An Overview of Public Domain Tools for Measuring the Sustainability of Environmental Remediation - 12060

John E. Claypool* and Scott Rogers*, P.E.
* AECOM, Denver, Colorado, 80202

ABSTRACT

The application of sustainability principles to the investigation and remediation of contaminated sites is an area of rapid development within the environmental profession, with new business practices, tools, and performance standards for identifying, evaluating, and managing the "collateral" impacts of cleanup projects to the environment, economy and society coming from many organizations. Guidelines, frameworks, and standards of practice for "green and sustainable remediation" (GSR) have been released and are under development by the Sustainable Remediation Forum (SURF), the American Society for Testing Materials (ASTM), the Interstate Technology Roundtable Commission (ITRC) and other organizations in the U.S. and internationally. In response to Executive Orders from the President, Federal government agencies have developed policies, procedures and guidelines for evaluating and reporting the sustainability of their environmental restoration projects. Private sector companies in the petroleum, utility, manufacturing, defense, and other sectors are developing their own corporate GSR programs to improve day-to-day management of contaminated sites and to support external reporting as part of their corporate social responsibility (CSR) efforts.

The explosion of mandates, policy, procedures and guidance raises the question of how to determine whether a remediation technology or cleanup approach is green and/or sustainable. The environmental profession has responded to this question by designing, developing and deploying a wide array of tools, calculators, and databases that enable regulatory agencies, site managers and environmental professionals to calculate the collateral impacts of their remediation projects in the environmental, social, and economic domains. Many of these tools are proprietary ones developed by environmental engineering/consulting firms for use in their consulting engagements and/or tailored specifically to meet the needs of their clients.

When it comes to the public domain, Federal government agencies are spearheading the development of software tools to measure and report emissions of air pollutants (e.g., carbon dioxide, other greenhouse gases, criteria air pollutants); consumption of energy, water and natural resources; accident and safety risks; project costs and other economic metrics. Most of the tools developed for the Government are available to environmental practitioners without charge, so they are growing in usage and popularity.

The key features and metrics calculated by the available public-domain tools for measuring the sustainability of environmental remediation projects share some commonalities but there are differences amongst the tools. The SiteWise™ sustainability tool developed for the Navy and US Army will be compared with the Sustainable Remediation Tool (SRT™) developed for the US Air Force (USAF). In addition, the USAF's Clean Solar and Wind Energy in Environmental Programs (CleanSWEEP), a soon-to-be-released tool for evaluating the economic feasibility of utilizing renewal energy for powering remediation systems will be described in the paper.

INTRODUCTION

Global attention to climate change and a growing awareness of potential adverse impacts resulting from energy-intensive systems have prompted Government agencies and the private sector to look for ways to reduce the environmental “footprint” of their operations and business activities. The business processes and technologies for investigating and cleaning up contaminated sites have not been immune from this trend. Relative to Federal government agencies, Executive Orders 13423 and 13514, issued in January 2007 and October 2009 respectively have triggered a new paradigm for managing contaminated sites. EO 13423 states that:

> “…Federal agencies…conduct their environmental…and energy-related activities…in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.”
>
> ”…sustainable means to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans.”

In light of this executive call to operate in a sustainable manner, environmental professionals were left with the need for tools to help identify and evaluate sustainable practices on remediation projects.

New policies, frameworks, analytical tools, and standards of practice for identifying, evaluating, and managing the “collateral” impacts of cleanup projects to the environment, economy and society are being developed and implemented by many organizations. Regulatory agencies including the U.S. Environmental Protection Agency (USEPA) and the Interstate Technology & Regulatory Council (ITRC) have been actively developing guidelines, practices, and procedures for quantifying the footprint of remediation activities. In September 2011, the USEPA issued a draft methodology for quantifying and reducing a project’s environmental footprint [2]. The USEPA methodology presents metrics associated with environmental cleanups and a four-step methodology for quantifying those metrics consistent with USEPA’s five core elements of green remediation [3]. The USEPA methodology also discusses considerations for analyzing and utilizing footprint results and approaches for reducing the footprint of a remediation technology or project.

In November 2011, the ITRC released a framework for green and sustainable remediation that includes best practices for conducting GSR evaluations. ITRC encourages three key tenets in a GSR footprint analysis:

- Using the simplest level of evaluation that is needed to meet the decision making goals.
- Keeping the analysis and process transparent.
- Conducting an uncertainty analysis of calculated footprint values to indicate how sensitive the GSR results are to changes in key assumptions.

Another guideline for conducting footprint evaluations and LCAs was issued by the U.S. Sustainable Remediation Forum (SURF) in June 2011 [4]. SURF proposed a nine-step process for conducting and documenting a footprint analysis and life-cycle assessment (LCA) for remediation projects consistent with International Standards Organization (ISO) standards [5, 6]. SURF’s vision for this guidance is to enable evaluation of the potential impacts resulting from remediation activities so that measures to mitigate adverse impacts can be identified and considered. The analytical process advocated by SURF is flexible and scalable to a full range of site types, remediation technologies, and footprinting tools.

PUBLIC DOMAIN TOOLS

SiteWise™ Tool

SiteWise is a spreadsheet-based "footprinting" tool developed jointly by the U.S. Navy Facilities Engineering Command (NAVFAC), the U.S. Army, the U.S. Army Corps of Engineers (USACE), and Battelle [8]. SiteWise assesses the footprint of a remedial alternative/technology in terms of a defined set of sustainability indicators:

- Greenhouse gas (GHG) emissions
- Energy consumption
- Emissions of criteria air pollutants including nitrogen oxide (NOx), sulfur oxide (SOx), and particulate matter (PM)
- Water consumption
- Resource consumption
- Worker safety

SiteWise uses a series of linked workbooks to calculate the metrics listed above for each lifecycle phase of the project, alternative, or scenario being evaluated. The four lifecycle phases are:

- Remedial investigation (RI)
- Remedial action construction (RA-C)
- Remedial action operations (RA-O)
- Long-term monitoring (LTM)

Each metric is calculated for each lifecycle phase individually, and then the results are summed for the final output. Given its modular design, SiteWise is flexible and can be used to calculate the footprint for any individual phase of work or for any combination of lifecycle phases. For example, the RI portion of SiteWise could be used a on a stand-alone basis for sites where the investigations are being planned or underway. On the other hand, the RA-C module can be used in conjunction with the RA-O and/or LTM modules, as appropriate, to calculate sustainability metrics for remedial alternatives as part of a feasibility study. The RA-O and/or LTM modules could be used to evaluate the sustainability of an existing groundwater treatment system as part of a remedial process optimization (RPO) evaluation.

The work flow within SiteWise begins with basic definitional data about the site. The Site Info sheet requires the date, site name, the remedial alternative name, and a name for the electronic file that will be generated when the analysis is complete. The user also must select the electricity region in which the site is situated. SiteWise uses the electricity region to apply emission factors that reflect the fuel mix (coal vs. oil vs. gas vs. nuclear, etc.) for electricity generation within that region of the country.

After the basic setup information has been entered, inputs are entered for each lifecycle phase that is included in the analysis. Each lifecycle phase is organized into a series of "activities" including material production, transportation, equipment use, residual handling, and resource consumption. The input sheets for each lifecycle phase accommodate up to six distinct items or groups of items. For example, the inputs for well materials can accommodate six groups with differing numbers of wells, differing depths, differing materials of construction, differing diameters, etc. Similarly, the Excavation inputs can accommodate six different types of equipment with differing types of fuel, differing volumes of soil to be excavated, and differing air pollution controls. Because the inputs are numerous and detailed, SiteWise can calculate sustainability metrics for a very wide variety of remediation technologies. The inputs for well materials are illustrated in Figure 1.

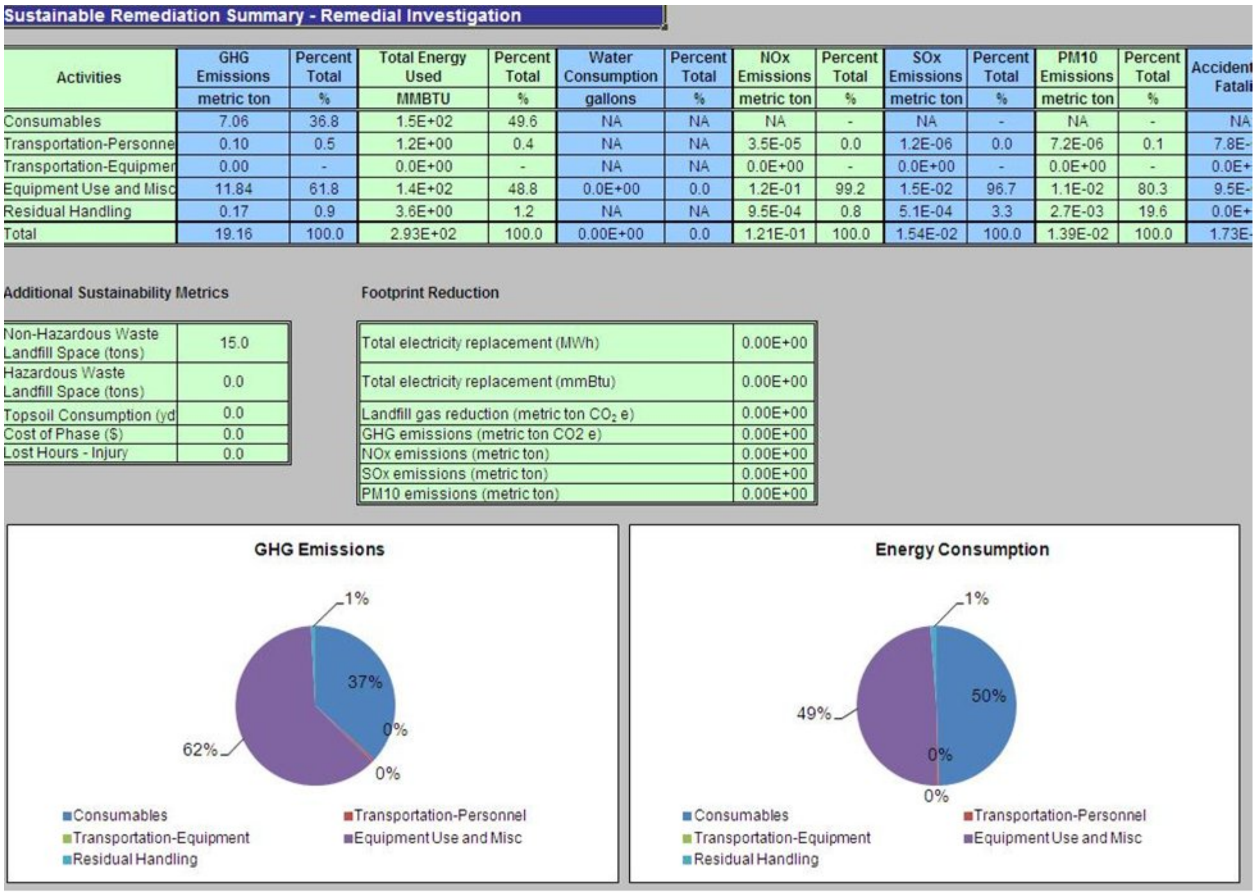
MATERIAL PRODUCTION

WELL MATERIALS	Well Type 1	Well Type 2	Well Type 3
Input number of wells	20	4	3
Input depth of wells (ft)	35	95	125
Choose specific material schedule from drop down menu	Sch 40 PVC	Sch 40 PVC	Sch 80 PVC
Choose well diameter (in) from drop down menu	4	6	6

Fig. 1. SiteWise Inputs for Well Materials

After entering inputs, SiteWise calculates the remedy footprint 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 uses impact factors that have been obtained from credible governmental or non-governmental research sources, all of which are documented in the user guide. SiteWise includes an evaluation of footprint reduction methods, mostly related to reduction in energy consumption. Footprint reduction techniques available within SiteWise include microturbines for landfill gas, solar energy, wind energy, and purchasing renewable energy certificates. The tool calculates the footprint reduction, investment/implementation cost, and avoided cost of electricity due to use of renewable energy. The costs calculated by SiteWise for footprint reduction do not include federal, state, and local incentives or tax rebates that may be available for new renewable energy projects.

After the analysis is complete, the user can view the results for each individual remedial alternative using the Summary Sheet workbook. Alternatively, multiple remedial alternatives can be loaded into the Final Summary workbook, which compares the outputs in table and graph forms. Figure 2 illustrates the output from SiteWise.



Sustainable Remediation Summary - Remedial Investigation

Activities	GHG Emissions (metric ton)	Percent Total (%)	Total Energy Used (MMBTU)	Percent Total (%)	Water Consumption (gallons)	Percent Total (%)	NOx Emissions (metric ton)	Percent Total (%)	SOx Emissions (metric ton)	Percent Total (%)	PM10 Emissions (metric ton)	Percent Total (%)	Acciden Fatali
Consumables	7.06	36.8	1.5E+02	49.6	NA	NA	NA	-	NA	-	NA	-	NA
Transportation-Personne	0.10	0.5	1.2E+00	0.4	NA	NA	3.5E-05	0.0	1.2E-06	0.0	7.2E-06	0.1	7.8E-
Transportation-Equipmer	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+
Equipment Use and Misc	11.84	61.8	1.4E+02	48.8	0.0E+00	0.0	1.2E-01	99.2	1.5E-02	96.7	1.1E-02	80.3	9.5E-
Residual Handling	0.17	0.9	3.6E+00	1.2	NA	NA	9.5E-04	0.8	5.1E-04	3.3	2.7E-03	19.6	0.0E+
Total	19.16	100.0	2.93E+02	100.0	0.00E+00	0.0	1.21E-01	100.0	1.54E-02	100.0	1.39E-02	100.0	1.73E-

Additional Sustainability Metrics

Non-Hazardous Waste Landfill Space (tons)	15.0
Hazardous Waste Landfill Space (tons)	0.0
Topsoil Consumption (yd	0.0
Cost of Phase ($)	0.0
Lost Hours - Injury	0.0

Footprint Reduction

Total electricity replacement (MWh)	0.00E+00
Total electricity replacement (mmBtu)	0.00E+00
Landfill gas reduction (metric ton CO_2 e)	0.00E+00
GHG emissions (metric ton CO2 e)	0.00E+00
NOx emissions (metric ton)	0.00E+00
SOx emissions (metric ton)	0.00E+00
PM10 emissions (metric ton)	0.00E+00

Fig. 2. SiteWise Outputs for Remedial Investigation

Sustainable Remediation Tool

The Sustainable Remediation Tool (SRT™) was developed by the Air Force Center for Engineering and the Environment (AFCEE) [9]. AFCEE's vision for the SRT was to create a tool that could be used in three distinct ways:

- Planning for the future implementation of remediation technologies at a particular site
- Comparing remediation approaches on the basis of sustainability metrics
- Providing a means to evaluate optimization of remediation technology systems already in place.

The SRT is a spreadsheet-based analytical tool that calculates sustainability metrics for eight technologies that are commonly used for soil and groundwater remediation at Air Force installations and other Federal facilities. Most of the technologies include "process options" that affect the approach, scope of work, equipment selection, duration, material quantities, energy consumption, and other factors used in the calculation of the sustainability metrics. The combination of eight remedial action technologies with corresponding process options provides considerable flexibility to address a wide range of remedial alternatives and approaches.

Three of the technologies available within the SRT address soil remediation: Excavation/Off-site Disposal; Soil Vapor Extraction (SVE); and, in-situ Thermal Treatment. Hazardous and non-hazardous waste disposal options are available for excavation and off-site disposal. Carbon adsorption and thermal/catalytic oxidation options are available for off-gas treatment within the SVE technology. Three different heating methods (thermal conductive heating, electrical resistivity heating, and steam injection) are available for in-situ Thermal Treatment.

The other five technologies within the SRT are commonly used methodologies for groundwater remediation:

- Pump and treat
- Enhanced bioremediation
- Permeable reactive barrier (PRB)
- In situ chemical oxidation (ISCO)
- Long-term monitoring/monitored natural attenuation (LTM/MNA)

Similar to the soil technologies described above, the SRT includes options for the groundwater remediation technologies. The pump and treat technology includes options for the remediation purpose (containment versus restoration) and the PRB technology includes two options for the purpose of the remediation: containment versus source remediation. The enhanced bioremediation and the ISCO modules include options to specify whether the technology is to be applied to the source zone only or whether it will treat both the source and the downgradient contaminated plume.

The SRT enables two “tiers” of analysis. Tier 1 is the simplest analysis; calculations are based on rules-of-thumb that are widely used in the environmental remediation industry. Because it relies heavily on default values and rules-of-thumb, Tier 1 is appropriate for early stage footprint analysis (e.g., screening technologies during a process optimization evaluation). Tier 2 calculations are much more detailed and incorporate numerous site-specific factors. Tier 2 is appropriate for evaluating existing systems and for projects that have advanced to the feasibility study (FS) stage.

The work flow within the SRT is linear and guided by navigation buttons and graphics. The user begins by entering basic information about the site (name and location), selecting the tier for the analysis, and selecting the lifecycle stages to be included in the analysis (capital construction, operations & maintenance or both). After the initial set up has been completed, the user enters parameters specific to the media (soil or groundwater or both) being evaluated. Media-specific inputs include size of contaminated area, depth to top of contamination, thickness of contaminated layer, soil/aquifer type, etc. Additional inputs are required if the user wishes to include improvements to “resource service” as one of the calculated metrics. Finally, the user enters technology-specific parameters for each remedial technology under consideration. The technology-specific inputs for the SVE technology are illustrated in Figure 3.

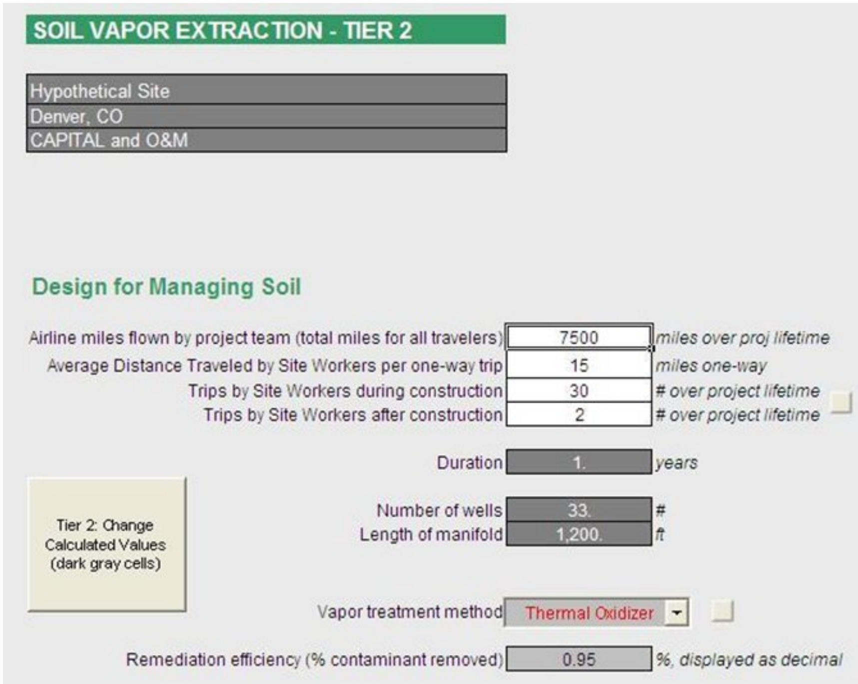


Fig. 3. SRT Tier 1 Inputs for Soil Vapor Extraction

Using the parameters entered by the user, the SRT calculates a number of intermediary "design" factors and the quantities of consumable items that feed into the ultimate calculation of the sustainability metrics. For example, the area of the contaminated soil, the type of soil and other factors are used to calculate the number of vapor extraction wells in the SVE module. The number of vapor extraction wells and the depth to groundwater are then used to calculate the length of casing and screen for the SVE wells. The length of the casing and screen are then used, in conjunction with the diameter and wall thickness of the SVE wells, to calculate the mass of material (steel or high-density polyethylene) required for construction of the wells. The mass of material required to construct the wells is carried forward into the next step in which the sustainability metrics are calculated. Most of the logic and formulas behind these intermediate calculations are displayed on screen; formulas that are not displayed on screen are provided in the detailed user guide.

Even though the SRT performs and displays these "design" calculations, the values calculated by the SRT are simply a means to an end, namely the calculation of sustainability metrics. AFCEE stresses that the SRT is not a design tool and the intermediary design calculations should not be used for actual sizing, design, or construction of a remediation system.

After the SRT has determined the design of the remediation system and calculated the quantities of consumables required for construction/implementation, it then calculates the value of each sustainability metric/indicator:

- Carbon dioxide emissions (expressed in tons, as well as in pounds of CO2 per pound of contaminant)
- Nitrogen oxides (NOx) emissions (tons)
- Sulfur oxides (SOx) emissions (tons)
- Particulate matter emissions (tons)

- Total energy consumption (in Megajoules and kilowatt-hours)
- Implementation cost (absolute and per pound of contaminant)
- Safety / accident risk (lost hours and injury risk)
- Change in resource service (million gallons for groundwater;)

The SRT output for air emissions (CO2, NOx, SOx and PM) for the soil excavation/off-site disposal and SVE technologies is illustrated in Figure 4.

Non-normalized

Calculations in natural units

	Carbon Dioxide Emissions to Atmosphere		NO_x*	SO_x	PM_{10}
	tons CO_2	lbs CO_2 per lb contam	tons NO_x	tons SOx	tons PM_{10}
Excavation	3,500.	5,000.	28.	0.027	1.3
SVE	54.	81.	0.18	0.26	0.046
Thermal	-	-	-	-	-

Fig. 4. Non-normalized Output from the SRT

After the metrics have been calculated, the SRT provides an option to normalize some of the metrics to U.S. dollars. Carbon emissions, energy consumption, implementation cost, and change in resource service can be normalized using financial models and factors built into the SRT. For example, to calculate the normalized value of the change in groundwater resource service, the volume of restored aquifer is converted to dollars based on the cost of raw water and the groundwater classification [10]. The SRT uses $0.20/1,000 gallons as the base value for groundwater. Weights of 1.25, 1.00, 0.5 and 0.1 are used as multipliers to calculate the value of Class I, IIA, IIB, and III groundwater respectively.

Similarly, the SRT converts CO2 emissions to dollars using the Chicago Climate Exchange values as a baseline. The user has the ability to modify the future market value of carbon to conduct sensitivity analysis and/or evaluate scenarios.

The SRT includes a feature called the Stakeholder Roundtable that enables the user to weight the normalized metrics to reflect the priorities and values of various stakeholders or groups of stakeholders. The Stakeholder Roundtable feature is available only if the sustainability metrics were normalized to dollars.

CleanSWEEP

Clean Solar and Wind Energy in Environmental Programs (CleanSWEEP) is a new tool currently under development by AFCEE. CleanSWEEP is a spreadsheet tool that enables users to evaluate the opportunity and economic feasibility of using wind and/or solar photovoltaic (PV) resources to operate small environmental remediation systems (i.e., less than 20 kW). The Air Force vision for this tool is to maximize the use of renewable energy for powering remediation systems wherever the economics are favorable.

CleanSWEEP requires some basic setup data such as site location and hydrogeological data, energy requirements for the new or existing remediation systems, and the projected duration of the remedy. From this data, CleanSWEEP identifies potential wind and solar options for the site, estimates the investment required to install the renewable energy equipment, and calculates the payback period under several future energy price scenarios.

For each analysis, CleanSWEEP evaluates two scenarios: 100% energy supplied by the electrical grid (i.e., baseline conditions), and a user-defined blend of renewable energy supplemented by the electrical grid (i.e., renewable energy scenario). Through this side-by-side comparison, users can decide whether renewable energy is appropriate for powering the systems at the site.

RESULTS

A comparison of the features and attributes of the two footprint calculators, SiteWise and the SRT, is presented in Tables I through III.

Table I. Comparison of Footprint Calculator Attributes

Comparison Factor/Attribute	**SRT**	**SiteWise**
Sponsoring / Funding Organizations	AFCEE	NAVFAC, USACE, Army
Platform / Environment	MS Excel	MS Excel
Number of Workbooks	1	37
Work Flow Within the Tool	Menu-driven UI	Self-navigate
Analyzes Multiple Alternatives Simultaneously	Yes (up to 4)	Yes (up to 6)
Remedial Technology Scope/Applicability	Focused on 8 remedial technologies (Primary AFCEE uses)	Not limited to any given remedial technology
User Guide	Yes	Yes
Help System	Yes	No
Current Version	2.2	2
Availability	Freeware	Freeware

Table II. Comparison of Footprint Calculator Environmental Metrics

Metric	**SRT**	**SiteWise**
Carbon Dioxide (CO_2) Emissions	X	X
Nitrogen Oxides (NO_x) Emissions	X	X
Sulfur Oxides (SO_x) Emissions	X	X
Particulate Matter (PM) Emissions	X	X
Energy Consumption	X	X
Water Consumption		X
Landfill		

Metric	SRT	SiteWise
Change in Groundwater Resource Service	X	
Change in Ecologic Resource Service of Land	X	
Carbon "footprint"	X	

Table III. Comparison of Footprint Calculator Social and Economic Metrics

Metric	SRT	SiteWise
Social Factors		
Worker Safety/Construction Accident Risk	X	X
Economic Factors		
Technology Construction / Implementation Cost	X	
Technology Operation & Maintenance Cost	X	
Change in Economic Resource Value of Land	X	
Change in Economic Resource Value of Groundwater	X	
Variable Cost scenarios for Carbon Offsets	X	
Variation of Energy cost	X	
Cost and Payback for Footprint Reduction		X

DISCUSSION

The emergence of GSR concepts and indicators as a supplementary input to remedy decision making has created a need for defensible standards of practice and reliable analytical tools to quantify collateral impacts of site investigation and remediation activities in the environmental, economic, and social domains. Government agencies have responded to this need by developing a suite of spreadsheet-based, public-domain tools that address the requirements of Executive Orders 13423/13514 and USEPA's core elements of green remediation. While the tools were developed for environmental restoration on military installations, they are generally applicable to other government installations, including DOE EM sites, as well as sites in the private sector. In addition, the SiteWise tool is sufficiently flexible that it can be applied to sites other than environmental restoration (e.g., D&D, legacy management, mine reclamation, etc.)

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