Geothermal Heating and Cooling

Summary:
This strategy capitalizes on the energy-effectiveness of geothermal or ground source heat pumps (GSHPs) in Pennsylvania's climate, and the accompanying reductions in carbon emissions and in demand for peak generation and transmission. Pennsylvania is already ranked as one of the top-tier states for experienced and competitive installation of GSHPs in its urban centers. This strategy would build on that strength, expanding the network of trained drillers and installers throughout the state. This strategy advocates GSHP installations for individual buildings and in district systems. Warren, PA, hosts one of the few district GSHP systems in the United States, and this strategy supports further development of such systems for their energy and environmental benefits and for economic revitalization.

Additional benefits of GSHPs include:

- Levels seasonal electrical demand and 42 percent-48 percent reduced demand for new capacity.[1] (DOE/ORNL, 12/08).
- Widely applicable.
- Elimination of bulky and noisy exterior equipment, such as cooling towers or condensing units and heating plants.
- Atmosphere not used as a heat sink.
- Economical operating costs due to high coefficient of performance (metered Department of Defense installations in Pennsylvania achieve mean Coefficient of Performance of 4.0 and energy efficiency ratio of 20.83)
- Water heating integrated at low cost (can be scavenged whenever compressors are running).
- The fossil fuel used is burned at a large, industrial generating facility where air scrubbers and other anti-pollution equipment can be installed due to the economy of scale.
- Excellent part-load performance.
- Maintenance simpler and less costly than conventional fossil fuel and cooling tower systems.
- Frees peak transmission and generation capacity for other purposes.
- Reduces the use of natural gas as a heating fuel.
- Reduces water consumption by power plants.

The calculations here are based on GSHP installations for individual buildings. District systems can offer economies of scale in the exterior infrastructure, but data on this are limited.

Goals:
Residential
Each year, 20 percent of new dwellings and 2 percent of existing dwellings will install GSHPs for heating and cooling, either on a building-by-building basis, or in district systems, serving multiple dwellings.

Commercial
By 2020, ~~40~~ 12.5 percent of existing commercial buildings and ~~12.5~~40 percent of new commercial buildings will be heated and cooled with GSHPs serving individual buildings or serving multiple buildings in district systems.

[1] Hughes, Patrick (2008). Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

Potential GHG Reductions:

Table 1. Estimated GHG Reductions and Cost-effectiveness

Annual Results (2020)			Cumulative Results (2013-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2$e)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2$e)
0.5	$332	-$664652	-2.30	$1,456	-$626727

Economic Cost:
See Table 1, above.

Key Assumptions:

Key Data and Assumptions	2013	2020	Units
First Year Results Accrue		**2013**	
Electricity			
Incremental Cost of Geothermal system			
Resdiential, household without central cooling		**$3,000**	$/housing unit
Residential, household with heating and central cooling		**$0**	$/housing unit
Input from V. Loftness & N.Baird. Because the ground infrastructure is warrantied for 50 years, assumption here is that the cost of installing ground source heat pumps is no greater than cost of conventional equipment. Cost here reflects 2-ton exterior heat exchange per unit.			
Cost of Geothermal system			
Commercial, existing buildings		**$14.4**	$/sq ft
G. Mattern, P.E., Adjunct Professor & geothermal specialist, Carnegie Mellon Univ., estimates $19.60/sf for retrofit installation, but because the ground infrastructure is warrantied for 50 years, assumption here is that the cost of installing ground source heat pumps is no greater than cost of conventional equipment. May be less.			
Commercial, new buildings		**$12.5**	$/sq ft
G. Mattern, P.E., Adjunct Professor & geothermal specialist, Carnegie Mellon Univ., estimates $17.00/sf for new installation, but because the ground infrastructure is warrantied for 50 years, assumption here is that the cost of installing ground source heat pumps is no greater than cost of conventional equipment. May be less.			
Cost of NG+AC VAV system (base case system)			
Commercial, existing buildings		**$14.4**	$/sq ft
Commercial, new buildings		**$12.5**	$/sq ft
Input from G, Mattern, P.E., Adjunct Professor, Carnegie Mellon Univ.			
Avoided Electricity Cost		**$130**	$/MWh
See "Common Factors" worksheet in this workbook.			
Avoided Natural Gas Cost		**$4.6**	$ / million Btu
See "NG prices aeo2006" and "Common Factors" worksheets in this workbook.			
Avoided Fuel Oil Cost	**$20.6**	**$24.1**	$ / million Btu
See "Common Factors" worksheets in this workbook.			
Emissions from additional Electricity Use		**0.46**	tCO_2/MWh
Results Summary	**2013**	**2020**	**Units**
Incremental GHG Emission Savings	**-0.11**	**-0.51**	MMtCO2e
Net Present Value		**$1,456**	$ million
Cumulative Emissions Reductions		**-2.32**	MMtCO2e

Cost-Effectiveness		-$626.20	$/tCO2e
Cost 2020		$332	$ million
Cost-Effectiveness 2020		-$652	$/tCO2e
Other Data, Assumptions, Calculations	**2013**	**2020/all**	**Units**
Inputs to/Intermediate Results of Calculation of Electricity and Gas Savings			
Total Commercial Floorspace in Pennsylvania *Estimated (see "PA_BLDG_Activities" worksheet in this workbook) based on USDOE EIA CBECS (commercial survey) data for the Mid-Atlantic region, extrapolated using DEP approach.*	5,227	5,604	million sq ft
Annual demolition of commercial floorspace *Taken from analysis by DEP, see PA_Bldg_activities sheet in this workbook. Based on analysis by AIA research corporation for Architecture 2030, national values.*		0.58%	
Est. area of new commercial space per year in PA *Calculated based on annual floorspace estimates above. Note high growth in 2006 and 2007 based on article from American Institute of Architects (see PA_Bldg_Activities page).*	83.5	86.7	million sq ft
Total Residential Housing Units in Pennsylvania *Assumes 2007 number of homes to increase following population through 2020. Based on 2007 PA housing units as provided in U.S Census Bureau annual data, http://www.census.gov/popest/housing/HU-EST2005.html.*	5,520,197	5,570,337	units
Implied persons per housing units in Pennsylvania (for reference only)	2.26	2.26	persons
Annual demolition of residential floorspace *Based on average lifespan of home of 70 years, placeholder estimate*		1.43%	
Estimated number of new residential units per year *Calculated based on estimates above.*	86,013	85,701	units
Assumes that heating and cooling with any fuel or with electricity can be replaced by ground source heat pump that uses electricity.			
Average Electricity Consumption per Square Foot Commercial Space (2003) *CBECS Table C17A mid-Atlantic conditional electrical energy intensity*		12.50	kWh/sq.ft.
Average Natural Gas Consumption per Square Foot Commercial Space (2003) *CBECS Table C24A mid-Atlantic*		43.80	thousand Btu/sq.ft.
Average Fuel Oil Consumption per Square Foot Commercial Space (2003) *CBECS Table C34A mid-Atlantic (conversion factor used: 149.793 kBTU/gal)*		23.97	thousand Btu/sq.ft.
Average Electricity Consumption per Housing Unit (2005) *RECS Table US9 (Mid-Atlantic site electricity, includes all electricity use)*		8.50	MWh
Average Natural Gas Consumption per Housing Unit *RECS Table US9 (Mid-Atlantic, in households that use natural gas, all uses)*		82	million Btu / household
Average Fuel Oil Consumption per Housing Unit *RECS Table US9 (mid-Atlantic, in households that use fuel oil, all uses)*		106	million Btu / household
Cofficient of Performance (COP) - Residential and Commercial *Write-up from Nina Baird, p.9*		3.7	

Energy savings due to ground source heatpumps	
Residential	**45%**
Commercial	**30%**
P Hughes, ORNL, 12/ 2008, p. 26	

Residential

- 50 percent of existing homes have HVAC systems that will need to be replaced before 2020.
- 30 percent of existing homes will decide to add air conditioning when this replacement is necessary.
- For the 20 percent replacement without air conditioning, the first cost differential of geothermal over conventional will be $3,000. Without cooling, the use of geothermal may not be as strategic as high-performance boilers and furnaces, especially integrated with domestic hot water (DHW) which would be a technology identified in the Appliance Standards work plan and Demand-side Management (DSM)-Natural Gas work plan.
- For the 30 percent with both heating replacement and air conditioning addition, the differential cost for geothermal over conventional will be $0. Energy savings will be substantial with two-season use.
- 45 percent savings relative to new heating and cooling equipment (Hughes, 2008).

Implementation Steps:

1. Require the DGS to do comprehensive life-cycle cost analysis for new buildings and building upgrades and advocate/support use of life-cycle cost analysis for all new and retrofit projects in the public and private sectors.
2. Educate designers/contractors/consumers about geothermal heat pump efficiency ratings (COP/EER), different from conventional gas furnace and air conditioner ratings, and highlight currently achievable efficiencies in PA climate, which are significantly higher than the ENERGY STAR standard.
3. Encourage the use of ESCOs to address first-cost hurdles.
4. To address the potential environmental impacts of ground loop, establish a mechanism for verifying the competence of drillers and external loop/well installers, and require that only state-approved drillers/installers are used (Oregon has such a policy).
5. Establish or encourage policies that will give ~~utilities~~ EDCs an incentive to install the external loop infrastructure and lease them on per-ton basis such as allowing aggregated savings from GSHPs to be a proxy for carbon trading credits.~~:~~

   ~~a. Allow utilities to count the energy savings from GSHPs toward a renewable portfolio standard (RPS) target.~~

   ~~Allow aggregated savings from GSHPs to be proxy for carbon-trading contracts.~~

   With these strategies, utilities will lose energy sales revenue, but will recoup some of it on loop leases and rate-based infrastructure. They'll also lose money on demand charges, but can earn credit under the Alternative Energy Portfolio Standard and look good for doing so. Consumers get some efficiency benefits. Reduction in peak demand reduces the need for new power plants and carbon emissions are reduced.
6. Recycle funding of the Renewable Energy Program and The Alternative and Clean Energy (ACE) program.

Assumptions:

Related to implementation step #5 above and to the extent that it is allowed, EDCs can and/or should be eligible to receive Tier II AEPS credits from the energy savings associated with the operation of GSHPs. The same should also be true for compliance with Act 129.

Potential Overlap:

- High Performance Buildings work plan

Potential integration with DOE/Oak Ridge National Laboratory's (ORNL's) interest in extending/funding infrastructure for geothermal heating and cooling. December 2008 report available at www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

Subcommittee Recommendations: