Incorporation of Carbon Footprint Estimates into Remedial Alternatives Evaluations

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Presentation Overview

- Purpose: To compare carbon footprint estimates of remedial technologies at two case study sites.
  - → 1) containment site, and 2) source area remediation site
  - → Evaluate the contributions to carbon footprint
  - → Evaluate sensitivity of inputs

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Definition

"A remedy or combinations of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources"

- Sustainable Remediation Forum (SuRF)

→ This paper focuses on the global effect of climate change

→ Local and regional effects such as air and water quality, economic development, quality of life, water use, accident risk, etc. are also important

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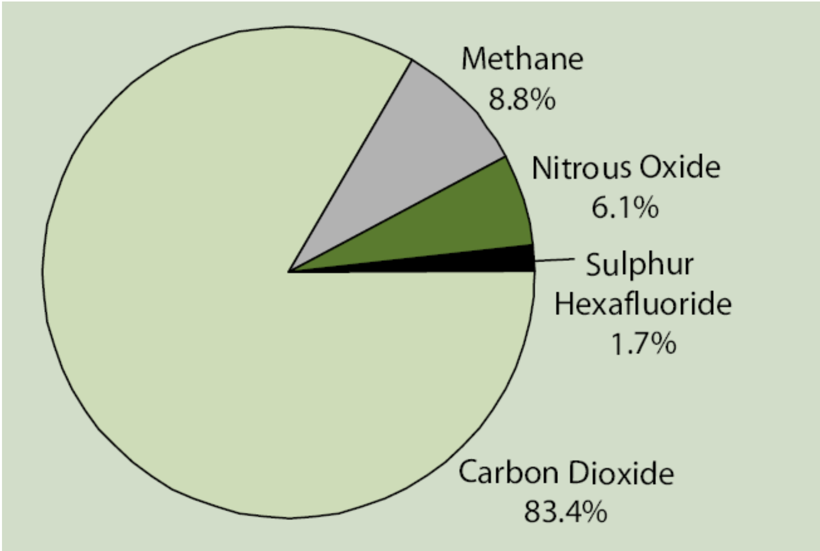
Causes

- Climate change is the gradual change in global temperature caused by accumulation of greenhouse gasses (GHG) in the atmosphere

- Six main contributors to climate change:
  - → Carbon Dioxide (CO_2)
  - → Methane (CH_4)
  - → Nitrous Oxide (N_2O)
  - → Hydrofluorocarbons (HFCs)
  - → Perfluorocarbons (PFCs)
  - → Sulphur hexafluoride (SF_6)



Climate Change

Impacts

- Flooding/Sea Level Rise
- Economic Disruption
- Increased Storm Severity
- Disease
- Water Shortages
- Disruption of Habitat and Ecosystems
- Damage to Global Treasures (glaciers, coral reefs, etc)

Background

- Carbon Footprint Assessment is an accounting of GHG emissions due to an action
  - → Direct: GHG source operated on-site
  - → Indirect: GHG emissions off-site as a result of the on-site activity (for example, due to manufacture of a material)

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Case Studies

- A Manufacturing Site in Santa Clara, California
- Chlorinated Solvent Plume in Groundwater
- Existing Groundwater Extraction and Treatment System (GWETS)
- Evaluating whether to replace GWETS with alternative containment technology

- Containment Technologies Considered:

  → **Continued GWETS Operation**
  → **In-Situ Reductive Biobarrier using Vegetable Oil**
  → In-Situ Permeable Reactive Barrier Using Iron

Case Studies

- Former Dry Cleaner in Modesto, California
- PCE Plume in Groundwater
- Evaluating technologies for remediation of groundwater “source area.”

- Remediation Technologies Considered:
  - → No Action
  - → **Air Sparging**
  - → **In-Situ Bioremediation using Vegetable Oil**
  - → Groundwater Extraction and Treatment
  - → Thermal Desorption
  - → In Situ Oxidation
  - → In Situ Reduction Using Zero Valent Iron

Carbon Footprint Assessment

Typical Categories for Remediation Projects

1) Transportation of Personnel
   → by car, plane, rail, etc
2) Transportation of Equipment and Supplies
   → by truck, big rig, train, etc
3) Fuel for Equipment Usage
   → e.g., drill rigs, trenchers, forklifts
4) On-Site Electricity Usage
   → e.g., pumps, blowers
5) Materials Production
   → Steel, PVC, reagents, well materials
6) Waste Disposal/Recycling
   → GAC, waste soils, etc

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Carbon Footprint Assessment

Basis for Calculation

• Our carbon footprint based on actual remedial designs for sites

• Carbon footprint calculation uses "middle-of-the road" input values from available sources

→ Other remediation tools (SRT and SiteWise)
→ U.S. Government/EPA
→ Trade/Industry Organizations

• The range of available inputs typically varied +/- 10-20% for most items, but some had a much greater variability

→ Items with highest variability highlighted in next slides

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Carbon Footprint Assessment

Basis for Calculation

	Units	Range of Values	Value	+/- Range
Personal Vehicle Fuel Efficiency	miles per gallon	N/A	17.6	N/A
Mid-Sized Truck Fuel Efficiency	miles per gallon	N/A	7.9	N/A
Full-Sized Truck Fuel Efficiency	miles per gallon	N/A	6.4	N/A
CO_2 per Train lb-mile	pounds per lb-mile	2.06×10^{-5} to 2.77×10^{-5}	2.77×10^{-5}	14%

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Carbon Footprint Assessment

Basis for Calculation

	Units	Range of Values	Value	+/- Range
Drill Rig Fuel Consumption (Direct Push)	gallons per hour	0.8 to 3.0	1.9	58%
Drill Rig Fuel Consumption (HSA)	gallons per hour	3.0 to 7.2	5.1	41%
Trencher Fuel Consumption	gallons per hour	N/A	6	N/A
Forklift Fuel Consumption	gallons per hour	N/A	2	N/A
CO_2 equiv per kWh of electricity	CO_2 eq per kWh	0.524 to 1.34	0.915	46%

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Carbon Footprint Assessment

Basis for Calculation

	Units	Range of Values	Value Used	+/- Range
CO_2 per pound of PVC produced	CO_2 eq per pound	1.824 to 2.50	2.162	16%
CO_2 per pound of Steel produced	CO_2 eq per pound	2.72 to 2.95	2.834	4%
CO_2 per pound of Edible Oil produced	CO_2 eq per pound	0.33 to 2.8	1.565	79%
CO_2 per pound of Sand produced	CO_2 eq per pound	N/A	0.005	N/A
CO_2 per pound of Grout produced	CO_2 eq per pound	0.83 to 1.0	0.915	9%
CO_2 per pound of GAC produced	CO_2 eq per pound	1.91 to 2.71	2.31	17%

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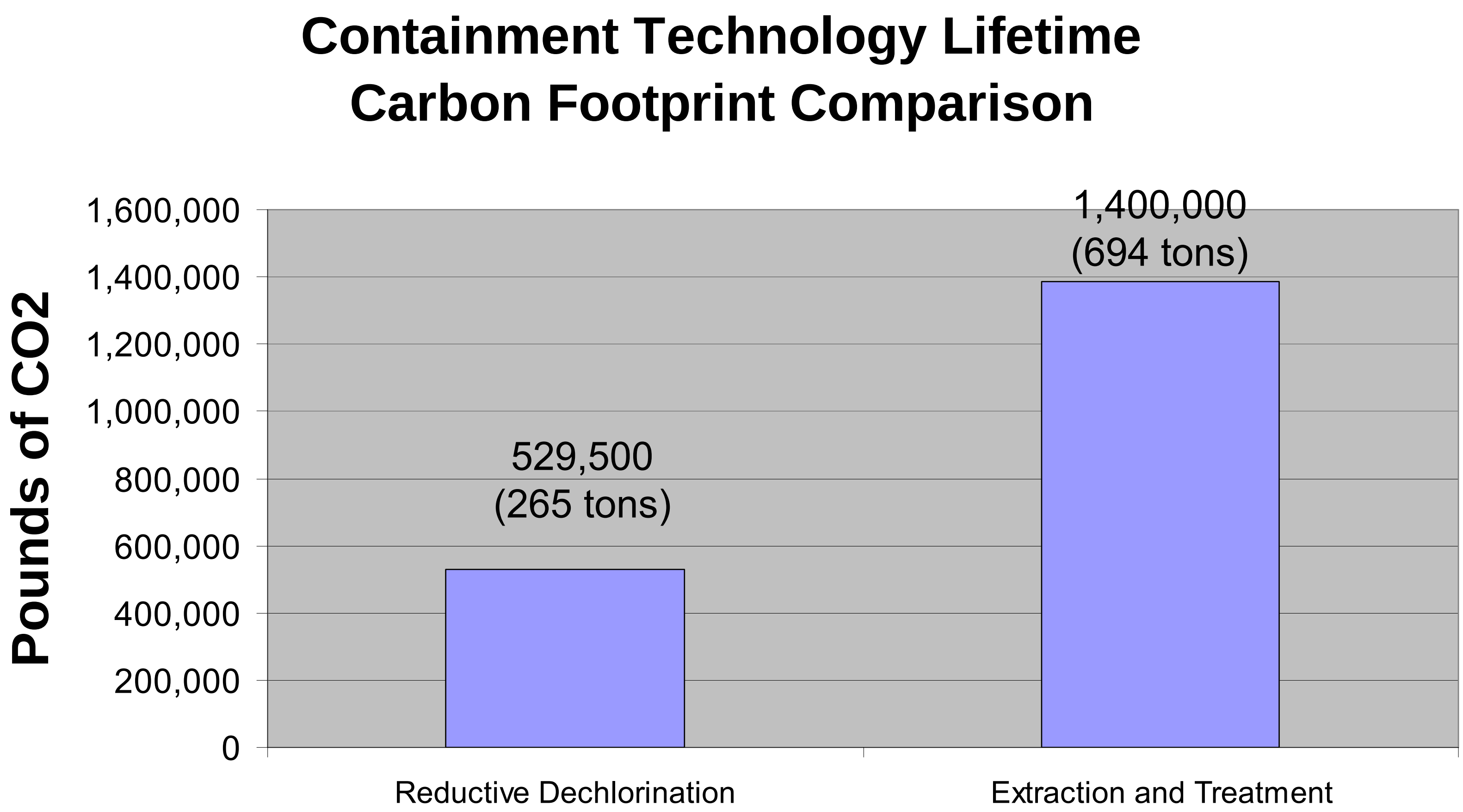
Results

The Bottom Line



• Extraction and Treatment has 2-3 times higher footprint than Reductive Dechlorination

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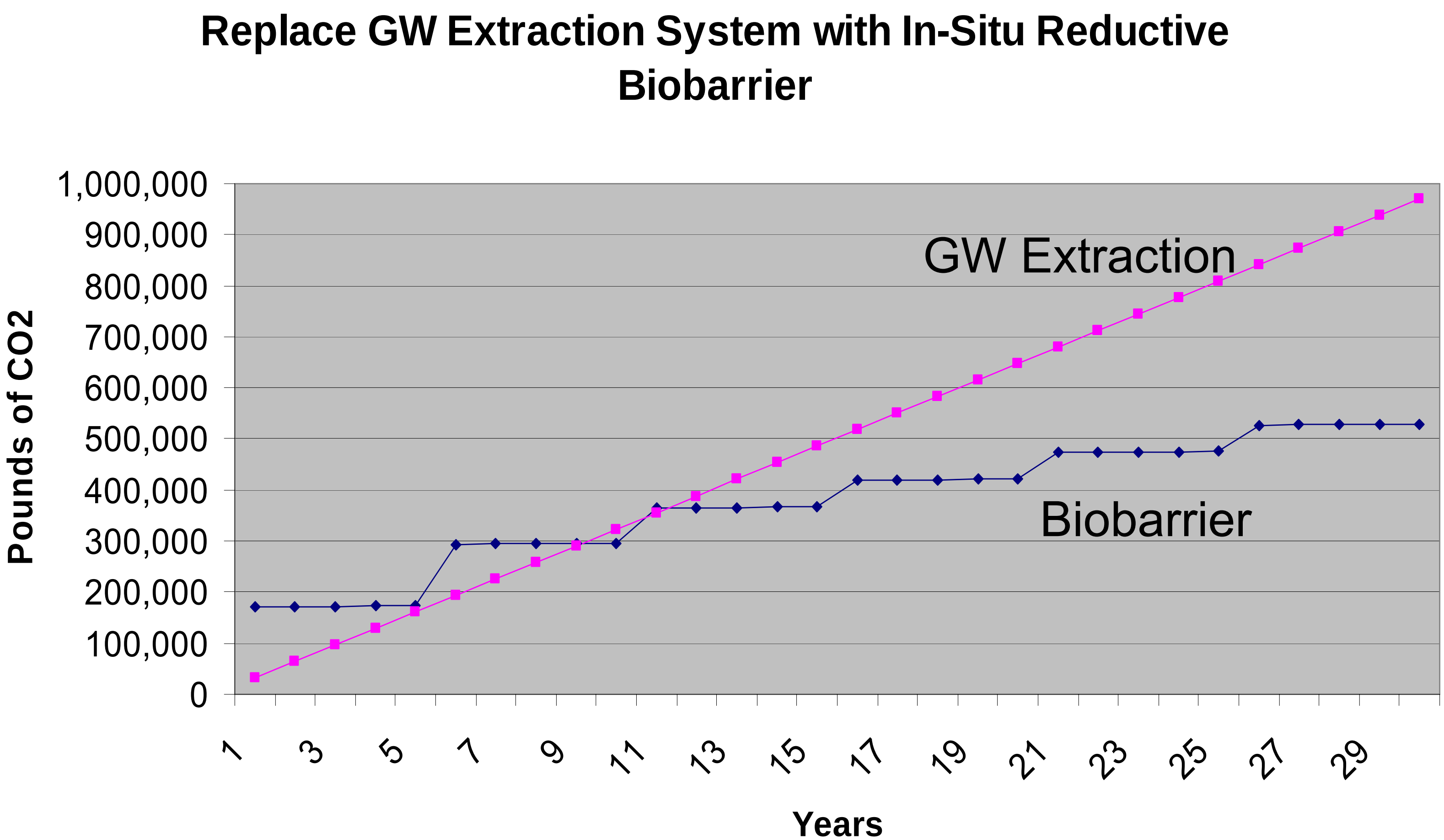
Results

The Bottom Line



• Replacing GW Extraction with In Situ Biobarrier results in long-term reduction in carbon footprint

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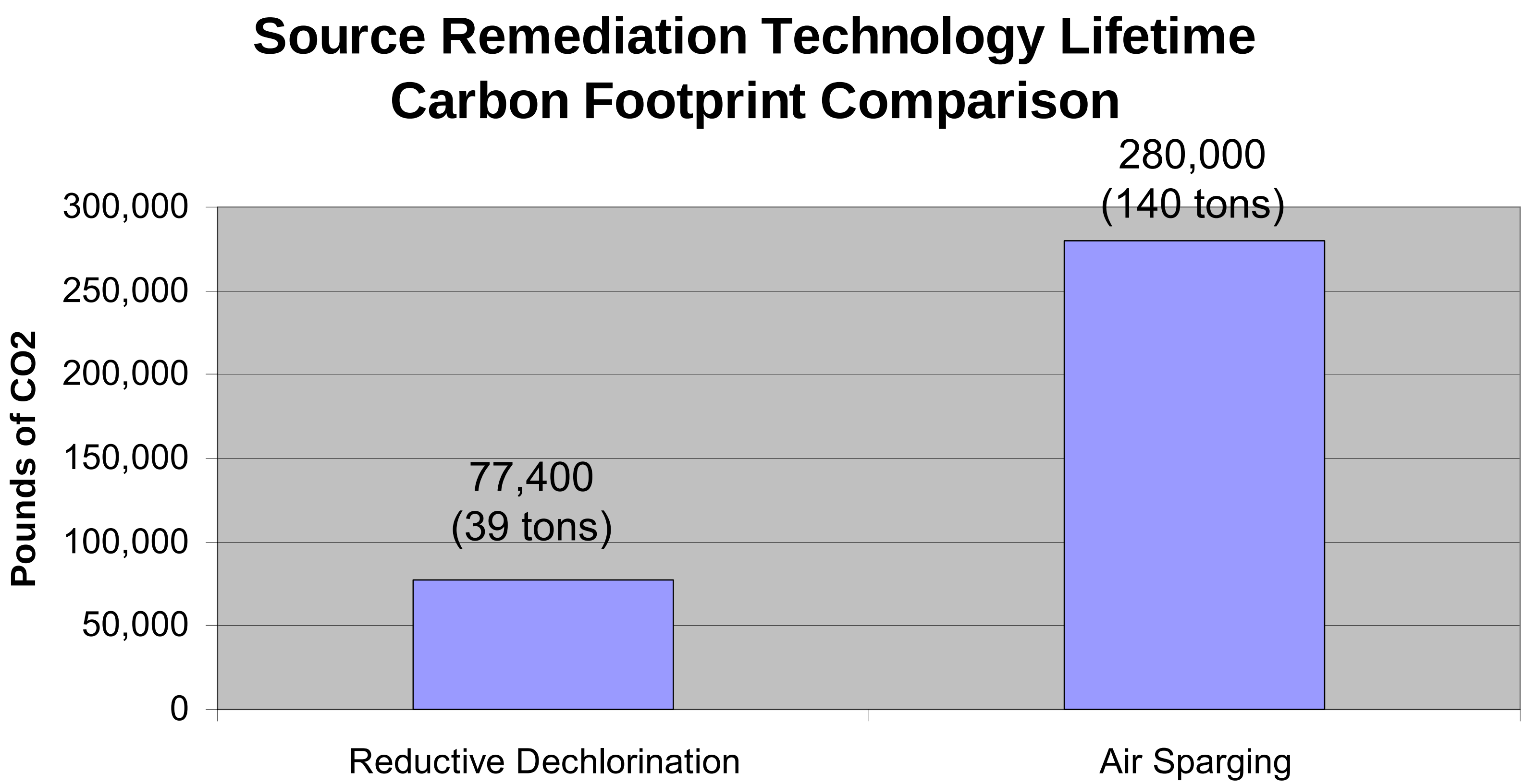
The Bottom Line



- Air Sparging has 3-4 times higher footprint than Reductive Dechlorination

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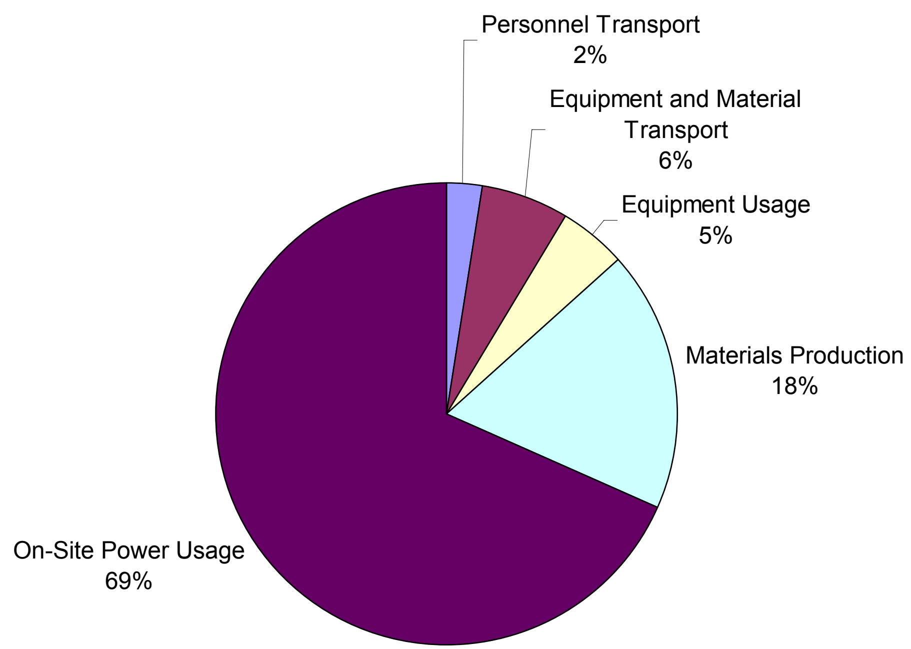
Contribution to Footprint

Contibution to Groundwater Extraction Carbon Footprint



- The largest contribution to the carbon footprint for groundwater extraction is the power usage for pumps and treatment system

  → Note that power usage footprint has wide range of uncertainty

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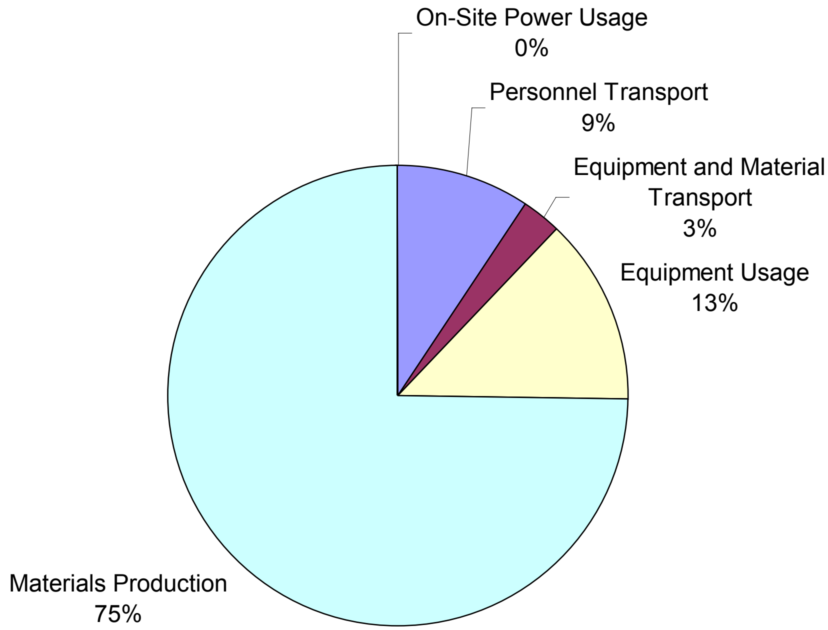
Contribution to Footprint

Contibution to Reductive Dechlorination Carbon Footprint



• The largest contribution to the carbon footprint for reductive dechlorination is the production of oil reagent

→ Note that oil reagent footprint has wide range of uncertainty

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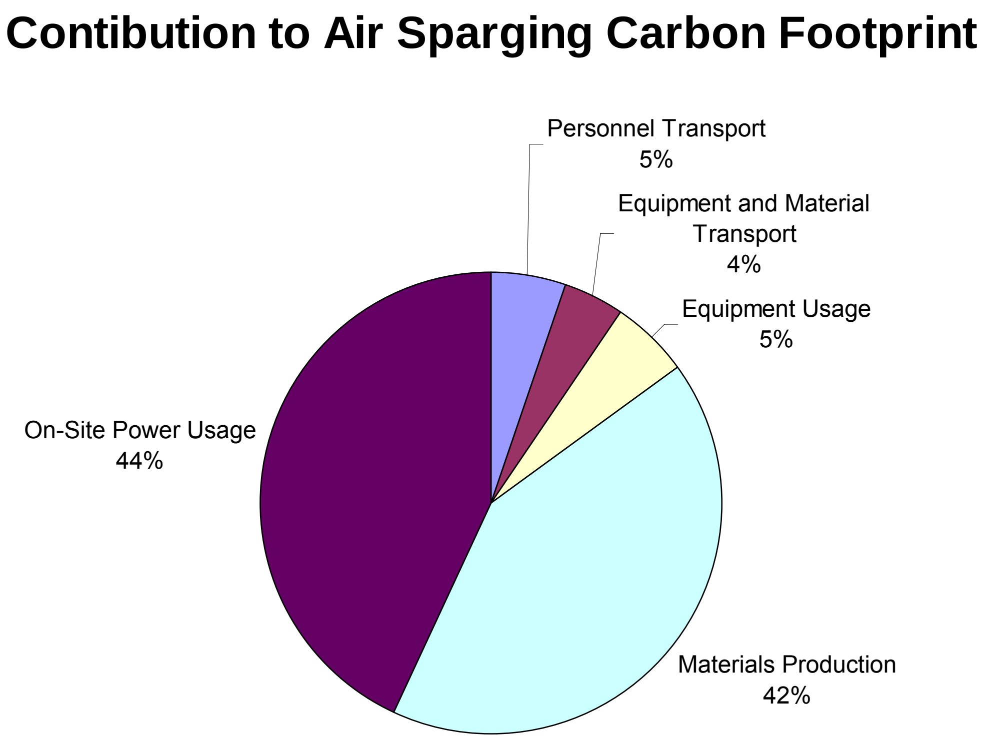
Results

Contribution to Footprint



• The contribution to the carbon footprint for air sparging is dominated by the power usage for blowers and production of GAC and materials for the treatment system and wells.

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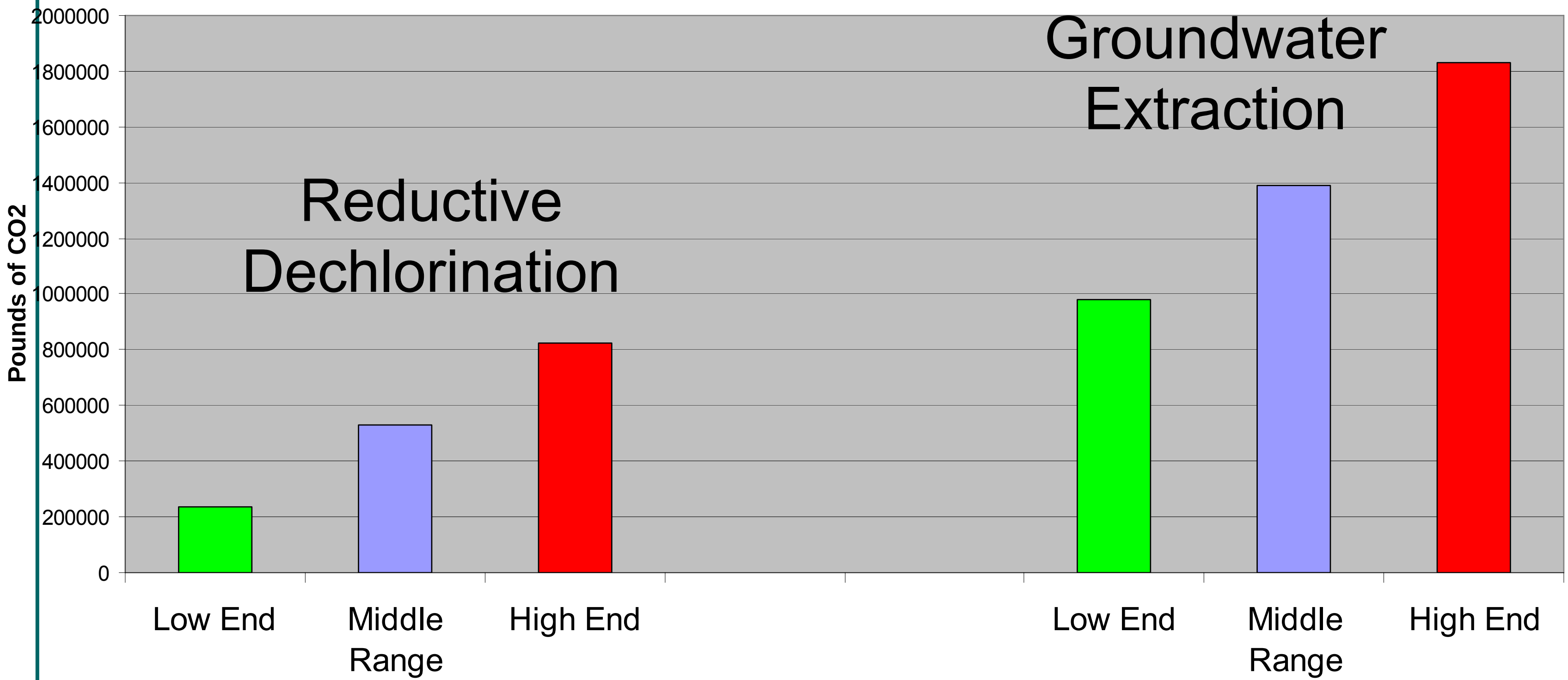
Results

Sensitivity Analysis

Ranges of Uncertainty in Carbon Footprint Calculation for Containment



- Reductive Dechlorination footprint range is always lower than for groundwater extraction, but the difference between the two is greatly affected by uncertainty.

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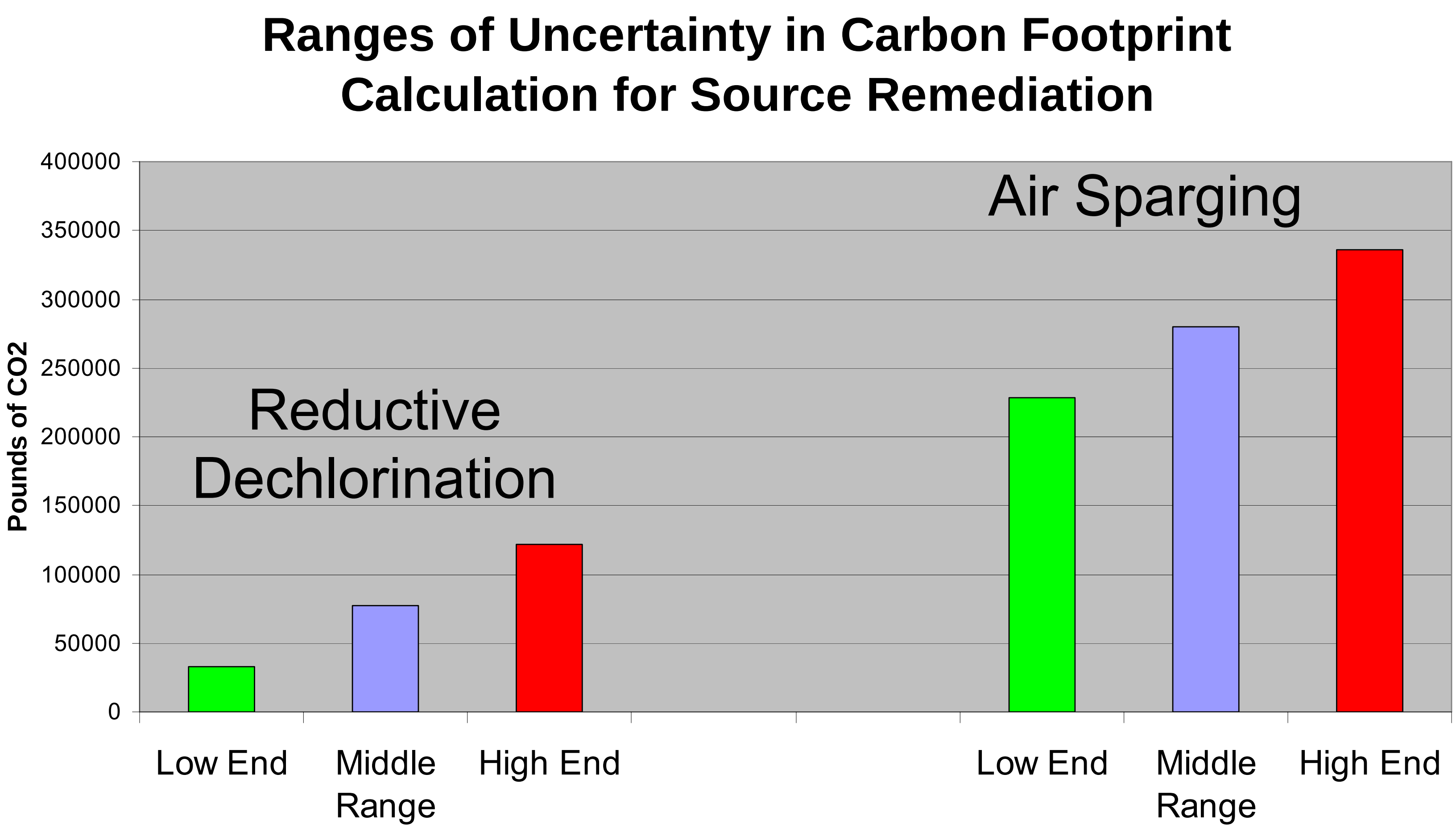
Sensitivity Analysis



- Reductive Dechlorination footprint range is always lower than for Air Sparging, but the difference between the two is somewhat affected by uncertainty.
  → Greater certainty would be desirable

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Conclusions

1) Replacement of an Existing GW Extraction System with an In Situ Reductive Dechlorination Biobarrier offers long-term reduction in carbon footprint.
2) In Situ Reductive Dechlorination offers more favorable carbon footprint than air sparging.
3) Can look at largest contributors “low hanging fruit” to reduce carbon footprint of technologies
   - → Renewable energy?
   - → Greener oil reagent?
   - → Greener GAC or alternative technologies?
4) Environmental field needs to work together to bridge large range of uncertainty in carbon footprint estimates for large contributors and incorporate into estimates
   - → Especially for vegetable oil reagent and electricity

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Questions?

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