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Green Remediation: Reducing the Environmental Footprint of Cleanups

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Office of Solid Waste and Emergency Response (OSWER)

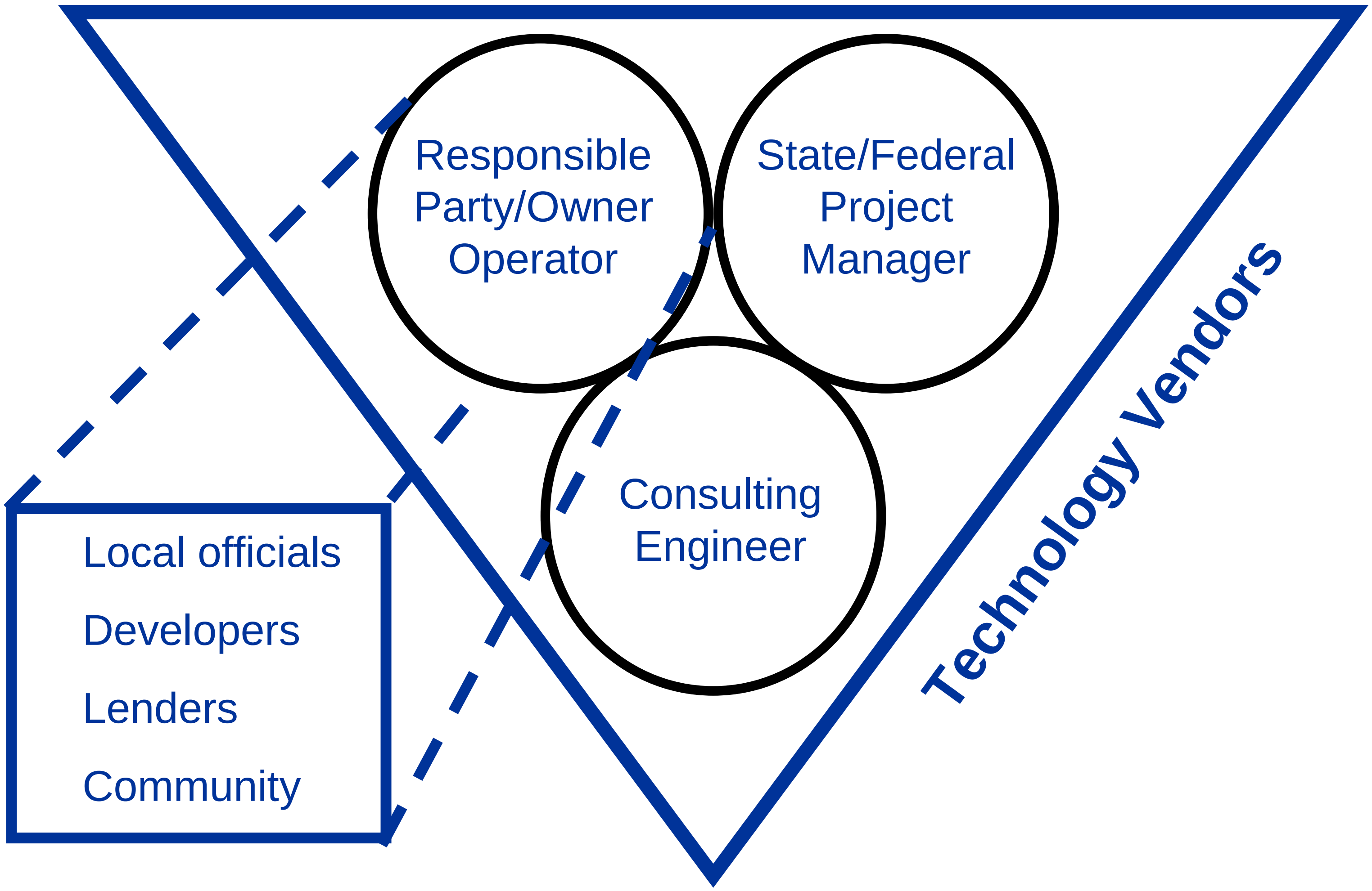
- Develops standards and regulations for hazardous and non-hazardous waste (RCRA)
- Promotes resource conservation and recovery (RCRA)
- Cleans up contaminated property and prepares it for reuse (Brownfields, RCRA, Superfund, UST)
- Helps to prevent, plan for, and respond to emergencies (Oil spills, chemical releases, decontamination)
- Promotes innovative technologies to assess and clean up contaminated soil, sediment, and water at waste sites (Technology Innovation)

Office of Superfund Remediation and Technology Innovation (OSRTI)

Technology Innovation Field Services Division (TIFSD)

- OSRTI - implements and manages Superfund program
- TIFSD Core Mission:
  - Advancing best practices in site cleanup
  - Technology support to EPA Regional project managers, states, local governments, tribes
  - Informational support to cleanup community at large
- Primary activity areas to advance mission:
  - Evaluate and document innovative technologies
  - Transfer knowledge through publications, training, internet, etc.
  - Provide direct technical support at sites in Superfund, Brownfields, RCRA, and UST
  - Manage analytical services for the Superfund program

Target Audience



Presentation Overview

- EPA's Definition of Green Remediation
- Business Case for Green Remediation
- EPA's Principles for Greener Cleanups
- Environmental Footprint Calculation
- Environmental Footprint Interpretation
- Reducing Environmental Footprints
- Case Studies
- Lessons Learned
- Footprint Analysis Methodology: Where We Are Headed?
- Questions

EPA's Definition of Green Remediation

Considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of a cleanup

THE BUSINESS CASE FOR GREEN REMEDIATION

Green Remediation Benefits

- Green remediation practices fall into two cost categories
  - Neutral or increased cost (e.g., use of biofuels)
  - Cost-effective (e.g., energy efficiency)
- Green remediation practices that are cost-neutral or have an increased cost may have significant intangible benefits

Financial Benefits

- Many green remediation practices result in cost savings
  - Remedy optimization
  - Energy efficiency recommendations
  - Reduction in materials use and waste disposal
- Primary contributors to footprints are often largest non-labor costs
  - Utilities
  - Materials
  - Waste disposal
  - Laboratory analysis
  - Off-site water treatment
- Reducing footprints therefore helps reduce cost

Intangible Benefits

- Practices with neutral or increased cost have intangible benefits
  - Compliance with executive orders or regulations
  - Improved relationships with site stakeholders
- Increased costs…
  - Are generally very low relative to remedy cost
  - Can yield impressive footprint reductions
- Green remediation evaluations are inexpensive but evaluate remedy from a different perspective

EPA'S PRINCIPLES FOR GREENER CLEANUPS

Green Remediation: A Priority at Many Levels

- EPA OSWER Policy: Principles for Greener Cleanups
- EPA Strategic Plan: Goal 5 Compliance and Environmental Stewardship
- Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance

EPA OSWER
Green Remediation Principles

- Consistent with existing laws and regulations, it is OSWER policy that all cleanups:
  - Protect human health and the environment
  - Comply with all applicable laws and regulations
  - Consult with communities regarding response action impacts consistent with existing requirements
  - Consider recommended five core elements of green remediation

Superfund Green Remediation Strategy

- Sets out the Superfund Program's plans to promote green remediation practices during site cleanups without compromising cleanup goals
- Covers three areas:
  - Policy and Guidance
  - Resource Development and Program Implementation
  - Evaluation
- Includes 9 "Key Actions"; each action includes several implementation activities (46 total)

EPA OSWER's Key Message from

- As a nation we still have site cleanup work to complete
- We can use green remediation practices to reduce the footprint of this cleanup to the maximum extent possible
- There is no "green remediation technology", but better practices in the design, build, and operation of current and future remedies
- Beware of changing the endpoint to reduce the environmental footprint
- There are multiple efforts underway, policy, technical, and programmatic

EPA Regional
Green Remediation Policies

- EPA Regions all have different Green Remediation policies
- Common elements for all policies:
  - Protect human health and the environment
  - Minimize total energy use
  - Maximize use of renewable energy
  - Minimize air emissions and greenhouse gas generation
  - Minimize water use and impacts to water resources
  - Reduce, reuse, and recycle materials and waste
  - Support the environmentally sustainable reuse of land
  - Applies to all sites under EPA oversight
  - Applies throughout remedial process
- Many Regions have measurement / tracking / reporting requirements

EPA Regional
Green Remediation Policies (continued)

- Each Region differs in its suggested language
- 8 of 10 Regions do not *require* green remediation
  - Implement green remediation “where practical and appropriate”
  - “Encourages” green remediation
  - “Promotes” green remediation
  - “Examine and implement” green remediation practices “where possible”

Regions 2 and 10 Are Exceptions

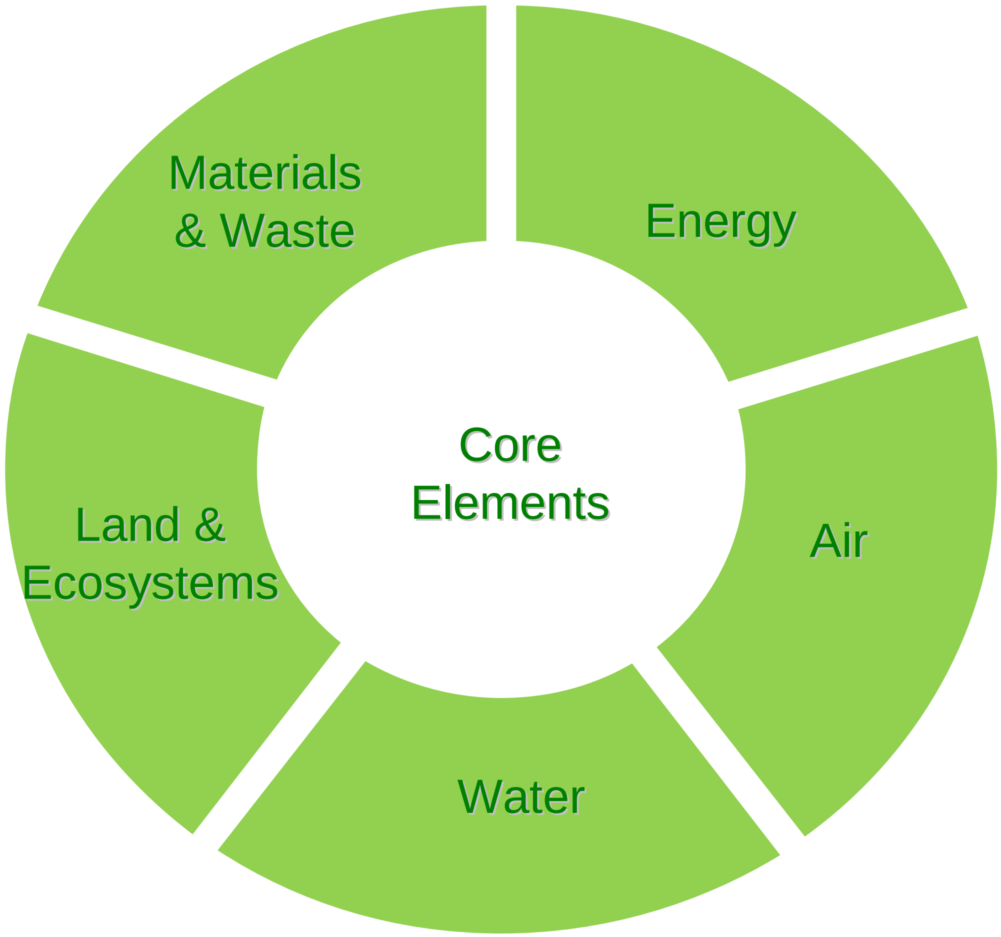
- Regions 2 and 10 are exceptions that *require* green remediation
  - Region 2 – Primarily New York and New Jersey
  - Region 10 – Northwest U.S.
- Touchstone practices *required* unless evaluation demonstrates impracticability, examples include
  - Use of 100% electricity from renewable resources
  - Clean diesel technologies
  - Materials reuse, reduction, and recycling

Other EPA Involvement

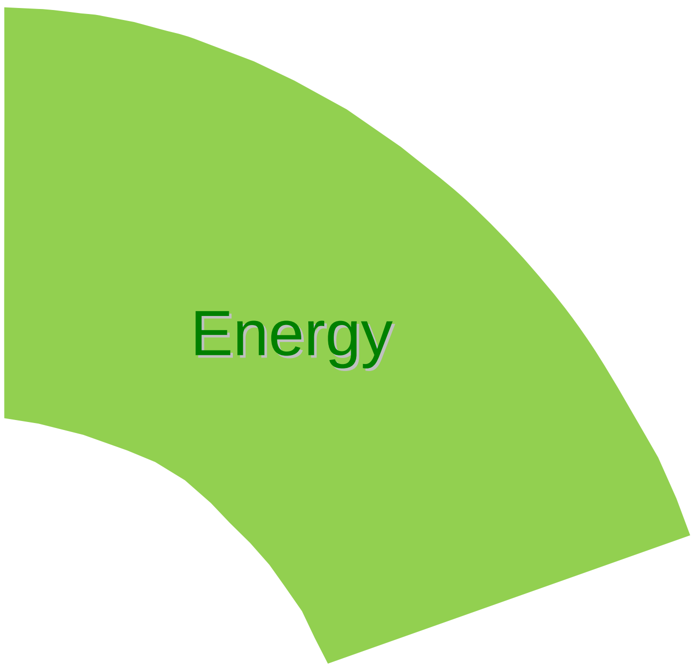
- Participation with other federal agencies in the Federal Remediation Technologies Roundtable
- Participation in the Sustainable Remediation Forum with other agencies and private parties (SuRF)
- Participation in Development of an ASTM Green Cleanups Standard

ENVIRONMENTAL FOOTPRINT CALCULATION

Environmental Parameters of Interest



Environmental Parameters of Interest



- Total energy used
- % of energy from renewable resources

Environmental Parameters of Interest

- Emissions of
  - Greenhouse gases
  - NOx, SOx, PM
  - Toxic air pollutants

Environmental Parameters of Interest

- Potable water use
- Other water use
  - o Quantity
  - o Source of water
  - o Fate of water

Environmental Parameters of Interest

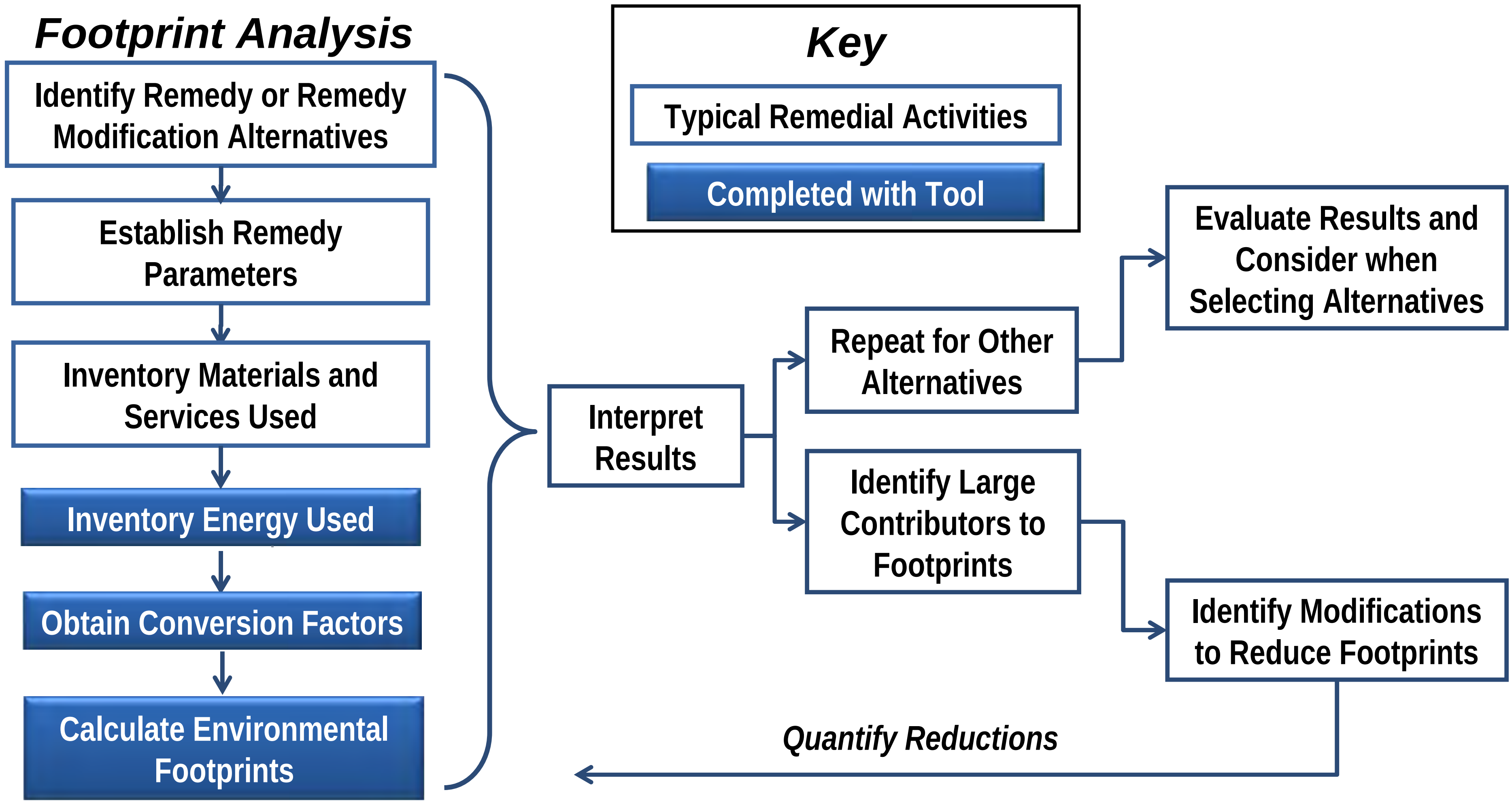
Land & Ecosystems

- Habitat created or disturbed
- Reuse or redevelopment of impacted land
- Time frame for reuse or redevelopment of land
- Creation or destruction of valuable “ecosystem service (e.g., soil erosion control)

Environmental Parameters of Interest

- Manufactured materials used (e.g., treatment chemicals, steel, plastic)
  - Quantity
  - % recycled
- Bulk, unrefined materials (e.g., sand, fill, soil)
  - Quantity and % recycled
- Waste
  - Hazardous waste generated (tons)
  - Non-hazardous waste generated (tons)
  - % of total potential waste recycled

Footprint Analysis Schematic



Footprint Conversion Factors

Inventory Energy Used

Remedy Selection	Remedy Design	Remedy Operation
Estimates	Better Estimates	Actual Usage

Electricity usage for pumps, motors, etc.
Fuel usage for on-site heavy equipment
Fuel usage for transportation of personnel, materials, waste

Obtain Conversion Factors

Life-cycle inventory databases
Construction materials
Treatment materials, chemicals, and nutrients
Fuel production
Waste disposal and off-site water treatment
Laboratory analysis

Footprint Analysis Tools

- What tools are available for footprint analysis?
- There are lots of them!!! But, there is no standardization.
  - SiteWise™
  - Sustainable Remediation Tool (SRT™)
  - GolderSET
  - BalancE3
  - Life-cycle assessment tools from manufacturing sector
  - GS-Rx
  - EPA Region 9 Spreadsheets
  - Many others!!!
- What do they do?
  - Estimate of fuel usage
  - Provide conversion factors
  - Calculate footprints and organize results

ENVIRONMENTAL FOOTPRINT INTERPRETATION

Parameters of Local Importance

Generally speaking…

- Remediation is of local interest and importance
- Green remediation is of local, regional, and global importance

Global	Regional	Local
Greenhouse gases	NOx, SOx, PM	NOx, SOx, PM
Energy use	Regional water use	Toxic pollutants
Toxic pollutants*	Energy use	Local water use
	Toxic pollutants*	Waste disposal
		Habitat created / destroyed
		Land reused

**Particularly more persistent toxic pollutants (e.g., mercury)*

Global vs. Local Parameters

- How do you interpret the information that comes out of a green remediation evaluation?
- What's more important?
  - Hazardous air pollution emissions
  - Greenhouse gases
  - NOx, SOx, and PM emissions
  - Potable water use
  - Materials use
  - Waste disposal

Involving Site Stakeholders

- Fortunately, many of the environmental parameters are linked to similar sources
- Site stakeholders are those most affected by the remedy
- The Superfund process, in particular, heavily involves the local community
  - Receive community input
  - Demonstrate green remediation and sustainability practices
  - Demonstrate that remedy implementation considers community concerns

Putting Footprint Results into Perspective

- How do remedy footprints compare to those of the American economy?

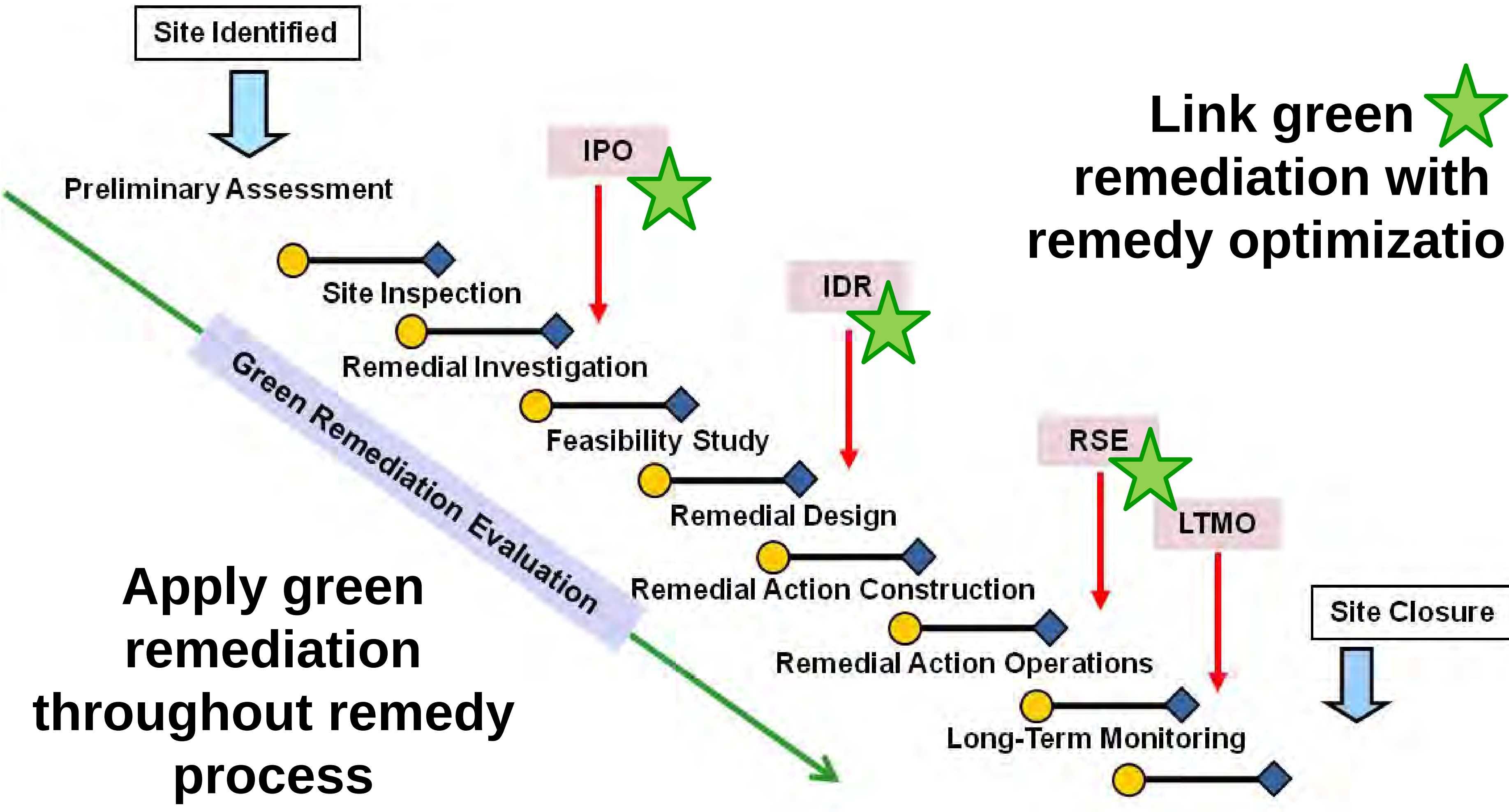
	P&T System	U.S. Per Capita
Total Energy	140,000 kWh/yr	95,400 kWh/yr
Water Use	52,000,000 gallons/yr	65,000 gallons/yr
Waste Generated	No significant waste	~0.85 tons/yr
Habitat/ecosystem affected	No habitat destroyed	Habitat destroyed with new construction and development

Notes:
P&T system is 100 gpm system for VOCs only
P&T energy is total energy (electricity, transportation, etc.)
Per capita energy from 2008 usage and population (www.eia.gov)
Per capita water is water from public supply (USGS Circular 1268)
Per capita waste from EPA Region 3

Energy footprints are comparable. Water footprint can be reduced with beneficial reuse of treated water.

REDUCING ENVIRONMENTAL FOOTPRINTS

Green Remediation throughout the Remedial Process



Link green remediation with remedy optimization

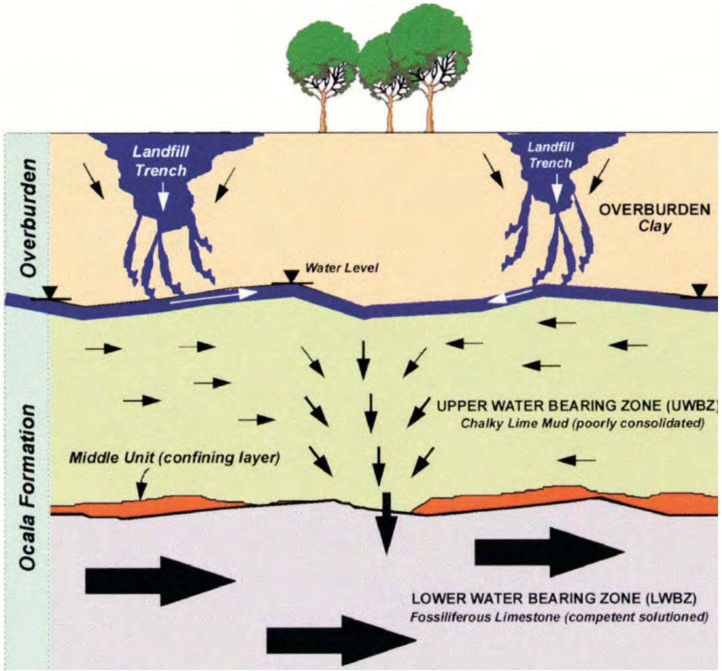
Apply green remediation throughout remedy process

Green Remediation throughout the Remedial Process

- Remedy Selection
  - Link footprint analysis with Feasibility Study
  - Integrate footprint analysis with consideration of alternatives
  - Identify large footprint contributors
- Remedy Design
  - Use footprint analysis information
  - Optimize or reduce environmental footprints
  - Evaluate data gaps and affect on footprints
- Remedy Operation
  - Revisit design parameters and final footprint results
  - Conduct footprint analysis
  - Identify large contributors to footprints

General Footprint Reduction

- Consistent with good science and engineering
- Minimizing footprints and large footprint reductions come from…
  - An accurate site conceptual model
  - Well-characterized source areas and contaminant plumes
  - Appropriate remedy selection
  - Good engineering
  - Streamlined performance monitoring



Energy and Emission Reductions

- Energy efficiency practices
  - High-efficiency equipment
  - Variable frequency drives
  - Low-emission vehicles and carpooling
  - Maintaining, repowering, or retrofitting diesel engines
  - Use of local materials and services
- Alternative and renewable energy
  - On-site renewable energy
  - Purchased renewable energy
  - Combined heat and power

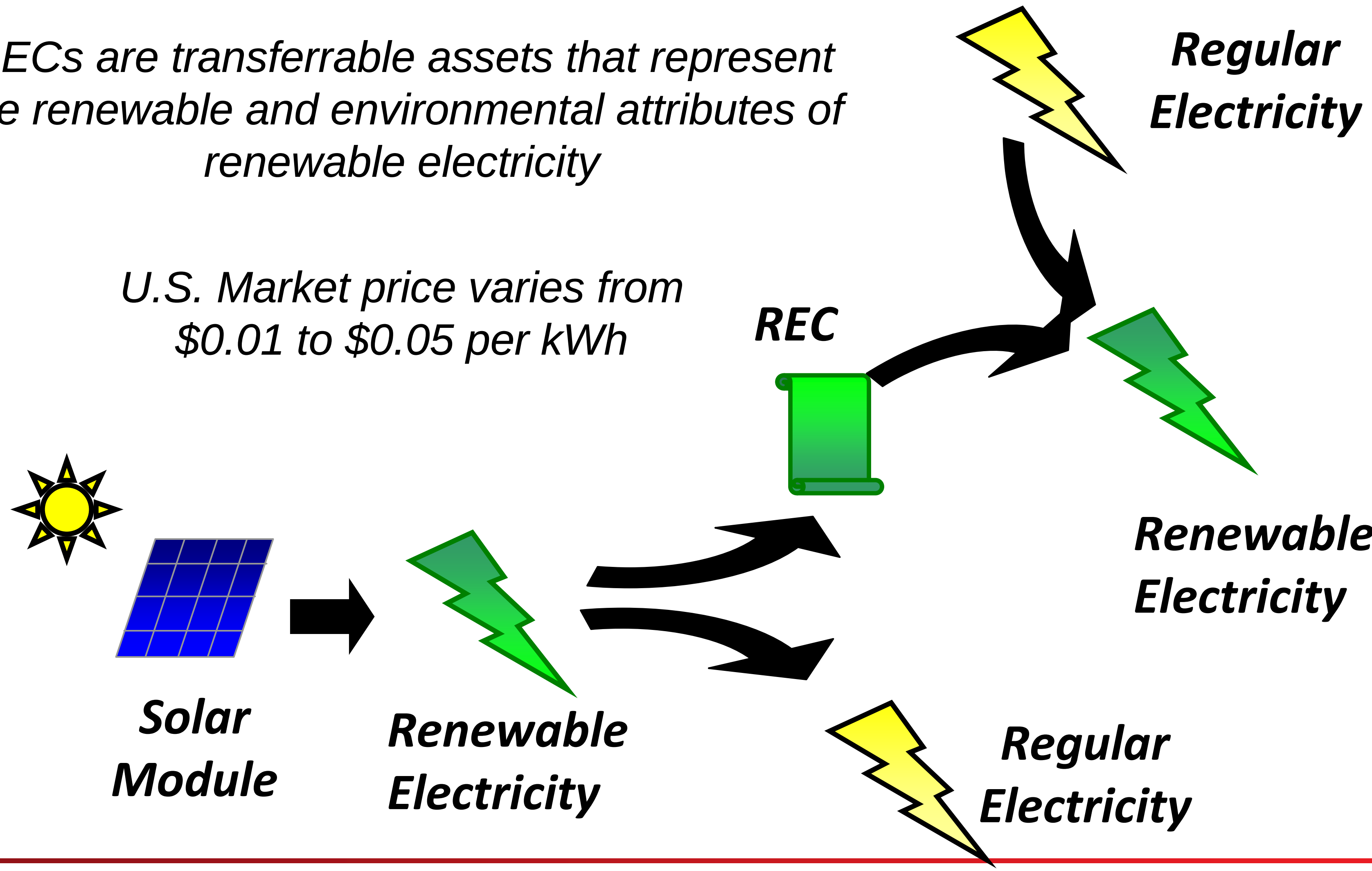
Notes about Renewable Energy

- Can apply renewable energy in several ways
  - On-site generation of electricity from renewable resources
  - Use of fuels from renewable resources
  - Purchase off-site renewable electricity
  - Use of materials/chemicals manufactured with renewable energy

Notes about Renewable Energy

RECs are transferrable assets that represent the renewable and environmental attributes of renewable electricity

U.S. Market price varies from $0.01 to $0.05 per kWh



Notes about Renewable Energy

- Wind vs. RECs for 200,000 kWh/yr at public and private facilities
  - Public facilities do not benefit from tax-based incentives

Location	Financial Position at 10 years		
	RECs	On-site Wind (Private)	On-site Wind (Public)
California	($60,000)	+$138,500	($134,000)
Colorado	($60,000)	($103,500)	($336,000)
Illinois	($60,000)	($61,500)	($324,000)
Virginia	($60,000)	($111,500)	($374,000)

Electricity costs from www.eia.gov. Electricity generation based on Northwind 100 specifications and a marginal average wind speed between 5.5 and 6.0 m/s. Install costs based on $5,000 per installed kW and applicable incentives that do not require sale of RECs. O&M costs of $0.025 to $0.03 per kWh. Private sector solar includes 30% federal tax credit and accelerated depreciation based on a 35% federal corporate tax.

RECs may be the cheapest way to meet renewable energy requirements and/or reduce footprints.

Notes about Renewable Energy

Example Remedies	Electricity Usage (kWh/yr)	% of Remedy CO2e Footprint	% Increase in Cost due to RECs	Significant Affect on Footprint?
P&T system (80 gpm, 500 ug/L of VOCs)	135,000	90%	3%	YES
SVE system (500 cfm, 1,000 lbs per year)	130,000	90%	3%	YES
Electric resistive heating (28,000 cy)	7,000,000	95%	4%	YES
In-Situ Bio or Chemical Oxidation	12,000	<1%	<1%	NO
Monitored Natural Attenuation	0	0%	$0	NO
Excavation/disposal	0	0%	$0	NO

For electricity intensive remedies, REC purchases result in substantial footprint reduction at a minor cost increase.

Water Conservation

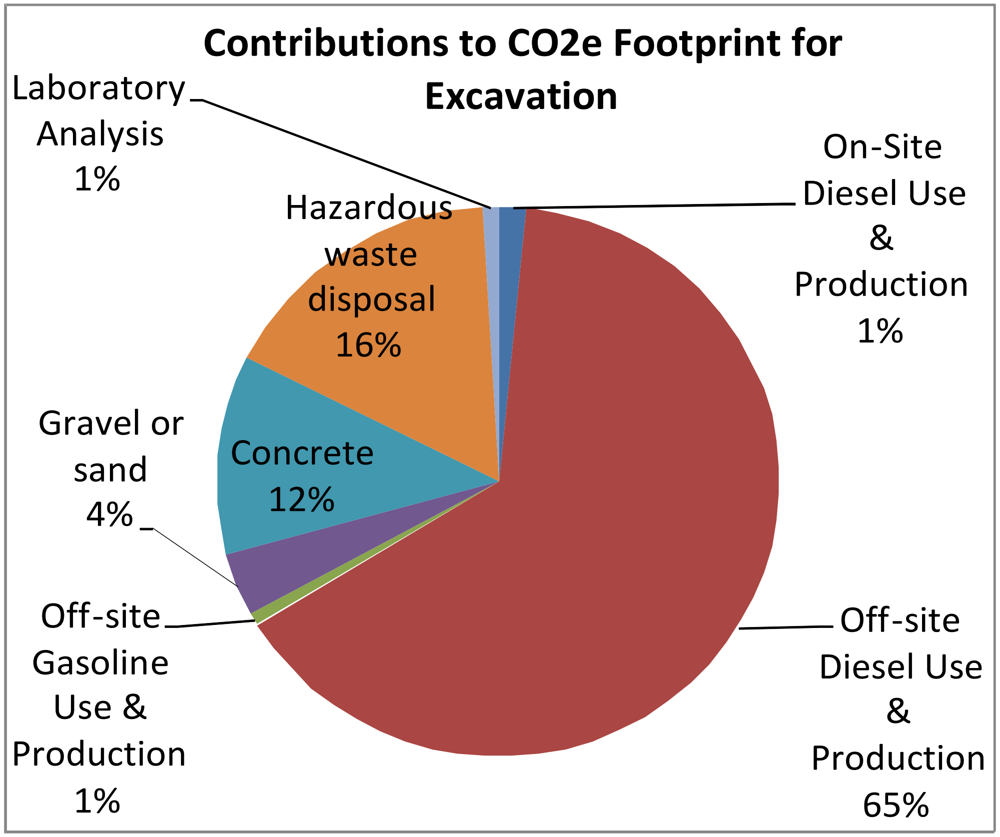
- Beneficial use of extracted/treated water
- Optimize capture zones of P&T systems
- Divert clean water around impacted area
- Infiltration of diverted storm water for aquifer storage
- Use of less refined water resources when possible

Material Reduction

- Reduce Material Use
  - Alternative materials or chemicals
  - Aeration instead of oxidants
  - Air stripping instead of carbon adsorption
  - Use of less refined materials
  - Products with recycled content
  - Products from waste or byproducts
- Identify local suppliers
- Identify “green” suppliers

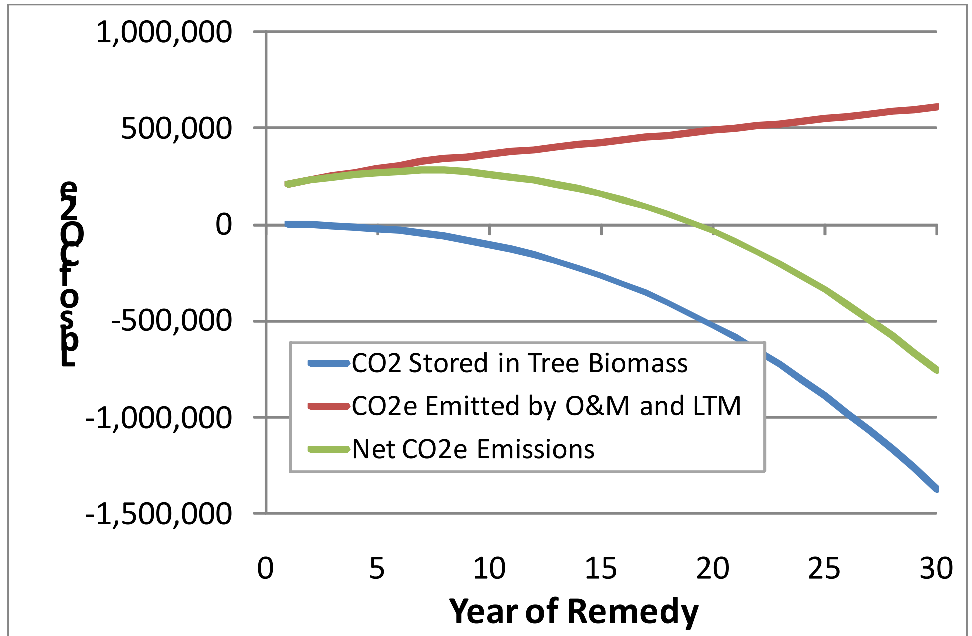
Waste Reduction

- Recycle or reuse materials
- Identify nearby disposal facilities
- Consider fate of waste
- Dewater waste before shipping
- Favor non-hazardous waste over hazardous waste



Land and Ecosystems

- Find beneficial use of land
  - Green space or park
  - Redevelop to avoid new construction elsewhere
  - Create habitat
- Minimize destruction of existing habitat
  - Avoid dewatering wetlands
  - Avoid destruction of vegetation
  - Minimize "footprint" of heavy equipment
  - Avoid release of chemicals/reagents to environment



Planting trees creates habitat and can store a substantial amount of carbon dioxide in biomass

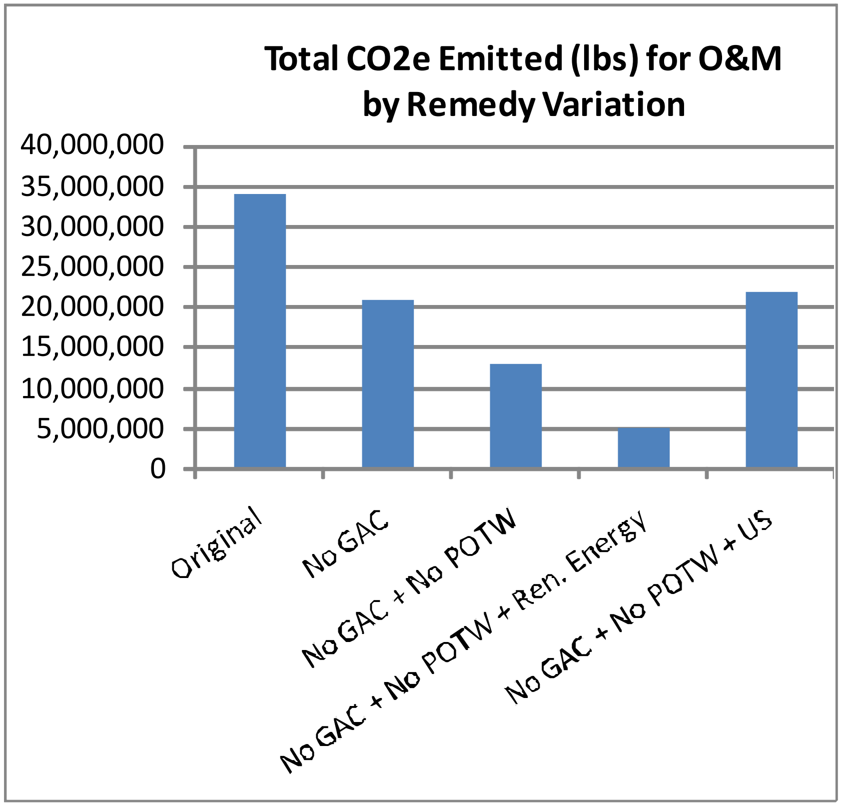
CASE STUDIES

Case Study #1

- Site in California with VOC contamination
- Interim P&T system operating for many years
- Considerations derived from green remediation evaluation:
  - VOCs more susceptible to air stripping than GAC
  - Increase air stripping and eliminate GAC and discharge to sewer
  - Purchase RECs to offset all electricity usage

Case Study #1 (cont.)

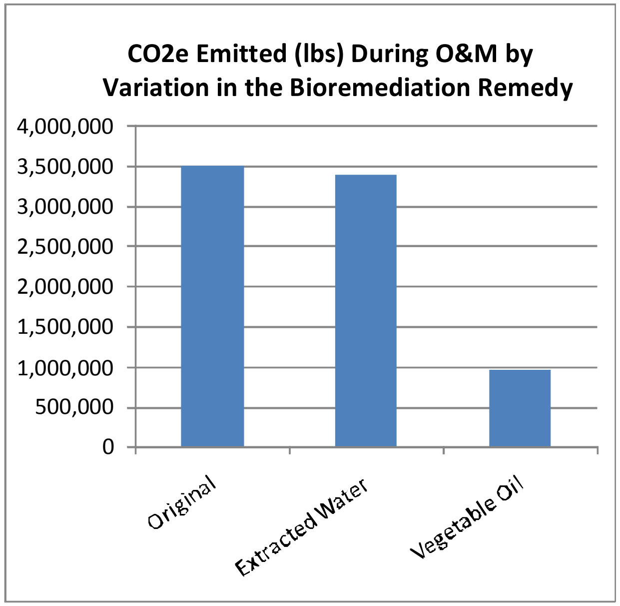
Using greenhouse gas emissions as an example parameter

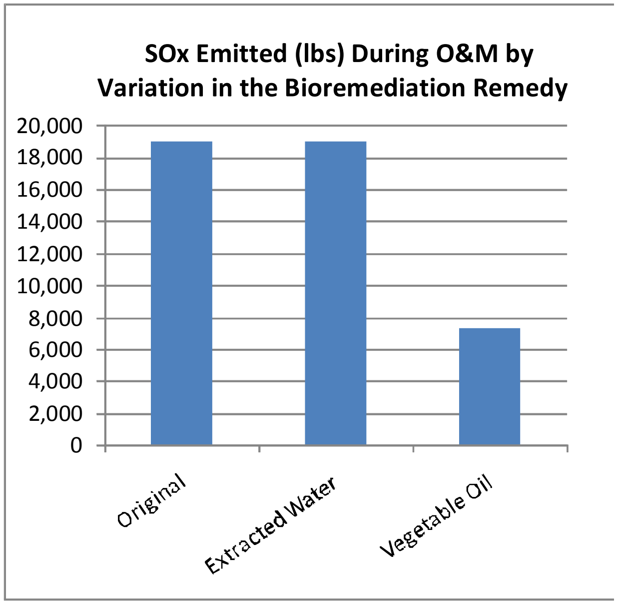


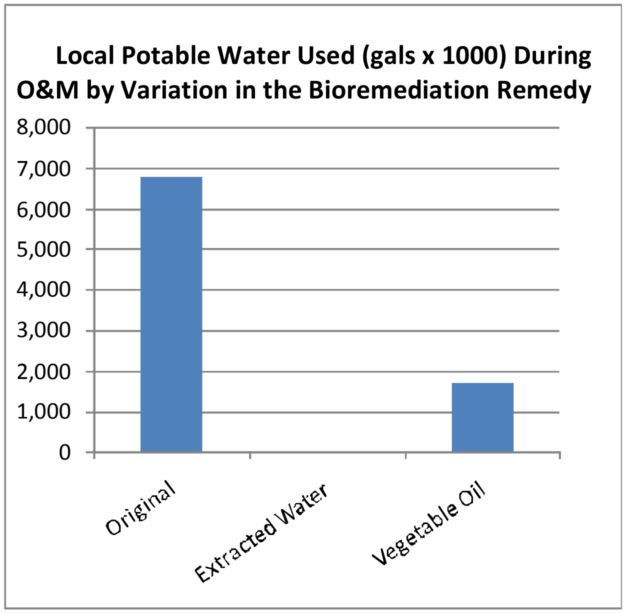
- Lessons learned
  - Good engineering and science result in more cost-effective and more sustainable remedies
  - Optimizing remedy resulted in less energy use and less energy to offset with renewable electricity
  - Optimizing remedy can lead to most substantial footprint reductions

Case Study #2

- Same site in California
- In-situ bioremediation planned with molasses and cheese whey
- Injections to use potable water
- Considerations derived from green remediation evaluation







Case Study #3

- Confidential facility in Southeast U.S.
- P&T system - Extracted water treated with GAC and discharged to surface water
- Meeting pH Discharge Criteria
  - Natural pH <5 is below discharge criteria of pH 6-9
  - pH adjustment required by authorities, NaOH added to adjust pH
- Optimization evaluation with green remediation component
  - Run water through limestone instead of NaOH addition for pH adjustment
  - Provide treated water to local agriculture facilities for irrigation
  - Eliminate extraneous parameters from long-term monitoring program
  - Use treated water instead of potable water to wet new batches of GAC
  - Consider use of water source heat pump for facility heating and cooling needs
- All recommendations result in improved cost-effectiveness

Case Study #4

- Closed on-site land disposal unit that requires management of leachate levels
- Three remedial options under consideration
  - Phytoremediation (plant ~5,000 trees)
  - Leachate extraction with wells and discharge to sewer
  - Cover regrading to limit infiltration
- Leachate Extraction footprints dominated by
  - Electricity to extract water
  - Transportation of settled sludge/solids to waste facility
- Phytoremediation has additional benefits
  - Substantial carbon storage in biomass
  - Deposition of NOx, SOx, and PM on leaves

Case Study #4 (continued)

- Comparison of footprint analysis output for three remedial alternatives

	Phytoremediation	Extraction Wells	Cover Regrading
Energy usage	Low	High	Intermediate
Energy related air emissions	Low	High	Intermediate
Toxic emissions	Low	High	Low
On-site water usage	Neutral	Neutral	Neutral
Off-site water usage	Low	Intermediate	Low
Manufactured materials usage	High	Intermediate	Low
Raw materials usage	Low	Low	High
Waste generated	Low	High	Low
Impact to ecosystems	Neutral	Neutral	Neutral
Remedy duration	Low	Intermediate	High
Truck traffic	Low	High	Intermediate
Hours of equipment operation	Low	Intermediate	High

- Footprint analysis results clearly indicate a “most favorable” remedy from the sustainability perspective

Case Study #5

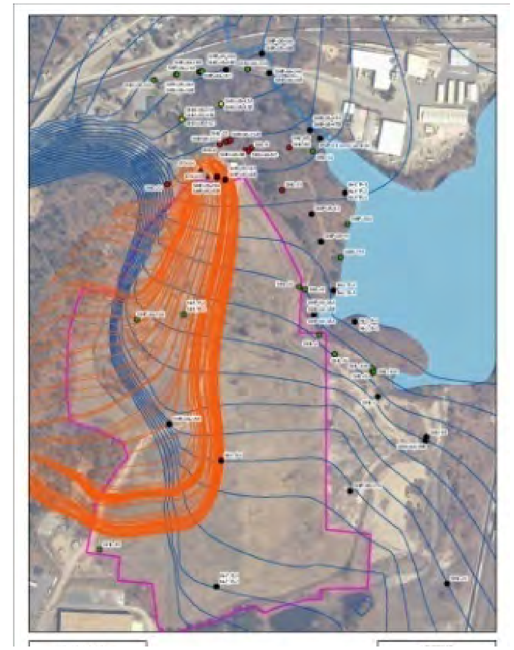
- Long-term P&T system with metals precipitation to address arsenic
- 100% of electricity generation from coal but offset by RECs
- 31,000 therms of natural gas for building heat each year
- Waste is listed hazardous waste, but does not have characteristics of hazardous waste
- 260 tons of waste (25% water) transported 700 miles to disposal facility each year

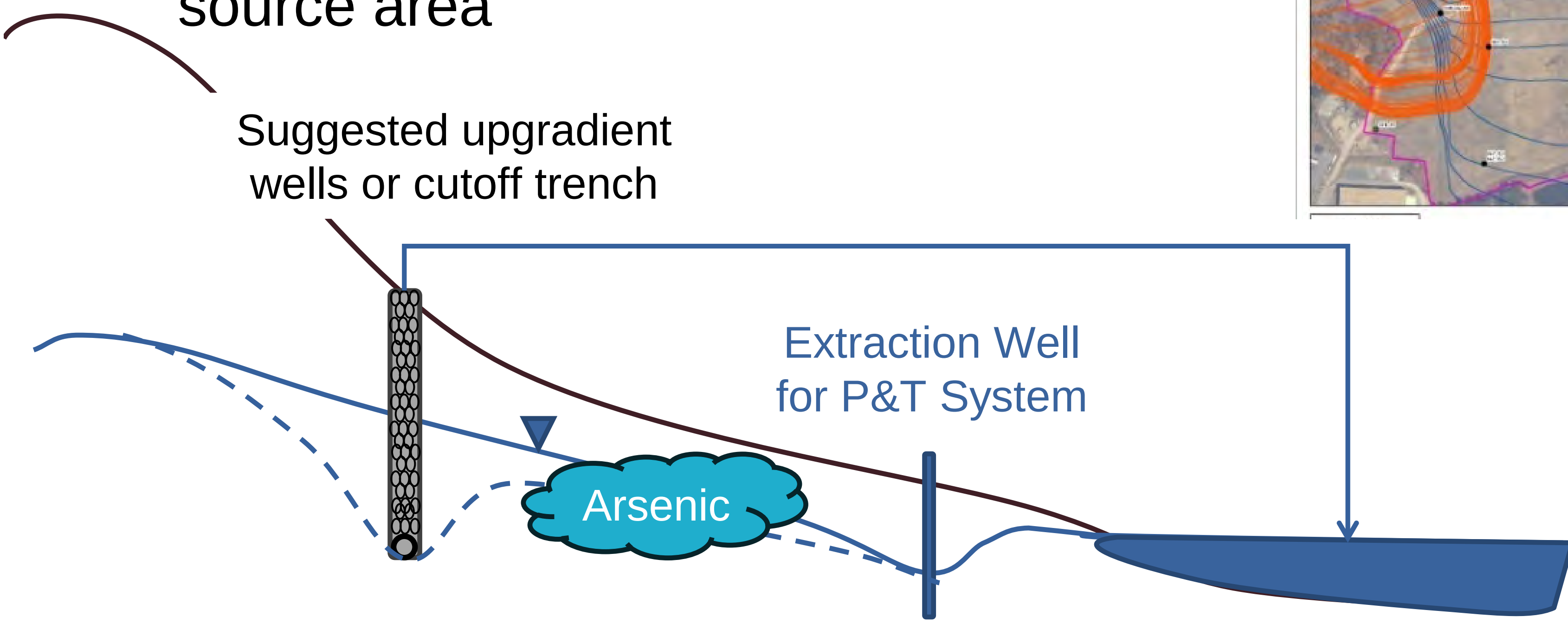
Case Study #5

- One consideration from optimization evaluation:
  - – Use of combined heat and power with natural gas to provide site electricity and useful process heat
    - Displaces coal use with natural gas
    - Use waste heat for building heat
    - Use remaining waste heat to help dewater sludge and reduce volume of waste for transport and disposal
  - – Purchase carbon offsets to reduce carbon footprint of natural gas usage
  - – Payback in less than 10 years (e.g., pays for itself)

Case Study #6

- Landfill site with P&T system
- P&T system involves chemical addition
- Consider diverting clean water around source area





LESSONS LEARNED

Technical Lessons Learned

- First step in footprint reduction is good science and engineering
- Electricity use is a significant contributor to many footprints
- Remedy footprints are highly dependent on
  - Remedy type
  - Location
  - Contaminant type
  - Geologic setting

Technical Lessons Learned

- Footprint analyses typically identify a few large contributors for each remedy type

Remedy	Primary Contributors
In-situ bio and ISCO	- Nutrient production & transportation - Performance monitoring - *Drilling or injection can be smaller than you think*
Excavation	- Waste transportation (esp. for haz. waste) - Waste disposal - *Equipment use may be smaller than you think*
P&T	- Electricity - Treatment chemicals/materials (e.g., GAC) - Monitoring (for low volume systems) - *Construction is quite small*

Technical Lessons Learned

- Information gathering is most labor intensive part but is also done during other remedial phases
- Guidance for energy use calculations are crucial for streamlining analyses
- Guidance for footprint calculations are crucial for streamlining analyses
- Uncertainty in estimating remedy performance and remedy cost transfers to footprint analysis
- Short-term, aggressive remediation typically has a lower footprint, if successful

Programmatic Lessons Learned

- Green remediation evaluations and practices complement optimization and should accompany typical remedial activities
- Parties are moving quickly to adopt green remediation and use it to their advantage
- Environmental footprints of remedies are small relative to overall economy
- Purchased renewable energy is an easy, cost-effective means of reducing remedy footprints

Programmatic Lessons Learned (continued)

- Green remediation overlaps with other EPA offices/activities and fosters collaboration
- Quantification of footprints and footprint reductions from green remediation is important
- Tracking footprint reductions and “progress” is difficult for a portfolio of sites
- How do you normalize reporting results given the changes in the portfolio status?

FOOTPRINT ANALYSIS METHODOLOGY: WHERE WE ARE HEADED?

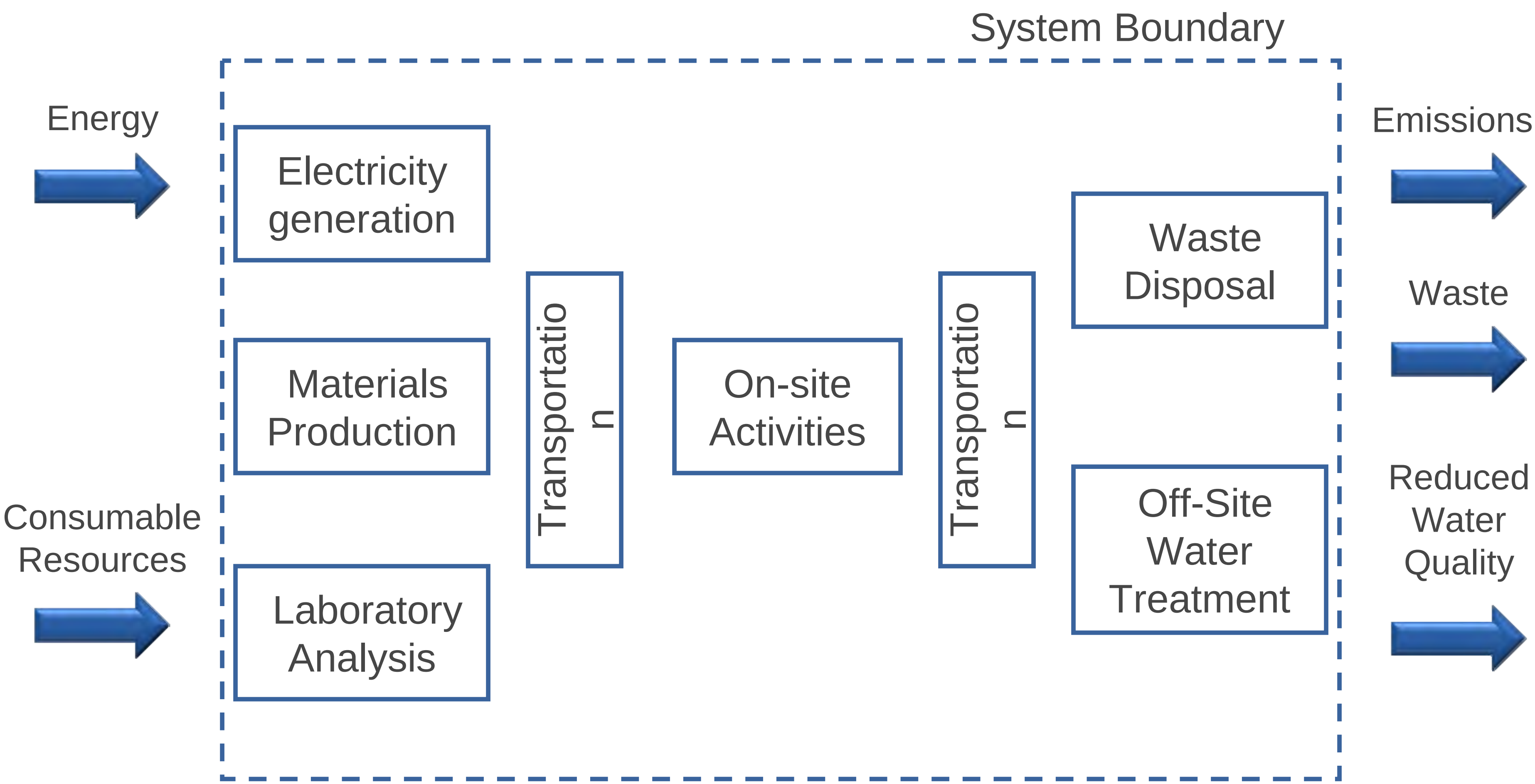
Goals of Footprint Methodology

- Outlines EPA’s expectations for remedy footprint evaluations
- Applies to evaluations conducted on behalf of EPA and submitted to EPA by other parties
- Encourages (does not require) footprint analysis
- Helps identify remedy components that can benefit most from applying green remediation concepts
- Helps quantify remedy footprints and footprint reductions and track progress
- Allow site team to evaluate remedy from a different perspective

Organizing Footprint Analysis Results

- Executive Order 13514 – *Federal Leadership in Environmental, Energy, and Economic Performance*
- EPA methodology opts for similar organization of results
  - On-site footprints (Scope 1)
  - Footprints from electricity generation (Scope 2)
  - Transportation (Scope 3a)
  - Manufacturing and off-site services (Scope 3b)
- Distinguish between conventional and renewable energy
  - Account for renewable energy certificates and emission offsets

System Boundaries for Footprint Analysis



Impacted land/habitat only considered for on-site

Example "Scope 1" Energy and Air Quality Footprint Table

			Energy		GWP		NOx	
Contributors to Footprints	**Units**	**Usage**	**Conv. Factor**	**MBtus**	**Conv. Factor**	**lbs CO2**	**Conv. Factor**	**lbs**
Scope 1 Renewable Energy								
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
Scope 1 Renewable Energy Subtotals				—		—		—
Scope 1 Conventional Energy								
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
Scope 1 Conventional Energy Subtotals				—		—		—
Other Scope 1 Contributions								
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
Scope 1 Totals				—		—		—
% of Energy from Renewable Resources			—					

- Scope 1 focuses on on-site energy use and emissions
- Includes process emissions and offsets
- Also includes SOx, PM, and air toxics (not shown)

Example "Scope 2" Energy and Air Quality Footprint Table

Contributors to Footprints	Units	Usage	Energy		GWP		NOx	
			Conv. Factor	MBtus	Conv. Factor	lbs CO2	Conv. Factor	lbs
Grid Electricity from Renewable Resources	…	…	…	…	…	…	…	…
Grid Electricity from Conventional Resources	…	…	…	…	…	…	…	…
Total Grid Electricity	…	—	…	—	…	—	…	—
Purchased RECs	…	…		…		…		…
Total Energy from Renewable Resources				—				
Total Energy from Conventional Resources				—				
Scope 2 Net Emissions				—		—		—

- Scope 2 focuses on electricity generation (conventional and renewable)
- Allows for use of Renewable Energy Certificates
- Also includes SOx, PM, and air toxics (not shown)

Example "Scope 3a" Energy and Air Quality Footprint Table

Category	Units	Usage	Energy		GWP		NOx	
			Conv. Factor	MBtus	Conv. Factor	lbs CO2	Conv. Factor	lbs
Scope 3 Transportation								
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
Conventional Fuel Subtotals				—		—		—
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
Renewable Fuel Subtotals				—		—		—
Scope 3 Transportation Totals				—		—		—
% of fuel energy from renewable resources			—					

- Scope 3a focuses on off-site transportation
- Considers conventional and renewable fuels used for transportation
- Transportation measured in quantity of fuel used
- Also includes SOx, PM, and air toxics (not shown)

Example "Scope 3b" Energy and Air Quality Footprint Table

Category	Units	Usage	Energy		GWP		NOx	
			Conv. Factor	MBtus	Conv. Factor	lbs CO2	Conv. Factor	lbs
Materials Manufacturing								
…	…	…	…	…	…	…	…	…
Manufacturing Subtotal				—		—		—
Off-site Services								
…	…	…	…	…	…	…	…	…
Off-site Services Subtotal				—		—		—
Indirect Elect. Generation and distribution								
Resource extraction	…	…	…	…	…	…	…	…
Transmission losses	…	…	…	…	…	…	…	…
Subtotal				—		—		—
Non-Transportation Scope 3 Totals				—		—		—

- Scope 3b focuses on non-transportation off-site activities
- Includes resource extraction for electricity generation and transmission losses
- Also includes SOx, PM, and air toxics (not shown)

Water Methodology Structure

- Water footprint methodology considers the following:
  - Type of water (e.g., groundwater, potable water, etc.)
  - Location of water source
  - Use of the water
  - Fate of the water
- Combines quantitative information and qualitative information to “paint a picture” for site stakeholders

Example Water Footprint Methodology

	Water Resource	Description of Quality of Water Used	Volume Used (1000 gallons)	Uses	Fate of Used Water
On-Site or Local Water Footprint	Public water supply				
	Extracted groundwater #1 Location/Aquifer:				
	Surface water Intake Location:				
	Reclaimed water Source:				
	Collected/diverted storm water				
	Other water resource				
	Maximum drawdown of water table 100 feet from pumping locations				
	Off-site water use				

- Both qualitative and quantitative
- Provide enough information for local stakeholder to understand use of local water resources and change in available resource quality and quantity

Materials and Waste Methodology Structure

- Refined materials used
  - Quantity of treatment chemicals used (lbs)
  - Quantity of construction materials (lbs)
  - % of materials derived from recycling or reuse
- Unrefined materials (e.g., sand, gravel, fill, etc.)
  - Quantity used (tons)
  - % derived from recycling or reuse)
- Waste
  - Quantity of hazardous waste generated
  - Quantity of non-hazardous waste generated
  - % of total potential waste diverted to recycling or reuse

Land/Ecosystem Methodology Structure

- Acres of habitat created or disturbed and years of disturbance
- Acres of land reuse or redevelopment of impacted land and time to prepare land for reuse or redevelopment
- Creation or destruction of valuable "ecosystem service" (e.g., soil erosion control)

Summary

- EPA…
  - Has defined core elements of green remediation and parameters/metrics for each element
  - Recognizes the challenges of conducting and interpreting footprint analyses for remedies
  - Has conducted a number of case studies and documented lessons learned
  - Is developing a methodology to standardize and facilitate footprint analysis

Information and Resources

- EPA information and resources
  - *www.cluin.org/greenremediation*
  - *www.epa.gov/cleanenergy/*
  - *www.epa.gov/cleandiesel/*
  - *www.epa.gov/epawaste/conserve/rrr/index.htm*
  - *www.epa.gov/WaterSense/*
- Also look for resources from
  - U.S. Department of Energy, National Renewable Energy Laboratory (www.nrel.gov)
  - U.S. Geological Survey (www.usgs.gov)

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QUESTIONS????