GEODELPHIA: THE GEOTHERMAL MICRO-GRID

Is Philadelphia ready for a better future?

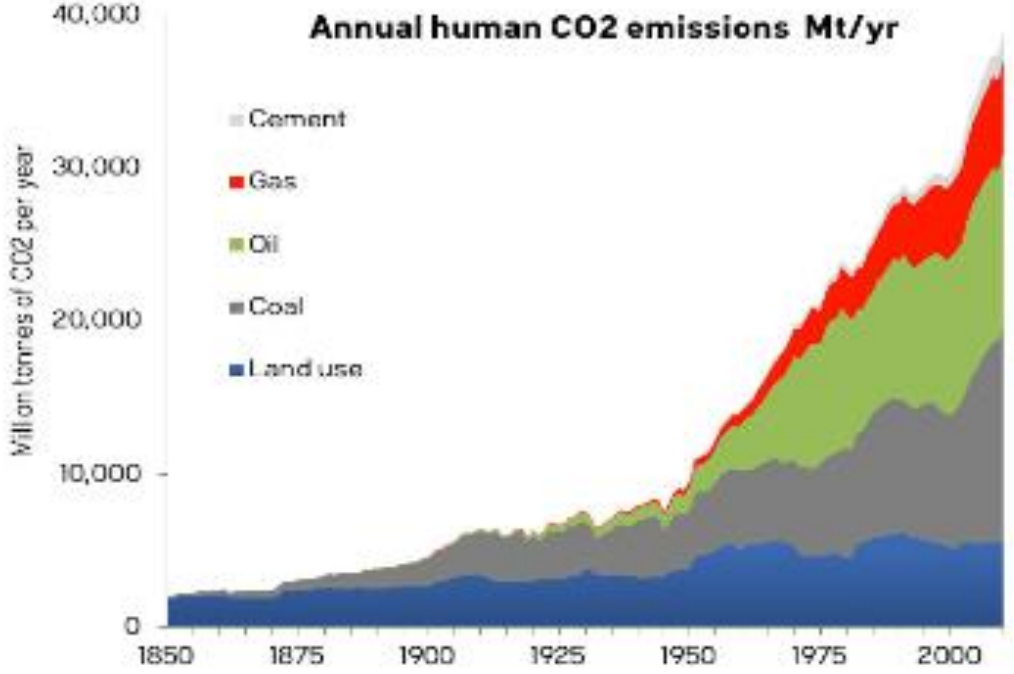
Geodelphia

A Geothermal Interest Group investigating geothermal energy in Philadelphia and beyond, consisting of

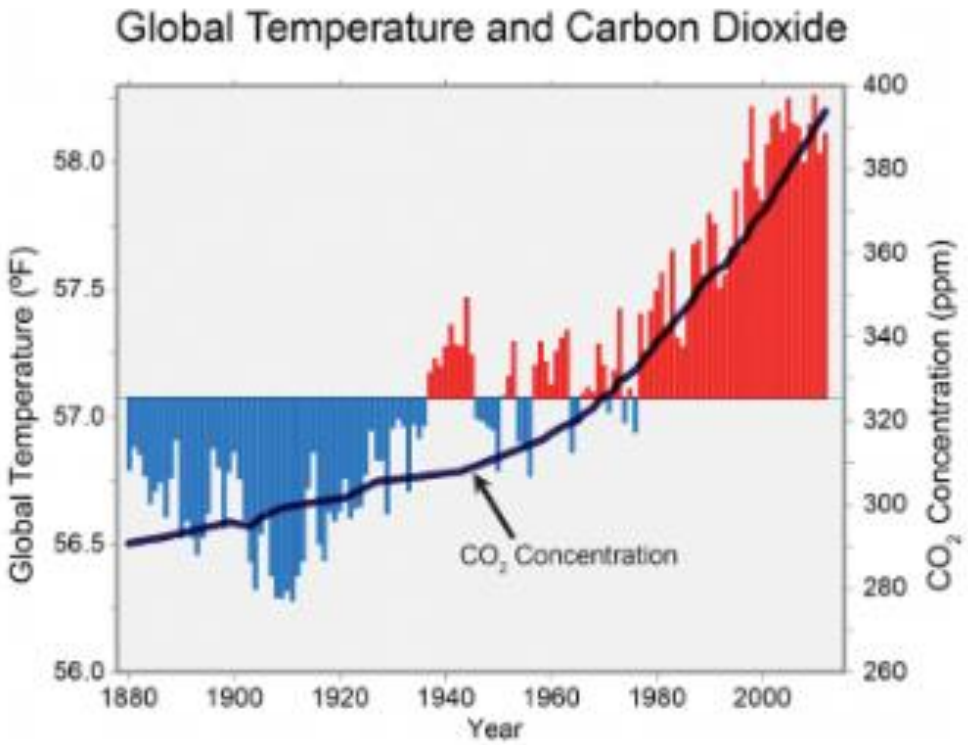
- Sierra Club - Southeast PA Group Philadelphia Ready for 100
- Association for Climate Health www.a4ch.org
- Other interested citizens

Interested in joining? Contact Mehdi Entezari <***entezari789@gmail.com***>

Greenhouse gas emissions are a threat to all life on Earth



https://skepticalscience.com/print.php?n=2928



https://www.globalchange.gov/browse/multimedia/global-temperature-and-carbon-dioxide

With flooding, crop losses, rising seas, more extreme weather, disease, famine, wildfires and other threats to life, worsening for every generation …

Heating and cooling are major contributors

Worldwide, over one-sixth of greenhouse gases come from energy use in buildings:

- **Residential buildings (10.9%):** energy-related emissions from heating, cooling and power for lights and appliances
- **Commercial buildings (6.6%):** energy-related emissions from heating, cooling and power in offices, restaurants, shops
- **Schools, hospitals, museums and manufacturing** also require heating, cooling and power

If we can supply heating and cooling without greenhouse gas, that will substantially help reach our climate goals and sustain life for generations to come

Data from Climate Watch, World Resources Institute, 2020

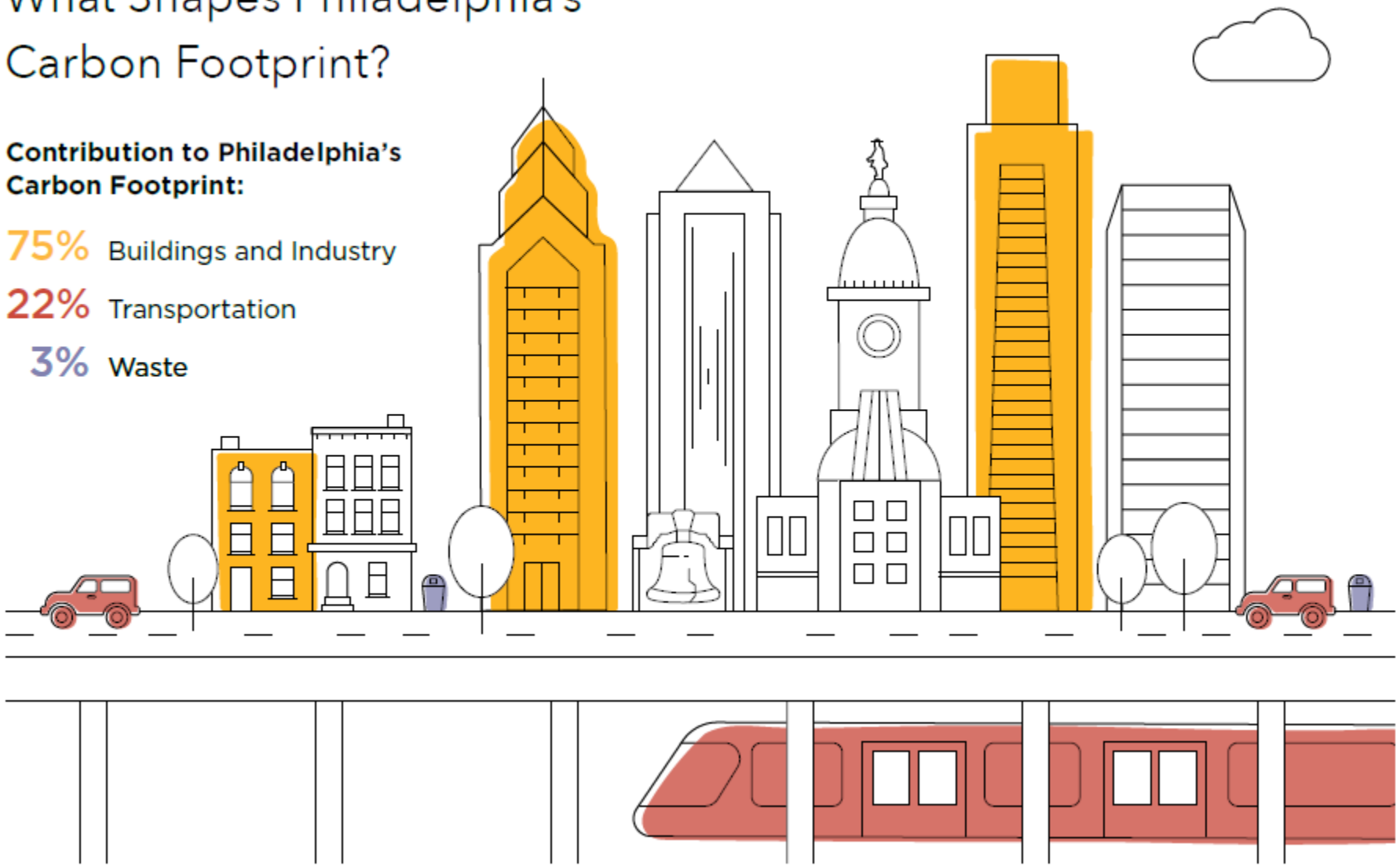
What Shapes Philadelphia's Carbon Footprint?

Contribution to Philadelphia's Carbon Footprint:

75% Buildings and Industry

22% Transportation

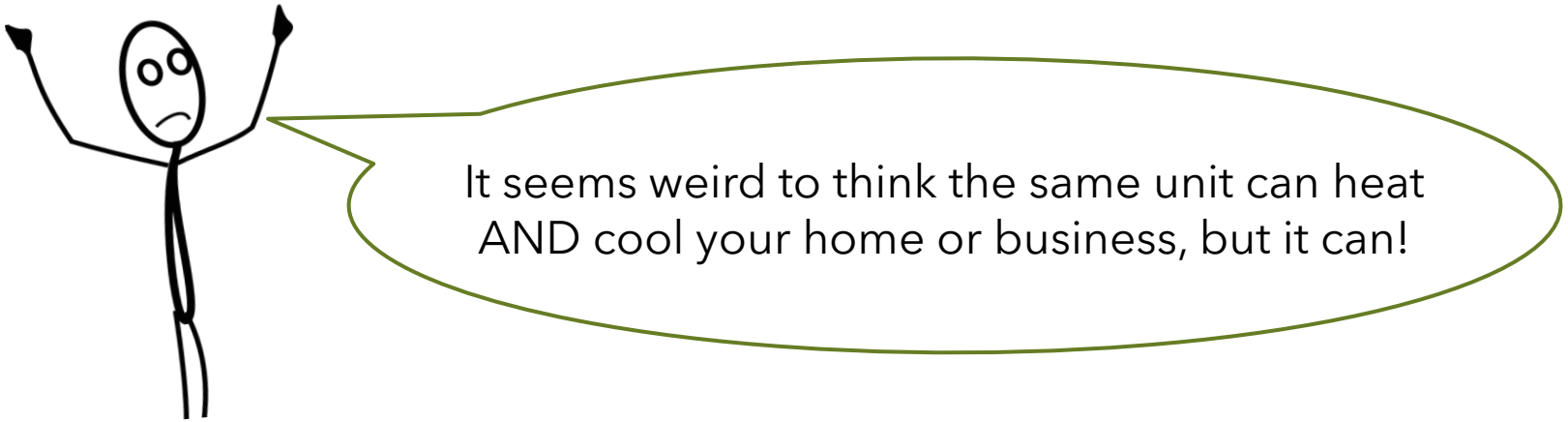
3% Waste



From *OOS Climate Action Playbook, 2021*

And it just so happens there is a no-emissions solution …

- Conventional heating and cooling **burns oil or gas** or uses electricity generated from fossil fuels. Result: more greenhouse gas
- Geothermal energy with heat pumps burn virtually **no fossil fuels**. They rely on the steady 54°F temperatures under the ground and simply **move energy back and forth** to cool the air or warm it, depending on the season. Ground-sourced heat pumps (GSHPs), sometimes known as geoexchange, harvest energy stored 10–1000 feet below the surface – almost for free!



Wait, what exactly is geothermal energy?

Geothermal energy comes from heat stored in the earth.

Source: Adapted from a National Energy Education Development Project graphic (public domain)

~10,800 °F

From 7200°F to 400 °F

Deep wells access higher temps to generate electricity

From 400°F to air temp at the surface. Includes the zone where it is **54° year-round**

Shallow wells in the Crust harvest moderate temps for geoexchange

In some places this heat vents through cracks and tectonic plates as volcanoes, hot springs or geysers. This energy can be put to use:

- Reykjavik, Iceland is entirely heated by volcanic geothermal energy. Geysers heat water to keep greenhouses warm enough to grow food all year round
- Boise, ID has been heated by hot springs since 1890

And we can capture this energy even where there are no volcanoes, hot springs or geysers

- **Drilling** gets to warmer zones with more energy. But drilling is expensive, and deeper = costlier.
- This tends to promote projects needing minimal drilling
- Projects often use shallow **horizontal** pipes, not much deeper than 10 feet down, to reduce costs
- Projects use deep, **vertical** pipes if not enough area for cooling or heat with a horizontal design, especially large buildings on small lots or high-rise units
- A feasibility study would tell us which arrangements would be best for which locations

Images taken from http://www.thermcoenergysystems.com/what_is_geothermal_ground_hot_loop.html and http://geothermalsolution.net/about-geothermal.html

Geoexchange - from ground heat to a comfy home or business …

- Water circulates through pipes in each building and out into the ground
- The ground, at 54°F, moderates the water for recirculation in hot weather and cold
- Water goes through a heat pump to exchange heat with a refrigerant (yes, it works like your refrigerator!)
- In cold weather, the heat pump moves heat from the circulating water into the air, warming the building.
- In warm weather, it moves heat from the air to the water, cooling the building
- All this is regulated by the thermostat

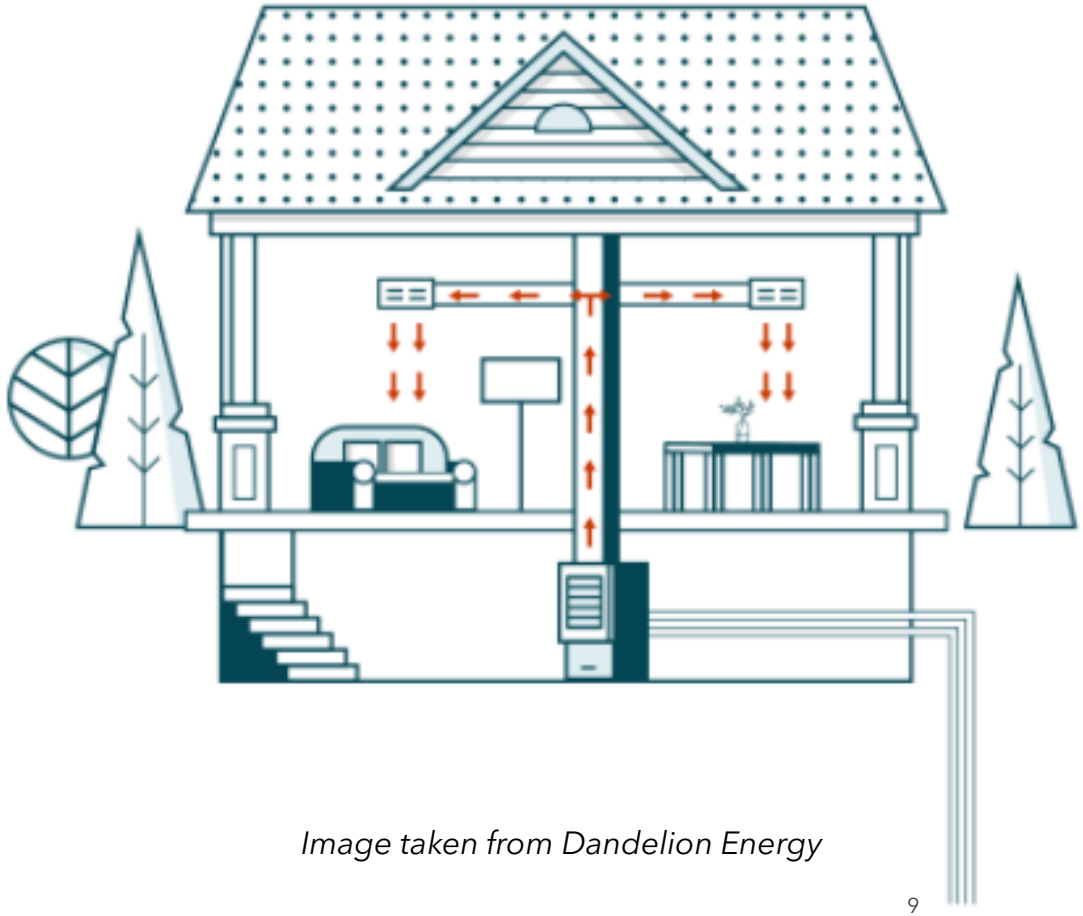


Image taken from Dandelion Energy

A heat pump???

- The heat pump is not new. It's a simple technology much like your refrigerator – moving heat from inside the box and transferring it to the room.
- Heat pumps are trustworthy. Even on a 90° day your freezer stays cold and the popsicles are still frozen.
- Heat pumps contain fluid that works like a sponge for heat
  - When the liquid expands, it absorbs heat
  - When compressed, it releases heat

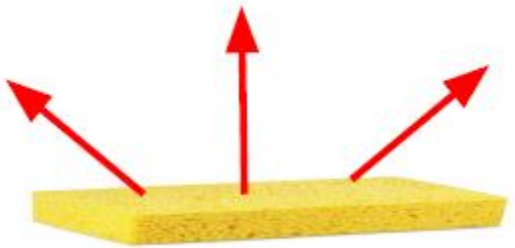
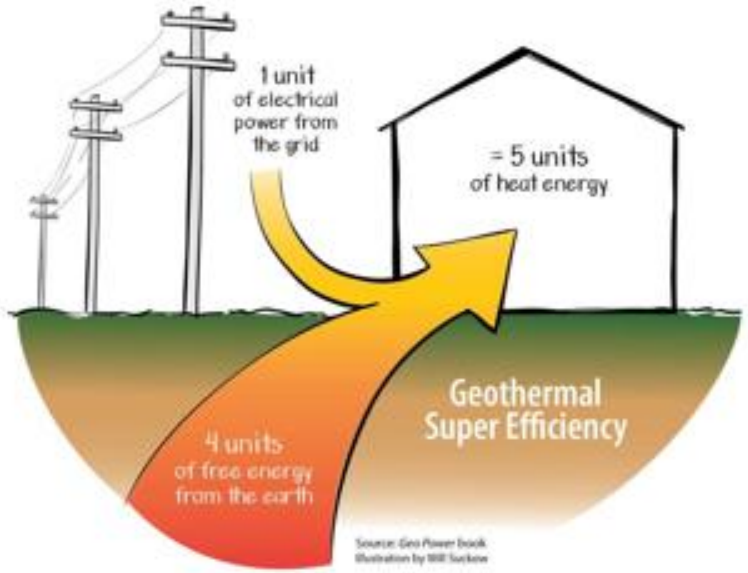


Image courtesy of HEET

- The ground is like a reservoir or a battery to store extra heat or cooling
  - On a cold day the heat pump sponges up heat from the ground and moves it inside, warming your home.
  - On a hot day the heat pump sponges up heat inside and moves it out, cooling your home.

Much more efficient, no carbon footprint

Conventional systems move 70-98 units of energy for every 100 taken in, wasting 2-30 units of energy in the process.
A geoexchange system moves 300-600 units of energy for every 100 units of power used.
And if those 100 units of power are solar- or wind-generated, the carbon footprint is nominal.



Source: *Geo Power Book*

And where buildings are networked, it gets even better …

- Achieve economies of scale in drilling, digging, installation → Costs less
- Energy not needed in one home or building is available to others → Costs less
- Energy not needed by any building is stored in the ground for later
  - Unused heat in summer is stored in the ground for use in winter → Costs less
- A large project could be done cooperatively with the City, PGW, others → Costs less

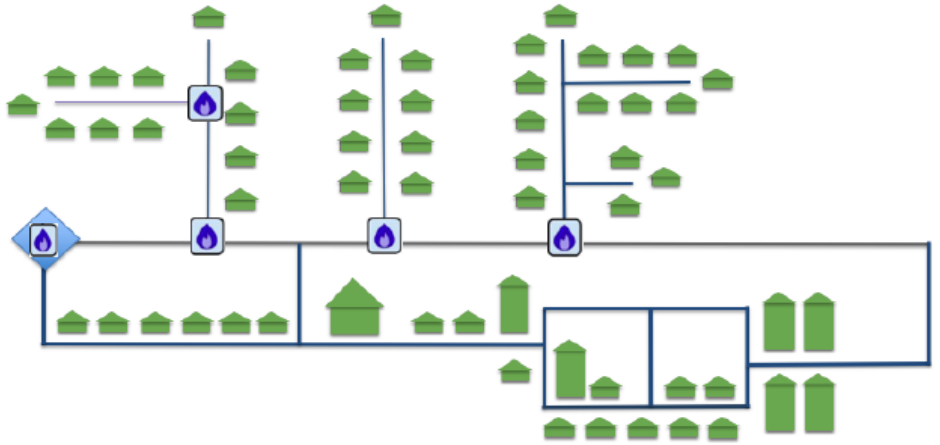
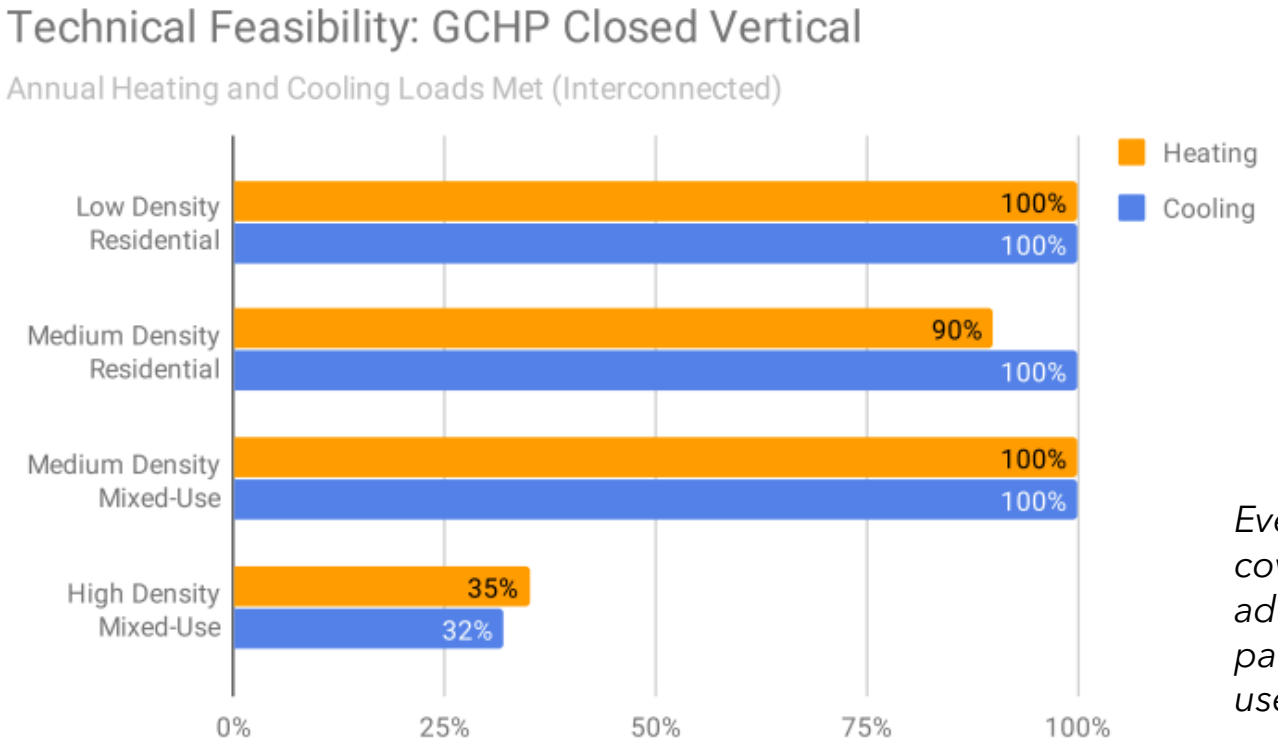


Image courtesy of HEET heet

Can geothermal cover all our heating needs?

Boston has a similar aging infrastructure and mix of housing with other buildings. Here's what their consultant found:



Geo Micro District Feasibility Study, Buro Happold and HEET, 2019

Even high-density buildings can be covered if you dig deeper or put additional piping under nearby parks, parking lots or other low-density uses.

If it's so great, why aren't we already doing it?

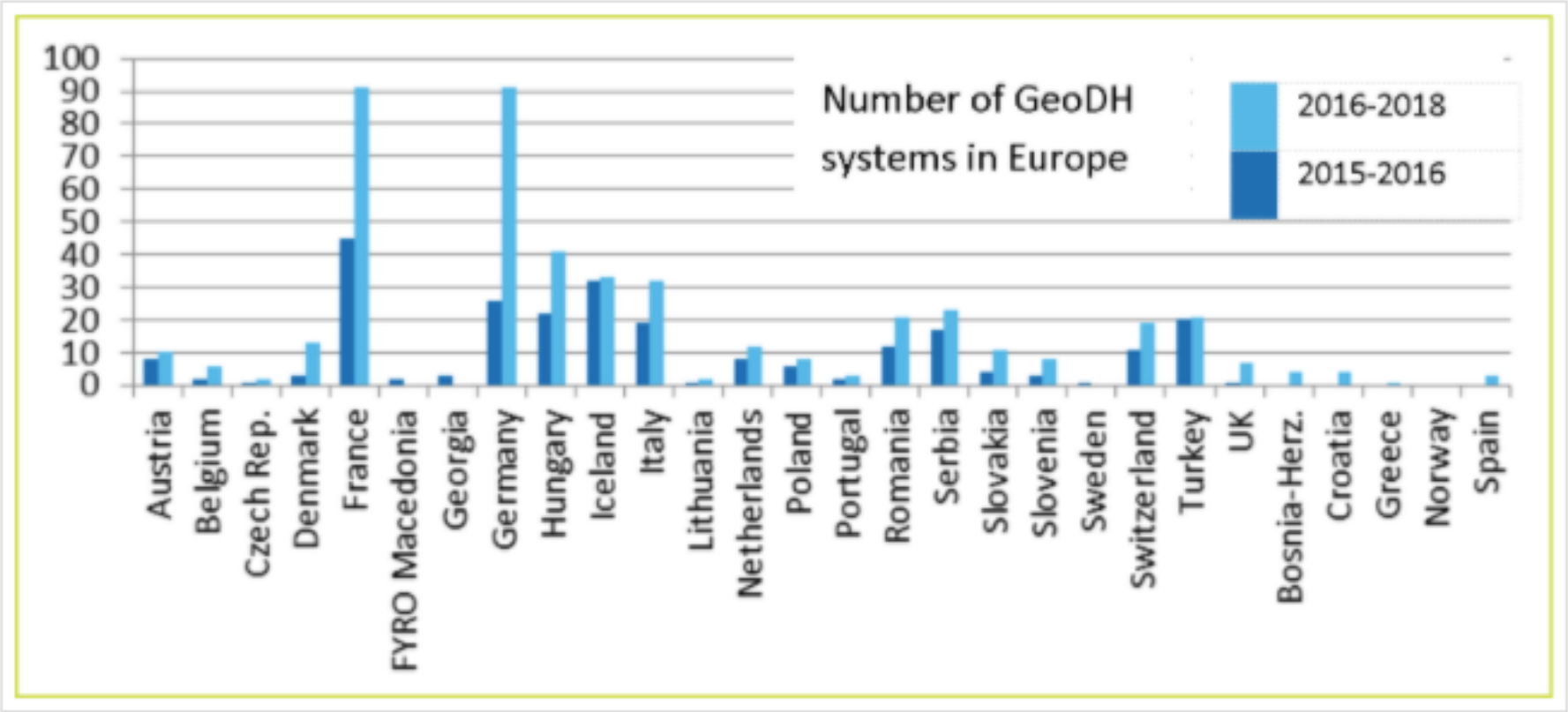
- The initial cost – especially for digging – can be high
  - But with many buildings included, the cost per building goes down
- Until recently it didn't seem important to use climate-sparing technologies
  - But now it does
  - And Boston's feasibility study indicated an immediate 60% reduction in emissions
- Besides, people **are** already doing it elsewhere

Who is already using geoexchange?

- Vancouver International Airport
- A 7,200 home development in Austin, TX
- A 900 home development in suburban Sydney
- 12 apartment buildings with 288 units in Brighton, CO
- Google's new headquarters campus
- IKEA in Centennial, CO
- Portland OR's 14-story Commonwealth Building
- Delta America headquarters, Freemont, CA
- The Gatehouse, an abused women's shelter in Grapevine, TX
- US academic institutions including Allegheny College in PA, Stockton University in NJ, Oregon Institute of Technology, Carlton College in MN, Ball State University in IN, U of Minn Bee and Pollinator Center
- Right here in Philadelphia – The Friends Center, German Society of Philadelphia, Bartram's Garden, Police Tactical Training Facility

Geo Outlook, 2019 Vol 16 No. 3
https://www.geooutlook.org/epub/GO2019No3/

There are more than 240 geothermal district heating systems in Europe alone



Source: EGEC Market Report 2014

http://geodh.eu/

Notable Philadelphia geothermal projects:

Friends Center began working on geothermal in 2004. Set in a historic district, they needed approval for the project, and received it based on preserving the visual historic character of the site.

Drilling began in February 2008 and went to 1550 feet below the surface. Because of the small lot size, they drilled 6 vertical wells in an open loop system. Groundwater exchanges heat with water from the building, with the two loops isolated from each other. Heat pumps were added and some radiators were replaced with fan coil units.

Total system cost: $2.3 million, more than half covered by grants.

Friends Center

Rig at work

Piping and valves

Water to air heat pumps

German Historic Society

In 2019 the German Historic Society completed a geothermal upgrade of the system heating and cooling their 130-year-old structure.

Their drilling contractor dug down through the soil and a layer of Wissahickon schist, hitting solid granite at 400 feet. At that point further drilling got slower and more expensive so the project is designed with 23 shallow wells to fit that depth. Total cost: $1.2 million.

The closed-loop, vertical pipe system has been running since then with monthly utility costs significantly below previous levels.

Bartram's Garden

In 2015 Bartram's Garden along the west bank of the Schuykill River installed a geoexchange system to heat and cool their 1728 house and buildings. They sank 12 wells 300 feet deep under their stable yard.

Police Tactical Training Facility

This new 30,000 square foot building was designed and built to LEED specifications. Operations began in 2013. Housing the department's SWAT, canine and bomb disposal units, it also includes training, conference and break rooms.

They had no problems with the geothermal portion of the system, but remind us:

- Heat pumps, running year-round, need more frequent maintenance and wear out faster than heat pumps running only in the winter
- Overall, less maintenance is required though, as the systems are simpler and need no cooling towers.

What do I need to know about geothermal in **my** home?

- Compared to forced-air, geothermal systems provide more even heating and cooling. The system runs longer but less intensely, so it is comfortable and quiet.
- Geothermal can distribute heat and cooling through ducts or radiators but not through steam radiators.
- You can leave the current system in place as a back-up for extreme temps.
- You can add an adapter to run your hot water heater off geothermal as well.
- If using gas for appliances, continue to use or switch them to electric. The geothermal connection would be additional to that.
- A 2017 survey of 24 building owners with geothermal heat pump systems found 75% are very satisfied re noise, cost, and indoor comfort. 85% would recommend this system to others. https://www.scirp.org/journal/paperinformation.aspx?paperid=77811

And what kind of money are we talking about?

- Various researchers say total monthly costs would be 25-80% below current utility bills. Electric bills would increase slightly to power the heat pump. The feasibility study can give a better estimate.
- Up front construction costs would be significant. A variety of options might keep this affordable:
  - Tax incentives for renewable energy
  - State or federal grants and low-interest loans
  - Possible financing with 15-20 year repayment through utility bills
  - Impact investors interested in renewable energy investing

Upfront Federal and State Incentives

- Federal Solar Investment Tax Credit of 26% (includes geothermal projects)
- Grants and low interest loans in state of Pennsylvania
  - https://dced.pa.gov/program/
- Alternative and Clean Energy Program
  - https://dced.pa.gov/programs/alternative-clean-energy-program-ace/

Operational Savings

- Geothermal Heat Pump Cost Savings can reach 30-70% on heating and 20-50% on cooling*
- Geothermal heat pump cost savings are realized because these systems have efficiency levels of 400 to 600% in terms of energy drawn from the power grid.
- Geothermal heating and cooling systems have a long service life.

* https://earthrivergeothermal.com/geothermal-heat-pump-cost-savings/

Energy and Money Savings – Residential example

Home with Fuel Oil Furnace	
Annual Heating Load (BTUs)	133,384,100
Fuel Oil Usage (Gallons)	1,239
Price Per Gallon	$3.30
Oil Efficiency *15 year old furnace	75%
Annual Heating Cost *A portion of the predicted heating costs are due to electricity consumption of the furnace	$4,212

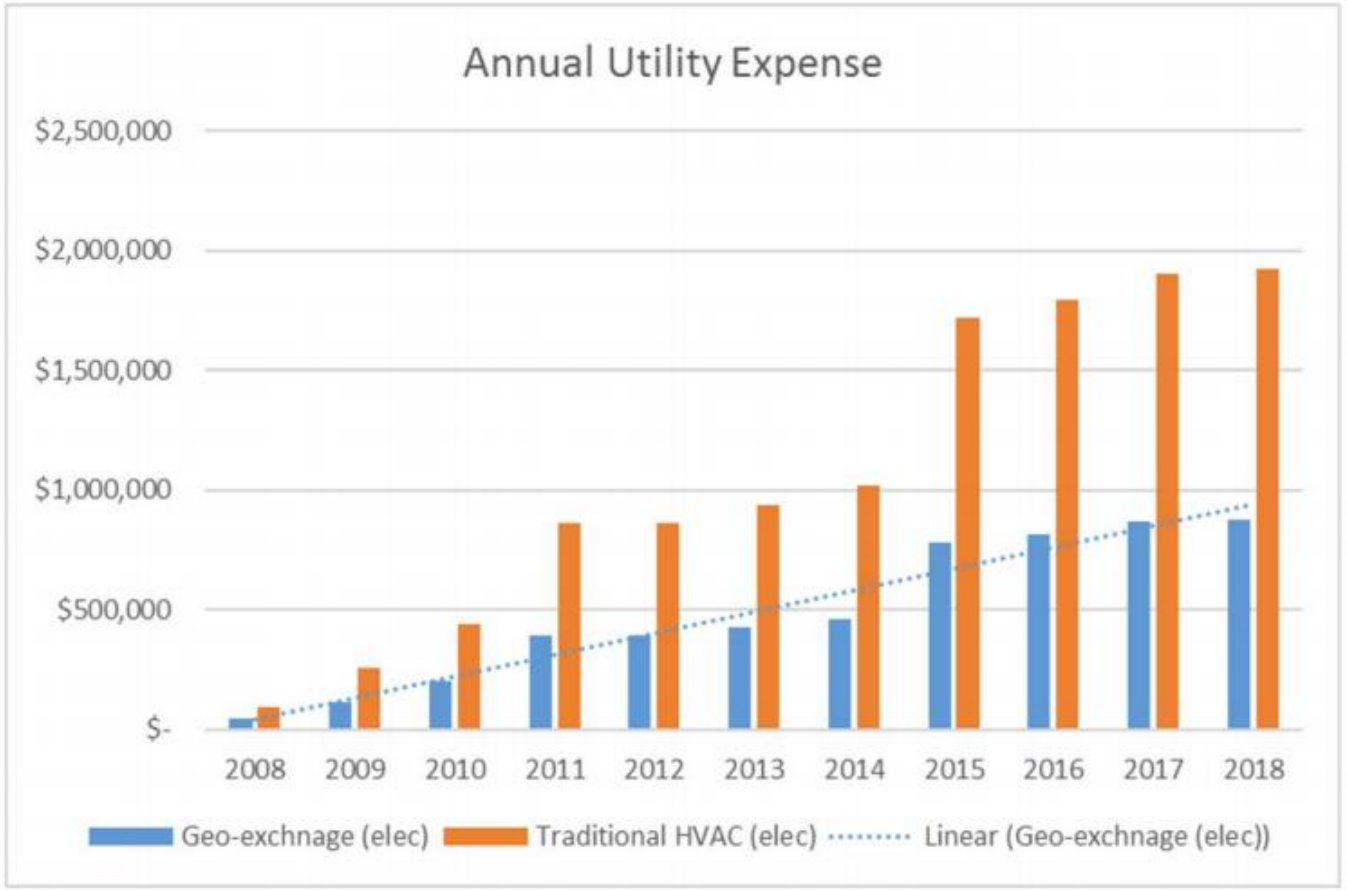
Home with Dandelion Geothermal System	
Annual Heating Load (BTUs)	133,384,100
Electric Usage (kWh)	11,858
Price Per kWh	$0.16
Heat Pump Efficiency (Avg. COP)	3.3
Annual Heating Cost	**$1,897**

Home with Central AC	
Annual Cooling Load (BTUs)	32,588,930
Electric Usage (kWh)	2,914
Price Per kWh	$0.16
Central AC Efficiency (EER)	11.51
Annual Cooling Cost	$466

Home with Dandelion Geothermal System	
Annual Cooling Load (BTUs)	32,588,930
Electric Usage (kWh)	1,680
Price Per kWh	$0.16
Heat Pump Efficiency (SEER)	19.96
Annual Cooling Cost	**$269**

Based on New York State data
https://dandelionenergy.com/how-much-does-dandelion-geothermal-cost

Energy & Money Savings - Institutional example



System cost:
$8.5 Million

Energy savings:
$1 Million/yr

COLORADO MESA UNIVERSITY

Courtesy of The GreyEdge Group©

What can geothermal offer Philadelphia?

These benefits and more IF we act now:

√ Save money for the city and its residents

√ Reduced safety risk from gas leaks, fires, explosions

√ Improved indoor air quality / reduced health risk for people with asthma and COPD

√ Help achieve Philly climate neutrality by 2050: ⬇fossil fuel use, ⬇methane gas leaks

√ Adds new skilled jobs

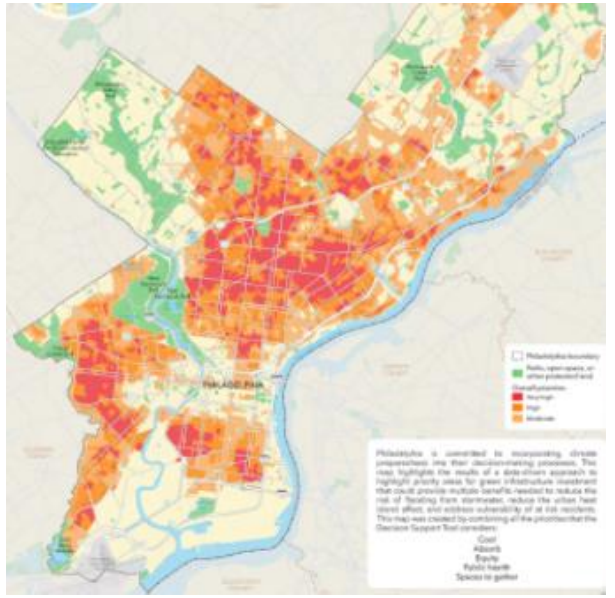
√ Could save existing PGW jobs

√ Air conditioning for residents who otherwise cannot afford it

√ May reduce cost for PGW to replace old, leaky pipes

√ Additional energy independence

√ Opportunity for climate leadership in the region



So what would this project look like?

If the feasibility study looks promising, we propose:

- Pilot projects of one to four geothermal micro-grid districts
- Microgrids featuring geoexchange systems
- Operated by or with the partnership of PGW
- Pilot projects to consist of small groups of buildings in a microgrid:
  - Several blocks of houses
  - Several blocks of mixed houses + businesses
  - Several large buildings – a campus, hospital, shopping area or museum complex
- Review of results
- Continue adding microgrids to build out the city where feasible

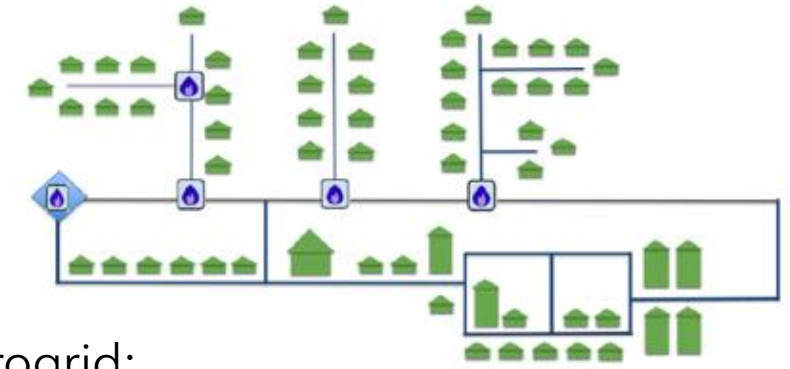
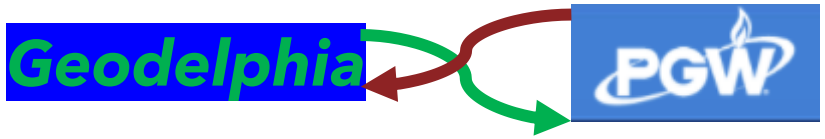


Image courtesy of HEET

PGW should be part of the solution

- We believe PGW is integral to geothermal adoption, though their role is not yet determined
- The big picture: PGW is all about delivering natural gas to the city. In a world where global warming threatens, natural gas is part of the problem. So, over the next 20 years natural gas revenues are likely to decline or disappear altogether. This means **higher rates for continuing customers** as more customers switch off the gas. It also means **losing thousands of jobs** in Philadelphia, and the loss of tremendous value for the assets. PGW's future is precarious if they do not change course. Why? Two problems:
  - Natural gas is relatively clean compared to coal but is still a fossil fuel creating greenhouse gas
  - Natural gas wells and pipelines leak methane, a highly potent greenhouse gas
- Cleaner geothermal heating and cooling can make use of PGW's underground network, expertise in digging, monitoring and repairing pipes, and reliable, well-trained workforce.
- It could be a marriage made in Heaven or a fight to the death. We hope to establish Heaven and enlist PGW as a trusted partner, operator or owner of the proposed systems. This is happening in Boston as it sets up pilot studies of geothermal with the full cooperation of its gas utility. We hope to work something out like that here.



PGW's current course is not in sync with PA climate goals

- City of Philadelphia announced a goal of **net zero** carbon emissions by **2050** in January 2021
- Commonwealth of Pennsylvania's 2018 Climate Action Plan sets goals of
  - 26 percent reduction in GHG emissions by 2025
  - 80 percent reduction in GHG emissions by 2050
- "Here at PGW, we exhaust all measures to take care of our environment, because as an energy company, we understand the footprint we leave … PGW has joined the city of Philadelphia in its commitment to combat global climate change" – PGW *Corporate Responsibility Report*
- PGW has committed to pipeline repairs and replacements to reduce natural gas/methane leaks by 2% per year. That's great – but is this incremental pledge enough to get to carbon neutral by 2050?
- Here is an opportunity for PGW to become part of the solution

What future will PGW choose?

Sync up with climate goals

- Adopt geothermal as additional line of business
- New revenue stream helps support declining natural gas sales, jobs, pensions, high fixed costs
- Strong leadership re climate goals

Can combine these two!

Modest efforts

- Continue with natural gas sales
- Add renewable gas sources*
- Cost increases and climate pressures reduce sales though more slowly
- Moderate leadership re climate goals

Lagging efforts

- Continue with natural gas sales only
- Climate pressures reduce sales
- Customers increasingly convert to electricity
- Declining revenues with high fixed costs, job losses, lost value of assets require City bailouts or fire-sale to outsiders

* Recycling from wastewater, landfills, food waste sources

Existing Gas Business Model Addresses Common GSHP Concerns

EVERSOURCE

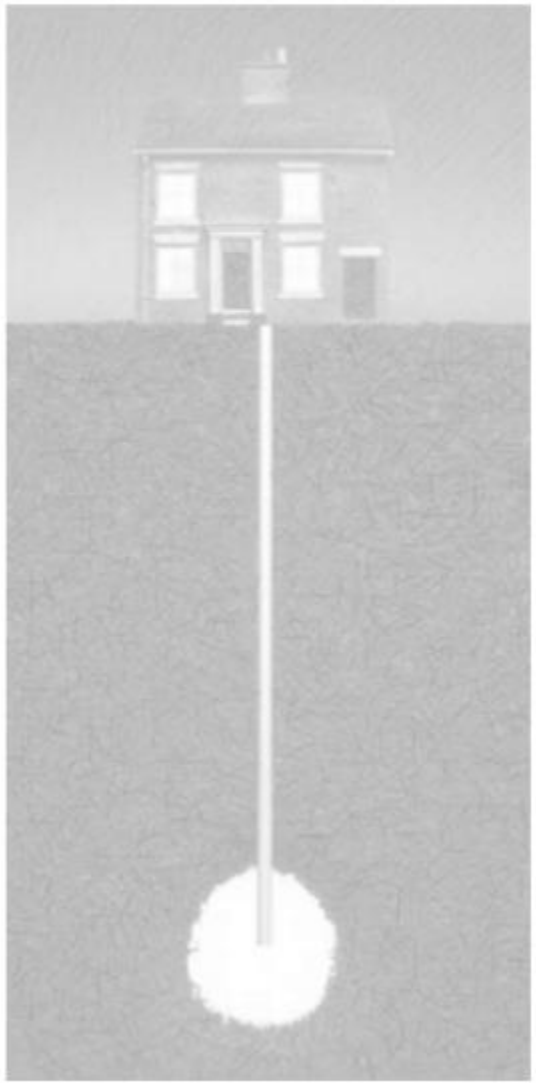
Existing gas business model and operations may be conducive to building, owning, and operating ground source heat pump networks

COMMON OBSTACLES TO GSHPS	EXISTING GAS BUSINESS OPERATIONS
Large upfront capital costs	Utility makes investment in capital projects and rate bases those assets across customers
Reluctance to spend money on infrastructure when customer might be in space for limited time period	Utility amortizes long lived assets over many years
Maintaining infrastructure outside of the customer's structure	Utility owns, operates, and maintains infrastructure in public/private ROWs

Many Similarities Exist Between Geothermal and Natural Gas Business

EVERSOURCE

From a big picture perspective, geothermal and natural gas businesses share many common aspects



- Capital Intensive
- Buried/Underground Infrastructure
- Long Lived Assets
- Regulated Service
- Monitoring System Conditions
- Similar Customer Barriers
- Similar Point of Common Coupling

Benefits for Different Stakeholders

EVERSOURCE

Utility

- Provide customers an additional choice/alternative for heating
- Possible new business line
- Capitalize on existing gas company core competencies
- Flatter load profiles, higher utilization of infrastructure

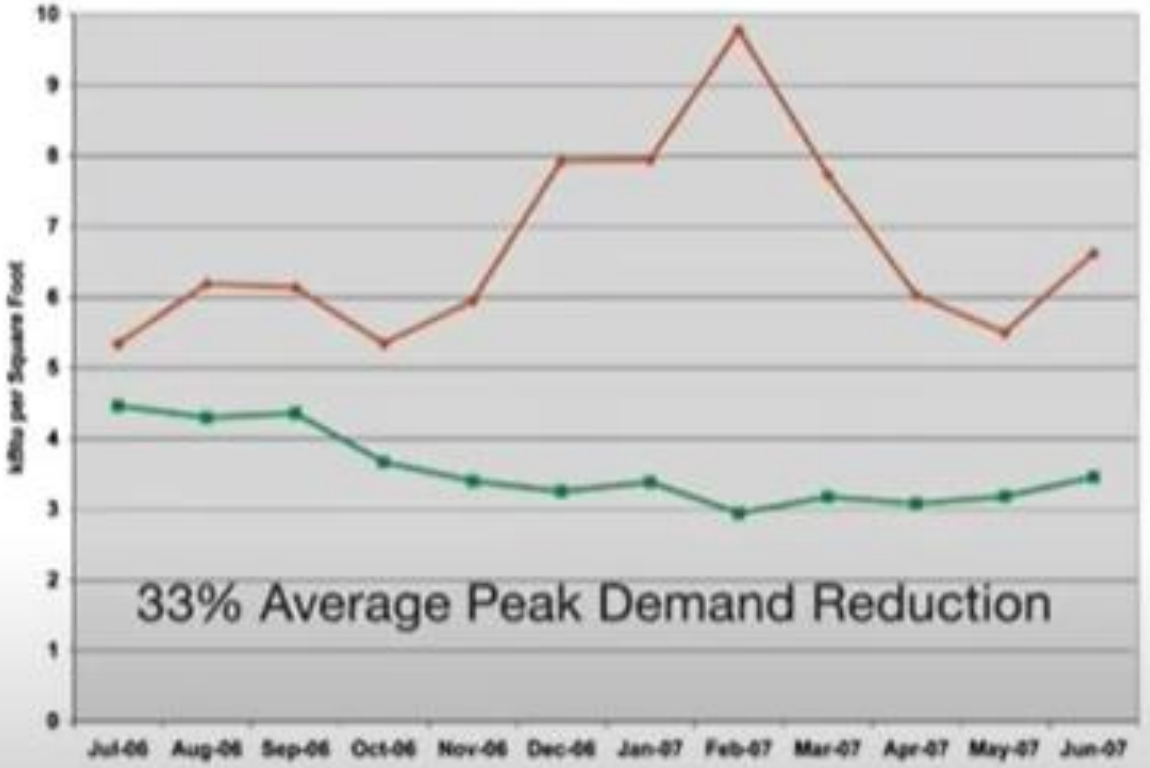
Customer

- Provide low-cost heating where gas is not available
- Cleaner, safer, quieter, reliable system
- Provides both heating and cooling
- GSHP equipment is located inside the building so there is an ease of repair/maintenance and no aesthetic impacts

State

- Provides state with another way to meet to climate goals
- Estimated 60%+ reduction in carbon emissions from combined heating and cooling for an average residence by installing GSHP

Utility Perspective: Geothermal provides grid benefits



Charts: EggGeo, LLC

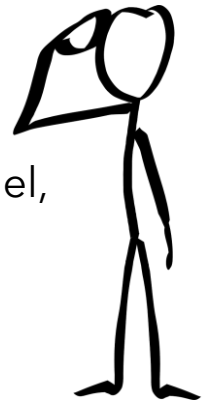
VAV System Geothermal

Based on data from ASHRAE building, Atlanta, designed to showcase different engineering solutions https://egggeo.com/why-geothermal-is-better/

Steps towards geothermal adoption

- Community outreach – along with …
- Discussions with City of Philadelphia, PGW, labor unions, DVRPC, universities and other major players
- Fundraising and grant writing for feasibility study
- Selection of one or more sites for pilot project
- Feasibility study
- Get approval from various stakeholders
- Build pilot projects, run and assess results
- Work towards wider adoption

FAQs



- Are you sure this is safe?
  - These systems have been around for a long time. They replace natural gas, a potentially explosive fuel, and instead circulate water at tap water temperatures, under pressure like that of a garden hose.
- Would this project be releasing any gas from the earth?
  - No.
- Would this project cause pollution to enter the water table?
  - No. This is based on a closed-loop system where the same liquid recirculates and is not released into the environment. Some geothermal systems take groundwater as a refrigerant and release it back to the source, like with the Friends Center, but this is not proposed here.
- Are earthquakes a risk for geothermal projects?
  - No. The geothermal pipes would be at no more risk than any other underground pipes.
- Is fracking a risk for geothermal projects?
  - Fracking can create ground instability and small earthquakes up to 30 miles away. However, the nearest fracking locations are over 100 miles from Philadelphia.
- This project sounds interesting! How can I get involved?
  - Contact Mehdi Entezari <**entezari789@gmail.com**>

Some useful references

- US Department of Energy, https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps#:~:text=Geothermal%20heat%20pumps%20(GHPs)%2C,of%20the%20outside%20air%20temperature.
- Energy Star Program https://www.energystar.gov/products/energy_star_most_efficient_2020/geothermal_heat_pumps
- www. HEET.org (Home Energy Efficiency Team), located in Boston, has a number of resources on their site
  - https://www.wbur.org/earthwhile/2020/01/13/heat-eversource-geothermal-energy-climate-change describes how HEET and Eversource, the MA gas utility, came to work together
  - Many slides for HEET and Eversource can be viewed at the Boston Green River Commission presentation https://www.youtube.com/watch?v=ucFUw93Ugd4&feature=youtu.be
- The International Ground Source Heat Pump Association https://igshpa.org/
- EnergySage https://www.energysage.com/clean-heating-cooling/geothermal-heat-pumps/costs-benefits-geothermal-heat-pumps/
- "Recent Development and Application of Geothermal Heat Pump Systems in Cold-Climate Regions of the US," Yu, et al, July 2017, https://www.scirp.org/journal/paperinformation.aspx?paperid=77811