_{10}	Kilograms required * grams/kilogram * conversion = metric tons	X	X	X	X	X	X

Footprint Reduction

Item	Formula	Landfill Gas Microturbines	Wind Power	Solar Power	RECs
Fuel Flow	SCF Methane/year * BTU/SCF * conversion = BTU/hour	X			
Total Capacity	System Capacity, kW * Desired Fuel Flow, BTU/hour / Actual Fuel Flow, BTU/hour * Efficiency * conversion = kWh/year	X			
	Desired MWh / Years of Operation * conversion = kWh/year		X	X	X
Cost Avoidance	$/kWh * years * kWh/year = $	X	X	X	
Simple Payback	Capital Cost / (Annual Cost Avoidance – Annual O&M Cost)	X	X	X	

Table A-2. Generic Materials in SiteWise^{TM} Tool

Generic Materials Guide

Category	CO2 Categorizer (per kg of material)	# of Materials in Each Category	Generic Values for each Category Based on SimaPro Results for Select Materials (for 1 kg of material)					Materials Each Category is Based on (In order from greatest CO_2 emissions to smallest)
			Energy (MJ)	CO_2 eq (kg)	NOx (kg)	SOx (kg)	PM (kg)	Text represents name of option as selected in SimaPro
Very High Category- 5	> 5 kg CO2 eq	2	100	10	0.02	0.02	0.001*	Potassium nitrate, as N, at regional storehouse/RER S Virgin GAC_Assembly_1kg
High Category- 4	> 2 - 5 kg CO2 eq	6	60	3	0.006	0.008	0.001*	Chromium steel 18/8, at plant/RER S Anionic resin, at plant/CH S PVC pipe E Glass fiber, at plant/RER S HDPE pipes E Regen_GAC_1kg
Medium Category- 3	> 1 - 2 kg CO2 eq	9	30	1	0.003	0.005	0.001*	Acetic acid, 98% in H_2O, at plant/RER S Reinforcing steel, at plant/RER S Cationic resin, at plant/CH S Ammonium nitrate phosphate, as P2O5, at regional storehouse/RER S Sodium persulfate, at plant/GLO S Green Sand_1kg Potassium permanganate, at plant/RER S Hydrogen peroxide, 50% in H2O, at plant/RER S Sodium hydroxide, 50% in H_2O, production mix, at plant/RER S
Low Category- 2	> 0.05 - 1 kg CO2 eq	12	10	0.5	0.001	0.002	0.0004	Soybean oil, at oil mill/US S Sodium hypochlorite, 15% in H_2O, at plant/RER S Iron (III) chloride, 40% in H_2O, at plant/CH S Carbon dioxide liquid, at plant/RER S Cement, unspecified, at plant/CH S Lime, hydrated, loose, at plant/CH S Bentonite, at processing/DE S Iron sulfate, at plant/RER S Sulfuric acid, liquid, at plant/RER S

Table A-2. Generic Materials in SiteWise™ Tool (Continued)

Category	CO2 Categorizer (per kg of material)	# of Materials in Each Category	Generic Values for each Category Based on SimaPro Results for Select Materials (for 1 kg of material)					Materials Each Category is Based on (In order from greatest CO_2 emissions to smallest)
			Energy (MJ)	CO_2 eq (kg)	NOx (kg)	SOx (kg)	PM (kg)	Text represents name of option as selected in SimaPro
								Molasses, from sugar beet, at sugar refinery/CH S
								Pellets, iron, at plant/GLO S
								Hydrochloric acid, 36% in H2O, from reacting propylene and chlorine, at plant/RER S
Very Low Category- 1	0 - 0.05 kg CO2 eq	3	0.2	0.01	4.00 E-05	3.00 E-05	2.00E-05	Graphite, at plant/RER S
								Gravel, unspecified, at mine/CH S
								Sand, at mine/CH S

* The generic value for PM is based on the average PM emissions of all materials in the top three categories (average of 17 materials)

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APPENDIX B
TABLES WITH THE EMISSION FACTORS FROM LOOK-UP TABLE

Table 1a. Global warming potentials for GHG other than CO_2

100-Year Global Warming Potential (GWP)		
N_2O GWP	310	CO_2 e
CH_4 GWP	21	CO_2 e

U.S. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008", EPA 430-R-10-006, page 1-7, Table 1-2 (April 15, 2010)

Table 1b: Pipe weight per unit length for PVC, Steel, Stainless Steel, and HDPE

Nominal Pipe Size	Pipe Outside Diameter [a]	Schedule 40 PVC [b]	Schedule 80 PVC [b]	Schedule 120 PVC [c]	Schedule 40 Steel [a]	Schedule 80 Steel [d]	Schedule 5S Stainless Steel [e]	Schedule 10S Stainless Steel [e]	Schedule 40S Stainless Steel [e]	Schedule 80S Stainless Steel [e]	SDR 9 HDPE [f]	SDR 11 HDPE [f]	SDR 17 HDPE [f]	Schedule 40 HDPE [f]	Schedule 80 HDPE [f]
(inches)	(inches)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft
1/8	0.410	0.051	0.063	-	0.24	0.31	-	0.19	0.25	0.32	-	-	-	-	-
1/4	0.540	0.086	0.105	-	0.42	0.54	-	0.33	0.42	0.54	-	-	-	-	-
3/8	0.680	0.115	0.146	-	0.57	0.74	-	0.42	0.57	0.74	-	-	-	-	-
1/2	0.840	0.17	0.213	0.236	0.85	1	0.54	0.67	0.85	1.09	0.10	0.09	-	-	-
3/4	1.050	0.226	0.289	0.311	1.13	1.47	0.69	0.86	1.13	1.48	0.15	0.13	0.09	0.15	0.19
1	1.320	0.333	0.424	0.464	1.68	2.17	0.87	1.40	1.68	2.18	0.24	0.20	0.14	0.22	0.28
1 1/4	1.660	0.45	0.586	0.649	2.27	3	1.12	1.81	2.28	3.00	0.37	0.31	0.22	0.30	0.38
1 1/2	1.900	0.537	0.711	0.787	2.72	3.65	1.28	2.09	2.73	3.64	0.49	0.41	0.28	0.35	0.47
2	2.380	0.72	0.984	1.111	3.65	5.02	1.61	2.64	3.66	5.03	0.76	0.64	0.43	0.47	0.64
2 1/2	2.880	1.136	1.5	1.615	5.79	7.66	2.48	3.53	5.81	7.66	1.12	0.94	0.63	0.74	0.98
3	3.500	1.488	2.01	2.306	7.58	10.3	3.04	4.34	7.59	10.28	1.66	1.39	0.93	0.97	1.32
4	4.500	2.118	2.938	3.713	10.79	14.9	3.92	5.62	10.82	14.98	2.74	2.29	1.54	1.65	1.92
5	5.560	2.874	4.078	-	14.61	20.8	6.36	7.79	14.65	20.83	4.18	3.51	2.35	1.90	2.67
6	6.630	3.733	5.61	7.132	18.97	28.6	7.59	9.34	19.02	28.63	5.93	4.97	3.34	2.44	3.67
8	8.630	5.619	8.522	11.277	28.55	43.4	9.95	13.44	28.56	43.41	-	-	-	-	-
10	10.750	7.966	12.635	-	40.48	64.4	15.25	18.68	40.59	54.77	-	-	-	-	-
12	12.750	10.534	17.384	-	53.6	88.6	21.03	24.26	49.66	65.45	-	-	-	-	-
14	14.000	12.462	20.852	-	63	107	-	-	-	-	-	-	-	-	-
16	16.000	16.286	26.81	-	78	137	-	-	-	-	-	-	-	-	-

Table 1b: Pipe weight per unit length for PVC, Steel, Stainless Steel, and HDPE

Nominal Pipe Size	Pipe Outside Diameter [a]	Schedule 40 PVC [b]	Schedule 80 PVC [b]	Schedule 120 PVC [c]	Schedule 40 Steel [a]	Schedule 80 Steel [d]	Schedule 5S Stainless Steel [e]	Schedule 10S Stainless Steel [e]	Schedule 40S Stainless Steel [e]	Schedule 80S Stainless Steel [e]	SDR 9 HDPE [f]	SDR 11 HDPE [f]	SDR 17 HDPE [f]	Schedule 40 HDPE [f]	Schedule 80 HDPE [f]
(inches)	(inches)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft	lb/ft
18	18.000	20.587	33.544	-	105	171	-	-	-	-	-	-	-	-	-
20	20.000	24.183	41.047	-	123	209	-	-	-	-	-	-	-	-	-
24	24.000	33.652	58.233	-	171	297	-	-	-	-	-	-	-	-	-

[a] Values obtained from http://www.engineeringtoolbox.com/ansi-steel-pipes-d_305.html
[b] Values obtained from http://www.harvel.com/pipepvc-sch40-80-dim.asp
[c] Values obtained from http://www.harvel.com/pipepvc-sch120-dim.asp
[d] Values obtained from http://www.engineeringtoolbox.com/ansi-steel-pipes-d_306.html
[e] Values obtained from http://www.engineeringtoolbox.com/ansi-stainless-steel-pipes-d_247.html. Values converted from kg/m to lb/ft
[f] Values obtained from http://www.bdiky.com/images/files/Pipe%20Dimensions%2011-10.pdf

Table 1c. Impact per kg of material

Material	kg CO2 e / kg	g NOx / kg	g SOx / kg	g PM10 / kg	MJ /kg	MWH /kg	Density (g /gal)	Density (kg /m3)	References
Acetic Acid	1.36E+00	4.08E+00	6.80E+00	1.36E+00	3.60E+01	1.00E-02	3.98E+03	1.05E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Asphalt	1.40E-01	2.80E-01	5.60E-01	1.12E-01	2.41E+00	6.69E-04	7.57E+03	2.00E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Bentonite	2.20E-01	4.40E-01	8.80E-01	1.76E-01	3.00E+00	8.33E-04	6.81E+03	1.80E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Fertilizer	2.75E+00	5.50E+00	5.50E+00	2.75E-01	3.69E+01	1.03E-02	7.99E+03	2.11E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Virgin GAC	4.50E+00	9.00E-03	9.00E-03	4.50E-04	2.51E+01	6.98E-03	9.09E+02	2.40E+02	Carbon dioxide equivalent emissions and embodied energy values from EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf. All other figures estimated by categorical ratios from ESTCP study.
General Concrete	1.30E-01	2.60E-01	5.20E-01	1.04E-01	9.50E-01	2.64E-04	8.98E+03	2.37E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Glass	8.50E-01	3.10E+00	1.70E+00	7.00E-01	1.50E+01	4.17E-03	9.08E+03	2.40E+03	Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press.
Gravel	1.70E-02	6.80E-02	8.50E-02	3.40E-02	3.00E-01	8.33E-05	6.37E+03	1.68E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
HDPE	2.00E+00	4.00E+00	5.33E+00	6.67E-01	8.44E+01	2.34E-02	3.65E+03	9.65E+02	Carbon dioxide equivalent emissions and embodied energy values for HDPE Pipe from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
HDPE Liner	3.00E+00	6.20E+00	1.10E+01	1.60E+00	1.04E+02	2.89E-02	3.65E+03	9.65E+02	Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press.
Ion Exchange Resin	3.73E+00	7.46E+00	9.95E+00	1.24E+00	8.72E+01	2.42E-02	9.09E+02	2.40E+02	Carbon dioxide equivalent emissions and embodied energy values estimated by Battelle. All other figures estimated by categorical ratios from ESTCP study
Hydrochloric Acid	1.48E+00	2.96E+00	5.92E+00	1.18E+00	2.36E+01	6.56E-03	4.53E+03	1.20E+03	Carbon dioxide equivalent emissions and embodied energy values from Life Cycle Inventory software GaBi (version 4.3.85.1). Developed by PE International and LCI Process Database (version 4.126). Developed by National Renewable Energy Laboratory. All other figures estimated by categorical ratios from ESTCP study
Hydrogen Peroxide	1.34E+00	8.70E+00	6.60E+00	2.50E+00	2.30E+01	6.39E-03	4.55E+03	1.20E+03	Boustead, I. and M. Fawer. 1997. "Ecoprofile of Hydrogen Peroxide." Section 5: Ecoprofile Results.
LDPE	1.70E+00	5.10E+00	8.50E+00	1.70E+00	7.81E+01	2.17E-02	3.50E+03	9.25E+02	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Lime	8.48E-01	1.70E+00	3.39E+00	6.78E-01	6.29E+00	1.75E-03	4.92E+03	1.30E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database; EGRID 2002 (Emissions and Generation Resource Integrated Database). U.S. EPA. (www.epa.gov/cleanenergy/egrid); EIA-906 Database: Monthly Utility Power Plant Database. Energy Information Administration. (http://www.eia.doe.gov/cneaf/electricity/page/eia906u.html); Energy and Environmental Profile of the U.S. Mining Industry. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 2002; AP-42 Emission Factors. Chapter 11.19.2. Crushed Stone Processing and Pulverized Mineral Processing. US EPA. August 2004; AP-42 Emission Factors. Chapter 11.17. Lime Manufacturing. US EPA. February 1998; US Geological Survey. Minerals Yearbook 2003. Lime. Table 1: Salient Lime Statistics; Energy Information Administration. Manufacturing Energy Consumption Survey. Table A12. Selected Combustible Inputs of Energy for Heat, Power, and Electricity Generation and Net Demand for Electricity by Fuel Type and End Use, 1994: Part 1 ; USGS Mineral Industry Surveys: Lime in the United States 1950 to 2001. M. Michael Miller; Discussions between Franklin Associates and confidential industry sources, January 1998 ; Assumptions by Franklin Associates; U.S. EPA, Inventory of U.S.

Table 1c. Impact per kg of material

Material	kg CO2 e / kg	g NOx / kg	g SOx / kg	g PM10 / kg	MJ /kg	MWH /kg	Density (g /gal)	Density (kg /m3)	References
									Greenhouse Gas Emissions and Sinks: 1990-2000. Chapter 3: Industrial Processes. All other figures estimated by categorical ratios from ESTCP study
Mulch	2.60E-01	1.41E+00	2.38E+00	1.80E-01	5.84E+00	1.62E-03	2.35E+03	6.20E+02	NREL LCI Database; EGRID 2002 (Emissions and Generation Resource Integrated Database). U.S. EPA. (www.epa.gov/cleanenergy/egrid); EIA-906 Database: Monthly Utility Power Plant Database. Energy Information Administration. (http://www.eia.doe.gov/cneaf/electricity/page/eia906u.html); US Dbase profile (process emissions only).
Phosphate Fertilizer	1.76E-01	1.75E+00	1.61E+01	2.08E-01	5.98E+00	1.66E-03	7.99E+03	2.11E+03	NREL LCI Database; EGRID 2002 (Emissions and Generation Resource Integrated Database). U.S. EPA. (www.epa.gov/cleanenergy/egrid); EIA-906 Database: Monthly Utility Power Plant Database. Energy Information Administration. (http://www.eia.doe.gov/cneaf/electricity/page/eia906u.html).
PVC	3.11E+00	6.00E+00	9.70E+00	1.40E+00	6.75E+01	1.88E-02	5.26E+03	1.39E+03	NREL LCI Database
Regenerated GAC	2.00E+00	4.00E+00	5.33E+00	6.67E-01	2.23E+01	6.19E-03	9.09E+02	2.40E+02	Carbon dioxide equivalent emissions and embodied energy values from EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf. All other figures estimated by categorical ratios from ESTCP study
Sand	5.00E-03	2.00E-02	2.50E-02	1.00E-02	1.00E-01	2.78E-05	7.00E+03	1.85E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Soda Ash	2.01E+00	4.02E+00	5.36E+00	6.70E-01	1.80E+01	4.99E-03	9.47E+03	2.50E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Sodium Hydroxide (dry, bulk)	1.37E+00	4.11E+00	6.85E+00	1.37E+00	1.54E+01	4.26E-03	8.06E+03	2.13E+03	Carbon dioxide equivalent emissions and embodied energy values from EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf. All other figures estimated by categorical ratios from ESTCP study
Sodium Hypochlorite	1.48E+00	2.96E+00	5.92E+00	1.18E+00	2.36E+01	6.56E-03	4.32E+03	1.14E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Soil	2.30E-02	9.20E-02	1.15E-01	4.60E-02	4.50E-01	1.25E-04	7.00E+03	1.85E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Steel	1.77E+00	5.31E+00	8.85E+00	1.77E+00	2.44E+01	6.78E-03	2.98E+04	7.86E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Stainless Steel	6.15E+00	1.23E+01	1.64E+01	2.05E+00	5.67E+01	1.58E-02	2.95E+04	7.80E+03	Carbon dioxide equivalent emissions and embodied energy values for stainless steel from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Typical Cement	8.30E-01	1.66E+00	3.32E+00	6.64E-01	4.60E+00	1.28E-03	5.70E+03	1.51E+03	Carbon dioxide equivalent emissions and embodied energy values from Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', Proc. Instn. Civil. Engrs: Energy, in press. All other figures estimated by categorical ratios from ESTCP study
Urea	2.75E+00	5.50E+00	7.33E+00	9.17E-01	3.69E+01	1.03E-02	5.00E+03	1.32E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Vegetable Oil	8.65E-01	1.73E+00	3.46E+00	6.92E-01	1.73E+01	4.81E-03	4.96E+03	1.31E+03	Embodied energy values from Huo, H., et al. 2008. Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels. Energy Systems Division, Argonne National Laboratory, ANL/ESD/08-2. All other figures estimated by categorical ratios from ESTCP study
ZVI	1.25E+00	2.50E+00	5.00E+00	1.00E+00	9.05E+00	2.51E-03	2.95E+04	7.80E+03	Carbon dioxide equivalent emissions and embodied energy values from NREL LCI Database. All other figures estimated by categorical ratios from ESTCP study
Material A									
Material B				5.6.1	5.6.2	5.6.3	5.6.4	5.6.5	5.6.6
Material C									
Material D									
Material E									
Material F									

Table 1c. Impact per kg of material

Material	kg CO2 e / kg	g NOx / kg	g SOx / kg	g PM10 / kg	MJ /kg	MWH /kg	Density (g /gal)	Density (kg /m3)	References
Very Low Impact Material (Generic)	1.00E+01	2.00E+01	2.00E+01	1.00E+00	1.00E+02	2.78E-02	3.79E+03	1.00E+03	**Generic emission factors from ESTCP study. Density for generic materials assumed to be that of water.**
Low Impact Material (Generic)	3.00E+00	6.00E+00	8.00E+00	1.00E+00	5.6.7 6.00E+01	5.6.8 1.67E-02	5.6.9 3.79E+03	5.6.10 1.00E+03	5.6.11 **Generic emission factors from ESTCP study. Density for generic materials assumed to be that of water.**
5.6.12 Medium Impact Material (Generic)	5.6.13 1.00E+00	5.6.14 3.00E+00	5.6.15 5.00E+00	5.6.16 1.00E+00	5.6.17 3.00E+01	5.6.18 8.33E-03	5.6.19 3.79E+03	5.6.20 1.00E+03	5.6.21 **Generic emission factors from ESTCP study. Density for generic materials assumed to be that of water.**
5.6.22 High Impact Material (Generic)	5.6.23 5.00E-01	5.6.24 1.00E+00	5.6.25 2.00E+00	5.6.26 4.00E-01	5.6.27 1.00E+01	5.6.28 2.78E-03	5.6.29 3.79E+03	5.6.30 1.00E+03	5.6.31 **Generic emission factors from ESTCP study. Density for generic materials assumed to be that of water.**
5.6.32 Very High Impact Material (Generic)	5.6.33 1.00E-02	5.6.34 4.00E-02	5.6.35 5.00E-02	5.6.36 2.00E-02	5.6.37 2.00E-01	5.6.38 5.56E-05	5.6.39 3.79E+03	5.6.40 1.00E+03	5.6.41 **Generic emission factors from ESTCP study. Density for generic materials assumed to be that of water.**
5.6.42	5.6.43	5.6.44	5.6.45	5.6.46	5.6.47	5.6.48	5.6.49	5.6.50	5.6.51

Data for blank spaces not available

Table 1d. Silt curtain material impact

Component	Material	Quantity per linear ft (kg)	kg CO2 e / ft	g NOx / ft	g SOx / ft	g PM10 / ft	MJ / ft	MWH / ft
Curtain (DOT 18oz curtain)[a]	PVC	0.057	1.76E-01	3.40E-01	5.50E-01	7.94E-02	3.83E+00	1.06E-03
Polystyrene Float	High Impact Material	0.272	8.16E-01	1.63E+00	2.18E+00	2.72E-01	1.63E+01	4.54E-03
Bottom Ballast Chain	Steel	0.499	8.83E-01	2.65E+00	4.42E+00	8.83E-01	1.22E+01	3.38E-03
Top Tension Cable	Steel	0.077	1.36E-01	4.09E-01	6.82E-01	1.36E-01	1.88E+00	5.23E-04
Flotation Kit: PVC Buoy[b]	PVC	0.025	7.90E-02	1.52E-01	2.46E-01	3.56E-02	1.71E+00	4.76E-04
Flotation Kit: Nylon Rope[b]	High Impact Material	0.018	5.44E-02	1.09E-01	1.45E-01	1.81E-02	1.09E+00	3.02E-04
Total Impact Per Square Ft	NA	NA	1.76E-01	3.40E-01	5.50E-01	7.94E-02	3.83E+00	1.06E-03
Total Impact Per Linear Ft	NA	NA	1.97E+00	4.95E+00	7.67E+00	1.35E+00	3.32E+01	9.22E-03

[a] Quantities for PVC curtain are in kg per square foot

[b] Two flotation kits are assumed per 50 linear feet; other flotation kit and curtain materials are assume to be reused or minimal (anchor, anchor chain, grommets, zip-ties, etc.)

[c] Total impact per square foot accounts for the DOT 18oz curtain material only

[d] Total impact per linear foot accounts for the polystyrene float, bottom ballast chain, top tension cable, and flotation kit

Table 2a. Emissions and energy impact of fuels

Fuel	kg CO_2 / gallon	g N_2O / gallon	g CH_4 / gallon	Btu / gallon
Gasoline	10.633	0.23	12.72	139,015
Diesel	10.955	0.12	12.35	135,847
Biodiesel 20	9.311	0.33	10.78	170,745
E-Diesel	10.683	0.42	12.19	144,738

U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

Table 2b. Passenger vehicle fuel consumptions and emission factors

		Conventional Gasoline [c]						Conventional Diesel [c]						Biodiesel 20 [c]						E-Diesel [c]					
Vehicle	MPG[a,b]	g CO_2/ mile	g N_2O/ mile	g CH_4/ mile	g NOx/ mile	g SOx/ mile	g PM10/ mile	g CO_2/ mile	g N_2O/ mile	g CH_4/ mile	g NOx/ mile	g SOx/ mile	g PM10 / mile	g CO_2/ mile	g N_2O/ mile	g CH_4/ mile	g NOx/ mile	g SOx/ mile	g PM10/ mile	g CO_2/ mile	g N_2O/ mile	g CH_4/ mile	g NOx/ mile	g SOx/ mile	g PM10/ mile
Cars	29	367	0.016	0.446	0.141	0.005	0.029	378	0.013	0.428	0.141	0.002	0.030	321	0.020	0.373	0.141	0.002	0.030	369	0.023	0.422	0.141	0.002	0.030
Hybrid cars	37	287	0.016	0.345	0.118	0.004	0.029	296	0.013	0.336	0.123	0.002	0.030	254	0.018	0.295	0.123	0.001	0.030	290	0.021	0.331	0.123	0.002	0.030
SUVs	24	443	0.017	0.536	0.141	0.006	0.029	456	0.013	0.516	0.141	0.003	0.030	388	0.022	0.450	0.141	0.002	0.030	446	0.026	0.509	0.141	0.002	0.030
Hybrid SUVs	31	343	0.016	0.411	0.118	0.005	0.029	353	0.013	0.400	0.123	0.002	0.030	303	0.019	0.352	0.123	0.002	0.030	345	0.023	0.395	0.123	0.002	0.030
Light truck	20	532	0.019	0.642	0.229	0.007	0.033	548	0.013	0.619	0.291	0.003	0.034	466	0.024	0.540	0.291	0.003	0.034	535	0.028	0.611	0.291	0.003	0.034
Hybrid trucks	23	462	0.018	0.552	0.192	0.006	0.033	476	0.013	0.539	0.253	0.003	0.034	408	0.022	0.474	0.253	0.002	0.034	465	0.026	0.532	0.253	0.003	0.034
Heavy Duty	7.4	1,329	0.028	1.590	0.442	0.018	0.036	1,369	0.015	1.544	0.442	0.008	0.039	1,164	0.041	1.347	0.442	0.006	0.039	1,335	0.053	1.523	0.442	0.007	0.039
Other A																									
Other B																									

[a] Values obtained from U.S. Department of Energy and U.S. Environmental Protection Agency, "Fuel Economy Guide: Model Year 2011". Department of Energy/EE-0333, pages 4, 8-13, & 17. Averages were calculated from the highway fuel economy of various vehicles in several categories.

[b] Value for Heavy Duty obtained from U.S. Department of Energy, Argonne National Laboratory, "Evaluation of Fuel Consumption Potential of Medium and Heavy Duty Vehicles through Modeling and Simulation" (October 23, 2009), page 24, Figure 11. Value was determined from interpretation of the fuel economy plot when payload was equal to zero.

[c] Values obtained from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

Values for CO_2, CH4, and N_2O are the total of GREET Feedstock, Fuel, and Vehicle Operation values. Values for NOx, SOx, and PM10 are GREET Vehicle Operation values only

Default assumptions were used in GREET except for Gasoline Equivalent MPG. The MPG for the desired fuel and engine types was adjusted to match the MPG averages calculated from the "Fuel Economy Guide: Model Year 2011".

Table 2c. Air travel impact

kg CO_2/passenger mile[a]	0.21
g N_2O/passenger mile[b]	0.0085
g CH_4/passenger mile[b]	0.0104
g NO_x/passenger mile[c]	0.59
g SO_2/passenger mile[c]	0.058
g PM_{10}/passenger mile[c]	0.0037
Gallons/mile[d]	2.65
BTU/passenger mile[a]	2843

[a] Values obtained from Chester, Mikhail, and Arpad Horvath. 2008. Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air v.2. UC Berkeley: UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, page 104, Table 89. Retrieved from: http://escholarship.org/uc/item/5670921q. Operational emission values for Boeing 737 were used. CO2 values were converted from g/PMT to kg/PMT, and energy values were converted from MJ/PMT to BTU/PMT.

[b] Values obtained from EPA Climate Leaders "Optional Emissions from Commuting, Business Travel and Product Transport", EPA 430-R-08-006, page 7, Table 4 (May 2008)

[c] Values obtained from Chester, Mikhail, and Arpad Horvath. 2008. Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air v.2. UC Berkeley: UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, page 105, Table 91. Retrieved from: http://escholarship.org/uc/item/5670921q. Operational emission values for Boeing 737 were used. Values were converted from mg/PMT to g/PMT.

[d] Value obtained from EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources", EPA 430-K-08-004, page 12, Table 4 (May 2008)

Table 2d. Air cargo transportation impact

kg CO_2/ton mile[a]	1.358
g N_2O/ton mile[b]	0.0479
g CH_4/ton mile[b]	0.0417
g NOx/ton mile[a]	4.2642
g SOx/ton mile[a]	0.3094
g PM_{10}/ton mile[a]	0.0324
BTU/ton mile[c]	9,600

[a] Values obtained from Facanha, Cristiano and Arpad Horvath. Evaluation of Life-Cycle Air Emission Factors of Freight Transportation. *Environ. Sci. Technol.* 2007, 41, 7138-7144, Table 2. Emission factor values for Boeing 747-400 were used. Values for operational emissions were calculated by multiplying the life-cycle emission factor by the tailpipe share percentage.

[b] Values obtained from EPA Climate Leaders "Optional Emissions from Commuting, Business Travel and Product Transport", EPA 430-R-08-006, page 12, Table 8 (May 2008)

[c] Values obtained from "Transportation Energy Data Book". U.S. Department of Energy (June 2008)

Table 2e. Rail travel impact

Rail type	kg CO_2/passenger mile[a]	g N_2O/passenger mile[b]	g CH_4/passenger mile [b]	g NOx/passenger mile	g SOx/passenger mile[c]	g PM_{10}/passenger mile[c]	BTU/mile[a]
Intercity rail	0.13	0.001	0.002	0.012	0.17	0.0018	1,517
Commuter rail	0.16	0.001	0.002	1.4	0.011	0.038	2,085
Transit rail	0.2	0.002	0.004	0.035	0.48	0.0052	2,843

[a] Values obtained from Chester, Mikhail, and Arpad Horvath. 2008. Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air v.2. UC Berkeley: UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, page 80, Table 67. Retrieved from: http://escholarship.org/uc/item/5670921q. Operational emission values for Caltrain, Muni, and CAHSR were used for Commuter, Transit, and Intercity, respectively. CO2 values were converted from g/PMT to kg/PMT, and energy values were converted from MJ/PMT to BTU/PMT.

[b] Values obtained from EPA Climate Leaders "Optional Emissions from Commuting, Business Travel and Product Transport", EPA 430-R-08-006, page 5, Table 2 (May 2008)

[c] Values obtained from Chester, Mikhail, and Arpad Horvath. 2008. Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air v.2. UC Berkeley: UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, page 82, Table 69. Retrieved from: http://escholarship.org/uc/item/5670921q. Operational emission values for Caltrain, Muni, and CAHSR were used for Commuter, Transit, and Intercity, respectively. Values were converted from mg/PMT to g/PMT.

Table 2f. Rail cargo transportation impact

kg CO_2/ton mile[a]	0.0400
g N_2O/ton mile[b]	0.0006
g CH_4/ton mile[b]	0.0020
g NOx/ton mile[a]	0.7252
g SOx/ton mile[a]	0.1068
g PM_{10}/ton mile[a]	0.0445
BTU/ton mile[c]	305

[a] Values obtained from Facanha, Cristiano and Arpad Horvath. Evaluation of Life-Cycle Air Emission Factors of Freight Transportation. *Environ. Sci. Technol.* 2007, 41, 7138-7144, Table 2. Emission factor values for Intermodal Rail were used. Values for operational emissions were calculated by multiplying the life-cycle emission factor by the tailpipe share percentage.

[b] Values obtained from EPA Climate Leaders "Optional Emissions from Commuting, Business Travel and Product Transport", EPA 430-R-08-006, page 12, Table 7 (May 2008)

[c] Value obtained from U.S. Department of Energy "Transportation Energy Data Book: Edition 29". ORNL-6985, page 2-20, Table 2.16 (July 2010). Value from 2008 was used.

Table 2g. Water cargo transportation impact

kg CO_2/ton mile[a]	0.0480
g N_2O/ton mile[a]	0.0014
g CH_4/ton mile[a]	0.0041
g NOx/ton mile	
g SOx/ton mile	
g PM_{10}/ton mile	
BTU/ton mile[b]	418

[a] Values obtained from EPA Climate Leaders "Optional Emissions from Commuting, Business Travel and Product Transport", EPA 430-R-08-006, page 12, Table 8 (May 2008)

[b] Value obtained from U.S. Department of Energy "Transportation Energy Data Book: Edition 29". ORNL-6985, page 2-20, Table 2.16 (July 2010). Value from 2008 was used.

Table 2h. Fatality and injury rates

Item	Fatality	Injury	Units	References	Lost Hours	Reference
Construction laborers	9.15E-08	2.30E-05	per hour	a,b	10	g, used "Construction and extraction…"
Operating engineers	5.35E-08	2.30E-05	per hour	a,b	10	g, used "Construction and extraction…"
Waste management services	5.95E-08	2.70E-05	per hour	a,b	8	g, used Total
Scientific and technical services	4.50E-09	5.50E-06	per hour	a,b	3	g, used Architecture and engineering…"
Other occupation						
Road Transportation	7.80E-09	6.28E-07	per passenger mile	c,d	8	g, used Total
Road Transportation - Equipment	7.80E-09	6.28E-07	per passenger mile	c,d	17	g, used "Truck drivers…"
Air Transportation	1.00E-10	2.67E-11	per passenger mile	c,e	8	g, used Total
Rail Transportation	4.00E-10	5.16E-08	per passenger mile	c,f	8	g, used Total

[a] Fatality rates from Bureau of Labor Statistics, Hours-based fatal injury rates by industry, occupation, and selected demographic characteristics, 2009 data. http://www.bls.gov/iif/oshwc/cfoi/cfoi_rates_2009hb.pdf. Site visited 10/4/2010. Values were converted from fatal occupational injuries per 100,000 FTEs to fatal occupational injuries per hour.

[b] Injury rates from Bureau of Labor Statistics, News Release, 10/29/2009, "Workplace Injuries and Illnesses - 2008", USDL-09-1302, Table 5. Values were converted from injuries per 100 FTEs to injuries per hour.

[c] Fatality rates from Air Transportation Association presentation, October 4, 2010. http://www.airlines.org/Economics/ReviewOutlook/Documents/ATAIndustryReview.pdf. Site visited 10/5/2010. Values were converted from rate/100,000,000 passenger miles to rate/passenger mile.

[d] Injury rate from NHTSA "Traffic Safety Facts: 2008 Data", DOT HS 811 162, page 3, Table 2. Values were calculated from average of 1998-2008 data. Calculation assumes 1.59 passengers per vehicle. This value is from Victoria Transport Policy Institute, TDM Encyclopedia, Table 6. http://www.vtpi.org/tdm/tdm58.htm. Site visited 10/5/2010.

[e] Injury rate from U.S. Department of Transportation, Research and Innovation Technology Administration, Bureau of Transportation Statistics. *National Transportation Statistics 2010*, Table 2-9. Values were calculated from average of 1996-2009 data. Calculation assumes 162 passengers per aircraft.

[f] Injury rate from Federal Railroad Administration, Office of Safety Analysis. http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/query/statsSas.aspx. Site visited 10/5/2010. Values were calculated from average of 1996-2009 data.

[g] Lost hours from Bureau of Labor Statistics, News Release, 11/24/2009, "Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, 2008", USDL-09-1454, Tables 9 and 10. Used median days away from work.

Table 3a. Efficiency factors for earthwork equipment use

Equipment	Work time	Load Factor	Bucket Fill	A Blade	U Blade	Grade	Visibility	Total of Factors
Dozer with A Blade	0.83	0.75	1.00	1.00	1.00	1.00	0.80	0.50
Dozer with U Blade	0.83	0.75	1.00	1.00	1.20	1.00	0.80	0.60
Loader/Backhoe	0.83	0.75	1.10	1.00	1.00	1.00	1.00	0.68
Excavator	0.83	0.75	1.10	1.00	1.00	1.00	1.00	0.68
Scraper	0.83	1.00	1.00	1.00	1.00	1.00	1.00	0.83

Rast, Richard R. 2003. RSMeans: Environmental Remediation Estimating Methods, 2nd edition, Reed Construction Data, pages 381-387. If no efficiency factor was given or the efficiency factor does not apply, a value of 1.00 has been inserted as a placeholder.

Table 3b. Earthwork equipment production rates and impact

EARTHWORK EQUIPMENT	Volume Range, CY		Diesel	Approximate	Consumption Rate[a]	Production Rate	grams/operating hour, Conventional Diesel[b,c,d]					
	Low	High	hp range	hp	(gal / hr)	(CY/hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
Dozer, 65 HP (D3) w/A Blade	0	1,001	50 to 75	65.1	5.1	100	29,589	1.1	2.6	166	41	21
Dozer, 80 HP (D4) w/A Blade	1,000	2,001	75 to 100	80.1	5.1	200	40,072	1.1	2.6	252	62	33
Dozer, 105 HP (D5) w/A Blade	2,000	3,501	100 to 175	105	7.9	300	57,344	1.7	4.0	351	87	32
Dozer, 140 HP (D6) w/A Blade	3,500	5,001	100 to 175	140	7.9	360	57,344	1.7	4.0	351	87	32
Dozer, 200 HP (D7) w/U Blade	5,000	6,501	175 to 300	200.1	16.5	700	104,376	3.6	8.3	578	151	47
Dozer, 335 HP (D8) w/U Blade	6,500	8,001	300 to 600	335	21.6	960	173,672	4.8	10.8	1,188	272	83
Dozer, 460 HP (D9) w/U Blade	8,000	10,001	300 to 600	460.1	21.6	1200	173,672	4.8	10.8	1,188	272	83
Dozer, 700 HP (D10) w/U Blade	10,000	1,000,000	600 to 750	700	31.8	1700	281,287	7.0	15.9	1,972	452	145
Loader, 65 HP, 1 CY	0	1,501	50 to 75	65.2	1.3	111	11,421	0.3	0.7	88	18	17
Loader, 80 HP, 1.5 CY	1,500	3,001	75 to 100	80.2	1.8	166	15,913	0.4	0.9	124	26	24
Loader, 100 HP, 2 CY	3,000	4,501	75 to 100	100	1.8	199	15,913	0.4	0.9	124	26	24
Loader, 155 HP, 3 CY	4,500	6,001	100 to 175	155	2.1	299	19,599	0.5	1.1	174	32	21
Loader, 200 HP, 4 CY	6,000	7,501	175 to 300	200.2	2.9	398	31,437	0.6	1.5	278	53	32
Loader, 270 HP, 5.25 CY	7,500	9,001	175 to 300	270.2	2.9	475	31,437	0.6	1.5	278	53	32
Loader, 375 HP, 7 CY	9,000	10,501	175 to 300	375	2.9	601	31,437	0.6	1.5	278	53	32
Loader, 690 HP, 13.5 CY	10,500	100,000	175 to 300	690	2.9	960	31,437	0.6	1.5	278	53	32
Excavator, Hydraulic, 1.5 CY	0	2,001	100 to 175	150	7.9	249	57,822	1.7	4.0	340	88	32
Excavator, Hydraulic, 1.25 CY	2,000	4,001	100 to 175	125	7.9	170	57,822	1.7	4.0	340	88	32
Excavator, Hydraulic, 2 CY	4,000	6,001	175 to 300	270.3	10.8	239	93,350	2.4	5.4	546	149	45
Excavator, Hydraulic, 3.125 CY	6,000	8,001	300 to 600	380	21.4	301	168,679	4.7	10.7	1,082	263	75
Excavator, Hydraulic, 4 CY	8,000	10,001	300 to 600	400	21.4	299	168,679	4.7	10.7	1,082	263	75
Excavator, Hydraulic, 5.5 CY	10,000	1,000,000	300 to 600	515	21.4	329	168,679	4.7	10.7	1,082	263	75
Scraper, Standard, 15 CY	0	5,001	300 to 600	330	16	300	137,112	3.5	8.0	944	219	66
Scraper, Standard, 22 CY	5,000	10,001	300 to 600	460.4	16	500	137,112	3.5	8.0	944	219	66
Scraper, Standard, 34 CY	10,000	1,000,000	300 to 600	500	16	690	137,112	3.5	8.0	944	219	66
Crawler Crane, 25 ton, 1 CY	0	25,001	100 to 175	175	3.3	26	40,311	0.8	4.7	308	46	20
Crawler Crane, 50 ton, 2 CY	25,000	50,001	100 to 175	175	3.3	65	33,897	0.8	4.7	308	46	20
Crawler Crane, 100 ton, 4 CY	50,000	75,001	175 to 300	300	5.3	124	43,494	1.4	7.7	479	76	27
Crawler Crane, 150 ton, 6 CY	75,000	100,001	175 to 300	300	5.3	190	33,087	1.4	7.7	479	76	27
Crawler Crane, 200 ton, 8 CY	100,000	1,000,000	300 to 600	600	9.3	249	33,087	2.4	13.3	990	131	54

[a] Fuel consumption rates were estimated from the Fuel Consumption Chart at www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx

[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.

[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).

[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 3c. Consumption rates for well drilling

Drilling Method	Average Consumption Rate (gal/hr)	Minimum Consumption Rate (gal/hr)	Maximum Consumption Rate (gal/hr)
Direct Push	0.8	0.6	1.0
Pump Rig	1.6	1.3	1.9
Sonic Drilling	5.7	5.0	6.3
Hollow Stem Auger	7.6	6.3	8.8
Mud Rotary	14.1	12.5	15.6
Air Rotary	25.0	21.9	28.1

Estimates from American Well Technologies (Gigi Marie, 717-919-8515)

Table 3d. Well drilling impact

Fuel Type	kg CO_2/gal[a]	g N_2O/gal[a]	g CH_4/gal[a]	g NOx/gal[b]	g SOx/gal[b]	g PM_{10}/gal[b]
Gasoline	10.633	0.23	12.72	46.60	2.10	1.40
Diesel	10.955	0.12	12.35	113.70	14.20	10.60

[a] Values obtained from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.[b] NOx, SOx, and PM10 operational emission factors were calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) emission factors (g/operating hour) by a calculated fuel consumption rate (gal/hour) for each horsepower range (See Table 4b, footnote a, for method). Values are the average for Bore/Drill Rigs, horsepower ranges 6 to 750 for diesel and 0 to 175 for gasoline.

Table 3e: Watercraft impact

Vessels	Load Factor	Primary Engine	Average Primary	Auxiliary Engine	Average Auxiliary	Consumption Rate[a]	grams / operating hour, Conventional Diesel[b, c]					
		kW	Engines	kW	Engines	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
Dredge Tender	0.69	711.4	1.9	55.7	1.5	67.3	832,501	22.0	1,071	10,119	1,504	492
Barge Tender	0.31	711.4	1.9	55.7	1.5	30.2	374,022	9.9	481	4,546	676	221
Research Vessel (very large)	0.43	275.9	1.8	55.7	0.6	15.5	191,601	5.1	246	2,329	346	91
Research Vessel (large)	0.43	111.9	2	0	0	6.5	66,401	1.9	9	943	125	38
Light Craft (medium)	0.43	74.6	1	0	0	2.2	22,134	0.6	3	314	42	29
Light Craft (small)	0.43	37.3	1	0	0	1.1	11,067	0.3	1	157	21	14
Light Craft (very small)	0.43	3.73	1	0	0	0.1	1,645	0.0	2	18	2	2

[a] Fuel consumption rates were estimated from operational CO2 emissions

[b] Emission factors assume Tier 1 engines; for dredge tenders and tugboats, 25% of primary engines were assumed to be Category 2 to calculate PM10 emissions.
[b] CO2, CH4, N2O, NOx, SOx, and PM10 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the operational emission factor from U.S. EPA. 2009. Current Methodologies in Preparing Mobile Source Port-Related Emissions Inventories.

[c] Life cycle emission factors for very small light craft were taken from Table 5A: Generator set impact for generators between 3 and 6 HP.

Table 3f: Dredging and capping production rates and impact

DREDGING EQUIPMENT	Volume Range, CY		Diesel	Approximate	Consumption Rate[a]	Production Rate	grams / operating hour, Conventional Diesel[b,c,d]					
	Low	High	hp range	hp	(gal / hr)	(CY/hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
Crawler Crane, 25 ton, 1 CY	0	25,001	100 to 175	175	3.3	26	40,311	0.8	4.7	308	46	20
Crawler Crane, 50 ton, 2 CY	25,000	50,001	100 to 175	175	3.3	65	33,897	0.8	4.7	308	46	20
Crawler Crane, 100 ton, 4 CY	50,000	75,001	175 to 300	300	5.3	124	43,494	1.4	7.7	479	76	27
Crawler Crane, 150 ton, 6 CY	75,000	100,001	175 to 300	300	5.3	190	33,087	1.4	7.7	479	76	27
Crawler Crane, 200 ton, 8 CY	100,000	1,000,000	300 to 600	600	9.3	249	33,087	2.4	13.3	990	131	54
Hydraulic Dredge Head, 15 cm	0	46,000	25 to 40	30	0.9	46	10,273	0.2	0.4	82	18	10
Hydraulic Dredge Head, 25 cm	46,001	1,000,000	75 to 100	90	2.1	262	25,850	0.5	1.1	226	44	28
Hopper Barge	0	1,000,000	NA	0	0	940	0	0.0	0.0	0	0	0

[a] Fuel consumption rates were estimated from operational CO2 emissions
[b] CO2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.

[c] CH4 and N2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).
[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 4a: Electricity use impact by State*

Profile Name	Abbreviation	(lb CO_2 / MWh) [a,b,c,d]	(lb N_2O / MWh) [a,b,c,d]	(lb CH_4 / MWh) [a,b,c,d]	(lb NOx / MWh) [a,b,c,d,e]	(lb SO_2 / MWh) [a,b,c,d,e]	(lb PM_{10} / MWh) [a,d,e]	(Electrical Energy Production Efficiency) [a,f]	(Percent of Electrical Energy from Renewable Sources) [a]
Alaska	AK	1302.08	0.00910	2.76182	4.1910	1.5038	0.6514	0.2968	0.1991
Alabama	AL	1154.31	0.01768	2.04995	1.0544	4.3231	1.7647	0.3881	0.1177
Arkansas	AR	1230.58	0.01934	2.10012	1.5940	2.8051	1.9656	0.3950	0.1031
Arizona	AZ	1236.53	0.01646	2.33537	1.5780	0.8509	1.6227	0.3806	0.0608
California	CA	679.37	0.00613	2.26561	0.5440	0.3020	0.0790	0.4259	0.2638
Colorado	CO	1955.27	0.02835	3.04973	3.1060	2.2591	2.8747	0.2932	0.0966
Connecticut	CT	659.84	0.01200	1.53392	0.6137	0.4967	0.3766	0.4712	0.0406
District of Columbia	DC	2880.29	0.02614	2.56257	5.9788	20.4731	0.3890	0.1518	0.0000
Delaware	DE	1983.92	0.02605	3.02767	2.5869	7.8408	3.4893	0.2846	0.0097
Florida	FL	1352.52	0.01630	2.96336	1.4965	2.5362	1.2490	0.3071	0.0228
Georgia	GA	1415.55	0.02268	2.28442	1.3009	4.7098	2.5548	0.3740	0.0496
Hawaii	HI	1854.01	0.02431	2.41772	4.5154	5.9567	1.2233	0.2487	0.0757
Iowa	IA	1764.87	0.02906	2.29938	1.9789	4.1185	3.4733	0.3450	0.1649
Idaho	ID	151.18	0.00264	0.52662	0.2210	0.2179	0.0443	0.7154	0.8708
Illinois	IL	1162.23	0.01894	1.52150	0.9901	2.7209	2.1077	0.4338	0.0190
Indiana	IN	2209.89	0.03664	2.97910	2.4053	7.8002	4.6855	0.2959	0.0194
Kansas	KS	1819.00	0.02908	2.34406	2.5041	2.4887	3.1392	0.3259	0.0621
Kentucky	KY	2224.71	0.03764	2.93230	2.1900	6.1030	4.2176	0.2904	0.0417
Louisiana	LA	1274.32	0.01429	2.68592	1.6511	2.1891	1.2833	0.3272	0.0418
Massachusetts	MA	1265.14	0.01926	2.89078	1.2449	2.3760	1.0718	0.3381	0.0484
Maryland	MD	1344.97	0.02365	1.88800	1.1869	10.0115	2.7720	0.3880	0.0535
Maine	ME	624.30	0.02425	1.98465	1.0668	0.8081	0.0734	0.3706	0.5045
Michigan	MI	1665.65	0.02843	2.37163	2.1072	6.1014	2.9722	0.3420	0.0311
Minnesota	MN	1523.64	0.02878	1.98554	2.0428	2.3673	2.8125	0.3463	0.1348
Missouri	MO	1964.21	0.03210	2.63381	1.6587	6.2347	3.7554	0.3235	0.0333
Mississippi	MS	1243.08	0.01506	2.65370	1.5584	2.0260	1.2522	0.3145	0.0327
Montana	MT	1561.56	0.02612	1.84914	1.9502	2.8707	2.5909	0.3675	0.3920
North Carolina	NC	1263.98	0.02152	1.84987	1.0014	2.2052	2.7695	0.4104	0.0590
North Dakota	ND	2228.04	0.03582	2.66019	4.2080	8.3115	3.8533	0.3053	0.1314
Nebraska	NE	1732.20	0.02868	2.10944	3.1176	4.7935	3.0776	0.3454	0.0425
New Hampshire	NH	687.75	0.01623	1.55600	0.7618	3.7835	0.7227	0.4337	0.1295
New Jersey	NJ	631.22	0.00694	1.56528	0.5683	0.6051	0.4581	0.4912	0.0124
New Mexico	NM	2046.32	0.03076	3.16279	4.0284	1.2519	3.3018	0.2932	0.0468
Nevada	NV	1244.35	0.01090	3.31328	1.3011	0.6712	0.9647	0.3485	0.1132
New York	NY	667.43	0.00736	1.56448	0.6779	0.9084	0.5072	0.4643	0.2421
Ohio	OH	1939.26	0.03217	2.71511	1.8866	9.8407	4.3423	0.3267	0.0086
Oklahoma	OK	1661.54	0.02062	3.15186	2.5866	3.0134	2.1447	0.2987	0.0884
Oregon	OR	433.76	0.00470	1.30262	0.5138	0.5282	0.3028	0.5703	0.6586
Pennsylvania	PA	1253.55	0.02052	2.00868	1.4227	6.2666	2.6592	0.3973	0.0243
Rhode Island	RI	1063.42	0.00378	3.73858	0.6669	0.2422	0.0183	0.3384	0.0194
South Carolina	SC	909.84	0.01484	1.45650	0.7329	2.3341	1.8869	0.4669	0.0295
South Dakota	SD	991.71	0.01630	1.25355	3.4095	3.2365	1.7821	0.4763	0.5918
Tennessee	TN	1167.91	0.01999	1.63363	0.9825	3.0234	2.4549	0.4416	0.1324
Texas	TX	1426.51	5.6.52 0.01651	5.6.53 2.98592	5.6.54 1.2614	5.6.55 2.6770	5.6.56 1.6794	5.6.57 0.3368	5.6.58 0.0562
Utah	UT	2078.83	0.03324	3.15066	3.5556	1.4402	3.7417	0.3007	0.0289
Virginia	VA	1104.32	0.01896	1.86043	1.2462	3.0979	1.6954	0.3838	0.0385
Vermont	VT	15.24	0.00783	0.08337	0.1888	0.0149	0.0187	0.7381	0.2631

Table 4a: Electricity use impact by State*

Profile Name	Abbreviation	(lb CO_2 / MWh) [a,b,c,d]	(lb N_2O / MWh) [a,b,c,d]	(lb CH_4 / MWh) [a,b,c,d]	(lb NOx / MWh) [a,b,c,d,e]	(lb SO_2 / MWh) [a,b,c,d,e]	(lb PM_{10} / MWh) [a,d,e]	(Electrical Energy Production Efficiency) [a,f]	(Percent of Electrical Energy from Renewable Sources) [a]
Washington	WA	332.16	0.00500	0.69132	0.3740	0.1441	0.3327	0.6405	0.7531
Wisconsin	WI	1655.67	0.02725	2.29963	1.5731	4.1158	2.8332	0.3392	0.0618
West Virginia	WV	2182.60	0.03663	2.95554	1.4421	5.5247	5.0096	0.3079	0.0339
Wyoming	WY	2352.84	0.03896	2.90868	3.5970	3.8517	4.3193	0.2816	0.0701
User Customizable	CUST								
U.S. Weighted Average	US Average	1353.29	0.02022	2.31018	1.4907	3.4282	2.1551	0.3650	0.1064

*Impact factors and state electricity source distributions were calculated from several sources.

[a] Values for regional transmission and distribution losses and subregion energy feedstock distributions by electricity generation obtained from USEPA, eGRID 2012 Version 1.0 Year 2009 Summary Tables.

[b] Values for plant emission factors obtained from USEPA, eGRID 2012 Version 1.0 Year 2009 Summary Tables.

[c] Values for Coal, Oil, Gas, Other Fossil Fuels, Biomass, Nuclear, and Geothermal well-to-pump impact factors (except Biomass NOx and SO_2 impact factors) obtained from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010. GREET data for emissions associated with production and delivery of nonrenewable feedstocks to the power plant were multiplied by the eGRID 2012 subregion percent resource mix for each feedstock and added to the eGRID 2012 subregion emissions.

[d] Values for Wind, Hydroelectric, and Solar lifecycle impact factors obtained from Weisser, Daniel. 2007. A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies. *Energy* 32, 1543-1559. Values for emissions were multiplied by the eGRID 2012 subregion percent resource mix for each feedstock and added to the eGRID 2012 subregion emissions.

[e] Values for all lifecycle PM_{10} emission factors and Biomass lifecycle NOx and SO_2 emissions factors obtained from US EPA's 2008 National Emission Inventory (NEI) Data. NEI data for NOx and SO2 emissions associated with production and delivery of nonrenewable feedstocks to the power plant were multiplied by the eGRID 2012 subregion percent resource mix for each feedstock and added to the eGRID 2012 subregion emissions; NEI data for PM10 emissions were multiplied by the eGRID 2012 subregion percent resource mix for each feedstock.

[f] Values for well-to-pump energy inputs by feedstock obtained from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010. Values for energy input and output at plant by feedstock obtained from USEPA, eGRID 2012 Version 1.0 Year 2009 Summary Tables. Values by feedstock for electricity delivered to site (after transmission and distribution losses) were divided by lifecycle values for energy input to determine lifecycle energy efficiency. Lifecycle values for energy input for renewable sources were assumed to satisfy the first law of thermodynamics.

Table 4b. Pump impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[a]	Grams/operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
1 to 3	0.1	897	0.0	0.0	9	2	1	2-Stroke: 0 to 1	0.1	860	0.0	0.0	1	0	7
3 to 6	0.1	1,562	0.0	0.1	16	3	2	2-Stroke: 1 to 3	0.2	1,730	0.0	0.1	2	0	11
6 to 11	0.2	2,531	0.0	0.1	26	4	3	2-Stroke: 25 to 40	2.8	29,882	0.7	1.6	19	5	226
11 to 16	0.3	4,107	0.1	0.2	37	7	4	2-Stroke: 50 to 75	4.0	42,856	1.0	2.3	21	7	322
16 to 25	0.5	6,496	0.1	0.3	58	11	7	4-Stroke: 3 to 6	0.4	4,243	0.1	0.2	7	1	1
25 to 40	0.9	10,273	0.2	0.4	82	18	10	4-Stroke: 6 to 11	0.7	7,256	0.2	0.4	16	1	1
40 to 50	1.1	13,405	0.2	0.6	107	23	13	4-Stroke: 11 to 16	1.2	12,890	0.3	0.7	28	2	1
50 to 75	1.6	18,683	0.3	0.8	165	32	20	4-Stroke: 16 to 25	1.5	16,130	0.4	0.9	37	3	1
75 to 100	2.1	25,850	0.5	1.1	226	44	28	4-Stroke: 25 to 40	1.9	20,677	0.5	1.1	107	4	2
100 to 175	3.0	35,693	0.7	1.5	358	61	30	4-Stroke: 40 to 50	2.8	29,770	0.7	1.6	154	5	2
175 to 300	5.5	65,575	1.2	2.7	634	112	51	4-Stroke: 50 to 75	3.8	40,897	1.0	2.2	264	7	3
300 to 600	8.9	107,248	2.0	4.5	1,035	183	74	4-Stroke: 75 to 100	5.2	54,832	1.3	3.0	354	9	4
								4-Stroke: 100 to 175	7.3	77,811	1.9	4.2	503	13	5

[a] Fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO_2 emission factor (g CO_2 /operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO2/gal).
[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.
[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).
[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 5a. Generator set impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[e]	grams/operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
3 to 6	0.1	1,645	0.0	2.0	18	2	2	0 to 1	0.1	717	0.0	1.0	1	0.3	5.0
6 to 11	0.2	2,588	0.1	3.2	28	4	3	1 to 3	0.1	1,489	0.1	2.1	2	0.7	8.7
11 to 16	0.3	4,170	0.1	5.1	40	6	5	3 to 6	0.4	4,378	0.2	6.2	11	2.1	1.2
16 to 25	0.5	6,546	0.2	8.0	63	9	7	6 to 11	0.7	7,934	0.3	11.3	22	3.8	1.4
25 to 40	0.8	10,289	0.2	12.6	88	14	10	11 to 16	1.2	12,905	0.4	18.4	36	6.2	2.3
40 to 50	1.1	13,904	0.3	17.0	118	20	14	16 to 25	1.8	19,385	0.7	27.6	57	9.3	3.5
50 to 75	1.5	18,470	0.4	22.6	168	26	19								
75 to 100	2.2	26,621	0.6	32.6	242	37	28								
100 to 175	3.0	37,625	0.9	46.1	385	53	31								
175 to 300	5.3	66,003	1.6	80.9	653	93	51								
300 to 600	9.4	116,326	2.8	142.6	1,148	164	80								

[a] Diesel fuel consumption rates were estimated from the Fuel Consumption Chart at www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx
[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO_2 /gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.
[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).
[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.
[e] Gasoline fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO_2 emission factor (g CO_2 /operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO2/gal).

Table 6a. Fuel well to pump impact

Fuel	Emissions (grams/mmBTU of fuel available)					
	CO_2	N_2O	CH_4	NOx	SOx	PM_{10}
Natural Gas	174,879	4.05	484	146.05	29.47	6.09
Liquid Propane	11,448	0.18	327	37.89	24.69	3.55
Jet fuel	10,042	0.14	119	36.50	17.81	4.38
Fuel oil	16,314	0.24	107	45.30	23.64	6.79
Other						
Gasoline	15,787	1.14	109	47.30	25.03	7.53
Diesel	16,314	0.24	107	45.30	23.64	6.79
Biodiesel 20	1,830	2.02	94	46.86	26.34	8.69
E-Diesel	14,352	2.86	106	48.61	26.22	8.78

U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

Table 6b. Heavy duty truck impact

Fuel	Fuel Economy (mile/gal)	Emissions (grams/mile)						Energy (Btu / mile)
		CO_2	N_2O	CH_4	NOx	SOx	PM_{10}	
Gasoline	8	1,329	0.028	1.590	0.442	0.018	0.036	17,377
Diesel	8	1,369	0.015	1.544	0.442	0.008	0.039	16,981
Biodiesel 20	8	1,164	0.041	1.347	0.442	0.006	0.039	21,343
E-Diesel	8	1,335	0.053	1.523	0.442	0.007	0.039	18,092

U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010. Values for CO_2, CH_4, N_2O, and Btu are the total of GREET Feedstock, Fuel, and Vehicle Operation values. Values for NOx, SOx, and PM10 are GREET Vehicle Operation values only. The gasoline equivalent MPG was changed to 8 to represent a heavy duty truck.

Table 6c. Power take-off horsepower multiplication factors by soil condition for primary tillage

Soil Condition	Multiply Drawbar HP by
Firm untilled soil	1.5
Previously tilled soil	1.8
Soft or sandy soil	2.1

Sumner, P.E. and E.J. Williams. *What Size Farm Tractor Do I Need?* University of Georgia. Table 1. http://www.tifton.uga.edu/eng/Publications/farm%20tractor.pdf. Accessed: 15 January, 2010.

Table 6d. Draft for offset disk harrow primary tillage by soil condition

Soil Condition	Draft (lb force/ft/in depth)
Clay Soil	134
Loamy Soil	117
Sandy Soil	104

Sumner, P.E. and E.J. Williams. *What Size Farm Tractor Do I Need?* University of Georgia. Table 2. http://www.tifton.uga.edu/eng/Publications/farm%20tractor.pdf. Accessed: 15 January, 2010.

Table 6e. Tillage tractor impact

Diesel	Fuel Consumption[a]	grams/operating hour [b,c,d]						Gasoline	Fuel Consumption[a]	grams/operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
16	0.6	6,830	0.2	8.4	51	10	6	16	0.6	6,442	0.2	9.8	18	3	2
25	0.7	8,951	0.2	11.0	67	13	8	25	1.1	11,064	0.4	16.8	32	6	2
40	1.1	13,879	0.3	17.0	100	20	13	40	2.0	20,690	0.8	31.4	41	9	3
50	1.6	19,823	0.5	24.3	143	28	18	50	4.2	43,210	1.6	65.6	156	20	6
75	2.1	26,547	0.6	32.5	220	37	32	75	5.6	57,995	2.1	88.1	205	26	9
100	3.0	36,776	0.9	45.1	305	52	45								
175	4.2	51,404	1.2	63.0	471	72	44								
300	7.4	91,020	2.2	111.6	801	128	71								

[a]

[a] Diesel and gasoline fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO2 emission factor (g CO2/operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO2/gal).
[b] CO2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.
[c] CH4 and N2O lifecycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) multiplied by the calculated fuel consumption rate (gal/hour).
[d] NOx, SOx, and PM10 lifecycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 6f. Soil and asphalt compactor and paver specifications

Type	Estimated operating speed (mph)	Operating Width (source)	HP (source)	Best Fit Equation [c]	Constants in Best Fit Equation	
Roller [a]	2	Specified roller width	Gross Power	(Maximum Required HP) = 8.7904748*exp(0.0000387*(Required Area Compacted/hr))	8.790474 8	0.000387
Paver [b]	1	One-half specified maximum paving width	Gross Power	(Maximum Required HP) = 0.0026754*(Required Area Paved/hr)	0.002679 4	

[a] Data are from www.cat.com and www.dynapac.com for all single-drum vibratory soil and asphalt compactor models. Accessed: 3 February, 2010.
[b] Data are from www.dynapac.com for all wheeled asphalt paver models. Accessed: 3 February, 2010.
[c] Area rates were determined by multiplying the estimated operating speed by operating width; fit equations were developed by plotting Horsepower vs. area rates. Calculated required area for pavers and rollers is equal to 20 times specified stabilized area to account for multiple passes, machine repositioning, and operating downtime.

Table 6g. Paver impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[a]	grams/ operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
25	0.8	9,098	0.2	0.4	59	16	7	6	0.4	4,609	0.1	0.3	7	1	1
40	1.1	13,641	0.2	0.6	90	23	11	11	0.7	7,753	0.2	0.4	17	1	1
50	1.6	18,855	0.3	0.8	124	32	15	16	1.0	10,439	0.3	0.6	23	2	1
75	2.2	26,163	0.5	1.1	183	45	24	25	1.6	17,372	0.4	0.9	38	3	2
100	3.0	36,007	0.7	1.5	253	61	34	40	1.8	18,639	0.5	1.0	72	3	1
175	4.2	50,397	0.9	2.1	361	86	33	75	3.7	39,326	1.0	2.1	238	7	3
300	6.9	82,805	1.5	3.4	564	141	46								
600	12.1	144,914	2.7	6.0	1152	247	85								

[a] Fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO_2 emission factor (g CO_2 /operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO_2/gal).

[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO_2 /gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.

[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).

[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 6h. Roller impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[a]	grams/operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
6	0.2	2,257	0.0	0.1	15	4	3	11	0.7	6,942	0.2	0.4	15	1	1
11	0.3	3,608	0.1	0.2	25	6	4	16	1.1	11,558	0.3	0.6	25	2	1
16	0.5	5,629	0.1	0.2	37	10	4	25	1.4	14,902	0.4	0.8	33	3	1
25	0.7	8,175	0.1	0.3	53	14	6	40	1.8	19,501	0.5	1.1	48	3	2
40	1.1	13,523	0.2	0.6	89	23	11	75	3.3	34,716	0.8	1.9	173	6	3
50	1.6	19,049	0.3	0.8	126	33	16	100	4.5	47,423	1.2	2.6	237	8	4
75	2.1	25,238	0.5	1.0	179	43	23								
100	2.9	35,219	0.6	1.5	251	60	34								
175	4.1	49,497	0.9	2.1	363	85	32								
300	6.8	81,267	1.5	3.4	568	139	46								
600	13.1	157,480	2.9	6.5	1287	269	96								

[a] Fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO_2 emission factor (g CO_2 /operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO_2 /gal).

[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO_2 /gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.

[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).

[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 6i. Cement and mortar mixer impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[a]	grams/operating hour[b,c,d]					
Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal / hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
3 to 6	0.1	1,788	0.0	0.1	20	3	3	1 to 3	0.2	2,344	0.1	0.1	5	0.0	0.0
6 to 11	0.2	2,415	0.0	0.1	27	4	3	3 to 6	0.4	4,235	0.1	0.2	9	1.0	1.0
11 to 16	0.3	3,908	0.1	0.2	38	7	5	6 to 11	0.6	6,515	0.2	0.4	16	1.0	1.0
16 to 25	0.5	6,298	0.1	0.3	62	11	7	11 to 16	1.0	10,521	0.3	0.6	26	2.0	1.0
25 to 40	0.8	9,799	0.2	0.4	84	17	11	16 to 25	1.4	14,781	0.4	0.8	33	3.0	1.0
50 to 75	1.5	17,840	0.3	0.7	173	30	18								
75 to 100	2.1	25,000	0.5	1.0	242	43	25								
100 to 175	2.9	34,752	0.6	1.4	381	59	27								
175 to 300	5.7	68,251	1.2	2.8	726	117	50								
300 to 600	9.0	108,524	2.0	4.5	1153	185	72								
600 to 750	15.8	190,114	3.5	7.9	2016	325	128								

[a] Fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO2 emission factor (g CO_2/operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO_2/gal).

[b] CO2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO_2/gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.

[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).

[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 6j. Internal combustion engine impact

Fuel	Emissions (grams/gallon)[a,b]						Energy
	CO_2	N_2O	CH_4	NOx	SOx	PM_{10}	BTU/gal[c]
Diesel	12,038	0.29	14.29	87.55	1.03	7.95	135,847
Biodiesel 20	10,265	0.50	12.51	87.55	0.84	7.95	170,745
E-Diesel	11,759	0.60	14.10	87.55	0.98	7.95	144,738
Gasoline	10,614	0.41	13.25	55.66	0.14	2.89	139,015
	Emissions (grams / scf) [a]						Energy
	CO_2	N_2O	CH_4	NOx	SOx	PM_{10}	BTU/scf[d]
Natural Gas	68	0.00	0.60	1.18	0.00	0.01	983

[a] U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010, Stationary Reciprocating Engine. Lifecycle emission factors were calculated for CO_2, CH_4, and N_2O by combining Stationary Reciprocating Engine and Well to Pump emission factors. Factors were converted from grams/mmBtu to grams/gal or grams/scf.

[b] Biodiesel and E-Diesel emission factors were calculated by multiplying the Diesel emission factors by the average ratio of Biodiesel or E-Diesel emissions to Diesel emissions obtained from U.S. DOE, Argonne National Laboratory, GREET 1.8d.1 Fuel-Cycle model (2010).

[c] Diesel, Biodiesel 20, E-Diesel, and Gasoline energy values from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

[d] Natural gas energy value from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

Table 6k. Trencher impact

Diesel	Fuel Consumption[a]	grams/operating hour[b,c,d]						Gasoline	Fuel Consumption[a]	grams/operating hour[b,c,d]					
Horsepower	(gal/hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}	Horsepower	(gal/hr)	CO_2	N_2O	CH_4	NOx	SO_2	PM_{10}
6 to 11	0.3	3,983	0.1	0.2	29	5	5	1 to 3	0.2	2,598	0.1	0.1	4	0.4	0.4
11 to 16	0.5	6,436	0.1	0.3	44	8	5	3 to 6	0.4	4,514	0.1	0.2	7	0.8	0.6
16 to 25	0.7	8,969	0.2	0.4	61	11	7	6 to 11	0.7	7,425	0.2	0.4	16	1.3	0.7
25 to 40	1.2	14,175	0.3	0.6	95	17	12	11 to 16	1.1	11,233	0.3	0.6	25	1.9	1.1
40 to 50	1.6	18,727	0.3	0.8	126	22	15	16 to 25	1.5	16,170	0.4	0.9	36	2.7	1.5
50 to 75	2.1	25,343	0.5	1.1	191	30	26	25 to 40	1.7	17,671	0.4	1.0	67	3.0	1.4
75 to 100	3.0	36,029	0.7	1.5	272	43	37	50 to 75	3.7	39,041	1.0	2.1	233	6.6	2.8
100 to 175	4.2	50,267	0.9	2.1	406	59	34	75 to 100	4.7	50,628	1.2	2.7	303	8.6	3.7
175 to 300	7.8	93,787	1.7	3.9	718	111	55								
300 to 600	12.9	5.6.59 155,181	5.6.60 2.8	5.6.61 6.5	5.6.62 1,405	5.6.63 183	5.6.64 110						5.6.65	5.6.66	5.6.67
600 to 750	23.1	277,640	5.1	11.5	2,509	328	201				5.6.68	5.6.69	5.6.70	5.6.71	5.6.72
1200 to 2000	46.7	560,989	10.3	23.3	6,066	663	447								

[a] Fuel consumption rate (gal/hour) was calculated by dividing the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) CO_2 emission factor (g CO_2 /operating hour) by the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) carbon emission factor (kg CO_2 /gal).
[b] CO_2 life cycle emission factors were calculated by multiplying GREET 1.8d.1 Well to Pump emissions (g CO_2 /gal) by the calculated fuel consumption rate (gal/hour) and adding this result to the U.S. EPA NONROAD Emission Inventory Model (Version 2005c) operational emission factor.
[c] CH_4 and N_2O emission factors were calculated by multiplying the U.S. EPA Climate Leaders "Direct Emissions from Mobile Combustion Sources" (EPA 430-K-08-004) emission factor (g/gal) by the calculated fuel consumption rate (gal/hour).
[d] NOx, SOx, and PM10 operational emission factors obtained from U.S. EPA NONROAD Emission Inventory Model, Version 2005c.

Table 6l. Ratios of emission factors relative to Conventional Diesel fueled vehicle

Fuel[a,b]	CO_2	N_2O	CH_4	NO_x	SO_x	PM_{10}
Diesel	1.00	1.00	1.00	1.00	1.00	1.00
Biodiesel 20	0.85	1.75	0.88	1.02	0.81	0.90
E-Diesel	0.98	2.10	0.99	1.00	0.95	1.00

[a] Values obtained from, unless otherwise noted, U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010. Ratios were calculated from the average ratio of Biodiesel or E-Diesel emissions to Diesel emissions
[b] Values for Biodiesel 20; NOx and PM10 obtained from EPA, 2002. A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. EPA420-P-02-001

Table 7a. Landfill waste impact

Landfill type	Emissions (lb/ton)				Energy	Electricity
	CO_2e	NOx	SOx	PM_{10}	MMBTU/ton	MWh/ton
Non-hazardous waste landfill	25	0.14	0.075	0.4	0.16	0.0077
Hazardous waste landfill	27.5	0.154	0.0825	0.44	0.176	0.0085

EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf.

Table 7b. Thermal oxidizer energy and efficiency factors

	Combustion temperature (°F)	Heat exchanger efficiency
Simple Thermal Oxidizer	1,500	0.00
Recuperative Thermal Oxidizer	1,500	0.50
Regenerative Thermal Oxidizer	1,800	0.95
Flameless Thermal Oxidizer	1,800	0.95
Recuperative Flameless Thermal Oxidizer	1,800	0.65
Fixed Bed Catalytic Oxidizer	600	0.00
Recuperative Catalytic Oxidizer	600	0.50

Rast, Richard R. 2003. *RSMeans: Environmental Remediation Estimating Methods*, 2nd edition, Reed Construction Data, page 321. If no efficiency factor was given, a value of 0 has been inserted.

Table 7c. External combustion sources energy and emission factors (operational)

Fuel[a]	Emissions (lb/MMBTU)[b,c,d,e]						Energy[f,g,h,i]
	CO_2	N_2O	CH_4	NOx	SOx	PM_{10}	BTU/gal or scf
Natural gas	152	0.004	1.354	2.640	0.001	0.012	983
Liquid Propane	137	0.0098	0.0022	0.1421	0.0011	0.0077	91,500
Jet fuel	204	0.0092	0.0112	0.6381	0.0627	0.0040	124,614
Fuel oil	167	0.0035	0.0019	0.3133	1.0847	0.0827	150,000
Gasoline	168	0.0065	0.2102	0.8827	0.0023	0.0459	139,015
Diesel	195	0.0047	0.2319	1.4208	0.0168	0.1290	135,847
Biodiesel 20	133	0.0065	0.1616	1.1304	0.0108	0.1026	170,745
E-Diesel	179	0.0092	0.2148	1.3335	0.0150	0.1210	144,738
Other							
	Emissions (lb / gal) or (lb/scf) [natural gas only]						Energy[j]
	CO_2	N_2O	CH_4	NOx	SOx	PM_{10}	BTU/scf
Natural gas	0.15	3.60E-06	1.33E-03	2.60E-03	5.81E-07	1.20E-05	983
Propane	12.5	0.0009	0.0002	0.0130	0.0001	0.0007	2,522
Jet fuel	25.4	0.0011	0.0014	0.0795	0.0078	0.0005	
Fuel oil	25.0	0.0005	0.0003	0.0470	0.1627	0.0124	
Other							

[a] Figures for gasoline, diesel, biodiesel 20, and E-diesel are reformatted from Table 6j.

[b] Natural gas emission factors from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010. Factors were converted from g/MMBTU to lb/MMBTU by dividing by 453.6 g/lb and from lb/MMBTU to lb/scf by the following equation: (lb pollutant/MMBTU)*(983 BTU/scf)*(1 MMBTU/1,000,000 BTU)=(lb pollutant/scf)

[c] Propane emission factors from USEPA "Emission Factor Documentation for AP-42 Section 1.5 Liquefied Petroleum Gas Combustion". July 2008. http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s05.pdf. Factors were converted from lb/1000 gal to lb/MMBTU by the following equation: (lb pollutant/'1000 gal')/(91500 or 102000 BTU/gal)*(10^6 BTU/MMBTU)/(10^3 gal/'1000 gal')

[d] Jet fuel CO2 emission factor from MIT, 2010. Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels. Partnership for Air Transportation Noise and Emissions Reduction. Page 17 of 133. Value converted from g/MJ to lb/mmBtu. Emission factors for N2O, CH4, NOx, SOx, and PM10 were calculated from values in Table 2c using the fuel consumption rate to convert g/mile to lb/gal.

[e] Fuel oil emission factors from USEPA "Emission Factor Documentation for AP-42 Section 1.3 Fuel Oil Combustion". May 2010. http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s03.pdf. Factors were converted from lb/1000 gal to lb/MMBTU by the following equation: (lb pollutant/'1000 gal')/(150000 BTU/gal)*(10^6 BTU/MMBTU)/(10^3 gal/'1000 gal')

[f] Natural gas energy value from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

[g] Propane energy value from USEPA "Emission Factor Documentation for AP-42 Section 1.5 Liquefied Petroleum Gas Combustion". July 2008. http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s05.pdf. Values were converted from mmBtu/1000 gal to Btu/gal.

[h] Jet fuel energy value from U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R&D Center, GREET 1.8d.1, Fuel-Cycle model, 2010.

[i] Fuel oil energy value from USEPA "Emission Factor Documentation for AP-42 Section 1.3 Fuel Oil Combustion". May 2010. http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s03.pdf. Value was converted from mmBtu/1000 gal to Btu/gal.

[j] Propane gas energy value from Rast, Richard R. 2003. *RSMeans: Environmental Remediation Estimating Methods*, 2nd edition, Reed Construction Data, page 322.

Table 7d. Water treatment impact

	kg CO_2e/gal	g NOx/gal	g SOx/gal	g PM_{10}/gal	Btu / gal
Municipal water treatment	2.3E-03	4.4E-03	2.7E-03	7.3E-03	9.2E+00
Wastewater treatment	2.0E-03	7.3E-03	6.8E-03	7.7E-04	1.5E+01

EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf.

Table 7e. Lab analysis impact

	CO_2e	NOx	SOx	PM_{10}	Energy
Laboratory analysis	lb/$	lb/$	lb/$	lb/$	MMBTU/$
	1	0.0048	0.0036	0.0004	0.00649

EPA, 2010. Environmental Footprint Analysis of Three Potential Remedies, BP Wood River, Wood River, Illinois. November. Available at http://www.clu-in.org/greenremediation/bpwoodriver/docs/final_BP_report_111510.pdf.

Table 8a: Other constants used in calculation workbook formulas

Particulate reduction technology for diesel vehicles [a]	0.3	fraction of original PM_{10}
Variables in equation to calculate fuel efficiency (mpg) by weight of load for road transportation [b]	=ax + b	
a =	-0.1024	
b =	7.4	
x =	load (tons)	
Conversions used to calculate electric pump horsepower		
Density of water	8.34	lb H2O/gal
	33013	ft lbs/min hp
Efficiency factor for generation and transmission of electricity [c]	0.33	fraction of original energy
Water used in electricity generation [d]	510	gal/MWh
Determining tractor horsepower [e]		
work day	8	hr/day
average speed	5	mi/hr
conversion factor	375	mi lbf/hr hp
efficiency factor for tractor use	0.121	
Area stabilization factor for rollers [f]	79.5	
Area stabilization factor for rollers [g]	26.3	
Thermal oxidizer constants used [h]		
Variables in best fit equation to calculate heat capacity at inlet, Btu/scf	=ax + b	
a =	0.0000009	
b =	0.0179	
x =	inlet temp (F)	
	24.055	molar gas volume at 293K
	86	
	454	
	28.3	
	18976	
	1.1	
	60	min/hr
Density of methane gas [i]	0.6443	kg/m^3
Ratio of dry sediment volume to saturated volume [j]	0.5254	
Efficiency factor for sediment earthwork [k]	1.28	
General Diesel Fueled Equipment Operational Factor [l]	0.6225	

[a] U.S. Environmental Protection Agency, "Clean Diesel Technologies & Alternative Fuels" fact sheet (March 2008). Value represents the average of the upper end of the ranges of DPF and DOC retrofit devices.

[b] Argonne National Laboratory, "Evaluation of Fuel Consumption Potential of Medium and Heavy Duty Vehicles through Modeling and Simulation" (October 23, 2009), page 24, Figure 11. Variables were determined from interpretation of the fuel economy plot.

[c] U.S. Department of Energy. http://www.energy.gov/energysources/electricpower.htm. Accessed: 28 April, 2011.

[d] Arizona Water Institute (AWI). 2007. The Water Costs of Electricity in Arizona. Available at: http://www.azwaterinstitute.org/media/Pasqualetti%20fact%20sheet. Value for electricity generation from coal was used.

[e] Sumner, P.E. and E.J. Williams. *What Size Farm Tractor Do I Need?* University of Georgia. Table 1. http://www.tifton.uga.edu/eng/Publications/farm%20tractor.pdf. Accessed: 15 January, 2010.

[f] Waier, Phillip R. 2012. *RSMeans: Building Construction Cost Data*, Reed Construction Data, pages 612 and 689. Area formula adjustment factors based on Plant-mixed Asphalt Paving with 3" binder course, 3" wearing course, and friction course with specified crew and equipment per course. Calculated operational requirements assume 150 HP rollers requiring total 0.009760 hr/SY.

[f] Waier, Phillip R. 2012. *RSMeans: Building Construction Cost Data*, Reed Construction Data, pages 612 and 689. Area formula adjustment factors based on Plant-mixed Asphalt Paving with 3" binder course, 3" wearing course, and friction course with specified crew and equipment per course. Calculated operational requirements assume 130 HP paver requiring total 0.004864 hr/SY.

[h] Rast, Richard R. 2003. *RSMeans: Environmental Remediation Estimating Methods*, 2nd edition, Reed Construction Data, page 321-323. Variables in best fit equation determined from Figure 35.5.

[i] CRC Handbook of Chemistry and Physics, 91st Ed.

[j] Volumetric ratios were calculated assuming a wet sediment density of 1.44 g/mL with a 40% moisture content (*USGS. 2012. Water Volume and Sediment Volume and Density in Lake Lignanore between Boyers Mill Road Bridge and Bens Branch, Frederick County, Maryland, 2012.*) with reduction to 20% moisture content and density of soil (1.85 g/mL).

[k] Efficiency factors were estimated using the ratio of wet sediment density of 1.44 g/mL (*USGS. 2012. Water Volume and Sediment Volume and Density in Lake Lignanore between Boyers Mill Road Bridge and Bens Branch, Frederick County, Maryland, 2012.*) to the density of soil (1.85 g/mL).

[l] Operational factors were assumed to be 0.83 operating time and 0.75 load factor, based on work time efficiency factors for earthwork equipment listed in Table 3a

Table 9a. Electrical power data

Census Division State	Average Retail Price ($ per kWh)				
	Residential	**Commercial**	**Industrial**	**Total**	**Wind Region**
AL	0.09	0.09	0.05	0.08	Southeast
AK	0.15	0.12	0.13	0.13	U.S. Average
AZ	0.10	0.08	0.06	0.09	Mountain
AR	0.09	0.07	0.05	0.07	Heartland
CA	0.14	0.13	0.10	0.13	California
CO	0.09	0.08	0.06	0.08	Mountain
CT	0.19	0.15	0.13	0.16	New England
DE	0.13	0.11	0.09	0.11	East
FL	0.11	0.10	0.08	0.10	Southeast
GA	0.09	0.08	0.06	0.08	Southeast
HI	0.24	0.22	0.18	0.21	U.S. Average
ID	0.06	0.05	0.04	0.05	Northwest
IL	0.10	0.09	0.07	0.08	Great Lakes
IN	0.08	0.07	0.05	0.07	Great Lakes
IA	0.09	0.07	0.05	0.07	Heartland
KS	0.08	0.07	0.05	0.07	Heartland
KY	0.07	0.07	0.04	0.06	East
LA	0.09	0.09	0.07	0.08	Southeast
ME	0.17	0.13	0.14	0.15	New England
MD	0.12	0.12	0.09	0.12	East
MA	0.16	0.15	0.13	0.15	New England
MI	0.10	0.09	0.06	0.09	Great Lakes
MN	0.09	0.07	0.06	0.07	Heartland
MS	0.09	0.09	0.06	0.08	Southeast
MO	0.08	0.06	0.05	0.07	Heartland
MT	0.09	0.08	0.05	0.07	Northwest
NE	0.08	0.06	0.05	0.06	Heartland
NV	0.12	0.10	0.08	0.10	Mountain
NH	0.15	0.14	0.12	0.14	New England
NJ	0.14	0.13	0.10	0.13	East
NM	0.09	0.08	0.06	0.07	Mountain
NY	0.17	0.16	0.09	0.15	East
NC	0.09	0.07	0.05	0.08	East
ND	0.07	0.07	0.05	0.06	Heartland
OH	0.10	0.09	0.06	0.08	Great Lakes
OK	0.09	0.07	0.05	0.07	Heartland
OR	0.08	0.07	0.05	0.07	Northwest
PA	0.11	0.09	0.07	0.09	East
RI	0.14	0.13	0.12	0.13	New England
SC	0.09	0.08	0.05	0.07	Southeast
SD	0.08	0.07	0.05	0.07	Heartland
TN	0.08	0.08	0.05	0.07	East
TX	0.12	0.10	0.08	0.10	Texas
UT	0.08	0.07	0.05	0.06	Mountain
VT	0.14	0.12	0.09	0.12	New England
VA	0.09	0.06	0.05	0.07	East
WA	0.07	0.07	0.05	0.06	Northwest
WV	0.07	0.06	0.04	0.05	East
WI	0.11	0.09	0.06	0.08	Great Lakes
WY	0.08	0.06	0.04	0.05	Mountain
U.S. Total	**0.11**	**0.10**	**0.06**	**0.09**	U.S. Average

Energy Information Administration. "Electric Power Annual 2007." http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html#seven

Table 9b. Microturbine cost and performance characteristics

Low fuel flow (Btu/hr)	High fuel flow (Btu/hr)	Capstone Microturbines	Fuel Flow (Btu/hr)	Electric Capacity (kW)	Equipment Costs ($)	O&M Costs ($/kWh)	Net Heat Rate, HHV (Btu/KWh)	Electrical Efficiency, HHV (%)
0	433,000	**CR30**	433,000	30	65,000	0.015	13,100	26
433,000	842,000	**CR65&CR65-ICHP**	842,000	65	120,000	0.015	11,800	29
842,000	2,280,000	**CR200**	2,280,000	200	320,000	0.015	10,300	33
2,280,000	6,840,000	**CR600**	6,840,000	600	900,000	0.015	103,000	33
6,840,000	9,120,000	**CR800**	9,120,000	800	1,120,000	0.015	10,300	33
9,120,000	12,000,000	**CR1000**	12,000,000	1000	1,300,000	0.015	10,300	33

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*Installation costs are standard for installation in rural environments in buildings under 5 stories. In metro areas the installation costs would increase by a factor of 2.

Table 9c. Microturbine Emissions at Full Load (lb/kWh)

CO_2	N2O	CH_4	NO_X	SO_2	TPM
3.45E+00		2.20E-03	8.21E-05	3.70E-02	6.00E-04

Southern Research Institute Greenhouse Gas Technology Center. "Environmental Technology Verification Report – Swine Waste Electric Power and Heat Production – Capstone 30 kW Microturbine System". September 2004.

Table 9d. Wind cost and performance characteristics

	Region [a]									
Cost and Performance Characteristics	**Texas**	**Heartland**	**Mountain**	**Great Lakes**	**Northwest**	**New England**	**California**	**East**	**Southeast**	**U.S. Average**
2007 Capacity Factor (%)	0.32	0.36	0.33	0.26	0.32	0.22	0.34	0.28	0.35	0.35
Installation Cost (2007 $/kW)	1,600	1,400	1,540	1,540	1,540	2,200	1,540	1,700	1,912	1,912
Wind Power Prices (2007 $/kW)	30	39	44	50	51	58	59	62	49	49
O&M Cost ($/MWh) [b]	8	8	8	8	8	8	8	8	8	8

[a] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. "Annual Report on U.S. Wind Power Installation, Cost and Performance Trends: 2007." May 2008.

[b] U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. "2008 Wind Technologies Market Report." July 2009.

Table 9e. Solar power data

State	Horizontal Flat Plate
	hours/day
AL	4.5
AK	2.5
AZ	5.5
AR	4.5
CA	5
CO	4.5
CT	3.5
DE	4.5
FL	4.5
GA	4.5
HI	5
ID	4
IL	4
IN	4
IA	4
KS	4.5
KY	4.5
LA	4.5
ME	3.5
MD	4
MA	3.5
MI	3.5
MN	3.5
MS	4.5
MO	4.5
MT	4
NE	4.5
NV	5
NH	3.5
NJ	3.5
NM	5.5
NY	3.5
NC	4.5
ND	3.5
OH	3.5
OK	4.5
OR	4.5
PA	3.5
RI	3.5
SC	4.5
SD	4.5
TN	4.5
TX	5
UT	4.5
VT	3.5
VA	4.5
WA	3.5
WV	3.5
WI	3.5
WY	4.5
U.S. Total	4.16

National Solar Radiation Data Base. Solar Radiation Data Manual for Flat-Plat and Concentrating Collectors. http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/

Table 9f. PV system sizing table

Minimum Capacity (kW)	Maximum Capacity (kW)	System Size Range (kW_{DC})	Installed Cost ($2010/$W_{DC}$) [a]	O&M Cost (% of installed) [b]
0	2	< 2	5.87	0.400
2	5	2 – 5	5.23	0.400
5	10	5 – 10	5.10	0.399
10	30	10 – 30	5.04	0.396
30	100	30 – 100	5.10	0.384
100	250	100 – 250	4.98	0.372
250	500	250 – 500	4.34	0.366
500	750	500 – 750	4.15	0.360
750	1000	> 750	4.47	0.353

[a] Wiser, R. Barbose, G., Peterman, C., and Darghouth, N. "Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998 – 2008." LBNL-2674E. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory. October 2009. 2008 values scaled by 0.638 to 2010 dollars by comparing values to Goodrich, A., James, T., and Woodhouse, M. "Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities." NREL/TP-6A20-53347. National Renewable Energy Laboratory. February 2012.

[b] O&M costs were calculated by linear interpolation from the values in Table 9g. Values represent the year 2008 to correspond to Installed Cost.

Table 9g. PV system annual O&M cost (% of installed cost)

Year:	2005	2011	2020
4 kW Residential Reference System	0.5	0.3	0.2
150 kW Commercial Reference System	0.45	0.3	0.2
10 MW Flat Plate Utility System	0.15	0.1	0.1

U.S. Department of Energy. Office of Energy Efficiency and Renewable Energy. "Office of Solar Energy Technologies Multi-Year Program Plan 2007 2011."

Table 9h. National Retail REC Products

Product Name	Certificate Marketer	Renewable Resources	Location of Renewable Resources	Residential Price Premiums*	Price Premium, $/kWh
Green Certificates	3 Phases Renewables	100% biomass, geothermal, hydro, solar, wind	Nationwide	1.2¢/kWh	0.012
Renewable Energy Certificates	3 Degrees	100% new wind	Nationwide	1.5¢/kWh	0.015
*Cool*Watts	*Native* Energy	100% new wind	Nationwide	0.8¢/kWh	0.008
Solar Green Tags	Bonneville Environmental Foundation	100% new solar	Nationwide	5.6¢/kWh	0.056
Wind & Solar Green Tags Blend	Bonneville Environmental Foundation	50% new wind, 50% new solar	Nationwide	2.4¢/kWh	0.024
Wind Green Tags	Bonneville Environmental Foundation	100% wind	Nationwide	2.0¢/kWh	0.020
Denali Green Tags (Alaska only)	Bonneville Environmental Foundation	100% new wind	10% Alaska, 90% Nationwide	2.0¢/kWh	0.020
CSG CleanBuild	Carbon Solutions Group	biomass, biogas, wind, solar, hydro	Nationwide	0.9¢/kWh	0.009
*My*GreenFuture	Carbonfund.org	99% new wind, 1% new solar	Nationwide	0.5¢/kWh	0.005
CleanWatts	Choose Renewables	100% new wind	Nationwide	1.7¢/kWh	0.017
NewWind Energy	Community Energy	100% new wind	Nationwide	2.5¢/kWh	0.025
Good Green RECs	Good Energy	various	Nationwide	0.4¢/kWh-1.5¢/kWh	0.015
BeGreen RECs	Green Mountain Energy	wind, solar, biomass	Nationwide	1.4¢/kWh	0.014
Positive Juice-Wind	Juice Energy	100% wind	Nationwide	1.1¢/kWh	0.011
Premier 100% Wind REC	Premier Energy Marketing	100% wind	Nationwide	0.95¢/kWh-2.0¢/kWh	0.020
American Wind	Renewable Choice Energy	100% new wind	Nationwide	0.5¢/kWh	0.005
Wind-e Renewable Energy	Sky Energy, Inc.	100% new wind	Nationwide	2.4¢/kWh	0.024
Sky Blue 40	Sky Blue Electric	100% wind	Nationwide	4.2¢/kWh	0.042
Sterling Wind	Sterling Planet	100% new wind	Nationwide	1.85¢/kWh	0.019
Green-e RECs	TerraPass	100% new wind	Nationwide	0.5¢/kWh	0.001
Village Green Power	Village Green Energy	solar, wind biogas	California, Nationwide	2.0¢/kWh-2.5¢/kWh	0.025
Renewable Energy Credit Program	WindStreet Energy	wind	Nationwide	~1.2¢/kWh	0.012
Renewable Energy	*Native* Energy	100% new biogas	Pennsylvania	0.8¢/kWh-1.0¢/kWh	0.010
Denali Green Tags (Alaska only)	Bonneville Environmental Foundation	100% new wind	10% Alaska, 90% Nationwide	2.0¢/kWh	0.020
Zephyr Energy	Bonneville	50% new low-	Midwest, West	2.0¢/kWh	0.020

Table 9h. National Retail REC Products

Product Name	Certificate Marketer	Renewable Resources	Location of Renewable Resources	Residential Price Premiums*	Price Premium, $/kWh
(Kansas only)	Environmental Foundation	impact hydropower			
PVUSA Solar Green Certificates	MMA Renewable Ventures	100% solar	California	3.3¢/kWh	0.033
Maine WindWatts	Maine Renewable Energy/Maine Interfaith Power & Light	100% new wind	Maine	2.0¢/kWh	0.020
New England Wind Fund	Mass Energy Consumers Alliance	100% new wind	New England	~5.0¢/kWh (donation)	0.050
SC Green Power	Santee Cooper	landfill gas, solar	South Carolina	3.0¢/kWh	0.030
Village Green Power	Village Green Energy	solar, wind biogas	California, Nationwide	2.0¢/kWh-2.5¢/kWh	0.025
Iowa Energy Tags	Waverly Light & Power	100% wind	Iowa	2.0¢/kWh	0.020
Chesapeake Windcurrent	WindCurrent	100% new wind	Mid-Atlantic States	2.5¢/kWh	0.025

Table 9i. Other footprint reduction items

Average cost of Biodiesel 20	3.14	$/gallon
Average cost of DOC unit [a]	540	$/machine

[a] U.S. Environmental Protection Agency, Office of Transportation and Air Quality. "Diesel Retrofit Technology: An Analysis of the Cost-Effectiveness of Reducing Particulate Matter Emissions from Heavy-Duty Diesel Engines Through Retrofits". EPA420-S-06-002. March 2006.

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