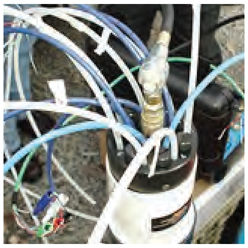
– Wisconsin Initiative for Sustainable Remediation and Redevelopment –

Green & Sustainable Remediation Manual

A Practical Guide to Green and Sustainable Remediation in the State of Wisconsin



WISCONSIN DEPT. OF NATURAL RESOURCES

Remediation and Redevelopment Program

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PURPOSE AND BACKGROUND

This guidance document is intended for use by the Department of Natural Resources (DNR), other state agency staff, responsible parties (RPs), consultants, and other interested parties. The primary purpose of this document is to provide information on sustainable cleanup practices at contaminated properties. This document is written to address both new sites and sites where existing systems are operating. It may be used along with published references and guidance documents, information from training courses and current professional journals. The material presented is based on available information and the knowledge and experience of the authors and the peer reviewers. The reader is referred to DNR's Bureau for Remediation and Redevelopment NR 700 rule series, along with supporting brownfields redevelopment and technical guidance on soil and groundwater contamination, site investigation, remediation and case closure.

DISCLAIMER

This document is intended solely as guidance and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or DNR. Any regulatory decisions made by DNR in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

This guidance may be more complete when used in conjunction with other documents prepared by the Bureau for Remediation and Redevelopment staff. These documents are found at: http://dnr.wisconsin.gov/org/aw/rr/archives/pub_index.html. Guidance documents may also be obtained by sending a request to Public Information Requests, Bureau for Remediation and Redevelopment, Department of Natural Resources, P.O. Box 7921, Madison WI 53707.

This guidance will be updated as needed. Comments and concerns may be sent to "GSR Guidance," Tom Coogan – RR/5, DNR, P.O. Box 7921, Madison, WI 53707, or to Thomas.coogan@wisconsin.gov.

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List of Acronyms

AC	Alternating current
AFCEE	Air Force Center for Engineering and Environment
ARARs	Applicable or relevant and appropriate requirements
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BMPs	Best management practices
BTU	British thermal unit
C&D	Construction and demolition
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFC	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DC	Direct current
DFS	Department of State Facilities
DNR	Wisconsin Department of Natural Resources
DO	Dissolved oxygen
DSIRE	Database for State Incentives for Renewables and Efficiency
EIA	Energy Information Administration
GAC	Granular activated carbon
GHG	Greenhouse gas
GSR	Green and sustainable remediation
GTP	Geothermal Technologies Program
HFCs	Hydrofluorocarbons
HVAC&R	Heating, ventilation, air conditioning and refrigeration
IDW	Investigative derived waste
IPCC	Intergovernmental Panel on Climate Change
ITRC	Interstate Technology & Regulatory Council
kWh	Kilowatt hour
LCA	Life cycle assessment
LEED	Leadership in Energy and Environmental Design
LFG	Landfill gas

LMOP	Landfill Methane Outreach Program
LU/ICs	Land use and institutional controls
LUST	Leaking underground storage tank
MREA	Midwest Renewable Energy Association
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
N_2O	Nitrous oxide
NO_x	Nitrogen oxide emissions
NREL	National Renewable Energy Laboratory
OEI	Office of Energy Independence
O&M	Operation and maintenance
OM&M	Operations, monitoring and maintenance
ORP	Oxidation reduction potential
PFCs	Perfluorocarbons
PM10	Particulate matter (particles with diameter of 10 micrometers or less)
PV	Photovoltaic
RACER™	Remedial Action Cost Engineering Requirements
RCRA	Resource Conservation and Recovery Act
RP	Responsible party
RPO	Remedial Process Optimization
RR	Remediation and Redevelopment
SERG	Smart Energy Resources Guide
SF_6	Sulfur hexafluoride
SO_x	Sulfur oxide emissions
SRT	Sustainable remediation tool
SURF	Sustainable Remediation Forum
SVE	Soil vapor extraction
TCE	Trichloroethylene
U.S. EPA	United States Environmental Protection Agency
UST	Underground storage tank
WBCSD	World Business Council for Sustainable Development
WISC	Wisconsin Initiative for Sustainable Cleanups
WISRR	Wisconsin Initiative for Sustainable Remediation and Redevelopment
WRI	World Resources Institute

1.0 Introduction

In April 2007, Wisconsin Department of Natural Resources (DNR) personnel attended the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) mid-year conference that focused on how sustainable activities can be applied to environmental cleanups. The Bureau of Remediation and Redevelopment (RR) Director, Mark Giesfeldt, thought that the concept of applying sustainability to environmental cleanups was an important step for DNR to explore.

In July 2007, the DNR Bureau for Remediation & Redevelopment decided to explore incorporating a "sustainable aspect" into environmental cleanups, emphasizing the application of green technologies to clean up contaminated sites. The sustainable aspect occurs at the nexus of the environmental, economic and social/community pillars of the state's environmental cleanup program (Figure 1-1).

Figure 1-1

This concept was formalized with the formation of the Wisconsin Initiative for Sustainable Cleanups (WISC) workgroup (renamed Wisconsin Initiative for Sustainable Remediation and Redevelopment or WISRR). One of the guiding principles of WISRR is,

"Sustainability should be considered in remedy selection, but must not compromise environmental protection."

DNR decided to develop this GSR Guidance Document to aid DNR project managers in evaluating and implementing sustainable remediation at state lead sites. The document would be available as a resource to other state agency staff, as well as RPs, consultants and other interested parties.

The purpose of the GSR Guidance Document is to develop meaningful sustainability performance metrics that provide both qualitative and quantitative measures of sustainable remediation options that can easily explain the costs and benefits of each sustainable option to stakeholders, administrators, and the public. The document also provides a pathway for green optimization of existing systems. The goal of the document is that it should be easy to use and broadly applicable to state and federal programs. It is assumed that the target audience for the GSR Guidance Document is qualified environmental professionals who have a good working knowledge of remediation activities.

2.0 Green and Sustainable Remediation - Overview

The concept of sustainability is derived from the realization that the earth's natural resources are limited, that man's activity is depleting these resources at an alarming rate, and that this activity is subsequently having a significant effect on the environment. The concept of sustainability first manifested itself in the form of sustainable development which was defined in the Brundtland Commission's 1987 report to the United Nations (United Nations, 1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." With the increasing focus on the environment spurred by issues such as climate change and resource conservation, sustainability has evolved to become a holistic approach to environmental management.

Sustainable practices are practices that consider economic and natural resources, ecology, human health and safety, and quality of life.

2.1 Green and Sustainable Remediation

Green and sustainable remediation (GSR) involves the integration of sustainable principles, practices and metrics into all phases of a remediation project, from initial investigation through site closure. The focus is on reducing the environmental "footprint" of remedial actions, including factors such as energy use, greenhouse gas (GHG) emissions, water and raw materials consumption and beneficial reuse of the property.

Although the terms green and sustainable remediation are sometimes used interchangeably, they have generally evolved to mean different things. For the purposes of this document, green remediation and sustainable remediation are defined as follows:

Green Remediation

The practice of implementing remedial actions in a manner that attempts to reduce environmental effects (such as greenhouse gas emissions) after selecting a remedy, but does not formally include those considerations in the evaluation and remedy selection processes. Green remediation is generally noncontroversial as green metrics are not considered in the remedy selection process. Green remediation has also evolved to primarily involve environmental metrics, and would not typically include an assessment of social and economic metrics.

Sustainable Remediation

Sustainable remediation encompasses green remediation and includes detailed analyses associated with remedies as part of the design and analysis of various alternatives, and may include the evaluation of economic and societal costs and benefits, along with traditional environmental considerations. Sustainable remediation expands the GSR analysis from *how* to remediate to the broader topics of *whether* to remediate and *how much* to remediate. Sustainable remediation analyses are performed during the remedy selection process, and are applied throughout the project life cycle.

2.2 Key Green and Sustainable Remediation Considerations

U.S. EPA has developed a framework that recommends evaluating a set of five core elements, either qualitatively or quantitatively, as a means to enhance remedy protectiveness, not as a disincentive to active remediation processes or an approach that reduces remedy protectiveness (U.S. EPA 2010). The overarching goal of this approach is to provide a remedy that reduces GHGs, energy and water use, and promotes the use of renewable energy and resources, recycling and waste minimization, and land revitalization. The U.S. EPA core elements are depicted in Figure 2-1.

Figure 2-1. U.S. EPA Core Elements

2.3 Green and Sustainable Remediation Drivers

Greenhouse Gas Generation

Increasing concerns regarding climate change have prompted major efforts across the globe to reduce GHG emissions caused by activities such as fossil fuel consumption. The six GHGs covered by the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). The U.S. EPA's current strategic plan calls for significant reductions in GHG emissions, as well as increases in energy efficiency as required by federal mandates such as *Executive Order 13423: Strengthening Federal Environmental, Energy, and Transportation Management* (Executive Order 13423, 2007). The Final Mandatory Reporting of the Greenhouse Gas Rule can be found at the following link: www.epa.gov/climatechange/emissions/ghgrulemaking.html.

Energy Consumption

Energy consumption has become an increasingly important aspect of implementing remedies at remediation sites. In the past, cost savings was the primary driver to decrease energy consumption. With the implementation of GSR, additional emphasis has been placed on the use of alternative energy derived from natural, renewable energy sources.

Water Use and Reuse

Water is an increasingly important resource. Even in Wisconsin where water was thought to be abundant, development and growth have taxed this resource to the point where resource protection and conservation has become a major concern.

Land Use

Land is also considered a limited resource. Considering end use or potential reuse of the impacted site will aid in the conservation of existing green space and assist in the revitalization of communities through brownfields redevelopment.

Waste and Material Use and Recycling

In recent years an increased emphasis has been placed on waste material use and recycling due to concerns about limited landfill space, introduction of pollution into the environment and the need to conserve our natural resources. Modifying remedies to reduce waste and increase recycling opportunities has a significant impact in decreasing the environmental footprint of the remedy.

2.4 Why Green and Sustainable Remediation Should be Considered

There are several good reasons why project managers and RPs should consider incorporating GSR into their remedial programs:

1. Although not currently required by code, DNR project managers and RPs can incorporate sustainable aspects into remedy selection and implementation, which will result in more sustainable and cost effective remedies. However, environmental protection is the ultimate goal during remedy selection. At no time should the incorporation of sustainable aspects into selected remedies compromise environmental protection.

2. There is a growing awareness of sustainability within U.S. EPA and the regulated community. U.S. EPA issued the *Superfund Green Remediation Strategy* (September 2010) that outlines a number of initiatives in this area (http://www.epa.gov/superfund/greenremediation/sf-gr-strategy.pdf).

Organizations such as the Department of Defense have already developed sustainable remediation polices and programs.

3. Implementing GSR should result in fewer resource- and energy-intensive remedies, which generally translates into lower environmental impacts and lower costs.

3.0 Integrating Green and Sustainable Remediation into all Phases of the Project Life Cycle

The greatest opportunity to reduce the environmental footprint of remediation is during the planning stage, before the remedy is selected and implemented. Although the most significant opportunity to influence sustainability metrics is at the remedy selection stage, there are opportunities to make a project more sustainable in all phases of the project life cycle. During the planning process, sustainable concepts can be incorporated and less sustainable technologies can be screened out. There may be occasions where the most sustainable remedy is not implemented at a site due to factors such as the increased time required to clean up the site, a potential increased public health risk, litigation-driven remediation, or a perceived or proven lack of effectiveness of the sustainable remedy. In these cases, once a final remedy is selected, project managers should look for ways to implement the selected remedy in the most sustainable or greenest manner possible.

3.1 Regulatory Status

Site remediation in Wisconsin is currently covered under the NR 700 Series of the Wisconsin Administrative Code (http://legis.wisconsin.gov/rsb/code/nr/nr700.html). Specifically, NR 722 and NR 724 cover new and existing remediation systems, respectively. Currently, sustainability concepts may be incorporated into remediation projects on a voluntary basis, as there is no codified requirement to incorporate or document sustainability considerations in either the remedy selection or implementation sections of the regulations. Future code revisions may require an evaluation of GSR considerations during remedy selection, implementation and throughout the life cycle of the project.

3.2 Sustainability Metrics

Sustainable remediation incorporates the pillars of Environmental, Economic, and Social/Community influences. As such, this guidance document categorizes metrics so that they correlate to each of the pillars. Following are metrics that can be used to measure the sustainability of a remediation project organized under each of these pillars. All metrics are not applicable to all sites and there may be some metrics that are unique to specific sites which aren't presented below. No standard set of metrics currently exists for evaluating the relative sustainability of remedial alternatives.

Environmental Metrics

Environmental metrics are the nuts and bolts of remediation and in many ways are the simplest to measure. Environmental metrics can be segregated into basic categories that cover energy, GHG emissions, water, waste, and contaminant mass removal.

Energy metrics cover the energy needed to conduct the remediation and include electricity, natural gas, propane and other solid or liquid fuels that are used or consumed during the remediation process. These metrics also include any renewable forms of energy that are incorporated into or are generated by the remediation process. Metrics used to measure energy include kilowatt hours for electricity, pounds or cubic meters for propane and natural gas, and gallons for liquid fuels.

GHG emissions are presented in pounds, kilograms or tons of carbon dioxide equivalents (CO_2e) and is a sum of all the GHGs emitted by implementation and execution of the remedy. The environmental metric which measures water includes water consumed by the remedy, water produced or extracted by the remedy, and potential storm water runoff. The output of this metric is presented in gallons. Waste generation and recycling is typically measured in tons. This metric is used to measure the total waste generated by remedy implementation at a site, as well as the amount of material that can potentially be salvaged or recycled. Land use and ecosystem can be measured in total area disturbed or enhanced by the remedy.

Contaminant mass removal rates are measured in units such as pounds, kilograms, or tons on a per day, per month or per year basis. This metric is used to measure the mass of contaminant that has been removed from a site or that has been remediated through a treatment process, and the rate at which this occurs.

Economic Metrics

Cost is an integral part of remediation and perhaps a main driver after protection of human health and the environment. Economic metrics present the developed environmental metrics in terms of costs. Economic metrics take into account the life cycle costs of the remediation, which include capital costs and ongoing operation and maintenance costs. These costs can be expressed in terms such as dollars per unit of contaminant removed, costs for energy in dollars per kilowatt hour or dollars per British thermal unit (BTU), and costs for implementing green building/Leadership in Energy and Environmental Design (LEED) applications.

Social and Community Metrics

Social and community metrics are used to measure the impacts of the remedy on the community. These metrics can focus on quantitative criteria such as safety (which can be measured in total reportable incidents), traffic (which can be measured in vehicles per day), and fugitive dust, vapors and noise (which can be measured in their relevant units). Social and community metrics may also include more qualitative metrics such as land reuse, engagement, jobs, building community assets (e.g. parks, greenspace, etc.) and transparency that revolve around community involvement in the remedial process.

Figure 3-1 shows some of the new metrics to consider when evaluating sustainability for a site.

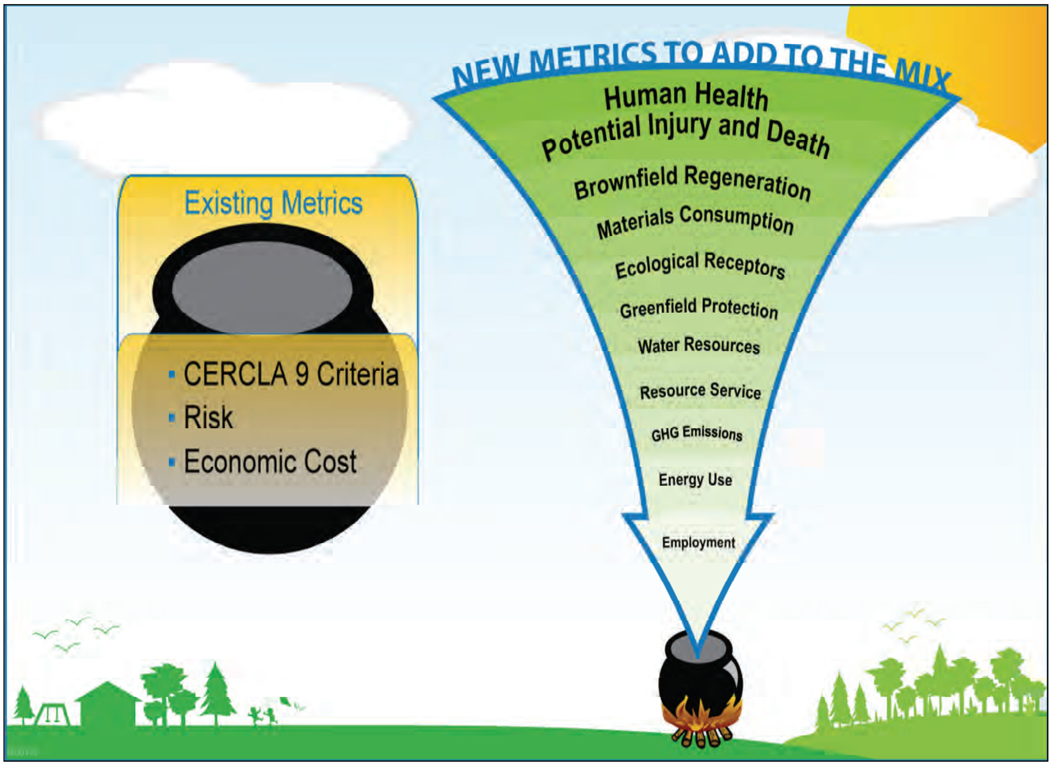


Figure 3-1. New Metrics to Consider during Sustainability Evaluations

3.3 Quantitative versus Qualitative Metrics

As noted above, sustainability metrics can either be measured quantitatively, where there is an actual measurement taken, or qualitatively, where assumptions are made based on observation.

Quantitative metrics are very focused and narrow in scope. The metrics are based on hard data and on what is empirically known about the remedy. They may include data related to the consumption and costs of energy and water, contaminant mass removal, how much waste is generated, etc. These metrics generally involve the hard engineering of the remedy.

Qualitative metrics may be simpler to understand since they deal with the broader issues of sustainability and they can be better communicated to a non-technical audience. Qualitative metrics may be better suited to evaluate community and social benefits where hard data is difficult to discern. Qualitative metrics can also be used at small or simple sites where a detailed sustainability analysis to develop quantitative metrics is not warranted.

3.4 GSR Process Implementation

The goal of the GSR process is to incorporate sustainability into all phases of the project life cycle: from site investigation through remediation and closure (Figure 3-2). Sustainability should be considered wherever possible, as long as environmental protection is not compromised.

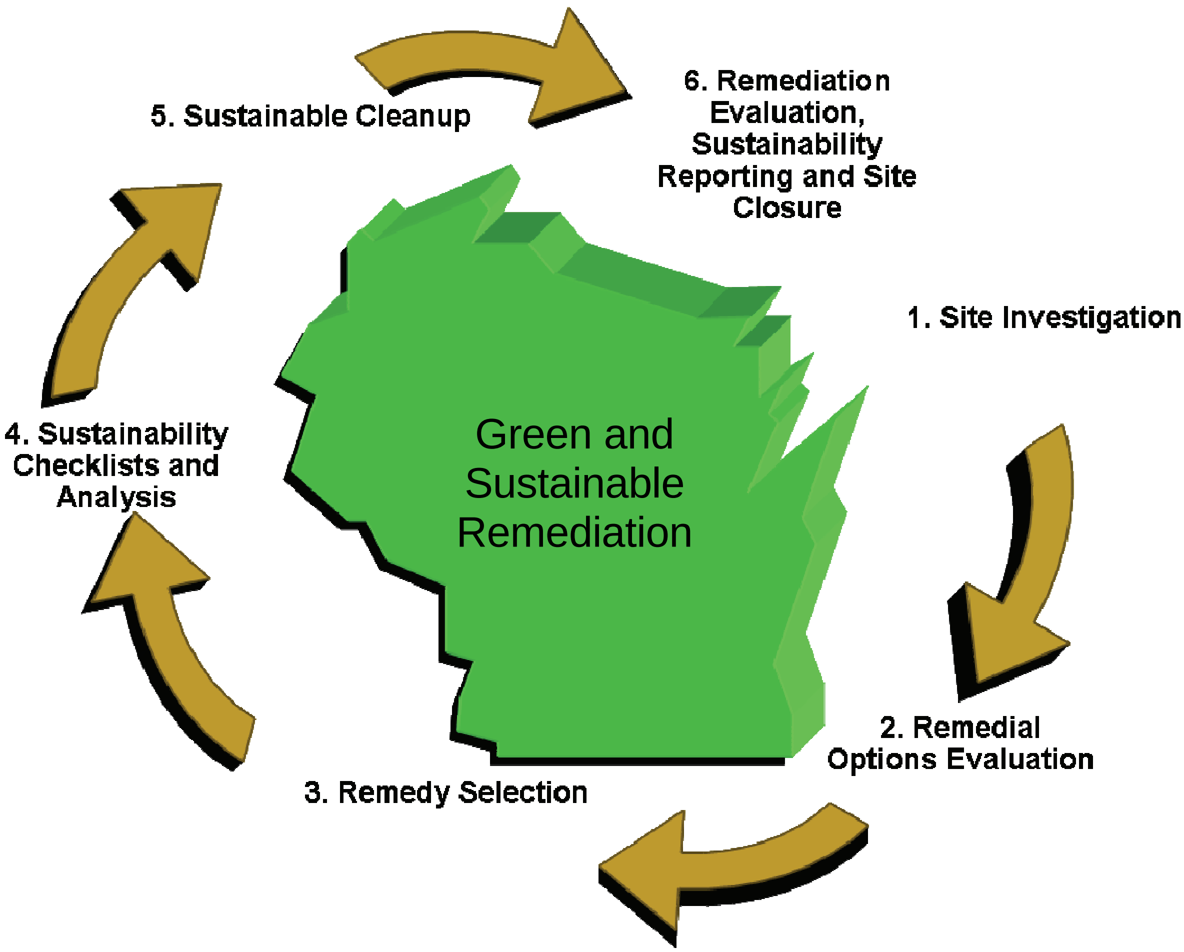


Figure 3-2. The GSR Process

The opportunity to implement a sustainable remedial option should not be considered an occasion to implement a "do nothing approach" to remediation. When sustainability is applied correctly to remedial actions, it can have the benefit of reducing the overall environmental footprint of the remedy, as well as provide potential cost savings.

When project managers go through the process of selecting and implementing remedial options, their thought process should first focus on the core elements of sustainability, how these elements can be measured or quantified, and what green management practices or considerations can be incorporated into the remediation to make it more sustainable. Figure 3-3 shows where sustainability can be implemented within Wisconsin's remedial process.

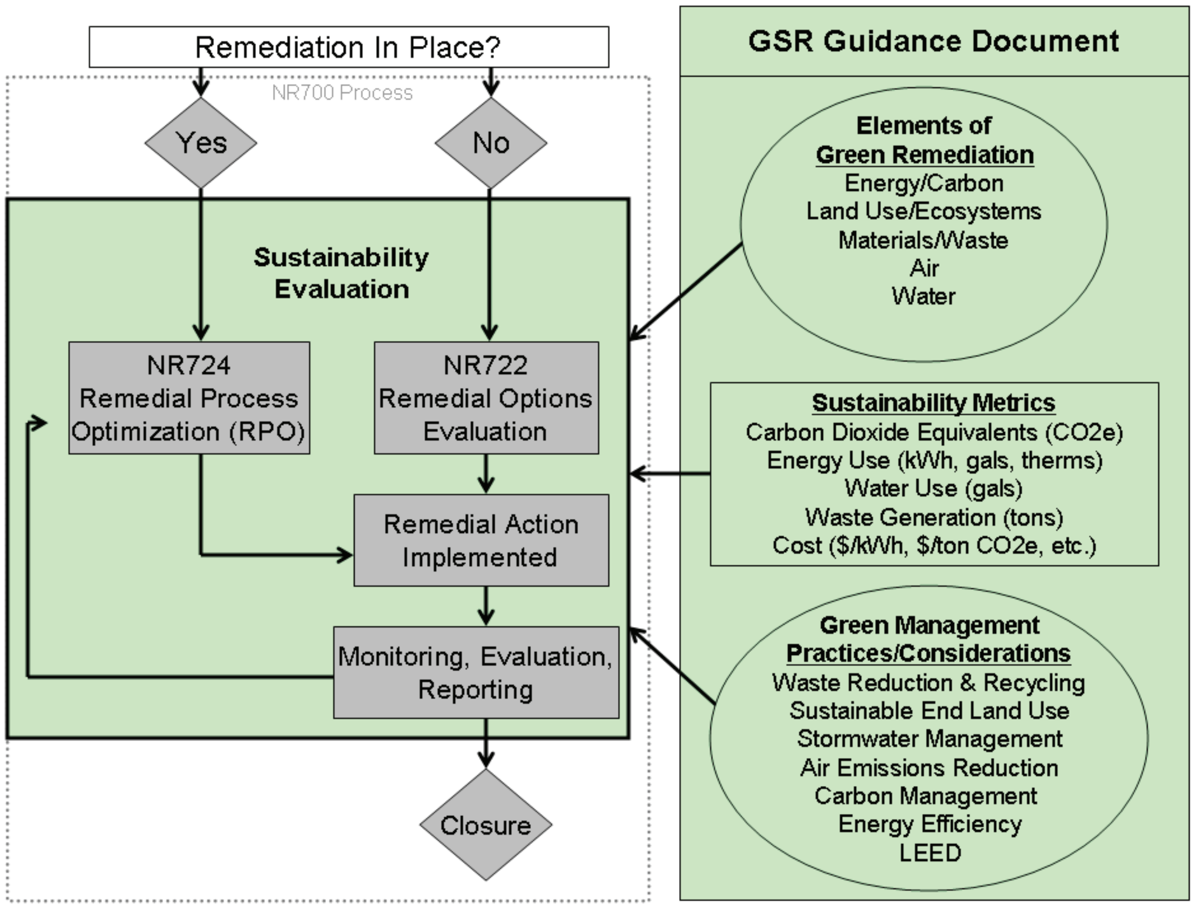


Figure 3-3 Consideration of Green and Sustainable Remediation

Generally speaking, the opportunities for the application of sustainable remedial solutions increase along with the size and complexity of the project (See Figure 3-4). As this figure also represents, opportunities for incorporating sustainability metrics also increase as the life cycle progresses, peaking at the remedy selection stage.

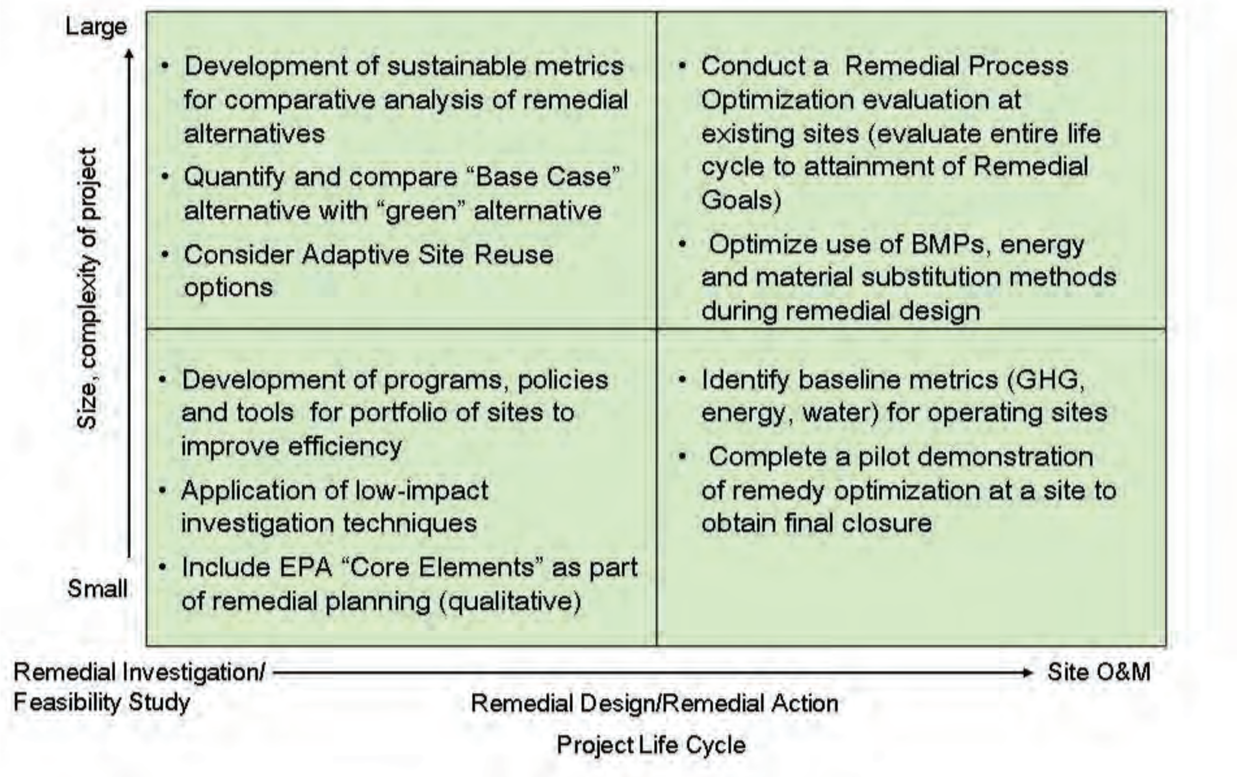


Figure 3-4. Opportunities for Incorporating Green and Sustainable Remediation

Examples of activities that can be integrated at different points in the project life cycle are shown in Table 3-1.

Table 3-1.
Examples for Integrating GSR into Site Investigation and Remediation Projects

	Environmental	Social	Economic
Site Investigation	✓ Collect data to understand risks associated with on-site treatment and containment of contaminated media ✓ Use direct push tools to reduce investigative derived waste (IDW) and energy consumption ✓ Use passive diffusion or grab-type samplers for groundwater samples to reduce IDW and energy consumption	✓ Conduct community outreach to communicate site conditions and risks and to engage in planning of site cleanup and reuse options ✓ Create key contacts list to facilitate communications	✓ Use field screening technologies to reduce IDW and off-site sample shipping
Feasibility Study/Response Action Plan	✓ Evaluate on-site and in-situ treatment and containment technologies ✓ Conduct energy use and emissions calculations to compare alternatives ✓ Identify opportunities to create habitat as part of site remediation ✓ Consider green technologies and green products	✓ Communicate site remediation options and risk reduction achieved ✓ Obtain input on site cleanup alternatives and community concerns/needs	✓ Determine short-term and long-term cost of site remediation alternatives contrasting with environmental and social costs/benefits
Remedial Design	✓ Identify low-energy, low-emission and low water intensive equipment ✓ Minimize water consumption and maximize water reuse ✓ Minimize impacts to local natural resources and habitats ✓ Maximize use of renewable energy and fuels ✓ Minimize off-site transport of contaminated materials ✓ Identify recycling options or use of green materials ✓ Utilize on-site treatment and containment approaches ✓ Integrate remote monitoring features into design	✓ Engage community leaders in design meetings to obtain input on configurations and timing of site work ✓ Communicate site remediation plan including short-term community impacts and long-term risk reduction ✓ Consider use of local materials and labor ✓ Evaluate community impacts and safety issues from site remediation actions	✓ Use on-site approaches to management of contamination to reduce costs of site cleanup and potential long-term liabilities associated with off-site disposal ✓ Use adaptive site-reuse approach incorporating existing structures into site reuse options ✓ Evaluate opportunities for capturing value of eco-assets such as wetlands credits or carbon sequestration
Remedial Action Implementation/ Construction Management	✓ Minimize equipment engine idling ✓ Control and mitigate dust, odors, noise and light impacts ✓ Conduct monitoring of air and, if needed, odors, noise and light ✓ Set-up comprehensive on-site recycling program for all wastes and residuals	✓ Conduct community meetings to inform of project progress ✓ Post information on monitoring programs and project progress/plans	✓ Determine cost impact to project from use of GSR approaches

Table 3-1.
Examples for Integrating GSR into Site Investigation and Remediation Projects

	Environmental	Social	Economic
Operations, Monitoring and Maintenance (OM&M)	✓ Utilize remote monitoring system to monitor effectiveness of treatment systems and reduce field travel ✓ Recycle sampling residuals ✓ Use recycled materials for sampling and monitoring to reduce IDW and fabrication of new material ✓ Design adaptive monitoring programs to reduce sampling frequency over time	✓ Communicate site remediation status using website and other public communication approaches	✓ Utilize low-energy intensive approaches to reduce energy costs ✓ Use on-site sample testing/screening approaches to reduce transportation of samples ✓ File electronic reports to reduce paper consumption

Sustainable considerations on small or simpler sites may be implemented through the use of a “best management practices” (BMP) program. The U.S. EPA has and continues to develop a series of BMPs for green remediation practices. Such a program would contain recommendations for sustainable remedies or concepts based on the nature of the site contamination or the remediation approach. Simpler sites may also be dealt with through the use of qualitative check lists or matrices that give the project manager a general idea of how sustainable the chosen remedy is. An example of a simple matrix is shown in Figure 3-5. An additional example of a checklist is included in Appendix A.

Evaluate, Quantify, and Rank Remedial Options for Negative and Positive Impacts

Core Element	Evaluate Negatives	Evaluate Positives
1. Energy	Total energy use: natural gas (BTU), electricity (kWh), fuel (gallons)	Renewable energy applied (KWh saved by solar, wind, geothermal, biomass energy)
2. Air	Total air pollutants, GHG emissions (CO_2e), dust	GHG emission reductions (CH_4 to CO_2)
3. Water	Total water use (gallons or liters)	Water recovery (gallons or liters)
4. Land	Total land disturbed (acres/tons); noise and lighting disturbances	Land reuse (acres/tons); ecosystems enhanced
5. Materials & Waste	Waste generated (tons)	Materials reused (tons)

Figure 3-5. Qualitative Sustainability Analysis Example

Sustainability will have different meanings to different stakeholders, and different stakeholders may place an increased emphasis on a particular issue. For instance, a community may wish for an expedited cleanup of a brownfields site that requires using energy and carbon intensive methods, versus a lower energy in-situ or natural attenuation solution, so that the land can be redeveloped sooner. The community may view this as a sustainable solution because they are redeveloping an existing site, potentially adding jobs and tax base to their community, and avoiding further development of greenfields. From a pure remedy standpoint, the remediation method itself may not be sustainable but put into the context of the situation it becomes apparent how the community stakeholders may view this as a sustainable alternative. Although qualitative and quantitative metrics are developed, the weighting (i.e. emphasis) placed on specific metrics may significantly influence the impact of GSR on the remedial process.

3.5 Sustainable Considerations in Remedy Selection

Sustainability should be considered throughout the remedial process. Table 3-2 is a sustainability considerations checklist that outlines various actions that may be taken while implementing green or sustainable remediation. If these actions are applicable for a site or remedy, the table outlines the potential effect the implementation of the action will have in terms of the U.S. EPA core elements.

Table 3-2. Sustainability Considerations Checklist

Action	Applicable (Y/N)	Air	Energy	Water	Land Use/ Material Recycling/Waste Generation
Collect data necessary to evaluate recycling options for waste and debris.		Improves decision-making and helps to prioritize action.			
Collect data necessary to evaluate alternative treatment methods.					
Develop and quantify "base case" remediation scenario.		Base case data allow comparison of "standard" cleanup with "greener" cleanup.			
Organize site layout to reduce equipment travel distances and excavation requirements during remedy construction and for post-construction operational needs.		Reduces air emissions from on-site construction equipment and from trucking waste materials.	Reduces fuel use in on-site construction equipment and in trucking waste materials.		Reduces waste material requiring off-site disposal.
Use engineered surface soil barriers such as a cover system, pavement or flooring.		Reduces air emissions from on-site construction equipment and from trucking waste materials.	Reduces fuel use in on-site construction equipment and in trucking waste materials.		Reduces waste material requiring off-site disposal.
Use permeable surface soil barriers such as vegetated top soil or gravel.				Increases long-term permeability of site to reduce stormwater runoff.	
Use institutional controls.		Reduces air emissions from on-site construction equipment and from trucking waste materials.	Reduces fuel use in on-site construction equipment and in trucking waste materials. Reduces energy use in remediation systems.		Reduces waste material requiring off-site disposal.
Use soil management zones.		Reduces air emissions from trucking waste materials.	Reduces fuel use in trucking waste materials.		Reduces waste material requiring off-site disposal.

Table 3-2. Sustainability Considerations Checklist

Action	Applicable (Y/N)	Air	Energy	Water	Land Use/ Material Recycling/Waste Generation
Develop sequencing plan for work to integrate cleanup with construction.		Reduces air emissions from on-site construction equipment by combining project phases.	Reduces fuel use in on-site construction equipment by combining project phases.	Reduces erosion.	Reduces waste material requiring off-site disposal and reduces interim fill requirements.
Identify recycling options for structures, waste and debris such as metal, C&D, slag, and tires.					Reduces waste material requiring off-site disposal.
Consider reuse options for existing structures.		Reduces air emissions from demolition activities.	Reduces fuel use in on-site construction equipment and in trucking waste materials.		Reduces waste material requiring off-site disposal.
Evaluate active in-situ treatment systems, such as soil vapor extraction, enhanced bioremediation or air sparging.		Reduces air emissions from on-site construction equipment and from trucking waste materials.		Reduces erosion and potable water use.	Reduces waste material requiring off-site disposal.
Evaluate passive in-situ treatment methods such as permeable reactive barriers, in-place oxidation or phytoremediation.		Reduces air emissions from on-site construction equipment and from trucking waste materials.	Reduces purchased energy use.	Reduces erosion and potable water use.	Reduces waste material requiring off-site disposal.
Evaluate remediation technologies that permanently destroy contaminants.		Reduces air emissions from on-site construction equipment and from trucking waste materials. Reduces future migration concerns.		Reduces future migration concerns.	Reduces future migration concerns.
Perform a life-cycle analysis of cleanup plan.		Life-cycle analysis supports informed decision-making considering time, cost, remedy effectiveness, and environmental impact of the alternatives.			

Table 3-2. Sustainability Considerations Checklist

Action	Applicable (Y/N)	Air	Energy	Water	Land Use/ Material Recycling/Waste Generation
Impose idling restrictions on construction equipment		Reduces air emissions from on-site construction equipment and from staged vehicles.	Reduces fuel use in on-site construction equipment and in trucking waste materials.		
Sequence work to minimize double-handling of materials.		Reduces air emissions from on-site construction equipment. Reduces nuisance dust from stockpiles.	Reduces fuel use in on-site construction equipment.	Reduces erosion.	
Cover stockpiles with tarps, apply alternate dust-control measures, or vegetate stockpiles.		Reduces nuisance dust from stockpiles.		Reduces erosion.	
Capture and treat gray water for reuse.				Reduces potable water use.	
Abandon rather than remove subsurface structures.			Reduces fuel use in on-site construction equipment and in trucking waste materials.		Reduces waste material requiring off-site disposal. Reduces off-site fill requirements.
Crush existing structures to optimize scrap recovery and produce fill materials.			Reduces fuel use in trucking waste material and fill material.		Reduces waste material requiring off-site disposal. Reduces off-site fill requirements.
Grind waste wood and other organics for on-site use.			Reduces fuel use in trucking waste material.		Reduces waste material requiring off-site disposal.
Use recycled materials for fill.					Reduces virgin fill requirements.
Routinely evaluate treatment processes for optimal performance.		Reduces air emissions from treatment processes.	Reduces purchased energy use.	Reduces potable water use and wastewater discharge from treatment processes.	Reduces waste material requiring off-site disposal.

Table 3-2. Sustainability Considerations Checklist					
Action	Applicable (Y/N)	Air	Energy	Water	Land Use/ Material Recycling/Waste Generation
Capture free product or emissions for on-site energy recovery.		Reduces air emissions from treatment processes.	Reduces purchased energy use.	Reduces wastewater discharge from treatment processes.	Reduces waste material requiring off-site disposal.
Incorporate renewable energy sources, such as wind or solar, into treatment systems.			Reduces purchased energy use.		
Use energy efficient systems and office equipment in job trailer.			Reduces purchased energy use.		

Note: Modified from Illinois EPA Greener Cleanup Matrix

4.0 Sustainability Baseline Development

The creation of a baseline or base case scenario allows for the comparison of a “standard” cleanup with “green or sustainable” cleanup options. Development of a baseline also helps identify opportunities for implementing sustainable remediation. The baseline evaluation quantifies a remedy’s sustainability footprint in terms of the core elements, which allows the project manager or RP to identify the core elements that are most adversely impacted by the remedy. Once the major impacts are known, sustainable strategies or techniques can be deployed to address these impacts allowing for the greatest potential improvement in the sustainability of the remedy.

The U.S. EPA core elements of air (carbon footprint), energy use, water use, materials and waste (including waste generation and recycling), and land use and ecosystems are presented in terms of sustainability metrics in the sustainability baseline.

4.1 Carbon Footprint

The carbon footprint of a remedial action is measured by the total amount of GHGs produced to support activities, both directly and indirectly. The carbon footprint is usually expressed in equivalent metric tons of carbon dioxide (CO_2e), which represents the heat trapping impact of one unit of a given GHG relative to one unit of $CO_{2.}$

The GHGs identified in the Kyoto Protocol are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These gasses are primarily emitted by combustion and manufacturing processes where liquid and solid carbon-based fuels or substances are consumed. Some of these gasses can also be emitted by natural processes such as respiration, digestion and anaerobic degradation of waste materials. To obtain CO_2e, the amount of each individual greenhouse gas produced is multiplied by its green house gas potential.

Table 4-1 presents the GHGs identified in the Kyoto protocol. Note there is a significant variation between gasses, which is primarily based on the heat trapping impact of each gas compared to CO_2.

Table 4-1. Greenhouse Gas Potentials

GHG	Potential (100-year)		
	SAR	TAR	AR4
CO_2	1	1	1
CH_4	21	23	25
N_2O	310	296	298
SF_6	23,900	22,200	22,800
HFCs	140 – 14,800		
PFCs	6,500 – 12,200		

Source: Intergovernmental Panel on Climate Change, Second Assessment Report (SAR) (1995), Third Assessment Report (TAR) (2001), and Fourth Assessment Report (AR4) (2007).

GHG emissions are broken down into three different categories or scopes of emissions: Scope 1, Scope 2 and Scope 3 (referred to as operational boundaries).

Scope 1

Scope 1 sources are limited to direct emissions under ownership or control of the site owner. These include stationary combustion activities such as natural gas heating and landfill gas flaring or mobile sources such as company-owned vehicles and gas powered generators.

Scope 2

Scope 2 sources consist of indirect emissions from purchased electricity, steam and heat.

Scope 3

Scope 3 sources include all other indirect emissions caused by activities at the site and included in the site's defined scope 3 operational boundaries.

Scope 1, 2 and 3 operational boundaries are depicted on Figure 4-1.

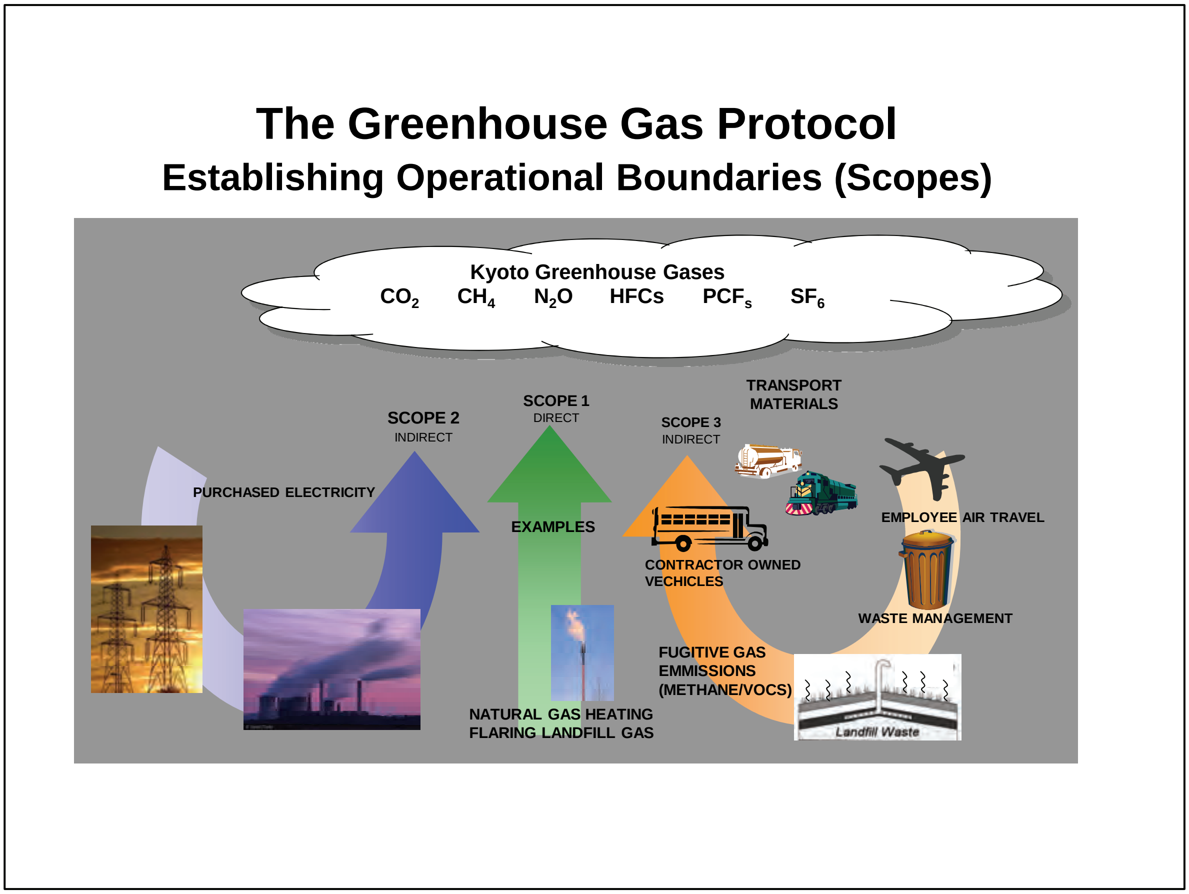


Figure 4-1. Establishing Operational Boundaries (modified from WRI 2004)

4.2 Carbon Footprint Development

4.2.1 Identification of Sources

<u>Scope 1</u>

Scope 1 sources are limited to direct emissions under ownership or control of the site owner. At a remediation site these sources generally consist of natural gas or propane burned on site for the purpose of heating, generating power or contaminant destruction (thermal oxidation, flaring of gas), and liquid fuels burned in site owner-operated vehicles or generators used to produce power.

The amount of natural gas consumed at a site is generally quantified on utility bills. In the case of landfill gas flaring, the amount of gas combusted at the site will be a product of the flow rate and landfill gas methane concentration. The flow rate is the rate at which the landfill gas influent is being extracted from the landfill and discharged to the flare. The concentration of methane is the percentage of methane within the extracted gas.

Liquid fuels consumed can physically be tracked by monitoring fuel consumption on use or by estimating fuel based on mileage and type of vehicle. Fuel use for generators also can be directly tracked or estimated based on run time and fuel consumption (U.S. EPA 2008).

Scope 2

Scope 2 sources consist of GHG emissions from purchased electricity. The quantity of electricity used at the site is usually metered and the total power consumption can either be measured at the meter or taken from the electric utility bill. In cases where the remediation system is not metered separately, an estimate of electricity use can be made by evaluating each component that consumes electricity and using the specifications of the electrical equipment to determine their power use per hour. Total electricity used can be determined by multiplying use per hour by the total hours operated. This procedure should be completed for each significant piece of equipment using electricity.

Once the total electrical use is determined, the GHG emissions for the purchased electricity must be calculated. Emissions vary based on the fuel mix used by the electric utility to produce electricity. Information on GHG emissions can be gathered from the supplying electric utility or from U.S. EPA's egrid website (http://cfpub.epa.gov/egridweb/) which allows the user to access emissions data on a state, regional and utility-specific basis. Unless the particular remedy is extremely electricity intensive, statewide average GHG emissions for an electric utility within the state would be sufficient to generate estimates of greenhouse gas emissions for electricity consumption. A map showing the state-wide electric utilities and electric cooperatives is shown in Figure 4-2.

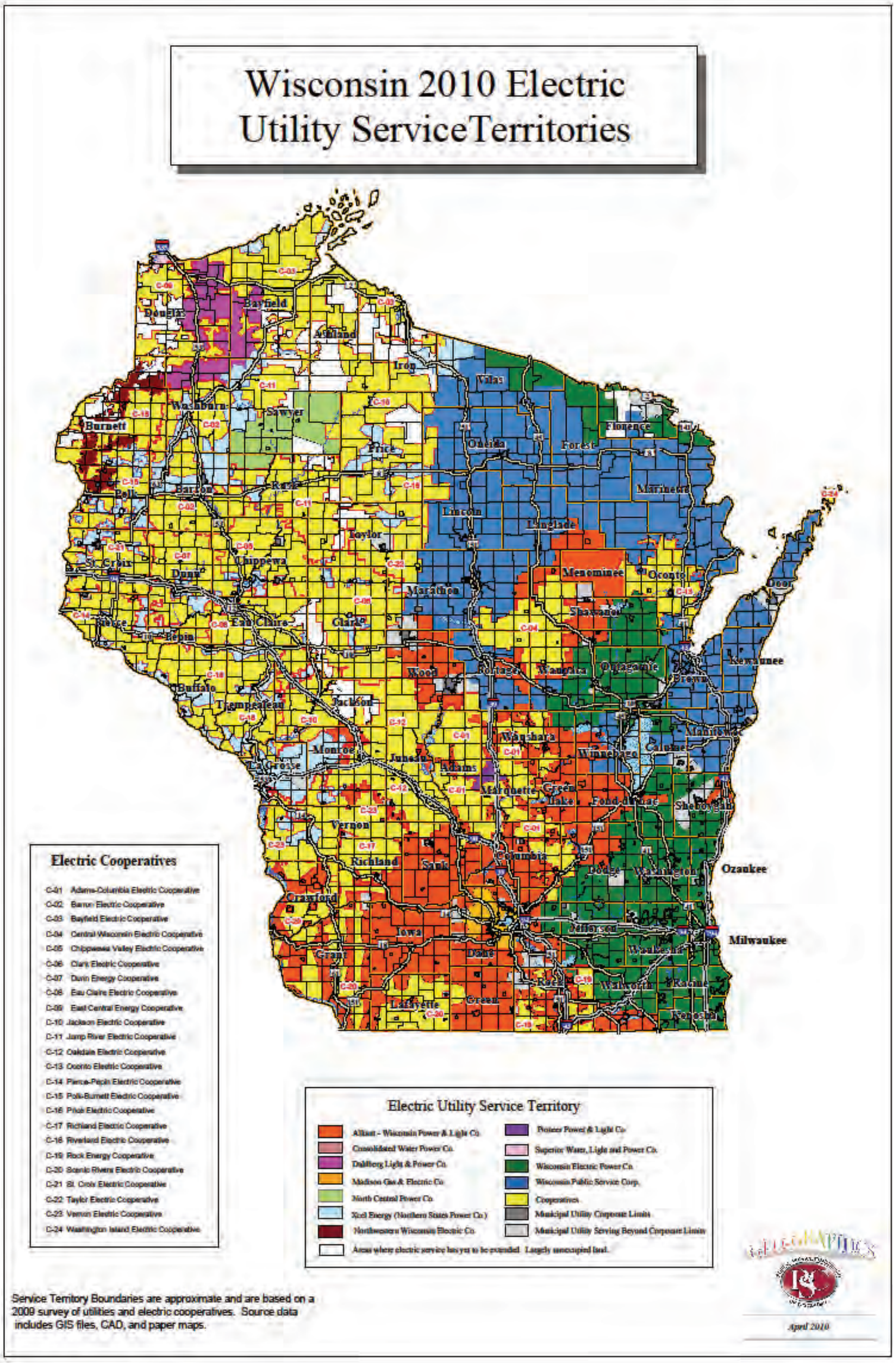


Figure 4-2. Electric Utility Service Territories in Wisconsin

Scope 3

Scope 3 sources include all other indirect sources resulting from implementation of the remedy and long-term operation, maintenance and monitoring of a site and encompasses the majority of activities that occur while implementing a remedy. Sources in this scope include, but are not limited to, travel back and forth to the site for an operation and maintenance contractor, shipping of major supplies to the site, construction of the remedy, waste and hazardous waste disposal, fugitive emissions from landfills, and emissions from vapor extraction systems or open excavations. If hazardous waste is incinerated this should also be included in Scope 3.

For the purpose of this document, Scope 3 GHG sources do not include carbon footprint relative to the manufacture of goods and equipment used at the site. A complete life cycle analysis that includes the carbon footprint of manufacturing is beyond the scope of this document. Care should be taken only to include the sources with credible GHG emissions data and which are major contributors to the carbon footprint at the site. The World Resources Institute and the World Business Council for Sustainable Development (WRI/WBCSD) have developed a Scope 3 standard that was published in September 2011.

4.2.2 Calculation of Carbon Footprint

After all of the Scope 1, 2 and 3 sources and GHGs have been identified, a carbon footprint can be developed for a remedy or remedial action. There are a variety of tools available with detailed guidance on how to calculate a carbon footprint for a remediation process including Scope 1, 2 and 3 sources. The GHG Protocol Initiative web site (www.ghgprotocol.org/calculation-tools/all-tools) provides guidance and calculation tools that can be used to estimate GHG emissions from fixed and mobile sources. Additional emission factors can be found on the United States Energy Information Administration (EIA) website (http://www.eia.gov/oiaf/1605/emission_factors.html) and the U.S. EPA Technology Transfer Clearing House for Inventories and Emission Factors web site (http://www.epa.gov/ttnchie1/). GHG emissions can be calculated using the following equation:

Scope 1 source use or activity data x Emission Factor x GHG Potential = CO_2e.

Table 4-2 presents an example of a GHG emission calculation that was generated for the combustion of natural gas used to heat a remediation building. This is considered a Scope 1 source. The emission factors will vary depending on the nature of the fuel and/or GHG emission source.

Table 4-2. Example of Total CO_2e Emissions for Scope 1 - Combustion of Natural Gas

Scope 1 Item			Emission Factors			Mass (use x emission factor)			Greenhouse Gas Potentials CO_2e			Total Emissions
									1	25	296	(mass x GHG potential)
Fuels Burned On-Site	Use (therms/yr)	Use (TJ/yr)	kg CO_2/TJ	kg CH_4/TJ	kg N_2O/TJ	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e
Natural Gas	1,714	0.18	64,200	10	0.6	11,606.9	1.81	0.11	11,606.94	45.20	32.1	11,684.2

Source Notes:

1.) *Utility use reported by We Energies.*
2.) *IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories, 2006, Volume 2: Energy Tables 1.4 and 2.4, Emission Factors, Commercial/Institutional - Stationary Combustion.*
3.) *Greenhouse Gas Potential for CH_4 taken from IPCC (2006). Greenhouse Gas Potential for N_2O taken from IPCC Third Assessment Report (2001).*

The tools that are used to calculate a carbon footprint will vary depending on the complexity of a site. For small projects or where a remedy is in the long-term O&M phase, a simple spreadsheet that uses emission factors and Scope 1, 2 and 3 sources may be sufficient to calculate a carbon footprint for the site. An example of a simple carbon footprint spreadsheet is included in Appendix A.

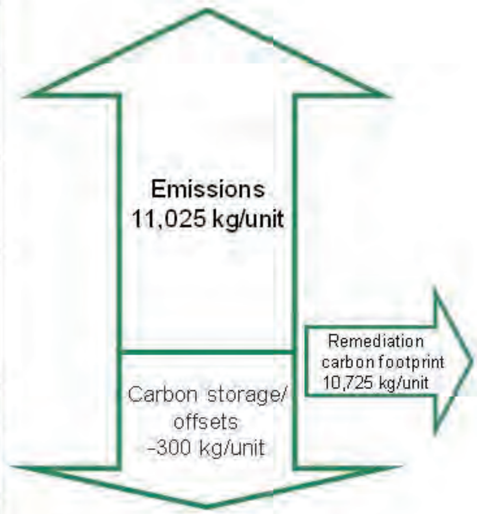
For larger or more complex remediation projects a public domain tool such as the Air Force Center for Engineering and Environment's (AFCEE) Sustainable Remediation Tool (SRT) (www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp) may be more appropriate to evaluate the carbon footprint at the site. These programs will include GHG emissions and other sustainability metrics as part of their output as well. A further discussion of these tools is presented in Section 4.8.

Figure 4-3 presents a theoretical illustration of how a carbon footprint may look for a typical remediation site that is in a long-term operation and maintenance phase.

Reporting of Carbon Footprint Results

Remediation Carbon Inventory (Example)

Carbon Location in Chain	Remediation (Kg CO_2-equiv./unit)
Scope 1 - Natural Gas used for heating - Vehicles	 450 25
Scope 2 - Purchased electricity - Purchased heat	 335 0
Scope 3 - Quarterly sampling events - Activated Carbon Disposal - Hazardous Waste Disposal - Business travel	 150 10,000 50 15
Total emission sources	**11,025**
Total Renewable Energy Offsets - Electricity back to Grid	 300
Total Renewable Energy offsets	**-300**
Product Carbon Footprint	**10,725**



All figures reported as kg CO_2-equiv./unit

Figure 4-3. Reporting of Carbon Footprint Results

Once the baseline carbon footprint is estimated it can be used to compare the effect of implementing GSR alternatives at the site.

4.3 Energy Use

Energy use is a key metric identified by the U.S. EPA as a core element. Energy use is also integral to other core elements such as air and GHG emissions, and is a significant economic factor in remediation.

Generally, energy is used in three forms during the implementation of a remedial action:

1. Fuels used or combusted onsite for the purpose of heating, electrical generation or contaminant destruction (Scope 1). This is predominantly natural gas but could also include petroleum based fuels.
2. Purchased electricity (Scope 2).
3. Combustion of fuels, predominantly petroleum, used in the process of the remediation by non owner entities (Scope 3)

Baseline energy use can be tracked by measuring consumption of fuels and electricity. Consumption of natural gas or electricity can generally be tracked through the utility providing the energy. This information is usually provided on the invoices from the utility. Consumption of petroleum used in vehicles can also be tracked from invoices or fuel use records.

When no mechanism for tracking consumption of energy exists, energy use estimates can be developed by evaluating the rate of energy consumption and duration of operation of the components of the system that utilize energy. For instance, if a furnace consumes two therms of natural gas per hour and it operates five hours per day, natural gas use would be ten therms per day. Similarly, if an electric motor consumes ten kilowatts per hour and runs three hours per day, the motor will consume thirty kilowatts per day.

Some common metrics used for energy are kilowatt hours, kilowatts, therms, joules, gallons, pounds, cubic meters, liters, and BTUs. These metrics can be further broken down into economic metrics, since the unit price for each is a defined value.

Once baseline energy use has been calculated, the effects of GSR alternatives at the site can be quantified and compared, including costs. This will in turn allow the project manager to make informed decisions relative to implementing sustainable remediation. Additional tools used to calculate energy use can be found at the U.S. EPA web site http://www.epa.gov/greenpower/pubs/tools.htm.

4.4 Water

Water is becoming an increasingly important resource. Water is a core element and is an important part of development of a GSR baseline. In remedial actions, water can be purchased and used in the treatment process, withdrawn from the aquifer for treatment, and discharged to a sanitary sewer, storm sewer or surface water. Each of these actions has an effect on the environment and the sustainability of the system. The metric for water is measured in gallons, cubic feet, liters or cubic meters. Generally, water use, pumping and discharge are metered so there is an accurate measurement of the amount consumed, extracted or discharged. For some of the uses, such as the purchase of water or discharge of water to a sanitary sewer, costs may be available for use in developing economic metrics.

4.5 Waste Generation and Recycling

Waste generation is generally measured in tons, metric tons, cubic yards or cubic meters for solid waste, and gallons or liters for liquid waste. Waste at a remediation site can be generated during the initial implementation or during the long-term O&M of a remedy. Generally, the greatest opportunities for waste minimization and recycling are at the beginning of the remedy implementation process, which often involves construction, demolition or excavation. Each of these activities involves the generation of a significant volume of waste which has historically been disposed of in landfills. Waste can consist of demolition debris, asphalt, concrete, contaminated soil, hazardous waste, aboveground storage tanks, underground storage tanks, contaminated water and sludge. The volume of waste generated can generally be quantified prior to implementing the remedy.

Waste is also generated during the long term O&M of a remedy. Waste from long-term O&M activities generally consists of spent granular activated carbon, used filters, hazardous waste, used and broken equipment and general refuse. Once a remedy is in place the waste volume and type of waste produced by the remedy is generally consistent over time and therefore predictable. Opportunities to recycle or minimize waste production may also occur during the long term O&M of a system through process or operational modifications. There is generally a cost associated with waste generation and subsequent disposal of the waste that allows economic metrics to be developed for waste generation.

For remedies where recycling is being considered, weights and volumes of materials can be estimated. As in waste generation, recycling of solid waste materials is usually quantified in tons, metric tons, cubic yards or cubic meters. Recycling of liquid waste materials is quantified in gallons or liters. In some cases, there will be no costs for recycling (e.g. gasoline pumped from a UST). The costs for generating and transporting recycled material can be used to develop an economic metric for this material.

4.6 Land Use and Ecosystems

Land use and ecosystems is the U.S. EPA core element that encompasses the effect the remedy will have on current and future use of the affected property. Land use and ecosystems elements may include ecological restoration and preservation, preservation of natural features, preservation of green space, sequestration of carbon, enhancement of biodiversity and wildlife habitat, and minimization of surface and subsurface disturbance.

Generally, the land use and ecosystem core element tends to be a qualitative metric as community benefit and ecosystems are taken into account. For example, stakeholders realize that creation of wetlands or habitats is beneficial but each stakeholder will place a different value on the benefit.

In some instances, land use and ecosystem metrics can also be dealt with in a quantitative manner, such as acres of habitat or surface disturbed or created, amount of impervious surface installed, increased value of land due to blight removal, or total amount of carbon sequestered by the remedy.

4.7 Life Cycle Costing

The term life cycle costing refers to the total project cost across the lifespan of a project including design, construction, O&M and closeout activities (ITRC 2006). Generally, life cycle cost projections should be considered in the remedy selection phase as costs and ongoing financial obligations of a remedy are often a key factor in determining which remedy gets implemented at a site. To effectively create a life cycle cost, a plan must be developed which takes a remedy stepwise from implementation through closure (ITRC 2006). An example of a stepwise approach to costing for a pump and treat remedy is presented in Figure 4-4. Life cycle assessment (LCA) is a formal process that can be applied to GSR evaluations but it is a complex process considered beyond the scope of this guidance.

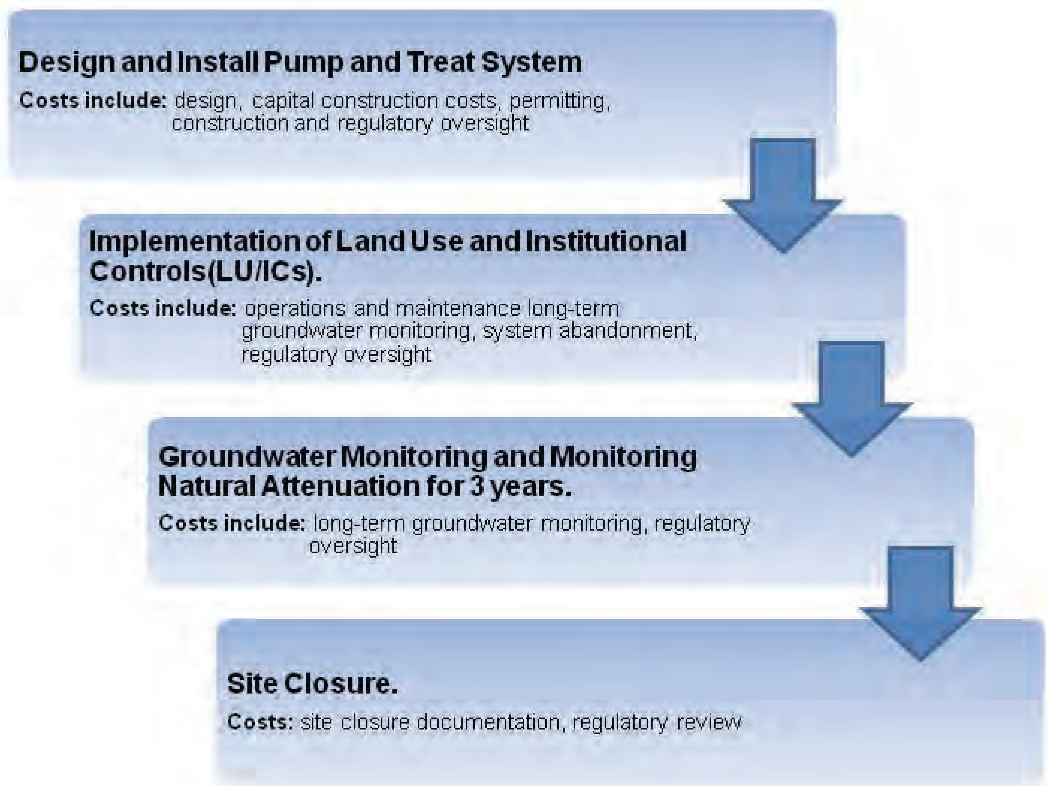


Figure 4-4. Example of a Stepwise Approach to Pump and Treat Remedy Implementation and Life Cycle Cost Development

This approach can also be used for other remedies where the installation of a treatment system is not part of the remedy. Figure 4-5 presents a stepwise life cycle costing approach for a remedy where excavation of source soils, land use and institutional controls and natural attenuation were the selected approach.

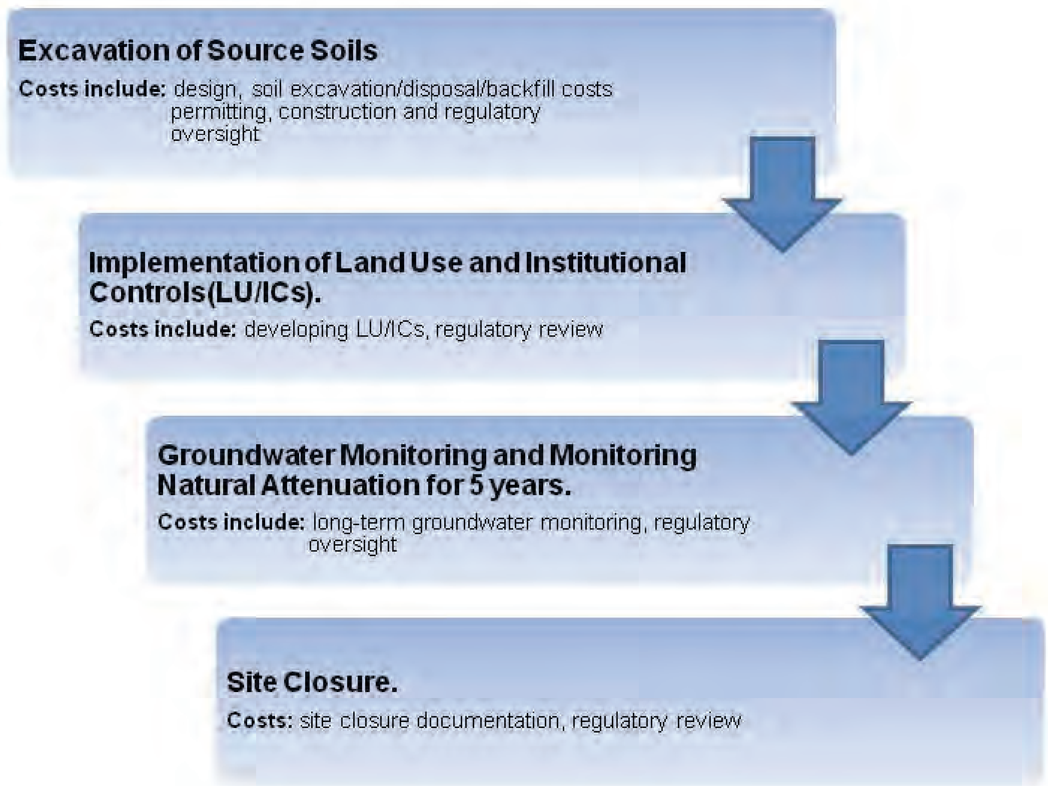


Figure 4-5. Example of a Stepwise Approach to Source Control/ Monitored Natural Attenuation Remedy Implementation and Life Cycle Cost Development

For the purpose of life cycle costing, costs can be aggregated under general categories. For instance, costs for an O&M category will include all the labor, materials and expendables, waste disposal, utilities, laboratory sampling and required reporting associated with the operation of a remedy. Similarly, a long-term groundwater monitoring category would include all the labor, materials and expendables, laboratory analysis and reporting required to complete the monitoring. These costs are generally readily available or can be easily developed based on past experiences.

In some instances where a remedy is already in place, a full life cycle cost analysis is not warranted since the capital to get the remedy to its current point has already been expended. Life cycle costing in this case will consider all costs required to fund the existing remedy through the remainder of the O&M phase and through closeout activities. These cost projections can be based on current annual O&M costs, long-term groundwater monitoring costs, estimated time to closure (remedy lifespan) and projected modifications to the remedy going forward (additions or deletions from the remedy). These costs should also include regulatory fees for managing the site. Modifications to the remedy may include component replacement such as pumps, blowers, extraction wells, trenches, etc. Modifications to O&M activities may include increased or decreased monitoring, shutting down or expanding a system, changing the treatment process, etc. A stepwise process, as presented above, can still be used to develop a path to closure with the starting point being the long-term O&M and long-term monitoring. An example of an interactive cost estimating spreadsheet is provided in Appendix B. Generally speaking the complexity of a life cycle cost estimate will vary depending on the complexity of the site and proposed remedy. Life cycle cost estimates are generally calculated manually. For complex or large sites, a commercial-estimating software such as the Remedial

Action Cost Engineering Requirements (RACER™) program that integrates the costs of environmental remediation projects from site investigation through system O&M and closure may provide a more efficient means of calculating life cycle costs. Additional information about RACER can be found at http://www.afcee.af.mil/resources/restoration/racer/index.asp.

Life cycle costs provide an economic metric that can be used to compare remedies. These costs can also be paired with mass removal to get a cost per unit mass removed or destroyed by the remedy.

4.8 Sustainability Tools

A variety of decision making tools exist which can be used to assist in determining sustainability metrics for a remedy. These include the Air Force Center for Engineering and the Environment Sustainable Remediation Tool (SRT), as well as tools developed by DuPont, National Grid, BP, Canadian National Railway, Battelle, Golder & Associates, and AECOM Italia. These tools provide for site-specific quantitative analysis of sustainability metrics. The carbon footprint calculators in these tools are generally framed around tiers of activities at the site rather than operational boundaries or scopes of emissions. Of the listed tools, the only tool that is currently available free to the public is the AFCEE SRT: http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp.

The SRT provides an easy-to-use mechanism by which remediation professionals can incorporate sustainability concepts into their decision-making while avoiding time-consuming hand calculations. The current version includes modules for the following technologies:

1. Excavation,
2. In Situ Soil Vapor Extraction,
3. In Situ Thermal Desorption,
4. Pump and Treat,
5. Enhanced Bioremediation,
6. In Situ Chemical Oxidation,
7. Biowalls, and
8. Monitored Natural Attenuation and Long-term Monitoring.

The metrics estimated in this version of the SRT include:

a) GHGs and other air emissions, including NO_x, SO_x, and PM_{10},

b) Energy consumed,

c) Technology cost,

d) Safety / Accident risk, and

e) Change in resource service.

In addition to estimating sustainability metrics, the SRT is being configured to accept inputs from existing RACER™ cost estimates, to allow for sustainability metric calculations for existing RACER™ estimates.

5.0 Remedial Process Optimization

Traditionally, Remedial Process Optimization (RPO) has been used as a systematic approach for evaluating existing remediation systems with the goal of improving the performance of the remedy while reducing overall site cleanup costs (ITRC 2004, AFCEE 2009). While RPO has, in the past, primarily focused on costs and effectiveness, there has also been a significant emphasis placed on energy consumption and waste reduction, as these generally comprise a significant portion of O&M costs of a remedy. RPO for the implementation of GSR takes this optimization a step further and examines how the selected remedy can be optimized to reduce its entire environmental footprint, addressing not only energy and waste generation but all of the U.S. EPA core elements.

Opportunities for implementing sustainable remediation can be considered throughout all stages of the remediation from design through implementation and O&M. For remedies in the design phase, it is important to consider how the remedy will change or evolve over time and to design the remedy such that opportunities for the inclusion of GSR components or methods can be maximized. For existing remedies, RPO follows the more traditional approach where the remedy is evaluated for opportunities to improve performance, cost and sustainability. Figure 5-1 presents a flow chart of RPO.

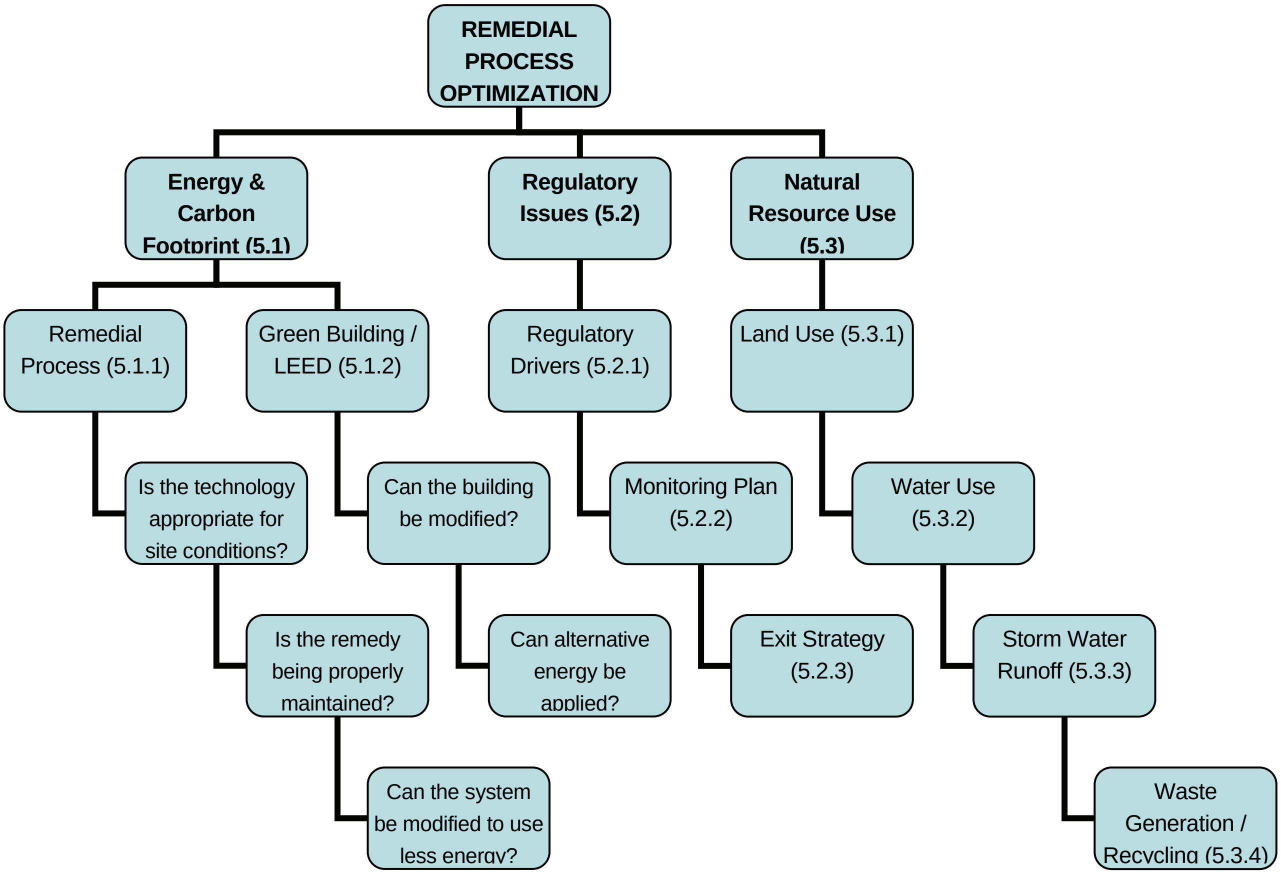


Figure 5-1. Remedial Process Optimization Flow Chart

RPO can be broken down into a series of questions. The first question to ask is whether the remedy is effectively moving the site towards closure. If the answer is no, then a different remedy must be considered. If the answer is yes, the remedy should be examined further to determine if there is potential to make the remedy more effective or sustainable, or to decrease the costs of implementing or maintaining the remedy. RPO described below divides the evaluation of the remedy into three categories: energy and carbon footprint, regulatory issues, and natural resource use. Many of the metrics used in RPO can be calculated from data developed in the baseline analysis (Chapter 4), including baseline O&M costs, contaminant mass removed, dollars per unit contaminant mass removed, water extraction/use, energy use, and others.

5.1 Energy and Carbon Footprint

Energy and carbon footprint encompass the major aspects of the remedy that use the most energy. For RPO, this can be broken down into two categories: 1) Remedial Process, where the mechanism of contaminant removal or destruction is examined; and 2) Green Building/LEED, where the sustainability of the building process and materials are examined. Other aspects of the remediation may impact the carbon footprint or energy use but their impacts are generally less significant.

5.1.1 Remedial Process

For the purpose of this document, remedial process is defined as the mechanism of contaminant removal or destruction. The remedial process can be classified as either active or passive. An example of an active remedy would include an engineered treatment system, while a passive remedy may be monitored natural attenuation. When evaluating the remedial process, the following questions should be asked.

Is the remedial technology employed at the site appropriate for current site conditions?

Many systems/remedies may be over-designed, since the design process generally considers worst case scenarios and adds a factor of safety. In addition, a large portion of the contaminant mass may be removed or destroyed in the first few years of operation, after which contaminant mass removal rates generally decrease. This is often the case for groundwater pump and treat remedies.

Given these two general factors, RPO often reveals that current site conditions do not match initial design conditions and much of the system that was put in place during the original design may not be needed or cost effective to complete the remediation. For instance, if a groundwater treatment system was designed to treat influent at 100 gallons per minute with concentrations of 1,200 µg/L trichloroethylene (TCE), the system may include an air stripper, two granular activated carbon (GAC) units and a catalytic oxidizer to remove the TCE from the vapor discharge of the air stripper. If, after a year of operation, actual site conditions are flows of 40 gallons per minute and influent TCE concentrations of 250 µg/l, a valid modification to the system would be to remove the air stripper and catalytic oxidizer from the treatment process and treat the influent with two GAC units plumbed in series. This removes two energy- and labor-intensive pieces of equipment from the treatment process, thereby lowering the O&M costs and decreasing the environmental footprint of the remedy.

Can green and sustainable technologies be employed to enhance the existing remedy, making it more sustainable, saving costs or bringing the site to closure more quickly?

RPO will examine site conditions and determine whether the existing remedy can be enhanced by employing green or sustainable technologies. These may include in situ chemical oxidation or enhanced monitored natural attenuation techniques, installation of passive venting, solar powered extraction wells or tertiary wetland treatment. These technologies may also include activities such as limited excavation and treatment of source area soils that will allow natural attenuation to be the remedy for residual contamination at a site as opposed to the installation of a remediation system.

Is the remedy being properly maintained?

As a remedy ages, equipment maintenance becomes an issue as parts wear out and need to be replaced. This generally occurs at the same time there is pressure to reduce O&M costs or the operation of the system has become a commodity cost item. System operation time, not effectiveness or efficiency, is often the criteria by which success is judged. Improper maintenance can lead to the system working inefficiently from both a contaminant removal and contaminant destruction aspect. Inefficient contaminant removal or degradation could lead to prolonging the remedial process at a site, while inefficient contaminant destruction could potentially lead to a violation of the regulatory discharge criteria. An example of this would be an improperly maintained air stripper that loses its contaminant mass removal efficiency due to clogging of the air flow pathways. If the stripper is designed to remove 99 percent of the contaminants in the influent and that mass removal efficiency drops to 50 percent due to clogging, the remaining 50 percent of contaminant mass will still be in the effluent from the stripper, which creates a problem.

Can the system operation be modified through either changes in equipment operation or technology to be equally or more effective but use less energy?

In the past, remedies often focused on contaminant destruction with little emphasis on energy conservation. During RPO, the remedy should be examined to determine if the remedial equipment or process can be altered to save energy or maximize contaminant mass removal using the existing process. An example of this would be operating a Soil Vapor Extraction (SVE) system such that the SVE blower would alternately extract vapor from different groups (legs) of wells for set time intervals. By using such a procedure, the SVE system would remove significant mass from one set of wells for a time period and then extract vapors from a different set of wells. During the period when soil vapor is not being extracted, contaminant mass on the soils is allowed to equilibrate with the soil vapor. This recharging of the soil vapor with contaminants allows for higher mass removal rates once the leg is reactivated. By employing this strategy, a higher contaminant mass removal rate could be achieved using a smaller SVE blower and vapor treatment system. This may be equally effective at removing contaminant mass but would use significantly less energy.

Can the system be designed so it can be taken offline in phases as the site is remediated?

For a system in the design stage, it is important to consider the operational lifespan and the stages that the remedy will go through (from remedy implementation to site closure) and to develop a strategy for moving through those stages. Once this is done, determine where flexibility can be built into the remedy design that will allow for easy and efficient transition between stages. For instance, an SVE system can be designed to be converted into a bioventing system to aid in the degradation of heavier compounds not yet stripped from the vadose zone.

5.1.2 Green Building/LEED

Green Building/LEED is where the efficiency and design of buildings is examined. This is particularly important if the remedy is still in the design phase where changes can easily be made with little or no cost impact. For sites with existing remedies, it is more difficult to implement this process because the facilities associated with the remedy are already constructed. When examining existing facilities most of the focus should be placed on items such as energy optimization, water use reduction, storm water reduction, waste minimization and potential use of alternative energy.

A Sustainable Remediation Facilities Checklist is presented in Table 5-1 and is based on a modified Wisconsin Department of State Facilities *Sustainable Facilities Standards Checklist.* The checklist is for new and existing sites and will help evaluate a remedy's sustainability from a construction and energy standpoint. Many of the categories listed in the Sustainable Remediation Facilities Checklist are also dealt with elsewhere in RPO but the checklist provides a good overview of aspects of the remedy that can be examined to improve sustainability.

Table 5-1. Sustainable Remediation Facilities Checklist

Project Name ______________________

Total Project Summary

Yes	No	
		Sustainable Sites
		Brownfield Redevelopment
		Alternative Transportation, Low Emitting & Fuel Efficient Vehicles
		Site Development, Protect or Restore Habitat
		Reduced Site Disturbance, Development Footprint
		Permanent Stormwater Management, Discharge Rate & Volume per NR 151
		Permanent Stormwater Management, Quality Treatment per NR 151
		Light Pollution Reduction
		Water Efficiency
		Water Efficient Landscaping, No Potable Use or No Irrigation
		Water Use Reduction
		Energy & Atmosphere
		Building Systems Commissioning
		Minimum Energy Performance
		CFC Reduction in HVAC&R Equipment
		Optimize Energy Performance — Energy Reduction: __%
		Renewable Energy
		Green Power

		Materials & Resources		
		Storage & Collection of Recyclables		
		Potential Building Reuse		
		Construction Waste Management	Recycled:	__%
		Resource Reuse	Reuse:	__%
		Recycled Content	Recycled:	__%
		Local/Regional Materials	Regional:	__%
		Assigned Accountability, Verification, and Reporting on Results		
		Accountability for Sustainability		
		Verification during Project Design		
		Verification during Project Construction		
		Verification following Construction		
		Reporting on Construction Results		

(Modified from Wisconsin Department of State Facilities (DFS) *Sustainable Facilities Standards Checklist*)

5.2 Regulatory Issues

Remediation is primarily driven by the need for regulatory compliance. When conducting RPO at a site the regulatory framework needs to be examined.

5.2.1 Regulatory Drivers

It is important to consider the regulations under which the remedy is being conducted. If there is an existing decision document for the site, the regulatory drivers or risks need to be examined to determine if they are still valid based on current conditions. Included in this discussion is whether the regulatory standards proposed at the site are appropriate given potential future land use or if they are technically impractical given current remedial technologies and site conditions. Examine the potential of proposing alternative concentration limits or alternative risk-based cleanup levels, if appropriate.

5.2.2 Monitoring Plan

Many remedies include significant long-term monitoring plans. Examine the monitoring plan to determine whether the plan can be optimized based on current data. In many situations, the remedy may include long-term quarterly monitoring for groundwater plumes that are moving a few feet per year. The number of sampling points, sampling frequency, and sampling parameters should be routinely examined. The monitoring plan affects both O&M as well as the environmental footprint of the remedy since samplers must mobilize to the site to collect samples and the samples must be shipped off site for analysis.

Emphasis should also be placed on collecting quality data, which provides information that is critical to the remedy. The quality of data is often overlooked. Generally, when long-term monitoring is conducted, field parameters are collected and samples are taken for laboratory analysis. The quality of the laboratory data is generally good but this is not always the case for field parameters. Field data, including dissolved oxygen (DO) and oxidation reduction potential (ORP), is often critical in making decisions relative to the remedy. This data can be used to determine whether oxidizing or reducing conditions are present in an aquifer. This is critical because if chlorinated solvents in groundwater are the contaminant of concern, it is unlikely that these would naturally attenuate under oxidizing conditions. Conversely, if petroleum contamination is in a reducing environment, it is likely that the degradation of these compounds would be relatively slow. The remedy could potentially be altered, changed or amended based on this data alone so it is important to emphasize collecting quality data. Additional information on monitoring plan optimization can be found at www.afcee.af.mil/resources/restoration/ltm/index.asp.

5.2.3 Exit Strategy

Remedies are often implemented with no clear path to closure other than when the established regulatory threshold is met, the remedy is considered complete and the site can be closed. This gives a beginning and an end to the process, but no directions to get from one point to the other within the process. An exit strategy is a brief document that provides a path to closure and lays out metrics that, once achieved, lead to the next step or phase of the remedy.

An exit strategy provides the shortest path to closure, which ultimately decreases the environmental footprint of the remedy. The exit strategy should be short and concise. It defines the cleanup goals and the methods that will be used to assess whether the goals are being attained. The exit strategy should address stakeholder concerns, meet all applicable regulations, identify all performance metrics, assess costs/risks/future use/benefits of the remedial actions and identify all requirements to terminate remedial activities at the site. It must also determine the following:

1. How performance of the remedy will be measured.
2. Which decision logic/metrics will be used to select operational changes.
3. How attainment of cleanup goals will be demonstrated.
4. How system(s) operation and long-term monitoring will be terminated.
5. How site closeout will be performed.

The regulatory process is simplified when stakeholders agree on the path to closure and the metrics that must be achieved to move through various phases of the remedy. The exit strategy also provides institutional knowledge and protects against changing stakeholder personnel.

5.3 Natural Resource Use

The third major category in RPO is natural resource use. In this category, beneficial end use of the property, water extraction/utilization, storm water runoff, and recycling opportunities and waste minimization are examined. These aspects are broken down into the general categories of land use, water use, storm water runoff and waste generation/recycling.

5.3.1 Land Use

Current and future land use is an important aspect of sustainability, and limiting the amount of land disturbed should be considered. However, this must be balanced against protection of human health and the environment. This is particularly crucial if the remedy is still in the design phase where changes can easily be made with little or no cost impact. Some things to consider during RPO are changing to a technology that requires less infrastructure or allowing the part of the property that has been remediated to be reused. Land use issues to consider in the design phase include habitat creation, use of less invasive technologies, and use of temporary or trailer-mounted treatment units that can easily be removed from the site once they are no longer needed as part of the remedy.

5.3.2 Water Use

In many locations water is increasingly considered an endangered resource and water conservation initiatives are becoming more common. There are two categories examined regarding water during RPO. The first is water use and the second is groundwater extraction.

Generally, water use is not a significant component of most remedies. Water may be used for things such as dust control, decontamination, mixing of chemicals, landscape maintenance and sanitation. RPO should consider ways to minimize water use but it is unlikely that significant sustainability gains could be made in this area.

Groundwater extraction, on the other hand, appears to be an area where significant sustainability gains can be realized. Even in a state that has historically been water rich like Wisconsin, the extraction of groundwater in certain areas has become a major political and environmental issue. In addition, many groundwater extraction systems discharge treated water to the sanitary sewer where additional energy is required to treat the water before it is discharged, a process which is often costly. For example, a groundwater extraction system pumping at a rate of 50 gallons per minute and discharging to the sanitary sewer may incur a monthly sewer charge of over $5,000.00.

RPO will first examine if the groundwater extraction technology used as a remedial component at the site is still an appropriate remedy for current site conditions. If so, groundwater extraction locations and contaminant concentrations at those locations should be examined to determine the minimum volume of water that can be extracted while still maintaining maximum treatment effectiveness. Often, remedies that have been in place for a period of time are operating extraction points or systems that no longer provide tangible remedial benefits. Shutting down these extraction points not only conserves the resource but also saves significant energy required to extract and treat the water.

For example, when a series of wells or extraction trenches are operating to maintain hydraulic containment of a plume, they often operate longer than necessary since they are regarded as being protective of human health and the environment. Once the source of the plume has been treated and decreasing contaminant trends are seen in the body of the plume, hydraulic containment may no longer be required as natural attenuation processes may be significant enough to prevent plume expansion. In this case, the wells can potentially be shut down with additional monitoring being added to verify that plume expansion is not occurring.

5.3.3 Storm Water Runoff

Storm water issues are often overlooked during the remedial design phase. While many remedies are designed to limit infiltration through impacted soils to prevent contaminants from migrating from the vadose zone into the groundwater, this often creates storm water issues. Sites should be designed to limit storm water runoff.

RPO may examine methods to control surface water runoff and re-infiltrate the water on the site in areas that will not impact existing contamination. Storm water runoff control is most easily incorporated during the design phase of the remedial process but can also be implemented post-remedy. Depending on site location, local or municipal ordinances may apply regarding storm water runoff.

5.3.4 Waste Generation/Recycling

Waster generation and recycling is another consideration that is most effectively incorporated into the remedy design phase where recycling of demolition debris such as asphalt, concrete and steel can be included as part of the work to be completed at a site. As the remedy progresses RPO will examine ways to minimize waste through recycling, process changes, or refining O&M procedures to eliminate waste or reduce the generation of waste.

6.0 Alternative Energy

Alternative energy sources may be used to directly power a remediation system or a portion of a system, and may provide heating, cooling, or lighting for a remediation system building. Alternative energy may also be used to reduce the carbon footprint of a remedial system by providing electrical power back to the utility grid. Alternative energy sources can be incorporated into new or existing systems. The greatest payback is often realized on remediation systems that operate energy-demanding technologies (e.g. SVE or pump & treat), systems with a long operational life, or systems that are located in remote areas.

Prior to considering alternative energy sources, it is essential that RPO be conducted to improve the efficiency of the remediation system. The greatest energy savings and carbon footprint reductions are typically identified and implemented most economically during RPO. Incorporating energy efficiency is always the first step in reducing a project's carbon footprint.

Alternative energy sources can also be considered near the end of the active operational life of a remediation system, when an RPO review indicates that system components can be eliminated, operated periodically, or replaced with more efficient equipment. The energy demands of an optimized remediation system may be met by an alternative energy source.

Figure 6-1 is an Alternative Energy Flow chart. To evaluate alternative energy options for a remediation site, follow the suggested steps. The options presented represent those that may be most easily applied to a typical remediation site. Each site is unique and the project manager should incorporate energy efficiency reductions first, followed by alternative energy options if appropriate.

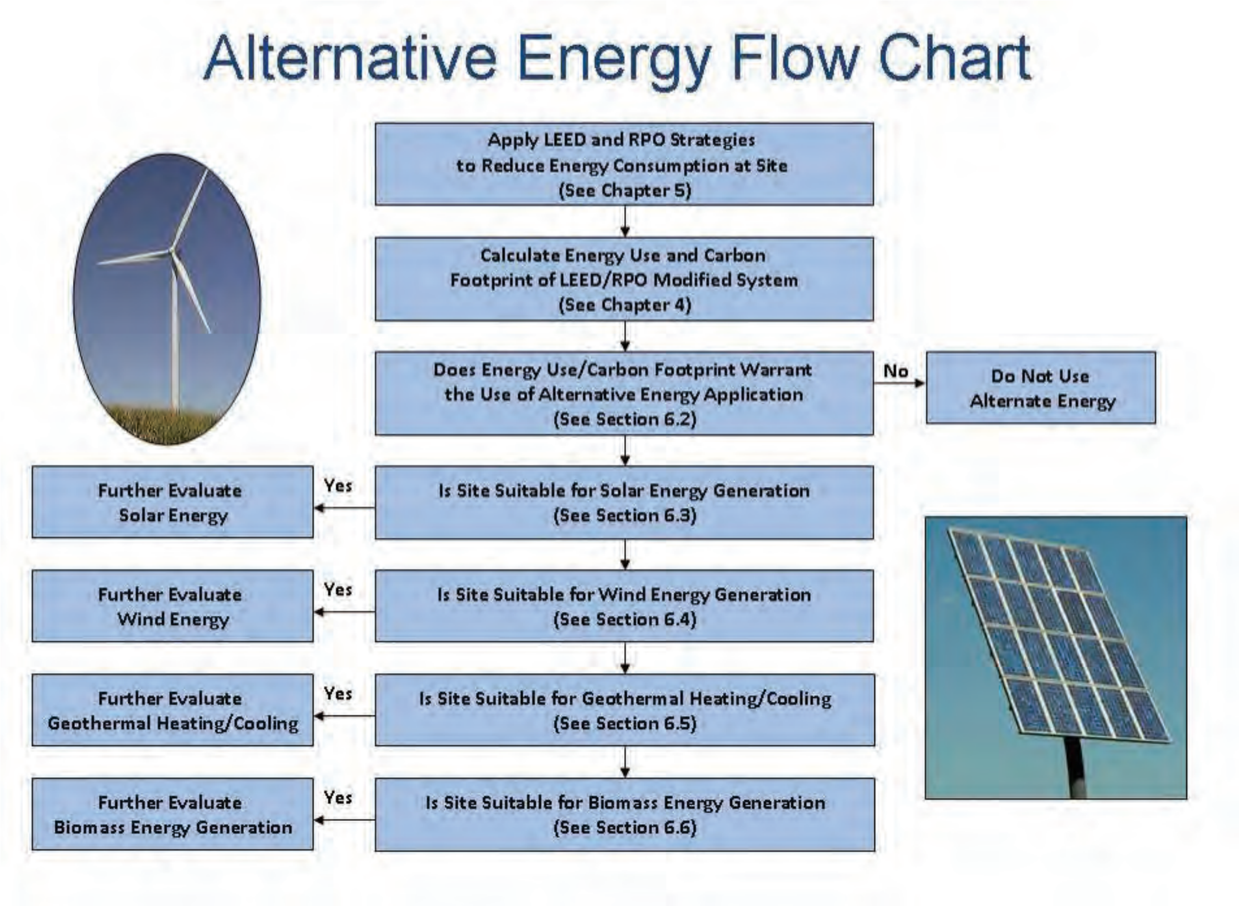


Figure 6-1. Alternative Energy Flow Chart

6.1 Does Energy Use/Carbon Footprint Warrant the Use of an Alternative Energy Application?

Project managers should have a basic understanding of energy generation, energy conservation and efficiency, and be familiar with renewable/alternative energy technologies. Chapter 2 of U.S. EPA's Smart Energy Resources Guide provides an excellent primer for project managers (www.epa.gov/nrmrl/pubs/600r08049/600r08049.pdf). By studying this material and other resources, a project manager will gain the knowledge necessary to begin the alternative energy evaluation process.

The evaluation of whether an alternative energy source is appropriate to a specific remediation system or site is an iterative process where the unique attributes of each site must be taken into consideration by first conducting an RPO review of a proposed or existing remediation system (see Chapter 5). By implementing changes identified in RPO the project manager will have "picked the low hanging fruit" in energy savings. The next step is to calculate the energy use and carbon footprint of the optimized remediation system (see Chapter 4). This information will be used to assess the application of alternative energy options. Additionally, the energy use and carbon footprint data can be used to compare the proposed or existing system operation with future system operation.

To assess the application of alternative energy options to a specific site, a project manager should take a commonsense approach to reviewing the site features, the remediation technology in use, and the applicable alternative energy technologies. The following questions are examples that could lead a project manager to dismiss or to further evaluate specific alternative energy options.

- Is the system going to operate or continue to operate for a "long" time?
- Does a change in the operation of a remediation system (e.g. reduced energy demand) provide the opportunity to use an alternative energy source?
- Can the alternative energy equipment be used at subsequent remediation sites over time?
- Is the remediation site remote, where the cost to bring in power from the utility grid out-weighs the cost of applying an alternative energy technology or technologies?
- Can the energy demands of the site (lighting, control power, equipment power, heating, etc.) be easily separated and addressed by different alternative energy supplies (a hybrid system)?
- Is the site large enough and exposed to wind such that a small wind energy system may be considered?
- Does the solar exposure of the site lend itself to one or more solar energy technologies?
- Is the site a landfill, where biomass energy generation (landfill gas) can be used?
- Does the area of a landfill cap or adjacent property provide space for the application of other alternative energy technologies (e.g. wind, solar)?
- Does the remediation system incorporate pump & treat technology, where the geothermal energy stored in the groundwater can be used for treatment building heating and cooling?
- Does any aspect of the remediation technology or site location provide an opportunity to apply alternative energy sources?

If the project manager cannot answer yes to any of these questions, the remediation site may not be a practical candidate for the application of alternative energy.

By answering yes to any of these questions the project manager has begun to narrow the selection of alternative energy technologies applicable to a specific site. With knowledge of the energy use, the system's carbon footprint, and a practical choice of what alternative energy technologies may apply, the project manager can begin the iterative process of comparing the costs associated with applying alternative energy systems to a remediation site.

To determine the costs of an alternative energy option, the project manager should go to the appropriate section of this chapter (solar, wind, biomass, etc), review the basic information presented, and follow the links to the recommended "tool box" application. The tool box will provide additional information such as technical reports; regulations, zoning, and building codes that may apply; cost estimating tools; funding opportunities; and other how-to guidance documents.

By using the tool box applications, a project manager should be able to

- Determine the expected operating life of the chosen alternative energy technology.
- Determine the life cycle costs to implement the chosen alternative energy technology.

- Compare the savings (cost in dollars and cost in carbon footprint) between the operating remediation system with and without the application of the alternative energy technology.

In addition to the strict cost-benefit analysis of the remediation site itself as described above, the project manager should also evaluate the global implications of implementing an alternative energy technology. These may include the following:

- Environmental impacts – How will the chosen alternative energy technology impact the global carbon footprint associated with the remediation site?

- Economic impacts – Will the chosen technology provide economic benefits beyond the local remediation site?

- Social impacts – Will the chosen alternative energy technology improve the neighborhood or the reuse opportunities of the site, or provide an example of environmental leadership (e.g. a demonstration project)?

Project managers will be able to determine which alternative energy options are most appropriate for a remediation site after considering all of these parameters.

6.2 Solar Energy Generation

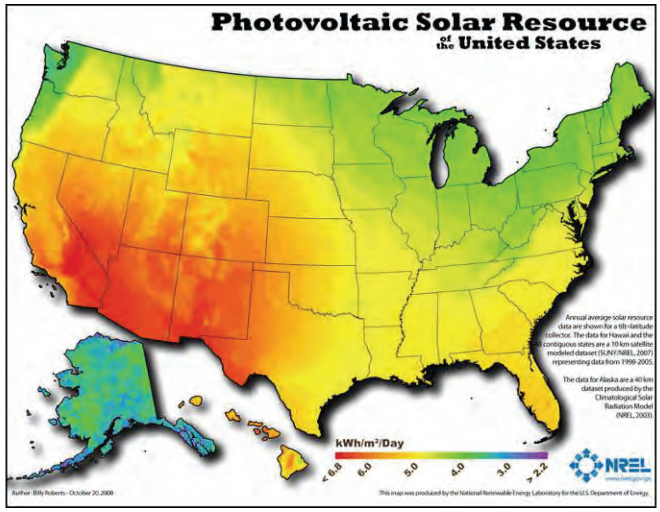
Solar energy technologies capture sunlight to provide heat, light, hot water, and electricity. Solar technologies include photovoltaic systems, concentrating solar systems, passive solar heating and daylighting, solar hot water, and solar process heat and space cooling.

Photovoltaic (PV) technology is used to convert solar energy directly to electrical energy. The base component of a PV system is the PV cell, where semiconductor materials convert sunlight to electricity. Many individual PV cells are wired together to create a PV module. A PV array is made up of interconnected modules. The PV arrays can be wired in various configurations to provide power using batteries, controllers, and inverters (e.g. direct DC power, DC power with battery storage, DC power to an inverter to provide AC power, etc.). PV systems can either be stand-alone systems, providing electricity only at the remediation site (off-grid), or grid-tied systems that are interconnected with the utility grid.

A well-engineered remediation system, including the building housing the remediation equipment, may use a combination of solar energy including PV, solar heat energy for passive solar heating and daylighting, solar hot water, and solar process heat. In general, concentrating solar systems are used in large-scale collectors that are not typically used at remediation sites.

Examples of remediation sites where solar energy may have the greatest impact include the following:

- At remote (off-grid) sites.
- In hybrid systems where it is used with wind or biomass energy generation.
- For systems that have long-term, low energy demands (e.g. low flow pumping).
- To augment grid power, either to provide a long-term on-site source of electricity or to reduce the carbon footprint of the site.



An excellent example of solar power use associated with the GSR Project is the installation of a 10kW PV demonstration system at the Refuse Hideaway Landfill site in Middleton, Wisconsin. During RPO, it was determined that the remediation system would be operating for a long time and that the site topography, a landfill cap with a clear south facing slope, was optimal for placement of a PV array. DNR, working in conjunction with U.S. EPA, Focus on Energy, and Madison Gas and Electric, installed a fixed tilt array PV system with a net metered direct grid connection that will reduce the carbon footprint of the site over the life of the project.

To determine if solar power is an appropriate alternative energy technology at a specific remediation site, project managers will need to use the detailed information provided in web-based tool boxes.

To begin, review Chapters 3 & 10 along with Appendix III of U.S. EPA's Smart Energy Resources Guide www.epa.gov/nrmrl/pubs/600r08049/600r08049.pdf. This will provide a good universal primer on solar energy along with additional links to other solar power tool boxes.

For PV solar power information specific to Wisconsin, go to the RENEW Wisconsin Small Photovoltaic Toolbox www.renewwisconsin.org/solar/PVtoolbox.htm. This site contains a wealth of information about working with utility partners; electrical, building, and zoning codes; case studies; and economic information including funding opportunities.

Using these resources the project manager should be able to

- Assess the physical and solar aspects of an individual site for the application of solar power.
- Determine the type and size of a solar system.
- Review the codes and regulations that may govern the installation of a solar system.
- Determine the economic and environmental costs of installing solar power.

With this knowledge, project managers should revisit the energy use and carbon footprint information discussed in Section 4.2 to make an educated decision about the application of solar energy to a remediation site. Additional resources about alternative energy use are listed in Section 8.7.

6.3 Wind Energy Generation

Wind turbines are used to convert kinetic energy from the wind into mechanical energy. The mechanical energy can be used to turn generators to create electricity or it can be used directly, such as a windmill, to pump air or water.

Wind turbines range in size from small turbines capable of providing a few hundred watts of power to large turbines that produce megawatts of power.

On a remediation site, a project manager may want to consider using a turbine to provide the mechanical energy to pump water. These types of turbines usually require a direct connection to the pumps, which means they are limited to where they can be located on the site. More typically, wind turbines are used to generate electricity that can be used anywhere on the site or be sold back to the utility grid.

There are minimum space and wind speed requirements for a wind power project to be feasible. The remediation site should be located on or near at least one acre of open, rural land. More importantly, consistent wind speed of at least 10 mph at an elevation of 33 feet is necessary.

In addition to the physical limitations to the use of wind power, there may also be regulatory restrictions in the form of zoning, set-back, and permitting requirements. A project manager should be familiar with all of these site-specific requirements before choosing small wind power as an alternative energy source.

To determine if small wind power technology is appropriate at a specific remediation site, project managers can use the detailed information provided in web-based tool boxes.

To begin, review Chapters 4 & 10 along with Appendix IV of U.S. EPA's Smart Energy Resources Guide www.epa.gov/nrmrl/pubs/600r08049/600r08049.pdf. This will provide a good primer on wind energy and links to other wind power tool boxes.

For small wind power information specific to Wisconsin, go to the RENEW Wisconsin Small Wind Toolbox www.renewwisconsin.org/wind/windtoolbox.htm.

Using these resources the project manager should be able to

- Assess the physical and wind aspects of an individual site.

- Determine the type and size of a small wind system.
- Review the codes and regulations that may govern the installation of a wind system.
- Determine the economic and environmental costs of installing a small wind system.

With this knowledge, project managers should revisit the energy use and carbon footprint information discussed in Section 4.2 to make an educated decision about the application of wind energy to a remediation site. Additional resources about alternative energy use are listed in Section 8.7.

6.4 Geothermal Energy Generation

Geothermal energy utilizes the energy stored beneath the earth's surface as a heating source or cooling sink. For the typical remediation site in Wisconsin, the thermal energy stored in shallow groundwater is the most readily accessible geothermal alternative energy source. Groundwater typically remains at a relatively constant temperature of about 55°F. This thermal energy can be utilized by either direct use or in conjunction with the use of a geothermal heat pump.

Direct use of groundwater involves using the energy in the water directly (without a heat pump) for such things as heating or cooling of buildings or industrial processes. The direct use of groundwater as an alternative energy source at remediation sites is primarily dependent on the depth of the groundwater extraction wells and water flow rate.

A geothermal heat pump is an electric appliance similar to an air conditioner unit that uses the earth or groundwater as a heat source in winter and a heat sink in summer. An "open loop" geothermal heat pump uses groundwater from a well, circulates it through the heat pump and returns it to the ground or discharges it to surface water. In a "closed loop" geothermal heat pump, water (or a mixture of water and anti-freeze) is circulated to either horizontal or vertical pipes that are in contact with the earth. After exchanging heat with the ground, the water is circulated back to the heat pump(s) in a closed loop.

An example of an "open loop, direct use" geothermal system at a remediation site is a groundwater pump & treat system where the treated groundwater is discharged to surface water. By using an aboveground water-to-air heat exchanger or radiant floor heating the treatment system can harness the thermal energy in the groundwater for heating or cooling of a remediation building.

To determine if either direct use or heat pump geothermal energy is appropriate for use at a pump & treat remediation site, a project manager can begin by using the detailed information provided in the web-based tool boxes.

The U.S. Department of Energy's Geothermal Technologies Program (GTP) web site (www1.eere.energy.gov/geothermal/heatpumps.html) provides a good primer on the use of geothermal heat pumps including selecting and installing a heat pump system. Additionally, the GTP web site provides information on direct use of geothermal energy (www1.eere.energy.gov/geothermal/pdfs/directuse.pdf). The site also includes links to other geothermal energy tool boxes.

Using these resources the project manager should be able to make a preliminary determination of whether a remediation site is a good candidate for the application of a geothermal energy system.

In recent years, the use of geothermal energy has grown as a commercially acceptable technology for residential and commercial use. Therefore, the project manager may want to work with a heating, ventilation, and air conditioning (HVAC) contractor experienced in geothermal systems for help in designing a system.

Once the energy requirements of the geothermal system are determined, the project manager should revisit the energy use and carbon footprint information discussed in Section 4.2 to make an educated decision about the application of geothermal energy to the site. Additional resources about alternative energy use are listed in Section 8.7.

6.5 Biomass Energy Generation

In Wisconsin, typical remediation sites that are candidates for the use of biomass to energy technologies are inactive or closed landfills that may be generating landfill gas (LFG). Methane is the principal component of LFG used to create energy. Methane has a greenhouse gas potential that is 23 times higher than carbon dioxide, so the use of methane as an alternative energy source will also greatly decrease the carbon footprint of a site.

The conversion of LFG to energy may be attained using a number of technologies including

- Microturbines,
- Internal combustion engines,
- Gas turbines, and
- Fuel Cells.

LFG energy facilities capture and combust the methane to produce energy. In the case of fuel cells, methane is used in a chemical reaction to produce electricity. The choice of technology is dependant on the scale of energy generation desired.

Additionally, external combustion of methane can be used to strictly burn off or "flare" the methane, without using the energy for additional benefits, or the thermal energy created by the combustion process using boilers can be used to evaporate landfill leachate or provide heat for dedicated mechanical operations.

In all cases, the viability of LFG as an alternative energy source is dependent on the long-term availability and reliability of the methane source. In general, this reliability is determined by the following:

- The depth of the landfill – a depth of at least 40 feet best suits anaerobic conditions for producing LFG.
- Amount of waste – a landfill with at least one million tons of municipal solid waste is optimal, although smaller landfills may also be good candidates.
- Type of waste – municipal solid waste landfills, with organic wastes such as paper and food scraps, produce the most LFG. Co-disposal landfills that include construction debris or industrial wastes may not be as productive.
- Age of the landfill – as a landfill ages, the rate of methane generation decreases. Therefore, recently closed landfills have the best potential for LFG-to-energy projects.

To determine if a landfill is a candidate for LFG alternative energy use, project managers should use the detailed information provided in web-based tool boxes.

To begin, review Chapters 5 & 10 along with Appendix V of U.S. EPA's Smart Energy Resources Guide www.epa.gov/nrmrl/pubs/600r08049/600r08049.pdf. This will provide a good universal primer on LFG-to-energy technologies and provide additional links to other tool boxes.

Additionally, U.S. EPA's Landfill Methane Outreach Program (www.epa.gov/lmop/) offers a wide array of technical, promotional, and informational tools as well as services to assist with the development of LFG energy projects. This includes a compilation of various publications, brochures, fact sheets, and software tools.

Using these resources, project managers should be able to make a preliminary determination of whether a landfill site is a candidate for the application of a LFG-to-energy project. Since the success of LFG to energy projects is dependent on many factors, the project manager may want to enroll the help of a LFG to energy expert in making a final determination.

Project managers should also keep in mind that landfill sites, due to their large area and openness, are prime candidates for the application of other alternative energy systems such as solar and wind energy. The application of these technologies can greatly reduce the carbon footprint of a landfill. Additional resources about alternative energy use are listed in Section 8.7.

7.0 Sustainability Options Evaluation

7.1 Sustainable Remediation Process

The first step is to determine what impacts the remedy has on the U.S. EPA core elements by creating a sustainability baseline for the remedy. This quantifies the effects the remedy has on each element in terms of sustainability metrics.

Once the baseline has been established, RPO is conducted to identify areas where the remedy can be improved to decrease the environmental footprint of the remedy, reduce energy consumption, improve efficiency, and reduce the operation and maintenance costs of the remedy. The evaluation of each option using the methods discussed in Chapter 4 will often involve only minor modifications to the existing sustainability baseline.

The options can be compared using a sustainability matrix that evaluates each selected option in terms of the costs and benefits of each option using the sustainability metrics. Each of these steps is discussed in further detail in the following sections.

Implementing GSR at a new or existing site is a stepwise process, as shown in Figure 7-1.

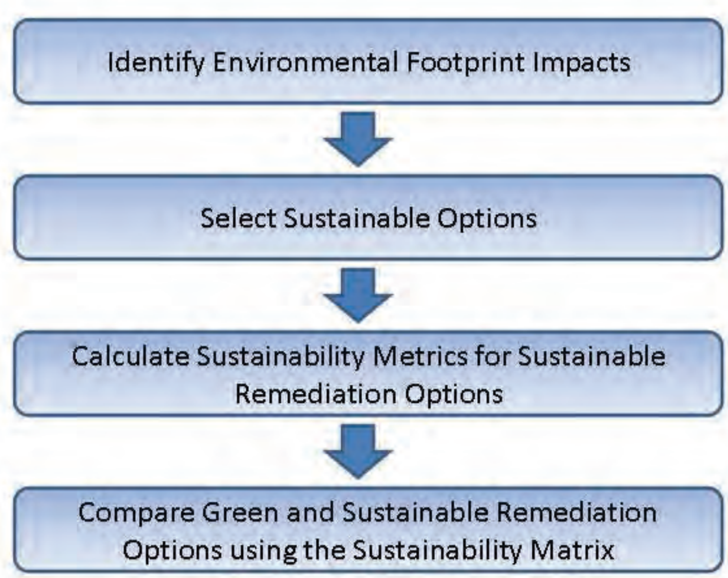


Figure 7-1. Sustainable Remediation Process

7.2 Identifying Environmental Footprint Impacts

Once the sustainability baseline (discussed in Chapter 4) is created, it is easy to determine which core elements are being impacted the most by the proposed or existing remedy. The baseline identifies and quantifies exactly what impacts the remedy is having on the core elements and the magnitude of those impacts. The impacts will vary from remedy to remedy. Some remedies such as steam stripping of contaminants from soils are very energy intensive, while others–such as groundwater extraction and carbon granular activated treatment–may have a relatively small energy demand but negative sustainability impacts, since large amounts of water are being mined from an aquifer.

7.3 Selecting Sustainable Options

Once a remedy's environmental footprint has been determined the next step is to examine how the environmental footprint can most effectively be minimized using traditional engineering or sustainable remediation techniques. RPO presented in Chapter 5 methodically evaluates the remedy and determines if it can be optimized to maximize sustainability and efficiency and reduce operational costs. Once the options have been determined or output from RPO has been finalized, the options should be examined to determine which ones best reduce the impact the remedy has on the five core elements. However, RPO should never result in proposed remedy modifications that do not protect human health and the environment.

When screening these options it is important to consider option viability. Option viability primarily centers on regulatory and public acceptance, whether the option can feasibly be implemented, and cost.

Regulatory and public acceptance of any proposed changes to a remedy is a key aspect to viability. For minor changes to the remedy, this generally is not a major concern, but when significant changes to a remedy are being proposed, this can be a more involved process. Significant modifications to existing systems will require substantive stakeholder involvement (for example: a recommendation to shut down a pump and treat system and move to a natural attenuation or enhanced natural attenuation remedy).

The second driver is the ability to implement the recommended options. RPO presented in this document is limited in scope and deals very generally with remedies. The resulting RPO options are not complete engineering evaluations, but rather a screening of items that should be further examined before being implemented. When these options are further examined, it may not be possible to implement a recommended option. For instance, if in situ chemical oxidation is recommended for a groundwater contaminant plume, further investigation might reveal that the biological and chemical oxygen demand of the aquifer are too great for in situ chemical oxidation to be feasible. This information may not have been available during RPO.

Cost of the proposed options is generally the deciding factor. If there are insufficient funds to implement the recommended option or there is not a significant enough benefit in terms of environmental footprint to justify acquiring additional funds, the option is not viable. An example of this would be implementation of a $50,000 dollar solar array to power a pump and treat system that cost $1,500.00 per year to operate. The treatment system would need to operate for approximately 33 years before the savings from the modification were recovered. The key question that needs to be asked in this case, and in all cases, is this: "Is the reduction in environmental footprint worth the capital cost of the modification?"

In some cases, options that may not be cost-effective may be pursued for other reasons such as the development and demonstration of promising new technologies.

7.4 Calculating Sustainability Metrics for Sustainable Remediation Options

Once the sustainable remediation options generated through RPO have been screened and two or three options have been selected for further evaluation, the environmental footprint can be estimated for each of the selected options, using the methods discussed in Chapter 4. Unless the remedial approach changes at a site, the remedial option environmental footprint can be created by modifying the original baseline to encompass any changes that would be implemented as part of the option. Delete or change parts of the existing remedy as needed.

For instance, if the use of solar panels to generate electricity at a site (to help offset existing electrical use) is determined to be a viable option, the cost of the option and the amount of electricity generated would be incorporated into the baseline. The amount of electricity generated would be deducted from total electricity used at the site to get total non-renewable electricity consumption for the site. This, in turn, would be used to modify the sustainability metrics.

If the option involves a change in remedial technology, it must be treated as a whole new remedy. A new environmental footprint would need to be developed for comparison to the original baseline environmental footprint. For instance, if one of the options examined was to change the remedy from pump and treat to enhanced monitored natural attenuation, there are no crossover components in the baseline. Thus, a new environmental footprint would need to be created to compare to the existing baseline.

7.5 Comparing Green and Sustainable Remediation Options using the Sustainability Matrix

The sustainability matrix is designed to be a summary table that compares the baseline environmental footprint of the original remedy to the modified environmental footprint that includes the option being considered. The sustainability matrix breaks down the sustainability metrics into categories that approximate the U.S. EPA core elements. Two additional categories have been added to the sustainability matrix: the first is a general category that describes the remedy or sustainable remedial option as well the restoration time frame. The second added category is a cost category that summarizes ongoing costs required to maintain the remedy, including O&M, sampling, utilities and regulatory oversight. This can be further parsed out into other sustainability metrics, such as cost-per-unit mass of contaminant removed and cost-per-ton CO_2e reduced. All sustainability metrics should be presented on an annual and lifecycle basis, if possible. The sustainability matrix is presented in Table 7-1.

Table 7-1. Sustainability Matrix

	Baseline[3]		Option 1		Option 2		Option 3	
Sustainability Metrics[1,2]	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**
General								
System Optimization (qualitative)								
Restoration Time Timeframe (yrs)								
Carbon Footprint/Air Emissions								
Tons CO_2e								
Tons CO_2 sequestered								
Dust/Particulates								
Energy Use								
Electricity (kWh)								
Natural Gas								
Cost								
Current Cost								
Cost of Modification								
Water								
Water Use/Resource Depletion (gallons)								
Water Recycled/Reused (gallons)								
Land & Ecosystems								
Total Area Disturbed or Requiring Institutional Controls (acres)								
Area Returned to Unrestricted Beneficial Use or Habitat Enhancement (acres)								
Community Benefits (qualitative)								
Materials & Waste Generation								
Recycled Material (tons or qualitative)								
Waste Materials Generated (tons)								
Landfill Capacity Used (yds)								

[1] Metrics may be either qualitative (+/-), not applicable or quantitative based on available information and scope of project.
[2] Metrics may be added or deleted based on site-specific conditions.
[3]Baseline: Current system operation.

The sustainability matrix can be modified to reflect proposed remedies and existing site conditions. Table 7-2 presents a sustainability evaluation conducted for an old landfill site. In this case, it was determined that there were no significant impacts to water in terms of use or to the resource itself, so the sustainability matrix was simplified by removing the core element water. Tons CO_2e emitted was generated as a total mass and then segregated into CO_2e generated by combustion from the onsite flare and CO_2e emitted in the form of fugitive methane being released to the atmosphere through the landfill cap.

As shown in Table 7-2, the sustainability matrix presents a cost/benefit analysis in terms of sustainability metrics that will provide stakeholders the information they need to best allocate funds to a project to maximize the reduction in the environmental footprint of the remedy. In this instance, it also presents stakeholders with an interesting scenario: given the projections presented in Table 7-2, the stakeholders can spend $25,000 to rebalance the landfill gas collection system and reduce the CO_2e emitted by 10,824 tons (32 percent), or install ten additional landfill gas extraction wells at a cost of $100,000 to reduce the CO_2e emitted by 13,530 tons (40 percent). There is an 8 percent reduction in CO_2e emitted, but $75,000 in implementation costs. In this case, the sustainability matrix provides the stakeholders quantifiable information on which option to choose. They can spend $25,000 and reduce CO_2e emitted by 32 percent, or spend $100,000 and reduce CO_2e emitted by 40 percent. The option they select, if any, then becomes a decision that could be based on external items such as available or programmed funding.

Table 7-2. Sustainability Matrix Delafield Landfill Site

	Baseline[3]		Option 1 LFG Extraction System Rebalancing		Option 2 Installation of 10 LFG Extraction Wells and Associated Header Piping		Option 3 Installation of Modified Flare for the Purpose of Leachate Reduction	
Sustainability Metrics[1,2]	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**
General								
System Optimization (Qualitative)	LFG system is removing 50% of LFG being generated		Modified LFG system would remove 70% of LFG being generated.		Modified LFG system would remove 70% of LFG being generated.		Will not increase the effectiveness of the remedy.	
Restoration Timeframe (yrs)	NA	25	NA	25	NA	25	NA	25
Carbon Footprint/Air Emissions								
Tons CO_2e	33,776	844,400	22,952	573,800	20,246	506,580	33,771	844,275
Tons CO_2e from combusted methane	3,344	83,600	4,682	117,050	5,016	125,400	3,344	83,600
Tons CO_2e from fugitive methane	30,404	760,100	18,242	456,050	15,202	380,050	30,404	760,100
Energy Use								
Electricity (kWh)	48,036	1,200,900	48,036	1,200,900	48,036	1,200,900	48,036	1,200,900
Propane (Pounds)	40	1,000	40	1,000	40	1,000	40	1,000
Cost								
O&M Cost (dollars)	$86,870	$2,171,750	$86,870	$2,171,750	$86,870	$2,171,750	$72,870	$1,821,750
Cost of Modification (dollars)	NA	NA	NA	$15,000 to $25,000	NA	$80,000 to $100,000	NA	$125,000 to $200,000
Cost per Ton CO_2e Reduced	NA	NA	$2.30	$0.09	$7.40	$0.30	$40,000	$1,600

Table 7-2. Sustainability Matrix Delafield Landfill Site

	Baseline[3]		Option 1 LFG Extraction System Rebalancing		Option 2 Installation of 10 LFG Extraction Wells and Associated Header Piping		Option 3 Installation of Modified Flare for the Purpose of Leachate Reduction	
Land & Ecosystems								
Community Benefits (qualitative)	NA	NA	Reduction in fugitive methane emitted		Reduction in fugitive methane emitted		Reduction in leachate discharged to WWTP	
Materials & Waste Generation								
Leachate Generation (gallons)	1,200,000	30,022,500	1,200,000	30,022,500	1,200,000	30,022,500	672,000	16,800,000

[1] Metrics may be either qualitative, not applicable (NA), or quantitative based on available information and scope of project.
[2] Metrics may be added or deleted based on site specific conditions.
[3]Baseline: Current system operation.
'* Assume upper limit costs are used for cost per ton CO_2e reduced.

A companion volume to this guidance document, titled *Site Specific Sustainability Analysis,* provides examples of how to employ the GSR process. The companion volume used the methods presented in this guidance to analyze four sites selected by DNR. The four sites were either State Lead Sites or sites where the State of Wisconsin had significant current or future financial obligations.

8.0 References

The resources and references presented below provide information on GSR and other aspects of sustainability. All reference links presented in Chapters 1 through 7 are listed here, along with other links to additional information. As with all web-based content, information obtained from these sites may not be current or may have changed since the original information was posted.

8.1 Preface

DNR Remediation and Redevelopment Publications
http://dnr.wisconsin.gov/org/aw/rr/archives/pub_index.html

8.2 Chapter 1 References and Links

The Association of State and Territorial Solid Waste Management Officials (ASTSWAMO) Greener Cleanups Task Force:
http://astswmo.org/Pages/Policies_and_Publications/Sustainability/Greener_Cleanups.html

8.3 Chapter 2 References and Links

U.S. EPA Publications *Green Remediation: Incorporating Sustainable Environmental Practices Into Remediation of Contaminated Sites* and the *Superfund Green Remediation Strategy*:
http://cluin.org/greenremediation.

U.S. EPA Greenhouse Gas Reporting Program:
http://www.epa.gov/climatechange/emissions/ghgrulemaking.html

Sustainable Remediation Forum, "Integrating sustainable principles, practices, and metrics into remediation projects," Remediation Journal, 19(3), pp 5 - 114, editors P. Hadley and D. Ellis, Summer 2009:
http://www.sustainableremediation.org/remediation-resources/

Illinois Greener Cleanup Guidance published by the State of Illinois: http://www.epa.state.il.us/land/greener-cleanups/.

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) Greener Cleanups Task Force:
http://astswmo.org/Pages/Policies_and_Publications/Sustainability/Greener_Cleanups.html.

AFCEE Sustainable Remediation Tool (SRT) which provides a Microsoft Excel-based platform for evaluating sustainability metrics such as GHG emissions:
http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp

Interstate Technology & Regulatory Council's *Green and Sustainable Remediation State of the Science and Practice:* http://www.itrcweb.org/guidancedocument.asp?TID=77

8.4 Chapter 3 References and Links

NR 722 and NR 724, which cover new and existing remediation systems, respectively: www.legis.wisconsin.gov/rsb/code/nr/nr700.pdfwww.legis.wisconsin.gov/rsb/code/nr/nr700.html.

U.S. EPA publications *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* and the *Superfund Green Remediation Strategy*: http://cluin.org/greenremediation.

A comprehensive peer reviewed paper on the topic: "Sustainable Remediation Forum. (2009). Integrating sustainable principles, practices, and metrics into remediation projects." Remediation Journal, 19(3), pp 5 - 114. Editors P. Hadley and D. Ellis: http://www.sustainableremediation.orghttp://www.sustainableremediation.org

Guidance published by the State of Illinois: http://www.epa.state.il.us/land/greener-cleanups/

Executive Order #13514, Federal Leadership in Environmental, Energy, and Economic Performance: http://www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf

The Association of State and Territorial Solid Waste Management Officials (ASTSWMO) task force on this topic: http://www.astswmo.org//Pages/Policies_and_Publications/Sustainability/Greener_Cleanups.html

The Sustainable Remediation Tool (SRT) which provides an excel-based platform for evaluating sustainability metrics such as GHG emissions: http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/index.asp .

Sustainable Remediation Forum United Kingdom (SuRF UK): http://www.claire.co.uk/index

Sustainable Remediation Forum Australia (SuRF Australia): http://www.landandgroundwater.com/SuRF.html

8.5 Chapter 4 References and Links

Air Force Center for Engineering and Environment's (AFCEE) Sustainable Remediation Tool: www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp

Greenhouse Gas Protocol Initiative web site: www.ghgprotocol.org/calculation-tools/all-tools
U.S. Energy Information Administration (EIA) website: www.eia.doe.gov/oiaf/1605/emission_factors.html

U.S. EPA Technology Transfer Clearing House for Inventories and Emission Factors web site: www.epa.gov/ttnchie1/.

U.S. EPA's egrid website: http://cfpub.epa.gov/egridweb/

Kyoto Protocol: http://unfccc.int/kyoto_protocol/items/2830.php

U.S. EPA Green Power partnership website: http://www.epa.gov/greenpower/pubs/tools.htm

AFCEE Remedial Action Cost Engineering Requirements (RACER™) program: http://www.afcee.af.mil/resources/restoration/racer/index.asp

8.6 Chapter 5 References and Links

AFCEE Monitoring Plan Optimization Information:
http://www.afcee.af.mil/resources/restoration/ltm/index.asp

AFCEE Remedial Process Optimization Information:
http://www.afcee.af.mil/resources/restoration/rpo/additionalresources/index.asp

http://www.afcee.af.mil/resources/restoration/rpo/index.asp

U.S. EPA Process Optimization Information:
http://www.epa.gov/superfund/cleanup/postconstruction/optimize.htm

ITRC Remedial Process Optimization Information: http://www.itrcweb.org/Documents/RPO-1.pdf

Department of the Navy Process Optimization Information:
https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_nfesc_pp/environmental/erb/wg-opt

State of Wisconsin Executive Order # 145 Relating to Conserve Wisconsin and the Creation of High Performance Green Building Standards and Energy Conservation for State Facilities and Operations.
http://docs.legis.wi.gov/code/executive_orders/2003_jim_doyle/2006-145.pdf

State of Wisconsin Department of Administration, Division of State Facilities. Information on Energy Polices related to LEED: http://www.doa.state.wi.us/category.asp?linkcatid=783&linkid=135&locid=4

U.S. Green Building Council, LEED Information: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=77

Wisconsin Green Building Alliance, LEED Information: http://wgba.shuttlepod.org/

8.7 Chapter 6 References and Links

National Resources:

U.S. EPA's Smart Energy Resources Guide (SERG) is a resource for project managers to help them assess and implement the reduction of emissions and energy use from remediation activities:
www.epa.gov/nrmrl/pubs/600r08049/600r08049.pdf

National Renewable Energy Laboratory (NREL) is dedicated to the research, development, commercialization and deployment of renewable energy and energy efficiency technologies: www.nrel.gov

The Database for State Incentives for Renewables and Efficiency (DSIRE) is a current and comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency: www.dsireusa.org

U.S. EPA's Landfill Methane Outreach Program (LMOP) is a voluntary assistance program that helps to reduce methane emissions from landfills by encouraging the recovery and beneficial use of landfill gas as an energy resource: http://www.epa.gov/lmop/

The U.S. Department of Energy's Geothermal Technologies Program (GTP) develops innovative geothermal energy technologies to find, access, and use the nation's geothermal resources:

http://www1.eere.energy.gov/geothermal/index.html http://www1.eere.energy.gov/geothermal/heatpumps.htmlhttp://www1.eere.energy.gov/geothermal/heatpumps.html

http://www1.eere.energy.gov/geothermal/pdfs/directuse.pdf

The U.S. Energy Information Administration (EIA) collects, analyzes, and disseminates independent and impartial energy information: www.eia.doe.gov/fuelrenewable.html

Wisconsin-Specific Resources:

Wisconsin Office of Energy Independence (OEI) leads the state's effort to advance the use of clean energy and biomass: http://energyindependence.wi.gov/

Focus on Energy works with eligible Wisconsin residents and businesses to install cost effective, energy efficient, renewable energy projects: www.focusonenergy.com

DSIRE database on Wisconsin incentives and policies for renewables & efficiency. www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=WI

RENEW Wisconsin is a nonprofit organization promoting clean energy strategies for powering the state's economy in an environmentally responsible manner: www.renewwisconsin.org

The Midwest Renewable Energy Association (MREA) promotes renewable energy, energy efficiency, and sustainable living through education and demonstration: www.midwestrenew.org

U.S. EIA energy statistical profile for Wisconsin: www.eia.gov/state/state-energy-profiles.cfm?sid=WI

U.S. Department of Energy's current list of utility contacts in Wisconsin. www.eia.doe.gov/cneaf/electricity/utility/utiltabs.html

Wisconsin Small Photovoltaic Toolbox: www.renewwisconsin.org/solar/PVtoolbox.htm

Wisconsin Small Wind Toolbox: www.renewwisconsin.org/wind/windtoolbox.htm

8.8 Additional Reference Material

U.S. EPA Region V Greener Cleanups: http://www.epa.gov/reg5rcra/wptdiv/cars/remediation/

U.S. EPA Superfund & Green Remediation: http://www.epa.gov/superfund/greenremediation/

8.9 Cited References

AFCEE (Air Force Center for Engineering and Environment). 2009. *Draft Remedial Process Optimization (RPO) Handbook*. (http://www.afcee.af.mil/shared/media/document/AFD-091217-079.pdf)

Federal Register. 2007. Executive Order 13423: Strengthening Federal Environmental, Energy, and Transportation Management. (http://edocket.access.gpo.gov/2007/pdf/07-374.pdf)

IPCC (Intergovernmental Panel on Climate Change) Second Assessment Report (1995), Third Assessment Report (2001), and Fourth Assessment Report (2007)

---. 2006, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan. (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html)

ITRC (Interstate Technology & Regulatory Council). 2004. *Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation*. RPO-1. Washington, D.C.: Interstate Technology & Regulatory Council, Remediation Process Optimization Team. http://www.itrcweb.org.

---. 2006. *Life Cycle Cost Analysis*. RPO-2. Washington D.C.: Interstate Technology & Regulatory Council, Remediation Process Optimization Team. http://www.itrcweb.org.

---. 2006. *Exit Strategy - Seeing the Forest Beyond the Trees.* RPO-3. Washington D.C.: Interstate Technology & Regulatory Council, Remediation Process Optimization Team. http://www.itrcweb.org, March 2006.

Sustainable Remediation Forum, "Integrating sustainable principles, practices, and metrics into remediation projects," Remediation Journal, 19(3), pp 5 – 114, editors P. Hadley and D. Ellis. (http://www.sustainableremediation.org/remediation-resources/)

United Nations. 1987. Report of the World Commission on Environment and Development, General Assembly Resolution 42/187, 11 December 1987. Retrieved: 2007-11-14. (http://www.un-documents.net/a42r187.htm)

U.S. EPA, Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008. (http://www.epa.gov/climateleaders/documents/resources/mobilesource_guidance.pdf)

U.S. EPA, Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation, *Superfund Green Remediation Strategy*, September 2010. (http://www.epa.gov/superfund/greenremediation/sf-gr-strategy.pdf)

World Resources Institute, World Business Council for Sustainable Development. 2004. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (Revised Edition). http://pdf.wri.org/ghg_protocol_2004.pdf.

Appendix A

Example Qualitative Checklist

Example Carbon Footprint Calculations

Carbon Footprint Calculations -Baseline

Delafield Sanitary Transfer Landfill #719
South Service Road
Delafield, WI 53018-2132

Scope 1

Gaseous Fuels Burned On-Site	Year	Usage (lbs/yr)	Emission Factors: lbs CO_2/gal	Emission Factors: lb CH_4/gal	Emission Factors: lb N_2O/gal	Mass: lb CO_2	Mass: kg CO_2	Mass: lb CH_4	Mass: kg CH_4	Mass: lb N_2O	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO_2e/kg CH_4	296: kg CO_2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Propane for Flare	2008	40.0	12.5	0.0002	0.0009	32,743.48	14,852.44	0.52	0.24	2.36	1.07	14,852.44	5.94	316.54	15,174.92	33,460.69	16.73
Methane Gas- Destroyed	2008	--	--	--	--	--	--	--	1,103,104.50	--	--	--	3,033,537	--	3,033,537.38	6,688,949.91	3,344.47
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

Purchased Electricity	Year	Usage (kWh)	Usage (GWh)	Emission Factors: lb CO_2/GWh	Emission Factors: lb CH_4/GWh	Emission Factors: lb N_2O/GWh	Mass: lb CO_2	Mass: lb CH_4	Mass: lb N_2O	CO_2e Greenhouse Gas Potentials 1: lb CO_2e/lb CO_2	25: lb CO_2e/lb CH_4	296: lb CO_2e/lb N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Leachate Collection System	2008	3,824	0.003824	1.66	19.24	27.59	0.01	0.07	0.11	0.01	1.84	31.23	72.92	33.07	0.02
Flare Blower	2008	44,212	0.044212	1.66	19.24	27.59	0.07	0.85	1.22	0.07	21.27	361.06	843.04	382.40	0.19
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

Sampling/O&M Vehicle Usage	Year	Usage (miles/yr)	Usage (gal/yr)	Emission Factors: kg CO_2/gallon	Emission Factors: kg CH_4/gallon	Emission Factors: kg N_2O/gallon	Mass: kg CO_2	Mass: kg CH_4	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO2e/kg CH_4	296: kg CO2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Unleaded Gasoline	2008	600	33.33	8.81	0.0036	0.0004	293.67	0.12	0.01	293.67	3.04	3.91	300.61	662.84	0.33
Diesel - Leachate Hauling	2008	7,200	900	10.15	0.000041	0.000038	9,135.00	0.04	0.03	9135.00	0.92	10.23	9,146.15	20,167.26	10.08
Methane Gas- Fugitive	2008	--	--	--	--	--	--	1,103,104.50	--	--	27,577,613	--	27,577,612.50	60,808,635.56	30,404.32
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals: kg CO_2e	Totals: lb CO_2e	Totals: ton CO_2e
30,636,687.51	67,552,291.74	33,776.15

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M activities.*
Diesel fuel used for leachate transport. Leachate disposed of in Waukesha, Wisconsin.
12 site visits/year for site sampling and O&M; 50 miles/visit (roundtrip).
20 site visits/month for leachate disposal; 12 months/year; 30 miles/visit (roundtrip).
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes: *1. Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009.*
2. Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..
3. Greenhouse Gas Potential for CH4 taken from IPCC (2006). Greenhouse Gas Potential for N2O taken from IPCC Third Assessment Report (2001).
4. For every pound of methane combusted there are 2.75 pounds of carbon produced.
5. Utility usage reported by We Energies.
6. EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Wisconsin Energy Corp. Pollutant Output Emission Rates, 2005.
7. EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.

Carbon Footprint Calculations - Option 1 Rebalancing Landfill Gas Extraction System

Delafield Sanitary Transfer Landfill #719
South Service Road
Delafield, WI 53018-2132

Scope 1

Gaseous Fuels Burned On-Site	Year	Usage (lbs/yr)	Emission Factors: lbs CO_2/gal	Emission Factors: lb CH_4/gal	Emission Factors: lb N_2O/gal	Mass: lb CO_2	Mass: kg CO_2	Mass: lb CH_4	Mass: kg CH_4	Mass: lb N_2O	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO_2e/kg CH_4	296: kg CO_2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Propane for Flare	2008	40.0	12.5	0.0002	0.0009	32,743.48	14,852.44	0.52	0.24	2.36	1.07	14,852.44	5.94	316.54	15,174.92	33,460.69	16.73
Methane Gas- Destroyed	2008	--	--	--	--	--	--	--	1,544,346.30	--	--	--	4,246,952	--	4,246,952.33	9,364,529.88	4,682.26
			See Note 1	See Note 1	See Note 1				See Note 2				See Note 3, 4	See Note 3			

Scope 2

Purchased Electricity	Year	Usage (kWh)	Usage (GWh)	Emission Factors: lb CO_2/GWh	Emission Factors: lb CH_4/GWh	Emission Factors: lb N_2O/GWh	Mass: lb CO_2	Mass: lb CH_4	Mass: lb N_2O	CO_2e Greenhouse Gas Potentials 1: lb CO_2e/lb CO_2	25: lb CO_2e/lb CH_4	296: lb CO_2e/lb N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Leachate Collection System	2008	3,824	0.003824	1.66	19.24	27.59	0.01	0.07	0.11	0.01	1.84	31.23	72.92	33.07	0.02
Flare Blower	2008	44,212	0.044212	1.66	19.24	27.59	0.07	0.85	1.22	0.07	21.27	361.06	843.04	382.40	0.19
		See Note 5		See Note 6	See Note 6	See Note 6					See Note 3	See Note 3			

Scope 3

Sampling/O&M Vehicle Usage	Year	Usage (miles/yr)	Usage (gal/yr)	Emission Factors: kg CO_2/gallon	Emission Factors: kg CH_4/gallon	Emission Factors: kg N_2O/gallon	Mass: kg CO_2	Mass: kg CH_4	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO2e/kg CH_4	296: kg CO2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Unleaded Gasoline	2008	600	33.33	8.81	0.0036	0.0004	293.67	0.12	0.01	293.67	3.04	3.91	300.61	662.84	0.33
Diesel - Leachate Hauling	2008	7,200	900	10.15	0.000041	0.000038	9,135.00	0.04	0.03	9135.00	0.92	10.23	9,146.15	20,167.26	10.08
Methane Gas- Fugitive	2008	--	--	--	--	--	--	661,862.70	--	--	16,546,568	--	16,546,567.50	36,485,181.34	18,242.59
				See Note 7	See Note 7	See Note 7		See Note 2			See Note 3	See Note 3			

Totals: kg CO_2e	Totals: lb CO_2e	Totals: ton CO_2e
20,819,057.46	45,904,417.48	22,952.21

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M activities.*
Diesel fuel used for leachate transport. Leachate disposed of in Waukesha, Wisconsin.
12 site visits/year for site sampling and O&M; 50 miles/visit (roundtrip).
20 site visits/month for leachate disposal; 12 months/year; 30 miles/visit (roundtrip).
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
Option 1 - assumes that LFG extraction system becomes 20 percent more efficient but LFG quality remains the same.

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009.*
2. *Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 taken from IPCC (2006). Greenhouse Gas Potential for N2O taken from IPCC Third Assessment Report (2001).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by We Energies.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Wisconsin Energy Corp. Pollutant Output Emission Rates, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*

Carbon Footprint Calculations - Option 2 - Addition of 10 LFG Extraction \Wells

Delafield Sanitary Transfer Landfill #719
South Service Road
Delafield, WI 53018-2132

Scope 1

			Emission Factors			Mass						CO_2e Greenhouse Gas Potentials: 1	25	296	Total		
Gaseous Fuels Burned On-Site	**Year**	**Usage (lbs/yr)**	lbs CO_2/gal	lb CH_4/gal	lb N_2O/gal	lb CO_2	kg CO_2	lb CH_4	kg CH_4	lb N_2O	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Propane for Flare	2008	40.0	12.5	0.0002	0.0009	32,743.48	14,852.44	0.52	0.24	2.36	1.07	14,852.44	5.94	316.54	15,174.92	33,460.69	16.73
Methane Gas- Destroyed	2008	--	--	--	--	--	--	--	1,654,656.75	--	--	--	4,550,306	--	4,550,306.06	10,033,424.87	5,016.71
			See Note 1	See Note 1	See Note 1				See Note 2				See Note 3, 4	See Note 3			

Scope 2

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials: 1	25	296	Total		
Purchased Electricity	**Year**	**Usage (kWh)**	**Usage (GWh)**	lb CO_2/GWh	lb CH_4/GWh	lb N_2O/GWh	lb CO_2	lb CH_4	lb N_2O	lb CO_2e/lb CO_2	lb CO_2e/lb CH_4	lb CO_2e/lb N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Leachate Collection System	2008	3,824	0.003824	1.66	19.24	27.59	0.01	0.07	0.11	0.01	1.84	31.23	72.92	33.07	0.02
Flare Blower	2008	44,212	0.044212	1.66	19.24	27.59	0.07	0.85	1.22	0.07	21.27	361.06	843.04	382.40	0.19
		See Note 5		See Note 6	See Note 6	See Note 6					See Note 3	See Note 3			

Scope 3

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials: 1	25	296	Total		
Sampling/O&M Vehicle Usage	**Year**	**Usage (miles/yr)**	**Usage (gal/yr)**	kg CO_2/gallon	kg CH_4/gallon	kg N_2O/gallon	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Unleaded Gasoline	2008	600	33.33	8.81	0.0036	0.0004	293.67	0.12	0.01	293.67	3.04	3.91	300.61	662.84	0.33
Diesel - Leachate Hauling	2008	7,200	900	10.15	0.000041	0.000038	9,135.00	0.04	0.03	9135.00	0.92	10.23	9,146.15	20,167.26	10.08
Methane Gas- Fugitive	2008	--	--	--	--	--	--	551,552.25	--	--	13,788,806	--	13,788,806.25	30,404,317.78	15,202.16
				See Note 7	See Note 7	See Note 7		See Note 2			See Note 3	See Note 3			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
18,364,649.94	40,492,448.92	20,246.22

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M actvities.*
Diesel fuel used for leachate transport. Leachate disposed of in Waukesha, Wisconsin.
12 site visits/year for site sampling and O&M; 50 miles/visit (roundtrip).
10 site visits/month for leachate disposal; 12 months/year; 30 miles/visit (roundtrip).
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
Option 2 - assumes that LFG extraction system becomes 25 percent more efficient but LFG quality remains the same.

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m ^{3} *(gas)*
Density of propane= 1.83 kg/m ^{3} *(gas)*

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009.*
2. *Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 taken from IPCC (2006). Greenhouse Gas Potential for N2O taken from IPCC Third Assessment Report (2001).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by We Energies.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Wisconsin Energy Corp. Pollutant Output Emission Rates, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2:* CH_4 *and* N_2O *Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*

Carbon Footprint Calculations - Option 3 - Installing Modified Flare for Leachate Reduction Purposes

Delafield Sanitary Transfer Landfill #719
South Service Road
Delafield, WI 53018-2132

Scope 1

Gaseous Fuels Burned On-Site	Year	Usage (lbs/yr)	Emission Factors: lbs CO_2/gal	Emission Factors: lb CH_4/gal	Emission Factors: lb N_2O/gal	Mass: lb CO_2	Mass: kg CO_2	Mass: lb CH_4	Mass: kg CH_4	Mass: lb N_2O	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO_2e/kg CH_4	296: kg CO_2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Propane for Flare	2008	40.0	12.5	0.0002	0.0009	32,743.48	14,852.44	0.52	0.24	2.36	1.07	14,852.44	5.94	316.54	15,174.92	33,460.69	16.73
Methane Gas- Destroyed	2008	--	--	--	--	--	--	--	1,103,104.50	--	--	--	3,033,537	--	3,033,537.38	6,688,949.91	3,344.47
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

Purchased Electricity	Year	Usage (kWh)	Usage (GWh)	Emission Factors: lb CO_2/GWh	Emission Factors: lb CH_4/GWh	Emission Factors: lb N_2O/GWh	Mass: lb CO_2	Mass: lb CH_4	Mass: lb N_2O	CO_2e Greenhouse Gas Potentials 1: lb CO_2e/lb CO_2	25: lb CO_2e/lb CH_4	296: lb CO_2e/lb N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Leachate Collection System	2008	3,824	0.003824	1.66	19.24	27.59	0.01	0.07	0.11	0.01	1.84	31.23	72.92	33.07	0.02
Flare Blower	2008	44,212	0.044212	1.66	19.24	27.59	0.07	0.85	1.22	0.07	21.27	361.06	843.04	382.40	0.19
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

Sampling/O&M Vehicle Usage	Year	Usage (miles/yr)	Usage (gal/yr)	Emission Factors: kg CO_2/gallon	Emission Factors: kg CH_4/gallon	Emission Factors: kg N_2O/gallon	Mass: kg CO_2	Mass: kg CH_4	Mass: kg N_2O	CO_2e Greenhouse Gas Potentials 1: kg CO_2e/kg CO_2	25: kg CO2e/kg CH_4	296: kg CO2e/kg N_2O	Total: kg CO_2e	Total: lb CO_2e	Total: ton CO_2e
Unleaded Gasoline	2008	600	33.33	8.81	0.0036	0.0004	293.67	0.12	0.01	293.67	3.04	3.91	300.61	662.84	0.33
Diesel - Leachate Hauling	2008	3,888	486	10.15	0.000041	0.000038	4,932.90	0.02	0.02	4932.90	0.50	5.52	4,938.92	10,890.32	5.45
Methane Gas- Fugitive	2008	--	--	--	--	--	--	1,103,104.50	--	--	27,577,613	--	27,577,612.50	60,808,635.56	30,404.32
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
30,632,480.28	67,543,014.81	33,771.51

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M activities.*
Diesel fuel used for leachate transport. Leachate disposed of in Waukesha, Wisconsin.
12 site visits/year for site sampling and O&M; 50 miles/visit (roundtrip).
10 site visits/month for leachate disposal; 12 months/year; 30 miles/visit (roundtrip).
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
Option 1 - assumes a 46 percent decrease in the leachate that needs to be hauled annually based on current conditions at the site.

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m ^{3} (gas)
Density of propane= 1.83 kg/m ^{3} (gas)

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009.*
2. *Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 taken from IPCC (2006). Greenhouse Gas Potential for N2O taken from IPCC Third Assessment Report (2001).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by We Energies.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Wisconsin Energy Corp. Pollutant Output Emission Rates, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*

Sustainable Remediation Qualitative Evaluation Checklist

Media or Impact	Positive Effect	Negative Effect
Greenhouse Gases & Energy		
Carbon Dioxide (CO_2 equivalents)	❑ Sequestered in-situ ❑ Sequestered by plants	❑ Generated by fuel & energy for cleanup ❑ Generated by management of residuals ❑ Sequestration loss by vegetation removal
Energy (kWh)	❑ Renewable energy created and used by remedy	❑ Used for remediation ❑ Used for management of residuals
Resource Conservation		
Soil/Solid Material (tons)	❑ Reused-recycled soil or soil-substitute ❑ Improved soil usability	❑ Off-site soil required for remedy ❑ Off-site disposal
Water (gallons)	❑ Reused-recycled	❑ Public or surface water use ❑ Groundwater captured for remediation – where resource is critical
Land (acres)	❑ No limitation to anticipated use ❑ Wetlands created or upgraded ❑ Conservation easement	❑ Permanent limited use

Appendix B

Example Life Cycle Cost Analysis

Example: Life Cycle Cost Analysis

Task Cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Design Costs	6,000.00										6,000.00
Construction Costs	24,000.00										24,000.00
Operation & Maintenance Costs	20,000.00	20,800.00	21,632.00	22,497.28	23,397.17	24,333.06	25,306.38	26,318.64	27,371.38	28,466.24	240,122.14
Sampling Costs	12,000.00	12,600.00	13,230.00	13,891.50	14,586.08	15,315.38	16,081.15	16,885.21	17,729.47	18,615.94	150,934.71
Regulatory Oversite Costs	2,000.00	2,060.00	2,121.80	2,185.45	2,251.02	2,318.55	2,388.10	2,459.75	2,533.54	2,609.55	22,927.76
Utility Costs - Electric	4,000.00	4,200.00	4,410.00	4,630.50	4,862.03	5,105.13	5,360.38	5,628.40	5,909.82	6,205.31	50,311.57
Utility Costs - Natural Gas	2,000.00	2,100.00	2,205.00	2,315.25	2,431.01	2,552.56	2,680.19	2,814.20	2,954.91	3,102.66	25,155.79
Utility Costs - Water & Sanitary	1,000.00	1,050.00	1,102.50	1,157.63	1,215.51	1,276.28	1,340.10	1,407.10	1,477.46	1,551.33	12,577.89
Utility Costs - Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abandonment Costs (Present $)	5,000.00	175.00	181.13	187.46	194.03	200.82	207.85	215.12	222.65	230.44	6,814.49
	============	=========	=========	=========	=========	========	========	========	========	========	==========
	76,000.00	42,985.00	44,882.43	46,865.07	48,936.83	51,101.77	53,364.15	55,728.41	58,199.22	60,781.46	538,844.35

Assumptions

	Annual Rate (%)
Utility Rate Increase/Decrease	5.00%
O&M Increase/Decrease	4.00%
Regulatory Oversite	3.00%
Sampling Costs	5.00%
Inflationary Increase	3.50%

Notes: [shaded cell] Requires data entry