Using Thermal Technologies to Lower the Carbon Footprint at Pump and Treat Projects

Based on EPA OSRTI/GeoTrans Study 2009
Baird&McGuire Superfund Site

Dorothy Allen, MA Department of Environmental Protection

Introduction

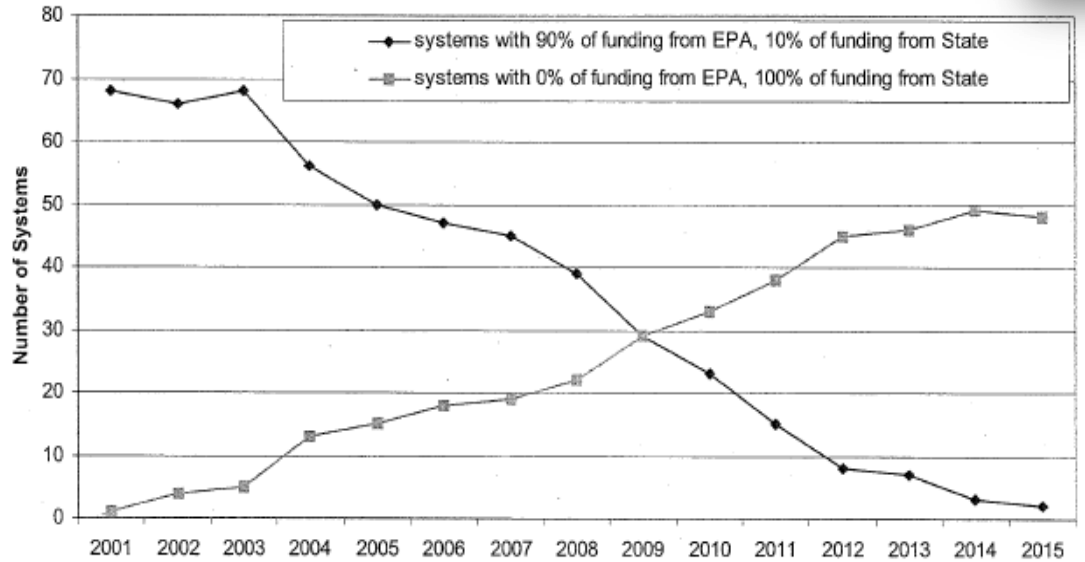
- Superfund Sites – large contaminated areas – required to meet substantive not administrative requirements
- 2009 Study planed to consider CHP and evolved into GWSHP
- FS level evaluation – performance of unit operations, heat and energy requirements, financial and GHG emissions assessments
- Presentation Content
  - » Reasons for Study
  - » Site and Treatment System Features
  - » Modifications
    - CHP
    - CHP with GWSHP
    - GWSHP only for process or heating
  - » Conclusions

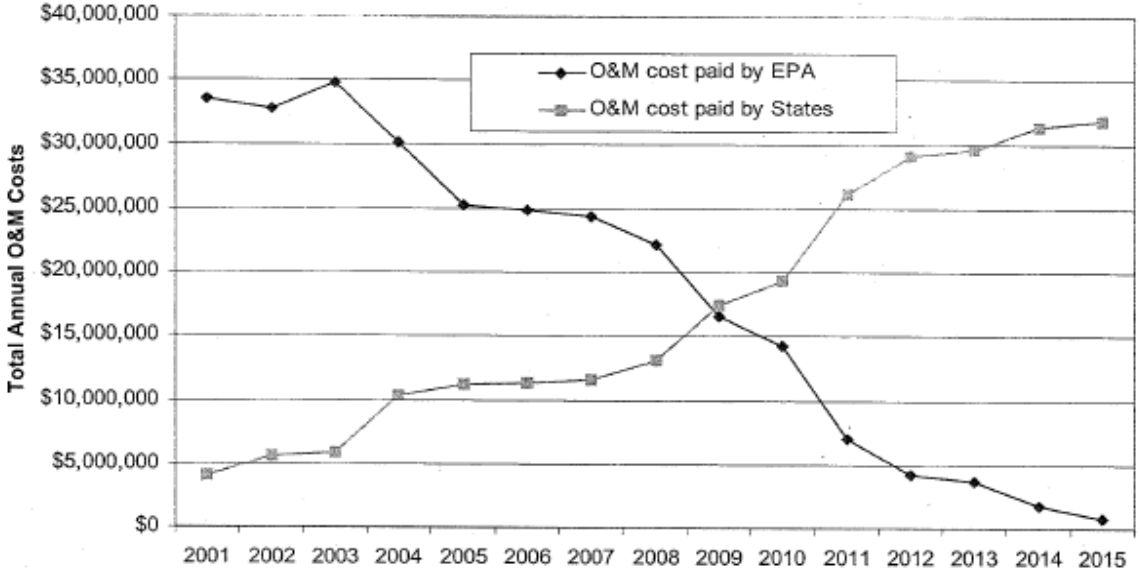
The Challenge: Carbon & Energy Footprints of Superfund Cleanup Technologies

Technology	Estimated Energy *Annual Average* (kWh*10^3)	Total Estimated Energy Use *in 2008-2030* (kWh*10^3)
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

State Lead Groundwater Pump and Treat Systems





Source: Groundwater Pump and Treat Systems: Summary of Selected Cost and Performance Information at Superfund-Financed Sites, 2001

EPA Interest in Lowering Remediation Environmental Footprint

Green Remediation Metrics

ASTM Standard Guide for Greener Cleanups

Core Element	Metric		Unit of Measure	Metric Value
Materials & Waste	M&W-1	Refined materials used on site	tons	
	M&W-2	Percent of refined materials from recycled or waste material	percent	
	M&W-3	Unrefined materials used on site	tons	
	M&W-4	Percent of unrefined materials from recycled or waste material	percent	
	M&W-5	Onsite hazardous waste generated	tons	
	M&W-6	Onsite non-hazardous waste generated	tons	
	M&W-7	Percent of total potential onsite waste that is recycled or reused	percent	
Water		Onsite water use (by source)		
	W-1	- Source, use, fate combination #1	millions of gals	
	W-2	- Source, use, fate combination #2	millions of gals	
	W-3	- Source, use, fate combination #3	millions of gals	
	W-4	- Source, use, fate combination #4	millions of gals	
Energy	E-1	Total energy use	MMBtu	
	E-2	Total energy voluntarily derived from renewable resources		
	E-2A	- Onsite generation or use and biodiesel use	MMBtu	
	E-2B	- Voluntary purchase of renewable electricity	MWh	
	E-2C	- Voluntary purchase of RECs	MWh	
Air	A-1	Onsite NOx, SOx, and PM10 emissions	lbs	
	A-2	Onsite HAP emissions	lbs	
	A-3	Total NOx, SOx, and PM10 emissions	lbs	
	A-4	Total HAP emissions	lbs	
	A-5	Total GHG emissions	tons CO_2e	
Land & Ecosystems	Qualitative description			

Source: USEPA OSWER OSRTI Methodology for Understanding and Reducing a Project's Environmental Footprint, 2011

EPA Interest in Lowering Remediation Environmental Footprint Cont.- CO2 eq Emissions

Item or Service Used		Suggested Conversion Factors: Parameters Used, Extracted, Emitted, or Generated						Reference
		Energy	CO_2e	NOx	SOx	PM	HAPs	
		Used	Emitted	Emitted	Emitted	Emitted	Emitted	
	Unit	MMBtu	lbs	lbs	lbs	lbs	lbs	
Construction Materials								
Cement	Dry-lb	0.0021	0.9	0.0018	0.00105	0.0000032	0.000029	5
Concrete	lb	0.00041	0.171	0.00035	0.00021	0.00001	0.00001	6
Gravel/sand/clay	lb	0.000028	0.0034	0.000017	0.000015	0.0000020	2.1E-10	7
HDPE	lb	0.031	1.9	0.0032	0.0041	0.00064	0.0000034	8
Photovoltaic system (installed)	Watt	0.034	4.5	0.015	0.032	0.00063	0.0000029	9
PVC	lb	0.022	2.6	0.0048	0.0076	0.0012	0.00047	10
Stainless Steel	lb	0.012	3.4	0.0075	0.012	0.0044	0.00014	11
Steel	lb	0.0044	1.1	0.0014	0.0017	0.00056	0.000067	12
Other refined construction materials	lb	0.014	1.9					
Other unrefined construction materials	lb	0.000028	0.003					

Item or Service Used		Suggested Conversion Factors: Parameters Used, Extracted, Emitted, or Generated						Reference
		Energy	CO_2e	NO x	SO x	PM	HAPs	
		Used	Emitted	Emitted	Emitted	Emitted	Emitted	
	Unit	MMBtu	lbs	lbs	lbs	lbs	lbs	
Treatment Materials and Chemicals								
Cheese Whey	lb	0.0025	0.031	0.000062	0.000033	0.000002	NP	15
Emulsified vegetable oil	lb	0.0077	3.44	0.0066	0.0019	0.000033	NP	16
Molasses	lb	0.0044	0.48	0.0011	0.00024	0.0000041	NP	17
Treatment materials and chemicals	lb	0.015	1.7	0.003	0.0065	0.00061	0.000016	18
Virgin GAC (coal based)	lb	0.015	8.5	0.014	0.034	0.00078	0.0012	19
Fuel Processing								
Biodiesel Produced	gal	0.029	-16.8	0.018	0.033	0.00082	NP	1
Diesel Produced	gal	0.019	2.7	0.0064	0.013	0.00034	0.00012	20
Gasoline Produced	gal	0.021	4.4	0.008	0.019	0.00052	0.00016	21
Natural Gas Produced	ccf	0.0052	2.2	0.0037	0.0046	0.000072	0.0000061	22
Public water	gal x 1000	0.0092	5	0.0097	0.0059	0.016	0.0000150	23

Source: USEPA OSWER OSRTI Methodology for Understanding and Reducing a Project's Environmental Footprint, 2011

MassDEP Tracks Its GHG Emissions in Climate Registry Information System – RGGI Requirement

CRIS: Climate Registry Information System

Entity Emissions Detailed Report

Massachusetts Department of Environmental Protection

(Public)

3/12/2012 17:10:10 EDT

Operational Control: National - US

DIRECT EMISSIONS (metric tons)	CO2e	CO2	CH4	N2O	HFCs (CO2e)	PFCs (CO2e)	SF6
Stationary Combustion - Scope 1	986.92748	981.37796	0.0169	0.01682	0	0	0
Mobile Combustion - Scope 1	384.97583	382.37707	0.01119	0.00756	0	0	0
Process - Scope 1	0	0	0	0	0	0	0
Fugitive - Scope 1	31.11343	0.06804	0.00607	0	30.9179	0	0
TOTAL DIRECT EMISSIONS	1,403.01674	1,363.82307					

INDIRECT EMISSIONS (metric tons)	CO2e	CO2
Purchased Electricity - Scope 2	1,969.4736	1,954.50859
Purchased Heating - Scope 2	0	0
Purchased Cooling - Scope 2	0	0
Purchased Steam - Scope 2	0	0
TOTAL INDIRECT EMISSIONS	1,969.4736	1,954.50859

CRIS: Climate Registry Information System

Entity Emissions Detailed Report

Massachusetts Department of Environmental Protection

(Public)

3/12/2012 17:10:10 EDT

TOTAL EMISSIONS: MassDEP - 21E site - Baird & McGuire

Does the Entity control the Facility's emissions? Yes

Equity Share (%) N/A

DIRECT EMISSIONS (metric tons)	CO2e	CO2	CH4	N2O	HFCs (CO2e)	PFCs (CO2e)
Stationary Combustion - Scope 1	90.33748	89.83166	0.0016	0.00152	0	0
Mobile Combustion - Scope 1	0	0	0	0	0	0
Process - Scope 1	0	0	0	0	0	0
Fugitive - Scope 1	0	0	0	0	0	0
TOTAL DIRECT EMISSIONS	90.33748	89.83166	0.0016	0.00152	0	0

INDIRECT EMISSIONS (metric tons)	CO2e	CO2	CH4	N2O	HFCs (CO2e)	PFCs (CO2e)
Purchased Electricity - Scope 2	246.58	244.71067	0.02282	0.00449	0	0
Purchased Heating - Scope 2	0	0	0	0	0	0
Purchased Cooling - Scope 2	0	0	0	0	0	0
Purchased Steam - Scope 2	0	0	0	0	0	0
TOTAL INDIRECT EMISSIONS	246.58	244.71067	0.02282	0.00449	0	0

Baird & McGuire 10% of all MassDEP emissions CO2 eq

Source: MassDEP 2008 Report GHG Emissions Report

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

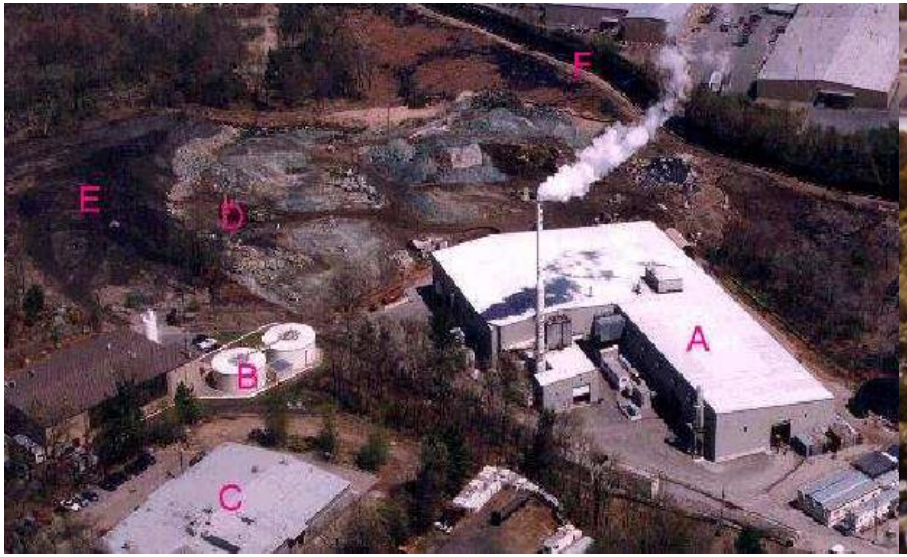
- Listed on NPL in 1983
- Direct discharge from lagoons and landfilling to soil, river and wetlands
- Soil, groundwater, and river sediment contamination with metals, SVOCs, VOCs, PAHs, and pesticides
- EPA completed RI/FS in 1983-1986
- ROD signed 1986

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

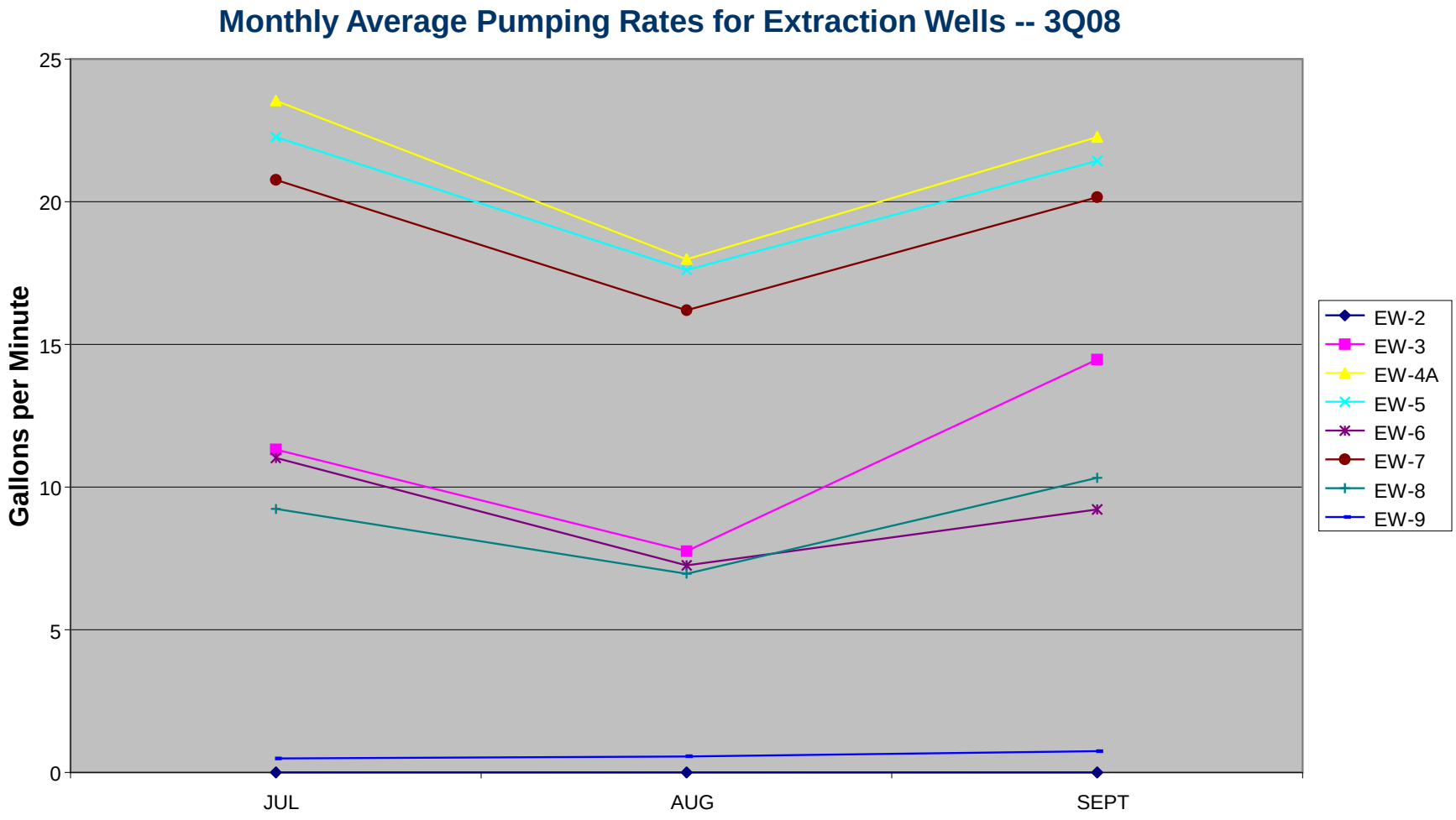
Remediation – 1996 to 2006



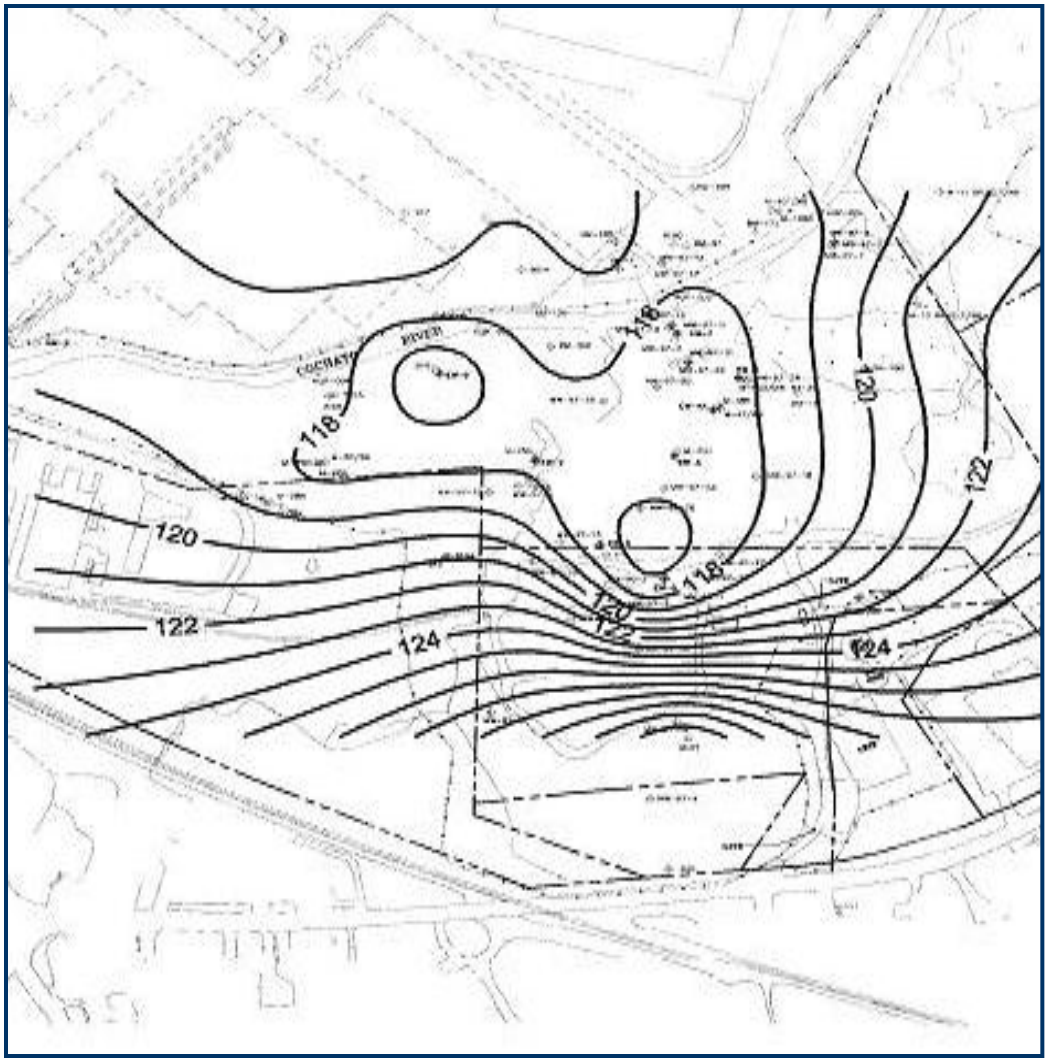
A) Incinerator & restored wetland
B) Groundwater treatment plant
C) Bauer, Inc.
D) Excavation
E) Backfilled incinerated ash
F) Cochato River
G) Infiltration Basins

Treatment goal: groundwater and effluent at MCLs drinking water standards

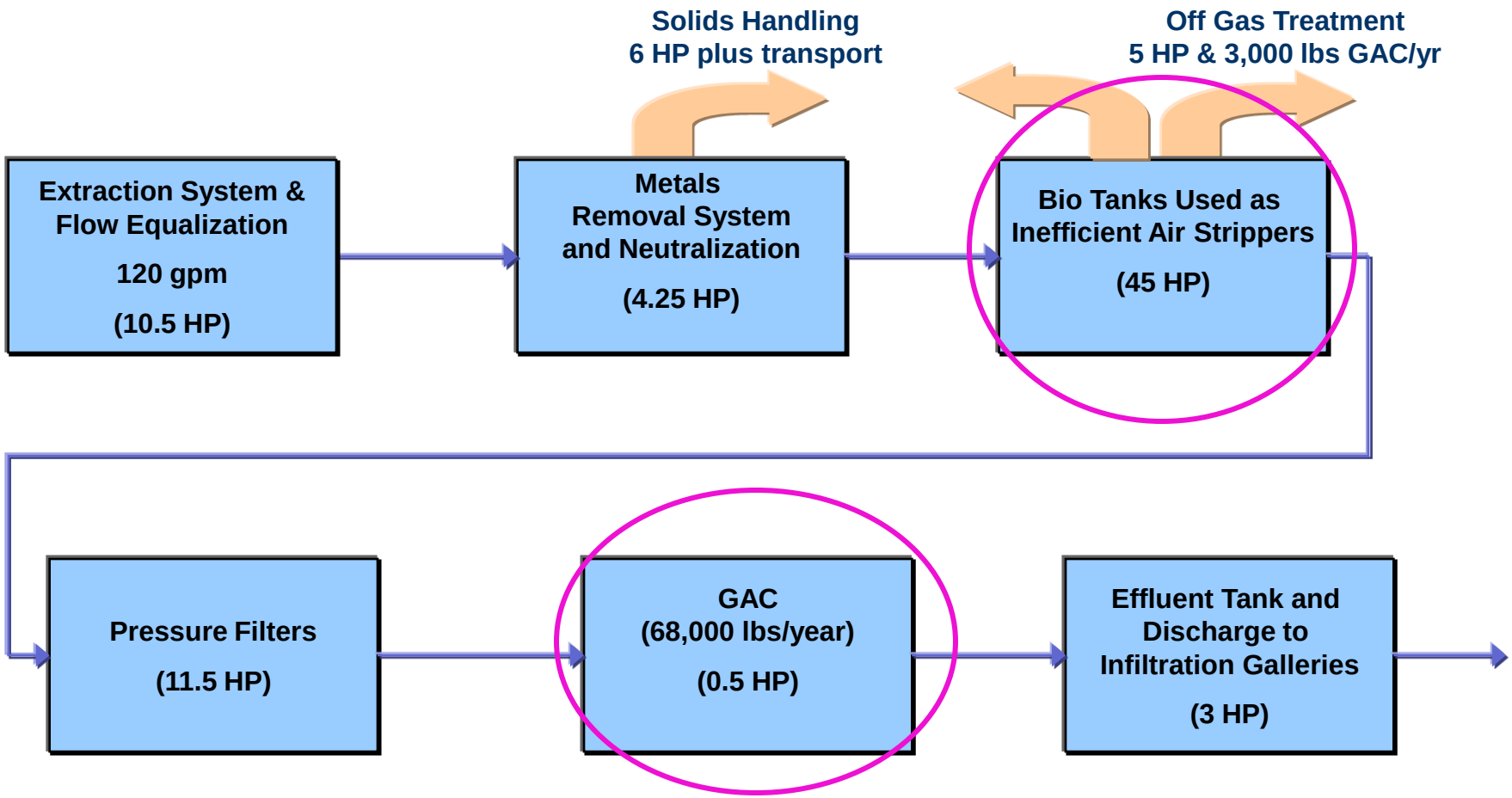
Pumping Rates: 75 – 140 gpm



Groundwater Contours Indicating Plume Capture

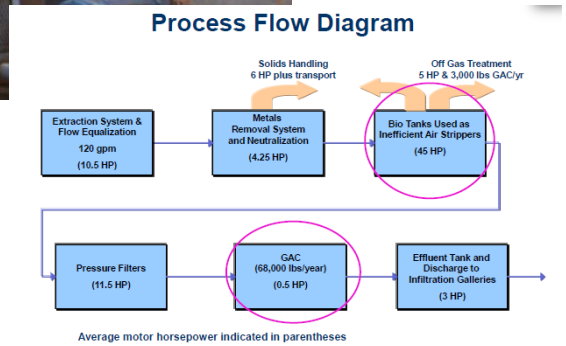


Process Flow Diagram



Average motor horsepower indicated in parentheses

Bio Tanks



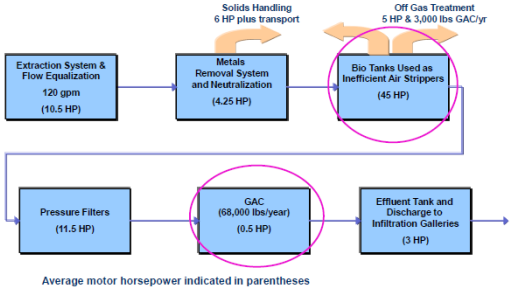
- Size: 172,458 gal
- Detention time: 28 hours at 100 gpm

Granular Activated Carbon

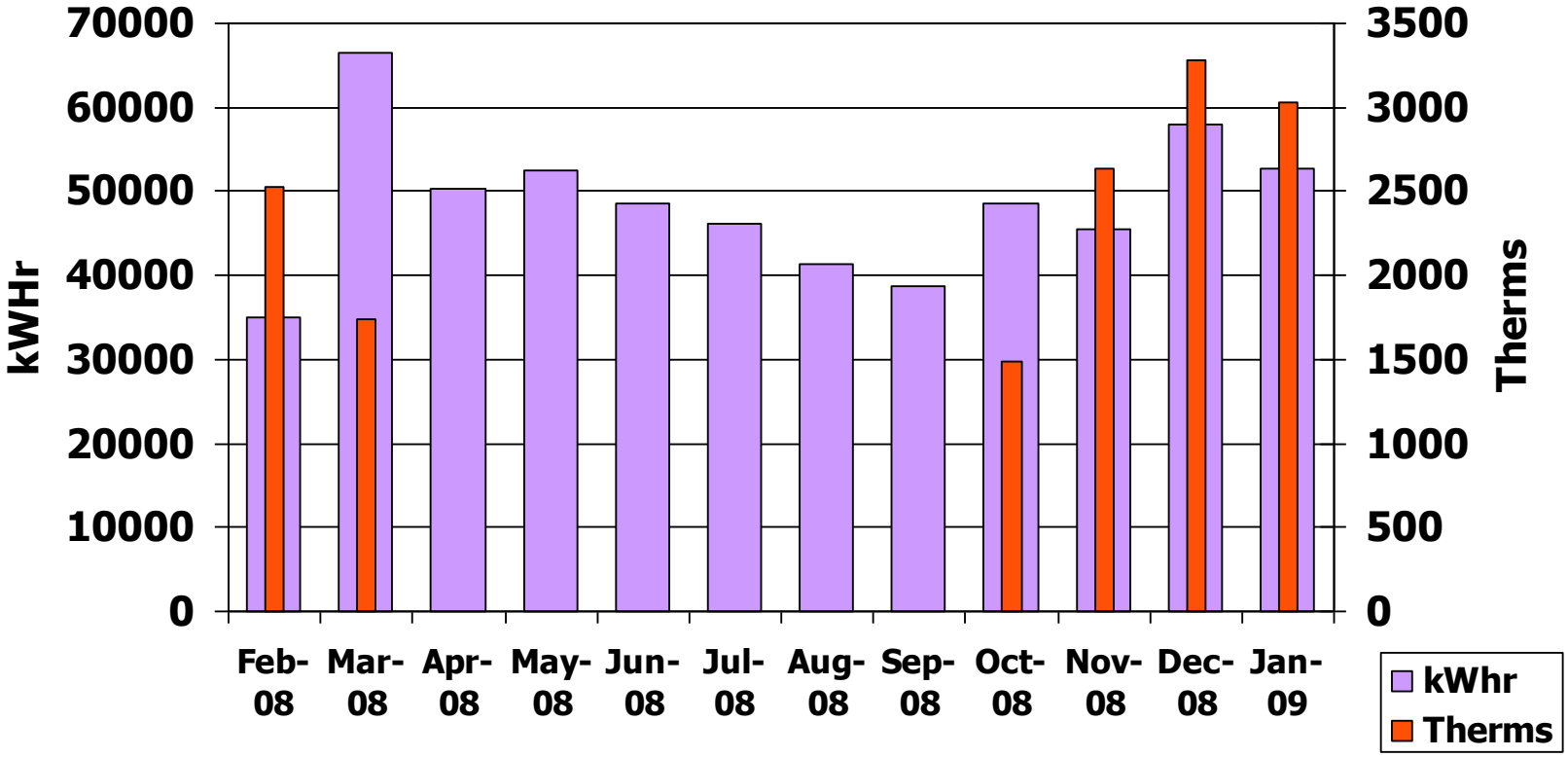
GAC A	GAC B	COMMENTS
		Filtersorb 300 pH recommended
	4/23/2004	
6/15/2004		
	9/29/2004	Filtersorb 300 pH
11/4/2004		Carbsorb 30pH
	1/19/2005	Carbsorb 30pH
3/2/2005		Carbsorb 30pH
	5/9/2005-	Carbsorb 30pH
7/21/2005		RX-pH POOL
	9/28/2005	RX-pH POOL
11/3/2005		RX-pH POOL
	2/1/2006	RX-pH POOL
3/9/2006		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

- GACs require 8,000 to 8,500 lbs filter media per change-out

Process Flow Diagram



Monthly Energy Usage



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 (5 tons CO_2/mo – 62 tons CO_2/yr)
- 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)

Plans for Long Term Treatment

- Removal of arsenic and naphthalene (some other organics) to achieve site restoration at drinking water standards (MCLs)
- Effluent at MCLs and GW1 to prevent contamination of infiltration basins
- Optimize plant/site operations
  - Replacement or elimination of Bio Tanks and clarifier modifications
  - Improve GAC operations
  - Establish extraction well redevelopment/replacement plan
  - Optimize extraction well pumping
  - Residual LNAPL investigation
- Minimize energy use and reduce emission of GHG
- Investigate additional remedies

Conceptual Investigation of Thermal Technologies (CHP and GWSHP)

- Lower energy and GHG emissions from
  - GACs (change-outs 6.45 lbs CO_2/lb GAC)
  - Bio Tanks (high energy requirements)
- Elimination of Bio Tanks and GAC units
- Addition of air stripping at elevated temperature
- Addition of CHP turbine to provide heat and power
- Use of GWSHP to optimize CHP performance
- Provide for maximum heat recovery

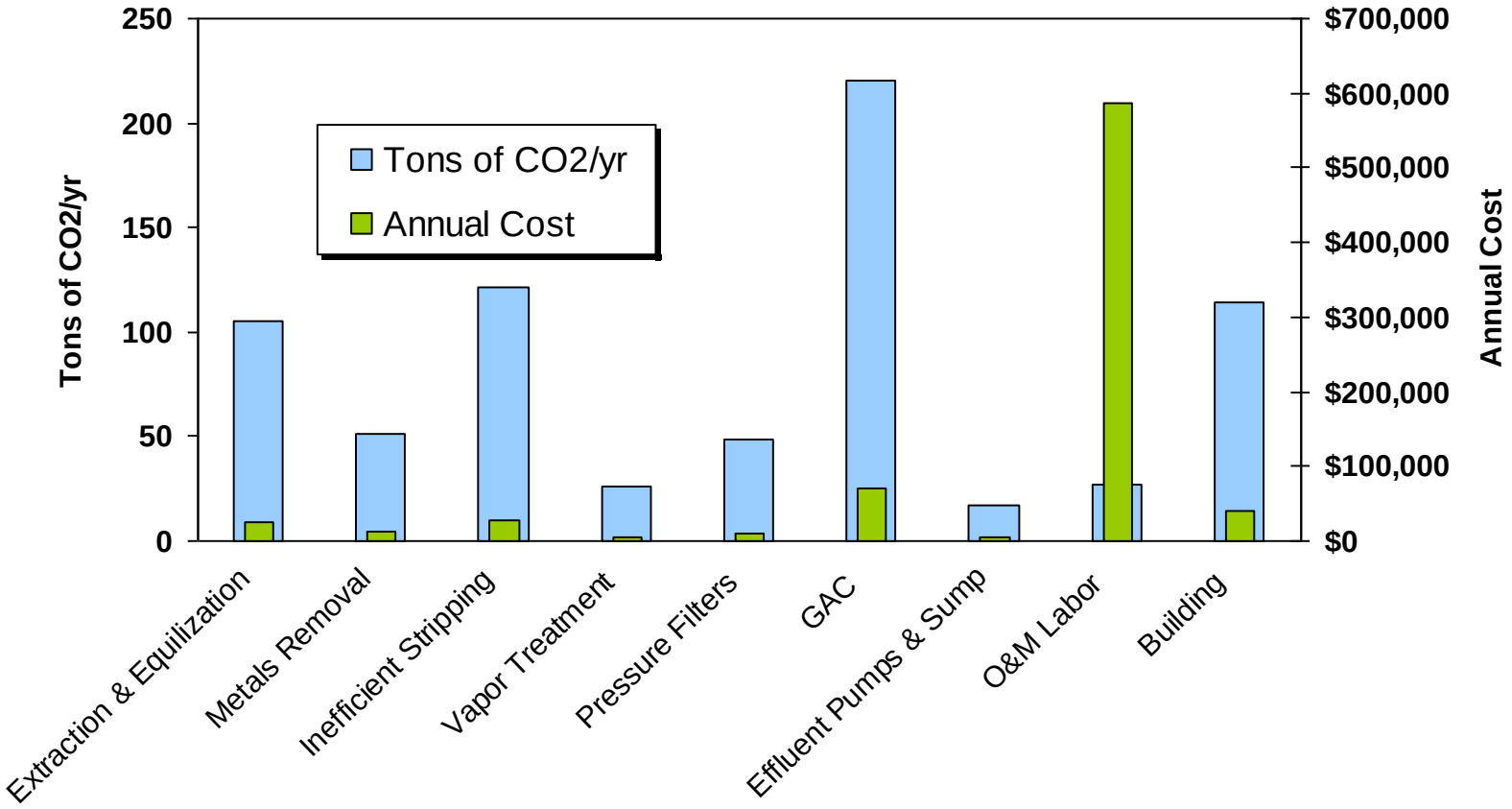
Parameters for the Study

- 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

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



Preliminary Analysis

- The GAC has a high carbon footprint and a high cost (largely due to frequent change-outs)
- 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.)
- Previous evaluations suggest capture is adequate but not much room for reducing extraction rates. VFD's on pumps, so assumption is that there is little room for reducing energy usage for extraction
- O&M labor costs are high, but the carbon footprint is relatively low

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

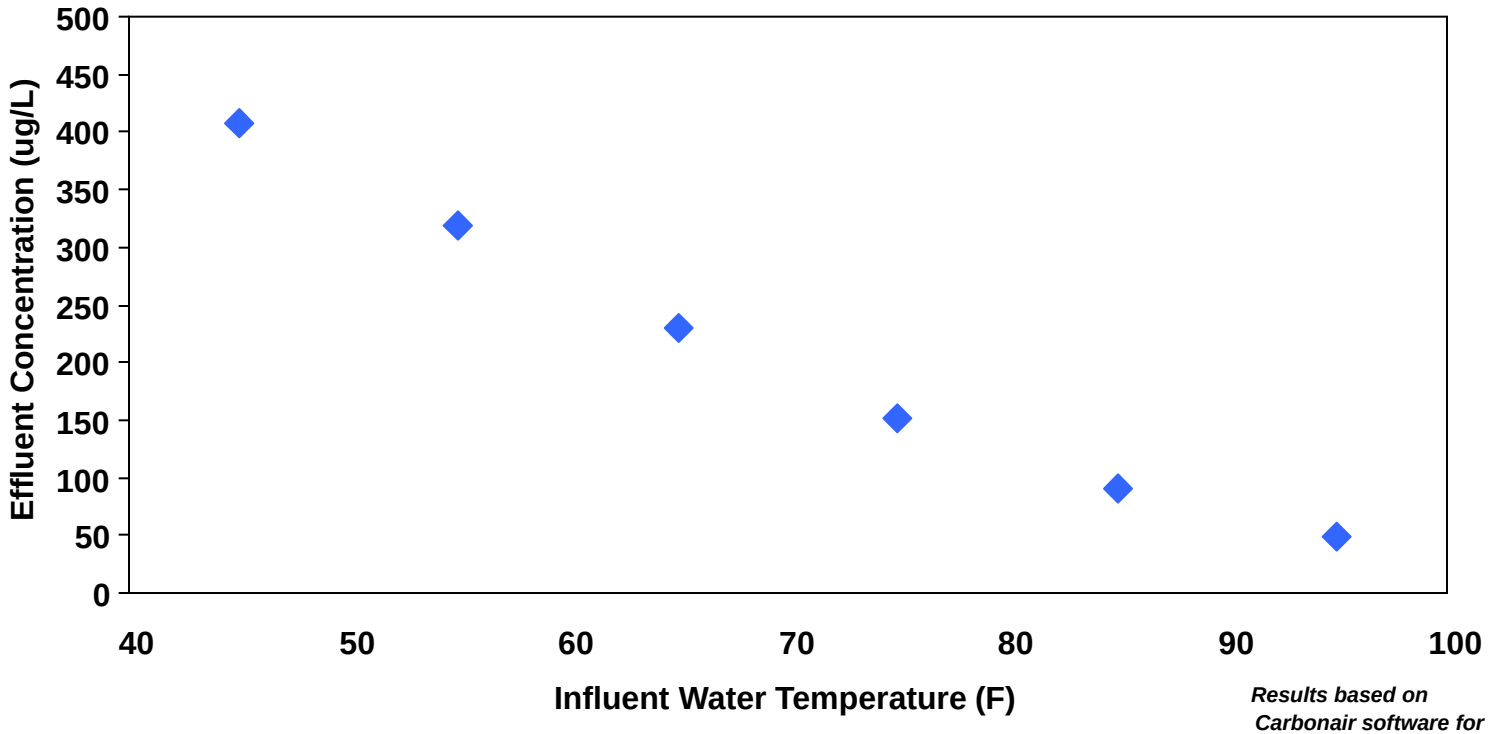
- Enhance stripping with waste heat from a combined heat and power unit (or GWSHP)
- Consider GWSHP for building heating/cooling

Breakdown for Various Options

Total Carbon Footprint: 787 tons of CO_2 per year
Total O&M Cost: $784,000 per year

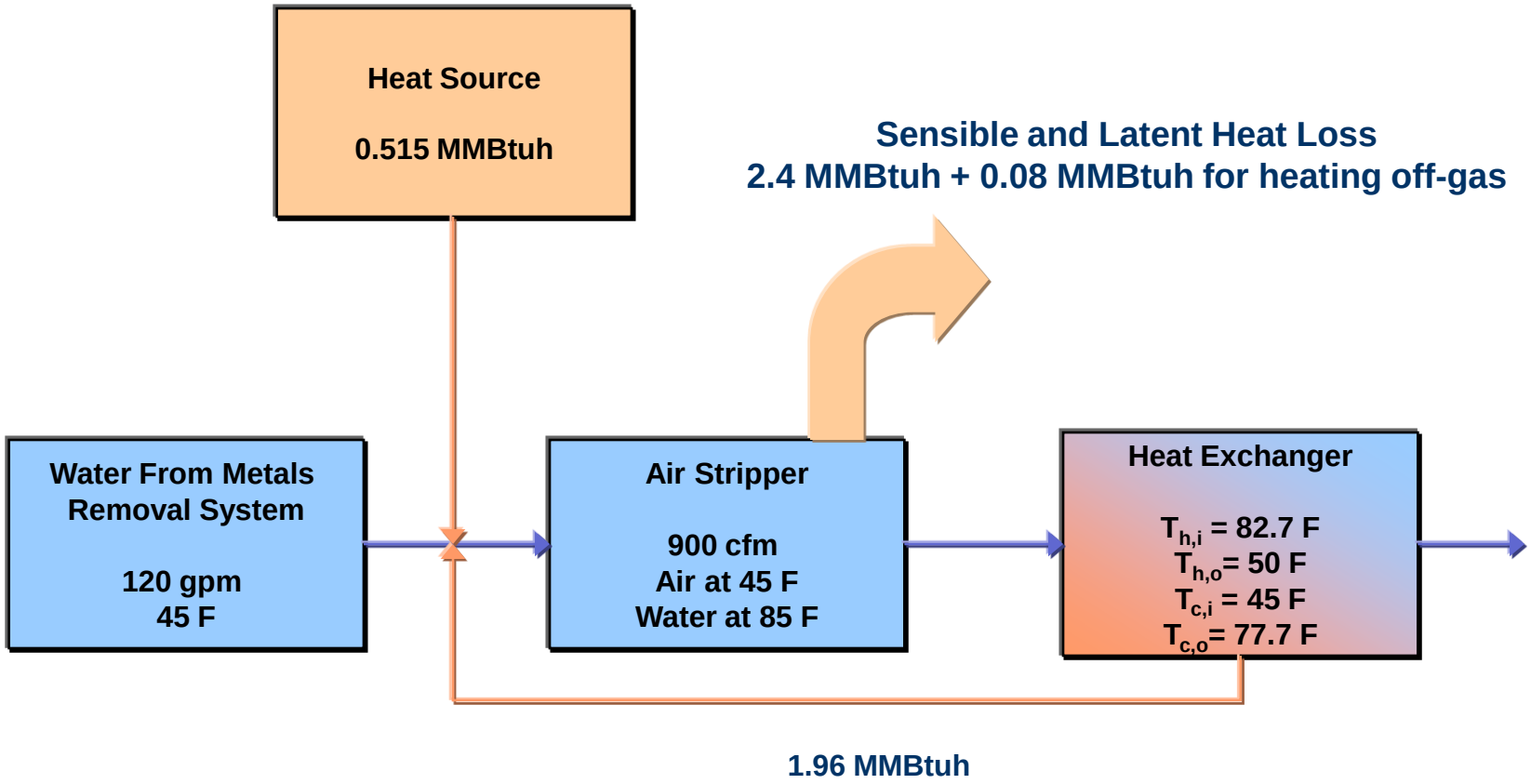
Stripping Effectiveness and Water Temperature

Naphthalene Effluent Concentration vs. Water Temperature with Water Flow of 120 gpm, Air Flow of 900 cfm, 6 Trays, and an Influent Concentration of 800 ug/L



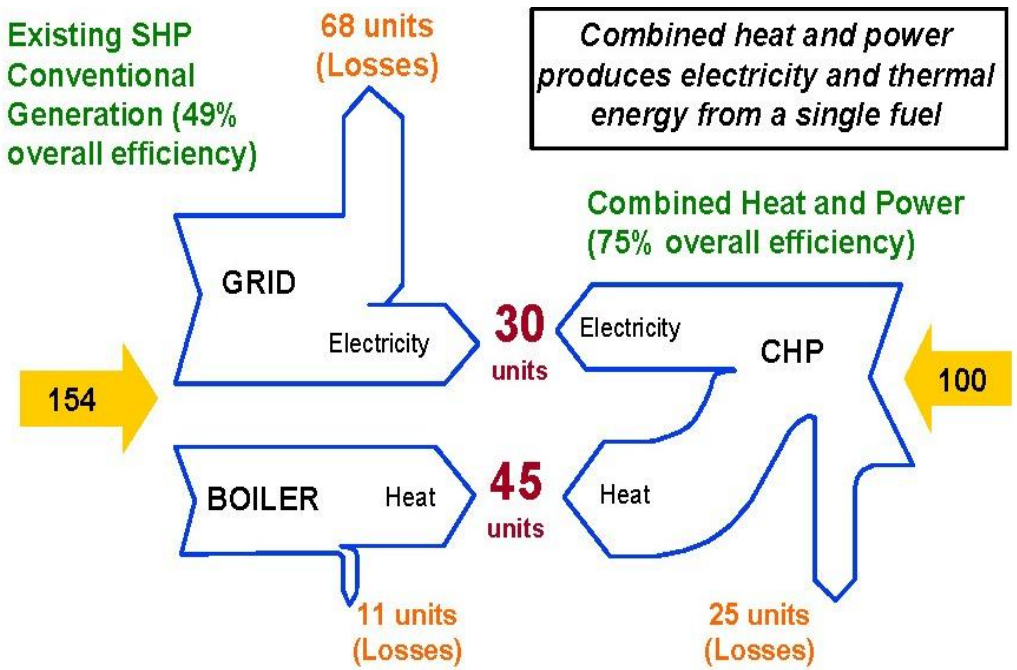
Results based on Carbonair software for STAT 180 unit

Heat-Enhanced Air Stripping

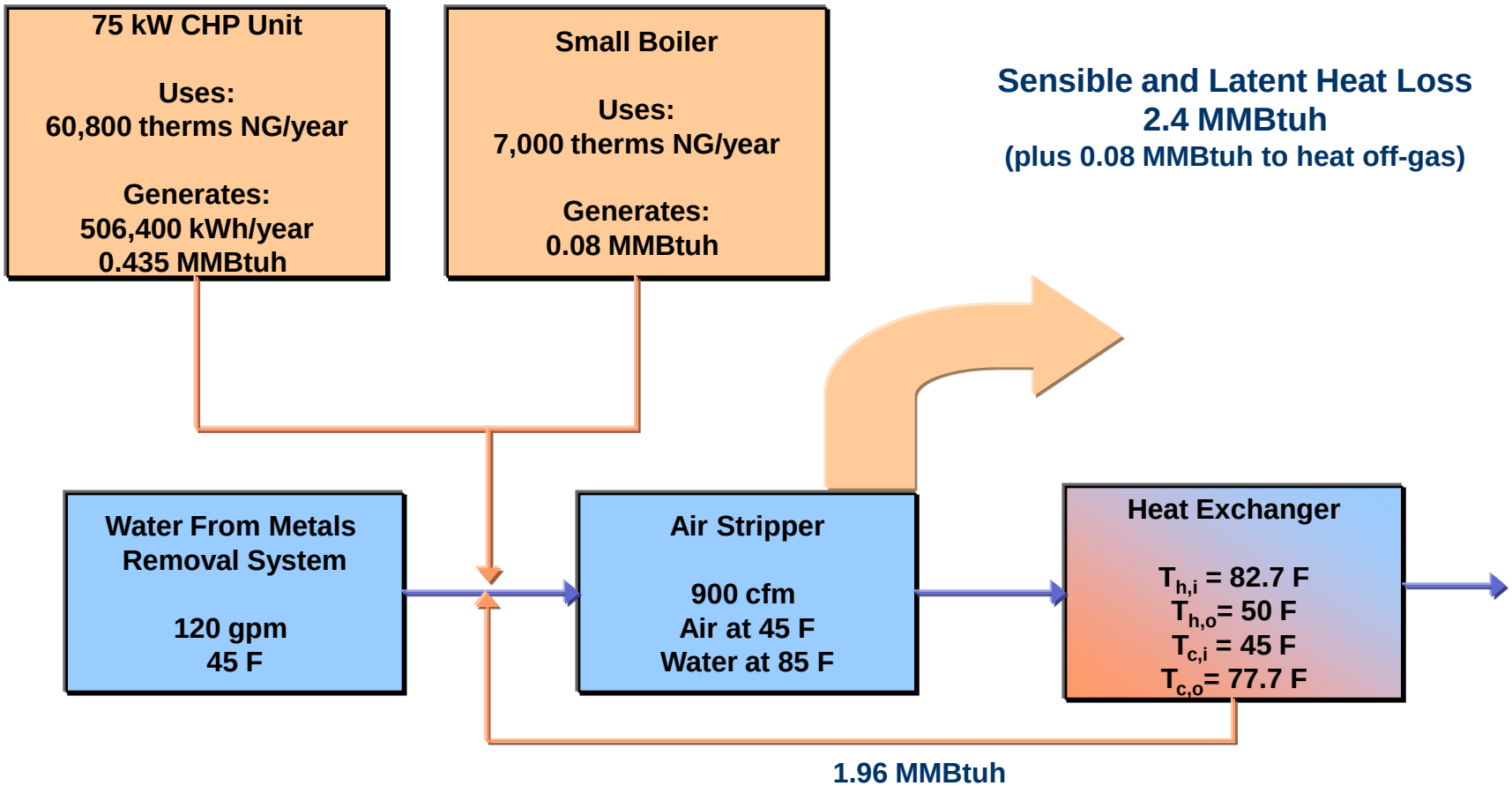


Combined Heat and Power

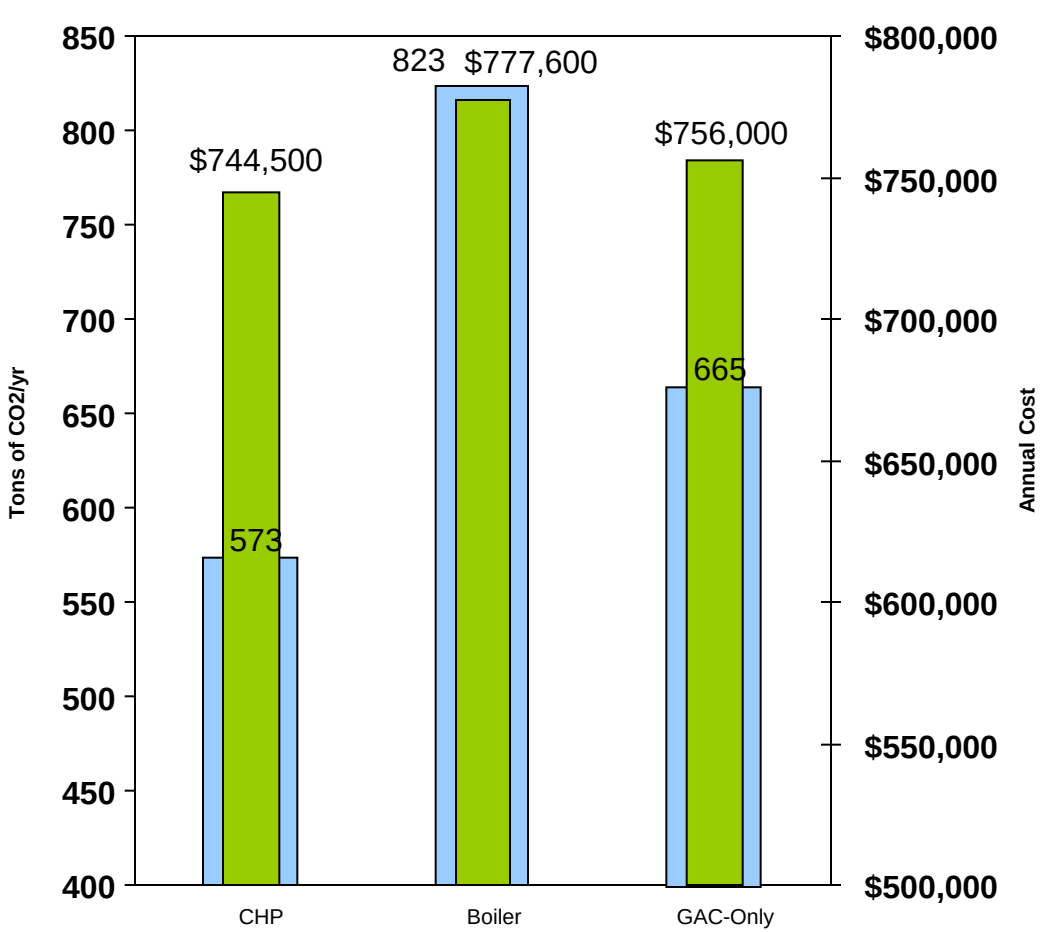
- Generate electricity on-site with a natural gas powered generator
- Rather than discharge heat to the atmosphere, use it for beneficial use
- Results in increased overall efficiency
- Only makes sense if electrical demand and heating demand are present and appropriate



CHP Heat-Enhanced Air Stripping



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)

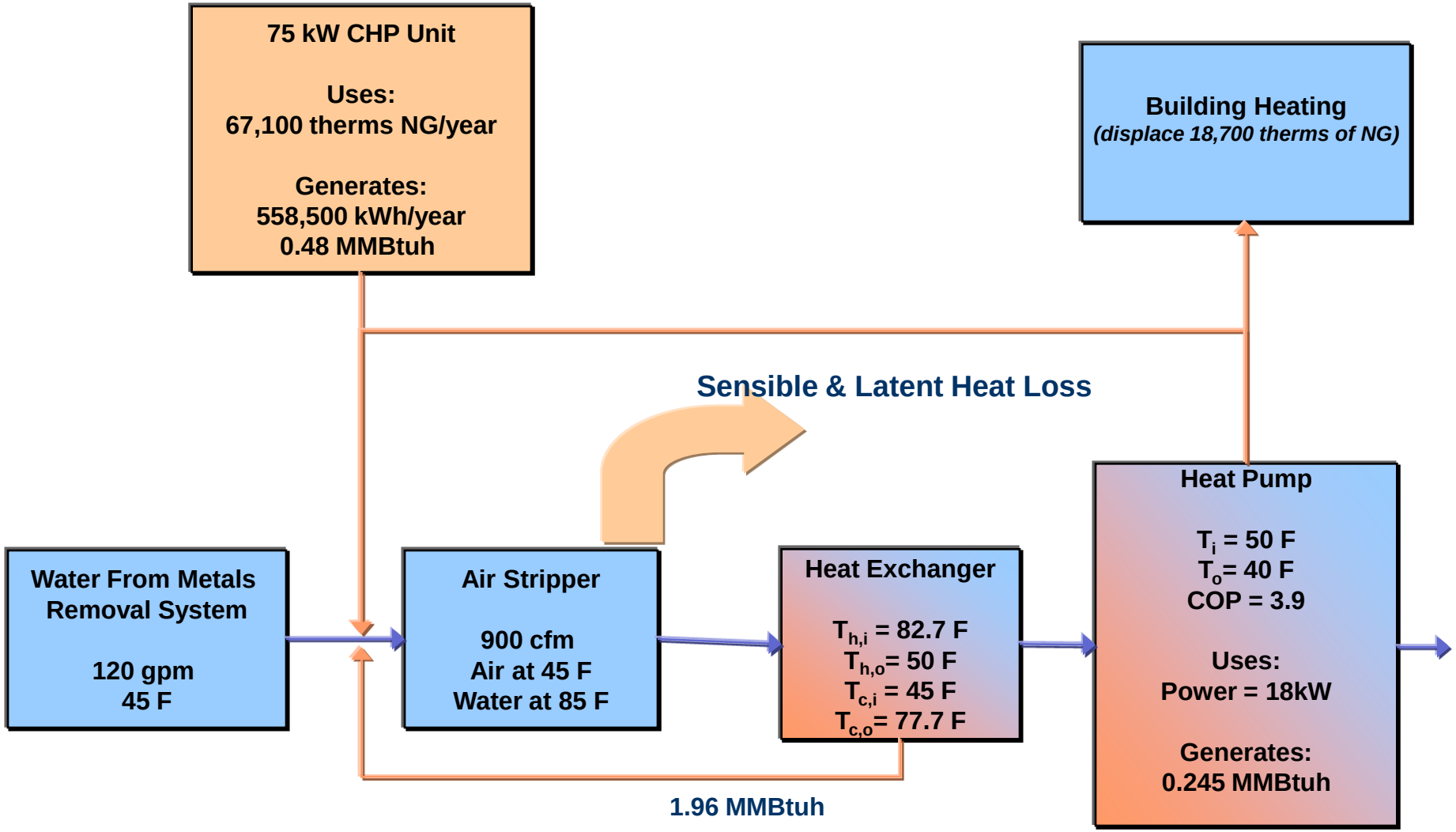
Boiler Option Uses:

- » 47,500 therms of NG per year

Boiler Generates:

- » 0.51 MMBtuh

CHP & Heat Pump

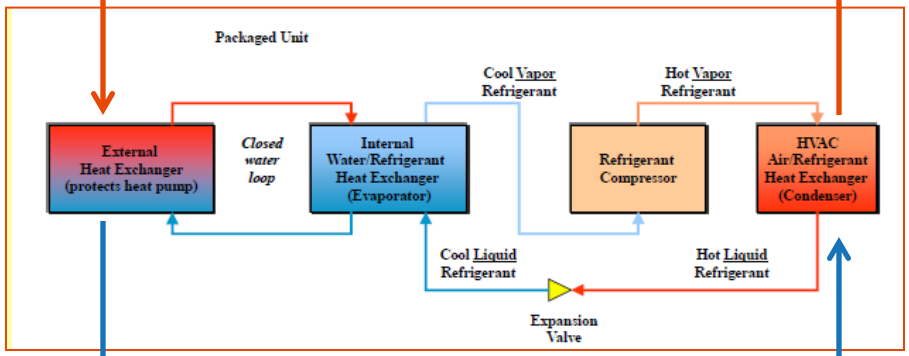


Groundwater Source Heat Pump in Heating Mode

- 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 refrigerant
- Heat from condensing refrigerant is transferred to building via HVAC system
- Heat is transferred via vaporization/condensation of refrigerant

Extracted groundwater after metals removal and HX

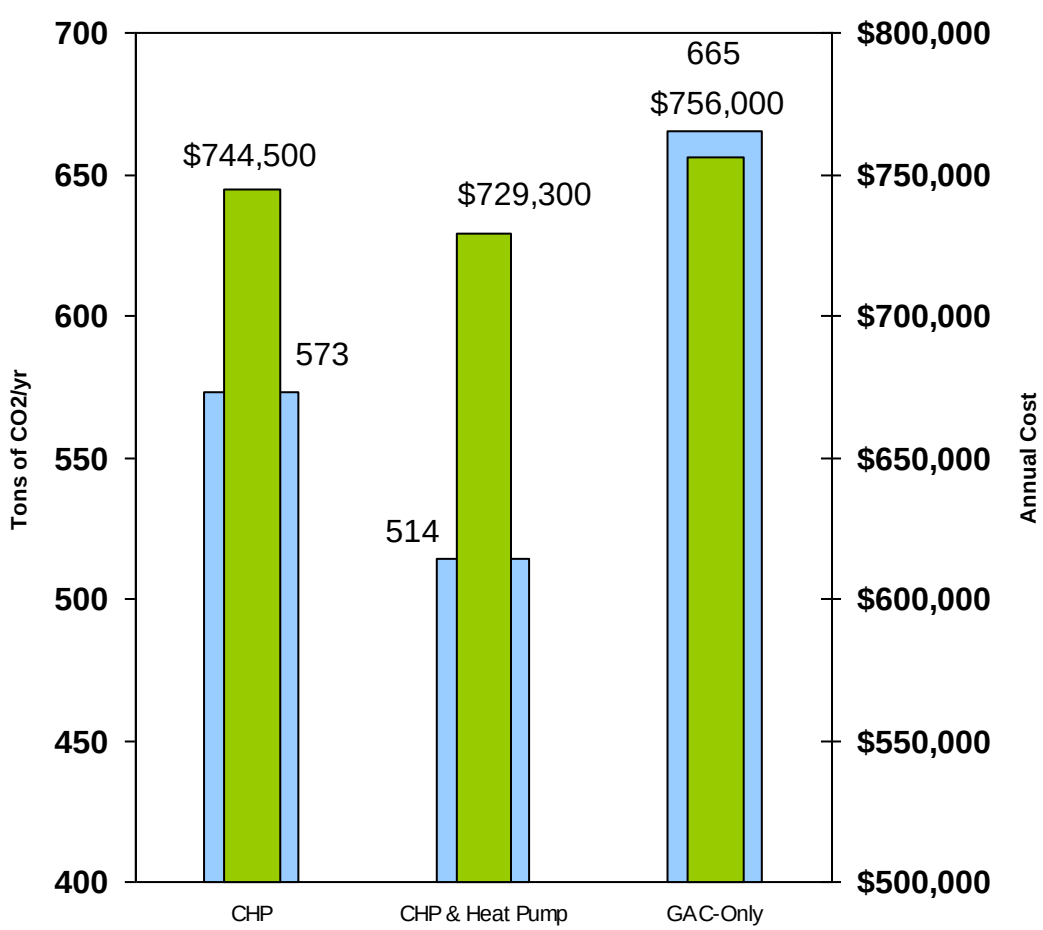
Hot water to distribution system (or stripper influent)



Treated groundwater < MCLs discharged to infiltration basins

Return water from the heating system (preheated gwtr from HX)

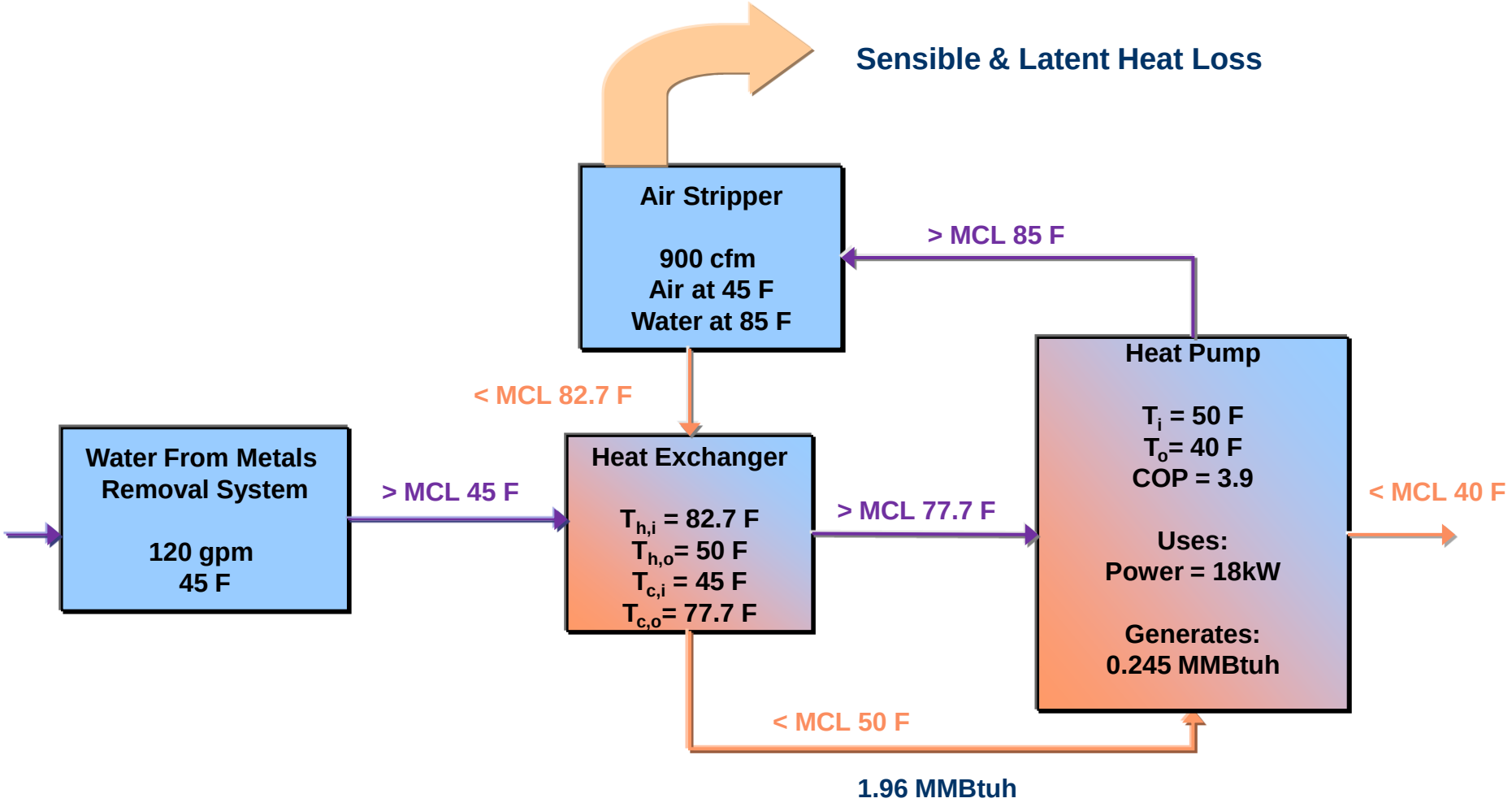
CHP Option
With and Without Heat Pump



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

Heat Pump for Heating Groundwater in Treatment



GHG Heating with GSHP or NG Heater

GHG Savings =
Heating Load [(FI/FEx1000kg/ton)-(EI/COPx3600sec/hr)]

Heating Load = .23 MMBtuh (2,164 GJ/yr)
Fuel Intensity NG = 50 kg (CO_2)/GJ
Emission Intensity = 590 ton/GWhr
Furnace Efficiency = 85%
Coefficient of Performance (COP) = 3.9

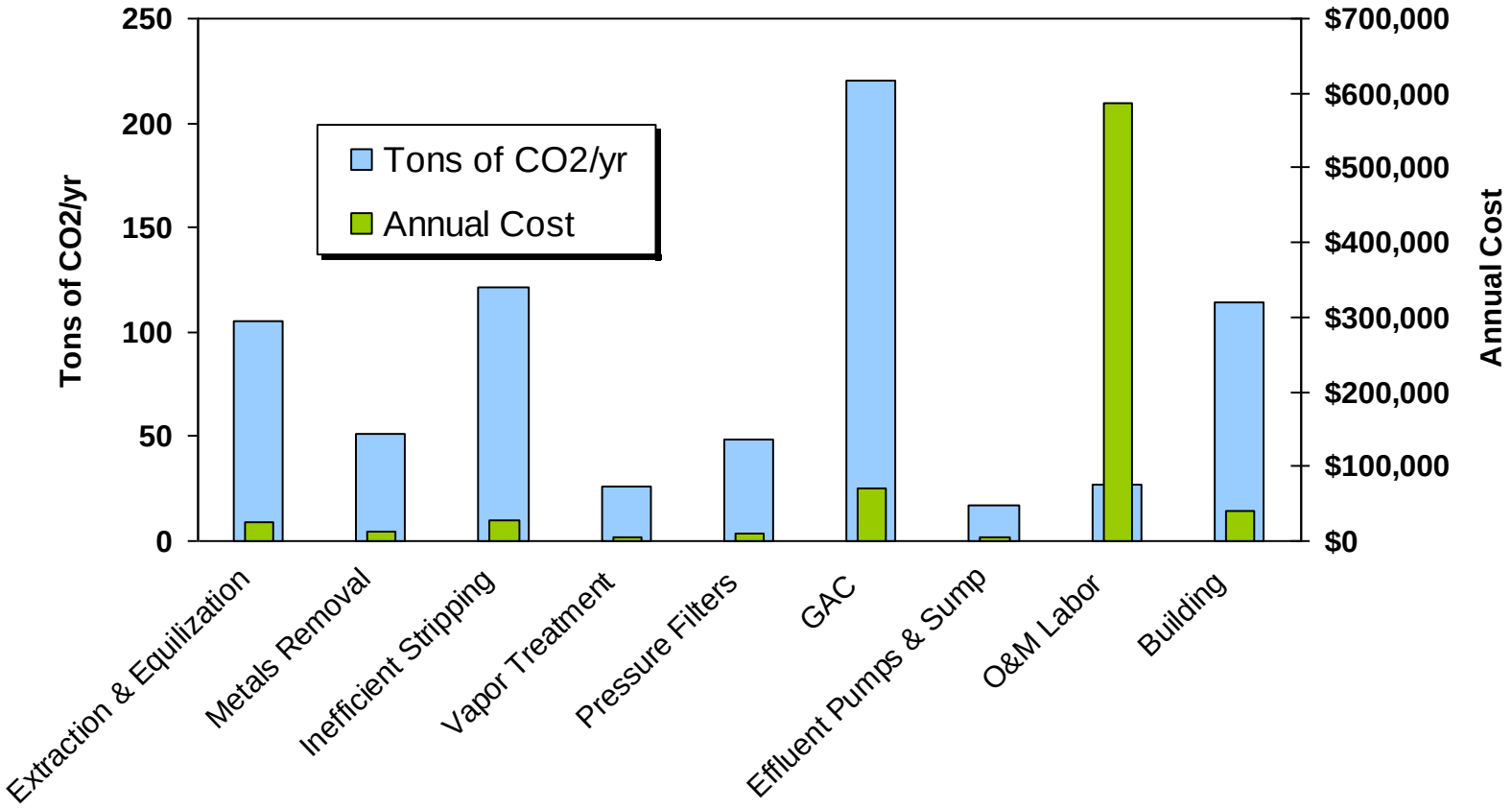
36.7 tons/yr
787 tons of CO_2 per year for P&T

Solar array of 140 kW and CF of 0.13 could provide necessary power for the GWSHP

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



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 with GWSHP option but concern regarding potential future reduced standards for naphthalene
- Consider GWSHP for building heat regardless especially with solar PV

Conclusions Regarding Technological Applications

- CHP (combined with heat exchangers and GWSHP) 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
- Heat enhanced stripping may be 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