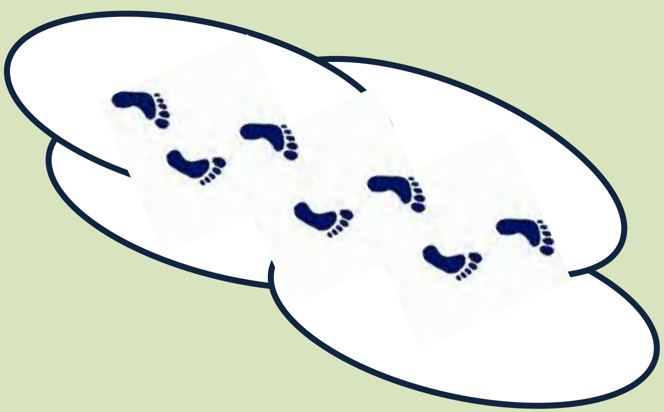
Greener Clean-ups

Estimating the Environmental Footprints of Clean-Up Remedies

US EPA Region 9



Karen Scheuermann
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1 February 2012

Environmental Clean-ups

Greener Clean-ups:

seeking to reduce the emissions and resource consumption resulting from site remediations

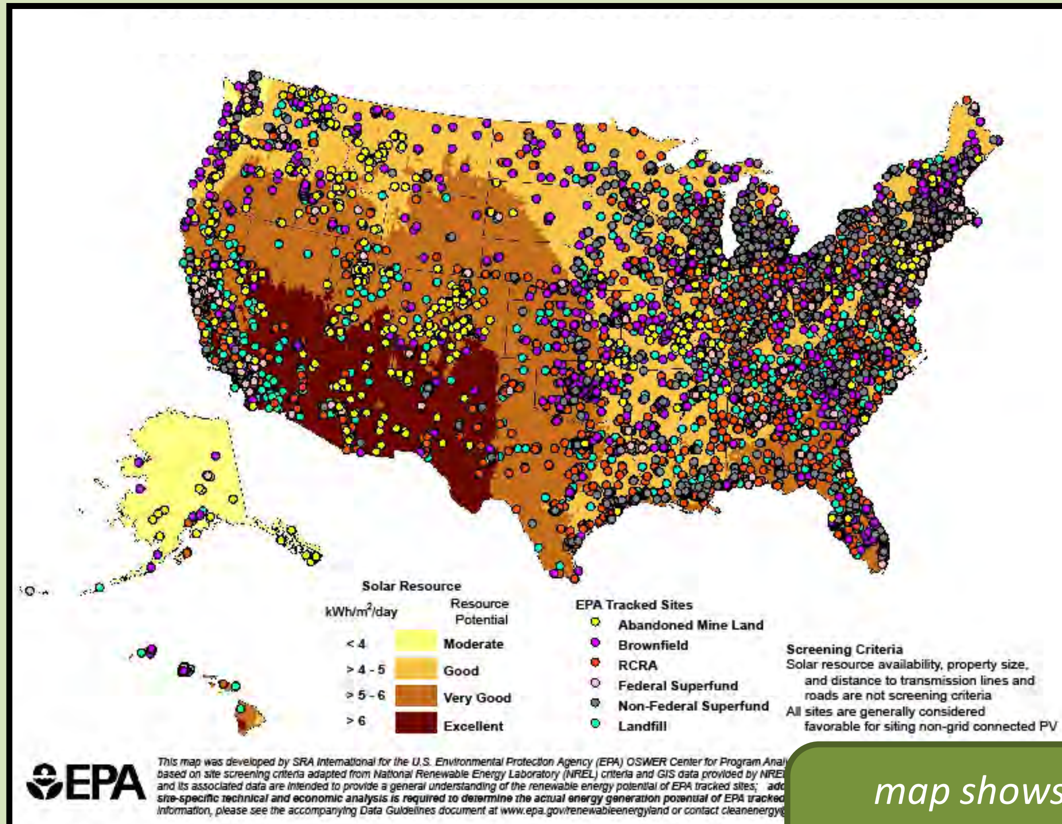
Planting saplings for control of leachate at a landfill at BP Wood River in Illinois

Photo courtesy of Illinois EPA and BP Wood River

Environmental Clean-ups

Often large amounts of energy and materials are required for clean-ups

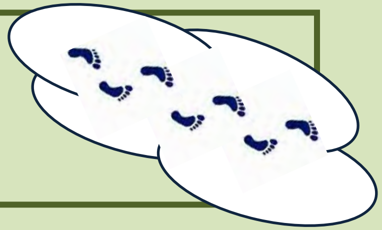
- → *electricity*
- → *transportation fuels*
- → *natural gas*
- → *construction materials*
- → *chemical reagents*
- → *water*



map shows 11,000 remediation sites

Source for map:
EPA OSWER Center for Program Analysis at
http://www.epa.gov/renewableenergyland/maps/pdfs/nongrid_pv_us.pdf

Environmental Footprint Analysis

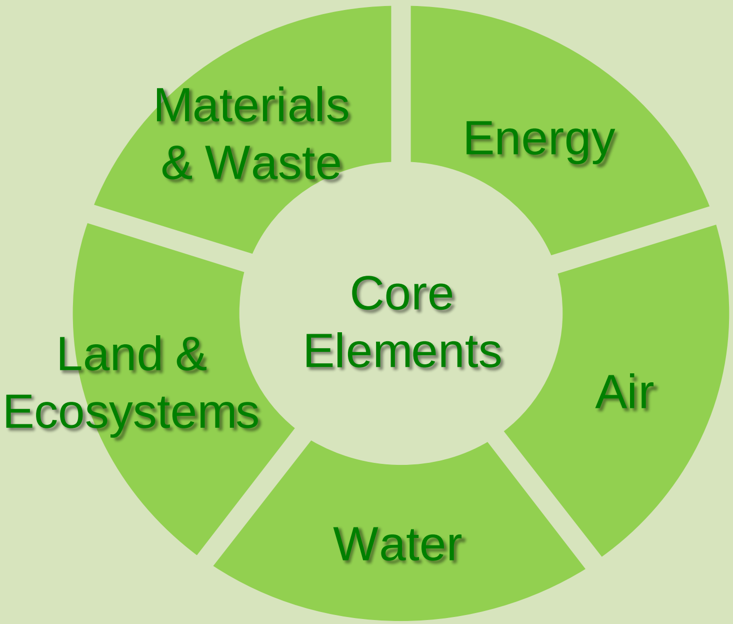


Environmental Footprint Analysis:

Make an inventory of on-site clean-up activities and off-site support activities

Evaluate the amount or intensity of the five core elements

Use results to target and reduce the greatest contributors to the footprint



Align the Footprint Analysis to EPA's Greener Clean-ups Core Elements

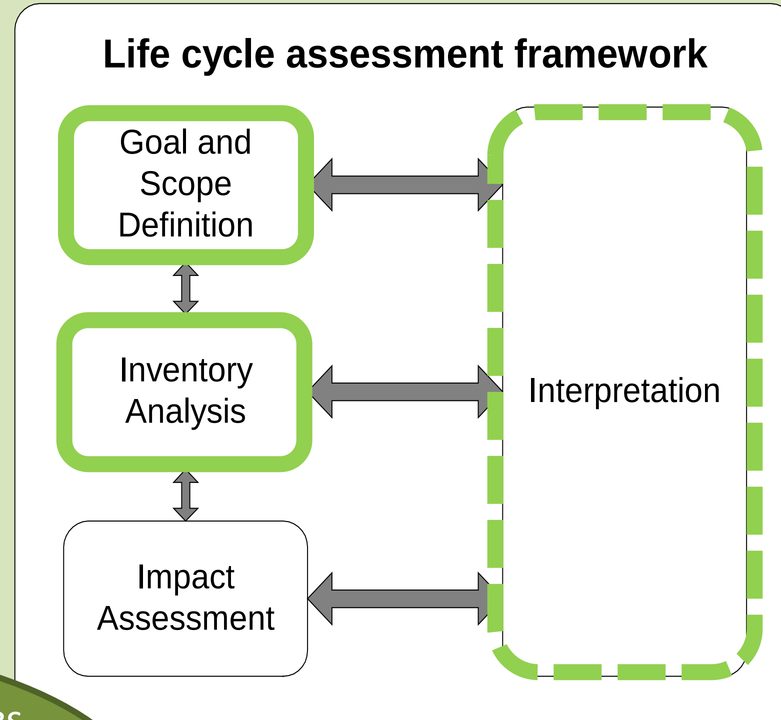
Graphics from EPA Green Remediation Web Page at http://www.clu-in.org/greenremediation/

Environmental Footprint Analysis

We use "Life-Cycle Assessment thinking" when we conduct our Footprint Analyses.

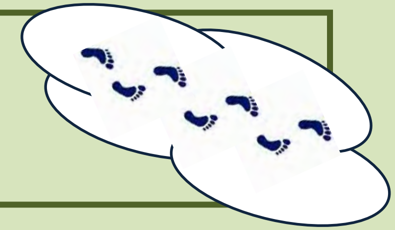
However, our Footprint Analyses are not Life-Cycle Assessments.

We follow a Footprinting Methodology that HQ has developed for clean-up sites and we use spreadsheets developed by HQ and Region 9.



our footprint analysis does not include an impact assessment, which is an important part of a Life-Cycle Assessment

Environmental Footprint Analysis



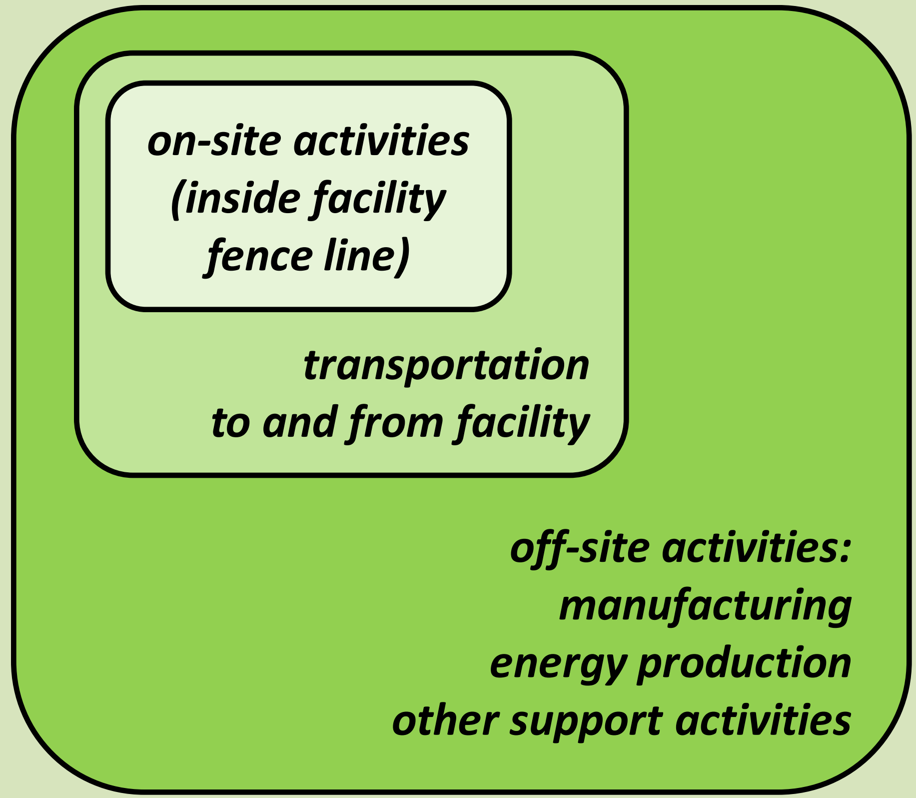
We include on-site activities, transportation, and off-site activities.

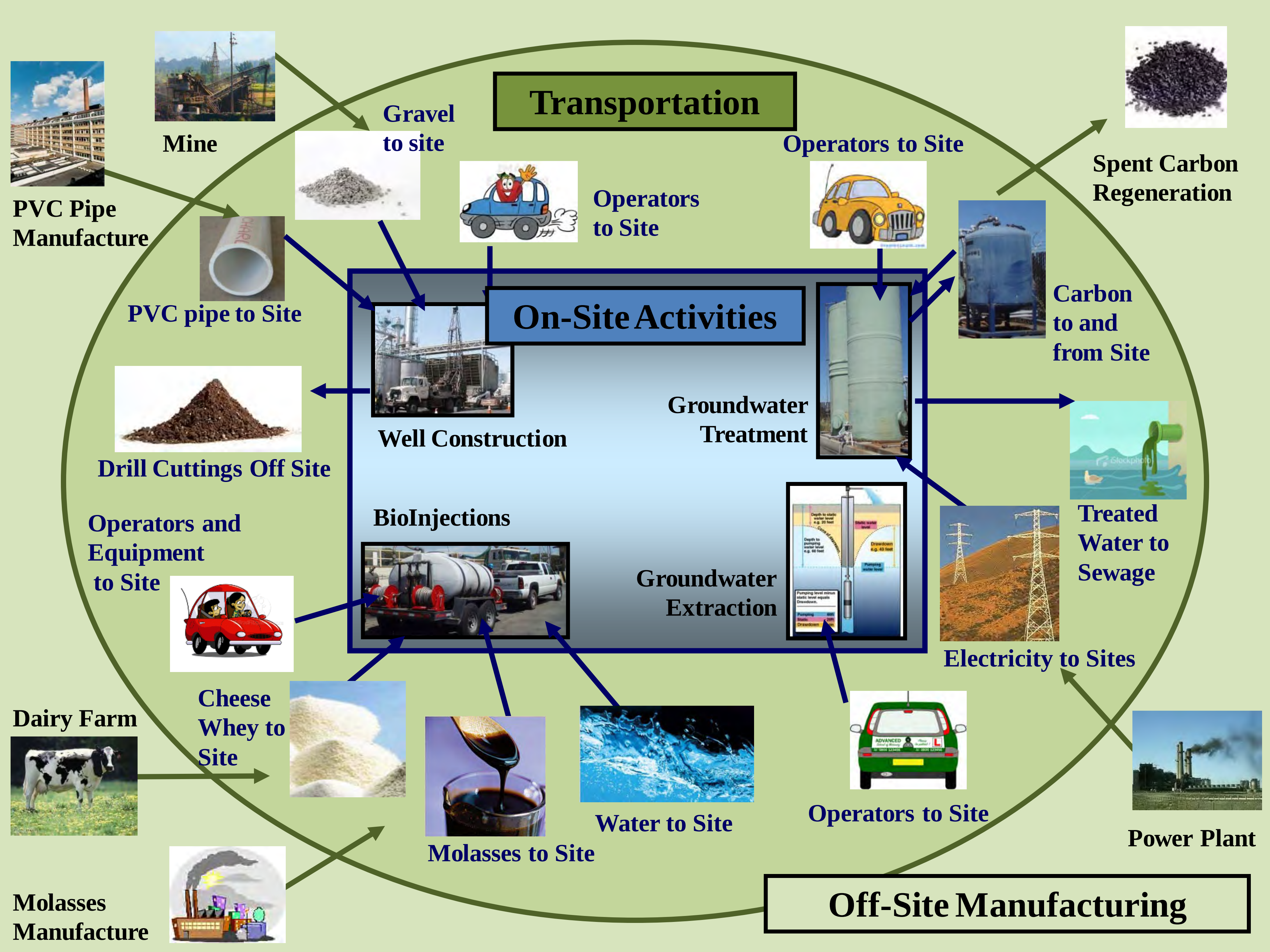
We include resource extraction wherever possible.

We include multiple stages of the remedies:

→ site investigation
→ remedy construction
→ operations & maintenance
→ long term monitoring
→ decommissioning

Environmental Footprint Analysis




Transportation
Mine
Gravel
to site
PVC Pipe
Manufacture
PVC pipe to Site
Operators
to Site
Operators to Site
Spent Carbon
Regeneration
On-Site Activities
Carbon
to and
from Site
Well Construction
Groundwater
Treatment
Drill Cuttings Off Site
Treated
Water to
Sewage
Operators and
Equipment
to Site
BioInjections
Groundwater
Extraction
Electricity to Sites
Cheese
Whey to
Site
Dairy Farm
Water to Site
Operators to Site
Power Plant
Molasses to Site
Molasses
Manufacture
Off-Site Manufacturing

Case Studies

Three Clean-up Sites

Site Descriptions

Results from Footprint Analyses

Case studies were conducted in 2009 - 2011 by Region 9 Waste Division with support from HQ

Case Studies

Romic East Palo Alto (California)

In-situ bioremediation of volatile organic compounds (VOCs) in groundwater, using injections of nutrients (cheese whey and molasses) into the aquifer

each bioinjection uses 10 gallons cheese whey, 15 gallons molasses, and 500 gallons water

installation of 270 injection wells

injections of nutrients in each well, 4 times per year

remedy to continue 10 years in order to clean up the ground water and protect nearby surface waters

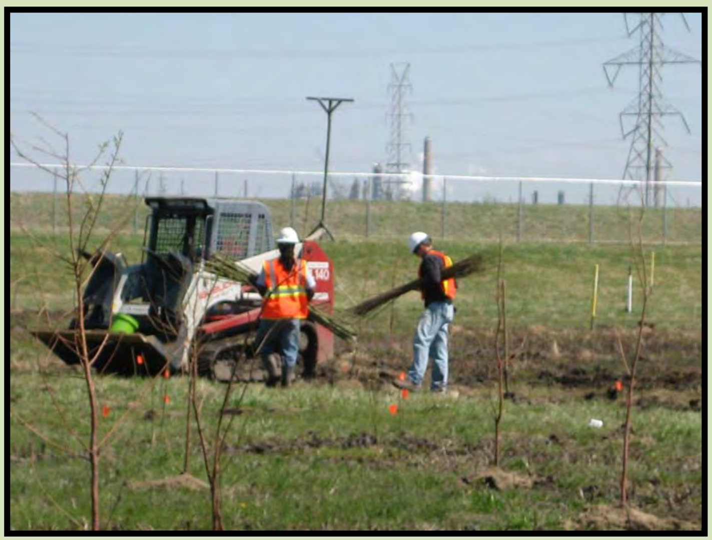
Photos and graphics courtesy of EPA Region 9

Case Studies

BP Wood River (Illinois)

Phytoremediation to control landfill leachate, using 3,500 trees of 5 species

through evapotranspiration, the trees are expected to reduce leachate to acceptable levels within 7 years



planting of sapling trees required 5 workers during 2 weeks

trees will cover 5 acres of the 24-acre landfill

white swamp oak 1 year after planting

Photos and graphics courtesy of BP Wood River and Illinois EPA

Case Studies

bioreactor and biobarrier remediations are expected to be completed within 10 years

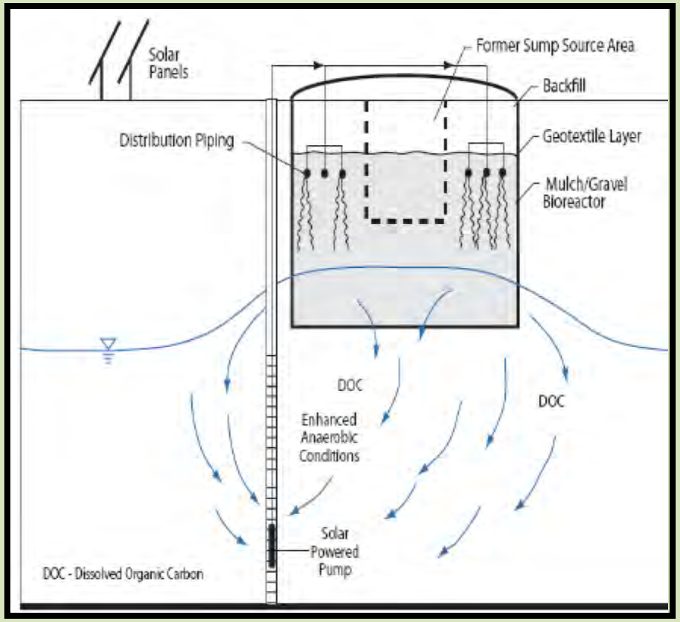
Travis Air Force Base (California)

Biobarrier uses injection of emulsified vegetable oil into the groundwater

Bioreactor circulates groundwater through a pit containing mulch

Biobarrier uses a row of 13 wells

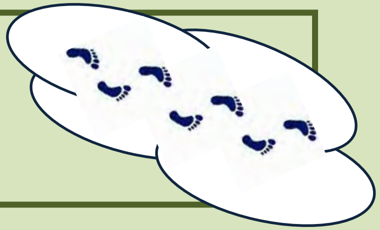
Contaminated soil removed and disposed as part of bioreactor construction



Bioreactor uses solar panels to run pumps for recirculating groundwater

Photos and graphics courtesy of Travis AFB

Case Studies



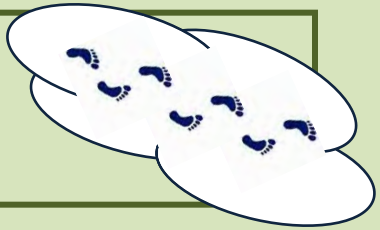
Large Array of Remedy Technologies

10 technologies in our case studies and many more at future sites

Broad Range of Site Conditions

Footprint Analysis is Unique at Each New Site

Results



→ **Analytic Techniques**

- 15 unique metrics
- compare stages of remedy
- compare remedy alternatives
- compare on-site vs off-site contributors

→ **Usefulness to Project Managers**

- understand contributors to footprints
- understand trade-offs

→ Energy Usage
→ NOx, SOx, and PM Emissions
→ Water Usage
→ CO2e Emissions

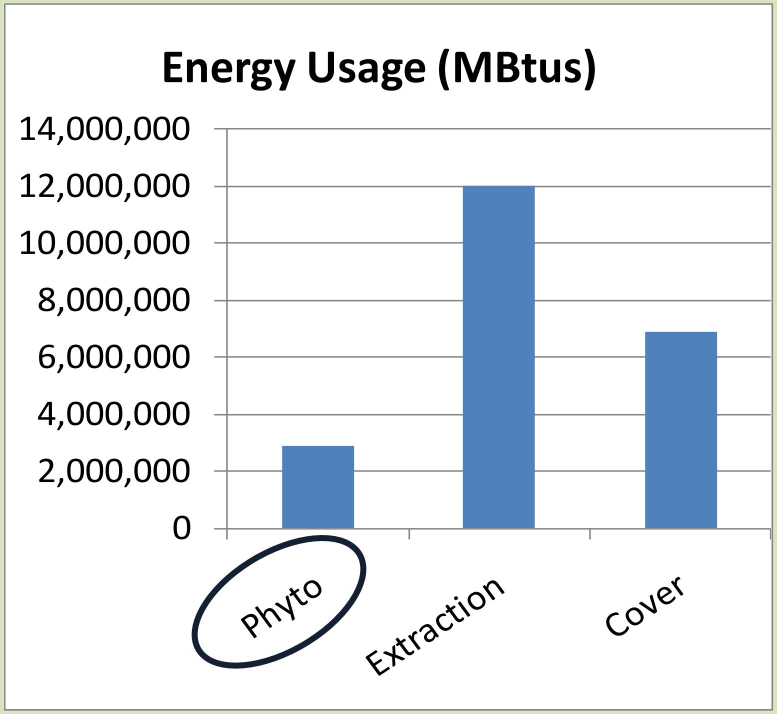
All results are estimates based on numerous site assumptions

Results

BP Wood River

Basic information such as total energy usage will be of interest to site managers.

This can help the site manager to understand benefits gained from the remedy selected, and to quantify improvements.



The phytoremediation alternative had the smallest footprint for energy usage.

Full documentation of BP Wood River analysis: www.clu-in.org/greenremediation/bpwoodriver

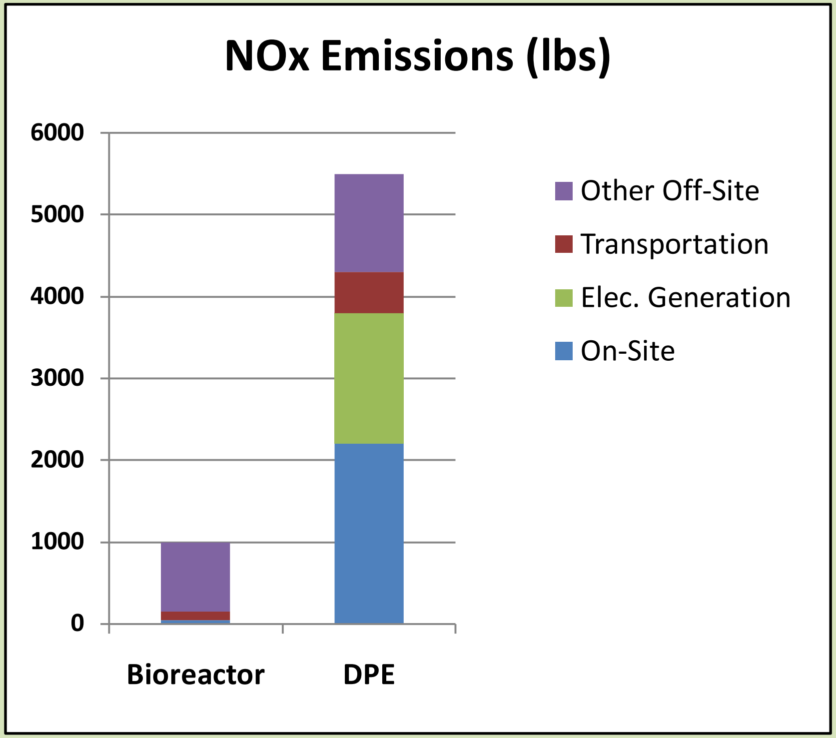
Results

Travis AFB

Understanding on-site versus off-site emissions is important to site managers.

On-site emissions are of interest to communities near the site.

Off-site emissions may have regional and global implications.



For many of the environmental parameters at Travis, off-site activities were the biggest contributors to the footprint.

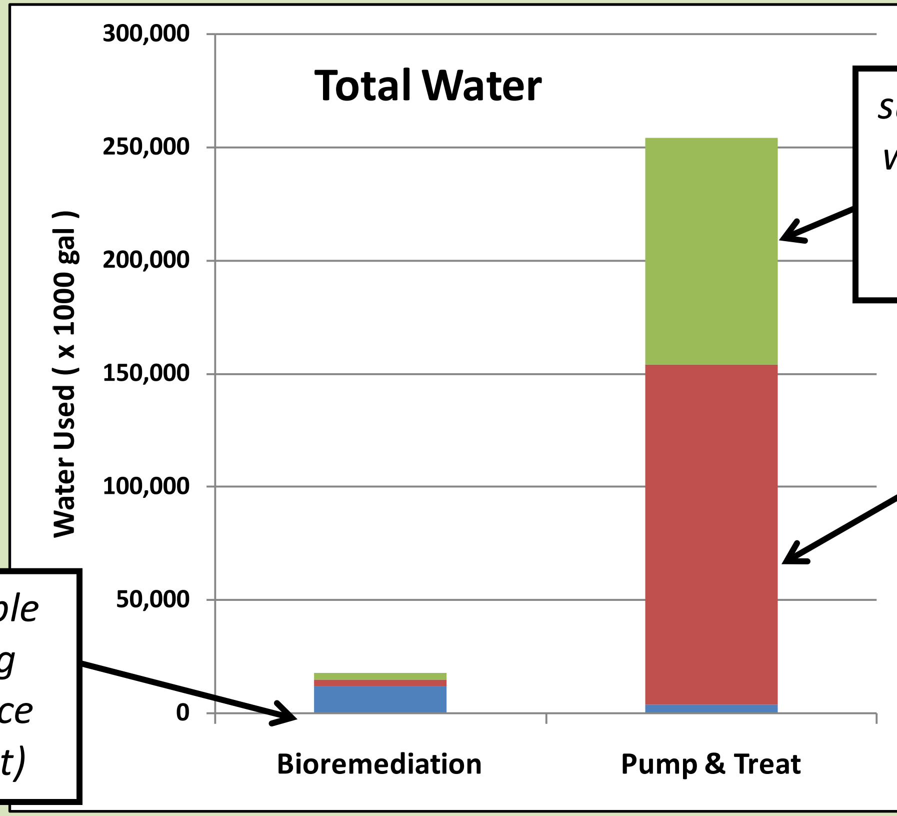
Full documentation of Travis AFB analysis: www.clu-in.org/greenremediation/travis

DPE = dual-phase extraction

Results

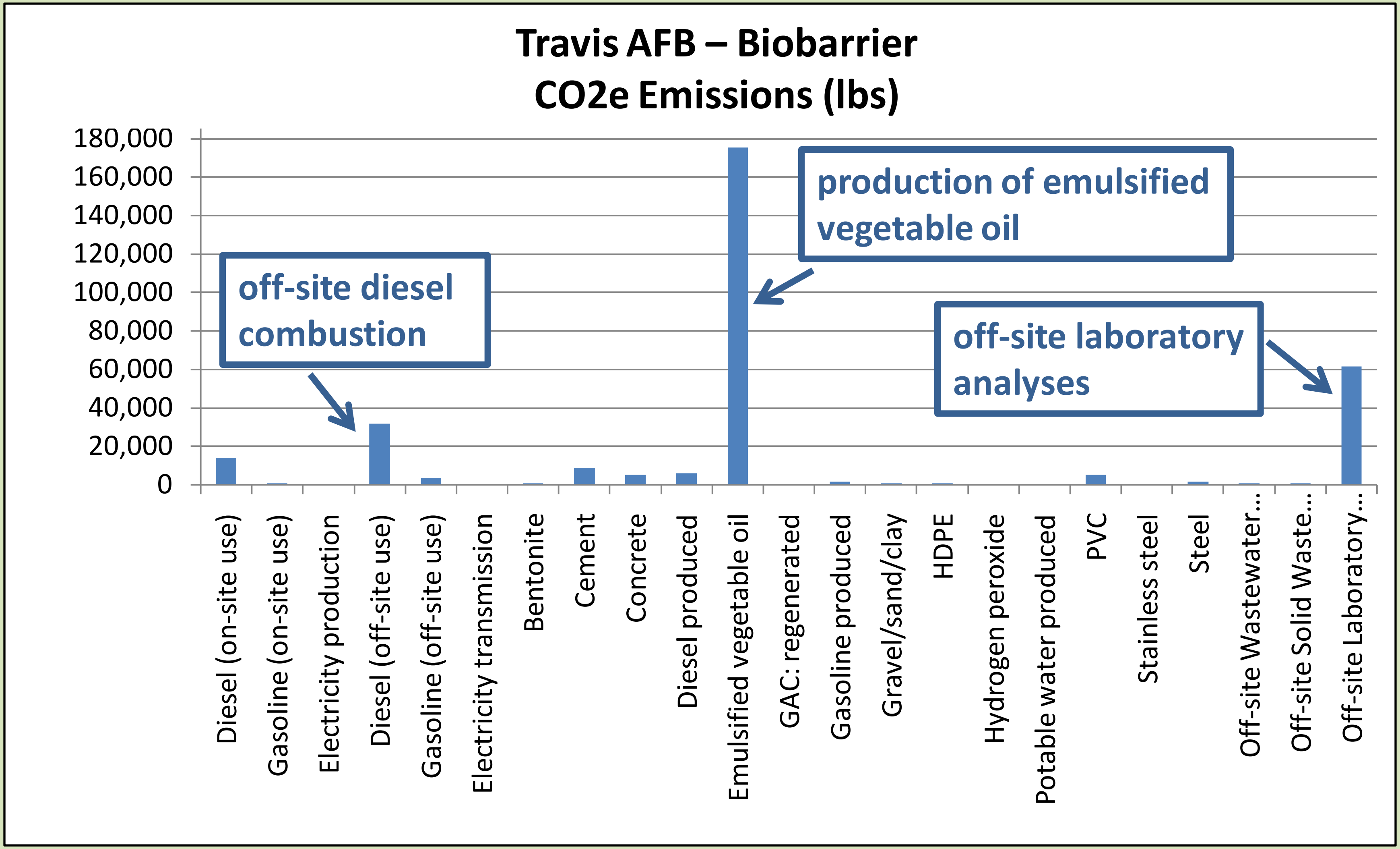
Romic East Palo Alto

It will be useful to the site manager to understand the different origins and quality of water required for the clean-up remedies.

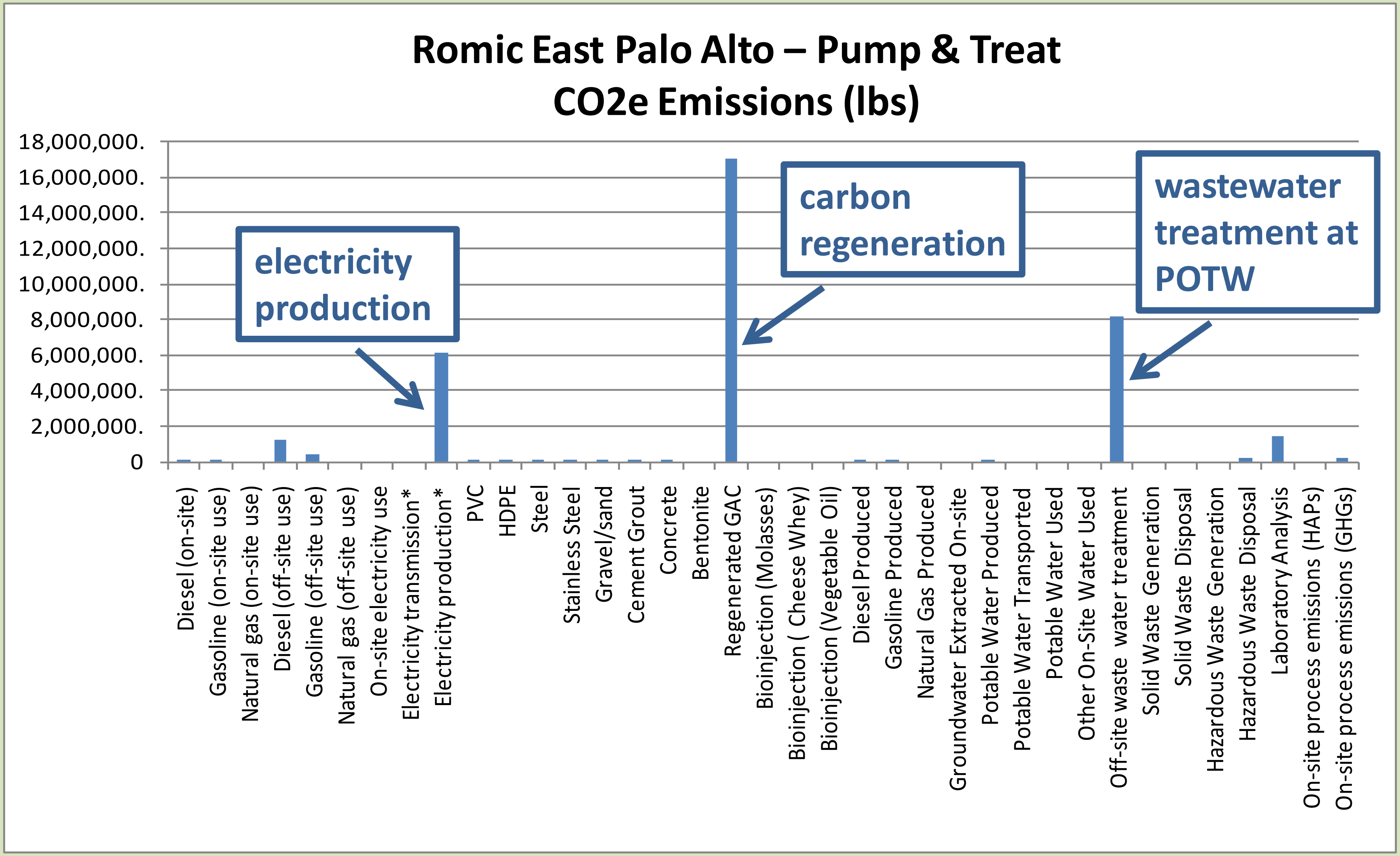


Graphics based Romic East Palo Alto analysis.

Results

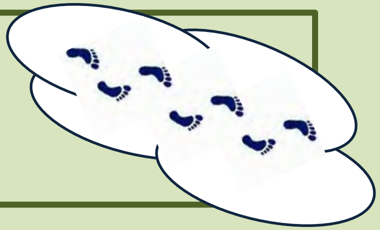

Travis AFB – Biobarrier
CO2e Emissions (lbs)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
off-site diesel combustion
production of emulsified vegetable oil
off-site laboratory analyses
Diesel (on-site use)
Gasoline (on-site use)
Electricity production
Diesel (off-site use)
Gasoline (off-site use)
Electricity transmission
Bentonite
Cement
Concrete
Diesel produced
Emulsified vegetable oil
GAC: regenerated
Gasoline produced
Gravel/sand/clay
HDPE
Hydrogen peroxide
Potable water produced
PVC
Stainless steel
Steel
Off-site Wastewater...
Off-site Solid Waste...
Off-site Laboratory...

Results

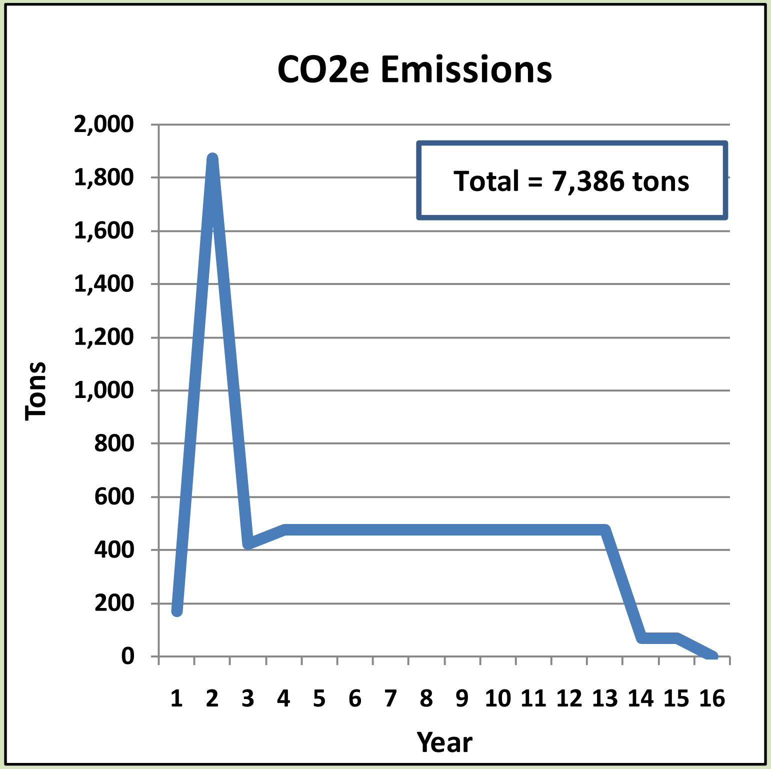


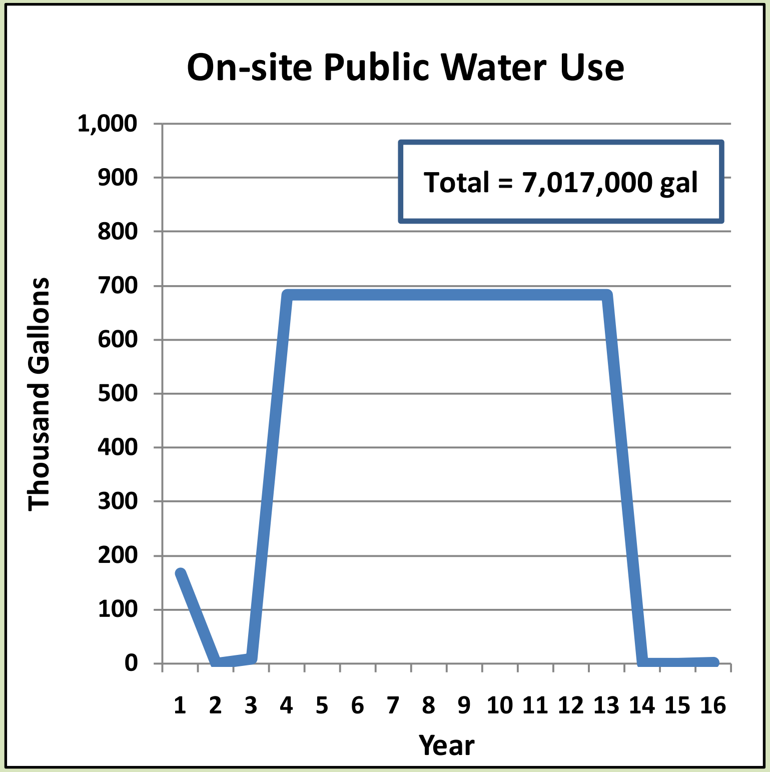
Romic East Palo Alto – Pump & Treat
CO2e Emissions (lbs)
18,000,000.
16,000,000.
14,000,000.
12,000,000.
10,000,000.
8,000,000.
6,000,000.
4,000,000.
2,000,000.
0
electricity production
carbon regeneration
wastewater treatment at POTW
Diesel (on-site)
Gasoline (on-site use)
Natural gas (on-site use)
Diesel (off-site use)
Gasoline (off-site use)
Natural gas (off-site use)
On-site electricity use
Electricity transmission*
Electricity production*
PVC
HDPE
Steel
Stainless Steel
Gravel/sand
Cement Grout
Concrete
Bentonite
Regenerated GAC
Bioinjection (Molasses)
Bioinjection (Cheese Whey)
Bioinjection (Vegetable Oil)
Diesel Produced
Gasoline Produced
Natural Gas Produced
Groundwater Extracted On-site
Potable Water Produced
Potable Water Transported
Potable Water Used
Other On-Site Water Used
Off-site waste water treatment
Solid Waste Generation
Solid Waste Disposal
Hazardous Waste Generation
Hazardous Waste Disposal
Laboratory Analysis
On-site process emissions (HAPs)
On-site process emissions (GHGs)

Results

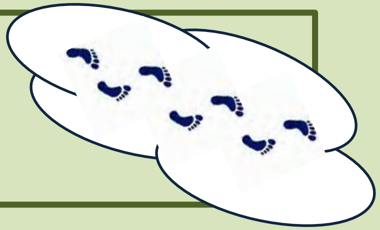


Romic East Palo Alto – Bioremediation

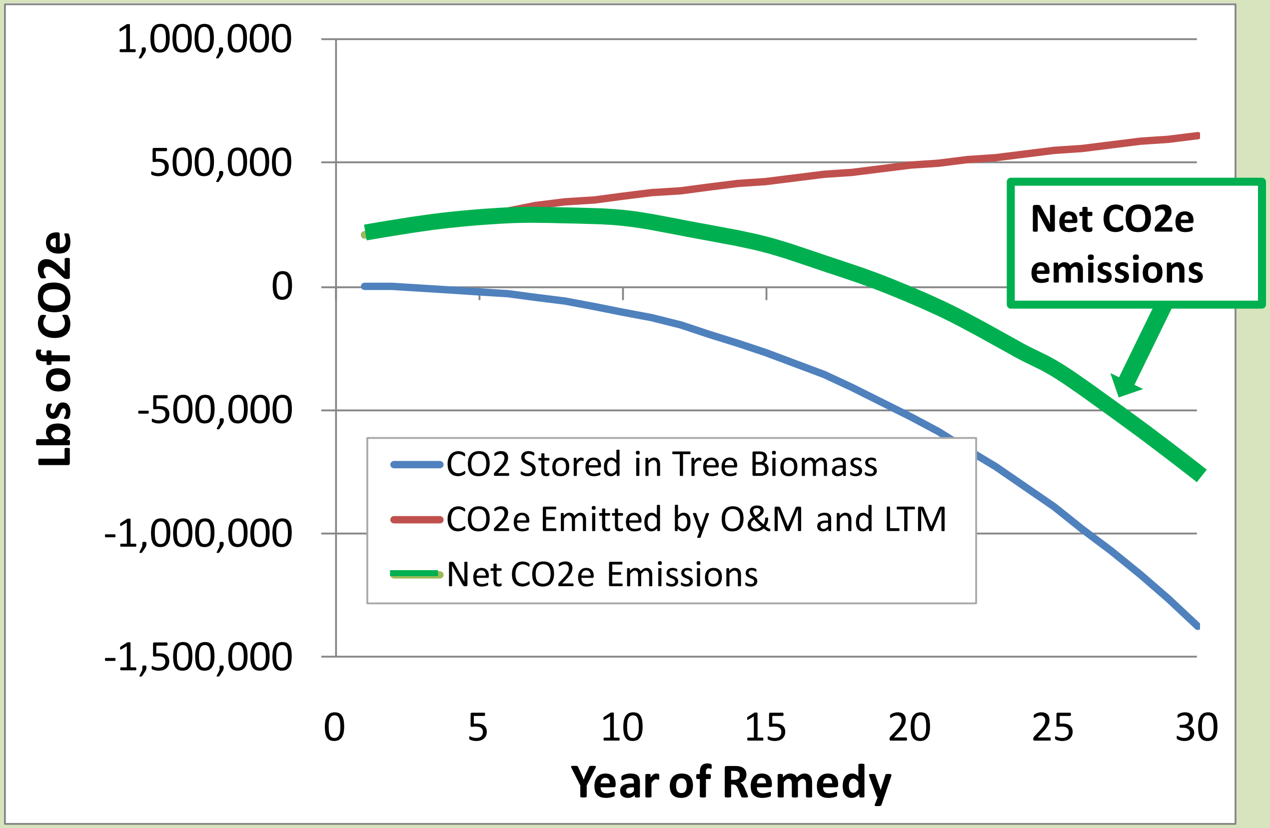




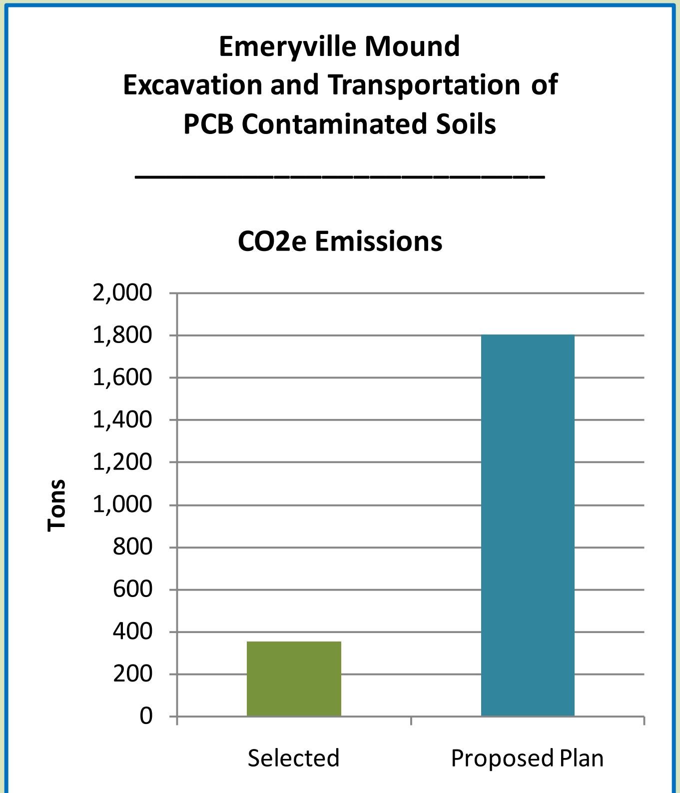
Results



BP Wood River – Phytoremediation



Focused Footprint Analysis



The selected project will result in 2,770 fewer round-trips for trucks hauling contaminated soil to landfill.

Selected Project - No below grade parking (14,000 cy excavated)
Proposed Plan - One level below grade parking (39,000 cy excavated)

Observations

Off-site activities can be a large part of the environmental footprint of our clean-up remedies. We indentified "hidden" contributors such as …

Wastewater treatment at a municipal treatment facility

Reactivation of granular activated carbon (GAC)

Laboratory analyses of groundwater samples

Production of bioremediation nutrients such as molasses, cheese whey, and emulsified vegetable oil

Observations

The results of a Footprint Analysis are only a few among many factors involved in site decision-making.

our clean-up remedies must first be protective of human health and the environment

the results of a footprint analysis can then be used as "balancing factors" in improving remedy implementation

Observations

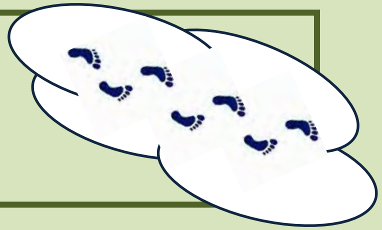
Site managers are the key to reducing the footprints of our clean-ups. Footprint analysis provides information to help them do this.

Footprint analyses will give our site managers a way to quantify the environmental footprint and target areas for reduction.

Many of our site managers are taking on this new challenge with enthusiasm!

Photos courtesy of EPA Region 9 and Illinois EPA

Putting Footprint Analysis to Work



- ✓ **HQ is finalizing the Methodology for footprint analysis at clean-up sites**
- ✓ **HQ and R9 Waste Division are finalizing the spreadsheets for running footprint analyses – and – UST program has posted footprint calculator**
- ✓ **Superfund will begin applying footprint analyses at 6 sites in 2012**
- ✓ **RCRA will begin applying footprint analyses at 5 sites in 2012**

We continue to look for ways to reduce the environmental footprints of our clean-ups

Acknowledgements

- **Technical and Engineering Support:**

  Doug Sutton, GeoTrans
- **Programmatic Support:**

  Carlos Pachon, US EPA OSRTI

  Steve Armann, US EPA Region 9

Assistance from Site Managers :

US EPA Region 9 and Illinois EPA

Assistance from EPA's ORD Lab:

NRMRL in Cincinnati

- **Thanks to our Pilot Sites for participating in the Pilot Study and providing site information:**

  Romic East Palo Alto (California)

  BP Wood River (Illinois)

  Travis Air Force Base (California)
- **Funding from:**

  EPA's Office of Superfund Remediation and Technology Innovation (OSRTI)

  EPA's Office of Resource Conservation and Recovery (ORCR)

Resources

Information about Greener Clean-ups is Posted on EPA HQ's Web Page at:

www.clu-in.org/greenremediation

Greener Clean-ups Contacts in Region 9:

Waste Division	**Superfund Division**
Karen Scheuermann	Jeff Dhont
Eric Magnan	Julie Santiago
Steve Armann	Mike Gill
	Harry Ball
	Barbara Maco

Promoting Greener Clean-ups

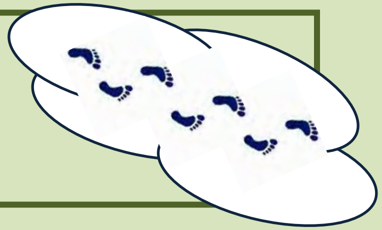
Reducing the Environmental Footprints of Our Clean-up Sites

Reserve Slides

Summary of Green Remediation Metrics

Core Element	Metric	Unit of Measure	Value
Materials & Waste	M&W-1. Refined materials used on-site	Tons	
	M&W-2. % of refined materials from recycled or waste material	%	
	M&W-3. Unrefined materials used on-site	Tons	
	M&W-4. % of unrefined materials from recycled or waste material	%	
	M&W-5. On-site hazardous waste disposed of off-site	Tons	
	M&W-6. On-site non-hazardous waste disposed of off-site	Tons	
	M&W-7. % of total potential waste recycled or reused	%	
Water	On-site water used (by source)		
	- W-1. Source, use, fate combination #1	Millions of gallons	
	- W-2. Source, use, fate combination #2	Millions of gallons	
	- W-3. Source, use, fate combination #3	Millions of gallons	
	- W-4. Source, use, fate combination #4	Millions of gallons	
Energy	E-1. Total energy used	MMBtu	
	E-2. Total energy voluntarily derived from renewable resources		
	- E-2A. On-site generation or use and biodiesel use	MMBtu	
	- E-2B. Renewable electricity purchase	MWh	
	- E-2C. Purchase of renewable energy certificates (RECs)	MWh	
Air	A-1. On-site NOx, SOx, and PM emissions	Pounds	
	A-2. On-site HAP emissions	Pounds	
	A-3. Total NOx, SOx, and PM emissions	Pounds	
	A-4. Total HAP emissions	Pounds	
	A-5. Total GHG emissions	Tons CO_2e	
Land & Ecosystems	Qualitative description		

Case Studies



We compared several remedy alternatives at 3 Pilot Sites involving 10 remediation technologies.

Romic East Palo Alto

Bioremediation
- *cheese whey*
- *molasses*

Pump and Treat
- *air stripper*
- *activated carbon*

Soil Excavation
- *hauled to landfill*

BP Wood River

Phytoremediation
- *trees*

Leachate Extraction
- *oil/water separator*

Landfill Regrading
- *clay cap & revegetation*

Travis AFB

Bioreactor
- *organic mulch*

Dual-Phase Extraction
- *UV oxidation*
- *thermal oxidation*
- *activated carbon*

Biobarrier
- *emulsified vegetable oil*

Permeable Reactive Barrier
- *zero-valent iron*

Case Studies

Environmental Parameters

Energy

Total energy
Grid electricity

Materials

Refined materials used
Unrefined materials used

Waste

Solid (non-hazardous) waste
Hazardous waste

Air Emissions

CO2 equivalents
NOx
SOx
Particulates
Air toxics

Water

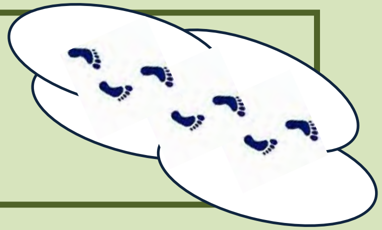
Local groundwater extracted
Local potable water used
Total water

Other Contaminants

Mercury
Lead
Dioxins

we chose all of these parameters for reasons of global, regional, or local interest

Case Studies



Common Remediation Materials and Services

Materials

Potable water
PVC
Steel
Concrete
Clay
Granular activated carbon
Emulsified vegetable oil
Trees
Fertilizers
Potassium permanganate
Hydroxide peroxide
Acetic acid
Zero-valent iron
UV lamps

Energy

Gasoline
Diesel fuel
Natural gas
Grid electricity
PV cells

Off-Site Services

Solid waste disposal
Hazardous waste disposal
Laboratory analysis
Wastewater treatment
Reactivation of granular activated carbon

approximately 40 common remediation materials or services

Case Studies

Life-Cycle Inventory (LCI) Databases

We used established LCI Databases for estimating the footprints of the majority of the materials and support activities in our Pilot Study

National Renewable Energy Laboratory (NREL)

LCA Food Database (Denmark)

European Reference Life Cycle Database (EUROPA ECLD)

LCI Estimates based on Journal Articles and Other Published Sources

→ Reactivation of granular activated carbon (energy usage)
→ Carbon storage in trees
→ Photovoltaic cells

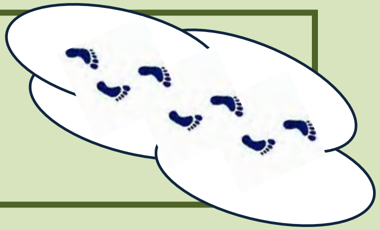
LCI Estimates Made Uniquely for this Pilot Study

→ Reactivation of granular activated carbon (water usage)
→ Laboratory analyses

we are always looking for ways to improve our LCI data

Full documentation of LCI data: www.clu-in.org/greenremediation/subtab_b3.cfm

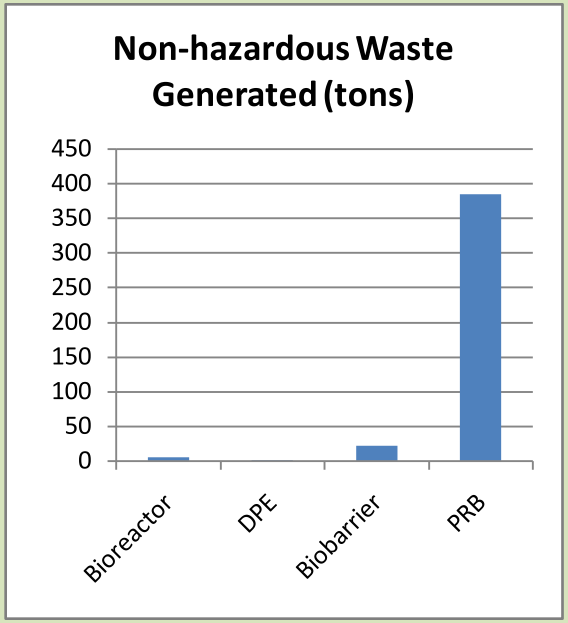
Results

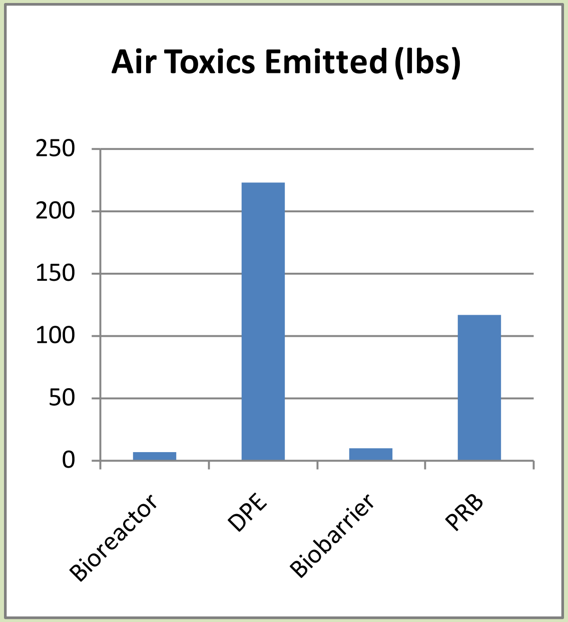


Travis Air Force Base

Sometimes the differences in footprints will be very striking.

Even though the results must be seen as estimates, they may still serve as a strong indication of which remedies have the largest footprints.



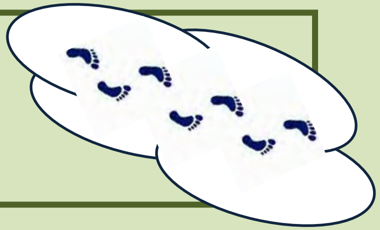


The high footprints for the PRB are due primarily to the off-site production of zero-valent iron. The high air toxics footprint for the DPE is primarily due to production of grid electricity.

Preliminary results, subject to change.
Full documentation of Travis Air Force Base analysis will be posted at:
www.clu-in.org/greenremediation/subtab_b3.cfm

DPE = dual-phase extraction
PRB = permeable reactive barrier

Results

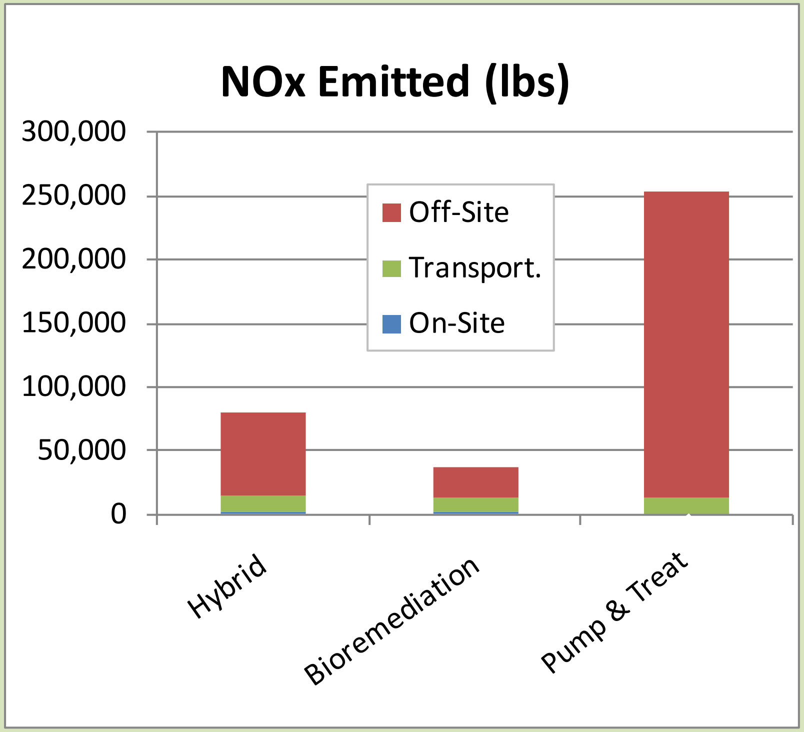


Romic East Palo Alto

Understanding on-site versus off-site emissions is important to site managers.

<u>On-site</u> emissions are of interest to communities near the site.

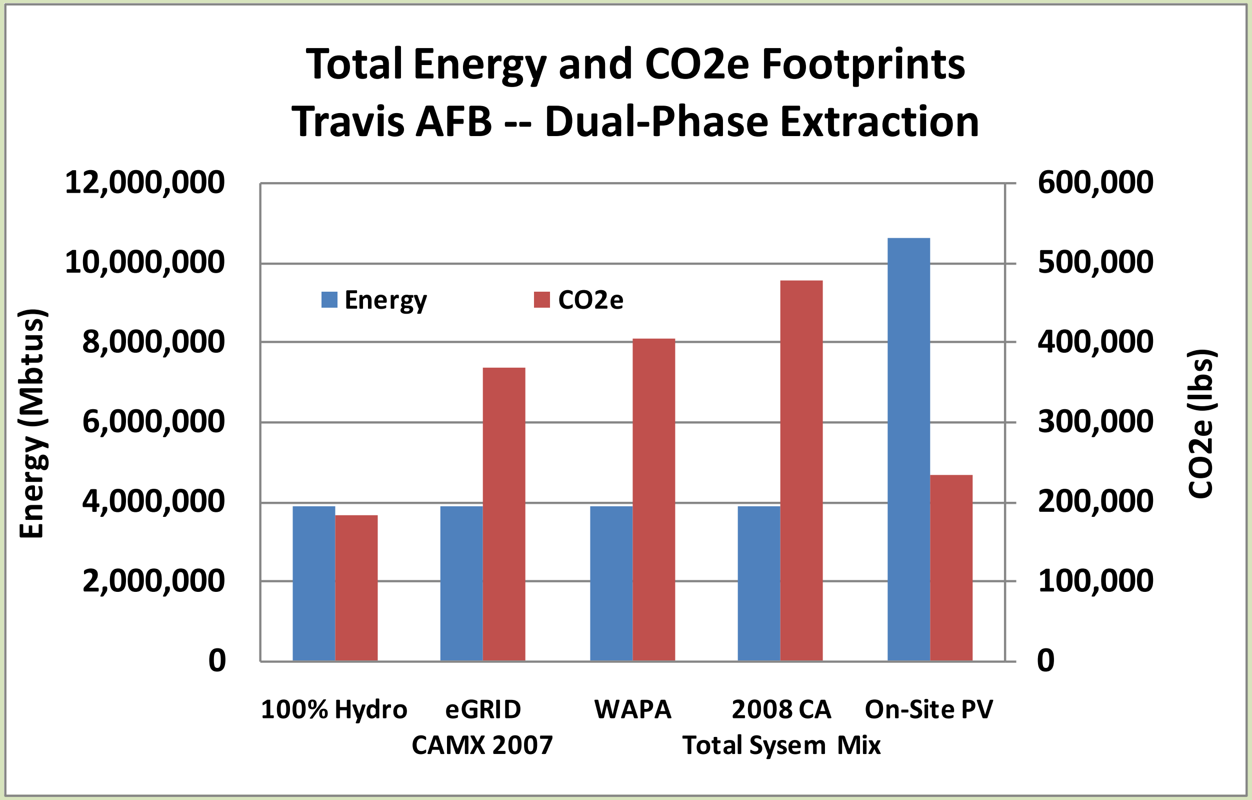
<u>Off-site</u> emissions may have regional and global implications.



Full documentation of Romic East Palo Alto analysis:
www.clu-in.org/greenremediation/romic

Results

Presenting information on sources of electricity can help the site manager decide whether to pursue alternative energy choices.



→ *WAPA (Western Area Power Administration) is a regional power supplier which provides grid electricity to Travis AFB*

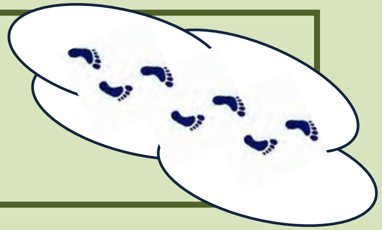
→ *On-Site PV = On-site Photovoltaic*

→ *100% Hydro = grid electricity based 100% on hydroelectric production*

Preliminary results, subject to change.

Full documentation of Travis Air Force Base analysis will be posted at: www.clu-in.org/greenremediation/subtab_b3.cfm

Results



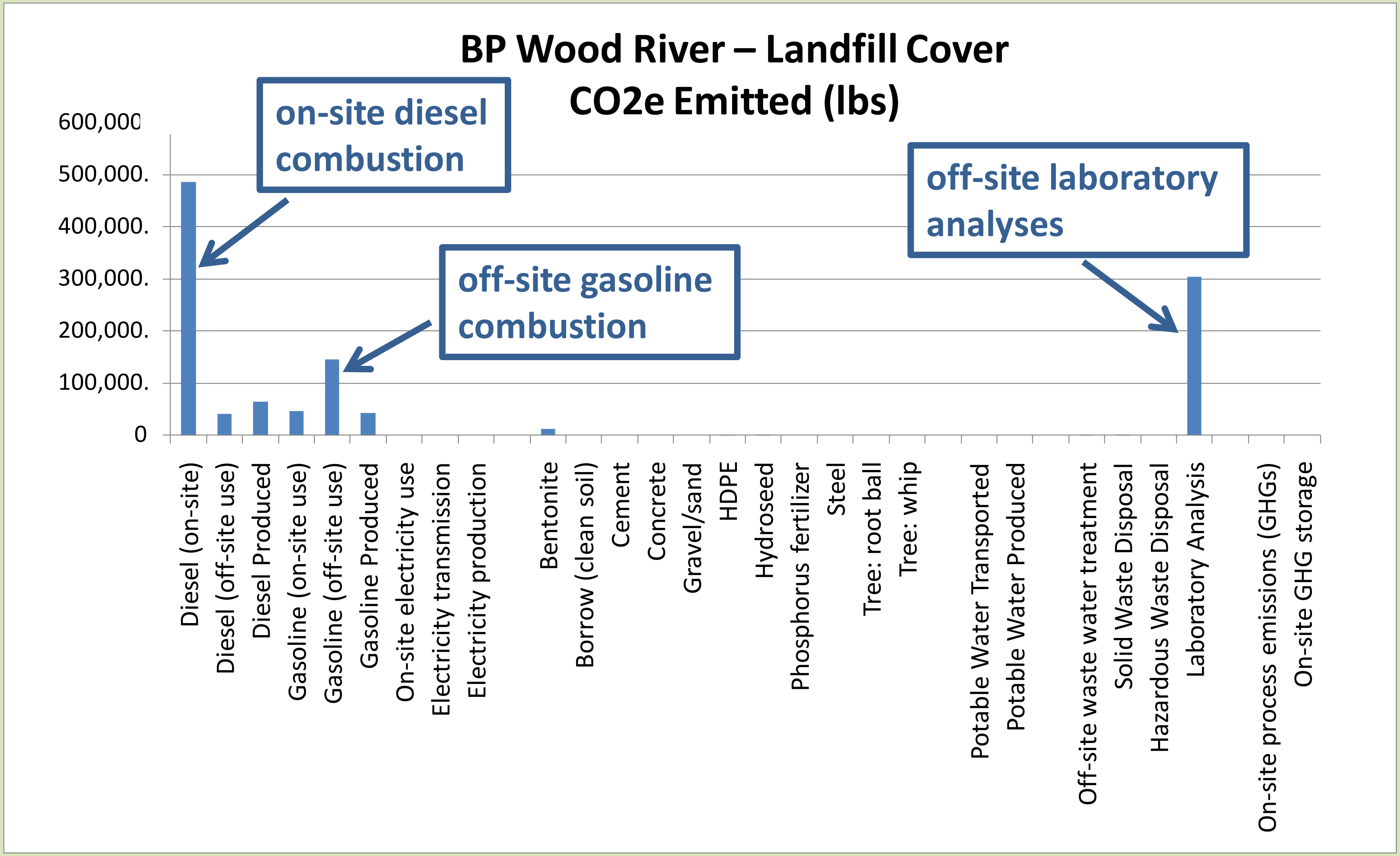
West Cap

Refined Materials		P&T	ISCO
Quantity Used	tons	1,110	93
% from Recycling/Reuse		75%	0%

Unrefined Materials		P&T	ISCO
Quantity Used	tons	560	11
% from Recycling/Reuse		0%	0%

		P&T	ISCO
Non-Hazardous Waste	tons	84	17
Hazardous Waste	tons	0	0
% Recycled or Reused		0%	0%

Results



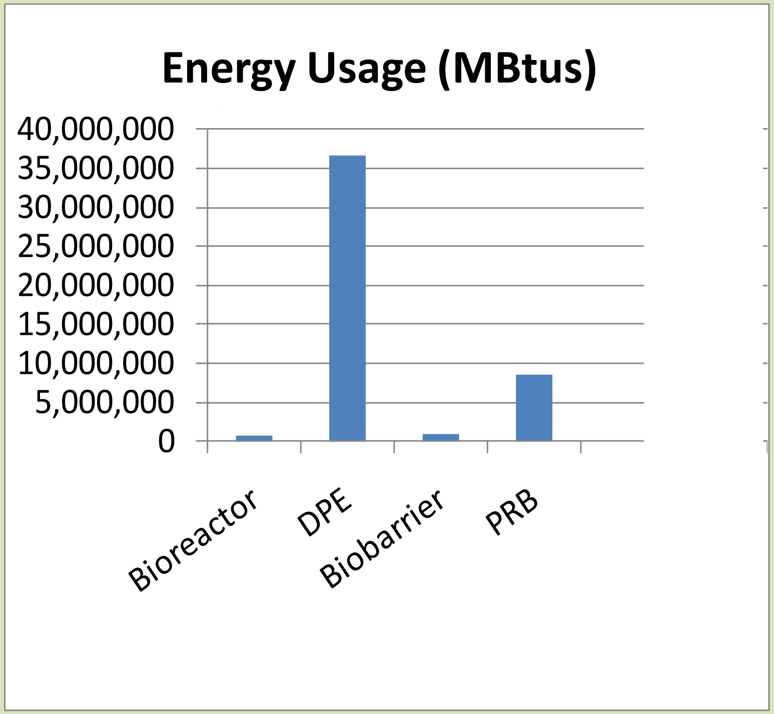
BP Wood River – Landfill Cover
CO2e Emitted (lbs)
on-site diesel combustion
off-site gasoline combustion
off-site laboratory analyses
600,000
500,000.
400,000.
300,000.
200,000.
100,000.
0
Diesel (on-site)
Diesel (off-site use)
Diesel Produced
Gasoline (on-site use)
Gasoline (off-site use)
Gasoline Produced
On-site electricity use
Electricity transmission
Electricity production
Bentonite
Borrow (clean soil)
Cement
Concrete
Gravel/sand
HDPE
Hydroseed
Phosphorus fertilizer
Steel
Tree: root ball
Tree: whip
Potable Water Transported
Potable Water Produced
Off-site waste water treatment
Solid Waste Disposal
Hazardous Waste Disposal
Laboratory Analysis
On-site process emissions (GHGs)
On-site GHG storage

Results

Travis AFB

Basic information such as total energy usage will be of interest to site managers.

This can help the site manager to understand benefits gained from the remedy selected, and to quantify improvements.



The bioreactor and biobarrier alternatives had the smallest footprints for energy usage.

Preliminary results, subject to change

DPE = dual-phase extraction
PRB = permeable reactive barrier