U.S. Mining Regions – The Saudia Arabia of Geothermal Energy

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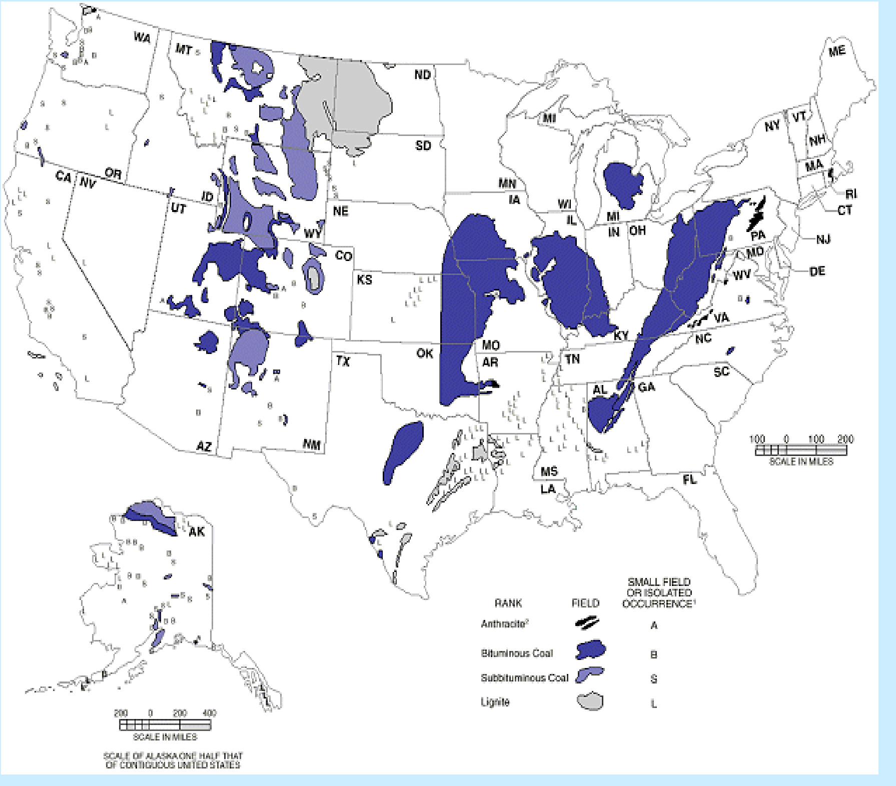
Agenda

- Geothermal Heat Pumps
- Coal Mining
- Mine Water
- Cost Savings
- Environmental Impact

U.S. Coal Mining Regions



“Conventional” Geothermal Heat Pump Applications

- One of the fastest growing types of renewable energy in the world (Lund 2001)

- Annual increases of 10% in approx. 30 countries in last 10 years (Lund 2001).

- Today, 500,000 geothermal units are used for residential heating and cooling in the U.S. and Canada with an additional 400,000 units in Europe (Manitoba Budget Papers 2004).

How Heat Pumps Work

3 to 4 kWh of thermal energy can be produced for every 1 kWh of electrical energy used to drive heat pump.

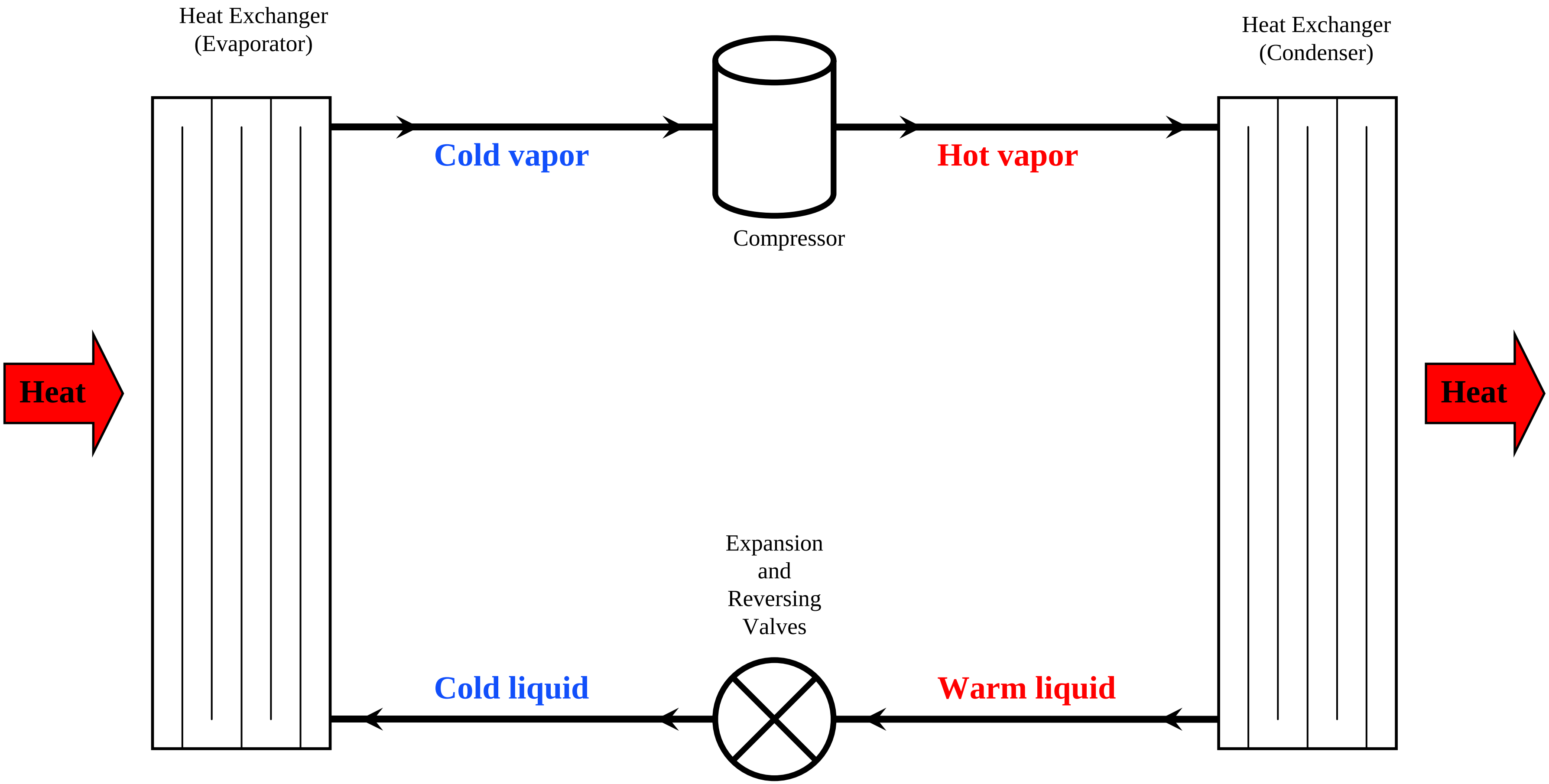
Ground Water input (50 - 59° F) --- Heat Pump output (104 - 127°)

The problem in comprehending such technology is that it is difficult to understand how heat extracted from say, 50 degree air (or water) can heat anything.

This is where the unit's compressor and the "phase-change" physical properties of the refrigerant come into play:

- **The compressor boosts the extracted heat to a much higher temperature gas**
- **The gas gives up its heat as it condenses to a liquid in the condensing coil**
- **Heat is distributed to the structure by the fan or blower in the air-handler.**

Schematic of a heat pump system in heating mode.



- *For heating, think of a heat pump as an air conditioner in reverse*

Exploitation of Geothermal Energy From Underground Mine Pools "Unconventional Application"

- Not a new concept
- Used on a global basis.
- Coal mines more than other types of mines due to broad-based accessibility
- Exploitation limited in past due to relatively low conventional energy costs.
- Accurate mapping is another limiting factor.
- Health and Safety and Environmental Issues has resulted in the recent and on-going development of GIS databases of modern and historic mining operations.

Evolution of Mining Methods – 200 Years

Pick and Shovel

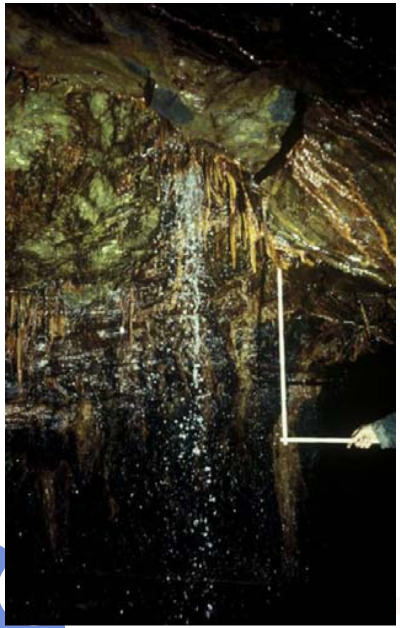
Drill and Blast

Continuous Miner

Longwall

Underground Conditions

DRY



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Deep Mine Discharges

Mine Water Reservoirs in Just the Pittsburgh Coal Seam

Mine Water (ground water):

10 to 15° C

or

50 to 59° F

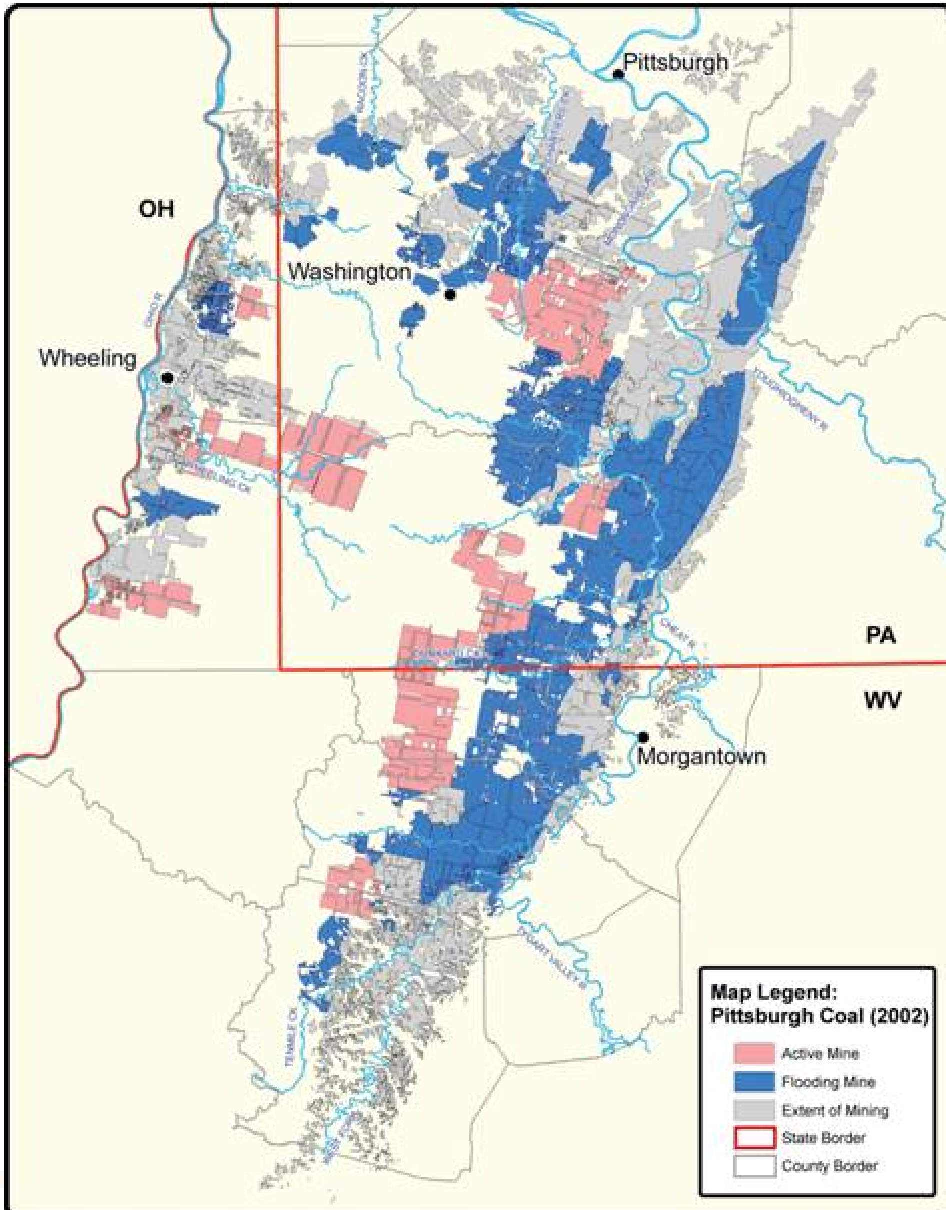
Flooded Underground Volume:

1.36 Trillion

Accessibility:

Surface (Artesian or gravity flow)

Drill & Pump



Northern Appalachia:

~5,000 sq. mi. Mined

200 years to develop, Longwall technique can do in 40 years.

Currently Flooded:

~2,000 sq. mi.

Discharge:

50 Billion gal/yr

Why use mine water?

- **Huge volume of water (in just Pgh seam)**
    - > 1 trillion gal stored
    - > 50 billion gal discharged/year

- **Widespread access**
    – Many flooded mines in area
- **Capital costs are low**
- **Operating costs are very low**
    – 70 to 80 % savings over conventional
- **Systems are very efficient**
    – COPs of 3 to 6

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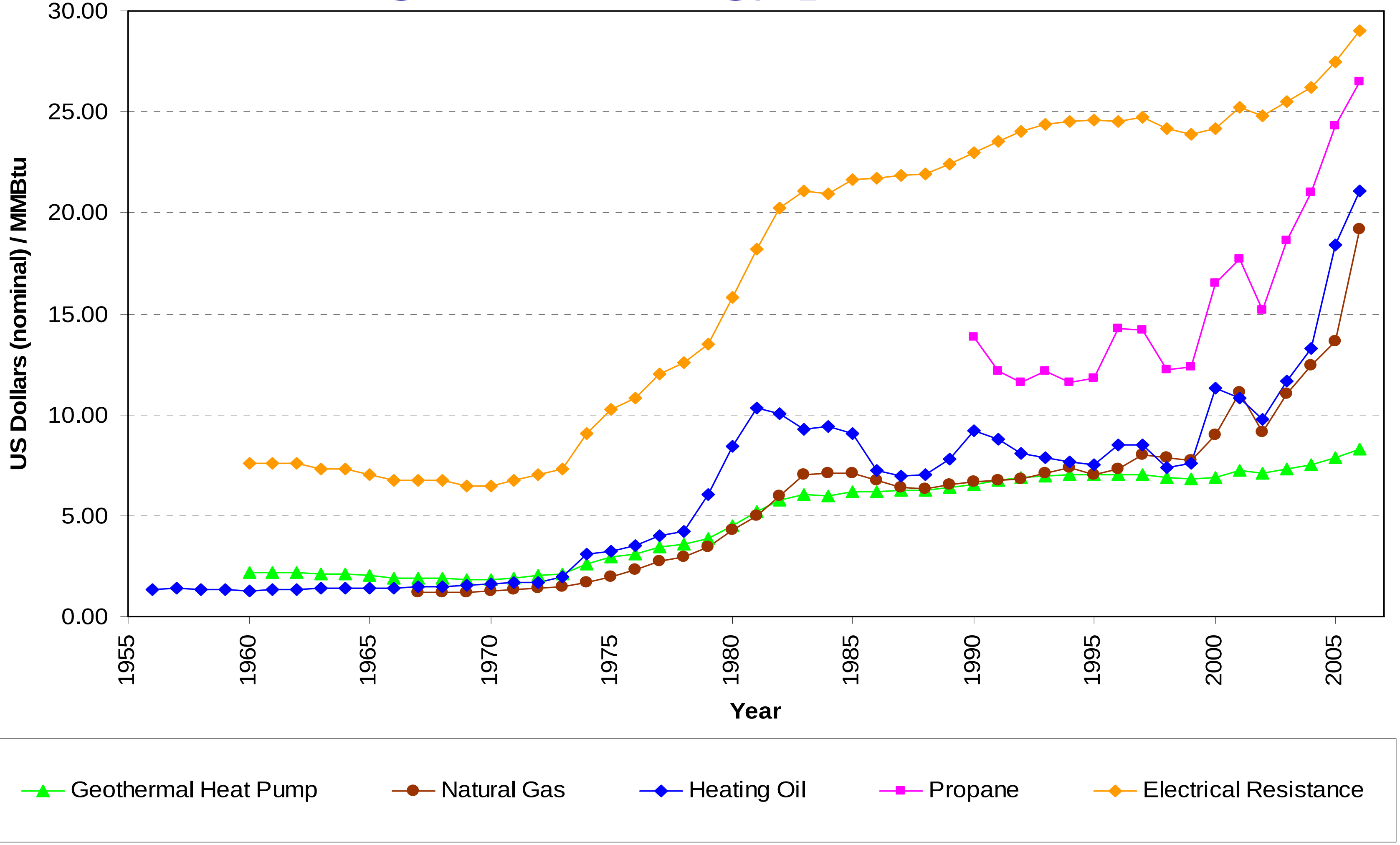
Significant Potential

- 1.4 trillion gallons of water stored in the Pittsburgh Coal Seam
  - Equivalent to 1 million football fields with 4 ft deep water
    OR
  - Equivalent to 1 football field with water ~ 700 miles deep
- 50 billion gallons/year discharged currently
  - Enough water to heat and cool 20,000 homes (or 1000 Wal-Marts) using geothermal heat pump technology
  - Potential savings of over $15 million per year over conventional heating and cooling

Mine drainage entering the Youghiogheny River near Pittsburgh, PA.

Costs for use of typical heating systems (based on average U. S. energy prices from 1990 – 2006)



Furnaces using propane, natural gas or fuel oil were assumed to be moderately efficient (84%).
Coefficient of performance (COP) of geothermal heat pump was assumed to be 3.5.

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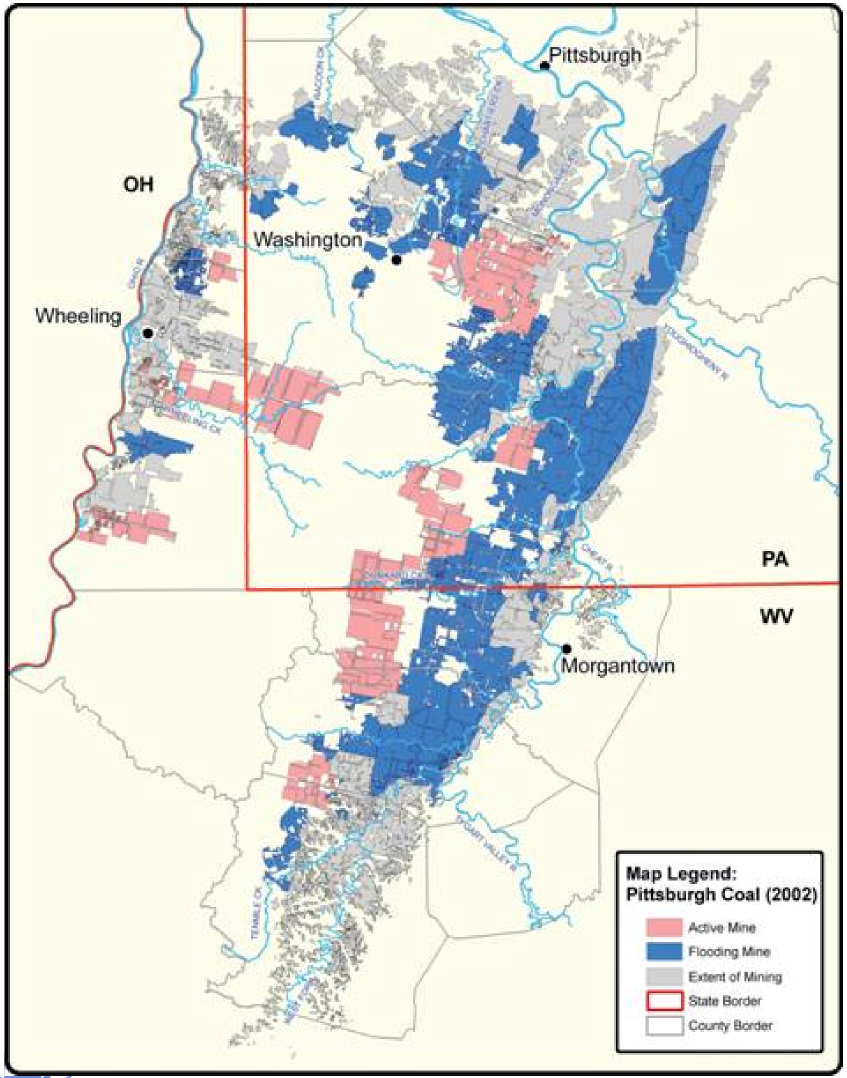
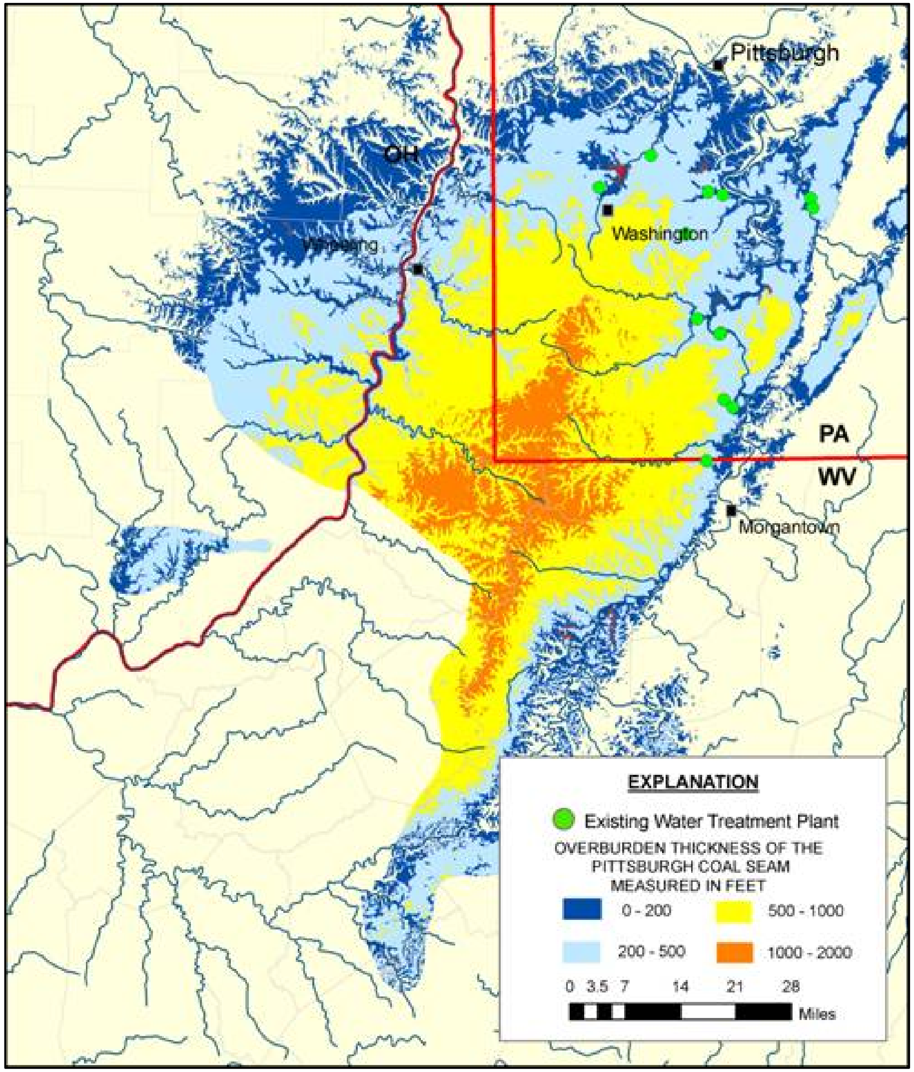
Energy costs for use of typical heating systems in southwestern Pennsylvania

Energy source	$ / Million Btu*
Propane	32.11
Electrical Resistance	20.80
Fuel Oil	20.28
Natural Gas	20.81
Geothermal Heat Pump (COP = 3.0)	6.93
Geothermal Heat Pump (COP = 3.5)	5.94
Geothermal Heat Pump (COP = 4.0)	5.20
Geothermal Heat Pump (COP = 6.0)	3.47

**Cost of fuels and electricity were based on actual delivered cost to the Pittsburgh, Pennsylvania area during the winter of 2006.*
Propane = $2.43/gallon, electricity = $0.071/kWh, fuel oil = $2.35/gallon and natural gas = $0.01802/cubic feet.
Furnaces using propane, natural gas or fuel oil were assumed to be moderately efficient (84%).
Most geothermal heat pumps operate at a COP between 3.0 and 4.0 with values as high as 6.0 reported in the literature.

Depth to Pittsburgh Coal in PA, OH and WV





Costs Based on Pumping Depth and Building Size

	Ground Source Pumping Costs per Year				
Mine Pool Depth (Feet)	2,000 $Feet^2$ Bldg	8,000 $Feet^2$ Bldg	100,000 $Feet^2$ Bldg	500,000 $Feet^2$ Bldg	$/1,000,000 Btu
0	$100	$400	$5,100	$25,000	0.15
100	$310	$1,200	$16,000	$71,000	0.46
250	$610	$2,000	$31,000	$133,000	0.92
500	$1,000	$4,000	$51,000	$245,000	1.69
1,000	$2,000	$8,200	$100,000	$460,000	3.23

Electricity and emissions reduction using mine water to heat and cool 20,000 homes

- **Compared to standard electrical heating and cooling**
  - 374,000 MWh per year savings
  - reductions in annual emissions
    - 2000 tons SO_X
    - 870 tons NO_X

- **Compared to air source heat pumps**
  - 204,000 MWh per year savings
  - reductions in annual emissions
    - 1100 tons SO_X
    - 470 tons NO_X

Research Needs

- **Water quality – corrosion and scaling issues**
  - Capture mine water anoxicly
  - Use of corrosion resistant materials
  - Use of secondary heat exchanger

- **Legal issues**
  - Who owns water
  - Return of water to mine

- **Costs**
  - Wells
  - Pumping

- **Need to demonstrate the technology**

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A minewater is a terrible thing to waste……