Tackling the Carbon Footprint at Pump and Treat Projects: A Case Study in Energy Efficiency

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Today's Topics

- U.S. Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (MA DEP) collaboration to:
  - Address energy challenges
  - Reduce greenhouse gas (GHG) emissions
- Summary of technical issues and approach used at one Superfund site employing pump and treat (P&T) technology
- Final proposal of using combined heat and power (CHP)
- Advancing the knowledge base for green remediation (GR)

Opportunities to Increase Sustainability in Site Cleanups

- Go beyond energy
- Exist throughout site investigation, design, construction, operation, and monitoring
- Apply to all cleanup programs

https://www.clu-in.org/greenremediation/subtab_b1.cfm

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OSWER Green Remediation "Strategy"

For the purpose of advancing green remediation best practices across cleanup programs, OSWER seeks to:

- Benchmark and document GR best management practices
- Assemble a toolkit of enablers
- Build networks of practitioners
- Develop performance metrics and tracking mechanisms

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The Challenge: Carbon & Energy Footprints of Superfund Cleanup Technologies

Technology	**Estimated Energy *Annual Average* (kWh*10³)**	**Total Estimated Energy Use *in 2008-2030* (kWh*10³)**
Pump & Treat	489,607	11,260,969
Thermal Desorption	92,919	2,137,126
Multi-Phase Extraction	18,679	429,625
Air Sparging	10,156	233,599
Soil Vapor Extraction	6,734	154,890
Technology Total	***618,095***	***14,216,209***

	Annual Carbon Footprint (MT CO_2)	
Sum of 5 Technologies	404,411	

Recap on Energy & Carbon Footprint Strategy

- Optimize systems to maximize efficiency and return per unit of energy invested
- Build renewable energy capacity at contaminated sites to power remedies
- Tap into grid renewable energy portfolios
- Leverage carbon sequestration from soil amendment treatment

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Identify alternatives to achieve energy savings at study site

Establish energy conservation and recovery approaches that can be applied at many sites

EPA – MA DEP Objectives at B&M

- Identify alternatives to achieve energy savings at study site that can be applied at many sites
- Document approaches for carbon footprint analyses at P&T sites
- Explore the potential of coupling CHP turbines to power treatment systems
- Share findings and challenges yet to be overcome
- Build communication among different areas of expertise such as energy, site cleanup, and project management

Current Site Features

32 Acres, Holbrook, MA

A) Treatment plant
B) Cochato River
C) Infiltration basins
D) Restored wetland
E) Lake Holbrook
F) South Street wells

Initial Conditions and Impacts

- Listed on NPL in 1983
- Direct discharge from lagoons and landfilling to soil, river and wetlands
- Soil, groundwater, and river sediment contamination with metals, SVOCs, VOCs, PAHs, and pesticides
- EPA completed RI/FS in 1983-1986

Remedial Action Components

- Incineration of soils and river sediments (250K yd^{3})
  - Began incineration in 1995 and completed in 1998
  - Excavated soil on 12.5 Acres
  - Buried residual ash onsite (300 yd^3 stabilized)

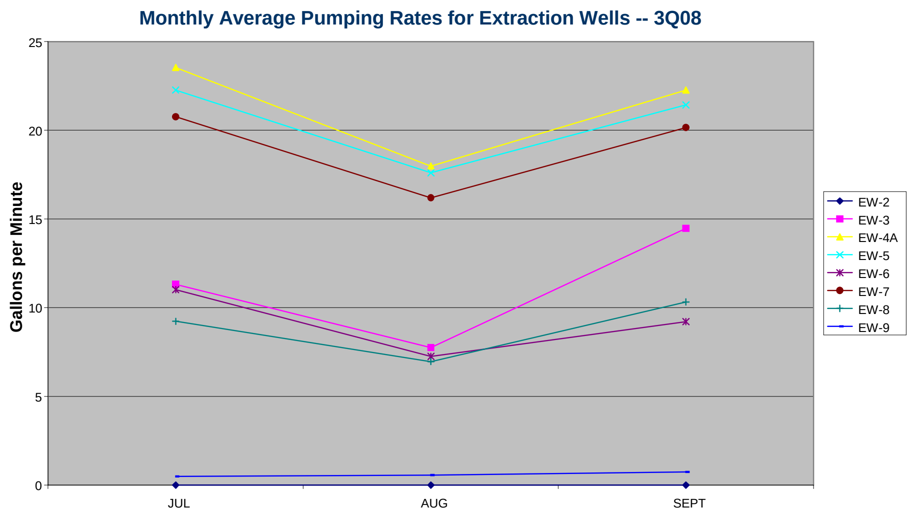
- P&T system for contaminated groundwater
  - Started in 1993
  - Initially served to treat incineration dewatering and process flows
  - Used from 1998 to the present for treatment of groundwater
  - Discharges effluent to infiltration basins

Remediation – 1996 to 2006

A) Incinerator & restored wetland
B) Groundwater treatment plant
C) Bauer, Inc.
D) Excavation
E) Backfilled incinerated ash
F) Cochato River

Treatment must achieve groundwater restoration at drinking water standards

Pumping Rates: 75 – 140 gpm



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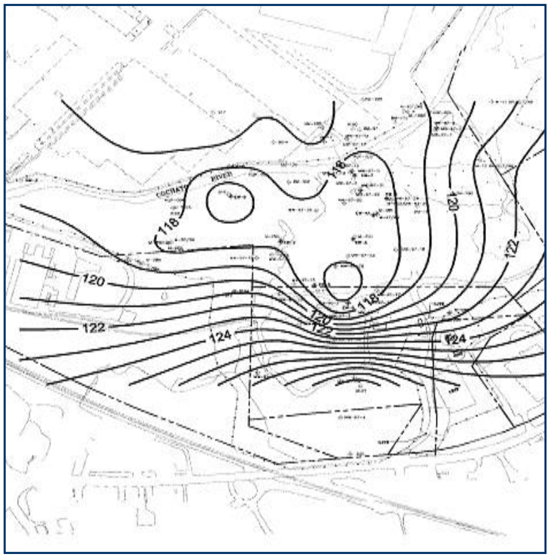
Groundwater Contours Indicating Plume Capture



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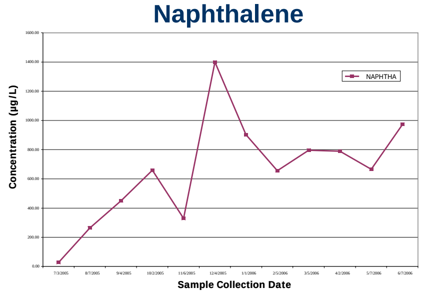
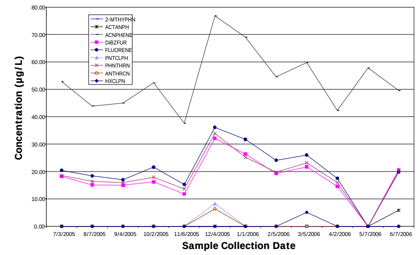
Influent Concentrations

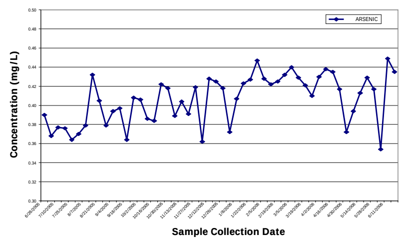
Naphthalene



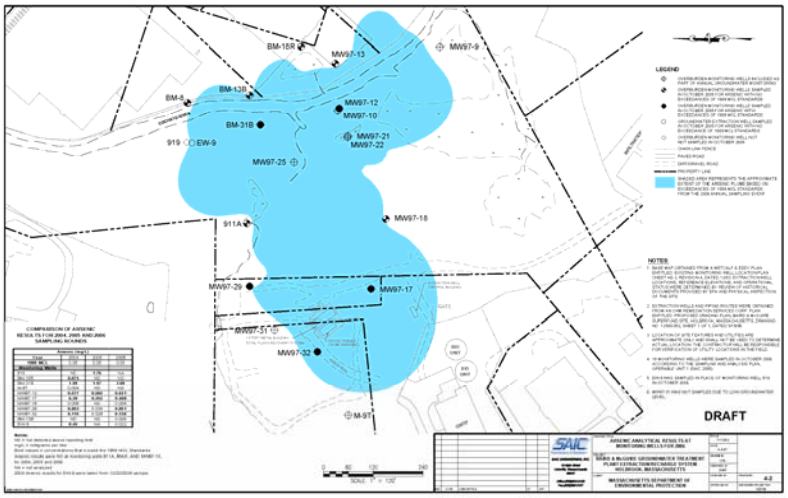
SVOCs



Arsenic



Extent of Arsenic Plume



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CERCLA – State Obligations

- For P&T remedies, the State assumes O&M after 10 years
- Annual treatment plant O&M costs $3.5 million
- In 2001, EPA initiated remediation system evaluations:
  - Automate plant: $1.3 million/yr personnel costs
  - Reduce process monitoring and eliminate offsite lab: $600,000/yr
  - Reduce security: $145,000/yr
  - Revise sludge disposal method: $6,000/yr
  - Improve LNAPL separation and disposal: $30,000/yr
  - Replace bio tanks with air strippers: $30,000/yr
  - Replace filter media: $50,000/yr
- State assumes O&M on June 22, 2004

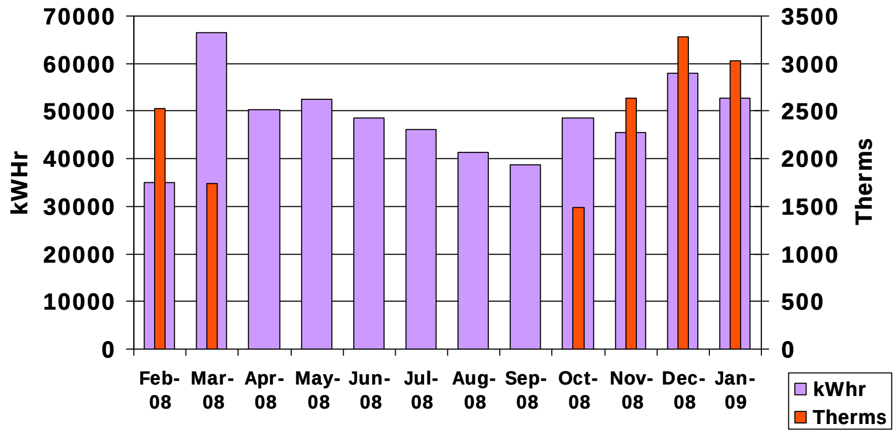
RSE Recommendations and Implementation

- RSE recommendations projected annual reductions at $2 million
- EPA implemented most of the recommendations for annual savings of $1.5 million
- State implements remaining and additional upgrades and achieves additional $1 million in annual savings:
  - Additional sensors and auto dialer improvements to SCADA system
  - Installation of computerized security system
  - Process sampling modified and use of off-site laboratory
  - Re-configure piping for GAC backwashing system
  - Process and site sampling plans modified
  - Elimination of the biocide application
  - Elimination of office trailers and site truck
- Costs reduced from $3.5 to 1 million

Recent Improvements and Annual Costs

- Extraction well redevelopment
- Replacement of pressure filter media (investigation of greensand and bag filters)
- Utility audits: installation of more efficient lighting, motion sensors (58 MWhr/yr), VFDs for extraction, influent and pressure filter pumps (23 MWhr/yr) resulting in 7 MWhr/mo reduction
- Staff: $635,000 for operations, site sampling, consulting, and reporting
- Direct costs: $294,000 for materials and laboratory analysis (GAC – $65,000 for 8 x 8,000 lbs at $1/lb)
- Energy: electricity $100,000 (50 MWhr/mo at $0.17 kWhr) and natural gas $23,000 (15,000 therms/year at $1.5/therm)

Monthly Energy Usage



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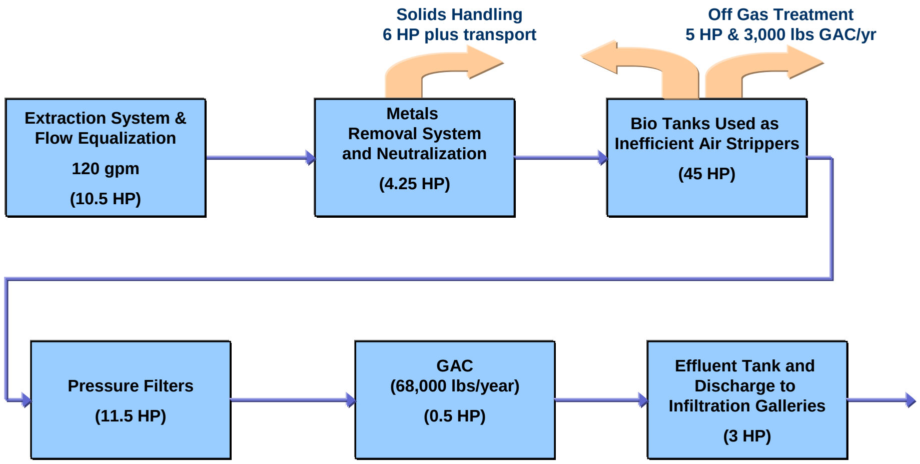
Treatment Process Flow



Average motor horsepower indicated in parentheses

Biotanks

- Size: 172,458 gal
- Detention time: 28 hours at 100 gpm
- Blower size: 20 hp

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Granular Activated Carbon

GAC A	GAC B	COMMENTS
		Filtersorb 300 pH recommended
	4/23/2004	
6/15/2004		
	9/29/2004	Filtersorb 300 pH
11/4/2004		Carbsorb 30pH
	1/19/2005	Carbsorb 30pH
3/2/2005		Carbsorb 30pH
	5/9/2005-	Carbsorb 30pH
7/21/2005		RX-pH POOL
	9/28/2005	RX-pH POOL
11/3/2005		RX-pH POOL
	2/1/2006	RX-pH POOL
3/9/2006		RX-pH POOL
	5/3/2006	RX-pH POOL
6/14/2006		RX-pH POOL
	9/14/2006	RX-pH POOL
10/11/2006		RX-pH POOL
12/7/2006	12/7/2006	RX-pH POOL
3/2/2007		RX-pH POOL
	3/13/2007	RX-pH POOL
6/8/2007		RX-pH POOL
	06/20/07	RX-pH POOL
10/04/07		DSRA React carbon, pH increase
	11/16/07	DSRA React carbon, pH increase
01/31/08		DSRA React carbon, pH increase
	02/28/08	DSRA React carbon, pH increase
04/22/08		DSRA React carbon, pH increase
	07/08/08	DSRA React carbon, pH increase
9/23/2008		DSRA React carbon, pH increase
	10/23/2008	DSRA React carbon, pH increase
12/10/2008		DSRA React carbon, pH increase
	2/13/2009	DSRA React carbon, pH increase

» GAC size 10,000 lbs requires 8,000 to 8,500 lbs per change-out

» Pressure drop from 2 psi to 15 psi

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Planning for the Future

- Long-term treatment to remove arsenic and dilute organics (naphthalene) for site restoration at drinking water standards
- Effluent MCLs and GW1 to prevent contamination of infiltration basins
- Additionally optimize plant/site operations
  - Placement of biotanks with clarifier modification
  - Improve GAC operations
  - Establish extraction well redevelopment/replacement plan
  - Optimize extraction well pumping
  - Soil sampling
- Minimize energy use
- Reduce emission of GHG

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State Focus on Energy and GHG Emissions

- Conservation charge: utility audits and rebates
- Renewable energy charge: funding through the MTC
- ISO forward capacity market
- Green Communities Act:
  - RGGI: cap and trade allowances for generators larger than 25 MW
  - Utilities required to purchase “negawatt” power
  - Resources to communities for efficiency and renewable energy
  - RPS expanded to include APS for CHP
- Global Warming Solutions Act: 10% to 25% below 1990 by 2020, etc.
  - Registration of emitters above 5,000 short tons/yr
  - Mass DEP voluntary reporting with the Climate Registry includes Baird & McGuire emissions (general reporting protocol)
- MEPA Policy: Governor’s zero emissions building initiative, zero net energy buildings by 2030, Clean Energy BioFuels Act

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Concept of CHP at Baird & McGuire

- Focus on energy and GHG emissions
  - GAC change-outs at 6.45 lbs CO_2/lb GAC
  - Biotank energy requirements
- Elimination of biotanks and GAC units
- Addition of air stripping at elevated temperature
- Addition of engine or turbine to provide heat and power
- Provide for maximum heat recovery

Parameters for the Study

- Carbon parameters
  - Electricity: 1.48 lbs of CO_2 per kWh (GRID 2005 for MA)
  - Natural gas: 12.2 lbs of CO_2 per therm (www.nrel.gov/lci)
  - GAC: 6.45 lbs of CO_2 per pound of GAC (discussion point)
  - Travel: 40 lbs of CO_2 per site visit (based on approximately 2 gallons of gas per visit)
- Cost parameters
  - Electricity: $0.17/kWh (bills)
  - Natural gas: $1.50/therm (bills)
  - GAC: $1.04/lb (contract estimate)
  - Service tech visit: $450 per visit

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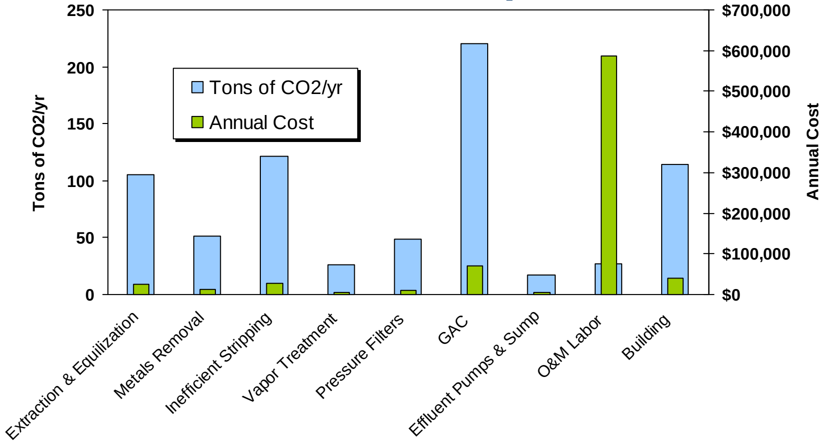
Breakdown of Current Carbon Footprint and O&M Cost

Total O&M Cost: $784,000 per year

Total Carbon Footprint: 787 tons of CO_2 per year



O&M costs and carbon footprint (for remainder of presentation) are for O&M of treatment plant and do not include other site activities including groundwater sampling

Preliminary Analysis

- The GAC has a high carbon footprint and a high cost (largely due to frequent change-outs)
- O&M labor costs are high, but the carbon footprint is relatively low
- Previous evaluations suggest capture is adequate but not much room for reducing extraction rates. VFD's on all extraction pumps, so assumption is that there is little room for reducing energy usage for extraction
- Inefficient air stripping has a substantial footprint
- Building footprint is also significant (18,700 therms of NG for heating, 75,000 kWh per year for ventilation, lighting, etc.)

Options

- Eliminate stripping and go to GAC-only for treatment of organics, attempt to decrease GAC change-out frequency
- Eliminate GAC and go with stripping only
- Enhance stripping with waste heat from a combined heat and power unit
- Consider alternatives for building heating/cooling

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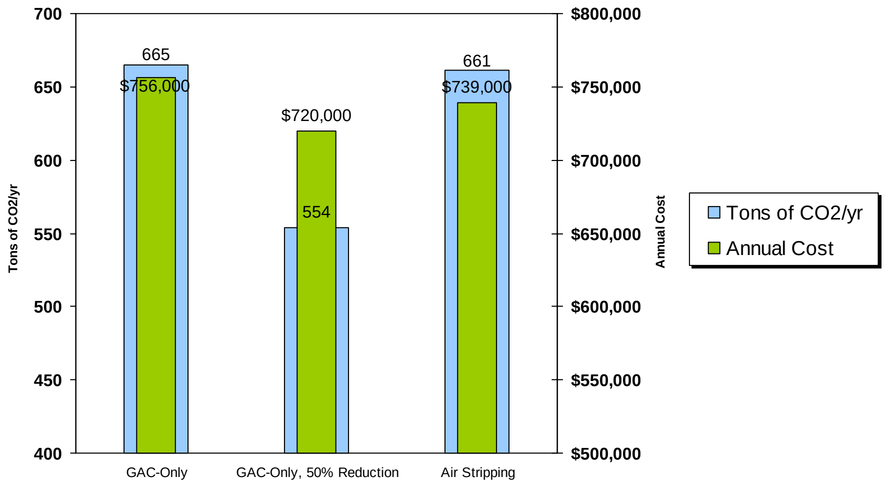
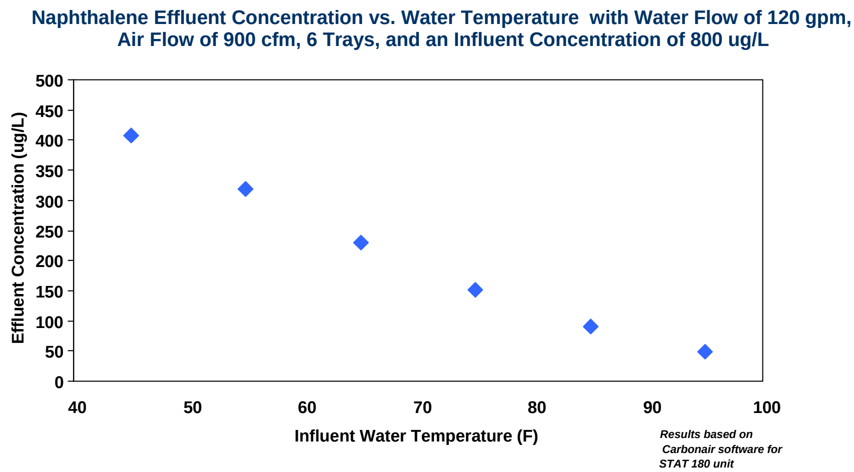
Breakdown for Various Options



Stripping Effectiveness and Water Temperature



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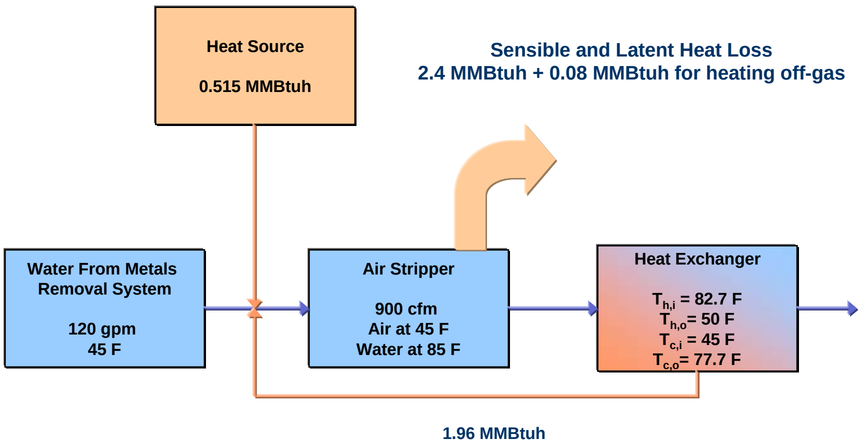
Heat-Enhanced Air Stripping



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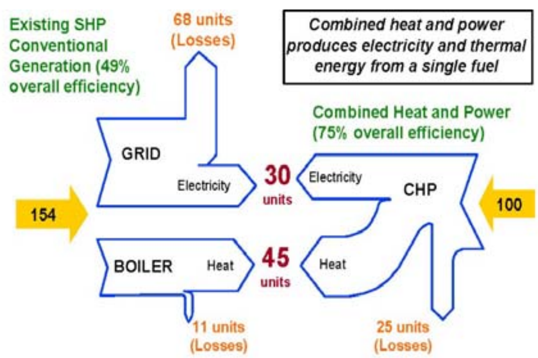
Combined Heat and Power

- Generate electricity on-site with a natural gas powered generator
- Rather than discharge heat to the atmosphere, use it for beneficial use
- Results in increased overall efficiency
- Only makes sense if electrical demand and heating demand are present and appropriate



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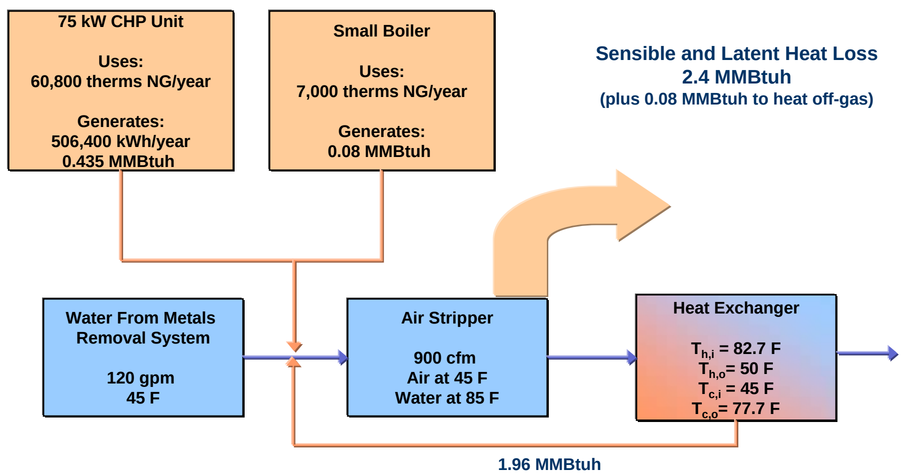
CHP Heat-Enhanced Air Stripping



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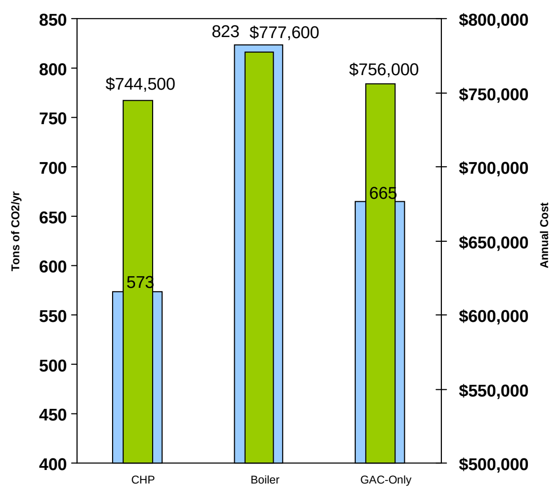
CHP Option vs. Boiler Option



CHP Option Uses:

- 60,800 therms of NG per year

CHP Generates:

- 506,400 kWh per year
- 0.435 MMBtuh

  (a boiler supplies additional 0.08 MMBtuh)

Boiler Option Uses:

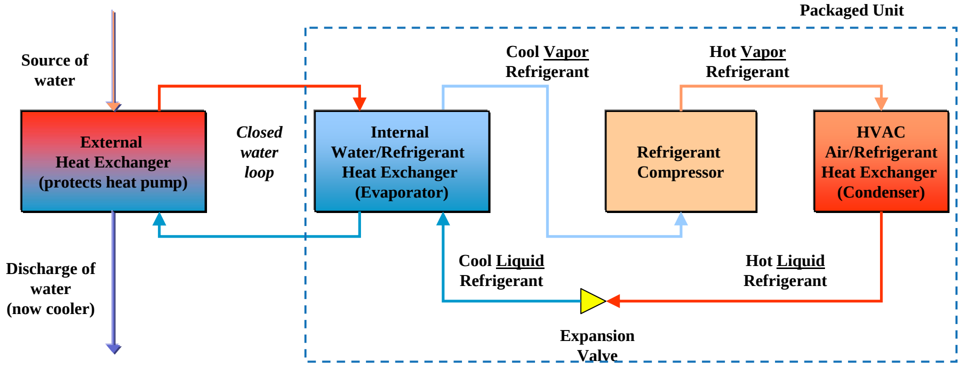
- 47,500 therms of NG per year

Boiler Generates:

- 0.51 MMBtuh

Water Source Heat Pumps (Heating Mode Shown)

- Similar concept to air conditioner or refrigerator but
  - Heats instead of cools air
  - Uses water not air as the heat source
- Heat from water vaporizes refridgerant
- Heat from condensing refridgerant is transferred to building via HVAC system
- Heat is transferred via vaporization/condensation of refridgerant



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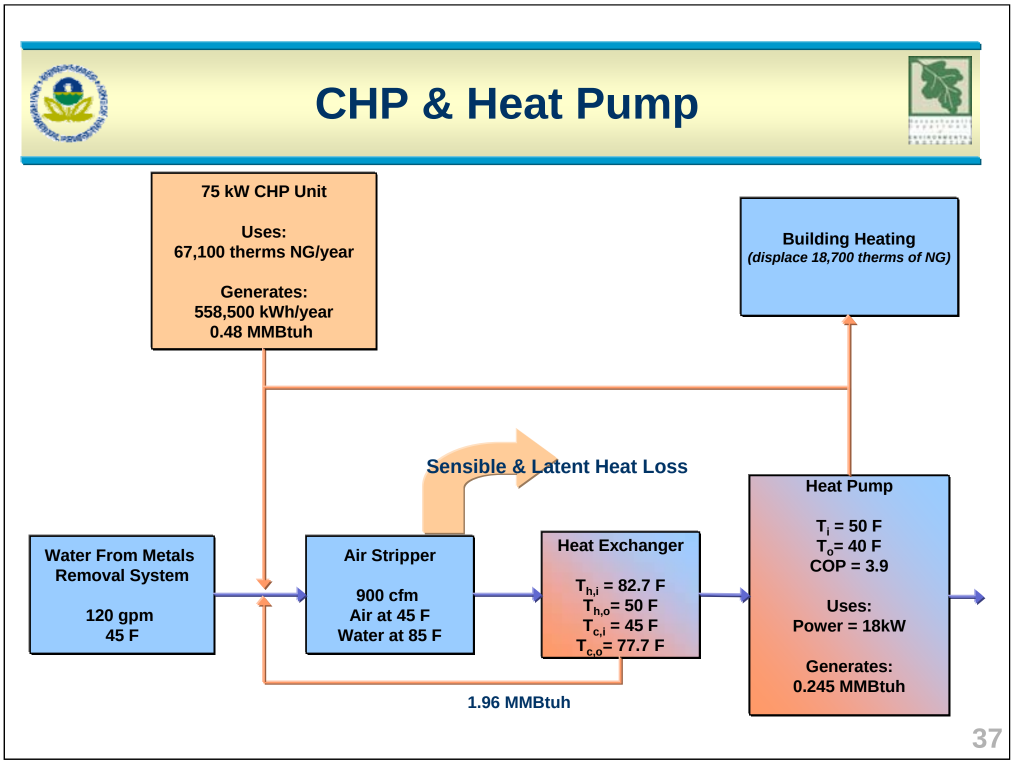
CHP & Heat Pump
75 kW CHP Unit
Uses:
67,100 therms NG/year
Generates:
558,500 kWh/year
0.48 MMBtuh
Building Heating
(displace 18,700 therms of NG)
Sensible & Latent Heat Loss
Water From Metals Removal System
120 gpm
45 F
Air Stripper
900 cfm
Air at 45 F
Water at 85 F
Heat Exchanger
$T_{h,i}$ = 82.7 F
$T_{h,o}$= 50 F
$T_{c,i}$ = 45 F
$T_{c,o}$= 77.7 F
Heat Pump
T_i = 50 F
T_o= 40 F
COP = 3.9
Uses:
Power = 18kW
Generates:
0.245 MMBtuh
1.96 MMBtuh
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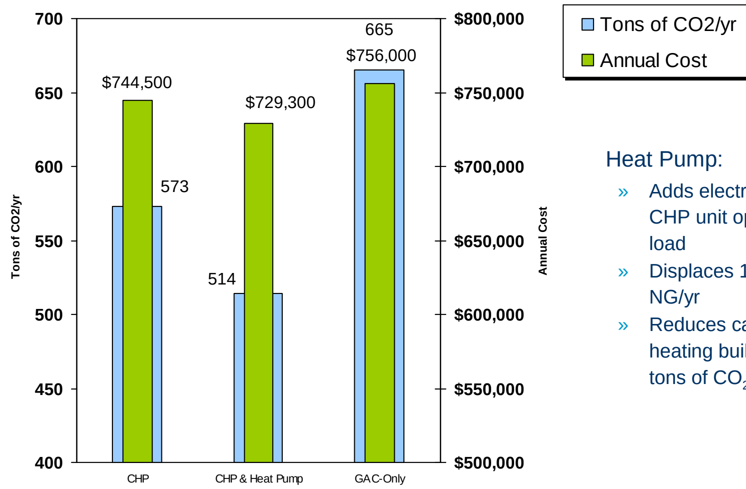
CHP Option
With and Without Heat Pump



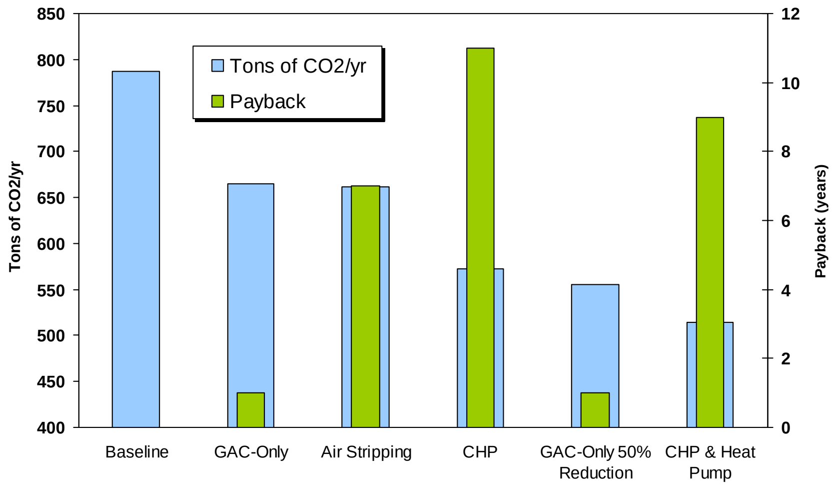
Heat Pump:

- Adds electrical load so that CHP unit operates at full load
- Displaces 18,700 therms of NG/yr
- Reduces carbon footprint for heating building by about 30 tons of CO_2/yr

% Reductions for Carbon Footprint and Cost

	% Reduction	
Option	Carbon Footprint	Annual O&M Cost
GAC-only	16%	4%
Air Stripping	16%	6%
CHP	27%	5%
GAC-only (50% reduction)	29%	9%
CHP & Heat pump	35%	7%

Payback of Various Options



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Conclusions Regarding Site

- Investigate GAC performance
  - Clarifier sizing
  - Metals removal chemistry
  - Filter effectiveness
  - Backwashing effectiveness
- Depending on GAC results pilot air stripping with and without heating
- Depending on pilot results consider CHP option but concern regarding potential future reduced standards for naphthalene
- Consider water source heat pump for building heat regardless

Conclusions Regarding Footprint Analysis

- Labor is high cost but has a relatively low footprint
- Electricity and energy is relatively low cost but has a high footprint
- Materials can have a high footprint
- Footprint for travel, electricity, and natural gas are relatively straightforward to calculate for various options
- Footprint for materials (e.g., GAC) can be substantial but are uncertain without manufacturer input… accurate carbon footprinting for groundwater remediation requires reliable carbon footprints for materials (GAC, chemicals, etc.)
- GAC footprint is not well understood
  - 6.45 lbs of CO_2 per pound of GAC from Goldblum, et al.
  - May be substantially more than 10 lbs of CO_2 per pound of GAC for virgin, coal-based carbon but could be substantially lower for regenerated carbon
  - Emphasis on using renewable resource for GAC feedstock

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Conclusions Regarding Technological Applications

- CHP (combined with heat exchangers) is a carbon and energy efficient method of heating process water
  - May be beneficial to some biological treatment systems
  - Enhances stripping efficiency
  - In-situ remedies (?)
- Optimize traditional treatment components when comparing to new or more complex treatment approaches
- CHP-enhanced stripping may be even more appropriate for contaminants such as MTBE that are difficult to remove via stripping and GAC
- Appropriately consider disadvantages associated with heating water before implementing a treatment approach that requires heating
  - Increased potential for fouling
  - System has to "come up to temperature" before effective treatment can begin
- Heat pumps for building heating and cooling may be appropriate at many P&T sites

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Conclusions Regarding Technological Applications

Questions ?

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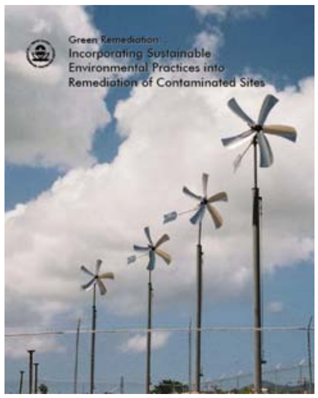
EPA Resources on Green Remediation



Site Name	State	Core Elements						
		Energy Efficiency	Renewable Energy	Air Emission	Water	Land & Ecosystem	Materials & Waste	Stewardship
Altus Air Force Base	OK		✓	✓	✓		✓	
Apache Powder	AZ		✓	✓	✓			✓
Barksdale AF Base	LA				✓	✓	✓	✓
BP Casper	WY					✓	✓	✓
BP Paulsboro	NJ		✓	✓				✓
California Gulch	CO			✓			✓	✓
Crozet Orchard	VA		✓	✓	✓			✓
De Sale Restoration Area	PA		✓	✓	✓	✓	✓	✓
Former Carswell Air Force Base	TX						✓	✓
Former Ferdula Landfill	NY		✓	✓				
Former Nebraska Ordnance Plant	NE		✓	✓				
Former St. Croix Alumina Plant	VI		✓	✓			✓	
Fort Carson	CO		✓	✓	✓		✓	✓

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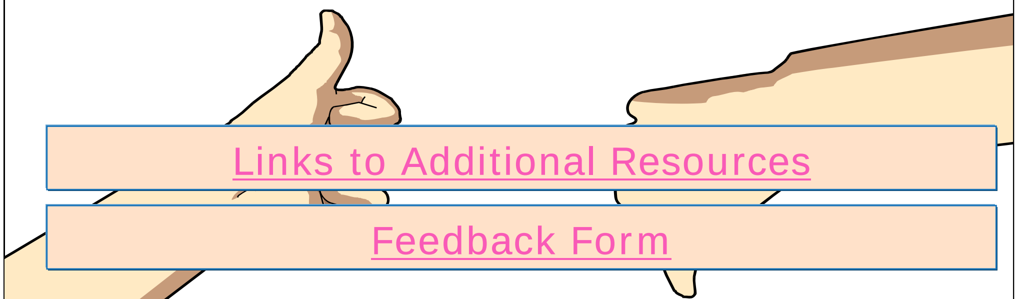
Thank You



[Links to Additional Resources]

[Feedback Form]

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