United States Environmental Protection Agency

U.S. AIR FORCE

Green and Sustainable Remediation Strategies

Environmental Footprint Pilot Study

U. S. Air Force
Air Force Civil Engineer Center

U. S. Environmental Protection Agency
Region 9
and
Office of Superfund Remediation and Technology Innovation

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&
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Memorandum of Understanding

Green and Sustainable Remediation Strategies Environmental Footprint Pilot Study

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Table of Contents

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) Pacific Southwest Region (Region 9) and the U.S. Air Force (AF) are committed to Green and Sustainable Remediation (GSR) and recognize the availability of multiple analytical tools to assess the environmental footprint of remedial actions. EPA Region 9 and AF senior officials signed a Memorandum of Understanding (MOU) "to collaborate and leverage their resources and technical expertise to support and expand GSR practices at the Air Force facilities within the region while continuing to comply with CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)." Specifically, the AF and EPA were to conduct a pilot study comparing the footprint analysis tools of each organization—the EPA Region 9 Spreadsheets for Environmental Footprinting Analysis (SEFA) and the AF Sustainable Remediation Tool (SRT™)—and then use the pilot study findings to make recommendations directed toward the use of life cycle analysis, green remediation (GR) practices, and a process to evaluate existing remedial actions to further reduce footprint.

APPROACH/ACTIVITIES

As directed by the MOU, EPA and AF representatives were appointed to further define the scope and objectives. This inter-agency team of EPA and AF experts further defined the objective of the MOU to include an evaluation of the advantages and disadvantages of their respective tools and make non-binding recommendations as to possible improvements and the advantages and disadvantages of each tool. The team also decided to leverage the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) demonstration project titled *Quantifying Life-Cycle Environmental Footprints of Soil and Groundwater Remedies* (#ER-201127) and EPA HQ funds to expand the pilot study to include the life cycle assessment (LCA) software tool SimaPro™, a third-party tool developed by Pré Consultants in the Netherlands.

The team conducted the pilot comparative study by evaluating the environmental footprint of two remedial actions at Travis AFB. The EPA SEFA and the AF SRT footprint tools were used to quantify the environmental footprint of a soil excavation remedy and a groundwater pump and treat remedial action. First, analyses were conducted by the respective tool owner (EPA or AF) using the same initial information and their best judgment. The results were then compared, the input aligned as much as possible, and the tools were run again. The team conducted a rigorous comparison of the calculations and numerical results in order to determine the cause for any differences in the results. The team then used their respective experience and observations of the usability and applicability of the tools to define the advantages and disadvantages of the tools and make recommendations to enhance the use of footprint tools in order to promote best GSR practice recommendations. Analysis was conducted simultaneously using SimaPro and compared to SEFA and SRT. These results are presented in Section 8 of this report.

SEFA AND SRT COMPARATIVE ANALYSIS FINDINGS

The SEFA and SRT footprint tools produced substantially different numerical results for both of the pilot study sites, up to a factor of 10 for some metrics. These differences were attributable to different input parameters, use of different simplifying assumptions, and use of different intermediate calculations. The footprint comparative analyses at the two sites led to the following key findings related to use of footprint tools (or "life cycle analyses approaches"), especially in the context of AF sites in the Pacific Southwest Region.

1. SRT may be best suited for a concise and timely comparison of the environmental footprint for most common AF technologies, either at remedy selection or in optimization review stages, particularly where the selected remedy involves a single or a combination of standard technologies and/or where limited site information is available. SRT can provide project managers with footprinting analyses without substantial time, cost, or detailed input data needs.
2. SEFA is adaptable and may be used for a concise analysis or for a more in-depth analysis of a remedy or technology. It is particularly applicable for evaluations of innovative and/or unusual remedial technologies. SEFA achieves the objectives established by EPA *Methodology for Understanding and Reducing a Project's Environmental Footprint* dated February 2012. SEFA is designed to accommodate more detailed levels of site information, and allows access to intermediate calculations to identify and rank different footprint contributors. SEFA can also more easily characterize the usage of renewable energy, water, and materials, as well as waste generation/soil consolidation.
3. The variation in the tools might affect the footprint results for the same remedial technologies or the weight of different footprint contributors for a specified remedy and thus, SEFA and SRT may rank a given set of remedial actions differently.

STRATEGY RECOMMENDATIONS

1. Develop a concise package of information that remedial managers can use to make informed choices regarding which footprint tool is best for their situation. Information included in the package should include any applicable guidance and recommended use of SEFA, SRT, and SimaPro; their advantages and disadvantages; and their consistency with the EPA Methodology (including this report).
2. Develop a mutual understanding of a process for efficient regulatory review and comment of footprint analyses in remedial decision making and remedy implementation.
3. Incorporate GSR in the scope of work for the Air Force Performance Based Contracts (PBC) and EPA Remedial Oversight Contracts.
4. Promote/advocate for footprint analysis in all Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) phases as an information point and to inform remedial decisions and optimization in balance with cost and timely site closeout goals. (The

AF PBC restricts AF ability to direct the use of a specific GSR remedy or practice, and contractors will not use a GSR remedy or practice unless it is cost effective). Communicate the advantages of conducting a footprint analysis to all stakeholders.

5. Update SEFA and SRT per the specific recommendations in the report and summarized below.[1]

- EPA should consider including a tutorial in the **SEFA** to assist first-time users, allow users to override the remaining default assumptions, and provide a post-processor to help the user compile intermediate calculations and results.
- The Air Force should consider updating **SRT** to reflect the elements of EPA's Footprint Methodology (particularly the metrics for renewable energy, water use, and materials management) and provide user access to intermediate calculations. Also, additional remediation technologies could be added as well as the flexibility for the user to add specific materials and activities not already included in the tool.

6. Promote GSR best business practices by coalescing GSR initiatives and best management practices available or in pilot demonstration (see References/Resource Section). This could include a database of EPA and DoD GSR practices to establish a baseline of existing practices and monitor progress of GSR implementation.
7. Coordinate with and leverage the efforts of other GSR initiatives, particularly those developed in the Federal Remediation Technologies Roundtable, the ESTCP and Strategic Environmental Research and Development Plan (SERDP), and the Interstate Technology Regulatory Council (ITRC). Commit to a regulatory backed initiative to provide concise training and support of overall GSR practices and tools focused on federal facilities via outreach, capacity building, and technology transfer.

The voluntary use of GSR practices is growing in importance nationally and internationally. While several state and federal agencies, including US EPA Regions have been voluntarily considering and evaluating GSR approaches in their remediation programs, responsible parties and stakeholders are also realizing the importance of including GSR considerations at sites within their control.

[1] The interagency team acknowledges that the results in this report are based on only two comparative analyses of this pilot effort.

1.0 INTRODUCTION/OVERVIEW

The U.S. Air Force (AF) and U.S. Environmental Protection Agency (EPA) Pacific Southwest Region (Region 9) entered a Memorandum of Understanding (MOU) for Green and Sustainable Remediation (GSR) strategies on September 23, 2011. EPA Region 9 and AF senior officials signed the MOU "to collaborate and leverage their resources and technical expertise to support and expand GSR practices at the Air Force facilities within the Region while continuing to comply with CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)." The GSR MOU is included as Appendix 1.

The MOU states that the parties will define how this pilot study analysis will be conducted. The AF and EPA first established an inter-agency team composed of technical and policy interests to represent each agency. The core team is advised by the EPA Green Remediation Steering Committee and reports to the AF/EPA partnering meeting team, and to all appropriate EPA and AF leadership. All actions and decisions are coordinated and confirmed by these representatives.

Under the GSR MOU, EPA and the AF commit to a collaborative effort to compare their environmental footprint analysis tools, and to make recommendations to support and expand GSR practices at other AF Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites. Specifically, the agencies sought to (1) understand the tools, their application, extent, and relevance in real site conditions, and (2) to recommend how the tools may be used in future sites to support and expand GSR practices at other AF CERCLA sites in the region and nationally. These recommendations are expected in the form of a strategy that includes the following:

1. The use of lifecycle analyses approaches of feasible cleanup alternatives
2. Best practices, such as water reuse, soil consolidation, alternative energy sources, and optimization of groundwater pump and treat remedies
3. Process of periodic evaluation of existing cleanup actions and/or technologies that could reduce the environmental footprint of cleanup activities.

The overall goal of the MOU is to reach a consensus on the optimal use of these tools to increase the use of best management practices that minimize the environmental footprint of cleanup actions while continuing to comply with CERCLA and the NCP. The MOU does not dictate the use of additional GSR practices or impose further requirements to use GSR or any other remedial action. There are no binding regulatory constraints obligated by the MOU. The audience for the MOU report includes the EPA and AF restoration employees and the general public based on both agencies sharing information gained from this effort on their respective websites.

This is the first time EPA has partnered with another federal agency to assess GSR practices by conducting environmental footprint analyses. Lessons learned from this pilot collaboration can inform the national discussion on the optimal use of environmental footprint analyses to support the expeditious and protective cleanup of Department of Defense (DoD) installations while maximizing the environmental benefits of these cleanups.

This joint pilot effort is focused on comparing the EPA Spreadsheets for Environmental Footprinting Analysis (SEFA) and the AF Sustainable Remediation Tool (SRT™). The EPA/AF team used the results of the tool comparison evaluation to make recommendations about the use of footprint analyses in the various stages of the cleanup process in support of the voluntary use of GSR practices. EPA and AF created an inter-agency team of experts and conducted cross-agency technology transfer on SEFA and the SRT. The team leveraged the DoD Environmental Security Technology Certification Program (ESTCP) demonstration project titled *Quantifying Life-Cycle Environmental Footprints of Soil and Groundwater Remedies* (#ER-201127) and EPA HQ funds to expand the pilot study to include the life cycle assessment (LCA) software tool SimaPro™, a third-party tool developed by Pré Consultants in the Netherlands.

2.0 POLICY DRIVERS

The Air Force and EPA are implementing the MOU through a collaborative approach that leverages expertise, reduces costs, and complies with the President's Executive Orders (EOs) 13514 and 13423. The AF/EPA R9 MOU is consistent with guidance recently issued by both DoD and EPA, including the revised *Defense Environmental Restoration Program (DERP) Management Manual* (DoD 2012) and the EPA *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012). The MOU-recommended strategies are also informed by recent public (DoD/EPA), ASTM, Interstate Technology and Regulatory Council (ITRC), and private sector initiatives on GSR footprint tools and best management practices.

The following policy and guidance affect GSR practices and are used by the EPA and Air Force.

2.1 EXECUTIVE ORDERS

Current DoD and EPA policy and practice regarding GSR/Green Remediation (GR) is driven by the following two EOs.

Executive Order 13514 *Federal Leadership in Environmental, Energy, and Economic Performance*

This EO seeks "to establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal Agencies" (Federal Register, October 8, 2009). The EO establishes goals for reductions in greenhouse gases, energy consumption, and potable and industrial water use by Federal agencies.

Executive Order 13423 *Strengthening Federal Environmental, Energy, and Transportation Management*

This EO is intended to "strengthen the environmental, energy, and transportation management of Federal agencies" (Federal Register, January 26, 2007), by improving energy efficiency, increasing the use of renewable energy, and implementing environmental management systems that are compliant with International Standards Organization (ISO) 14001 by conducting agencies' mission in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.

2.2 DEPARTMENT OF DEFENSE

The Defense Environmental Restoration Program (DERP) Management Manual Procedures Revised March 09, 2012 (DoD 2012) identifies Procedures 6 (d) Green and Sustainable Remediation as

> (1) Green and sustainable remediation expands on DoD's current environmental practices and employs strategies for environmental restoration that use natural resources and energy efficiently, reduce negative impacts on the environment, minimize or eliminate pollution at its source, and reduce waste to the greatest extent possible. Green and sustainable

remediation uses strategies that consider all environmental effects of remedy implementation and operation and incorporates options to maximize the overall environmental benefit of environmental response actions.

(2) Opportunities to increase sustainability considerations throughout all phases of remediation (i.e., site investigation, remedy evaluation, design, construction, operation, monitoring, and site closeout) may exist, regardless of the selected remedy.

(3) The DoD Component should consider and implement green and sustainable remediation opportunities in current and future remedial activities when feasible. The DoD Component should not under most circumstances re-open DDs and agreements that may be in place or under negotiation with environmental regulators.

(4) Pursuant to E.O. 13514 the DoD Component shall, where practicable based on economic and social benefits and costs, ensure green and sustainable remediation practices by increasing energy efficiency; conserving and protecting water resources through efficiency, reuse, and storm water management; eliminating waste, recycling, and preventing pollution; leveraging agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services; and strengthening the vitality and livability of the communities in which Federal facilities are located.

2.3 UNITED STATES AIR FORCE

The AF *Sustainable Ops Policy Statement* (AF, 2001) states that "it is Air Force policy to apply sustainable development concepts in the planning, design, construction, environmental management, operation, maintenance and disposal of facilities and infrastructure projects, consistent with budget and mission requirements." Further, in 2007, HQ AF issued the AF Sustainable Design and Development (SDD) Policy. The goal of this policy is to reduce the environmental impact and total ownership cost of facilities; improve energy efficiency and water conservation; and provide safe, healthy, and productive working environments. This policy also directs facilities to be consistent with the Energy Policy Act of 2005 and EO 13423 (AF SDD, 2007)

2.4 UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The EPA Superfund program encompasses the three pillars of sustainability: social, economic and environment as summarized below.

2.4.1 SOCIAL

- Engaging communities in site cleanup decisions
- Turning contaminated sites into community assets

2.4.2 ECONOMIC

- Redevelopment in blighted areas (aligns with smart growth goals)
- Fostering employment opportunities in communities where sites are cleaned up

- Rising property values in communities

2.4.3 Environment

- Protecting Human Health and the Environment
- Liberating contaminated sites for reuse (one remediated acre redeveloped equals four acres of green field development)

EPA defines GR as the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprint of cleanup actions. The EPA's GR policies are summarized in the *Principles for Greener Cleanups*, the *Superfund Green Remediation Strategy*, and the *EPA 9 Regional Greener Cleanups* policies. All of these EPA documents are available at www.cluin.org/greenremediation.

EPA's *Principles for Green Remediation* policy contains five core elements:

1. Reduce total energy use and increase the percentage of renewable energy
2. Reduce air pollutants and greenhouse gas (GHG) emissions
3. Reduce water use and negative impacts on water resources
4. Improve materials management and waste reduction efforts
5. Protect ecosystem services.

Further, as part of EPA Strategic Plan 2011-2015, Goal 3: *Cleaning Up Communities and Advancing Sustainable Development,* Administrator Lisa Jackson has pledged that the "EPA's Superfund program will implement its GR strategy to reduce the energy, water, and materials used during site cleanups while ensuring that protective remedies are implemented."

3.0 ROLE OF ENVIRONMENTAL REMEDIATION FOOTPRINT ANALYSIS

An environmental remediation footprint is the sum of environmental effects that result from the cleanup of a hazardous site. As noted in the EPA Principles for Greener Cleanups, "…cleanup activities use energy, water and materials resources to achieve cleanup objectives. The process of cleanup therefore creates an environmental footprint of its own. Parties can optimize and implement protective cleanups that are greener by increasing their understanding of the environmental footprint and, when appropriate, taking steps to minimize that footprint. The quantified information can then be used to identify opportunities for adjusting the project's operating parameters, optimize environmental performance and apply Greener Cleanup Best Management Practices in ways that reduce the footprint."

Consistent with the EPA *Principles for Greener Cleanups,* EPA developed the *Methodology for Understanding and Reducing a Project's Environmental Footprint* (Methodology). (OSWER EPA 542-R-12-002, February 2012) (EPA 2012). The *Methodology* identifies 15 metrics associated with a site's environmental footprint and describes a process for quantifying those metrics. The methodology metrics are calculated for the following categories: materials and waste, water, energy, and air. Ecosystems Services are currently assessed qualitatively.

4.0 DESCRIPTION OF ENVIRONMENTAL FOOTPRINT TOOLS

Several analytical tools have been developed to assist with quantifying the environmental footprints of remedies. In addition, LCA tools developed for and used in the manufacturing sector can be applied to remedies to help quantify an environmental footprint. This EPA/AF MOU effort evaluates the environmental footprint of a given remedy using three environmental footprint tools: SRT, SEFA, and SimaPro. This section describes their different histories of development and their purpose and application.

4.1 SUSTAINABLE REMEDIATION TOOL (SRT)

The SRT was developed by the Air Force Civil Engineer Center (AFCEC) and its partners to (1) plan for the future implementation of remediation technologies at a particular site, (2) compare remediation approaches on the basis of sustainability metrics, and (3) provide a means to evaluate optimization of remediation technology systems already in place. The tool allows users to estimate sustainability metrics for specific remedial action technologies. Versions of the tool were released in May 2009 and May 2010, and the revised January 2012 version includes simplified data entry process for users of the Remedial Action Cost Engineering and Requirements (RACER™) software application that can be used by AF and other users with a RACER user license.

The SRT produces numerical environmental footprint/sustainability metrics and social and economic factors. SRT is limited to nine technologies or remedial actions. The following technologies are currently included in the SRT:

- Excavation
- Soil Vapor Extraction
- Thermal Treatment Technologies
- Pump and Treat
- Enhanced In Situ Bioremediation
- In Situ Chemical Oxidation (ISCO)
- Permeable Reactive Barrier (PRB)
- Long-term Monitoring (LTM) / Monitored Natural Attenuation (MNA)

SRT features two levels or tiers of increasing complexity to accommodate user needs—the information available about a site and the detail or confidence needed in the evaluation of the GSR metrics. Tier 2 requires more detailed inputs than Tier 1. In addition, Tier 2 allows the user to modify many of the general assumptions made in the analysis, whereas Tier 1 does not allow modification of assumptions. In general, Tier 1 takes 1-2 hours to execute, whereas Tier 2 could take up to 1-2 days of effort.

SRT has been used by federal and state agencies and private companies, as well as globally by practitioners in Australia, Brazil, and other countries. It has also been used in research studies comparing social indicator decision support tools (Beames 2012, Eskes 2012).

4.2 SPREADSHEETS FOR ENVIRONMENTAL FOOTPRINT ANALYSIS (SEFA)

SEFA is a set of workbooks designed for conducting environmental footprint analyses compatible with the EPA's *Methodology* (US EPA, 2012), which in turn reflects EPA's five core elements for GR. SEFA can be used in any stage of site cleanup, including evaluating remedy alternatives, completing remedy designs, or optimizing remedies already in operation. Input includes materials use, water use, waste disposal, transportation, equipment use, and other items. Output is provided for all metrics defined in the *Methodology*. Time to conduct SEFA depends on the amount of data and level of detail desired, but generally requires a day of data input once the pertinent remedy information has been collected and reviewed.

SEFA has also been used by federal and state agencies, and used internationally to identify an environmental footprint of soil remediation and support urban redevelopment in Venice, Italy. (Barbanti 2012)

4.3 LIFE-CYCLE ASSESSMENTS - SIMAPRO

SimaPro was developed and marketed by Pré Consultants in the Netherlands, to facilitate LCA studies in accordance with ISO Standards 14040 and 14044. SimaPro can cost between $3,000 and $12,000 (typically $9,000 for professionals) to purchase depending on the type of license, number of user licenses, and features required. Service and support packages are available for additional cost. The SimaPro LCA software provides a user interface and tools to facilitate the use of life-cycle inventory. SimaPro comes fully integrated with several life cycle databases including the extensive proprietary EcoInvent database. Additional databases and methods are included to convert footprint information (such as sulfur oxide emissions) into environmental impacts (such as acidification). The time to conduct SimaPro analyses depends on the amount of data and level of detail desired, but generally takes more than a day to input data by an experienced SimaPro user once pertinent remedy information has been collected and reviewed.

5.0 TECHNICAL COMPARATIVE ANALYSIS PILOT STUDY APPROACH

The parties first established an inter-agency team of programmatic representatives and technical experts to define how the pilot study would be conducted, and accomplish the MOU. This team relied on the Travis AFB Remedial Project Mangers (RPMs) from the AF, EPA Region 9, as well as from California EPA. The team was advised by the EPA Green Remediation Steering Committee and committed to providing reports to AF/EPA Partnering Meeting Team, and to all appropriate EPA and AF leadership. All actions and decisions were coordinated and confirmed by these representatives. The team agreed that the intention and objective of the MOU was to compare the output from the footprint tools for various sites. It was not intended to inform a remedial action decision or to compare various competing alternatives for remedy selection. To accomplish the technical footprint analyses and comparisons, a technical team of GSR footprinting experts then was formed as a subset to the inter-agency team.

5.1 SITE SELECTION

The team began with a kick-off meeting on November 18, 2011, to further refine the scope and select a pilot site. Site DP039 at Travis AFB had previously adopted GSR remedial actions and thus was nominated by the Air Force as a pilot study site. The group discussed the benefit of using the EPA and AF footprint tools on a variety of remedial technologies, such as a soil, in addition to the groundwater remedy used at DP039. The Travis RPMs suggested a soil site, FT005, and the inter-agency team concurred.

Travis AFB, in Solano County, California, is host to the 60th Air Mobility Wing and operates C-5 and C-17 cargo aircraft and KC-10 refueling aircraft. It is also home to the David Grant Medical Center and other tenant organizations. It consists of aircraft runways and parking ramps, hangars, and related support facilities. Industrial operations include aircraft refueling and maintenance activities that involve the cleaning of aircraft components with chlorinated solvents.

Site DP039 consists of a solvent plume that originated from a former rock-filled acid neutralization sump approximately 65 feet west of Building 755, in the northern portion of the West/Annexes/ Basewide Operable Unit (WABOU). Contaminants of concern (COCs) include lead for soil and chlorinated solvents for groundwater. The base removed the sump in 1993 and the building in 2009.

Site FT005 is a former fire training area, and the primary COCs in soil include Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (TPH), polychlorinated biphenyls (PCBs), and Dioxin. The Record of Decision (ROD) remedy was soil excavation to industrial levels.

5.2 APPROACH SCHEDULE

The team determined the actions needed to complete the comparative analysis portion of the GSR MOU, such as which agency should use which tool. A threshold task was used to cross-train EPA and AF on their respective tools. A capacity building/tech-transfer session was planned and scoped to coincide with actual working sessions by the team to conduct analyses and occurred according to the schedule below:

Table 1. Study Milestone Schedule.

Date	Milestone
1/5/12	First Travis AFB pilot working session
2/9 /12	GSR MOU steering committee
2/23/12	Working session to prepare for Travis AFB pilot
2/27/12	Training on SEFA
3/5/12	AFCEC training on the SRT
3/8/12	On site Travis meeting to execute SRT & Region 9 SS on Travis Soil Remedy; first hotwash
4/18/12	EPA Methodology webinar
5/17/12	DP039 hotwash (second hotwash) and FT005 draft report

The DP 039 and FT 005 pilot studies were conducted independently, with the technical team sharing written results and observations after the comparisons were completed. The specifics of the methods, results, and observations in the pilot studies are in provided in Appendices B and C for Sites FT005 and DP039, respectively. Note that while the specific conclusions from the two pilot studies are different because the studies were conducted at different sites with different remedy technologies, generalizations can be drawn from the studies.

The AF and EPA were aware of the ESTCP Project *Demonstration Project For Quantifying Life-Cycle Environmental Footprints of Soil And Groundwater Remedie*s (ESTCP Project # Er-201127), which is similar to the AF/EPA R9 MOU study as it compares the environmental footprint analysis tools of SRT and the Army/Navy SiteWise tools with the LCA software SimaPro at six military service installations nationwide, including Travis AFB. The final report is scheduled to be released in 2013.

5.3 METHOD OF COMPARATIVE ANALYSIS

The technical objective of the AF/EPA R9 MOU was completed by conducting substantive environmental footprint comparative analyses on two actual remedial actions previously conducted at Travis AFB. The inter-agency team conducted side-by-side analysis of the SEFA and SRT tools on a soil excavation site and a groundwater pump and treat site. The results from SimaPro were also used from the groundwater site. The method of comparison conducted for the soil and groundwater sites was conceptually the same. Initially the tools were applied to a specific site by the tool owner (EPA or AF) using their best judgment. The technical team for each study site then confirmed that the inputs to the tools were as similar as possible and worked together to align the inputs to the tools as much as possible for the site. Differences in inputs were sometimes unavoidable because of the different structure and function of the tools. The technical team then compared the numerical results provided by the tools and attempted to determine the cause for any differences in the results. The team used the results to complete the other objective of the MOU by preparing a set of observations on the usability and applicability of the tools and making recommendations to improve both SEFA and SRT and also develop best GSR practice recommendations.

There were some differences in how the comparative analysis pilot studies were conducted at each site. For the groundwater Site DP039, all three tools (SRT, SEFA, and SimaPro) were applied and compared. For the soil Site FT005, only SRT and SEFA were compared. Also, for Site DP039, two remedy technologies were evaluated, while for FT005, one remedy technology was evaluated along with an addendum expanding that remedy. In addition, for DP039, several sensitivity studies were conducted, whereas for FT005 no sensitivity studies were conducted.

5.4 OUTPUT METRICS AND INITIAL OBSERVATIONS

The SRT, SEFA, and SimaPro tools do not provide identical output metrics but they do provide the same core set of metrics for air emissions and energy usage. However, the three tools define and calculate those core metrics differently due to their designed purpose, and each tool provides additional metrics beyond the core metrics. For example, SEFA calculates contributions to energy use from electricity use, fuel consumption, materials production, and off-site activities (e.g., landfill disposal) whereas SRT only considers energy use from electricity and fuel combustion. Beyond the core metrics, SRT provides metrics pertaining to certain sustainability concepts (e.g., worker safety, technology resource services). SEFA provides metrics on materials, waste, and water, and SimaPro provides metrics regarding human health and ecological effects.

One reason for the difference in metrics in the two tools is that SEFA was designed to reflect the core elements of EPA's *Environmental Footprinting Methodology*, while SRT, which was built several years before the *Methodology* was issued, was designed to reflect sustainability parameters for a number of remedial technologies commonly used by AF for a typical environmental footprint analysis. Other differences are that the SRT provides a metric for GHG emissions per pound of contaminant removed, while SEFA provides metrics for renewable energy used. In determining which tool to apply to a site for footprinting, the user should first determine which metrics would be the most useful at the site. Table 2 identifies the output metrics/sustainability parameters produced by each of the pilot study tools.

Table 2. Metrics provided by SRT, SEFA, and SimaPro.

Metrics	SRT	SEFA	SimaPro
CO2e*		✓	✓
CO2	✓		
CO2 per lb of contaminant removed	✓		
NO_x	✓	✓	✓
SO_x	✓	✓	✓
PM	✓	✓	✓
HAPs		✓	✓
Total energy	✓	✓	✓
Renewable energy		✓	✓
Water usage (on-site)		✓	
Materials usage (on-site)		✓	
Waste generation (on-site)		✓	
Technology cost	✓		
Safety accident risk (accident risk, lost hours, insurance cost)	✓		
Resource service	✓		

*CO_2e above includes CO_2, methane and nitrous oxide for SEFA and those gases plus several other greenhouse gases for SimaPro.

The metrics presented in the above table are those identified in SEFA or SRT. SimaPro has many other metrics that were not included in this study because SEFA and SRT do not have analogous metrics available for comparison.

6.0 OVERVIEW OF FOOTPRINT ANALYSES SOIL SITE FT005

The technical team compared SRT and SEFA on three levels for site FT005. First, the output metrics that are estimated by each of the tools were compared. Second, the analytic mechanisms in each of the tools were compared. And finally, numerical outputs of the two tools were compared. The comparison of the output metrics was relevant only for the five parameters that are common to the two tools (CO_2e, NO_x, SO_x, PM, and total energy). After the initial assessment of site FT005, it was clear that SEFA and SRT produced significantly different results.

The team focused on a greenhouse gas metric (CO_2e), and identified the top five contributors to this metric. SEFA identified off-site waste management and on-site diesel use as the greatest contributors to the CO_2e footprint. SRT does not include off-site waste management in its footprint calculations, and so identified on-site diesel usage as the key contributor to the CO_2 footprint at FT005. The analysis also included a detailed comparison of the second largest contributor to the CO_2e footprint, on-site diesel fuel. SRT calculated approximately 22,000 lbs CO_2 (10 tons) from combustion of diesel fuel on-site and SEFA calculated 47,000 lbs CO_2e (21 tons). Even after aligning the inputs to ensure that the input parameters used in both the models were as similar as possible in order to produce similar intermediate calculations, there were still large differences in the results. See Table 3 below.

Table 3. Comparison of SRT and SEFA output metrics at Travis AFB, Site FT005

Metrics	SRT	SEFA
CO_2e		660 tons
CO_2	170 tons	
NO_x	2,000 lbs.	8,000 lbs.
SO_x	2 lbs.	2,900 lbs.
PM	10 lbs.	8,700 lbs.
HAPs	Not calculated	50 lbs.
Total energy	1,704 MMBtu	8,600 MMBtu
Renewable energy	Not calculated	0 MMBtu–
Water usage (on-site)	Not calculated	1.06 million gallons
Materials usage (on-site)	Not calculated	16,900 tons
Waste generation (on-site)	Not calculated	21,300 tons
Energy cost	$43,000	Not calculated
Technology cost	$1,400,000	Not calculated
Safety accident risk (accident risk, lost hours, insurance cost)	2.95 hours lost 0.061 injury risk	Not calculated
Resource service	Net Gain Economic $6,000 Ecologic $6.800	Not calculated

The differences in emissions of CO_2e, NO_x, SO_x, and PM, and the difference in total energy, are due in large part to the exclusion of off-site waste management and off-site laboratory analysis from SRT, and the inclusion of these activities in SEFA. In addition, SEFA considers the life cycle of the diesel fuel, including crude oil extraction and processing in a refinery. SRT considers only the combustion of the diesel fuel. This difference in representing the footprint associated with diesel use is the primary reason why the calculated SOx emissions are so different for the two tools.

The FT005 technical report (Appendix B) provides a full and detailed breakdown of the GHG contributions from individual field activities performed at the Site FT005. Figure 1 below shows that the primary contributors to GHG emissions are on-site diesel usage and the management of the excavated soils at an off-site landfill. This type of chart is not automatically produced by SRT or SEFA, but may be created by the user through access to intermediate calculations and results.

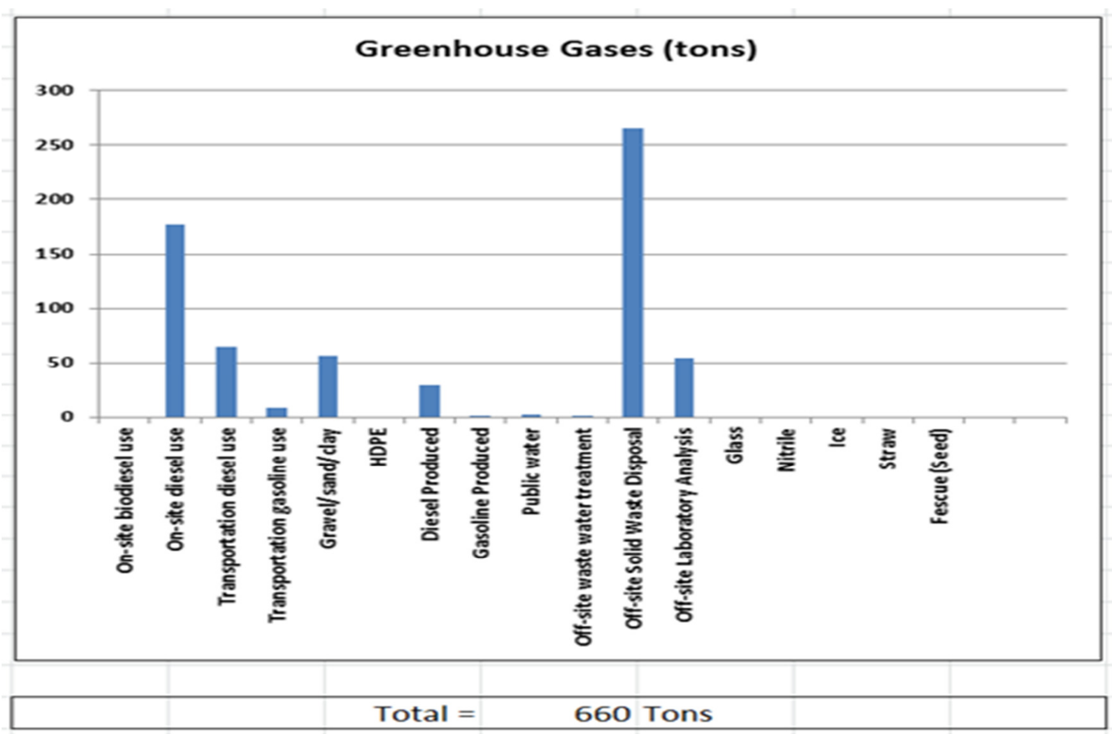

Figure 1. Greenhouse gas contributions from Site FT005 individual field activities. Chart produced from the SEFA evaluations.

7.0 OVERVIEW OF GROUNDWATER SITE DP039 FOOTPRINT ANALYSES

To complement the comparative analysis of a soil excavation remedy, footprint analyses were prepared for the following two groundwater remedial alternatives at Travis AFB Site DP039:

- Alternative 1: Pump and treat system for 30 years
- Alternative 2: Phytoremediation, bioreactor, biobarrier injection wells, MNA of a down gradient portion of the plume

For each alternative, the following steps were involved in the approach to compare footprint tools:

- Obtain the input information used for SRT and SimaPro
- Input the same information into SEFA
- Compare the SRT, SimaPro, and SEFA results.

Where feasible, input for the three tools was made as similar as practical so that differences in the results could be attributed to differences in model calculations rather than differences in user input assumptions.

Tables 4 and 5 below provide the results for environmental footprint metrics for Alternatives 1 and 2. Output from the various tools has been converted into common units to facilitate comparison. Using SEFA as an arbitrary benchmark, results that differ from the SEFA results are highlighted accordingly:

- White – Different by a factor of less than 1.2
- Yellow – Different by a factor of 1.2 to 2
- Orange – Different by a factor of 2 to 10
- Red – Different by a factor of 10 or more

Table 4. Comparison of calculated footprint metrics for Site DP039, Alternative 1

Metric	Unit	SRT	SEFA	SimaPro
Total Energy Used	MMBtu	20,000	23,200	20,700
Total NOx Emissions	lbs.	15,400	3,560	2,860
Total SOx Emissions	lbs.	28,000	12,600	15,300
Total PM Emissions	lbs.	5,400	99	136
Total HAP Emissions	lbs.	N/A	256	340
Total GHG Emissions	tons	1,310	918	1,010

The NOx, SOx, and PM emission values for SRT are much higher than the values calculated by the other tools. The SRT was applied using default electricity conversion factors, which is a nationwide average. By contrast, SEFA and SimaPro used the 2005 CAMX regional energy mix from eGRID, which is representative of the generation mix for a large portion of California. The CAMX mix has a higher percentage of natural gas and renewable energy use and lower coal use than a national average. The energy footprints for SRT and SimaPro are similar because SimaPro considers energy losses due to electricity transmission and distribution, like SEFA, but does not account for energy associated with hydroelectric power. For example, it is not accounting for the hydroelectric power offsets, the added energy associated with the transmission and distribution losses. This comparison of electricity among the three tools is unique to this site and the specific fuel blend used to generate grid electricity. A comparison at a different site would likely yield significantly different results.

Table 5. Comparison of calculated footprint metrics for Site DP039, Alternative 2

Metric	Unit	SRT	SEFA	SimaPro
Total Energy Used	MMBtu	184	3,860	2,950
Total NOx Emissions	lbs.	142	3,310	5,370
Total SOx Emissions	lbs.	26.4	947	755
Total PM Emissions	lbs.	7.16	192	56.7
Total HAP Emissions	lbs.	N/A	2	131
Total GHG Emissions	tons	621	805	126

The Alternative 2 remedy, as analyzed by the tools, involves substantial use of bioremediation substrate (i.e., emulsified vegetable oil). Therefore, many of the differences in Table 5 can be attributed to how the tools convert this substrate into footprint metrics.

Table 6 presents the ranking of the top contributors to various calculated footprint metrics for each of the tools applied to DP039 Alternative 2. Note that the materials, waste, and water metrics are not included because they are not calculated by SRT and SimaPro. A similar table is not provided for Alternative 1 because electricity is the only main contributor.

Table 6. Comparison of footprint contribution ranking for DP039, Alternative 2

Rank	SRT	SEFA	SimaPro
Energy			
1	Personnel transport	Substrate	Substrate
2	Drill rig	Drill rig	Gravel/mulch backfill
3	PVC for wells	Bioreactor excavation	Drill rig
4	Bioreactor excavation	Soil disposal	Soil disposal
5		PVC for wells	PVC for wells
6		Personnel transport	Personnel transport
7		Substrate transport	Substrate transport

Rank	SRT	SEFA	SimaPro
8		Gravel/mulch backfill	Water
9		Solar energy	Bioreactor excavation
GHG Emissions			
1	Substrate	Substrate	Substrate
2	Personnel transport	Drill rig	Gravel/mulch backfill
3	Drill rig	Bioreactor excavation	Drill rig
4	PVC for wells	Soil disposal	PVC for wells
5	Excavator	Personnel transport	Soil disposal
6		PVC for wells	Personnel transport
7		Water	Substrate transport
8		Substrate transport	Bioreactor excavation
9		Gravel/mulch backfill	Water

"Substrate" = emulsified vegetable oil or comparable bioremediation electron donor applied to the bioreactor and biobarrier remedy components
"Drill rig" = fuel use associated with installing bioreactor excavation refers to excavator and dump truck use
"Bioreactor excavation" = fuel use for excavator and dump truck use to excavate and backfill bioreactor

8.0 COMBINED PILOT STUDY RESULTS

8.1 NUMERICAL RESULTS

The numerical results from the SRT and SEFA differed substantially at each of the study sites. For DP039, the numerical results among the three tools differed by a factor of 10 for some footprinting metrics. No tool consistently produced the highest or lowest result for given metric, and the tool showing the highest result depended on which remedy technology was being evaluated. For FT005, the numerical results between the two tools differed by three orders of magnitude for some footprint metrics. In addition, for each site, the tools identified key contributors to the footprint in somewhat different orders of importance. For both DP039 and FT005, the differences in numerical results were attributed to differing inputs to the tools, different scope of analysis and analytic assumptions within the tools, and different conversion factors used in the tools. There are significant differences in how each tool ranks the various contributions to a footprint. In addition, SRT includes fewer potential contributors. For example, for the DP039 Alternative 2 remedy, SRT only included four or five footprint contributors, whereas SEFA and SimaPro included up to nine footprint contributors.

8.2 COMPARISON WITH EPA FOOTPRINTING METHODOLOGY

Application of all the tools for this study did not necessarily follow the EPA *Methodology* due to several simplifying assumptions, demonstrating that use of a particular tool does not guarantee adherence to the *Methodology*. SRT and SimaPro were developed before the EPA *Methodology* was developed and for purposes other than compliance with the methodology. As would be expected, SEFA (an EPA footprinting tool) substantially conforms to EPA's *Footprinting Methodology*. SRT differs from the *Methodology* in that it does not include several of the metrics recommended, and its scope of analysis is somewhat more limited than that of the *Methodology*. SRT and SimaPro do not include features to assist with calculating the materials, waste, and water footprints described in the *Methodology*, but these calculations could be conducted outside of SRT or SimaPro by a user-prepared spreadsheet. SimaPro differs from the *Methodology* in that it may have a broader scope of analysis. Finally, neither SRT nor SimaPro distinguishes between on-site and off-site emissions in the presentation of results, as recommended in the *Methodology*.

Structural features of SRT and SimaPro present additional challenges when using these tools to implement the *Methodology*. For example, neither tool can straightforwardly calculate the on-site NOx+SOx+PM footprint described in the *Methodology*. In addition, SRT does not calculate energy use, NOx, SOx, or PM emissions associated with several significant contributors to these emissions, which prevents SRT from calculating the total energy used or total NOx+SOx+PM footprints as described in the *Methodology*. SRT also does not calculate the on-site or total HAPs footprints.

8.3 OBSERVATIONS ON TOOL CHARACTERISTICS, USES AND STRENGTHS

To complete the second portion of the MOU, the inter-agency team used the results of the comparative analysis pilot studies to assess the characteristics and identify the strengths in order to facilitate the best use of the different tools. The team found that each tool has different characteristics that align with their initial development. The SRT is designed to model specific technologies and situations and requires less effort in inputting site data, while SEFA is designed to be flexible, to accommodate any remedy technology and site configuration. Consequently, SEFA typically requires more user effort in inputting site data. SimaPro requires significantly more user effort regarding input because it is not designed specifically for environmental remediation applications, and there are many user input choices that challenge a typical environmental professional. A set of observations on the structure and function of the three tools is provided in Table 7, *General comparison of SRT, SEFA and SimaPro tools,* along with observed strengths and weakness of each tool. The full set of observations and the method of the comparisons for DP039 and FT005 can be found in Appendices B and C.

Table 7. General comparison of SRT, SEFA and SimaPro tools

SRT	SEFA	SimaPro
Quick learning curve (less than one day).	Intermediate learning curve (approximately one day).	Long learning curve (more than one week).
User-friendly interface not requiring familiarity with Excel worksheets.	Requires familiarity with Excel worksheets.	User interface requires knowledge of specific software.
Once user is familiar with SRT, can complete footprinting at each site more quickly than SEFA.	Once user is familiar with SEFA, may take longer to complete footprinting at each site compared with SRT, depending on the level of detail sought in the analysis.	Once the user is familiar with SimaPro will take substantially longer to complete footprinting than SRT or SEFA.
Remediation technology-based tool pre-configured with eight common technologies.	Remediation activity-based tool; "blank slate" for any remedy technology.	Manufacturing sector tool that is adaptable and can be applied to any remedy technology.
Cannot easily be applied to technologies not already present in the tool.	Flexibility allows for more aspects of a complicated remedy to be analyzed.	Flexibility allows for more aspects of a complicated remedy to be analyzed.
Focuses on soil and groundwater media.	Can be applied to any medium.	Can be applied to any medium.
Requires basic understanding of site-specific parameters.	Requires more detailed understanding of site-specific parameters.	Requires more detailed understanding of site-specific parameters.
User's Guide details all the equations used and assumptions made.	No User's Guide. Equations can be viewed in the worksheet cells and some assumptions are documented in notes in the	User's guide and tutorial provides basic understanding of tool application.

SRT	SEFA	SimaPro
	worksheets.	
Many assumptions are made within the tool; user makes few assumptions explicitly.	Few assumptions are made within the tool; user makes most of the assumptions explicitly.	Few assumptions are made within the tool; user makes most of the assumptions explicitly.
Many of the default assumptions can be over-ridden.	Default assumptions can be over-ridden.	Default assumptions can be over-ridden.
Conversion factors are provided for a limited number of clean-up parameters.	Conversion factors are provided for a limited number of clean-up parameters, but for more parameters than SRT.	Conversion factors are provided for a wide variety of materials and processes in multiple libraries. Selecting an appropriate material or process to model the remedial component can be challenging due to the number of options available. Conversion factors are not available for all materials and processes used in remediation.
Does not allow for addition of conversion factors.	Ability to add conversion factors for clean-up parameters not already included in tool.	Ability to add conversion factors for any user-defined material, process, or service.
Designed to compare multiple remedies, but a single remedy can be modeled.	Designed to model a single remedy, but multiple remedies can be compared.	Designed to model a single remedy, but multiple remedies can be compared.
Graphs and charts are not included in SRT's outputs but can be developed by the user with additional effort as needed.	Graphs and charts are not included in SEFA's outputs, but can be developed by the user with additional effort and time.	Graphs and charts are not included in SimaPro output, but some metrics considered in this study require data extraction and processing prior to graphing.
Provides output in the form of numerical metrics as two worksheets (one for soil and the other groundwater media) in the same spreadsheet file.	Provides output in the form of numerical metrics in a single spreadsheet conforming with EPA's *Methodology* with additional spreadsheets providing access to intermediate results/calculations.	Provides output in a visual tree-like format supplemented by extensive data tables that can be exported into spreadsheet/ database format with many user options for further interpreting and characterizing those outputs.

SRT	SEFA	SimaPro
Focuses on on-site equipment use, transportation, electricity usage, and manufacturing of a limited number of materials used in the remedy. On-site and off-site footprints are reported as one combined number for each metric.	Considers on-site equipment use, electricity, transportation, off-site manufacturing of materials, and off-site services that directly support the remedy. Output is organized into the following categories: (1) on-site, (2) electricity generation, (3) transportation, and (4) other, including items such as materials manufacturing, landfill disposal and other supporting services, and processing of fuels in refineries.	Materials and processes used in SimaPro are by default considered from the raw materials stage to final processing and use on a global scale. Disposal options can be added to represent the end-of-life footprint of the materials and processes.

While the purpose of this MOU was not to evaluate the accuracy of each footprinting tool, the team concluded that confidence in the results affects their strength and applicability for use. Increasing confidence in the results would require further evaluation of the potential footprint conversion factors available for use, the reasons for differences in the conversion factors, and the most appropriate conversion factors to use. The differences between SEFA and SimaPro could likely be attributed to the following few items:

- Fuel use input assumptions associated with dump truck use
- Footprint conversion factors for in-situ bioremediation substrate
- Footprint conversion factors for soil disposal (e.g., landfill activities).

Of the three tools, SRT requires the least effort to learn, and once learned would likely take the least time to complete the analysis. SEFA takes somewhat more effort to learn, and once learned likely would take longer than SRT complete. Finally, SimaPro requires intensive training and experience to execute properly, and once learned would take longer than SEFA to complete. It is likely that SRT could be executed by a project manager at his/her site without special training, which was most likely a goal in the development of SRT. SEFA could also be executed by a project manager, but only after approximately four hours of training or exploration by someone familiar with spreadsheets. More likely, experienced support staff or contractors would execute SEFA and provide the results to the project manager. Finally, it seems unlikely that SimaPro would be used by a project manager. In addition to a very long learning curve, expertise in the techniques of LCA is needed to execute SimaPro properly and interpret the results.

All three tools can be applied at any stage of the remediation process. Choosing one of the tools over the other will likely not depend on the stage of the cleanup remedy. It is more likely to depend on other considerations, such as the level of detail desired, the amount of time and effort to be invested, and the number of remedy components that the tool is expected to represent.

Based on these results, the team concluded it is not appropriate to identify any footprinting tool as the best one at this time. However, on a site specific basis, a user can use the observations contained in this report to select the best tool for their situation. In determining which tool would be the most appropriate, the user should first determine which strengths would be the most advantageous to the situation at hand, and which weaknesses are irrelevant or can be accommodated in other ways. See Table 8 for a summary of the pros and cons of the three tools.

Table 8. Using SRT and SEFA

SRT maybe best applied…	SEFA maybe best applied…	SimaPro may be best applied…
To site conditions and remedy technologies found in SRT (see list below)	To site conditions and remedy technologies of any type	To site conditions and remedy technologies of any type, and where materials/ processes beyond those available in SRT and SEFA are of interest
When access to intermediate calculations is not needed	When access to intermediate calculations is advantageous	When enough resources are available to construct the project within the tool in a manner that provides any detailed output that is desired
When metrics specific to SRT are of interest	When metrics specific to SEFA are of interest	When a list of metrics beyond those in SRT or SEFA is of interest
	EPA/AF MOU identified metrics: for RE, Water, Materials Management	
Key considerations are worker safety and technology cost	Key considerations are (1) off site waste management, (2) significant diesel consumption, (3) offsite laboratory services	
	Energy use is key component of remedy	Energy use is key component of the remedy
Where time and resource constraints do not allow an in-depth analysis	Where time and resources are sufficient to allow an in-depth analysis	Where time and resources are sufficient to allow an in-depth analysis.

9.0 RECOMMENDATIONS/PROPOSED STRATEGY

This study has resulted in two major strategic recommendations:

1. ***Optimize the Life Cycle Analyses Approach***
2. ***Incorporate GSR Best Practices.***

This section provides specific details on the incorporation of these recommendations into the analysis of environmental footprints.

9.1 OPTIMIZE THE LIFE CYCLE ANALYSES APPROACH

To optimize the use of *Life Cycle Analyses Approaches* or environmental footprinting as warranted by site conditions, the inter-agency team recommends a strategy that encompasses three specific areas:

1. **Information Sharing:** Inform RPMs of the AF/EPA R9 MOU and the results of this study.
2. **Process Efficiencies:** Develop a process for efficient development, review and comment, and regulatory approval to support timely remedial decision making.
3. **Tool Improvement:** Promote updates and improvements to SRT and SEFA per the specific recommendations in this report.

9.1.1 INFORMATION SHARING

Inform RPMs through technology transfer of the results of this study and the AF/EPA R9 MOU including recommendations and advice for using SRT, SEFA, and SimaPro, and for consistency with the EPA *Methodology*.

- Build more capacity with AF and EPA personnel and contractors to perform GSR footprint analyses through education and technology transfer using training materials developed under this pilot. AF and EPA SMEs are also available to support this technology transfer effort. This information can then be shared with other federal and state project managers.
- Educate users (particularly AF, EPA, and state RPMs) about the differences and strengths of SRT, SEFA and SimaPro, so they can use the best footprint tool for their site and use the results with confidence.
- Incorporate GSR in the scope of work for the AF PBC and EPA Remedial Oversight Contracts, as possible.

9.1.2 PROCESS EFFICIENCIES

Develop a process for efficient development, review, and comment of footprint analyses and in the context of remedial decision making and remedy implementation.

- Any GSR footprint analysis should begin with base level program managers' consideration of the intent and objective of the GSR remedy in context of the CERCLA objectives. The managers should discuss the value, goals, and scope of the footprint analysis itself, as well as what metrics are needed, and weigh these considerations against the time and resources available. It may be possible to optimize current practices by applying best management practices to reduce the environmental impact or footprint of a remedial action.
- If a GSR footprint analysis is conducted, the responsible party should document the rationale used as to which footprint tool is used. Additionally the responsible party should anticipate that the EPA will expect the analysis to conform to the EPA *Methodology*. The *Methodology* seeks to provide a standard approach for conducting environmental footprint analyses at cleanup sites. Currently, EPA considers conducting footprint analyses at cleanup sites to be optional. If a footprint analysis is conducted at a site in an EPA cleanup program, however, EPA prefers that the tool adhere to the *Methodology,* which establishes footprinting metrics to be quantified, the scope of the analysis, a process for conducting and documenting the analysis, and an approach for organizing and interpreting the results. These four key aspects are described briefly below.
    1. *Footprinting Metrics:* The *Methodology* establishes approximately 15 metrics for quantification. These metrics are provided in Tables 2 and 3 of this report, and are associated with EPA's core elements of greener cleanups: materials and waste, water, energy, and air and atmosphere. The parameters of greatest importance depend on the site-specific conditions and site stakeholder priorities.
    2. *Scope of the Analysis:* The *Methodology* establishes a scope for the footprint analysis. The analysis should include activities at the cleanup site, along with transportation of personnel, materials, waste, and equipment to and from the site. In addition, the analysis should include off-site support activities such as electricity generation, manufacturing of materials, management of waste, treatment of wastewater, and running laboratory analyses.
    3. *Conducting and Documenting the Analysis:* The *Methodology* recommends a process for conducting the footprint analysis. This process includes gathering site and remedy information, screening the information to exclude minor contributors, and applying footprint conversion factors. The *Methodology* also emphasizes the importance of documenting the inputs to the analysis, and documenting the screening process and key assumptions made during the analysis. It also recommends that the calculations made during the analysis be "transparent" so that reviewers are able to access and understand the footprint analysis.
    4. *Organizing and Interpreting the Results:* The *Methodology* recommends a process for organizing and interpreting the results. For example, in organizing the results, it recommends distinguishing between on-site and off-site emissions for some metrics; distinguishing between conventional and renewable energy sources; distinguishing

among water resources; reporting the proportion of recycled materials used; and reporting the proportion of waste that is reused or recycled. These approaches for organizing the results are expected to assist the user in identifying opportunities and documenting improvements to reduce the footprint from the cleanup. In addition, in interpreting the results, the *Methodology* does not emphasize any one core element or any single metric above others, nor does it combine metrics for a "single score." Instead, it recommends balancing the metrics against each other, in light of site specifics such as local community, limited resources, and policy considerations.

The following considerations are offered to help balance the time and effort of regulatory review and approval.

- GSR offers potential to optimize a remediation and should be pursued, however there is no regulatory requirement to implement GSR practices, to assess the environmental footprint of remedial actions, or to achieve a GSR or footprint metric.
- Footprint tools to quantify GSR metrics or expected improvements are conducted based on the best information available and address key stakeholders concerns.
- The remedy selection and implementation should follow the existing Superfund requirements and the NCP nine criteria analysis. A GSR environmental footprinting evaluation should inform and enhance remedial decisions.
- A GSR footprint analysis should address the EPA *Methodology* (see key elements summarized above). Other guidelines such as ASTM standards, ITRC framework and the National Optimization Plan may also be consulted.
- GSR/GR recommendations should focus on the biggest contributors to the metrics of greatest importance at the site.
- The follow up to a GSR evaluation, such as best management practices, should add value and not hinder the overall cleanup process and milestones.
- When a GSR evaluation is done post remedy implementation for base-lining or other program needs, additional follow up actions should not be required.
- As much as practicable, all components of the project should be considered in a GSR analysis and not just one phase or a single milestone in the overall remediation process. In addition, the GSR analysis should consider as many aspects as possible of the life cycle of the remedy activities, such as off-site production of remedy materials and off-site disposal of wastes from the remedy. Where possible, emphasis should be on evaluation of environmental metrics; with sufficient data, sustainable elements of social and economic best management practices should be considered.
- All things being equal, if two remedies give the same level of protection, the remedy that incorporates the best management practices with better environmental benefits and/or reduced environmental footprint should be considered for implementation. GSR

evaluations should enhance the remedial process and not replace the approved cleanup decisions. In other words, remedy decisions cannot be solely based on GSR results.

- Regulators support timely consensus or an "agree to disagree" conclusion should be reached.

9.1.3 Tool Improvements

Both SRT and SEFA can benefit from revision and update to improve its functionality. Some of the identified improvements are structural in nature, and others are related to ease of use of the tools. These recommendations arise from the application of SRT and SEFA at the Travis sites. Other improvements may be identified at other sites and other remedy technologies and from other studies including the EPAR9/Department of the Navy environmental footprinting pilot and the ESTCP Life Cycle Analysis Demonstration Project.

Table 9. General Recommendations for SRT and SEFA Improvements

	SRT	SEFA
Structural	Include additional off-site activities	In the intermediate calculation sheets, report total NOx, SOx, and PM separately for each remedy component and for the remedy as a whole
	Allow over-riding of default conversion factors	In addition to allowing the user to provide user-defined vehicle types, add additional pre-defined types of vehicles for personnel transportation and allow the user to modify the fuel usage for each type
	Include support equipment for on-site construction activities	Prepare a user manual or tutorial to inform the user how to use various features, including overriding default conversion factors for fuel combustion
	Add water usage to the footprinting metrics	
	Add HAPs emissions to the footprinting metrics	
	For consistency, provide calculation for energy, NOx, SOx, and PM for all materials and activities or none of the materials and activities	To improve usability, a post-processor should be provided to help compile some of the intermediate calculations and prepare charts
Ease of Use	Provide access to intermediate calculations and results including various footprint contributions	
	Make the formula tool bar visible	
	To improve usability, additional fields of input should be added so that the user can include the use of additional materials or activities in a particular remedy module	Add more lines to the input table for Off-Site Laboratory Analysis
	Add fields to include user-defined materials and associated conversion factors	Add a notes column to the input sheets for materials, waste, and water

9.2 STRATEGY TO INCORPORATE GSR BEST PRACTICES

To support the expanded (and voluntary) use of GSR practices at AF installations, the inter-agency team recommends the following two-part strategy:

1. Build on current EPA and AF best practices
2. Leverage other federal GSR initiatives.

This two pronged approach will capture the most useful practices available and promote consensus throughout the largest stakeholders.

9.2.1 BUILD ON CURRENT EPA AND AF BEST PRACTICES

Build on the current EPA GR and AF GSR initiatives and best management practices available or in pilot demonstration (see examples below). As part of these efforts, conduct technology transfer focused on federal facilities. Suggested topics include the AF CleanSWEEP—Clean Solar and Wind Energy in Environmental Programs—when finalized and the EPA *Best Practices for Siting Solar PV on Landfill*. EPA GR resources are available at www.cluin.org/greenremediation and include Special Issues Primers, Technical Bulletins, Case Studies, Project Profiles, Vendor Support and BMP fact sheets for common cleanup approaches. The fact sheets published to date address the following topics:

- Excavation and Surface Restoration
- Site Investigation
- Pump and Treat Technologies
- Bioremediation
- Soil Vapor Extraction & Air Sparging
- Clean Fuel & Emission Technologies for Site Cleanup
- Integrating Renewable Energy into Site Cleanup
- Sites with Leaking Underground Storage Tank Systems
- Landfill Cover Systems & Energy Production
- Mining Sites
- Implementing In Situ Thermal Technologies
- Overview of EPA's Methodology to Address the Environmental Footprint of Site Cleanup

There are a number of Air Force GSR initiatives underway. One of the most notable and visible AF environmental clean-up projects using renewable energy is underway at the Massachusetts Military Reservation. Three 1.5 megawatt wind turbines provide 100 percent of the power needed to clean more than 12 million gallons of groundwater a day. The Air Force is also using solar-powered remediation systems at 13 other sites across the nation, which will produce at least 4.7 kilowatts when fully functional. Most of the projects are smaller-scale or pilot projects and many of these sites having non-permanent solar arrays that are removed after completion of the study.

One of the pilot projects showing promise is a solar-powered recirculation system treating ground water contamination at Air Force Plant PJKS, Systems and Components Area, in Colorado. The former AF property is now owned by Lockheed Martin. The site was originally the testing ground for the Titan missile, and as the original owner, AF is responsible for the clean-up. The clean-up technology is demonstrating an effective use of a renewable energy source and turning out better than expected GSR results. The clean-up performance of this system will be evaluated for at least another year, but could move to full-scale remedy if results continue to be favorable.

CleanSWEEP assesses the potential to switch from non-renewable energy to renewable energy to power remediation systems. It also evaluates the potential of using renewable energy based on a site's location away from the power grid.

Information on these efforts can be found at the following website:
http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/

9.2.2 LEVERAGE OTHER FEDERAL GSR INITIATIVES

Other federal GSR initiatives can be leveraged for best practices, particularly the Federal Remediation Technologies Roundtable (FRTR) and the ITRC in a phased approach to implement and document GSR practices.

Federal Agencies and Interagency Forums

- The FRTR promotes interagency cooperation to advance the use of innovative technologies to clean up hazardous waste contamination. Members include the DoD, AF, U.S. Army U.S. Navy, U.S. Department of Energy , U.S. Department of the Interior, EPA, and the National Aeronautics and Space Administration. The FRTR works toward a more consistent and unified federal approach to technology evaluation and regulatory acceptance, and uses a variety of technology transfer tools and other information resources. The FRTR has worked on a number of decision support tools for hazardous waste cleanup, and has formed a GSR subgroup that is compiling GSR best management practices and existing federal policies for GSR/GR.

- GSR Approaches can be included into the AF standardized Environmental Management System.

- Final *ESTCP Life Cycle Analysis* report can include additional considerations for the use of SRT and SimaPro.

- US ARMY study report *Evaluation of Consideration and Incorporation of GSR Practices* can be used to propagate the use of GSR Approaches.

State Associations and Forums

- ITRC's GSR team and guidance document, entitled *Green and Sustainable Remediation: A Practical Framework* is a good resource. ITRC is a state-led organization that brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and streamline documents, provide training courses and maximize the resources for implementation of innovative technologies and processes. The GSR team has been developing guidance and overview documents and presenting training sessions through the internet and at various conferences.

- Association of State and Territorial Solid Waste Management Officials (ASTSWMO) has a good network of state regulatory officials who are engaged in developing position papers, documents and other resources.

- Individual state programs such as Minnesota, California, New Jersey, and Wisconsin all have solid GSR programs developed for implementation in their states. AF and EPA can take advantage of their network to help propagate the GSR MOU objectives and application of SRT and SEFA in the implementation in those states.

Other Forums and Associations

- ASTM International (formerly American Society for Testing and Materials) has two work groups working on standard guides on Greener Cleanups and Sustainable Cleanups documents respectively. These documents: *Standard Guide for Greener Cleanups* (ASTM E2893-13) and *Standard Guide for Integrating Sustainable Objectives into Cleanup* (ASTM E2876-13) have been finalized and are available for public use.

- Sustainable Remediation Forum (SuRF) is an industry led organization that promotes the use of sustainable practices during remedial action activities with the objective of balancing economic viability, conservation of natural resources and biodiversity, and enhancement of quality of life in surrounding communities. They work with several sustainable remediation groups worldwide and published numerous documents on topics related to sustainable remediation.

The team recommends working with these above groups in educating and training within the regions and states, whenever possible, and encourages moving forward with application of GSR and tools as needed.

10.0 COMMUNICATION AND OUTREACH

To facilitate support and leveraging of expertise and resources, and expand the use of the environmental footprints and best management practices, the inter-agency team agreed to coordinate with internal and external stakeholders, including the following:

1. Coordinate with EPA HQ, EPA GR work group, other regions and military service branches;
2. Collaborate with the FRTR; proposed report-out at the FRTR Spring 2015 meeting; and
3. Communicate the MOU and pilot study findings.

Key Communication effort to date:

- http://www.epa.gov/region9/superfund/greener-cleanup/ AFCEC link:
- The EPA Region 9/AF Greener Cleanups MOU was the lead story in the **FED CENTER Daily Newsletter,** a resource for federal agencies on environmental compliance and sustainability: "*EPA and Air Force Collaborate on Greener Cleanups*" (12/28/2011)
- **Federal News Radio.** On January 11, 2012, the **Federal News Radio** interviewed Timothy Bridge, Deputy Assistant Secretary of the Air Force for Environment, Safety & Occupational Health, on the recent AF/EPA Region 9 Greener Cleanups MOU. http://www.federalnewsradio.com/741/2702006/Air-Force-EPA-partner-for-greener- base-cleanups

Future communication activities include development of outreach materials, including a slide deck and footprint graphics.

Table 10. EPA R9/AF MOU Inter-Agency Team

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United States Air Force
And the
United States Environmental Protection Agency Region 9

Memorandum of Understanding
Green and Sustainable Remediation Strategies

Whereas, the U.S. Environmental Protection Agency, Region 9 ("EPA"), and the U.S. Air Force ("Air Force') commend the Green and Sustainable Remediation (GSR) practices already achieved at Air Force installations in the Southwest Region (Region).

Whereas, GSR employs strategies for cleanups that use natural resources and energy efficiently, reduce negative impacts on the environment, minimize or eliminate pollution at its source, protect and benefit the community at large, and reduce waste to the greatest extent practicable. GSR considers all environmental effects of remedy investigation, design, implementation and operation, and incorporates options to minimize the environmental/ecological footprint while meeting statutory mandates of CERCLA and the National Contingency Plan (NCP) criteria.

Whereas, EPA and the Air Force have also made great progress in developing life cycle approaches for the remediation of contaminated sites which may be used to reduce the environmental impact of CERCLA cleanups nationwide, and

Whereas, EPA and the Air Force seek to collaborate to develop a process that can serve as a national model to use GSR to achieve these federal mandates:

- EO 13423: Strengthening Federal Environmental, Energy, and Transportation Management
- EO 13514: Federal leadership in Environmental, Energy and Economic Performance

THEREFORE, the representatives of the Air Force and the EPA agree to collaborate and leverage their resources and technical expertise to support and expand GSR practices at the Air Force facilities within the Region and reduce the negative environmental/ecological impacts of our cleanup actions while continuing to comply with the NCP. Specifically, the signers agree to the following objectives:

1. By October 15, 2011, meet and identify one or two Air Force CERCLA sites (i.e., an Operating Unit or installation or remedy) to participate in a pilot study where the EPA Region 9 footprint analysis tool and Air Force SRT will be conducted for comparison. The parties will define how this pilot study analysis will be conducted.
2. By March 15, 2012, report on the pilot study findings and jointly make recommendations for follow up action. These recommendations should include developing a strategy for how to apply the pilot study findings to other appropriate Air Force CERCLA sites in the Region. This strategy should address (a) the use of life cycle analyses approaches for remedial alternatives in future Feasibility Studies; (b) green remediation practices, such as water reuse, soil consolidation, alternative energy sources, and optimization of pump and treat remedies in RD/RA work; and/or (c) a process (i.e., optimization or five year reviews) to periodically evaluate existing remedial actions and/or technologies that could reduce the environmental/ecological footprint and improve the environmental benefits of our CERCLA cleanups.

Each facility will work with the installation project management team to identify and employ practices that best suit its operations and clean-up activities, using site-specific information and targeting base-specific operations, factoring in timely responses, and utilizing all CERCLA evaluation criteria to allow implementation of best available technology and other relevant considerations.

The signers agree to evaluate the effectiveness of the GSR practices implementation efforts. Information on GSR implementation will be provided at quarterly and annual EPA and Air Force meetings and shared on their respective web sites. The signatories will continue partnerships with States and other Federal agencies.

Beyond the scope of the pilot projects, all future undertakings under this MOU will be subject to the availability of appropriated funds.

Date: 28 Sep 11

Mr. Timothy K. Bridges, SES
Deputy Assistant Secretary of the Air Force
(Environment, Safety & Occupational Health)

Date: 8/23/2011

Ms. Jane Diamond, SES
Superfund Division Director
U.S. Environmental Protection Agency, Region 9

Appendix B

SITE FT005 REPORT

SRT and SEFA Comparison for

GSR Evaluations for

Site FT005, Travis AFB

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September 2012

Appendix B Table of Contents

List of Tables

List of Figures

List of Acronyms

AF	Air Force
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
CO2e	carbon dioxide equivalent
EPA	Environmental Protection Agency
GSR	Green and Sustainable Remediation
IRP	Installation Restoration Program
ISCO	*in situ* Chemical Oxidation
HAPs	hazardous air pollutants
lbs.	pounds
LTM	Long-term Monitoring
MG	Millions of gallons
MMBtu	Million Metric British Thermal Units
MNA	Monitored Natural Attenuation
MOU	Memorandum of Understanding
NEWIOU	North/East/West Industrial Operable Unit
NOx	Nitrogen Oxide Emissions
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	polychlorinated biphenyls
PM_{10}	Particulate Matter
PRB	Permeable Reactive Barrier
RACER	Remedial Action Cost Engineering and Requirements
ROD	Record of Decisions
SEFA	Spreadsheets for Environmental Footprint Analysis
SOx	Sulfur Oxide Emissions
SRT	Sustainable Remediation Tool
TPH	Total Petroleum Hydrocarbons

SITE FT005 REPORT

SRT and SEFA Comparison for GSR Evaluations

1.0 Introduction

This Appendix presents the technical aspects of a pilot study comparing two footprinting tools: the Sustainable Remediation Tool (SRT) and U.S. Environmental Protection Agency's (EPA) Spreadsheets for Environmental Footprint Analysis (SEFA). The cleanup site is FT005, which is an Installation Restoration Program (IRP) site at Travis Air Force Base (AFB). Historically it was used as a Fire Training Area and the primary contaminants of concern include Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (TPH), polychlorinated biphenyls (PCBs), and Dioxin. Per the 2006 North/East/West Industrial Operable Unit (NEWIOU) Record of Decision (ROD), the remediation strategy chosen for the site is excavation of soils to industrial cleanup standards (Travis AFB, 2006). Figure 1 on the following page shows the excavations conducted at FT005.

1.1 Technical team

The technical team that conducted the pilot study consisted of the EPA and AF technical leads and the two contractors supporting them. Capacity building and technology transfer sessions were conducted to facilitate an open and free exchange of knowledge. The team met on four occasions, about two hours each, and made good progress in understanding capabilities and limitation of each tool.

1.2 Why this study?

Over a hundred different tools can be used to evaluate the environmental footprint of a cleanup site, most address primarily the carbon dioxide equivalent (CO_2e) footprint. The AF has been using SRT since 2009 with most of the tool users working in isolation. The EPA's SEFA was made available in April 2012. One of the goals of the MOU was to clearly understand the differences between the SRT and SEFA tools, and determine their advantages and disadvantages.

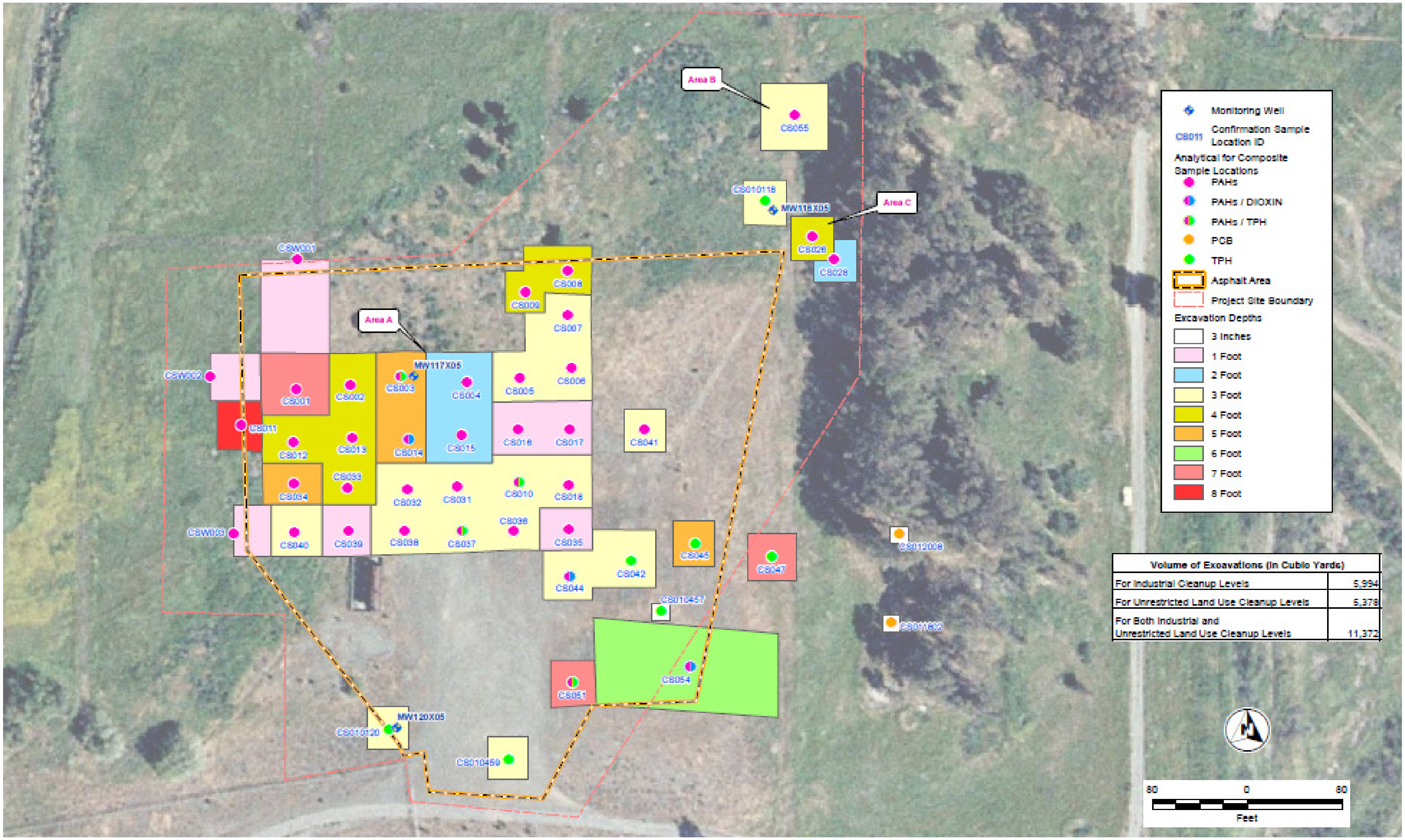


Figure 1: Excavations conducted at FT005.

1.3 What is expected out of this pilot study?

The purpose of this pilot study is two-fold: 1) to understand the tools, their application, extent, and relevance in real site conditions, and 2) to recommend how the tools may be used in future site evaluations, especially in the context of AF sites in Region 9. The main MOU report provides additional and detailed notes about how the comparison at FT005 fits into the purpose of the MOU as a whole.

For the purposes of this pilot study the tools were evaluated to determine the following:

- The strengths and weaknesses of each tool
- How rigid or flexible the tools are in changing default values such as
  - Intermediate assumptions
  - Conversion factors
- The types of input data required
- The level of difficulty in learning and applying the tools
- Specific situations where the tools can be better used.

1.4 Site FT005 selection

After considering several sites at AF facilities in Region 9, the Fire Training area (site FT005) at Travis AFB was selected as the pilot site to compare SRT and SEFA. Site FT005 is a soil remediation site where extensive excavation was conducted to address contamination in the soil. SRT and SEFA were tested on the single soil remediation technology, and the conclusions drawn from the comparison may be limited to this or similar technologies. Broader conclusions are noted in this report wherever possible.

The soil remediation at FT005 was nearly complete at the time that this pilot study was conducted. Therefore, the results of this pilot study did not have effects on remedial decisions at FT005. Excavation is nearly 90 percent completed, with a portion of the cleanup still remaining for dioxin and PAHs to residential cleanup levels. This is expected to be addressed with another limited excavation to follow. (Please see Attachment B -- The Last Scoop).

2.0 Description of SRT and SEFA

The two tools compared in this pilot study, SRT and SEFA, use Microsoft Excel as the platform; however, basic characteristics of these two tools are very different. Histories of development, approaches on which they were based, strategies used to develop the tools, and their purpose and application are different.

2.1 SRT

The Sustainable Remediation, or SRT, was developed by the Air Force Center for Engineering and the Environment (AFCEE) and its partners in 2008, as a simple solution to remedy the lack of any sustainability assessment tools within the Air Force Environmental Restoration Program. Versions were released in May 2009 and May 2010, and the latest version, released in January 2012, includes an input interface with the AF's RACER costing tool.

SRT was developed to serve two general purposes: 1) planning for future implementation of remediation technologies at a particular site, and 2) a means to evaluate optimization of remediation technology systems already in place or to compare remediation approaches based on sustainability metrics. SRT allows users to estimate sustainability metrics for specific cleanup technologies. The following technologies are included in the SRT:

- Excavation
- Soil Vapor Extraction
- Thermal Treatment Technologies
- Pump and Treat
- Enhanced In Situ Bioremediation
- In Situ Chemical Oxidation (ISCO)
- Permeable Reactive Barrier (PRB)
- Long-term Monitoring (LTM) / Monitored Natural Attenuation (MNA)

The sustainability metrics calculated for the technologies above include the following:

- Carbon Dioxide Equivalents Emissions

- Nitrogen Oxide Emissions
- Sulfur Oxide Emissions
- PM_{10}
- Total Energy Consumed
- Change in Resource Service
- Technology Cost
- Safety/Accident Risk

Certain elements of the SRT are unique to the tool. For example, the tool offers a choice between a Tier 1 and Tier 2 approach, based on the information available about a site and the complexity needed in the evaluation of the green and sustainable remediation (GSR) metrics. Both Tier 1 and 2 are based on user-entered values regarding the site and the clean-up effort, but Tier 2 requires more detailed inputs than Tier 1. In addition, Tier 2 allows the user to modify many of the general assumptions made in the analysis, whereas Tier 1 does not allow modification of assumptions. In general, Tier 1 takes about 1-2 hours to run whereas Tier 2 could take up to 1-2 days of effort.

The tool is intuitive and leads the user through a series of input worksheets for general site information and specific information related to the cleanup technology. In addition to the output parameters noted above, the tool provides a roundtable approach to weigh the results and recommend consensus for interpretation of the results. This is designed to aid the user in making remediation related decisions. Figure 2 is a schematic of the overall SRT process. The first part of the schematic shows the user's choice of a Tier 1 or Tier 2 analysis. The second part of the schematic shows the different remedial technologies available for soil and groundwater media and the third part shows how the output metrics are presented.

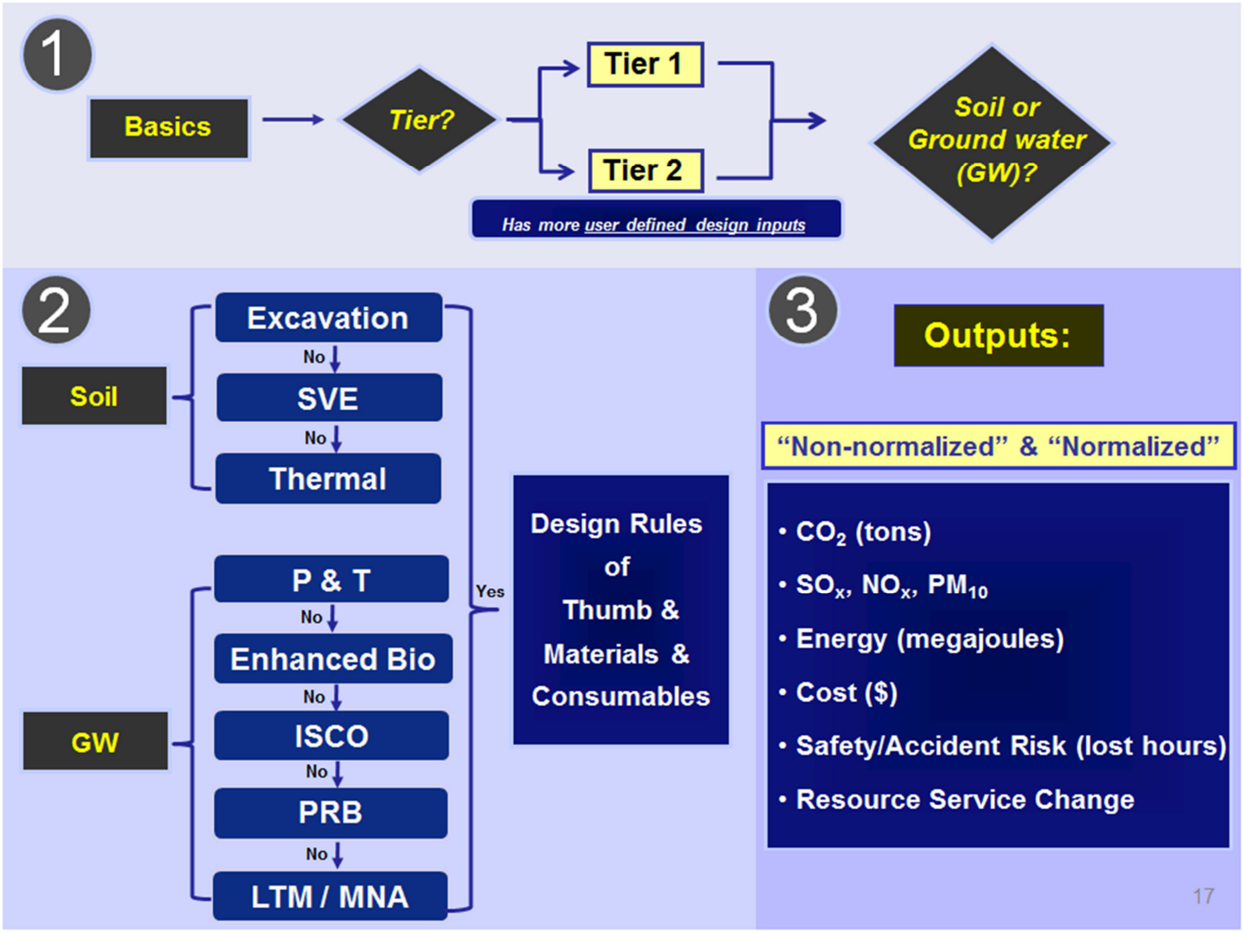


Figure 2. Schematic representation of SRT process highlights.

2.2 SEFA

SEFA, or Spreadsheets for Environmental Footprint Analysis, was originally developed for internal use by EPA staff and contractors. It was used in earlier formats within EPA, and was made publicly available in its current format in 2012 for the benefit of other users. EPA is currently providing technical support for SEFA only for users within EPA. SEFA is designed to be compatible with the EPA's *Greener Cleanups Methodology for Understanding and Reducing a Project's Environmental Footprint* (US EPA, 2012),which in turn reflects EPA's five core elements for Green Remediation illustrated in Figure 3. (Note that the comparison of tools at FT005 uses a 2011 preliminary version of SEFA.)

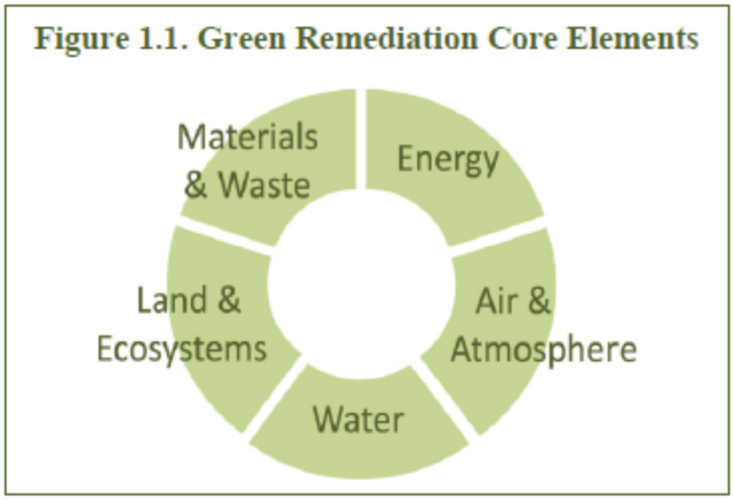


Figure 3. Green remediation core elements, as given in Figure 1.1 of the Methodology. (US EPA, 2012)

The *Methodology* is based on simple concepts of 1) establishing footprint parameters (metrics) and 2) establishing a straightforward process (methodology) for quantifying the metrics. Figure 4 shows the 15 to 20 metrics recommended in the *Methodology*, and evaluated in SEFA.

Table 2.1. Summary of Green Remediation Metrics

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

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

Figure 4. Metrics recommended in EPA's Footprinting Methodology, as given in Table 2.1 of the *Methodology* (USEPA, 2012)

The following seven-step process to quantify the metrics is presented in the *Methodology*. (USEPA, 2012)

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

Upon completion of Steps 1 and 2, the user inputs the information into SEFA to complete Steps 3, 4, and 5, and SEFA calculates the results for Step 7. The inputs, calculations, and outputs are accomplished in three interlinked workbooks entitled "Main," "Energy," and "Calculations". (Note that the Land and Ecosystems portion of the *Methodology* is described in qualitative terms only, and is not included as a metric in SEFA.)

The three workbooks in SEFA are linked as shown in Figure 5.

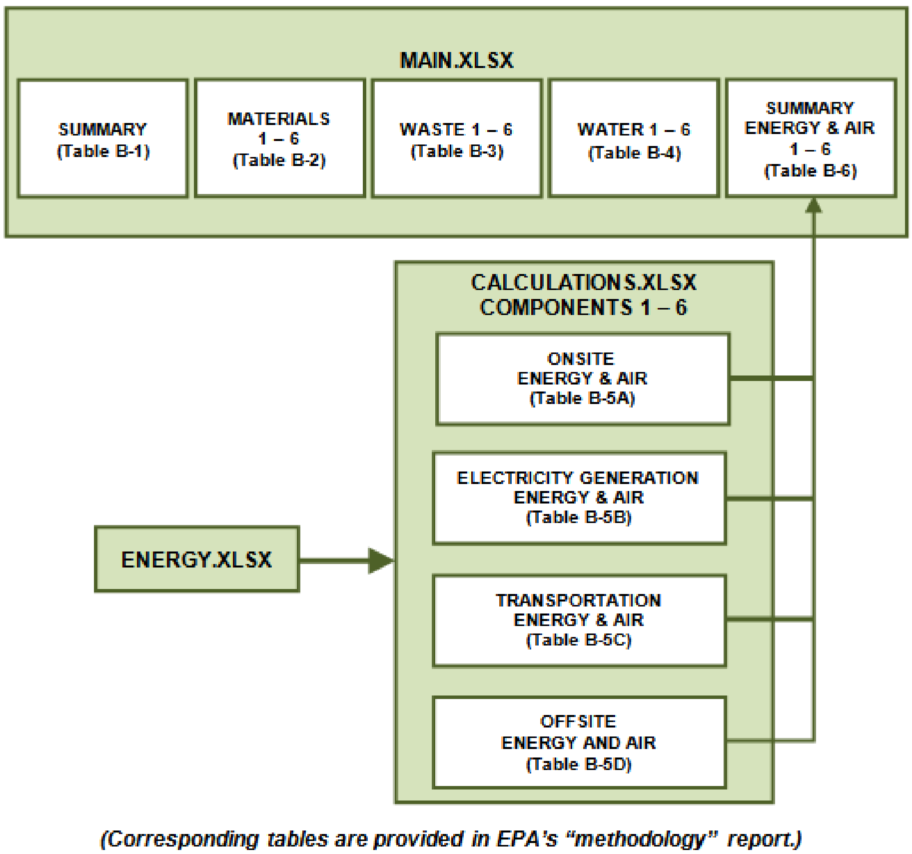


Figure 5. Relationship between the three workbooks in SEFA.

3.0 Tool Comparisons – Travis FT005

The technical team made the comparison of SRT and SEFA on three levels. First, a simple comparison was made regarding the basic metrics evaluated by each of the tools. Second, a comparison was made of the analytic mechanisms found in each of the tools.

Third, a comparison was made of the numerical outputs of the two tools, when applied to the test site FT005. These three levels of comparison are discussed below.

3.1 Comparison of Basic Metrics

The following table summarizes the metrics quantified in the two tools. Several of the metrics (CO2e, NOx, SOx, PM, and total energy) are similar; however, due to the different structure and purpose of each of the tools, there is a different emphasis on the remaining parameters. The SRT quantifies CO2e per pound of contaminant removed, technology cost, safety accident risk, and resource service, and SEFA does not. On the other hand, SEFA quantifies HAPs emissions, renewable energy used, water and materials used, and waste generated, and SRT does not.

Table 1: Comparison of metrics measured within SRT and SEFA.

Metrics	SRT	SEFA
CO_2e	√	√
CO2e per lb. of contaminant removed	√	
NO_x	√	√
SO_x	√	√
PM	√	√
HAPs		√
Total energy	√	√
Renewable energy		√
Water usage (on-site)		√
Materials usage (on-site)		√
Waste generation (on-site)		√
Technology cost	√	
Safety accident risk (accident risk, lost hours, insurance cost)	√	
Resource service	√	

3.2 Comparison of Analytical Mechanisms

The analytical equations used to calculate the metrics are similar in both SRT and SEFA, taking advantage of common engineering formulas. There are, however, differences in how the analytical mechanisms in each of the tools are organized and presented.

3.2.1 SRT

SRT is designed to compare the footprints of different remedy technologies at the same site. In order to run the SRT, data are input into the Mainscreen, InputSoil, and/or InputGW screens, respectively for soil and groundwater remediation. Then the worksheets for specific technologies are populated to get the Soil or Groundwater Output as needed. The input sequence is similar regardless of whether Tier 1 or Tier 2 is being used.

All the results are presented in a single table, with an option to present the metrics normalized on the basis of cost. This helps in recognizing and comparing the economic burdens for each technology.

The SRT User's Guide provides the details of each calculation that is performed on every worksheet. Assumptions and default values are provided, as well as appropriate references cited for each entry. The footprint conversion factors are taken from the Life Cycle Inventory database (NREL, 2009) based on standard business practices and are used to compute values as provided in the reference document for the tool: the User's Guide (AFCEE, 2011). A detailed description of the various factors and sources of reference are also provided in the Conversion Factors and Outputs Table of SRT User's Guide document.

3.2.2 SEFA

SEFA is designed in a flexible format to accommodate any remedy technology or any set of comparisons. In order to run SEFA, data are input into two workbooks (the Main and Energy workbooks). Calculations are made automatically in a third workbook (the Calculations workbook). To accommodate any remedy technology, SEFA is set up as a "blank template" in which the user enters data unique to the site and the remedy. To accommodate any set of comparisons, SEFA requires the user to set up unique analytic structures to reflect the comparisons of interest. For example, the user may set up the workbooks to compare several individual steps of a single remedy, or several design options for the same remedy.

Results are provided in tabular form, following the format of Table 2.1 of EPA's *Methodology*. Additional results highlighting specific areas of interest may be obtained by accessing intermediate summaries and calculation tables in the three workbooks.

Aside from a brief description in the Main workbook, there is no user's guide for SEFA. Information about calculations in SEFA is provided by viewing the spreadsheet cells for calculations of interest. Separate documentation of the analytic equations is not provided. SEFA provides documentation for default footprint conversion factors, and also allows the user to add footprint conversion factors specific to the site and remedy.

3.3 Comparison of Results and Alignment of Inputs and Default Assumptions

The comparison of the results of the two tools for Site FT005 was based on a simple approach. The tools were independently applied to FT005 using input data derived from supporting documents related to the remedy. Once the evaluations were completed, the technical team met and shared analyses and output metrics. To maintain consistency, the input parameters to each of the tools and the default assumption within the tools, were then compared and aligned where possible. The values of the output metrics were compared again and any remaining differences were noted and explained.

3.3.1 Method for Comparing Results

The comparison of the output metrics was relevant only for the five parameters common to the two tools (CO2e, NOx, SOx, PM, and total energy). At the first comparison, the technical team noted large differences in the results for these parameters. In order to keep the project manageable, the technical team focused on the CO2e metric, and identified the following top five contributors to this metric (in order of magnitude):

1. Off-site solid waste disposal
2. On-site diesel use
3. Transportation diesel use
4. Backfill material, and
5. Off-site laboratory analysis.

The team then tracked back through the calculations to the original inputs for each of these top five contributors to note where the calculations and inputs differed for the two tools. Where differences in inputs were noted, these were aligned so the inputs were similar or the same for the two tools. Where differences in default assumptions were noted, these were modified where possible. In some cases, differences in general analytic approach or structure of the tools were observed, but it was not possible to modify these differences, and so they were simply noted. After completing this step-by-step comparison, the technical team gained an understanding of the tools' workings, and was able to document the remaining differences in the outputs.

3.3.2 Following a Specific Comparison from Beginning to End: On-site Diesel Fuel

For purposes of brevity, this report provides a detailed description of the comparison process for only one of the five items noted above: on-site diesel fuel. The technical team noted that combustion of diesel fuel on-site was the second largest contributor to the CO2e footprint. The team also noted that the two tools provided a different result for this component: SRT calculated approximately 22,000 lbs. CO2e from combustion of diesel fuel on-site and SEFA calculated 47,000 lbs. CO2e. The technical team noted that the only contributor to on-site diesel fuel combustion was the equipment used during excavation of the contaminated soils.

There are three main factors required to estimate the CO2e emissions from on-site equipment, as illustrated in Figure 6.

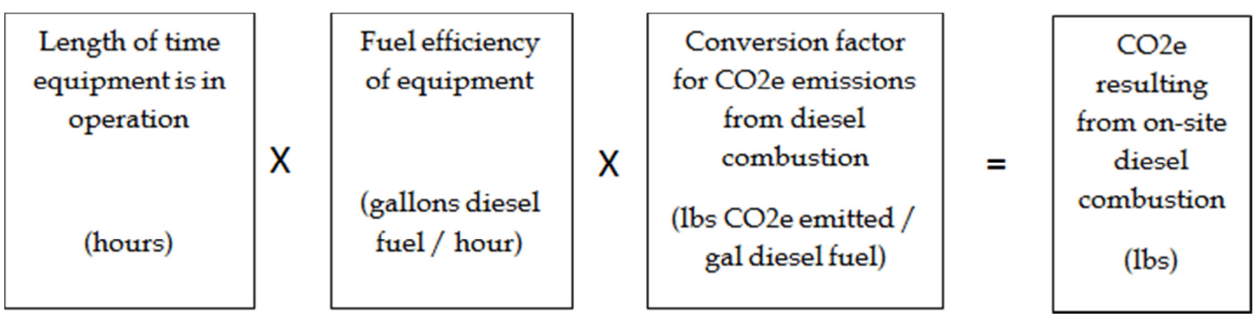


Figure 6. Example CO2e emissions from on-site diesel combustion.

The technical team discovered differences in all three factors, as noted in Table 2:

Table 2. Example preliminary comparison of metrics for CO2e evaluation

Factor	SRT Value	SEFA Value
(1) Length of time equipment is in operation	280 hours	320 hours
(2) Fuel efficiency of equipment	3 gal diesel fuel / hour	6.6 gal diesel fuel / hour
(3) Conversion factor for CO2e emissions from diesel combustion	25.8 lbs CO2e emitted / gal diesel fuel combusted	22.5 lbs CO2e emitted / gal diesel fuel combusted

The technical team considered alignment of these factors as follows:

- **Aligning Factor 1:** The technical team aligned the number of hours the on-site equipment was in operation. Although it would seem to be a simple matter to align this input, the structure of the two tools differs in terms of how this information is entered by the user. SRT asks the user to input the volume of soil to be excavated, and automatically calculates the equipment time required for that volume of excavation. SEFA is a "blank template" in which the user must independently determine the equipment time required for the excavation. Therefore, the technical team could align the inputs by either (a) aligning SRT with SEFA by altering the amount of soil to be excavated in SRT, or (b) aligning SEFA to SRT by altering the engineering assumptions made for equipment operation time required for the given amount of soil. An added complexity is that SRT accounts for only the excavator involved in the soil excavation, whereas the technical team modeled SEFA to include, in addition to the excavator, five types of support equipment, such as loaders for managing the excavated soil and water trucks for dust control. Therefore, the alignment SEFA with SRT would also include removing the additional five types of support equipment from the analysis. In order to align the equipment operation time, the technical team increased the amount of soil to be excavated in the SRT.

- **Aligning Factor 2:** The technical team aligned the fuel efficiency for the on-site equipment. Although both tools allow for altering the fuel efficiency of on-site equipment, this adjustment is more straightforward in SRT; therefore, the technical team changed the fuel efficiency in SRT from 3 gal/hr to 6.6 gal/hr.

- **Aligning Factor 3:** The technical team was not able to align the conversion factor for CO2e emissions from diesel combustion. Neither SRT nor SEFA allow the adjustment of this conversion factor. The conversion factors in both tools came from documented public sources. Conversion factors for fuel combustion may vary slightly from various different documented sources.

After alignment of Factors 1 and 2 above, the SRT calculated approximately 54,000 lbs CO2e from combustion of diesel fuel on-site and SEFA calculated 47,000 lbs CO2e. The alignment resulted in a large change in estimated CO2e emissions from the operation of equipment on-site, as noted in Table 3.

Table 3. Estimated CO2e emissions from the operation of equipment on-site (lbs.)

Tool	Before Alignment	After Alignment
SRT	22,000	54,000
SEFA	47,000	47,000
% difference	114%	-13%

As noted above, this is only one of several "alignments" that the technical team made to SRT and SEFA for the FT005 analysis. Other alignments were made as noted in Section 3.3.3 below, although for purposes of brevity the analytic and discussion process of the technical team is not described.

3.3.3 Additional Alignments of Inputs and Default Assumptions

Table 4 shows some of the alignments made to the inputs to SRT and SEFA for the FT005 analysis. The Table also notes where alignments may have been useful, but were not made due to the structure of the two tools or for other reasons.

Table 4. Additional alignments and non-aligned and differing parameters for comparison at FT005

Metric or Default Assumption	Inputs Aligned	Inputs not Aligned	Comment
Off-site waste management		√	Alignment was not attempted because off-site waste management is included in SEFA and not in SRT.
Off-site laboratory analysis		√	Alignment was not attempted because off-site laboratory analysis is included in SEFA and not in SRT.
Contaminated soil amounts		√	Alignment was not attempted because inputting format and structure differs for SRT and SEFA.

Metric or Default Assumption	Inputs Aligned	Inputs not Aligned	Comment
Number of trips for personnel vehicles	√		Inputs for number of trips differed significantly. Aligned the inputs to the two tools so that the number of trips is equivalent.
Fuel consumption rates for personnel vehicles	√		Default values are slightly different. Alignment achieved by changing the SRT default value.
Number of trips for truck transport	√		Inputs for number of trips differed significantly. Aligned the inputs to SRT so the number of trips is equivalent.
Fuel consumption rates for truck transportation	√		Default values are slightly different. Alignment achieved by changing the SRT default value.
Several conversion factors		√	SRT and SEFA have built in default values for several conversion factors that cannot be easily altered.

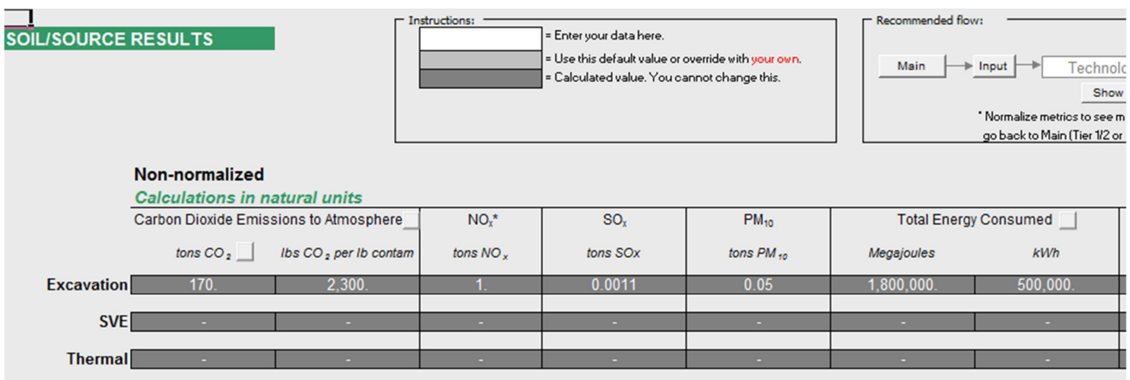
3.4 Comparison of Numerical Outputs

One of the most basic questions to ask when comparing the two tools is "how do the numerical outputs compare?" The comparison of the numerical results are provided in Table 5, and note that even after alignment, there are large differences in the results. The differences in emissions of CO2e, NOx, SOx, and PM, and the difference in total energy are due in large part to the exclusion of off-site waste management and off-site laboratory analysis from SRT, and the inclusion of these activities in SEFA.

Table 5. Comparison of actual metrics calculated for two tools

Metrics	SRT	SEFA
CO2e	170 tons	660 tons
NOx	2,000 lbs.	8,000 lbs.
SOx	2 lbs.	2,900 lbs.
PM	10 lbs.	8,700 lbs.
HAPs	X	50 lbs.
Total energy	1,704 MMBtu	8,600 MMBtu
Renewable energy	X	–
Water usage (on-site)	X	1,060 million gallons

Materials usage (on-site)	X	16,900 tons
Waste generation (on-site)	X	21,300 tons
Energy cost	$43,000	X
Technology cost	$1,400,000	X
Safety accident risk (accident risk, lost hours, insurance cost)	2.95 hours lost 0.061 injury risk	X
Resource service	Net Gain Economic $6,000 Ecologic $6.800	X



	Carbon Dioxide Emissions to Atmosphere		NO_x*	SO_x	PM_{10}	Total Energy Consumed	
	tons CO_2	lbs CO_2 per lb contam	tons NO_x	tons SOx	tons PM_{10}	Megajoules	kWh
Excavation	170.	2,300.	1.	0.0011	0.05	1,800,000.	500,000.
SVE	-	-	-	-	-	-	-
Thermal	-	-	-	-	-	-	-

Figure 7. Output metrics for the SRT

For the SEFA, the various sources that contributed to the overall CO_2e are shown in Figure 8. These are arranged per the different phases of actions conducted at Site FT005. This chart illustrates that the Excavation phase is the greatest contributor to greenhouse gas emissions from the FT005 remedy. This is due primarily to the on-site diesel usage and the management of the excavated soils at an off-site landfill. Note that this type of chart is not automatically produced by SRT, but may be created by the user through access to intermediate calculations and results.

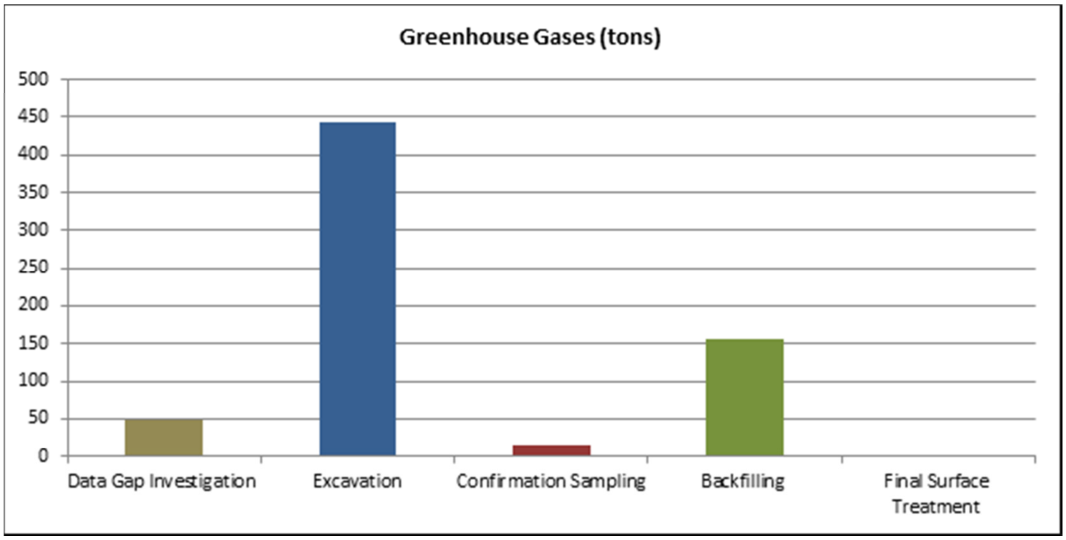


Figure 8. Comparison of the greenhouse gases estimated from the SEFA for each phase.

Also for SEFA, Figure 9 shows a comparison of greenhouse gas contributions presented according to a further breakdown of individual activities conducted, materials used, or off-site services that supported the site. Consistent with the notes above, this chart shows that the primary contributors to greenhouse gas emissions are on-site diesel usage and the management of the excavated soils at an off-site landfill. Also as noted above, this type of chart is not automatically produced by SRT, but may be created by the user through access to intermediate calculations and results.

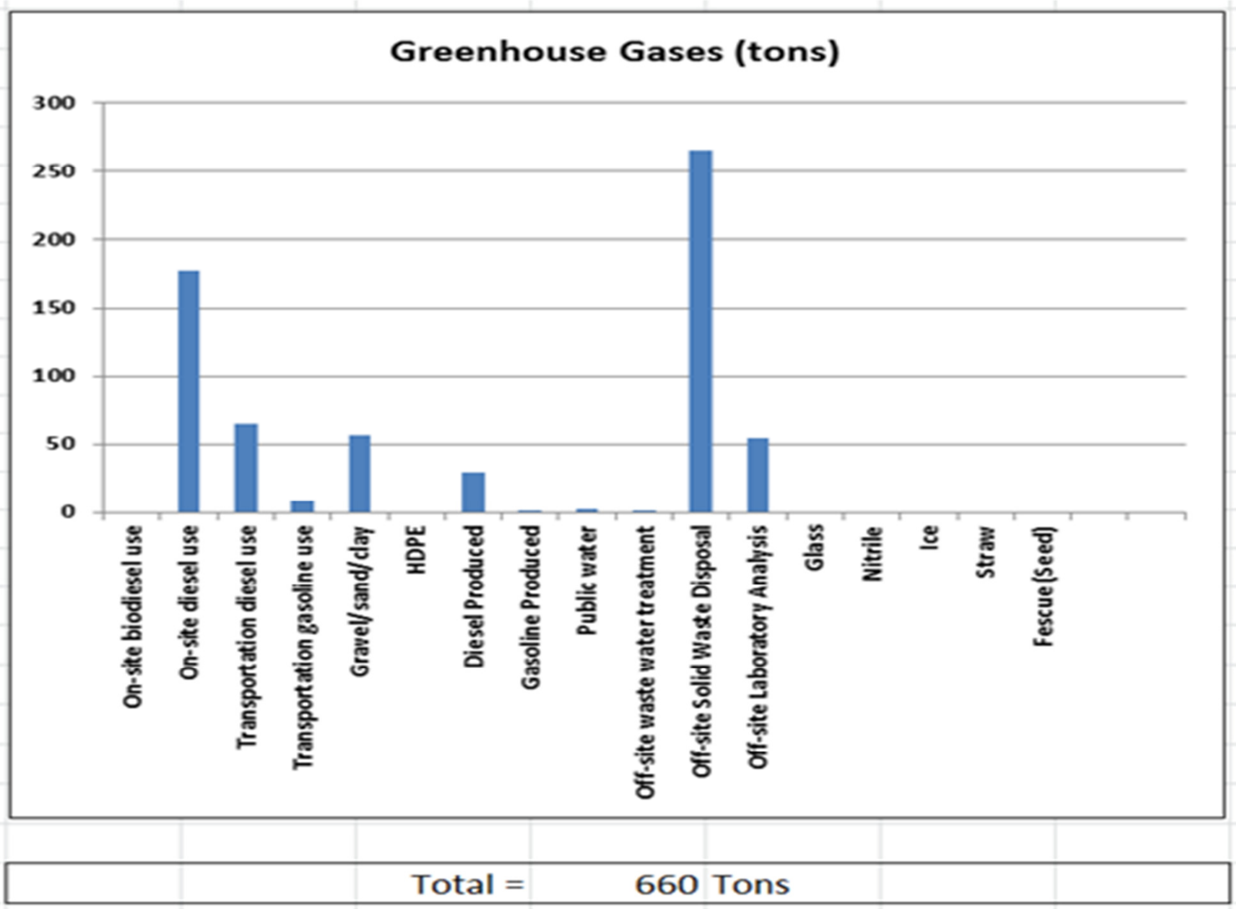


Figure 9. Further breakdown of greenhouse gas contributions from individual field activities performed at Site FT005 as evaluated by SEFA

4.0 Observations

As a result of the comparison project, the technical team gained valuable understanding of SRT and SEFA. From the simple test case of soil excavation and restoration at Site FT005, the team found that the two tools were effective in estimating the environmental footprint. Throughout the project, in addition to comparing the numerical results from the two tools, the team noted the similarities and differences between the metrics provided by the two tools, and observed the strengths and weaknesses of structure and functioning of each tool. These observations are noted below.

4.1 Observations Regarding the Metrics

As noted in Table 1, the SRT and SEFA have five metrics in common. These are metrics for air emissions and energy usage. Besides these common metrics, the SRT emphasizes sustainability-related metrics whereas SEFA does not. On the other hand, besides the common metrics, SEFA emphasizes materials, waste, and water metrics, whereas the SRT does not. One reason for the difference in metrics in the two tools is that SEFA was designed to reflect the core elements of EPA's *Environmental Footprinting Methodology*, while SRT, which was built several years before the *Methodology* was issued, was designed to reflect sustainability parameters outside a typical environmental footprint analysis. Other differences are that the SRT provides a metric for greenhouse gas emissions per pound of contaminant removed, while SEFA provides metrics for renewable energy used. In determining which tool to apply to a site for footprinting, the user should first determine which metrics would be the most useful at the site.

4.2 Observations Regarding the Numerical Outputs

Numerical observations pertaining to the FT005 site are noted below. These are followed by generalizations where appropriate. Since comparisons will be different for different cleanup technologies and different site configurations, it is difficult to extend the specific numerical observations to other technologies and sites, and care should be taken in interpreting the specific results.

4.2.1 Total Footprint Metrics

After alignment of inputs and assumptions, SEFA provided results for CO2e, NOx, SOx, PM, and total energy that were higher than SRT's results by a factor of 4 to 1,000, depending on the metric (see Table 2). The majority of the difference can be attributed to the fact that SEFA included the footprint from off-site waste management and off-site laboratory analyses in its calculations, while SRT did not.

A few general observations may be made regarding total footprint metrics:

- → Based on a test case at one site, it is not possible to determine whether, on average, one tool will give higher or lower results than the other tool for any one metric. The results from each tool depend on several factors and intermediate steps within the tools, and the level of detail desired in the analysis. The results also depend on site-specific factors such as location, site configuration, and remedial technology.

- → In a footprint analysis at a different site and cleanup technology (for example, in which off-site waste management and off-site laboratory analyses are not major components), the difference in the numerical results between SRT and SEFA may be expected to be smaller than it was for FT005. However, the difference could also be larger, since there may be other factors unique to another site or technology that would cause other differences. Without testing multiple technologies at different sites, it is not possible to determine how much the numerical results from the two tools may typically differ from one another.

→ Examples of differences in numerical results between SRT and SEFA that may be encountered for other sites or technologies include the following:

  - If the site is located at great distance from sources of materials or locations for waste disposal, then the differences in fuel efficiencies assumed by each of the tools may become an important factor for differences in the numerical results.

  - If the site has high electricity use, then the assumptions made in each of the tools regarding the power mix for grid electricity may become an important factor for differences in the numerical results.

→ The technical team put a great deal of effort into "aligning" the inputs and assumptions for the two tools. It is not expected that a typical user would run both tools on a single site and scrutinize the inputs, assumptions, and calculations in the way that the technical team did. Therefore, many of the adjustments made by the technical team as a part of this project (and especially those made to assumptions intrinsic to the tools), would not likely be made by the typical user. As a result, during footprinting, the typical user would likely obtain the preliminary (pre-adjustment) results from whichever tool is used, rather than refined (post-adjustment) results. Also note that the adjustments made to align the inputs of the two tools were made in Tier 2 of SRT. These adjustments are not possible in Tier 1, which many users may apply to their sites because of its ease of use.

→ In many cases, particularly when comparing technologies during the remedy selection stage or remedy optimization stage, the objective of conducting an environmental footprint analysis is to compare the remedial technologies with each other at the same site. In such cases, the relative difference between the SRT outputs and the SEFA outputs would not be of primary importance. Rather, the relative difference in footprint values between technologies using the same tool is more important, as it would help us in identifying a greener technology (all other requirements being equal).

4.2.2 Key Contributors

The two tools identified the key contributors to the footprint differently for Site FT005, and so the user might be directed toward different actions to reduce the footprint, depending on which tool is used. SEFA identified off-site waste management and on-site diesel use as the greatest contributors to the CO2e footprint. SRT does not include off-site waste management in its footprint calculations, and so identified on-site diesel usage as the key contributor to the CO2e footprint at FT005. Transportation diesel usage and provision of backfill material are considered secondary contributors by both SRT and SEFA. Finally, off-site laboratory analysis is also considered a secondary contributor in the SEFA analysis, but is not included in the SRT analysis.

Based on the key contributors identified by the two tools, the user might proceed differently with efforts for footprint reduction. If using the results from SEFA, the user might make a greater effort to reduce the amount of soil sent off-site for disposal. If using the results from SRT, the user might make a greater effort to find a disposal site closer for the same amount of excavated soil.

A few general observations may be made regarding key contributors:

- → Because each clean-up site is unique, key contributors will likely be unique for each individual cleanup technology and site configuration. For example, at a site with high electricity usage and a small amount off-site waste disposal, the footprint from electricity production may be the key contributor, while off-site waste management may be a minimal contributor. The user of SRT and SEFA should not take the footprinting results from one site as a guide for the expected results at other sites with different technologies and configurations.

- → At some sites, SRT and SEFA may provide differing sets of key contributors, as they did for Site FT005; however, SRT and SEFA may provide the same sets of key contributors at other sites. This will depend on the remedy technology and the site configuration. In the former case, the user may pursue different footprint reduction strategies, depending on which tool is being used for the footprint analysis. In the latter case, the user may reduce the footprint in the same way regardless of which tool is being used. In general all reductions to the footprint are advantageous, regardless of whether the reduction is to a "key contributor" or to a "secondary contributor." The main advantage to identifying the key contributors is to understand which contributors may allow for the greatest reductions for the least investment in time and resources.

4.3 Observations Regarding the Structure and Functioning of Each Tool

The analytic structure and functioning of each tool is described in Section 3.2. Differences in approach to the footprinting task between SRT and SEFA results in different strengths and weaknesses for each tool. An overarching observation is that SRT is designed to model specific technologies and situations, and requires less effort in inputting site data. SEFA, however, is designed to be flexible to accommodate any remedy technology and site configuration, and requires more user effort in inputting site data. In determining which tool to apply to a site for footprinting, the user should first determine which strengths would be the most advantageous at the site, and which weaknesses are irrelevant or can be accommodated in other ways. A set of observations on the structure and function of the two tools is provided below, noting strengths and weakness of each tool.

4.3.1 Basic Function, Time Commitment, and Cost

Both SRT and SEFA can model a single remedy or compare remedies. SRT presents and compares metrics for each technology, whereas SEFA requires additional compilation of the results to compare technologies.

There is a short learning curve for using SRT, and once learned, the footprinting at each additional site may be conducted quickly. There is a fairly steep learning curve for using SEFA, and once learned, the footprinting at each additional site may be time-intensive, depending on the complexity of the site and the level of detail desired. Running SRT for FT005, including data input and analysis, took about an hour for Tier 1 and about eight hours for Tier 2. Running SEFA for FT005 took about 20 hours for data input and analysis.

Both tools are free to the public and available on-line. The cost associated with conducting a footprint analysis in SRT is likely to be much less than that for SEFA, depending on the level of detail desired by the user.

4.3.2 Ease of Use versus Flexibility

The SRT is set up in modular fashion with a user-friendly interface. The user is led through input screens and asked to input general and specific parameters regarding the site and cleanup technology. Structures for making technology comparisons are hard-wired into the tool. SRT can evaluate eight remedy technologies (chosen because they are commonly applied at Air Force installations) in two media (soil and groundwater). This will likely cover a large portion of current and upcoming remedies at cleanup sites; however, any remedy technology that is not already included in the SRT, or any unusual site configuration, will be difficult or impossible to model.

SEFA is set up in "blank slate" fashion with input worksheets the user arranges and fills out uniquely for the remedy technology and site configuration at hand. The user may model both common remedy technologies and new and innovative technologies, in any media, and for any site configuration. The user may also set up the worksheets to make any set of comparisons that may be of interest at the site.

4.3.3 Data Required

SRT is run on a limited number of input parameters from a site, with more input parameters required for Tier 2 than for Tier 1. In addition, the same type of information is requested of the user for each remedy technology, regardless of the site being footprinted. For example, for soil excavation, information on the volume of soil to be excavated and the soil type are requested for any site that is being evaluated by SRT.

SEFA typically requires more specific information from the site. For example, for an excavation remedy, the user must obtain information such as types of equipment used and number of hours each piece of equipment is operated. However, depending on the situation at hand and the interests of the user, SEFA can also be run on sparse data. For example, if the user's primary interest in the excavation remedy is the footprint from transporting the excavated soil, then SEFA can quickly and easily be set up to model only that portion of the remedy.

4.3.4 Assumptions Made in the Tools

In SRT, many assumptions are contained within the tool regarding the parameters for the clean-up remedy. For example, for excavation, SRT makes assumptions on what type of equipment will be used and how long that equipment will operate for a given volume of soil. Although these assumptions are clearly documented in the User's Guide, the typical user may not access the guide to ensure that the assumptions are appropriate for the site at hand. If the assumptions are not appropriate, this may lead to inaccuracies in the results. On the other hand, if the assumptions made within SRT closely track the remedy technology and site configuration, then the results may be accurate.

Very few assumptions are made in SEFA regarding the parameters for the clean-up remedy. Instead, the user makes the majority of assumptions explicitly, based on professional judgment. For example, for excavation, if information such as type of equipment and length of operation is not available from site records, the user must make assumptions for these inputs. The user, in making these assumptions, has the opportunity to more accurately represent the site at hand. However, there is the possibility of errors in professional judgment, which may lead to inaccuracies in the results.

4.3.5 User Over-riding Assumptions in the Tools

Both SRT and SEFA allow for over-riding assumptions and default parameters, but in different ways. For example, SRT allows for easy override of fuel efficiency of vehicles, while SEFA allows for input of new vehicle type and specification of its fuel efficiency. As another example, SRT allows data entry for increased CO2e emissions to adjust for specific conversion factors, while SEFA allows for inputs of specific conversion factors to replace default conversion factors.

SRT overrides are indicated with red font for ease of tracking and SEFA overrides are tracked in drop-down menus and new lines of inputs. For both SRT and SEFA, overrides on some of default values may result in unintended consequences for unrelated calculations, especially if the structures of the tools are not clearly understood by the user.

4.3.6 Inclusion of Off-site Activities

SRT includes in the remedy footprint certain off-site activities, such as manufacture of common remediation materials, production of fuels, and generation of grid electricity. SEFA includes a number of off-site activities in addition to those noted above, such as off-site waste management and off-site laboratory analysis. SEFA also allows the user to include additional activities and materials not already in the tool. For a remedy and site with off-site activities not already in the tool, SRT may not provide an accurate footprint. For the same site, SEFA may provide a more accurate footprint, if the user augments the tool with the missing activities.

4.3.7 Designation of Footprint Conversion Factors

Both SRT and SEFA supply default footprint conversion factors for the user. Neither SRT nor SEFA allows the user to change the default values. In both cases, the footprint conversion factors are generalized averages (either U.S. or European), and may not always be accurate for the situation at hand. However, SEFA allows the user to add new materials, fuels, or activities and provide unique conversion factors for those items. Of course, adding a new item with its conversion factors requires the user to invest extra effort in researching and documenting the information being added. For a remedy and site that is not well-represented by default conversion factors, SRT may not provide an accurate footprint. For the same site, SEFA may provide a more accurate footprint if the user independently provides the more representative conversion factors.

4.3.8 Access to Intermediate Calculations and Results

In some cases, it will be useful for the user during footprinting and reporting to have access to intermediate calculations and results. Studying intermediate results can help the user understand the individual contributors to the footprint and focus on how best to reduce the footprint. Both SRT and SEFA allow access to intermediate calculations, although SRT to a lesser degree than SEFA.

SRT calculates the overall metrics by summing individual contributors, but the intermediate calculations are made in the background, in worksheets not accessible to the user. SEFA also calculates overall metrics by summing individual contributors, with the intermediate calculations and results contained in worksheets that are accessible to the user. Therefore, the user may not be able to fully understand the contributors to the footprint in SRT, but is able to in SEFA. At the same time, care is required in correctly locating and summing the intermediate results in SEFA.

4.3.9 Likelihood of User Error

Both SRT and SEFA may be subject to user error, but in different ways. SRT makes several assumptions in the model construction that protects the user from error in judgment regarding assumptions, but the user may not always be aware of the assumptions, and may run SRT on a site or remedy for which SRT is not well suited. SEFA, on the other hand, makes fewer assumptions, requiring the user to make those assumptions independently. This may lead to user error if the assumptions are not well-founded or are not suitable for the site at hand.

4.3.10 Format and Presentation of Outputs

SRT also provides a "Stakeholder Roundtable" function in which metrics are given weights leading to a single rating that combines all metrics and allows comparison between remedy technologies. However, the "Stakeholder Roundtable" format may lead to over-simplification of the results, and care should be used in interpreting outputs in that format.

In SEFA, outputs are provided in tabular format. Graphs and charts are not included in SEFA's outputs, but can be developed by the user with additional effort and time. SEFA does not provide a single rating combining all metrics. Care should be used in interpreting the individual outputs and balancing one against the other.

4.3.11 Footprinting at Any Stage of the Remedy

Both SRT and SEFA can be applied at any stage of the remediation process. This is because both tools may be used to compare remedy alternatives, compare different designs for a single remedy alternative, or estimate the footprint of an operating remedy. Choosing one of the tools over the other will likely not be dependent on the stage of the clean-up remedy, but more likely on other considerations noted above, such as the level of detail desired, the amount of time and effort to be invested, and the accuracy the tool is expected to provide. However, in either case, it is important to continue with one tool throughout the life-cycle of a project to maintain consistency in decision-making and tracking of improvements.

4.3.12 Additional Features

Each tool has additional features that are not available in the other tool. These are noted below.

The SRT has the following features. (a) For both energy and CO2e calculations, three different scenarios can be considered for Net Present Value estimates: with a steady business model, a Bank of America model that is steady at a higher value, or an exponential scenario that has the same annual change for several years. (b) Project-specific items can be added to the CO2e footprint, if the user independently estimates the CO2e footprint for those items. (c) Default values that are overridden by the user are color-coded in red. This is a very useful formatting feature that helps the user remain aware of assumptions that have been modified during the footprint analysis.

SEFA has the following features. (a) Template formats are provided for individualized inputs related to landfill gas combustion, electrical equipment usage, power mixes for local grid electricity, and usage of renewable energy. (b) Formats are also provided for unique sources or sinks of greenhouse gas emissions (such as uptake and storage of CO2 by trees) and other sources of other air emissions (such as direct off-gassing of soil contaminants).

4.4 Overview of Tool Comparisons

The following comparison table provides a short-hand overview of the comparison of the tools discussed in Sections 4.1 through 4.3.

Table 6. General Comparison of SRT and SEFA Tools

SRT	SEFA
Quick learning curve.	Longer learning curve.
User-friendly interface not requiring familiarity with Excel worksheets.	Requires familiarity with Excel worksheets.
Once user is familiar with SRT, can complete footprinting at each site more quickly than SEFA.	Once user is familiar with SEFA, takes longer to complete footprinting at each site, compared with SRT.
Remediation technology-based tool. Pre-configured with eight common technologies.	Remediation activity-based tool. "Blank slate" for any remedial technology.
Cannot easily be applied to technologies not already present in the tool.	Can be used to model any remedy technology.
Focuses on soil and groundwater media.	Can be applied to any medium.
Requires basic understanding of site-specific parameters.	Requires more detailed understanding of site-specific parameters.
User's Guide details all the equations used and assumptions made.	No User's Guide. Equations can be viewed in the worksheet cells. Some assumptions are documented in notes in the worksheets.
Many assumptions are made within the tool. User makes few assumptions explicitly.	Few assumptions are made within the tool. User makes most of the assumptions explicitly.
Many of the default assumptions can be over-ridden.	Difficult to override default assumptions directly. May override indirectly by inputting the data in different ways.
Conversion factors are provided for a limited number of clean-up parameters.	Conversion factors are provided for a limited number of clean-up parameters.
Does not allow for addition of conversion factors.	Ability to add conversion factors for clean-up parameters not already included in tool.
Designed to compare multiple remedies, but a single remedy can be modeled.	Designed to model a single remedy, but multiple remedies can be compared.

SRT	SEFA
Graphs and charts are not included in SRT's outputs but can be developed by the user with additional effort as needed.	Graphs and charts are not included in SEFA's outputs, but can be developed by the user with additional effort and time.
Both SRT and SEFA can model remedy footprints at any stage of the remediation process: 1) during remedy evaluation or design (when it is common to have incomplete or general remedy information), and 2) during remedy operation or optimization (when it is common to have fully detailed remedy information)	

5.0 Summary

The main message that comes clearly out of the comparison of SRT and SEFA, using Site FT005 as a test site, is that neither SRT nor SEFA is definitively better than the other. At any given site, one tool may be preferred to the other, depending on site-specific considerations. An overview of situations in which one tool might be preferred over the other is shown in Figure 10.

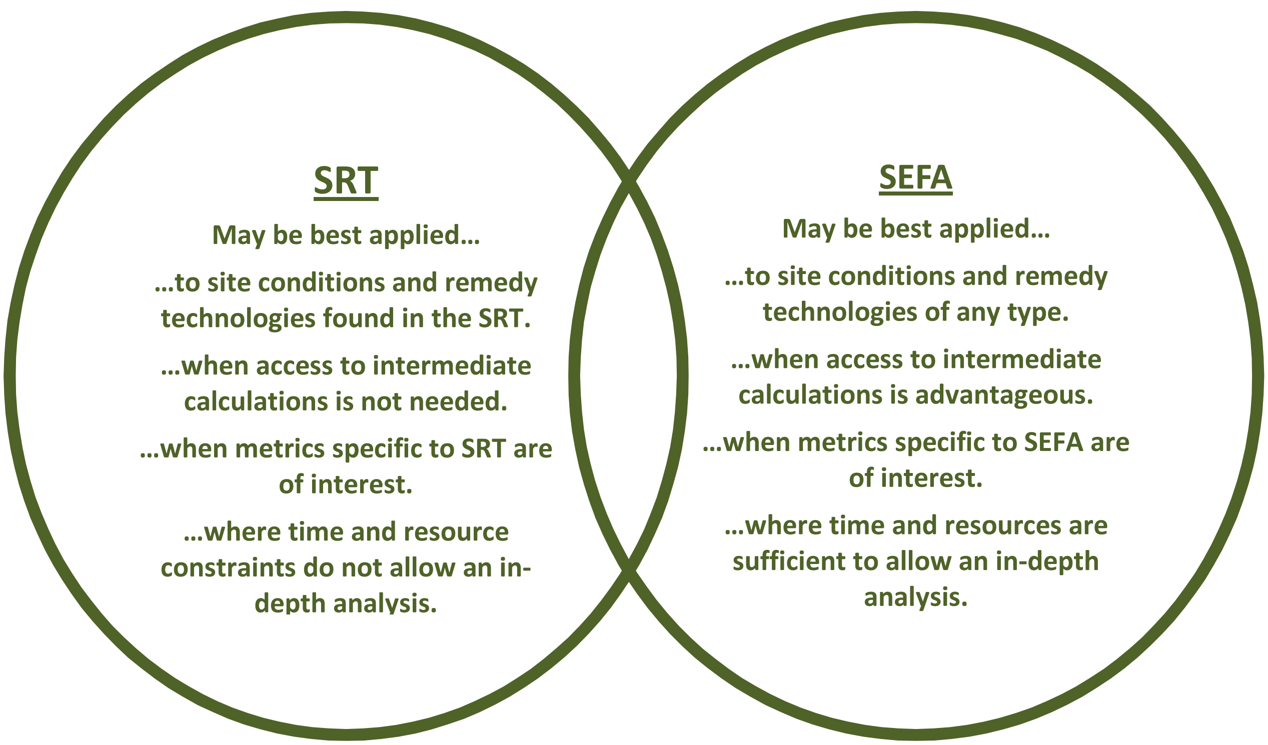


Figure 10. Summary of Comparisons for SRT and SEFA

Both SRT and SEFA may be used during any stage of a remedy. Choosing one of the tools over the other will likely be dependent on the considerations noted in the graphic above, rather than the remedy stage.

For evaluating a variety of technologies, the SRT may be best suited, assuming all the technologies are represented in the tool. SEFA may be better suited for in-depth analysis for a single technology, and for any innovative or unusual remedy technology.

For simple and quick calculations with limited site information, SRT may be best suited. SEFA may also be applied to sites with limited information, but is designed to accommodate more detailed levels of information, and allows access to intermediate calculations.

The metrics of interest at a site will also be important, and the amount of time and resources available to conduct the footprint analysis will be a consideration, in choosing one tool over the other.

An overarching observation is that the original intended purposes of the tools were different, leading to different structures and different strengths. The original purpose of SRT was to compare technologies at remedy selection and optimization stages, while SEFA was developed to conduct footprint analyses based on the EPA methodology.

Both SRT and SEFA can benefit from further improvements. For example, SRT could be updated to reflect all the elements of EPA's *Footprinting Methodology*. Additional remediation technologies can be added to enhance the usability of the SRT to technologies not currently captured within SRT. In addition, adding a wider variety of user inputs to accommodate greater variation in remedy technologies and site configurations would make the tool more robust. SEFA could be improved by providing a tutorial to assist first-time users, by allowing users to override the remaining default assumptions, and by presenting outputs in graphical format in addition to the current tabular format.

Although improvements would be valuable, each tool is currently being used at active clean-up sites. With certain precautions in data entry and interpretation of the results, both SRT and SEFA are useful for conducting footprint analyses and promoting greener clean-ups.

References:

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USEPA 2012b. SEFA at http://clu-in.org/greenremediation/methodology/index.cfm

Attachment A: Example Input and Output Metrics for the Two Tools

The following screen shots are provided to illustrate some of the features of the SRT and SEFA discussed in the main text.

The input parameters for SRT are shown in Figures A-1 and the intermediate steps in Figure A-2.

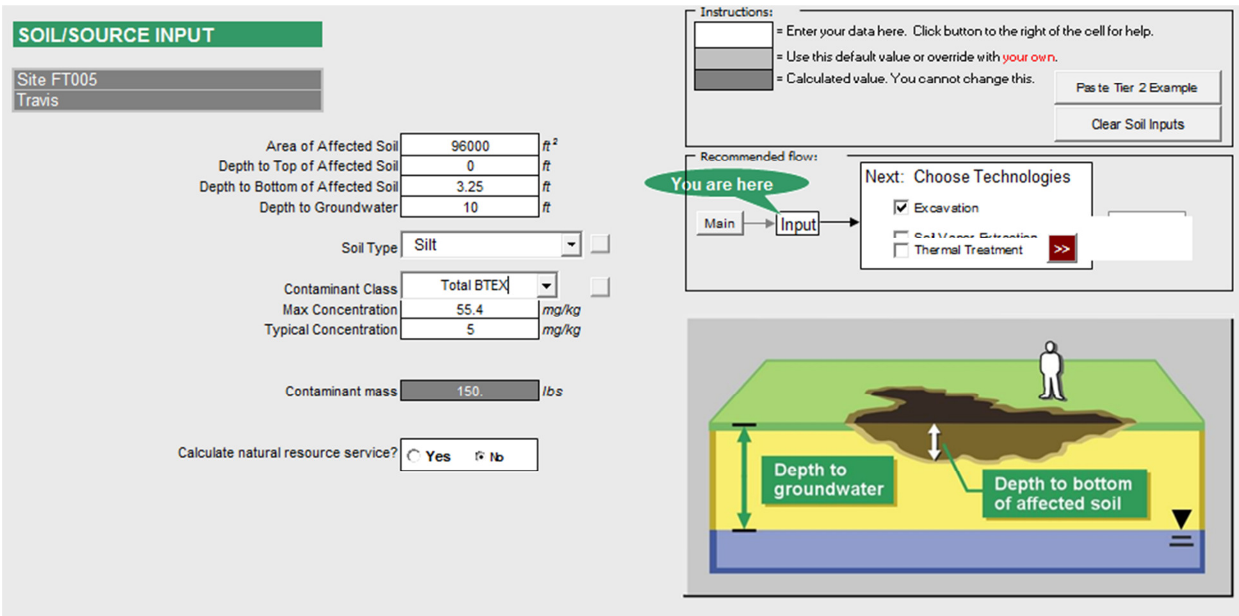


Figure A-1. The basic input for soil screenshot from the SRT run.

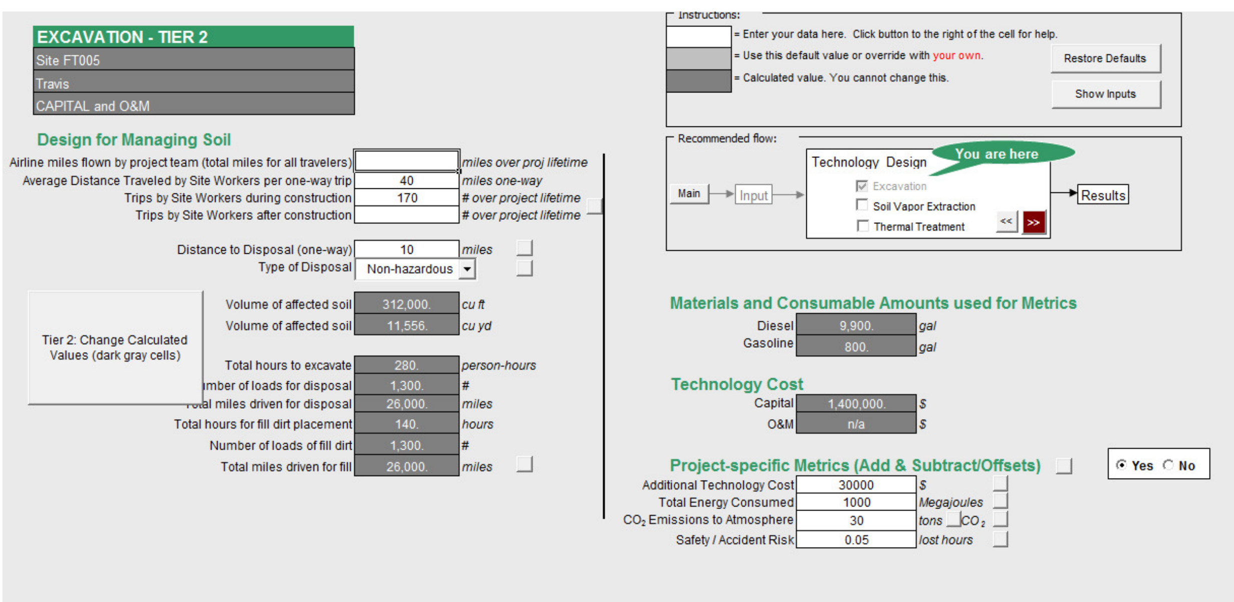


Figure A-2. Details of Tier 2 input screens for the Excavation portion of the SRT.

Design Calculations - Excavation

Area of Affected Soil	96,000.	ft2
Total Thickness of Affected Soil	3.25	ft
Volume of affected soil	312,000.	ft3
Volume of affected soil	11,556.	cu yd
Soil density	95.	lb/ft3
Excavation rate	53.	tons/hr
Total hours to excavate	280.	person-hours
Fluff factor (excavated soil)	1.3	
Dump truck volume for disposal	12.	cu yd
Number of loads for disposal	1,300.	# loads
Total miles driven for disposal	26,000.	miles
Fluff factor (fill)	1.3	
Dump truck volume for moving fill	12.	cu yd
Number of loads of fill dirt	1,300.	# loads
Fill spread rate	448.5	cu yd/hr
Water compaction rate	174.3	cu yd/hr
Spread/compaction rate	654.	cu yd/hr
Total hours for fill dirt placement	140.	hrs
Distance from site to fill source (one way)	10.	miles
Total miles driven for fill	26,000.	miles

Materials and Consumable Calculations - Excavation

Excavator fuel consumption rate	3.	gal/hr
Dump truck fuel use rate	6.	mpg
Total fuel (diesel)	9,900.	gals
Jet fuel use rate per passenger	0.0000097	gal/mi
Weight of passenger + luggage	200.	lbs
Total air miles (all passengers; input above)	0.	miles
Total jet fuel	0.	gal
Vehicle Mileage	17.	mpg
Total fuel (gasoline + jet fuel)	800.	gal

Figure A-3. Intermediate steps in the SRT. Items in red indicate deviations from the default values input by the users.

The input data for the SEFA are given in the following table.

Table A-1. SEFA Input Tables

General Scope	*Example Items Eliminated through Screening Process*
Narrative to be added	

Labor, Mobilizations, Mileage, and Fuel

Participant	Crew Size	Number of Days	Hours Worked Per Day	Total Hours Worked	Trips to Site*	Roundtrip Miles to Site	Mode of Transport.	Fuel Type	Total Miles **	Fuel Usage Rate	Total Fuel Used***
Samplers/Daily Crew	2	45	8	720	40	80	Light-Duty Truck	Gasoline	3200	17	188
Excavation Crew	3	45	8	1080	40	80	Light-Duty Truck	Gasoline	3200	17	188
Supervisor	1	10	8	80	40	80	Light-Duty Truck	Gasoline	3200	17	188

On-Site Equipment Use, Mobilization, and Fuel Usage

Equipment Type*	HP	Load Factor **	Equip. Fuel Type	Units of Fuel Used per Hour	Total Hours Operated	Gallons of Fuel Used On-Site	Trips to Site	Roundtrip Miles to Site	Total Miles Transported	Transport Fuel Type	Fuel Usage Rate	Total Fuel Used for Transport***
Dump truck (400 HP)	400	0.75	Diesel	15	240	3600	1	30	30	Diesel	6	5
Excavator - medium (175 HP)	175	0.75	Diesel	6.5625	320	2100	1	30	30	Diesel	6	5
Loader (200 HP)	200	0.75	Diesel	7.5	320	2400	1	30	30	Diesel	6	5
Generator - HP varies	20	0.75	Diesel	0.75	320	240	1	30	30	Diesel	6	5
Water truck (400 HP)	400	0.75	Diesel	15	200	3000	1	30	30	Diesel	6	5

Materials Use (including Potable Water) and Transportation

Material Type or Public Water	Unit	Quantity	Tons	Default One-Way Miles	Site-Spec. One-Way Distance (miles)*	Number of Trips	Mode of Transport.	Fuel Type	Fuel Usage Rate (gptm or mpg)	Total Fuel Used (gallons)	
HDPE	lb	3018	1.509	500	500	3	Truck (mpg)	Diesel	6	250	
			0		500	3	Truck (mpg)	Diesel	6	250	Empty return t
Straw	ton	3.5	3.5	500	25	1	Truck (mpg)	Diesel	6	4.2	
			0		25	1	Truck (mpg)	Diesel	6	4.2	Empty return t
Gravel/sand/clay	lb	144100	72.05	25	25	1	Truck (mpg)	Diesel	6	4.2	
			0		25	1	Truck (mpg)	Diesel	6	4.2	Empty return t
Public water	gal x 1000	704	2935.68	25							Used for dust
			0								
			0								
			0								
			0								
			0								
			0								
			0								
			0								
			0								
			0								
			0								

** Leave site-specific one-way miles blank if value is not known and a default will be used for calculating total-one way miles*

Fuel Use Rate reported in miles per gallon (mpg) and gallons per to
gptm fuel use rate includes empty return trips of transport vehicles,

Waste Transportation and Disposal

Waste Destination	Unit	Quantity	Tons	Default One-Way Miles	Site-Spec. One-Way Distance (miles)	Number of Trips	Mode of Transport.	Fuel Type	Fuel Use Rate (gptm or mpg)	Total Fuel Use (gallons)	
Non-hazardous landfill	tons	21266	21266	25	10	966	Truck (mpg)	Diesel	6	1610	Potrero Hills l
			0		10	966	Truck (mpg)	Diesel	6	1610	Return Trip Er
POTW	gal x 1000	175	729.75	50							Waste water
			0								
			0								
			0								

** Leave site-specific one-way miles blank if value is not known and a default will be used for calculating total-one way miles*

Fuel Use Rate reported in miles per gallon (mpg) and gallons per to
gptm fuel use rate includes empty return trips of transport vehicles,

From the above we can see that the SRT calculated a total of 9,900 gallons for diesel used for excavation and the corresponding number totals to 11,340 gallons for SEFA. Similarly, the gasoline consumed is estimated to be 800 gallons for SRT and 878 gallons for SEFA.

Table A-2. Excavation Materials Footprint Summary

Excavation - Refined Materials Footprint Summary						
Material and Use	Units	Quantity	Conversion Factor to Lbs	% Recycled or Reused Content	Quantity (lbs)	
					Virgin	Recycled
Refined Materials						
HDPE Plastic liners 10 mm (top of stockpile) 20 ft by 100 feet 96 lbs per roll, source plastic sheeting supply company	roll	100	96	0%	9600	0
HDPE Plastic liners 20 mm (bottom of Stockpile) assumed to be twice the 10mm	roll	36	192	0%	6912	0
HDPE Plastic sandbags Appendix C RA Report 2012	bags	2882	0.1	0%	288.2	0

Excavation - Unrefined Materials Footprint Summary						
Material and Use	Units	Quantity	Conversion Factor to Tons	% Recycled or Reused Content	Quantity (tons)	
					Virgin	Recycled
Unrefined Materials						
Rice straw (182 wattles sediment control, 8"x 25' per wattle, 8.7 cubic feet per wattle, 450 cu ft per ton, Silo measurements from Michigan State University) Appendix C RA Report 2012	cubic feet	3.5	1	0%	3.5	0
sand (sand bag fill material, 50 lbs per bag, 2882 bags) Appendix C RA Report 2012	lbs	144100	0.0005	0%	72.05	0
					0	0

The above tables show the original tables to calculate refined and unrefined footprint summaries as given in the SEFA analysis. Currently these minor items are no longer being included; however, if required, these can be included in the output as needed.

Attachment B: Last Scoop Analysis

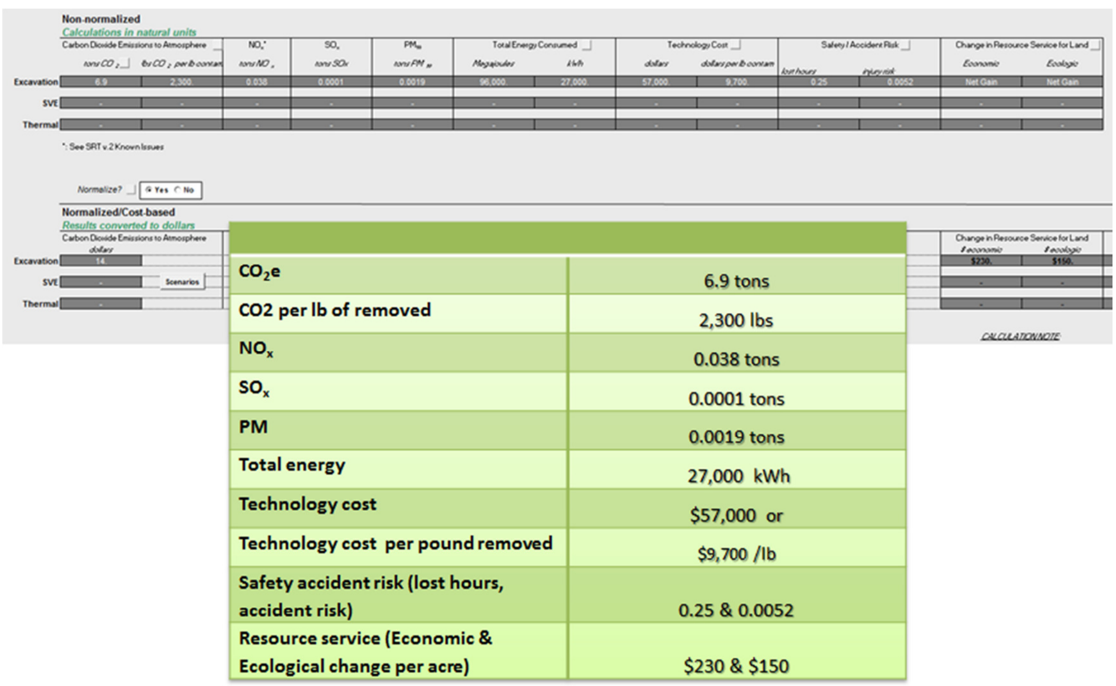
As part of a remaining portion of the excavation to be conducted at FT005, this section provides a preliminary Footprint comparison of excavation for an additional 420 cubic yards to achieve unrestricted use versus institutional controls.

Unrestricted Use Footprint Key Assumptions

- 420 cubic yards is slightly less than 4% of the initial remediation, therefore, all reasonably scalable items were reduced proportionally
- Number of trips by field crew did not appear scalable, therefore, 14 days of work was assumed

Institutional Controls Key Assumptions

- No materials or water was required and no waste was generated
- Travel for one annual inspection was modeled for 30 years (reality in perpetuity)



CO_2e	6.9 tons
CO2 per lb of removed	2,300 lbs
NO_x	0.038 tons
SO_x	0.0001 tons
PM	0.0019 tons
Total energy	27,000 kWh
Technology cost	$57,000 or
Technology cost per pound removed	$9,700 /lb
Safety accident risk (lost hours, accident risk)	0.25 & 0.0052
Resource service (Economic & Ecological change per acre)	$230 & $150

Figure B-1. SRT analysis for the last scoop.

Metric	Amount	Units
Refined materials used on-site	-	Tons
Unrefined materials used on-site	-	Tons
Hazardous waste disposed of off-site	-	Tons
Non-hazardous waste disposed of off-site	800	Tons
Public water used on-site	110	MG
Groundwater used on-site	-	MG
Total energy used	400	MMBtu
Total NOx emissions	400	Pounds
Total SOx emissions	100	Pounds
Total PM emissions	5	Pounds
Total HAP emissions	??	Pounds
Total greenhouse gas emissions	30	Tons

Figure B-2. SEFA analysis for the Last Scoop.

It can be seen that the SEFA calculated results are much higher in this case than the SRT evaluations. This is because of the inherent assumptions in the two tools and how the activities are treated separately in the two tools. The major controlling factor for this difference is a large contribution from management of non-hazardous waste in an off-site landfill.

Comparison of Footprint Quantification Tools Relative to Each Other and the EPA Footprint Methodology

Site DP-039
Travis Air Force Base, Washington

October 23, 2012

NOTICE

Work described herein was performed by Tetra Tech GEO for the U.S. Environmental Protection Agency (EPA). Work conducted by Tetra Tech GEO, including preparation of this report, was performed under Work Assignment #2-73 of EPA contract EP-W-07-078 with Tetra Tech EM, Inc., Chicago, Illinois. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared as part of a collaborative effort between the U.S. Air Force, EPA Region 9, and the EPA Office of Superfund Remediation and Technology Innovation (OSRTI). This report is available for download from www.cluin.org/greenremediation.

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TABLE OF CONTENTS

TABLES

CHARTS

ATTACHMENTS

LIST OF ACRONYMS

ug/L	microgram per liter
AFB	Air Force Base
CAMX	eGRID subregion representing the California area
CO2e	carbon dioxide equivalents of global warming potential
DPE	dual phase extraction
EPA	U.S. Environmental Protection Agency
EVO	emulsified vegetable oil
ESTCP	Environmental Security Technology Certification Program
GAC	granular activated carbon
GETS	groundwater extraction and treatment system
GHGs	greenhouse gases
gpm	gallons per minute
GSR	Green and Sustainable Remediation
HAP	Hazardous air pollutant as defined by the Clean Air Act
ISCO	*in situ* chemical oxidation
ISO	International Standards Organization
kW	kilowatt
kWh	kilowatt-hour
lbs	pounds
LCA	life-cycle assessment
LCI	life-cycle inventory
LTM	long-term monitoring
MNA	monitored natural attenuation
MJ/kWh	megajoules to kWh

MMBtus	millions of British Thermal Units
MWh	megawatt-hour
N/A	not available
NOx	nitrogen oxides (for example, nitrogen dioxide)
PA	preliminary assessment
PM10	particulate matter (particles 10 microns or less in diameter)
PRB	permeable reactive barrier
PVC	polyvinyl chloride
RECs	Renewable Energy Certificates
SOx	sulfur oxides (for example, sulfur dioxide)
SVE	soil vapor extraction
SRT™	Sustainable Remediation Tool™
TCE	trichloroethene
USCLI	U.S. Life-Cycle Inventory
UV/OX	ultraviolet oxidation
VOC	volatile organic compound
WAPA	Western Area Power Authority
WECC	Western Electricity Coordinating Council

1.0 INTRODUCTION

1.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) defines green remediation as the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprint of cleanup actions. When appropriate, green remediation involves quantifying the environmental effects or environmental footprint of a remedy. The EPA's *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 542-R-12-002), February 2012 ("Methodology") defines the metrics that comprise the environmental footprint and the process for quantifying those metrics. Metrics are calculated for the following categories:

- Materials and Waste
- Water
- Energy
- Air

Several tools have been developed to assist with quantifying the environmental footprints of remedies. In addition, life-cycle assessment (LCA) tools developed for and used in the manufacturing sector can be applied to remedies to help quantify an environmental footprint.

1.2 PURPOSE

This study evaluates the environmental footprint of a remedy using multiple footprint quantification tools to evaluate consistency among the tools and consistency with the EPA footprint methodology. The tools are not applied to compare various competing alternatives. The tools used in this study are as follows:

- Sustainable Remediation Tool (SRT™) – Developed in May 2009 (and updated in May 2010) on behalf of the U.S. Air Force as a screening tool to quantify the energy, emissions, and other impacts associated with environmental cleanup projects.

- Spreadsheets for Environmental Footprint Analysis (SEFA) – Released in April 2012 by the EPA to assist with applying the Methodology.

- SimaPro™ – developed and marked by Pré Consultants in the Netherlands, to facilitate LCA studies in accordance with International Standards Organization (ISO) Standards.

Input parameters and results for SRT™ and SimaPro™ were obtained from a currently underway Environmental Security Technology Certification Program (ESTCP) project titled Quantifying Life-Cycle Environmental Footprints of Soil and Groundwater Remedies (ESTCP Project # ER-201127). Input parameters and results for SEFA were developed and calculated as part of this analysis and reporting effort under contract to the EPA.

1.3 Description of Tools

1.3.1 SRT™

SRT™ is a publicly-available tool built on the Microsoft Excel® platform that is structured using analytical "tiers". In Tier 1 (simpler tier), calculations are based on rules-of-thumb that are widely used in the environmental remediation industry. In Tier 2, calculations are more detailed and incorporate more site-specific factors. The current version of SRT™ is Version 2.1 (AFCEE, May 2010). Tier 2 was used for this study. Information on SRT™, including files available for download, can be found at:

http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp).

The tool was developed to help screen and compare various remedial alternatives and was developed prior to the EPA Methodology. The tool allows users to estimate sustainability metrics for the following soil and groundwater remediation technologies:

Soil Remediation:

- Excavation
- Soil Vapor Extraction (SVE)
- Thermal Treatment

Groundwater Remediation:

- Pump and Treat
- Enhanced Bioremediation
- Permeable Reactive Barrier (PRB)
- *In Situ* Chemical Oxidation (ISCO)
- Long-term Monitoring (LTM)/ Monitored Natural Attenuation (MNA)

Input information varies by Tier and remedial technology. Results are provided for the following metrics:

- Carbon dioxide emissions
- Nitrogen oxide (NOx), sulfur oxide (SOx), and particulate matter (PM) emissions
- Energy consumption
- Safety / accident risk
- Change in resource service from land and/or groundwater

1.3.2 SEFA

SEFA is a collection of Microsoft Excel® spreadsheets designed to apply the Methodology. The spreadsheets are publicly available at the following website:

http://www.cluin.org/greenremediation/methodology

The spreadsheets allow information to be organized in up to six different components that can be defined by the user. Input and output are not constrained by specific technology modules. Input includes materials use, water use, waste disposal, transportation, equipment use, and other items. Output is provided for all metrics defined in the Methodology (see Table 1.)

Table 1. Metrics defined in the Methodology

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

RECs = Renewable energy certificates
NOx = Nitrogen oxides
SOx = Sulfur oxides
PM10 = Particulate matter smaller than 10 microns in size
HAP = Hazardous Air Pollutants as defined by the Clean Air Act
MWh = megawatt-hour
MMBtu = million British thermal units

1.3.3 SimaPro™

The SimaPro™ LCA software developed by PRé (www.pre-sustainability.com) provides a user interface and tools to facilitate the use of life-cycle inventory (LCI) databases in LCA studies that are consistent with governing ISO Standards 14040:2006 and 14044:2006. SimaPro™ comes fully integrated with several LCI databases including the extensive proprietary Ecoinvent database.

Using project-specific information, a SimaPro™ user compiles a number of materials, processes, and disposal practices from the LCI databases into user-made assemblies and life-cycles that describe the overall project. Footprint information or environmental impacts can then be obtained from the assemblies and life-cycles. Input is project specific and there are hundreds of output parameters, including: total energy use, greenhouse gas emissions, NOx emissions, SOx emissions, PM emissions, and the environmental impacts associated with these various emissions.

SimaPro™ can cost between $3,000 and $12,000 (typically $9,000 for professionals) to purchase depending on the type of license, number of user licenses, and features. Service and support packages are available for additional cost. Additional databases and methods are included to convert footprint information (such as SOx emissions) into environmental impacts (such as acidification).

1.4 Brief Site Background and Remedy Components Analyzed

Travis Air Force Base (AFB), located in Solano County, California, serves as Military Air Command Headquarters to the 22nd Air force, as well as a medical center. It consists largely of airfield runways and related operations facilities. Industrial operations include various shops where aircraft components were cleaned with solvents. Site DP039 consists of a former rock-filled acid neutralization sump located approximately 65 feet west of Building 755, in the northern portion of the West/Annexes/Basewide Operable Unit (WABOU). Until 1978, a pipeline ran from a sink drain within Building 755 to the sump. Based on preliminary assessment (PA) data, Building 755 was originally used to test rocket engines, but only petroleum-based liquid fuel was used at the site as part of rocket engine testing. Since 1968, Building 755 has been the location of the Battery and Electric Shop. Before 1978, battery acid solutions and chlorinated solvents reportedly were discharged into the Building 755 sink and drained to the sump. A 500 microgram per liter (ug/L) trichloroethene (TCE) groundwater contamination plume extends approximately 1,400 feet downgradient (southeast) of the known source area. In July 1993, the sump and surrounding soil were removed and disposed off-base.

Until 2008, the Site DP039 groundwater extraction system (GETS) consisted of two dual phase extraction (DPE) wells that addressed source area groundwater and soil vapor. In November 2008, both extraction wells were taken offline to facilitate construction and operation of a source area bioreactor as an AFCEE technology demonstration project. The bioreactor was constructed in an approximately 400-square-foot excavation surrounding one extraction well. The 20-feet deep excavation was backfilled with a 50/50 mixture of gravel and tree mulch sprayed with emulsified vegetable oil (EVO). An extraction well in the immediate area was salvaged and is currently used as a monitoring well for the bioreactor study. One extraction well is located approximately 8 feet downgradient of the edge of the bioreactor and is currently used to circulate groundwater within the bioreactor. This extraction well is equipped with a solar-powered pump which circulates water from the source area and into the top of the bioreactor.

A large phytoremediation treatability study area has been established downgradient of the bioreactor. The phytoremediation treatability study area consists of 400 tree plantings engineered to hydraulically control and remove volatile organic compound (VOC) mass from the shallow groundwater. A biobarrier consisting of several injection wells has also been constructed and is operated. Monitored Natural Attenuation (MNA) is the assumed remedy for the remainder of the plume.

Input parameters and results for SRT™ used in the ESTCP project and in this analysis were obtained from the following sources:

- Sustainable Remediation Tool Application at Site DP039, Travis Air Force Base, (CH2MHill, March 2012)

- SRT™ Spreadsheets: "SRT rev2_1_DP39_Alt 1.xls" and "Copy of SRT rev2_1_DP39_Alt 2.xls" (provided by Doug Downey, CHM2Hill by e-mail attachment on 3/12/2012)

Two remedial alternatives for the site were evaluated in the ESTCP project and this analysis.

Alternative 1: This alternative includes continued operation of the groundwater portion of the DPE system for 30 years. The extracted water is treated in a larger central treatment system, but for the simplicity of this analysis is assumed to be treated with an air stripper prior to discharge into a nearby creek or to an irrigation system. An electricity usage of 7.5 kilowatts (kW) (1,900,000 kilowatt-hours (kWh) over 30 years) is assumed. Because there is currently an interim pumping system on site that is available for restarting, the metrics considered for this analysis include only those for re-starting the system and for the operation and maintenance of that system. Construction is assumed for well replacement only.

Alternative 2: This alternative includes the discontinuation of the current GETS operations, operation of the on-going phytoremediation remedy, construction and operation of the bioreactor, construction and operation of the biobarrier injection wells, and MNA of a downgradient portion of the plume.

1.5 Approach and Model Input

The approach used for this comparison involves the following steps:

- Obtain the input information used for SRT™ and SimaPro™ .
- Input the same information into SEFA.
- Compare the SRT™, SimaPro™, and SEFA results.
- Evaluate the potential use of each tool for applying the Methodology.

The model inputs used by the three tools are provided in Attachment A. The tables in Attachment A are the tables compiled for the ESTCP project modified with an additional column to present the SEFA input. Where feasible, input for the three tools was made as similar as practical so that differences in the results could be attributed to differences in model calculations rather than differences in user input assumptions.

The remedy components were simplified for the SRT™ application. Examples of the simplifications made for input into SRT™ are as follows:

- Groundwater extraction at a rate of 2.4 gallons per minute (gpm) with treatment of extracted groundwater in a ultraviolet oxidation (UV/OX) central treatment plant was simplified to SRT™ input of 10 horsepower (7.5 kW) of electricity. Granular activated carbon (GAC) was under consideration for actual treatment of the groundwater but was not evaluated.
- Materials or services not available in SRT™, such as corn syrup, pyrite, mulch, well grout, photovoltaic modules, and laboratory analysis, were not included in the SRT™ analysis.
- Some remedy components, such as the following, were not included in the SRT™ analysis:
    - Polyvinyl chloride (PVC) bioreactor irrigation system,
    - Installation of seven monitoring wells for the bioreactor remedy,

- Disposal of some hazardous waste from excavation,
- Tree planting, supplemental watering, fertilizer, or carbon storage associated with phytoremediation.

As a result of the simplified SRT™ application and the effort to keep the input information uniform across tool applications, the SimaPro™ and SEFA applications were also simplified. The influence of these simplifications is considered in a sensitivity analysis discussed in Section 2.

2.0 RESULTS

2.1 Comparison of Calculated Environmental Footprint Metrics

Tables 2 and 3 provide the results for environmental footprint metrics for Alternative 1 and Alternative 2 that were calculated by two or more of the tools. Output from the various tools has been converted into common units to facilitate comparison. Using SEFA as an arbitrary benchmark, results that differ from the SEFA results are highlighted as follows:

- White – Different by a factor of less than 1.2
- Yellow – Different by a factor of 1.2 to 2
- Orange – Different by a factor of 2 to 10
- Red – Different by a factor of 10 or more

Table 2. Comparison of calculated footprint metrics for Alternative 1

Metric	Unit	SRT™	SEFA	SimaPro™
Total Energy Used	MMBtu	20,000	23,200	20,650
Total NOx Emissions	Lbs	15,400	3,560	2,860
Total SOx Emissions	Lbs	28,000	12,600	15,300
Total PM Emissions	Lbs	5,400	99	136
Total HAP Emissions	Lbs	N/A	256	332
Total GHG Emissions	Tons	1,310	918	1,013

Table 3. Comparison of calculated footprint metrics for Alternative 2

Metric	Unit	SRT™	SEFA	SimaPro™
Total Energy Used	MMBtu	184	3,860	9,130
Total NOx Emissions	Lbs	142	3,310	1,360
Total SOx Emissions	Lbs	26.4	947	622
Total PM Emissions	Lbs	7.16	192	128
Total HAP Emissions	Lbs	N/A	2	22
Total GHG Emissions	Tons	621	805	229

Notes for Tables 2 and 3: Lbs=pounds; MMBtu=million British Thermal Units; NOx=nitrogen oxides; SOx=sulfur oxides; PM=particulate matter; HAP=hazardous air pollutions; GHG=greenhouse gas.

The differences highlighted above are discussed below.

<u>Alternative 1</u>

The Alternative 1 remedy as analyzed by the tools primarily involves electricity use. Therefore, all of the differences in Table 2 can be attributed to how the tools consider electricity. Some of the differences include:

- The SRT™ NOx, SOx, and PM emission values are much higher than the values calculated by the other tools because the SRT™ user applied the default electricity conversion factors, which represent a nationwide average. By contrast, SEFA and SimaPro™ used the 2005 CAMX regional energy mix from eGRID, which is representative of the generation mix for a large portion of California. The CAMX mix has a higher percentage of natural gas and renewable energy use and lower coal use than a national average. Information on eGRID and the CAMX subregion can be found at http://www.epa.gov/egrid.

- SEFA and SimaPro™ both consider the footprints associated with extracting the fuel used for electricity generation and transmission and distribution losses of transmitting electricity over the grid. SRT™ does not consider these two items. Despite these additional footprint contributions considered in SEFA and SimaPro™, the SRT™ values for GHG emissions are still higher than both SEFA and SimaPro™ because the national average generation mix incorporates more coal and less renewable energy than the CAMX generation mix.

- SRT™ uses a conversion factor of 11 megajoules per kWh (MJ/kWh) (approximately 3.05 as a dimensionless factor) and SEFA uses a dimensionless conversion factor of 3.0 to convert kWh of electricity used to energy required to generate that electricity. The difference in energy use between SRT™ and SEFA is generally explained by the fuel extraction and transmission losses discussed in the previous bullet.

- The SimaPro™ LCI databases employed by the user specify unique energy conversion factors depending on the electricity source. For example, SimaPro™ considers hydropower (and other renewable energy) considerably more than 90% efficient, even though this efficiency does not fully consider the energy lost in the transformation of potential energy of water behind a dam to usable electric energy. For this reason, SimaPro™ will output lower overall energy use than SEFA for a given amount of electricity derived from hydropower. This difference in converting electricity use to energy use explains the observed difference between the SEFA and SimaPro™ results and masks differences that would otherwise be apparent between the SRT™ and SimaPro™ results.

- Although SEFA and SimaPro™ used the same generation mix, different LCIs were used to convert the electricity use into emissions. For example, SEFA uses the publicly available U.S. Life-Cycle Inventory (USLCI) databases and SimaPro™ used a combination of the USLCI databases and the proprietary Ecoinvent databases.

- The differences among the results for Alternative 1 are only representative for electricity-dominated remedies in the California area. Different regions of the country use different generation mixes.

Alternative 2

The Alternative 2 remedy, as analyzed by the tools, involves substantial use of bioremediation substrate (i.e., EVO). Therefore, much of the differences in Table 3 can be attributed to how the tools convert this substrate into footprint metrics. Some of the differences are described below:

- SRT™ only considers the GHG emissions associated with substrate manufacturing. Therefore, the energy, NOx, SOx, and PM metrics for SRT™ do not include any contribution for manufacturing 450,000 lbs of substrate.

- For this analysis, SEFA and SimaPro™ used different LCI databases to convert substrate into environmental footprints. SEFA uses a vegetable oil entry from a publicly available LCI database from Denmark. For this application of SimaPro™, the user selected an entry from the proprietary Ecoinvent database for soybean oil. Neither SEFA nor SimaPro™ considered the various additives or mixing process for producing emulsified vegetable oil from vegetable oil.

2.2 FOOTPRINT CONTRIBUTIONS

Table 4 presents the ranking of the top contributors to various calculated footprint metrics for each of the tools as applied to Alternative 2. Note that the materials, waste, and water metrics are not included because they are not calculated by SRT™ and SimaPro™. A similar table is not provided for Alternative 1 because electricity is the only main contributor.

Table 4. Comparison of footprint contribution ranking for Alternative 2

Rank	SRT™	SEFA	SimaPro™
Energy			
1	Personnel transport	Substrate	Substrate
2	Drill rig	Drill rig	Drill rig
3	PVC for wells	Bioreactor excavation	PVC for wells
4	Bioreactor excavation	Soil disposal	Soil disposal
5		PVC for wells	Personnel transport
6		Personnel transport	Substrate transport
7		Substrate transport	Water
8		Gravel/mulch backfill	Bioreactor excavation
9		Solar energy	Gravel/mulch backfill
GHG Emissions			
1	Substrate	Substrate	Substrate
2	Personnel transport	Drill rig	Drill rig
3	Drill rig	Bioreactor excavation	PVC for wells
4	PVC for wells	Soil disposal	Soil disposal
5	Excavator	Personnel transport	Personnel transport
6		PVC for wells	Substrate transport
7		Water	Bioreactor excavation
8		Substrate transport	Water
9		Gravel/mulch backfill	Gravel/mulch backfill
NOx+SOx+PM Emissions			
1	Drill rig	Substrate	Substrate
2	Excavator	Soil disposal	Drill rig
3	PVC for wells	Drill rig	Soil disposal
4	Personnel transport	Bioreactor excavation	Bioreactor excavation
5		Personnel transport	PVC for wells
6		Substrate transport	Personnel transport
7		PVC for wells	Substrate transport
8		Water	Gravel/mulch backfill
9		Gravel/mulch backfill	Water

Notes: NOx=nitrogen oxides; SOx=sulfur oxides; PM=particulate matter; HAP=hazardous air pollutions; GHG=greenhouse gas; PVC=polyvinyl chloride.

"Substrate" = emulsified vegetable oil or comparable bioremediation electron donor applied to the bioreactor and biobarrier remedy components
"Drill rig" = fuel use associated with installing bioreactor excavation refers to excavator and dump truck use

"Bioreactor excavation" = fuel use for excavator and dump truck use to excavate and backfill bioreactor
"Soil disposal" = landfill activities associated with disposal of approximately 300 cubic yards of soil excavated from the bioreactor
"PVC for wells" = manufacturing of PVC used for biobarrier injection wells and MNA monitoring wells
"Personnel transport" = all personnel transport associated with the phytoremediation, bioreactor, biobarrier, and MNA components of Alternative 2
"Substrate transport" = transportation of substrate from distribution point to the point of use (assumed distance of 50 miles).
"Gravel/mulch backfill" = processing/manufacturing of gravel and mulch for bioreactor backfill
"Solar energy" = energy content of electricity generated by solar panels

Charts 1 through 6 (provided at the end of this report) illustrate the various contributions identified in Table 4. Charts 2, 4, and 6 are similar to Charts 1, 3, and 5 but have excluded one or more very large contributors so that the variation in the smaller contributors can be observed.

Observations pertaining to Table 4 and Charts 1 through 6 include the following:

- As calculated by all tools, the GHG emission contributions from substrate production dominate the GHG emissions footprint of the remedy. Substrate production also dominates the energy footprint as calculated by SEFA and SimaPro™. Substrate production does not factor into the energy footprint calculations for SRT™.

- SRT™ includes four or five fewer contributors than SEFA and SimaPro™. Despite simplifying assumptions made to the input for SEFA and SimaPro™ to make input to all tools consistent, the SEFA and SimaPro™ applications include soil disposal, gravel/mulch backfill, water, and substrate transport even though the SRT™ application does not include them. Reasons for inclusion in the SEFA and SimaPro™ applications are as follows:
    - Soil disposal – SRT™ considers the footprint for transportation of excavated soil. It was reasonable, therefore, to include the footprint for disposal in the SEFA and SimaPro™ applications given that these two tools have the capability to include soil disposal.
    - Gravel/mulch backfill – The SRT™-related documents provided to the ESTCP project specified this backfill. Additionally, SRT™ includes the equipment use for the backfill. It was reasonable, therefore, to include the footprint for the specified backfill in the SEFA and SimaPro™ applications given that these two tools have the capability to include the footprint for specified backfill material.
    - Water – Substrate, which is included in the SRT™ analysis, is blended with water during injection. It was reasonable, therefore, to include the footprint for the water used in blending in the SEFA and SimaPro™ applications given that these two tools have the capability to include the footprint for water.
    - Substrate transport – SRT™ includes the use of substrate. It was reasonable, therefore, to include the footprint for transporting the substrate in the SEFA and SimaPro™ applications given that these two tools have the capability to include the footprint for transporting the substrate.

- Each tool ranks contributors differently. Some of the different rankings are due to one tool including more items than another (for example, SEFA considers the energy from the solar panels). However, much of the difference in rankings is because each tool uses different conversion factors to convert materials or activities into environmental footprints.

- Some of the variations are the result of assumptions made in the input. For example, SRT™ and SimaPro™ estimated dump truck fuel use based on typical freight fuel efficiencies. By contrast, SEFA input assumed a given size dump truck, load factor, and duration of operation.

2.3 COMPARISON TO THE METHODOLOGY

The Methodology discusses several green remediation metrics and provides several suggestions for gathering and screening site information, estimating unknown input values, and reporting results. Use of a particular tool, including SEFA, does not guarantee adherence to the Methodology. Because the information used for this project was obtained from an ESTCP project, and the ESTCP project included previously run SRT™ applications as in-kind support for the project, the application of SRT™ (and consequently the other tools) did not necessarily follow the Methodology. Key differences between the Methodology and the project-specific applications of these tools are as follows:

- Items were excluded based on tool structure rather than the Methodology screening approach or other equivalent documented screening approach.

- Simplifying assumptions, such as representing groundwater extraction and treatment in Alternative 1 as 7.5 kW of electrical power, were made due to tool structure that might otherwise not have been made.

- The SRT™ application used default nationwide average conversion factors to convert electricity into the footprint parameters for this study. Because the conversion factors vary by fuel, using the default conversion factors can result in footprint overestimates in some locations and footprint underestimates in other locations. The SRT™ default conversion factors also did not account for the resource extraction and transmission losses associated with electricity use. Excluding these items will result in consistently underestimating footprints associated with electricity use.

In addition, the structure of SRT™ and SimaPro™, which were developed prior to the Methodology, and for purposes other than applying the Methodology, somewhat limit the ability of these tools to fully adhere to the Methodology.

- In its current form SRT™ includes NOx, SOx, and PM contributions from some activities and materials, but not for others. The remedy NOx, SOx, and PM calculations, therefore, do not represent all potentially significant contributors or represent the NOx+SOx+PM metric in the Methodology.

- SRT™ and SimaPro™ are not organized to document or present all green remediation metrics defined in the Methodology. However, some of these metrics (for example, the materials, waste, and water metrics) can be quantified in a straightforward manner consistent with the Methodology without a complex footprint analysis tool.

- SRT™ and SimaPro™ cannot calculate the on-site emission metrics defined in the Methodology. Although SimaPro™ has significant flexibility, it is difficult to separate the footprint associated with on-site fossil fuel combustion from the footprint associated with extracting the fossil fuel and processing it at a refinery.

- Conversion factors in SRT™ and SimaPro™ are not necessarily consistent with the conversion factors provided in the Methodology. The SRT™ and SimaPro™ conversion factors are documented, defensible conversion factors. Therefore, the difference in conversion factors among the tools does not mean that the conversion factors in SRT™ and SimaPro™ are inappropriate. Rather, the differences emphasize the inherent difficulty in identifying robust conversion factors. Selection of appropriate conversion factors is further complicated in SimaPro™ where many options from many LCI databases are available for use.

- SRT™ and SimaPro™ are both limited in transparency relative to expectations of the Methodology. For example, SRT™ hides the Microsoft Excel® formula bar, preventing the user from viewing the calculations occurring in each cell. SRT™ also does not show calculations or results for individual contributions. If the user wants to determine the footprint parameters due to fuel usage, PVC, substrate, electricity, or any other contributor to a footprint, the user needs to reference the SRT™ conversion factors and repeat the calculations separately. For SimaPro™, the proprietary nature of the primary database (Ecoinvent), the vast amounts of results produced, and the upfront cost for the software limit the ability to share and view results. Also, due to the library nature of SimaPro™, sharing project files is difficult even between SimaPro™ users because so many files and data (perhaps up to 1 gigabyte in size) need to be shared.

2.4 Sensitivity Analysis

A sensitivity analysis is typically recommended to evaluate the sensitivity of results to variation or uncertainty in the input parameters or environmental footprint conversion factors. For the purpose of this document, the sensitivity analysis focuses on input assumptions that might have been different if the footprint analysis study had more directly considered the Methodology. Sensitivity analyses are conducted separately for Alternatives 1 and 2.

2.4.1 Alternative 1

Remedy Simplification

The SRT™ and SimaPro™ applications from the ESTCP project simplified the remedy to represent the GETS as 7.5 kW of continuous electricity use. In reality, extracted groundwater is treated in a central treatment plant by UV/OX. The exact parameters of the actual remedy were not provided for this study, but a previous EPA study conducted at DP039 used the following information to represent the remedy:

- Groundwater extraction and treatment for 20 years
- 1 horsepower extraction pump operating continuously at 30% load and 60% efficiency over 20 years
- Treatment by the central treatment plant at 0.68 kW for a total of 119,200 kWh over 20 years
- 26,260 lbs of total hydrogen peroxide used over 20 years

Chart 7 illustrates the SEFA GHG emission results for both the simplified treatment assumptions and the more detailed treatment assumptions. The simplified treatment assumptions use 7.5 kW of electricity over 30 years, as was assumed in the ESTCP study and this study. The detailed assumptions use information presented in the bullet list above. The simplified assumptions overestimate the extraction and treatment footprint by a factor of 6.8. The hydrogen peroxide use represents approximately 17% of the GHG emissions calculated using the detailed results. These findings demonstrate the potential adverse effects of oversimplifying remedy parameters.

Generation Mix

The SRT™ application assumed a nationwide average generation mix, and the SimaPro™ and SEFA applications assumed the eGRID CAMX subregion generation mix. In reality, Travis AFB obtains its electricity from Western Area Power Authority (WAPA), which has a different generation mix than the default SRT™ nationwide generation mix or the CAMX eGRID generation mix. Chart 8 presents the GHG emissions for 1,000 kWh of electricity using the generation mixes summarized in Table 5. Chart 9 presents the NOx+SOx+PM emissions for 1,000 kWh for the same set of generation mixes. All calculations were done in SEFA to avoid variations in LCI databases that may be used in different tools. The SEFA results include resource extraction, electricity generation, and transmission losses. The charts show that the results between the site-specific generation mix and the eGRID CAMX sub-region generation mix differ by a factor of 1.2, and that the results between the site-specific generation mix and the national average generation mix differ by a factor of 1.7.

Table 5. Various electricity generation mixes that could be applied to electricity use at Travis AFB

	Coal	**Oil**	**Gas**	**Other Fossil**	**Biomass**	**Hydro**	**Nuclear**	**Wind Solar or Geo.**
U.S. Average	44.5%	1.1%	23.4%	0.3%	1.4%	6.8%	20.2%	2.3%
California	1.0%	1.4%	55.8%	0.2%	3.0%	13.7%	15.5%	9.4%
CAMX	7.3%	1.4%	53.3%	0.2%	2.7%	12.7%	14.9%	7.5%
WECC	28.7%	0.5%	32.2%	0.1%	1.3%	22.8%	9.5%	4.9%
WAPA	17.4%	0%	28.1%	0%	1.4%	40%	8.7%	4.4%

All generation mixes obtained from www.epa.gov/egrid - eGRID2012V1_0_2009. Unknown or purchased fuel sources were assumed to be natural gas.
CAMX = eGRID subregion representing the California area
WAPA = Western Area Power Authority
WECC = Western Electricity Coordinating Council

2.4.2 Alternative 2

The SRT™ and SimaPro™ applications from the ESTCP project simplified the bioreactor component of Alternative 2 to consist of excavation, backfill, and addition of vegetable oil. In reality, the bioreactor is more complex. The exact parameters of the actual remedy were not provided for this study, but a previous EPA study conducted at DP039 used the following information to represent the remedy:

- Additional heavy equipment for excavation was used resulting in a total excavation fuel usage of approximately 446 gallons of diesel.
- Approximately 7 cubic yards of soil was disposed off-site as hazardous waste.
- Remaining soil was stock-piled elsewhere on-site.
- The bioreactor was backfilled with the following materials:
  - 133 cubic yards of gravel
  - 133 cubic yards of mulch
  - 4,312 lbs of emulsified vegetable oil
  - 3,000 lbs of pyrite
  - 1,266 lbs of corn syrup

- A PVC irrigation system was installed to help recirculate groundwater extracted by solar powered pumps.
- Seven monitoring wells were installed to monitor remedy performance.
- Over 16,000 lbs of additional EVO would be added over 10 years.
- Performance monitoring occurs semi-annually for a variety of parameters over a 10-year time period.

Chart 10 presents the GHG emissions for various remedy contributors for both the original simplified input assumptions and these more detailed assumptions. Note that the more detailed assumptions also include different assumed distances for materials transportation. There is a factor of 1.7 difference between the applications with simplified and detailed assumptions. The majority of the difference is the result of the footprint associated with laboratory analysis, which is subject to uncertainty associated with the laboratory analysis conversion factors. Chart 11 is the same as Chart 10 except that in the detailed assumption, the vegetable oil substrate is replaced with an equal amount of cheese whey substrate. With this change in substrate, the GHG emissions are the same for the simplified and detailed assumptions, but the primary GHG emission contributions are very different depending on the assumptions.

3.0 CONCLUSIONS

The following conclusions have been made based on the above-described analyses:

Conclusions Regarding Direct Comparison of Tools

There are significant differences in the calculated results from each of the tools. Differences greater than a factor of more than an order of magnitude are common and result from a number of different influences, including different input assumptions and differences in footprint conversion factors that are inherent to each tool.

There are significant differences in how each tool ranks the various contributions to a footprint. In addition, SRT™ includes fewer potential contributors. For example, for the Alternative 2 remedy, SRT™ only included four or five footprint contributions, whereas SEFA and SimaPro™ included up to nine footprint contributions.

Conclusions Regarding Comparison of Tools and Results to the Methodology

Application of all the tools for this study did not necessarily follow the Methodology due to several simplifying assumptions, demonstrating that use of a particular tool does not guarantee adherence to the Methodology. Simplifying assumptions may be made during SRT™ applications because it was designed and intended for use as a screening tool. Simplifying assumptions may be made during SimaPro™ applications because of its complexity. Although SEFA was prepared to assist with implementing the Methodology, simplifying input assumptions for this study did not follow the Methodology, primarily because the study involves comparing SEFA results to SRT™ and SimaPro™ results, and the SEFA inputs were generally made consistent with the inputs for the other tools.

SRT™ and SimaPro™ do not include features to assist with calculating the materials, waste, and water footprints described in the Methodology, but these calculations would be straightforward to conduct in a user-prepared spreadsheet.

Structural features of SRT™ and SimaPro™ present additional challenges when using these tools to implement the Methodology. For example, both tools cannot calculate the on-site NOx+SOx+PM footprint described in the Methodology in a straightforward manner. In addition, SRT™ does not calculate energy use, or NOx, SOx, or PM emissions associated with several significant contributors to these emissions, which prevents SRT™ from calculating the total energy used or total NOx+SOx+PM footprints as described in the Methodology. SRT™ also does not calculate the on-site or total HAPs footprints.

Both of these tools also have unique challenges with respect to transparency and reporting of results.

Conclusions Regarding Confidence in Results

The wide variation in results from the three different tools, despite effort to use consistent input information, suggests potential concerns regarding the confidence a user should have in the results, depending on how that user chooses to use the information. Increasing confidence in the results would require further evaluation of the potential footprint conversion factors available for use, the reasons for differences in the conversion factors, and the most appropriate conversion factors to use. The differences between SEFA and SimaPro™ could likely be attributed to the following few items:

- Different fuel use input assumptions associated with dump truck use
- Footprint conversion factors for *in situ* bioremediation substrate
- Footprint conversion factors for soil disposal (for example, landfill activities)

<u>Suggested Changes to Tools to Improve Usability and Applicability</u>

Suggested changes to tools are only provided for SRT™ and SEFA.

SRT™ would benefit from the following changes:

- To improve transparency, the user should be able to see the formula tool bar.
- To improve transparency, the additional worksheets showing intermediate calculations and various footprint contributions should be included so that the user does not need to reproduce calculations.
- To improve consistency, energy, NOx, SOx, and PM should be calculated for all materials and activities or none of the materials and activities.
- To improve usability, additional fields of input should be added so that the user can include the use of additional materials or activities in a particular remedy module. For example, in order to simulate the bioreactor with SRT™, the user needed to enter values in both the excavation and bioremediation modules. This necessity further complicated data evaluation because the bioremediation module was also being used to simulate the biobarrier remedy component.
- To improve usability, fields should be added to include user-defined materials and associated conversion factors.

SEFA would benefit from the following change:

- To improve usability, a post-processor should be provided to help compile some of the intermediate calculations. For example, if a user wants to identify the footprint associated with electricity use, the user must add the results from three separate fields (electricity generation, resource extraction, and transmission losses). Additionally, if a user wants to identify the footprint associated with diesel equipment, the user must add the results from fuel use for that equipment and then add the footprint results associated with the production of that fuel.

CHARTS

Chart 1. Energy use contributions to Alternative 2 as quantified by each tool

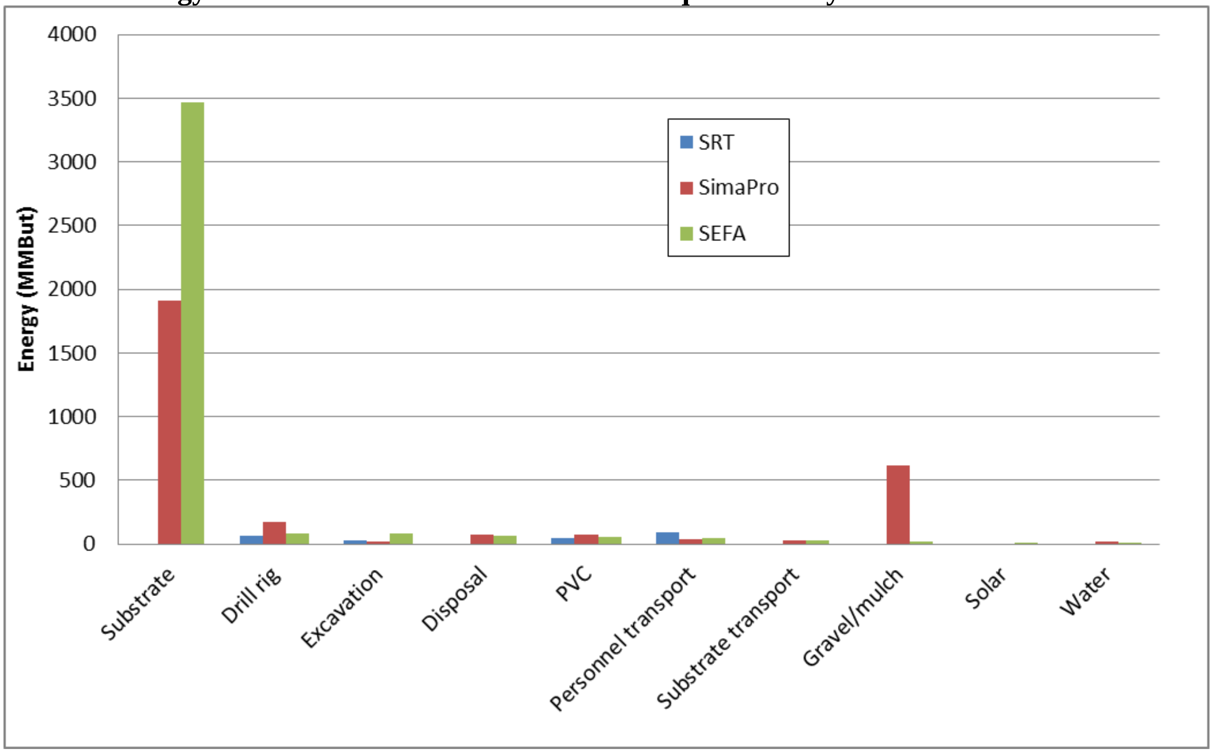


Chart 2. Energy use contributions to Alternative 2 (excluding substrate) as quantified by each tool

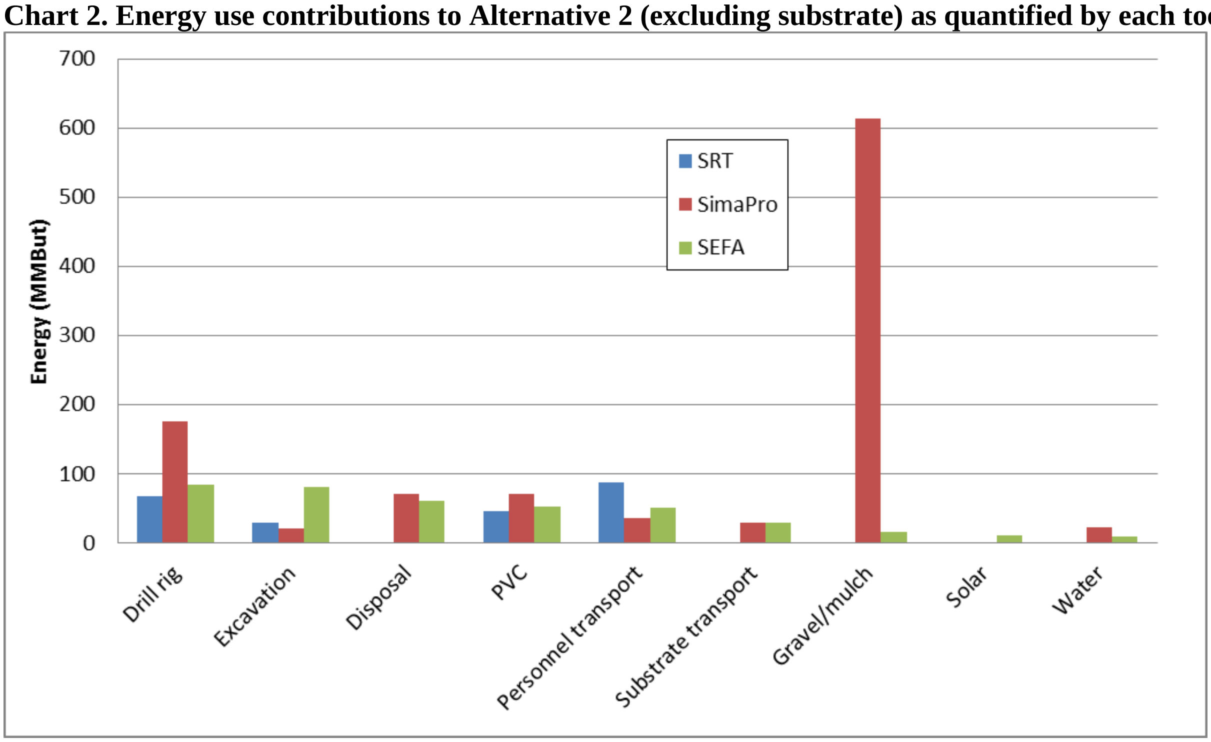


Chart 3. GHG emission contributions to Alternative 2 as quantified by each tool

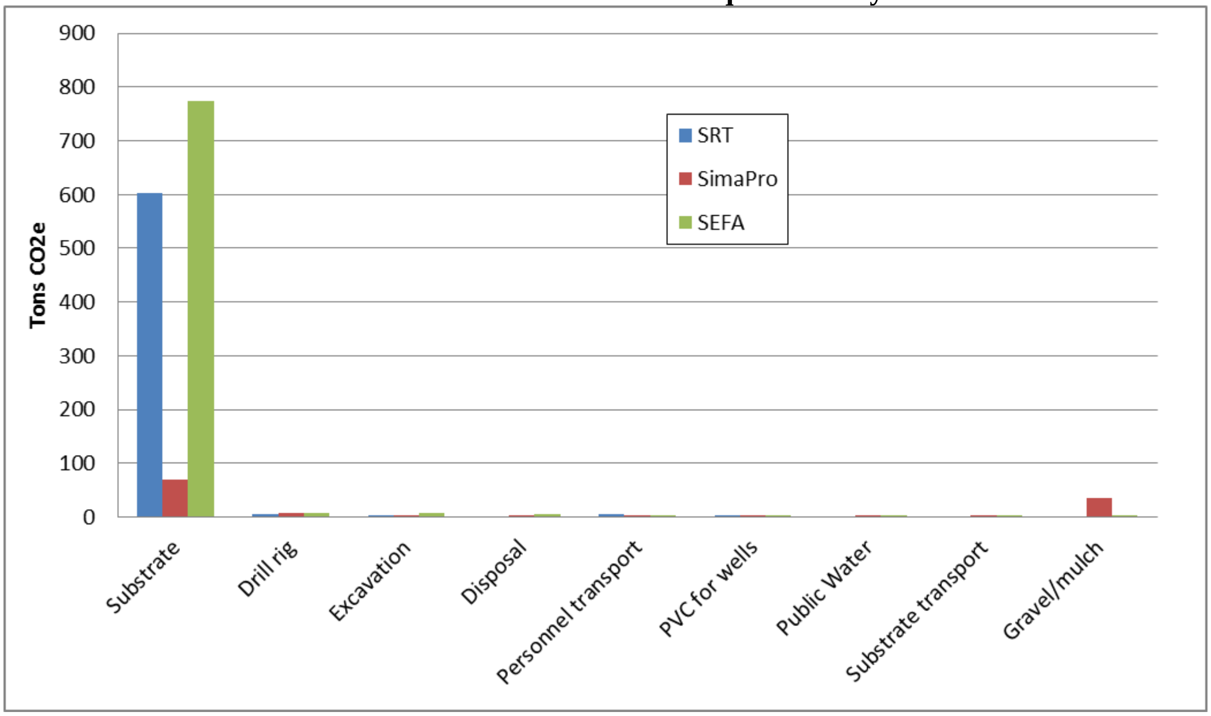


Chart 4. GHG emission contributions to Alternative 2 (excluding substrate) as quantified by each tool

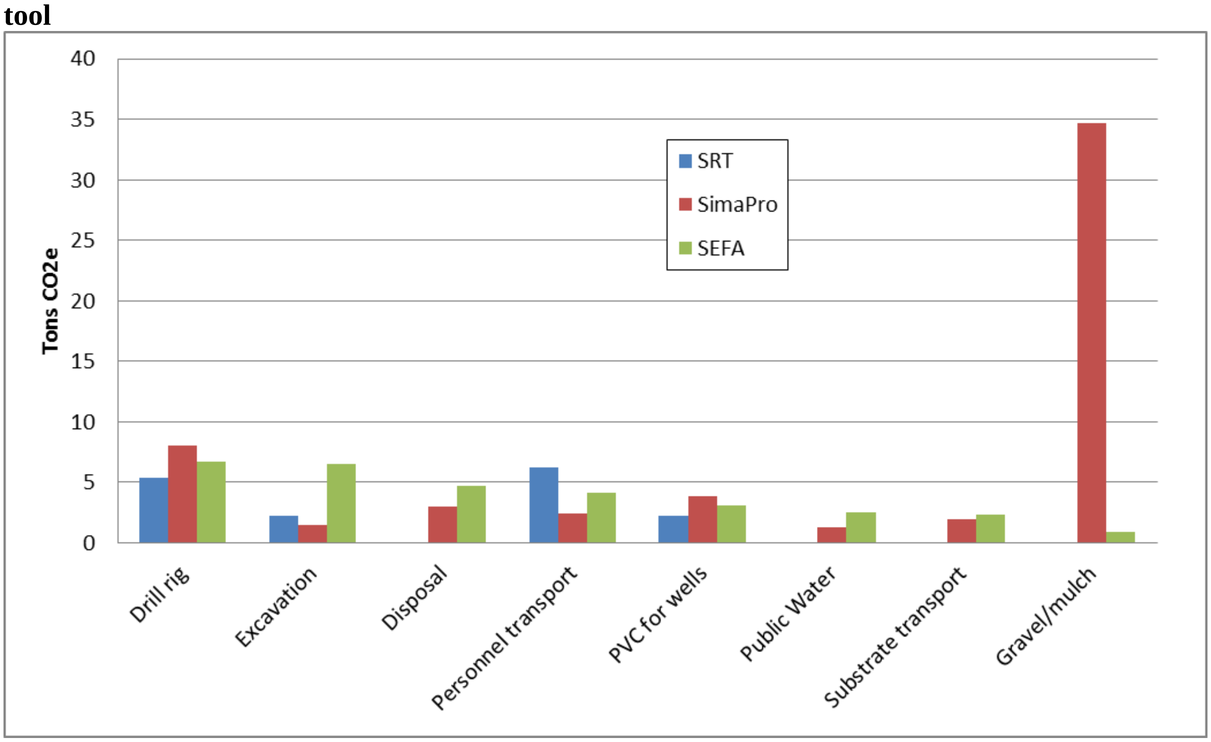


Chart 5. NOx+SOx+PM emission contributions to Alternative 2 as quantified by each tool

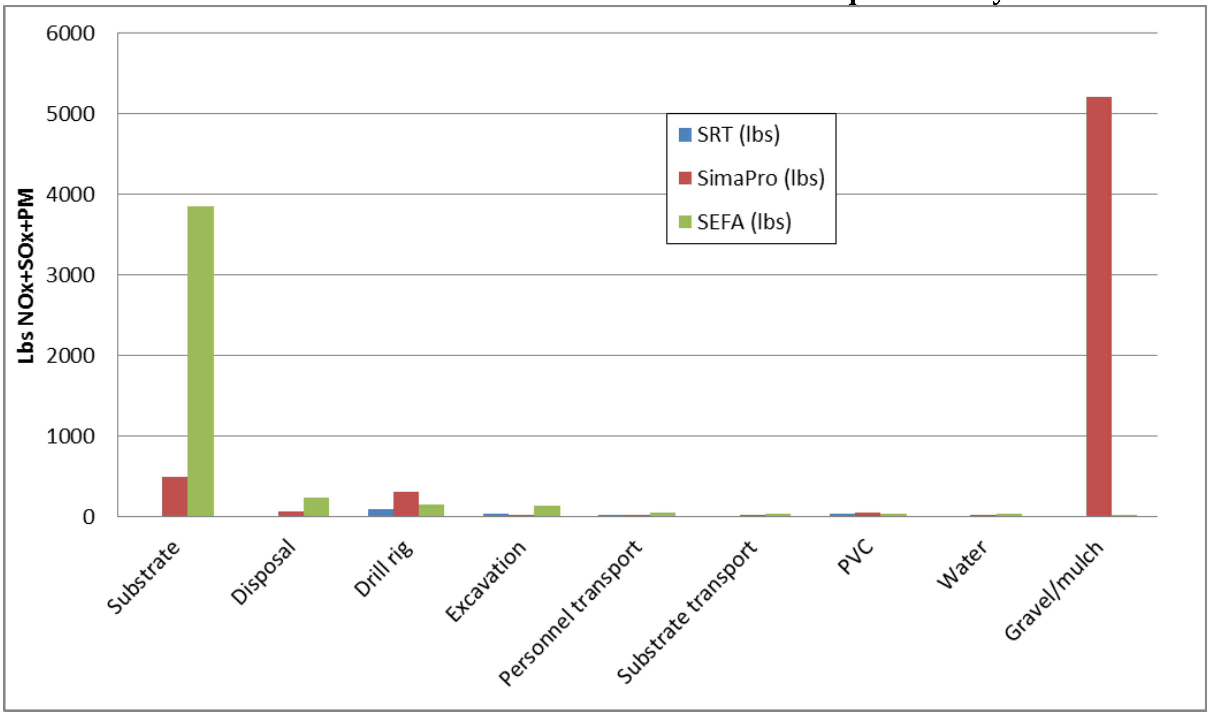


Chart 6. NOx+SOx+PM emission contributions to Alternative 2 (excluding substrate and gravel/mulch) as quantified by each tool

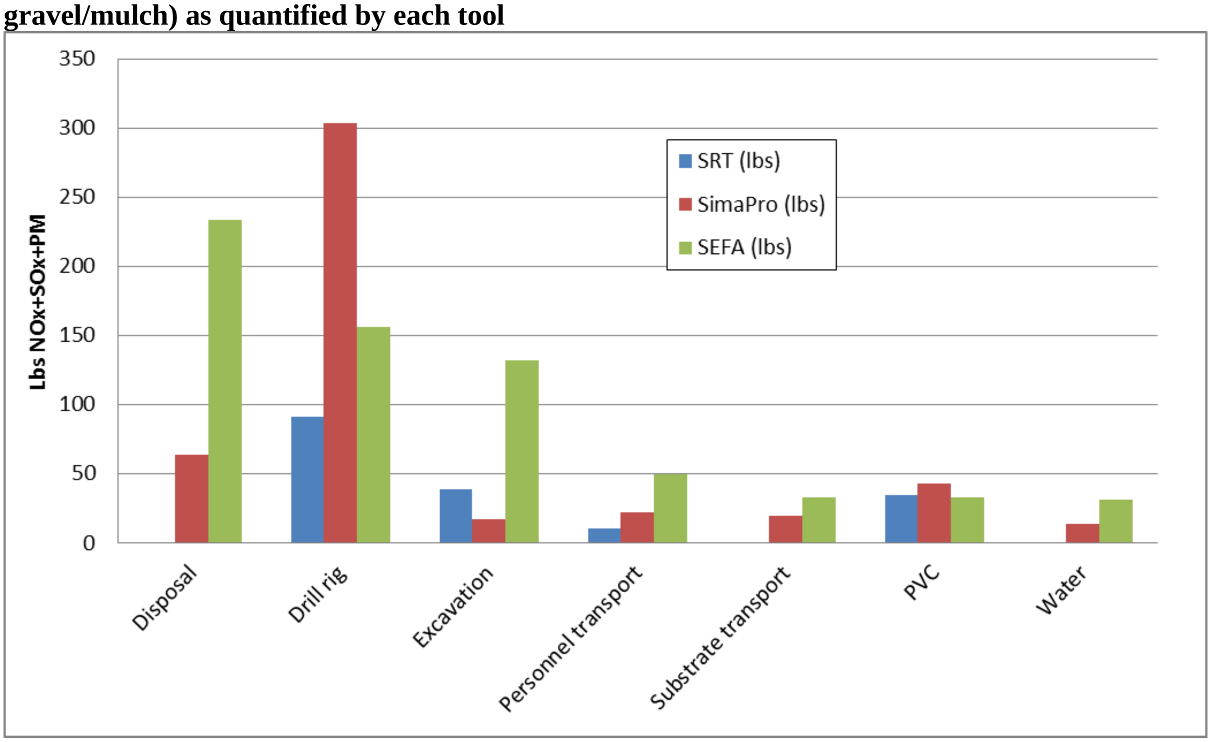


Chart 7. SEFA application with two different input assumptions for groundwater extraction and treatment

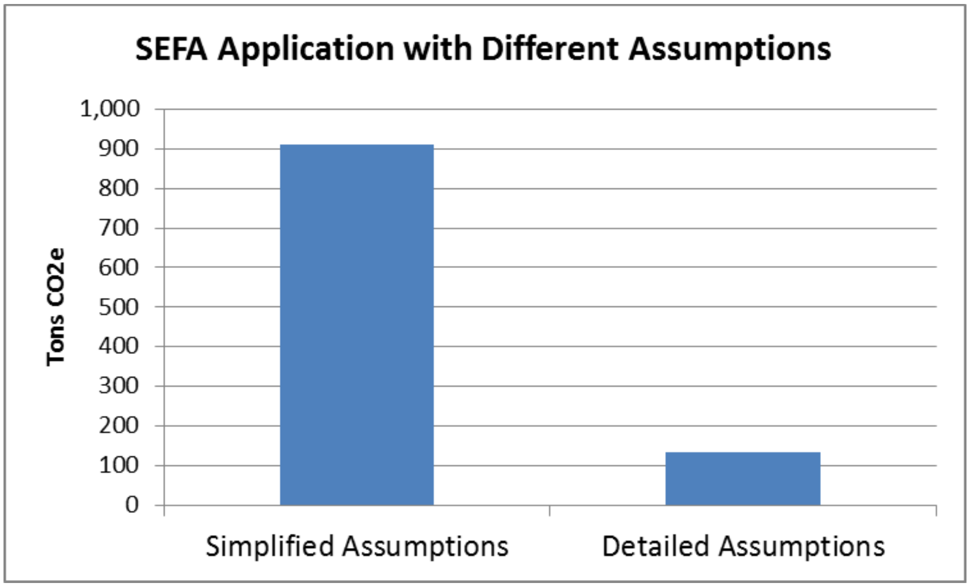


Chart 8. GHG emissions from SEFA application of 1,000 kWh with various assumptions for generation mixes provided by eGRID2012 Version 1.0

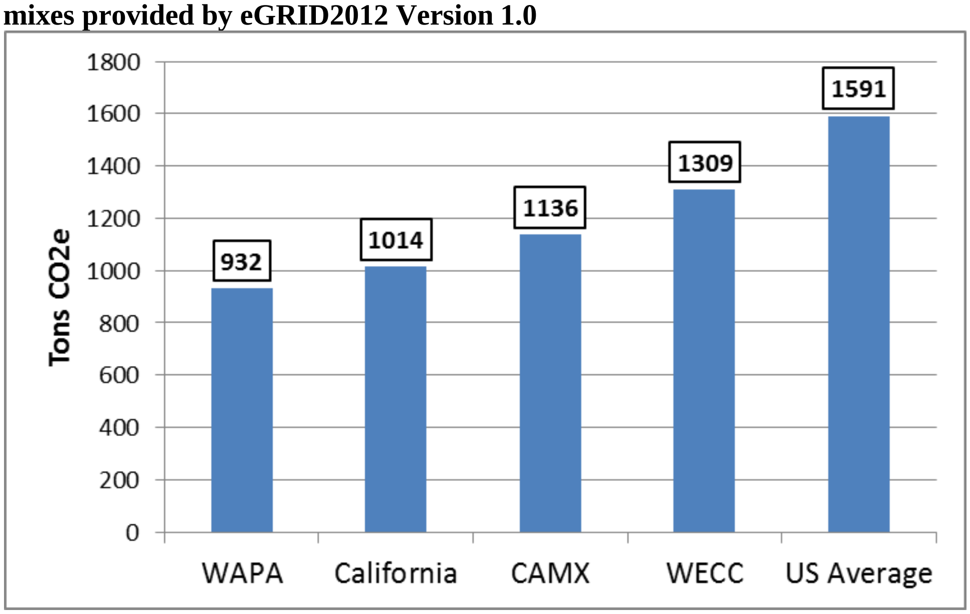


Chart 9. NOx+SOx+PM emissions from SEFA application of 1,000 kWh with various assumptions for generation mixes provided by eGRID2012 Version 1.0

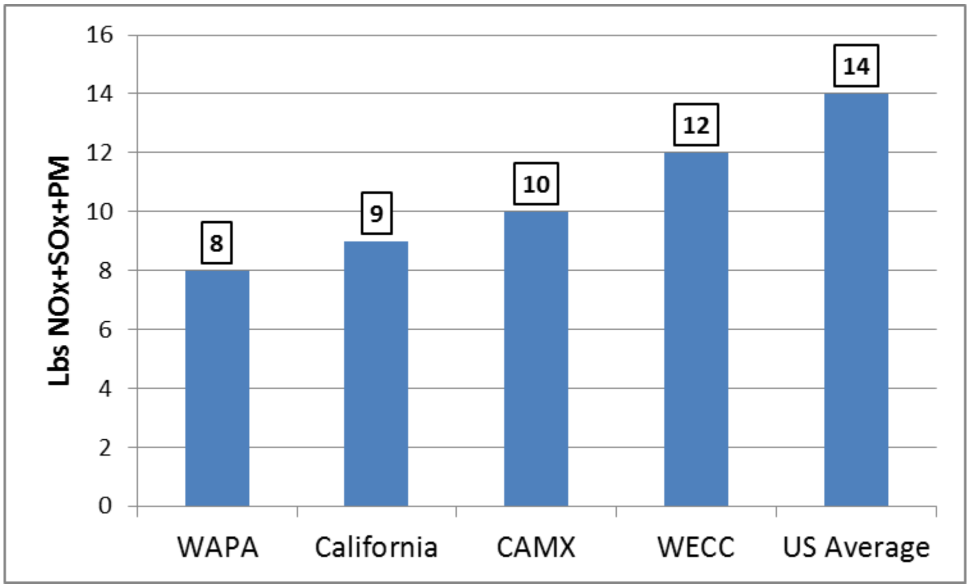


Chart 10. GHG emissions from SEFA application of bioreactor remedy with simplified and detailed assumptions for input parameters

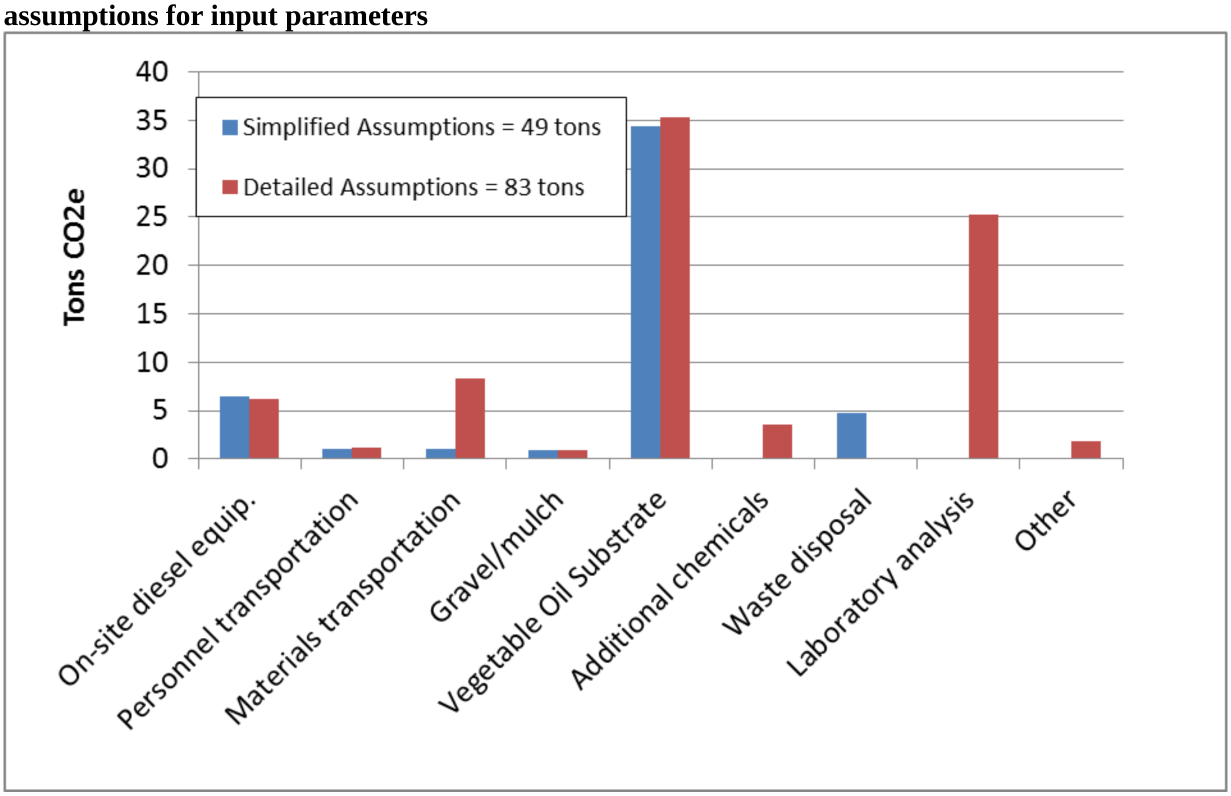
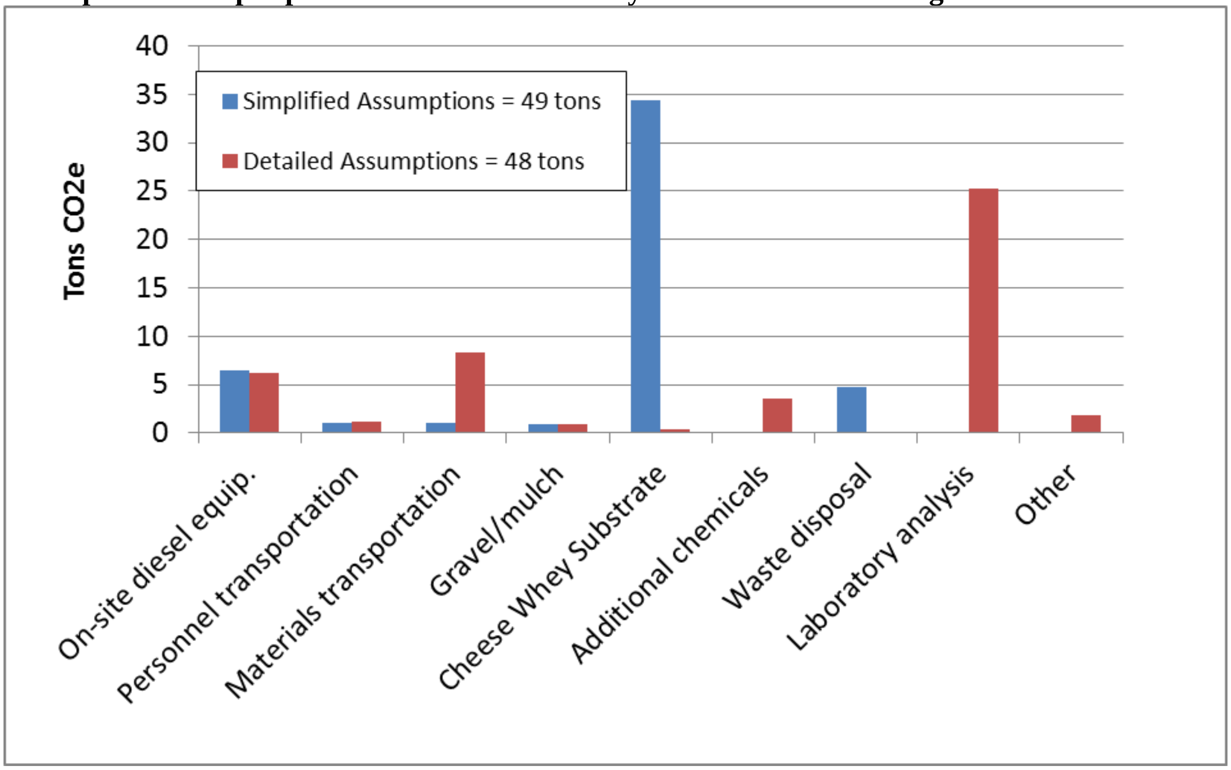


Chart 11. GHG emissions from SEFA application of bioreactor remedy with simplified and detailed assumptions for input parameters and cheese whey substrate instead of vegetable oil substrate



ATTACHMENT A

Summary of Model Input

(Provided by the ESTCP Project with Information Added for SEFA)

Final 2/12/13
Modified with SEFA Input on 5/3/12

Coordination of Site Data Input: Travis Air Force Base, Site DP039 *MODIFIED*

FOR

QUANTIFYING LIFE-CYCLE ENVIRONMENTAL FOOTPRINTS OF SOIL AND GROUNDWATER REMEDIES

ESTCP Project # ER-201127

The content of this coordination file has been modified to include input information for the Spreadsheets for Environmental Footprint Analysis (SEFA) for work conducted by Tetra Tech GEO for the U.S. Environmental Protection Agency (EPA) under Work Assignment #2-73 of EPA contract EP-W-07-078 with Tetra Tech EM, Inc., Chicago, Illinois. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table of Contents

Introduction

Travis Air Force Base, in Solano County, California, serves as Military Air Command Headquarters to the 22nd Air Force, as well as a medical center. It consists largely of runways and related installations. Industrial operations include various shops where aircraft components were cleaned with solvents. Site DP039 consists of a former rock-filled acid neutralization sump located approximately 65 feet (ft) west of Building 755, in the northern portion of the West/Annexes/Basewide Operable Unit (WABOU). Until 1978, a pipeline ran from a sink drain within Building 755 to the sump. Based on preliminary assessment data, Building 755 was originally used to test rocket engines, but only petroleum-based liquid fuel was used at the site as part of rocket engine testing. Since 1968, Building 755 has been the location of the Battery and Electric Shop. Before 1978, battery acid solutions and chlorinated solvents reportedly were discharged into the Building 755 sink and drained to the sump. In July 1993, the sump and surrounding soil were removed and disposed of off-base.

Information and data required for a Green and Sustainable Remediation (GSR) footprint evaluation of the current remedy and one future alternative remedy were developed from the following sources:

- Sustainable Remediation Tool (SRT) Application at Site DP039, Travis Air Force Base, (CH2MHill, March 2012)
- SRT Spreadsheets: “SRT rev2_1_DP39_Alt 1.xls” and “Copy of SRT rev2_1_DP39_Alt 2.xls” (provided by Doug Downey, CHM2Hill by e-mail attachment on 3/12/2012)

The groundwater chemicals of concern (COC) are trichloroethene (TCE), 1,1-Dichloroethene (1,1-DCE) 1,2-Dichloroethane (1,2-DCA), 1,1,1-Trichloroethane (1,1,1-TCA), tetrachloroethene (PCE), methylene chloride, bromodichloromethane, and acetone. TCE is the most prevalent COC for Site DP039. A groundwater contamination plume, with TCE concentrations as high as 500 micrograms per liter (µg/L), extends approximately 1,400 ft downgradient (southeast) of the known source area.

Until 2008, the Site DP039 groundwater extraction system (GETS) consisted of two (2) dual phase extraction (DPE) wells that addressed source area groundwater and soil vapor. In November 2008, both of these extraction wells were taken offline to facilitate construction and operation of a source area bioreactor as an Air Force Center for Engineering and Environment (AFCEE) technology demonstration project. The bioreactor was constructed in an approximately 400-square-foot excavation surrounding one extraction well. The 20 ft deep excavation was backfilled with a 50/50 mixture of gravel and tree mulch sprayed with emulsified vegetable oil (EVO). An extraction well in the immediate area was salvaged and is currently used as a monitoring well for the bioreactor study. One extraction well is located approximately 8 ft downgradient of the edge of the bioreactor and is currently used to circulate groundwater within the bioreactor. This extraction well is equipped with a solar-powered pump which circulates water from the source area and into the top of the bioreactor.

Downgradient of the bioreactor, a large phytoremediation treatability study area has been established. The area consists of 400 tree plantings engineered to hydraulically control and remove volatile organic compound (VOC) mass from the shallow groundwater. A biobarrier consisting of several injection wells has also been constructed and is operated. Monitored natural attenuation (MNA) is assumed for the downgradient portion of the plume.

The SRT was employed to evaluate the following two alternatives offered in the Feasibility Study:

<u>Alternative 1:</u>
This alternative includes the continuation of the GETS system. The extracted water is treated in a larger central treatment system, but for the simplicity of this analysis is assumed to be treated with an air stripper prior to discharge into a nearby creek or to an irrigation system. Since there is currently an interim pumping system on site that can be restarted, metrics considered for the GSR analysis include only those for (1) re-start of the system and (2) operation and maintenance (O&M) of that system. Construction costs are assumed for well replacement only.

<u>Alternative 2:</u>
This alternative includes the discontinuation of the current GETS operations, continued operation of the phytoremediation remedy, construction and operation of the bioreactor, construction and operation of the biobarrier injection wells and MNA for a downgradient portion of the plume.

Alternative 1:
Continuation of GETS and MNA

Overview of Alternative 1

The key items included in Alternative 1 with respect to footprint results are the two groundwater extraction pumps (estimated to continue operation for 30 years) with a combined pumping rate of 2.4 gallons per minute (gpm). The extracted water is treated in a central treatment plant, but for the simplicity of this analysis, the extracted water is assumed to be treated with an air stripper before discharge or use in irrigation. The remedy requires O&M once per week for 30 years and requires semi-annual sampling of 15 monitoring wells for 30 years. The 15 monitoring wells and two extraction wells are assumed to require replacement after 15 years.

Input data to the SRT for Alternative 1 was established in one SRT file. In addition to the "Main Screen Inputs", Alternative 1 was represented in SRT by the Pump and Treat and the MNA/Long Term Monitoring (LTM) modules. The "Main Screen Inputs" included the following:

Groundwater Inputs				
	Zone 1	Zone 2	Zone 3	Zone 4
width (ft)	210	300	500	
length (ft)	400	500	1,400	
Concentration low (µg/L)	500	400	100	
Concentration high (µg/L)	8,000	500	400	
Contaminant class	Chlorinated VOCs (CVOCs)			
Depth to groundwater (ft)	20			
Depth to top of formation (ft)	20			
Thickness of water bearing media (ft)	25			
Aquifer media	Sand (well graded)			
Hydraulic gradient	0.001			

Components of Alternative 1 used in the "Pump and Treat" and "MNA/LTM" modules include the following:

- Electricity: 10 horsepower (HP) (7.5 kilowatts [kW]) is assumed by the site team to provide sufficient electricity to power the remedy, including the following considerations:
  - Two extraction wells have a combined pumping rate of 2.4 gpm and will be operated for 30 years (SRT Application at Site DP039, Results).
  - Water treatment is provided by an air stripper.
  - Operating time equals 8,320 hours per year for 30 years.

- Transport of personnel:
  - O&M visits for the GETS were estimated at 15 miles one way, once a week for 30 years for a sum of 1,560 miles annually (47,000 miles over the 30 year remedy).
  - Semi-annual sampling of 15 monitoring wells is implemented for 30 years, 60 miles per year (30 miles round trip, twice per year [3,600 miles over the 30 year monitoring period]).

- Replacement monitoring wells are implemented as specified by the site team: 15 monitoring wells, each with a depth of 45 ft (for a total depth of 675 ft).

- Replacement of the extraction wells are installed as implied by the site team:
  - Two extraction wells, each with a depth of 55 ft for a total depth of 90 ft
  - 10 ft of steel screen and 45 ft of polyvinyl chloride (PVC) screen
  - 1,300 pounds of steel for steel screen and other steel involved in extraction well construction.

Alternative 2:
Phytoremediation, Bioreactor, Biobarrier, and MNA
(Discontinuation of GETS)

Overview of Alternative 2

The remedy for Alternative 2 assumes that the existing GETS would be permanently removed from service. The remedy would include operation of the on-going phytoremediation remedy, construction and operation of the bioreactor, construction and operation of the biobarrier injection wells and MNA for the downgradient portion of the plume.

Input data to the SRT for Alternative 2 was established in one SRT file. In addition to the "Main Screen Inputs", Alternative 2 was represented in SRT by the Excavation module (Bioreactor and phytoremediation), the Enhanced Bioremediation module (EVO Biobarrier) and the MNA/LTM module. The "Main Screen Inputs" included the following:

Soil/Source Inputs				
Area of affected soil (square feet [ft^2])	420			
Depth to top of affected soil (ft)	1			
Depth to bottom of affected soil (ft)	20			
Depth to groundwater (ft)	20			
Soil type	Silt			
Contaminant class	CVOCs			
Maximum concentration (milligram per kilogram [mg/Kg])	1000			
Typical concentration (mg/Kg)	10			
Groundwater Inputs				
	Zone 1	Zone 2	Zone 3	Zone 4
width (ft)	210	300	400	
length (ft)	400	500	1000	
Concentration low (µg/L)	1,000	700	500	
Concentration high (µg/L)	8,000	1,000	700	
Contaminant class	CVOCs			
Depth to groundwater (ft)	20			
Depth to top of formation (ft)	20			
Thickness of water bearing media (ft)	25			
Aquifer media	Sand (well graded)			
Hydraulic gradient	0.001			

Additional information for Alternative 2 includes the following:

- O&M for the phytoremediation remedy consists of one visit per year for 30 years and is represented using the EXDesign module by adding 30 visits on top of the existing 40 visits for bioreactor O&M.

- The bioreactor construction and operation includes the following information, which is input into SRT in the EXDesign module and EBDesign module:
    - EXDesign Module
        - Construction of the bioreactor includes excavation and disposal of 296 cubic yards (yd^3) of original soil and backfill with mulch/gravel mixture.
        - Contaminated water will be pumped through organic mulch mixture using an existing extraction well powered by solar panels.
        - O&M is assumed to require four visits per year for 10 years (total of 40 visits).
    - EBDesign Module
        - Rejuvenation of the bioreactor uses 500 gallons (gal) of EVO every 2 years for 10 years of operation (a total 2,500 gal added over five events).

- Biobarrier (EBDesign module)
    - Installation of 10 injection wells was included in analysis (with one additional well included in the EBDesign module to account for EVO used in the bioreactor).
    - One initial EVO injection and five follow-up injections are included, with 9,000 gal of substrate injected per event for a total of 54,000 gal.
    - O&M includes semi-annual site visits for performance monitoring for 30 years.

- MNA (MNADesign module)
    - Semi-annual sampling at 30 miles per round trip for 30 years (1,800 miles over the 30 year monitoring period).

Table 1-A: Electricity Use: Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
GET				
Extraction Wells and Air Stripper	• SRT Application at Site DP039 (SRT Alternative 1 Assumptions) includes estimate of 10 HP (7.5 kW) of electricity needed to extract and treat water • SRT Users Guide, pg 54: kWh = power requirement in horsepower x 0.7457 x operating time (hours)	1,900,000 kWh *alt1_energy_(050312).xlsx → Template → Cell G59* *Grid mix shown in Table 1-J entered into alt1_energy_(505312).xlsx → Grid Electricity → Fuel Mix for Grid Electricity*	• 1,900,000 kWh *SimaPro Assembly Name: XX Materials/Assemblies used: 1000 KWh WECC Source Mix AT CONSUMER Amount input: 1,900 p*	Input to "PTDesign" tab of SRT includes: • Purpose – Remediation • Duration – 30 years • Treatment Method – Air Stripping • Total pumping rate – 2.4 gpm

Table 1-B: Fuel Use for Equipment (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
GET				
Fuel Use for Extraction Well Replacement • Drill for extraction well installation • Two extraction wells, 55 ft each	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) • SRT calculates 110 linear feet of drilling, a drilling rate of 100 ft/day, and a fuel consumption rate of 32 gal per day (gpd), for total diesel fuel use of 35 gal. • To calculate fuel use for SimaPro (and inputs for EPA tool) assume 110 ft of drilling with a hollow stem auger (HSA) and use EPA methodology (including production rate of 100 ft per 8-hour day) for fuel consumption: Fuel Use (gal) = HP x hrs x BSFC x PLF = 150 x 8.8 x 0.050 x 0.75 = 49.5 gals (refer to EPA, 2012, pg 59)	Selected "Drilling – medium rig", 150 HP, 75 percent (%) load factor, diesel fuel, 8.8 hours operated *alt1_energy_(050312).xlsx → Template → Row 31*	• Fuel Use = 49.5 gal (diesel) *SimaPro Assembly Name: Fuel use_Alt1_extraction well installation* *Materials/Assemblies used: Diesel, at refinery/l/US* *Amount input: 49.5 gal*[*]	Input to "PTDesign" tab of SRT includes: • Number of wells – Two (2 acres, one well per acre) • Length of PVC per well – 45 ft • Steel casing per well – 10 ft
MNA				
Fuel Use for Monitoring Well Replacement • Drill for monitoring well installation • 15 monitoring wells, 45 ft each	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) • SRT calculates 675 linear feet of drilling, a drilling rate of 100 ft/day, and a fuel consumption rate of 32 gpd, for total diesel fuel use of 216 gal. • To calculate fuel use for SimaPro (and inputs for EPA tool) assume 675 ft of drilling with a HSA and use EPA methodology (including production rate of 100 ft per 8-hour day) for fuel consumption: Fuel Use (gal) = HP x hrs x BSFC x PLF = 150 x 54 x 0.050 x 0.75 = 304 gals (refer to EPA, 2012, pg 59)	Selected "Drilling – medium rig", 150 HP, 75% load factor, diesel fuel, 54 hrs operated *alt1_energy_(050312).xlsx → Template (2) → Row 31*	• Fuel use = 304 gal *SimaPro Assembly Name: Fuel use_Alt1_monitoring well installation* *Materials/Assemblies used: Diesel, at refinery/l/US* *Amount input: 304 gal*[*]	Input to "MNADesign" tab of SRT includes: • Number of wells – 15 • Length of PVC per well – 45 ft

Table 1-C: Materials Use (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		GET		
PVC for extraction well replacement • Two wells • PVC length: 45 feet per well	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) • SRT uses a conversion factor of 2.03 pounds (lbs)/ft of 4-inch PVC, for a total of 180 lbs of PVC • For SimaPro, use the same amount of PVC as calculated by SRT • EPA Methodology (Exhibit 3.6) uses a conversion factor of 2.012 lbs/ft of 4-inch PVC casing, for a total of ~180 lbs of PVC	PVC, 180 lbs *alt1_energy_(050312).xlsx → Template → Row 67* 180 lbs of refined materials, 0% recycled *alt1_main_(050312).xlsx → Materials 1 → Row 9*	• 180 lbs of PVC *SimaPro Assembly Name: PVC_Alt1_extraction wells* *Materials/Assemblies used: PVC pipe E* *Amount input: 180 lbs*	Input to "PTDesign" tab of SRT includes: • Number of wells – Two (2 acres, one well per acre) • Length of PVC per well – 45 ft
Steel for extraction wells screens and other items	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) ○ Two wells ○ 10 ft of steel pipe per well ○ 50 lbs other steel per well ○ 950 lbs of other steel for system ○ Total of 1300 lbs of steel • EPA Methodology (Exhibit 3.6) uses a conversion factor of 10.79 lbs/ft of steel casing, for a total of 1,266 lbs of steel (round to nearest l00 lbs)	Steel, 1,300 lbs *alt1_energy_(050312).xlsx → Template → Row 68* 1,300 lbs of refined materials, 0% recycled *alt1_main_(050312).xlsx → Materials 1 → Row 10*	• 1,300 lbs of steel *SimaPro Assembly Name: Steel, low-alloyed, at plant/RER S* *Materials/Assemblies used: PVC pipe E* *Amount input: 1,300 lbs*	Input to "PTDesign" tab of SRT includes: • Number of wells – Two (2 acres, one well per acre) • 10 ft of steel pipe per well • 50 lbs other steel per well • 950 lbs of other steel for system
		MNA		
PVC for monitoring well replacement • 15 wells • Well length: 45 ft per well	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) ○ 15 wells ○ 45 ft per well ○ 2.03 lbs of PVC per foot (assumes a 4-inch well) ○ round to nearest 100 lbs • EPA Methodology (Exhibit 3.6) uses a conversion factor of 2.012 lbs/ft of 4-inch PVC casing, for a total of 1,358 lbs of PVC (round to nearest 100 lbs)	PVC, 1,400 lbs *alt1_energy_(050312).xlsx → Template (2) → Row 67* 1,400 lbs of refined materials, 0% recycled *alt1_main_(050312).xlsx → Materials 2 → Row 9*	• 1,400 lbs of PVC *SimaPro Assembly Name: PVC_Alt1_Monitoring Wells* *Materials/Assemblies used: PVC pipe E* *Amount input: 1400 lbs*	Input to "MNADesign" tab of SRT includes: • Number of wells – 15 • Length of PVC per well – 45 ft

Table 1-D: Transport for Materials, Equipment, and Samples: Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
Transport of PVC and steel for extraction well and monitoring well replacement	PVC and steel are assumed to be transported to the site by the driller. Driller transport is considered de minimis for EPA Tool and SimaPro and is not calculated by SRT.			

Table 1-E: Waste Transport/Disposal: Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
Drill cuttings	Drill cuttings are assumed to be spread at the drilling location. Therefore, there is no input to the EPA Tool or SimaPro for this item.			

Table 1-F: Transport for Personnel Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		GET		
Vehicle use for O&M • O&M is assumed to require weekly visits for 30 yrs (1,560 trips total), with 30 mile round trips	• SRT Application at Site DP039, "Sustainability metrics for vehicle use for GETS O&M" • SRT input file (SRT rev2_1_DP39_Alt 1.xls) • SRT assumes 15 miles per gallon (mpg) (cell E109 on PTDesign tab)	O&M labor, assumed 1-person crew, 1,560 days worked, assumed 8 hrs per day, 1,560 roundtrips, 30 miles roundtrip, assume car, gasoline *alt1_energy_(050312).xlsx → Template → Row 16*	• 1,560 trips of 30 miles round trip = 46,800 miles • Assume car, gasoline *SimaPro Assembly Name: Transport Personnel_Alt1_O&M Process used: Transport, passenger car/RER U Amount input: 46800 pmi*	Input to "PTDesign" tab of SRT includes: Average distance traveled by site workers per one-way trip – 15 miles; trips by site workers after construction – 1,560 over project lifetime; duration – 30 yrs In SRT, gasoline use = 47,000 miles traveled / 15 mpg = 3,134 gal
Vehicle used for well replacement	• Not calculated by SRT • Considered to be de minimis for SimaPro and EPA Tool			
		MNA		
Vehicle use for well sampling • Assumes semi-annual sampling, 30 miles round trip (60 miles annually), for 30 yrs	• SRT Application at Site DP039, "Sustainability metrics for vehicle use for semi-annual sampling" • SRT input file (SRT rev2_1_DP39_Alt 1.xls) ○ Zero baseline events ○ Two events in the first yr ○ Two events per yr in subsequent yrs ○ Sampling for 30 yrs	sampling labor, assumed 2-person crew, 60 days worked, assumed 8 hrs per day, 60 roundtrips, 30 miles roundtrip, assume light-duty truck, gasoline *alt1_energy_(050312).xlsx → Template (2) → Row 16*	• 1,800 miles • Assume small truck, gasoline *SimaPro Assembly Name: Transport Personnel_Alt1_sampling Process used: Transport, passenger car/RER U Amount input: 1800 pmi*	Input to "MNADesign" tab of SRT includes: • Zero baseline events • Two events in the first year • Two events per year in subsequent years • Sampling for 30 years
Vehicle used for well replacement	• Not calculated by SRT • Considered to be de minimis for SimaPro and EPA Tool			

Table 1-G: Potable Water Use Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
Potable water use for well drilling, equipment decontamination, and groundwater sampling is	This item is assumed to be de minimis. Therefore, there is not input to the EPA Tool or SimaPro for this item.			

Table 1-H: Non-Potable Water Use Alternative 1 (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
No significant non-potable water use identified other than groundwater extraction for treatment. Therefore, there is not input to the EPA Tool or SimaPro for this item.				

Table 1-I: Known Use of On-Site Renewables (GETS/MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
None	No inputs are included for this item.			

**Does not include percentage of renewable energy associated with electricity mix from grid*.

Table 1-J: eGRID Subregion CAMX—WECC California, 2005 Characteristics

Electricity Source	Fuel Mix %	Megawatt-hours (MWh)
Nonrenewable Resource		
Coal	11.9033	26,141,141.50
Oil	1.1747	2,579,750.70
Gas	42.2704	92,830,630.50
Other Fossil	1.0291	2,259,976.30
Nuclear	16.4631	36,154,898.00
Other Unknown / Purchased Fuel	0.0943	207,005.90
Nonrenewable Total	72.9348	160,173,402.90
Renewable Resource		
Wind	1.9396	4,259,490.6
Solar	0.2444	536,713.3
Geothermal	4.6211	10,148,526.6
Biomass	2.6088	5,729,247.8
Hydro	17.6513	38,764,274.9
Renewable Total	27.0652	59,438,253.3

Table 2-A: Electricity Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
None noted. Solar panels provide the electrical power to the extraction well pump for the recirculation through the bioreactor.	• SRT Application at Site DP039, "Bioreactor"	None	None	none

Table 2-B: Fuel Use for Equipment: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		ISB		
Excavator and dump truck for construction of 296 yd^3 bioreactor	• SRT input file (Copy of SRT rev2_1_DP39_Alt 2.xls) • SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • At 95 lbs per ft^3 (SRT, EXDesign cell E41), affected soil = 296 yd^3 x 2565 lbs per yd^3 = 759,000 lbs or 380 tons	Assumed "Excavator – medium", 175 HP, 75% load factor, diesel fuel, 3.3 hours operated (based on production rate of 720 yd^3/day, assuming 8 hour days) *alt2_energy_(050312).xlsx → Template (2) → Row 31* Selected "Dump truck", 400 HP, 75% load factor, diesel fuel, 33 hours operated (based on 1,320 total miles driven, assuming avg. 40 mph) *alt2_energy_(050312).xlsx → Template (2) → Row 32*	• Excavator • Removal of 296 yd3 and • Dump Truck, to landfill • 10 miles, one way • 10 miles x 380 tons = 3,800 tmi *Empty return trip included in SimaPro calculations* *SimaPro Assembly Name: Fuel use_Alt2_Equip for construction Materials/Assemblies used: Excavation, hydraulic digger/RER U (296 yd^3) and Transport, lorr 7.5-16t, EURO5/RER U (3800tmi*)*	Input to "EXDesign" tab of SRT includes: • Volume of affected soil – 296 yd^3 • one-way distance to disposal – 10 miles • total miles driven for disposal and fill – 1,320 miles SRT calculates total hours to excavate = volume of affected soil (296 yd^3, or 7,980 ft^3) x soil density (95 lbs/ ft^3) x (1 ton / 2,000 lbs) x (1 / rate of excavation of 53 tons/hr) = 7.2 hrs SRT calculates total diesel use based on an excavator fuel consumption rate of 3 gal/hr, a dump truck fuel use rate of 8 mpg, for a total of 200 gal diesel
		Biobarrier		
Drill for installation of biobarrier EVO 50-ft deep injection wells (10 wells)	• SRT input file (Copy of SRT rev2_1_DP39_Alt 2.xls) • To calculate fuel use for SimaPro (and inputs for EPA tool) assume 500 ft of drilling (10 wells) with a HSA and use EPA methodology (including production rate of 100 ft per 8-hour day): Fuel Use (gal) = HP x hrs x BSFC x PLF = 150 x 40 x 0.050 x 0.75 = 225 gals (refer to EPA, 2012, pg 59)	Selected "Drilling – medium rig", 150 HP, 75% load factor, diesel fuel, 40 hrs operated *alt2_energy_(050312).xlsx → Template (3) → Row 31*	• Fuel use= 225 gallons *SimaPro Assembly Name: Fuel use_Alt2_EVO wells Materials/Assemblies used: Diesel, at refinery/l/US Amount input: 225 gal**	Input to "EBDesign" tab of SRT includes: • Area treated – 4,000 ft^2 • Injection well spacing – 23 ft • Calculated value of 10 wells • Length of PVC: 50 ft per well SRT calculates 500 linear feet of drilling, a drilling rate of 100 ft/day, and a fuel consumption rate of 32 gpd, for total diesel fuel use of 160 gallons.

Table 2-B: Fuel Use for Equipment: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA) – CONTINUED

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		MNA		
Fuel Use for Monitoring Well Replacement (same as Alternative 1) • Drill for monitoring well installation • 15 monitoring wells, 45 ft each	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) • SRT calculates 675 linear feet of drilling, a drilling rate of 100 ft/day, and a fuel consumption rate of 32 gpd, for total diesel fuel use of 216 gallons. • To calculate fuel use for SimaPro (and inputs for EPA tool) assume 675 ft of drilling with a hollow stem auger and use EPA methodology (including production rate of 100 ft per 8-hour day) for fuel consumption: Fuel Use (gal) = HP x hrs x BSFC x PLF = 150 x 54 x 0.050 x 0.75 = 304 gals (refer to EPA, 2012, pg 59)	Selected "Drilling – medium rig", 150 HP, 75% load factor, diesel fuel, 54 hours operated *alt2_energy_(050312).xlsx → Template (4) → Row 31*	• Fuel use = 304 gallons *SimaPro Assembly Name: Fuel use_Alt1_monitoring well installation* *Materials/Assemblies used: Diesel, at refinery/l/US* *Amount input: 304 gal**	Input to "MNADesign" tab of SRT includes: • Number of wells – 15 • Length of PVC per well – 45 ft

Table 2-C: Materials Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		Phytoremediation		
Fertilizer for phytoremediation	• Considered to be de minimis for SimaPro and EPA Tool • Not calculated by SRT			
		ISB and Biobarrier		
Mulch/gravel backfill, assumed to be 296 yd^3	• SRT input file (Copy of SRT rev2_1_DP39_Alt 2.xls) • SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • 50/50 mix of mulch/gravel (according to "Current Remedy" section of SRT document) • Bulk density of mulch = 0.4 tons per yd^3 (EPA, 2012) • Bulk density of gravel = 1.5 tons per yd^3	Bioreactor – Other unrefined construction materials, 118,000 lbs *alt2_energy_(050312).xlsx → Template (2) → Row 67* 118,000 lbs of unrefined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 2 → Row 56* -------- Biobarrier – Gravel/sand/clay, 444,000 lbs *alt2_energy_(050312).xlsx → Template (2) → Row 68* 444,000 lbs of unrefined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 2 → Row 57*	• Mulch: 150 yd^3 x 0.4 tons per yd^3 = 59 tons and • Gravel 150 yards x 1.5 tons per yd^3 = 222 tons *SimaPro Assembly Name: Material_Alt2_mulch/gravel Materials/Assemblies used: Bark mulch, at oriented strand board production, US SE/kg/US (59 tn.sh) and Gravel, unspecified, at mine/XH S (222 tn.sh)*	• SRT does not account for footprint of gravel or mulch

Table 2-C: Materials Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA) – CONTINUED

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
PVC for 10 biobarrier injection wells	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" states 50 ft per injection well for 10 wells for a total of 500 ft. • SRT uses a conversion factor of 2.03 lbs/ft of 4-inch PVC for 1,000 lbs of PVC • For SimaPro, use the same amount as calculated by SRT • EPA Methodology (Exhibit 3.6) uses a conversion factor of 2.012 lbs/ft of 4-inch PVC casing, for a total of ~1,000 lbs	PVC, 1,000 lbs *alt2_energy_(050312).xlsx → Template (3) → Row 70* 1,000 lbs of refined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 3 → Row 10*	• 1,000 lbs of PVC *SimaPro Assembly Name: PVC_Alt2_injection wells* *Materials/Assemblies used: PVC pipe E* *Amount input: 1,000 lbs*	Input to "EBDesign" tab of SRT includes: • Area treated – 4,000 ft^2 • Injection well spacing – 23 ft • Calculated value of 10 wells • Length of PVC – 50 ft • SRT uses a conversion factor of 2.03 lbs/ft of PVC, for a total of 1,000 lbs of PVC

Table 2-C: Materials Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA) – CONTINUED

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
EVO for bioreactor and biobarrier	• SRT input file (Copy of SRT rev2_1_DP39_Alt 2.xls) • SRT Application at Site DP039 states bioreactor will require rejuvenation with 500 gallons of EVO every 2 years for 10 years of bioreactor operation (2,500 gallons total) • SRT Application at Site DP039 states biobarrier will require an initial injection plus five follow-up injections, with 9,000 gallons EVO per event (54,000 gal total, calculated by SRT) • Total EVO used throughout remedy = 2,500 + 54,000 gallons = 56,500 gallons of EVO • SRT uses a default density for "donor" of 7.89 lbs per gal	Emulsified vegetable oil, 20,000 lbs after rounding (assuming density of 7.89 lbs per gal * 2500 gal) *alt2_energy_(050312).xlsx → Template (2) → Row 69* 20,000 lbs of refined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 2 → Row 9* ------ Emulsified vegetable oil, 430,000 lbs after rounding (assuming density of 7.89 lbs per gal * 54,000 gal) *alt2_energy_(050312).xlsx → Template (3) → Row 69* 430,000 lbs of refined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 3 → Row 9*	• 56,500 gallons of vegetable oil x 7.89 lbs/gal = 450,000 lbs after rounding *SimaPro Assembly Name: Materials_Alt2_EVO* *Materials/Assemblies used: Vegetable oil methyl ester, at esterification lant/FR U* *Amount input: 450,000 lbs*	Input to "EBDesign" tab of SRT includes: Substrate volume for biobarrier calculated by SRT based on aquifer volume. The following entries were modified to account for multiple follow-up injections and also include substrate needed for bioreactor (since the excavation tab does not allow inclusion of bioremediation substrate): • Area treated – 4,000 ft^2 • Volume treated – 755,300 ft^3 ○ Volume of 120,000 ft^3 for one biobarrier injection ○ Multiply by 6 to account for six injections ○ Additional volume to account for bioreactor These inputs yield a total calculated volume of 57,000 gallons of EVO after rounding and a weight of 450,000 lbs after rounding

Table 2-C: Materials Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA) – CONTINUED

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		MNA		
PVC for monitoring well replacement • 15 wells • Well length: 45 ft per well	• SRT input file (SRT rev2_1_DP39_Alt 1.xls) ○ 15 wells ○ 45 ft per well ○ 2.03 lbs of PVC per foot (assumes a 4-inch well) ○ round to nearest 100 lbs • EPA Methodology (Exhibit 3.6) uses a conversion factor of 2.012 lbs/ft of 4-inch PVC casing, for a total of 1,358 lbs of PVC (round to nearest 100 lbs)	PVC, 1,400 lbs *alt2_energy_(050312).xlsx → Template (4) → Row 67* 1,400 lbs of refined materials, 0% recycled *alt2_main_(050312).xlsx → Materials 4 → Row 9*	• 1,400 lbs of PVC *SimaPro Assembly Name: PVC_Alt1_Monitoring Wells* *Materials/Assemblies used: PVC pipe E* *Amount input: 1,400 lbs*	Input to "MNADesign" tab of SRT includes: • Number of wells – 15 • Length of PVC per well – 45

Table 2-D: Transport for Materials, Equipment, and Samples: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		ISB, Biobarrier and MNA		
Transport of PVC for wells	• Assumed to be transported to site by driller. Driller transport is considered de minimis for SimaPro and EPA tool and is not calculated by SRT			
EVO Transport	• See Table 2-C for EVO amounts: • 450,000 lbs total ○ 20,000 lbs for bioreactor ○ 430,000 lbs of biobarrier • Divide by 2,000 pounds per ton = 225 tons • Tetra Tech estimate of 50 miles one-way for delivery	Bioreactor EVO – site-specific one-way distance of 50 miles, 5 trips to site, truck (mpg), diesel empty return trip added as separate entry *alt2_energy_(050312).xlsx → Template (2) → Rows 69&70* -------- Biobarrier EVO – site-specific one-way distance of 50 miles, six trips to site, truck (mpg), diesel empty return trip added as separate entry *alt2_energy_(050312).xlsx → Template (3) → Rows 67&68*	• 50 x 225 tons = 11,250 tmi *Empty return trips accounted for in SimaPro* *SimaPro Assembly Name:Transport_Al2_EVO biobar and bioreact* *Process used: Transport, lorry >32t, EURO5/RER U* *Amount input: 11,250 tmi**	Transport of bioremediation reagents is not calculated by SRT.

Table 2-E: Waste Transport/Disposal: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		ISB		
296 yd^3 of affected soil from bioreactor excavation was disposed of within 10 miles of the site	• See Table 2-B for tons of soil for disposal (380 tons)	Non-hazardous waste, 380 tons Transport included in Table 2-B *alt2_energy_(050312).xlsx → Template (2) → Row 89* Non-hazardous waste, "Affected soil from bioreactor excavation sent to landfill", 380 tons *alt2_main_(050312).xlsx → Waste 2 → Row 47*	• Transport included in Table 2-B and • Disposal to landfill: 380 tons *SimaPro Disposal Scenario Name: Disposal of Excavated Soil to Landfill Referring to Assembly: Dummy soil excavated* *Waste Scenario: Landfill/CH U* *Amount input: 100%*	Dump truck fuel use accounted for above. SRT does not include any additional footprints for landfilling of waste materials.

Table 2-F: Transport for Personnel: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		Phytoremediation		
O&M	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • One trip annually for 30 years • 15 miles each way (30 mile round trip)	phytoremediation O&M labor, assumed 1-person crew, 30 days worked, assumed 8 hrs per day, 1,560 roundtrips, 30 miles roundtrip, assume car, gasoline *alt2_energy_(050312).xlsx → Template → Row 16*	• 30 trips x 30 miles = 900 miles *SimaPro Assembly Name: Transport Personnel_Alt2_phytoremediatio n* *Process used: Transport, passenger car/RER U* *Amount input: 900 pmi*	Input to "EXDesign" tab of SRT includes: • Average distance traveled by site workers per one-way trip – 15 miles • Trips by site workers after construction is 70, of which 30 is for phytoremediation and 40 is for bioreactor (see below)
		ISB		
Construction	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • 30 trips during construction • 15 miles each way (30 mile round trip)	Construction labor, assumed 1-person crew, 30 days worked, assumed 8 hrs per day, 30 roundtrips, 30 miles roundtrip, assume car, gasoline *alt2_energy_(050312).xlsx → Template (2) → Row 16*	• 30 trips x 30 miles = 900 miles *SimaPro Assembly Name: Transport Personnel_Alt2_phytoremediatio n* *Process used: Transport, passenger car/RER U* *Amount input: 900 pmi*	Input to "EXDesign" tab of SRT includes: • Average distance traveled by site workers per one-way trip – 15 miles • Trips by site workers during construction is 30
O&M	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • Four trips annually for 10 years • 15 miles each way (30 mile round trip)	O&M labor, assumed 1-person crew, 40 days worked, assumed 8 hrs per day, 40 roundtrips, 30 miles roundtrip, assume car, gasoline *alt2_energy_(050312).xlsx → Template (2) → Row 17*	• 40 trips x 30 miles = 1,200 miles *SimaPro Assembly Name: Transport Personnel_Alt2_phytoremediatio n* *Process used: Transport, passenger car/RER U* *Amount input: 1,200 pmi*	Input to "EXDesign" tab of SRT includes: • Average distance traveled by site workers per one-way trip – 15 miles • Trips by site workers after construction is 70, of which 30 is for phytoremediation and 40 is for bioreactor (see above)

Table 2-F: Transport for Personnel: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA) – CONTINUED

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
Biobarrier				
Construction	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • 30 trips during construction • 15 miles each way (30 mile round trip)	Construction labor, assumed 1-person crew, 30 days worked, assumed 8 hrs per day, 30 roundtrips, 30 miles roundtrip, assume car, gasoline *alt2_energy_(050312).xlsx → Template (3) → Row 16*	• 30 trips x 30 miles = 900 miles *SimaPro Assembly Name: Transport Personnel_Alt2_phytoremediation* *Process used: Transport, passenger car/RER U* *Amount input: 900 pmi*	Input to "EBDesign" tab of SRT includes: • Average distance traveled by site workers per one-way trip – 15 miles • Trips by site workers during construction is 30
O&M	• SRT Application at Site DP039, "Sustainability metrics for Bioreactor Construction and O&M activities" • Semi-annual trips for 30 years for site visits and performance monitoring (60 trips) • 15 miles each way (30 mile round trip)	O&M labor, assumed 1-person crew, 60 days worked, assumed 8 hrs per day, 60 roundtrips, 30 miles roundtrip, assume car, gasoline *alt2_energy_(050312).xlsx → Template (3) → Row 17*	• 1,800 miles traveled • Assume small truck, gasoline *SimaPro Assembly Name: Transport Personnel_Alt2_biobarrier* *Process used: Transport, passenger car/RER U* *Amount input: 1800pmi*	Input to "EBDesign" tab of SRT includes: • Average distance traveled by site workers per one-way trip – 15 miles • Trips by site workers after construction is 60
MNA				
Vehicle use for well sampling • Assumes semi-annual sampling, 30 mile round trip (60 miles annually), for 30 years	• SRT Application at Site DP039, "Sustainability metrics for vehicle use for semi-annual sampling" • SRT input file (SRT rev2_1_DP39_Alt 1.xls) ○ Zero baseline events ○ Two events in the first year ○ Two events per year in subsequent years ○ Sampling for 30 years	sampling labor, assumed two-person crew, 60 days worked, assumed 8 hrs per day, 60 roundtrips, 30 mile roundtrip, assume light-duty truck, gasoline *alt1_energy_(050312).xlsx → Template (2) → Row 16*	• 1,800 miles • Assume small truck, gasoline *SimaPro Assembly Name: Transport Personnel_Alt1_sampling* *Process used: Transport, passenger car/RER U* *Amount input: 1,800 pmi*	Input to "MNADesign" tab of SRT includes: • Zero baseline events • Two events in the first year • Two events per year in subsequent years • Sampling for 30 years
Vehicle used for well replacement	• Not calculated by SRT • Considered to be de minimis for SimaPro and EPA Tool			

Table 2-G: Potable Water Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		ISB and Biobarrier		
Water use for EVO injections	Tetra Tech estimate: assume a 5% donor solution is injected. 450,000 lbs divided by 5% is 9,000,000 lbs of which 95% is water. Water is 8.34 lbs per gallon such approximately 1,000,000 gallons of water is used. (4.4% of which is for the bioreactor and 95.6 % of which is for the biobarrier)	Bioreactor – Public water, 44.4 gal x 1000 *alt2_energy_(050312).xlsx → Template (2) → Row 71* public supply water, potable, 44.4 gal x 1,000, bioreactor donor solution, injected to ground *alt2_main_(050312).xlsx → Water 2 → Row 8* ----- Biobarrier – Public water, 955.6 gal x 1,000 *alt2_energy_(050312).xlsx → Template (3) → Row 69* public supply water, potable, 955.6 gal x 1,000; biobarrier donor solution, injected to ground *alt2_main_(050312).xlsx → Water 3 → Row 8*	• 1,000,000 gal of potable water	The footprint associated with potable water use is not calculated by the EBDesign module in SRT.

Table 2-H: Non-Potable Water Use: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
No significant non-potable water use identified other than groundwater extraction for treatment.				

Table 2-I: Known Use of On-Site Renewables: Alternative 2 (Phytoremediation, ISB, Bioreactor, and MNA)

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to EPA Tool	Input Values to SimaPro	Input Values to SRT
		ISB		
• Solar powered pump for recirculation of extracted water for bioreactor • Consists of five 50-watt, 17.4V solar panels	(for EPA Tool inputs only): 5x50 watts = 250 watts ~1,300kWh/kW installed 1,300kWh/kW x 0.25kW = 325kWh/yr x 10 years of operation = 3,250 kwh	3,250 kWh *alt2_energy_(050312).xlsx → Template (2) → Cell G58*		The use of renewable energy is not represented in SRT.

**Does not include percentage of renewable energy associated with electricity mix from grid*