Manufacturer's Roundtable

Ground Source Heat Pumps

February 27, 2025

CEDA
California Energy Design Assistance

nbi new buildings institute

WHAT IS CEDA?

The California Energy Design Assistance (CEDA) program is the only statewide utility incentive program for new construction and major renovations.

- Promotes **electrification** and **decarbonization**
- CEDA works in collaboration with project teams to reduce energy demand, consumption, and carbon emissions.
- Serves commercial, public, high-rise multifamily, industrial, and agricultural projects in Pacific Gas & Electric (PG&E), Southern California Edison (SCE), SoCalGas (SCG), and San Diego Gas & Electric (SDG&E) service areas.

WHY PARTICIPATE IN CEDA?

- Receive complimentary **decarbonization** analysis tailored to project goals to identify most effective measures to implement
- Gain analysis of **energy costs and paybacks**
- Receive **financial incentives** to help offset the costs of decarbonization measures
- Demonstrate commitment to high performance building practices and design

INCENTIVES

$2,800
+
measure package
incentive

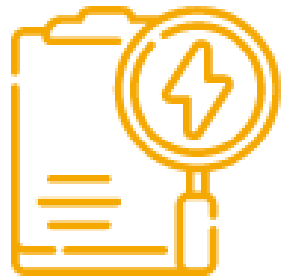
- $2800 Design team incentive per project as a thank you for participation
- Based on the project measure package the design team chooses for implementation

HIGH PERFORMANCE MEASURES

CEDA aims to exceed California's decarbonization standards by identifying high performance measures and providing educational opportunities to explore use cases and best practices.

This not only advances the market, but also qualifies participants for enhanced incentives through our program.

A current list of eligible high-performance measures can be found on our website here.



HAVE A PROJECT TO DISCUSS?

For more information, please contact our program outreach specialists, visit our website, or fill out an interest form

Scan me to enroll a project

CaliforniaEDA.com

Sean M. Williams | Outreach Specialist
swilliams@willdan.com

Tina Hendrix | Program Outreach Specialist
thendrix@willdan.com
760.585.7577

Roundtable Agenda

Presenter	Title	Time
Sean Williams, CEDA	Intro and CEDA	10:00 – 10:05
Will Lange, WaterFurnace	Ground Source Heat Pumps	10:05 – 10:20
Matthew Rash, MEA	Water Source Considerations	10:20 – 10:35
Andrew Iliff, HEET	Think Thermal, Together	10:35 – 10:50
Stuart Yanow, Geotility	Orca Energy: Making Geothermal Easy and Affordable	10:50 – 11:05
Joselyn Lai, Bedrock Energy	Electrification and Energy Savings with Geothermal Heating and Cooling	11:05 – 11:20
Noah Gabriel, NBI	Panel Questions and Closing	11:20 – 11:30

Today’s Discussion Topics

The benefits of ground source heat pumps

GSHP barriers and solutions

Commercial building applications

Multi-home and district level options for geothermal energy

Innovative technology and drilling approaches

Today’s Panelists

Stuart Yanow
Geotility

Joselyn Lai
Bedrock Energy

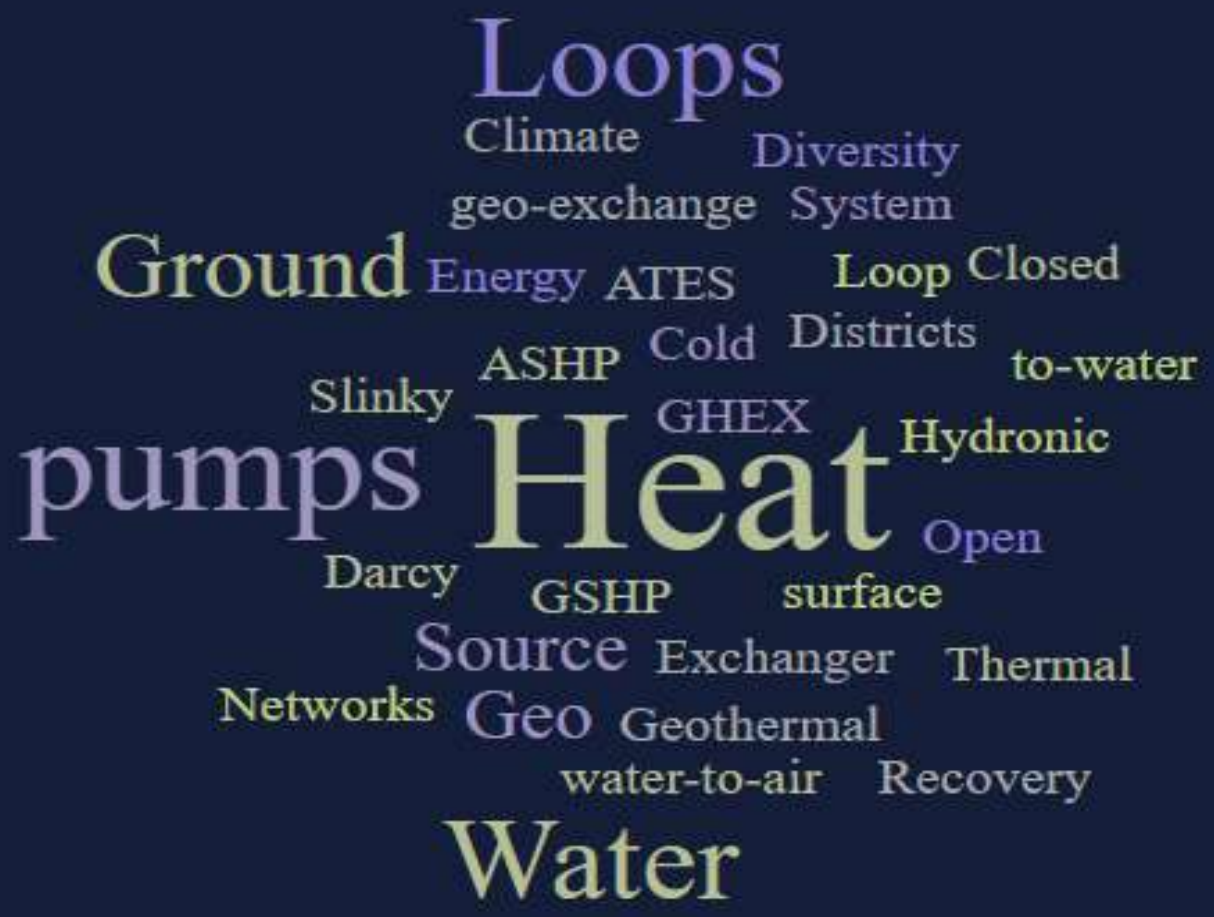
Matt Rash
Mitsubishi Electric
Trane

Andrew Iliff
HEET

Will Lange
Water Furnace

Ground Source Heat Pumps

WaterFurnace
Smarter from the Ground Up™


Loops
Climate
Diversity
geo-exchange
System
Ground
Energy
ATES
Loop
Closed
Districts
Cold
ASHP
to-water
Slinky
GHEX
pumps
Heat
Hydronic
Open
Darcy
GSHP
surface
Source
Exchanger
Thermal
Networks
Geo
Geothermal
water-to-air
Recovery
Water

There Are Ground Source Heat Pumps for *Every Building*

Conventional Air Conditioner or Heat Pump

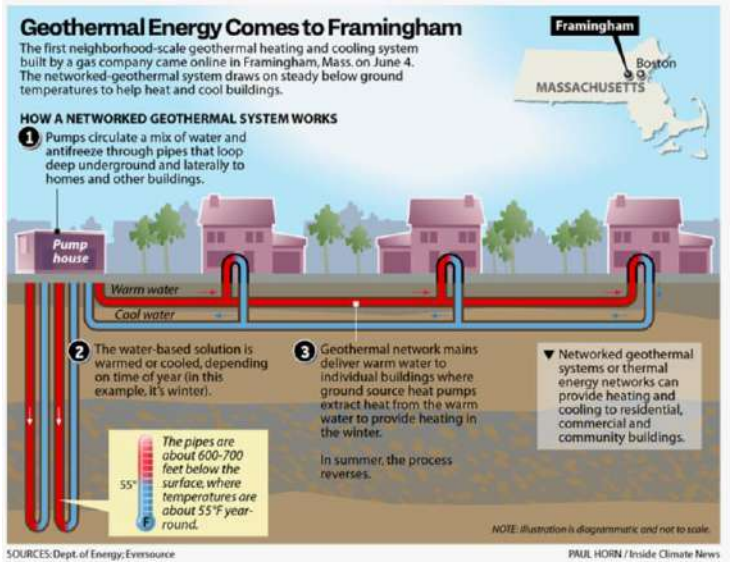
WaterFurnace
Smarter from the Ground Up™

Ground Source Heat Pump

WaterFurnace
Smarter from the Ground Up™

If you use a lawnmower, there’s a loop for you…

…and if you don’t, there’s a new future for you.



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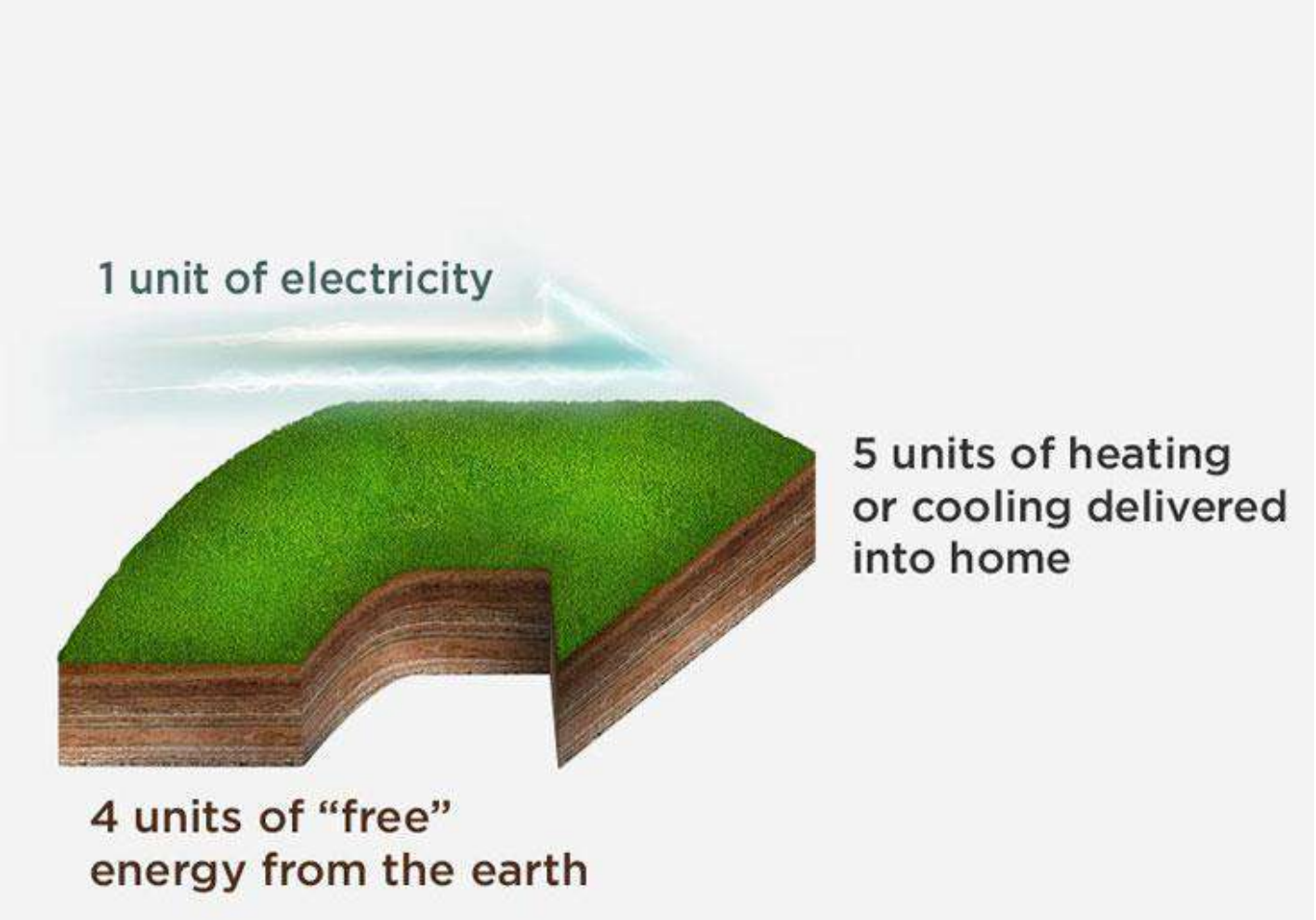
Renewable Energy Heat Pumps



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State of the Technology

- Inverter Drive: Variable Capacity Compressor, Airflow, & Water Flow
- Complete System Remote Diagnostics & Control
- Active Dehumidification (Reheat)
- Vapor Injection

"The Box"

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Ground Source Heat Pumps are the *Original Cold Climate Heat Pump*

…and still the best

Performance & Capacity
<u>Reduced</u> by Hot & Cold Weather

Is it cold outside?

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The 26 Most Efficient 5-Ton Air Source Heat Pumps Registered with The DoE

AHRI Reference Number	Outdoor Unit Brand Name	Outdoor Unit Model Number	Product Type	SEER2 (Btu/Wh)	EER2 (Btu/Wh)	HSPF2 (Btu/Wh)	Cooling Capacity (Btu/h)	Heating Capacity at 47Â°F (Btu/h)	Heating Capacity at 17Â°F (Btu/h)	Heating Capacity at 5Â°F	COP at 5Â°F
216558230	Hisense	AOH-60U3T24P	HP - Split Syst	19	11	9	57000	57000	37000	42000	2.46
214855379	Hisense	AUWR-6024P	HP - Split Syst	19	11	9	57000	57000	37000	42000	2.46
214802098	Hisense	AUWR-60U3TH5	HP - Split Syst	19	11	9	57000	57000	37000	42000	2.46
215381148	Zephyr	ZE-660HPA	HP - Split Syst	19	11	9	57000	57000	37000	42000	2.46
215434510	Zephyr	ZE-660HPA	HP - Split Syst	19	11	9	57000	57000	37000	42000	2.46
216054508	Lennox	VPD060H6M-5P	HP - Mini or M	23	13.8	11	60000	66000	43000	47000	2.4
216032696	Samsung	AM060FCMDCG1	HP - Mini or M	23	13.8	11	60000	66000	43000	47000	2.4
216741754	Samsung	AM060FCMDCG1	HP - Mini or M	21	12.75	10.75	60000	60000	43000	47000	2.35
216054512	Lennox	VPD060H6M-5P	HP - Mini or	19	11.7	10.5	60000	66000	43000	47000	2.3
216016316	Samsung	AM060FCMDCG1	HP -		11.7	10.5	60000	66000	43000	47000	2.3
216054507	Lennox	VPD060S6M-5P		0	12	10.2	60000	66000	43000	47000	2.2
216032695	Samsung	AM060FCMDC		20	12	10.2	60000	66000	43000	47000	2.2
216741753	Samsung	AM060FCMDCG	or M	18.25	11	9.85	60000	60000	43000	47000	2.15
214914943	LG	ZRUM060GSS0	HP - Mini or M	23	13	10	60000	67000	37000	54000	2.1
215223213	LG	ZRUM060GSS0	HP - Mini or M	19.6	12.35	9.55	60000	67000	40000	54000	2
215685468	Mitsubishi Electric	MXZ-SM60NL***	HP - Mini or M	20	12	10.5	60000	66000	41500	46500	2
214914945	LG	ZRUM060GSS0	HP - Mini or M	16.2	11.7	9.1	60000	67000	43000	54000	2
215866831	GREE	GK-H05TC/NHA-D(U)	HP - Single Pa	18	11.2	8.3	56000	57000	34000	51000	2
216662570	Hisense	AR-60U3R25U	HP - Single Pa	17	10.6	7.7	57000	57000	35000	41000	2
216662476	Hisense	AR-60U3RBHM	HP - Single Pa	17	10.6	7.7	57000	57000	35000	41000	2
216776123	Lennox	SL22KLV-060-230A**	HP - Split Syst	20.5	11.7	9.5	56000	56000	60000	42000	1.96
216776121	Lennox	SL22KLV-060-230A**	HP - Split Syst	20	11.7	9.4	56000	56000	60000	42500	1.94
216776122	Lennox	SL22KLV-060-230A**	HP - Split Syst	20	11.7	9.4	56000	56000	60000	42500	1.94
215712170	Mitsubishi Electric	MXZ-SM60NL***	HP - Mini or M	18.2	10.7	10	60000	66000	41000	46500	1.9
216776134	Lennox	SL22KLV-060-230A**	HP - Split Syst	20	11.7	8.5	55500	55500	54000	41500	1.88
216011943	Bosch	BPBA-60RCB-M18S	HP - Single Pa	19	11.2	9	57000	57000	43000	40000	1.85
215894250	Midea	MRD-60HWD1N10-M18G	HP - Single Pa	19	11.2	9	57000	57000	43000	40000	1.85

The Best of the Best

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AHRI Reference Number	Outdoor Unit Brand Name	Outdoor Unit Model Number	Product Type	SEER2 (Btu/Wh)	EER2 (Btu/Wh)	HSPF2 (Btu/Wh)	Cooling Capacity (Btu/h)	Heating Capacity at 47Â°F (Btu/h)	Heating Capacity at 17Â°F (Btu/h)	Heating Capacity at 5Â°F (Btu/h)	COP at 5Â°F
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214855379	Hisense	AUWR-6024P	HP - Split Syst	19							
214802098	Hisense	AUWR-60U3TH5	HP - Split Syst	19							
215381148	Zephyr	ZE-660HPA	HP - Split Syst	19							
215434510	Zephyr	ZE-660HPA	HP - Split Syst	19							
216054508	Lennox	VPD060H6M-5P	HP - Mini or M	23							
216032696	Samsung	AM060FCMDCG1									
216741754	Samsung										
216054512	Lennox										
216016316	Samsung										
216054507	Lennox										
216032695	Samsung										
216741753	Samsung			18.25							
214914943	LG		HP - Mini or M	23							
215223213	LG	ZRUM060GSS0	HP - Mini or M	19.6							
215685468	Mitsubishi Electric	MXZ-SM60NL***	HP - Mini or M	20							
214914945	LG	ZRUM060GSS0	HP - Mini or M	16.2							
215866831	GREE	GK-H05TC/NHA-D(U)	HP - Single Pa	18							
216662570	Hisense	AR-60U3R25U	HP - Single Pa	17							
216662476	Hisense	AR-60U3RBHM	HP - Single Pa	17							
216776123	Lennox	SL22KLV-060-230A**	HP - Split Syst	20.5							
216776121	Lennox	SL22KLV-060-230A**	HP - Split Syst	20							
216776122	Lennox	SL22KLV-060-230A**	HP - Split Syst	20							
215712170	Mitsubishi Electric	MXZ-SM60NL***	HP - Mini or M	18.2							
216776134	Lennox	SL22KLV-060-230A**	HP - Split Syst	20							
216011943	Bosch	BPBA-60RCB-M18S	HP - Single Pa	19							
215894250	Midea	MRD-60HWD1N10-M18G	HP - Single Pa	19							

Ratings For a Modern 5-Ton Ground Source Heat Pump

ISO/AHRI 13256-1

	Model & Size	Closed Loop Cooling EER	Closed Loop Heating COP	Open Loop Cooling EER	Open Loop Heating COP
024	Full Load	23.6	4.1	37.8	5.0
	Part Load	45.0	5.1	57.4	6.0
036	Full Load	18.1	3.8	28.7	4.7
	Part Load	45.0	5.1	51.6	5.9
048	Full Load	18.9	3.6	27.4	4.2
	Part Load	47.0	5.1	56.0	6.1
060	Full Load	17.1	3.5	23.4	4.3
	Part Load	42.0	5.2	54.2	5.9

ENERGY STAR Most Efficient 2025 www.energystar.gov

AHRI CERTIFIED www.ahridirectory.org Water Source HP ANSI/AHRI/ASHRAE/ISO13256-1

WaterFurnace Smarter from the Ground Up

Could you save

Energy?

Carbon?

Repairs?

Money?

How Much Can You Save?

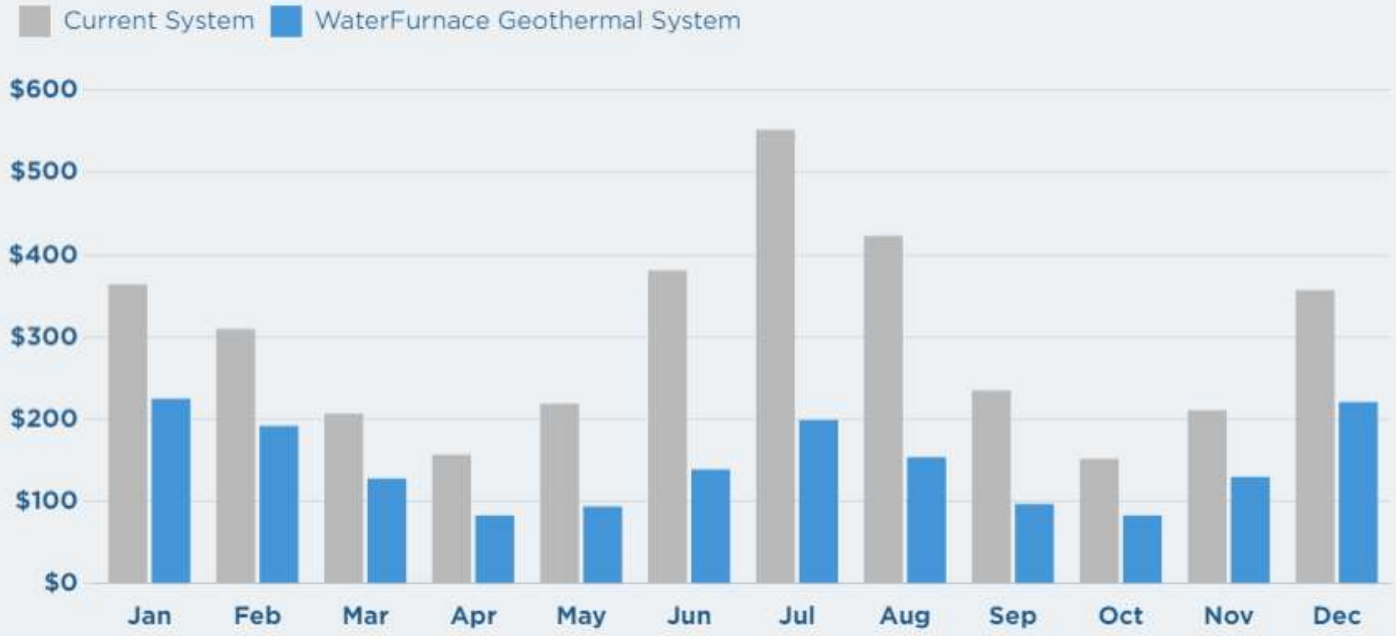
See just how much you can save on your energy bills by replacing your existing heating and cooling system with a WaterFurnace geothermal system.

Home | Your Report | Geothermal Concierge

Geothermal Savings Report

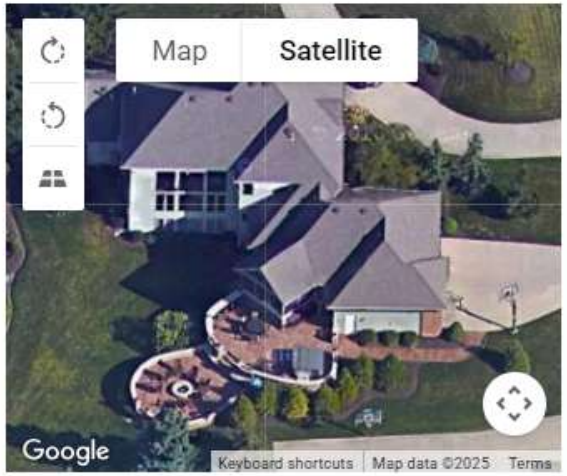
Savings | Energy Consumption | Carbon Footprint | Recommended Systems

Potential Operating Costs by Month



Connect with Us

Step 2 of 3



Savings results for
11211 Crosstree Ct, Fort Wayne, IN 46814

Change Address

Heating Savings	$690
Cooling Savings	$1133
Hot Water Savings	$140

Estimated Annual Savings

$1963

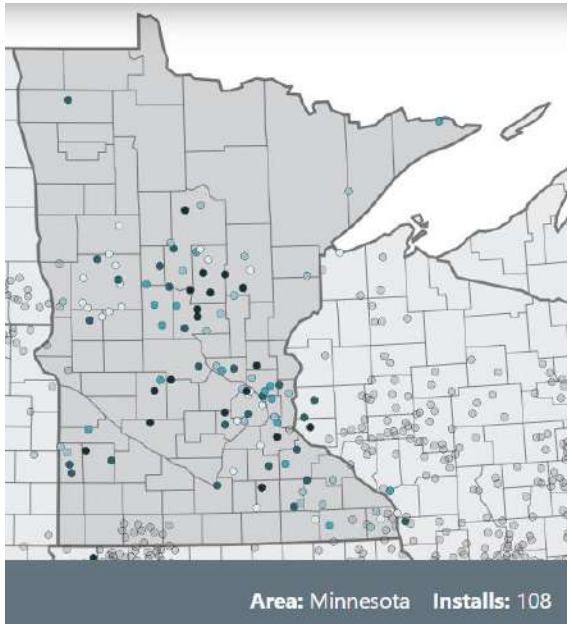
View & Adjust Our Assumed Details

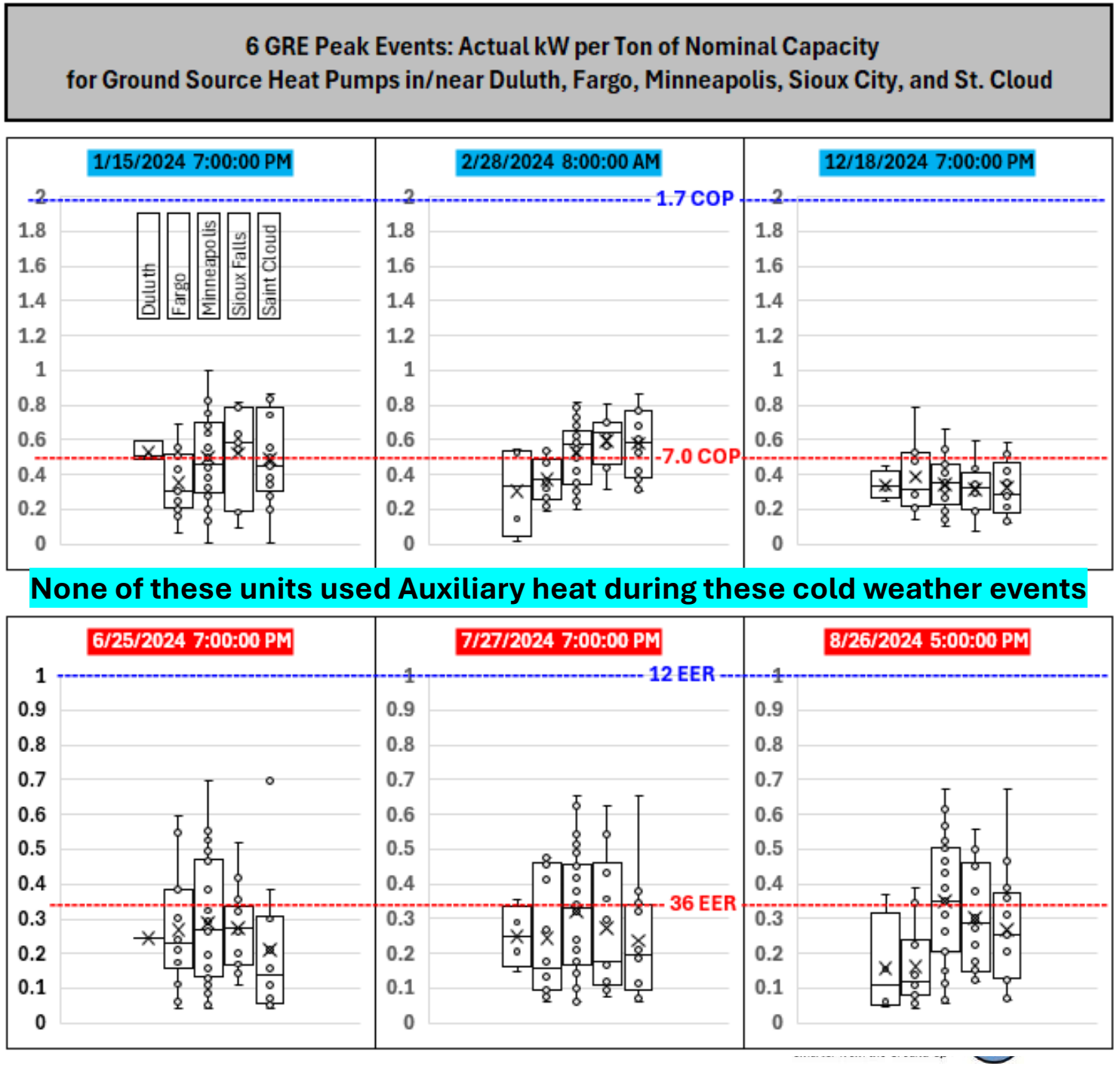
All those numbers were just comparisons of “laboratory testing data.”

Sure, that’s DoE certified and legally binding, but what about real world performance?

In the worst possible conditions?

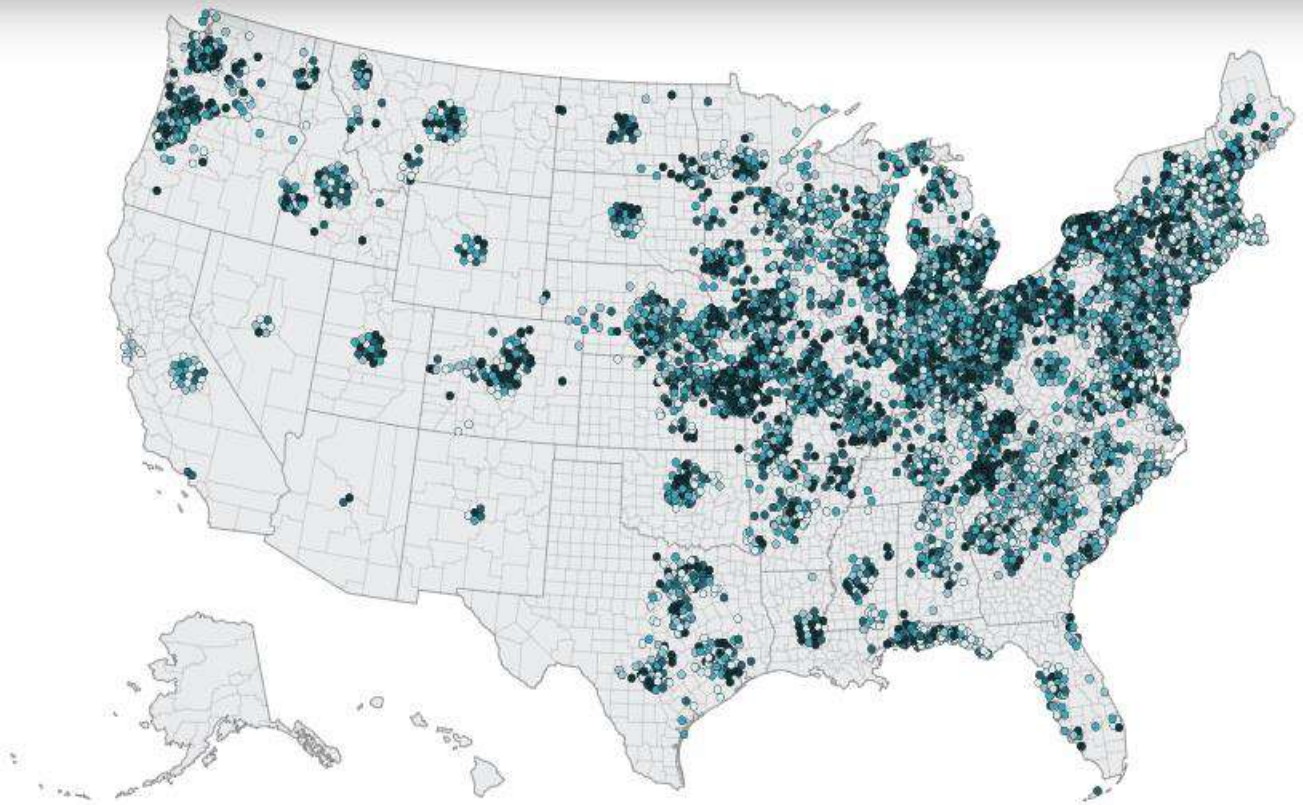
How about the 3 coldest hours and the 3 hottest hours of 2024 in Minnesota?





Symphony Insight

Filters & Settings



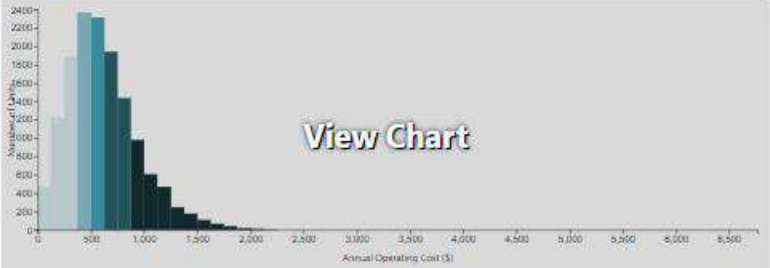
Relative Energy Use

- Low
- Average
- High

Total Annual Averages **Area:** United States **Installs:** 14385

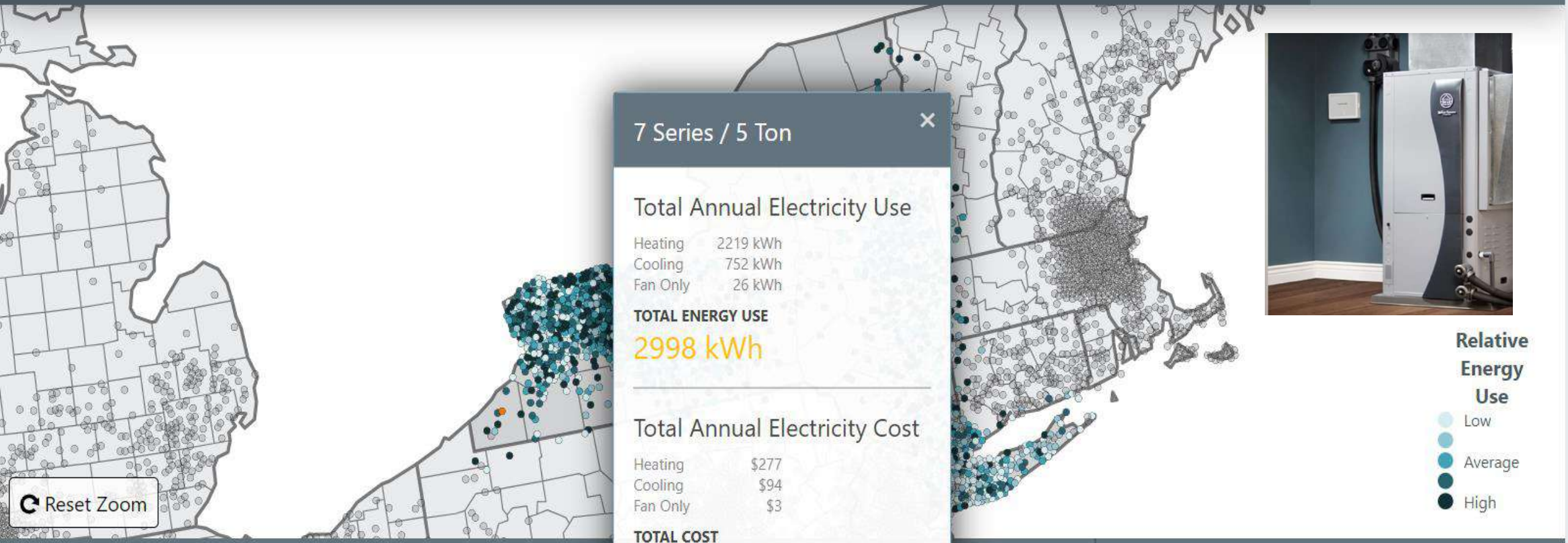
Operating Cost Distribution

HEATING COST	COOLING COST	TOTAL COST	MONTHLY COST
$402	$204	$614	$51



Symphony Insight

Filters & Settings



7 Series / 5 Ton

Total Annual Electricity Use

Heating	2219 kWh
Cooling	752 kWh
Fan Only	26 kWh

TOTAL ENERGY USE

2998 kWh

Total Annual Electricity Cost

Heating	$277
Cooling	$94
Fan Only	$3

TOTAL COST

$375 OR $31/mo

Relative Energy Use

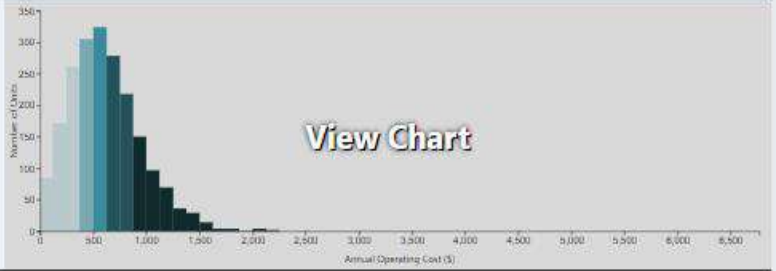
- Low
- Average
- High

Total Annual Averages

Installs: 2048

Operating Cost Distribution

HEATING COST	COOLING COST	TOTAL COST	MONTHLY COST
$514	$98	$618	$52



Complete homeowner awareness and control.

Symphony

DASHBOARD THERMOSTAT WF ENERGY

AID TOOL NOTES HISTORICAL DATA TROUBLESHOOTING

WFI CONSUMER >> WATERFURNACE LAB >> **7 SERIES - TRAINING LAB (MODEL: NVV048A111NTR1KN S/N: 141201725)**

CURRENT STATUS:

4:51 PM Tue 8/4 Eastern

Cooling Speed 3

THERMOSTAT SUMMARY

Zone 1	Zone 2	Zone 3	Zone 4
74° (74° / 62°)	72° (85° / 62°)	74° (85° / 62°)	73° (85° / 62°)
Cool	Off	Cool	Auto

FORT WAYNE, IN

80° / 58°

Current Temp: 80°

Wednesday	83° 58°
Thursday	79° 61°
Friday	82° 58°
Saturday	85° 58°
Sunday	87° 62°

EQUIPMENT SUMMARY

Series: 7 Series
Model: NVV048A111NTR1KN
Serial #: 141201725
Supply Air: 57.9°F

Humidity
Level: 49%
Setpoint: 50%

Comp Speed 3
Fan Motor 5
Aux Elect Heat OFF

CURRENT ENERGY USE

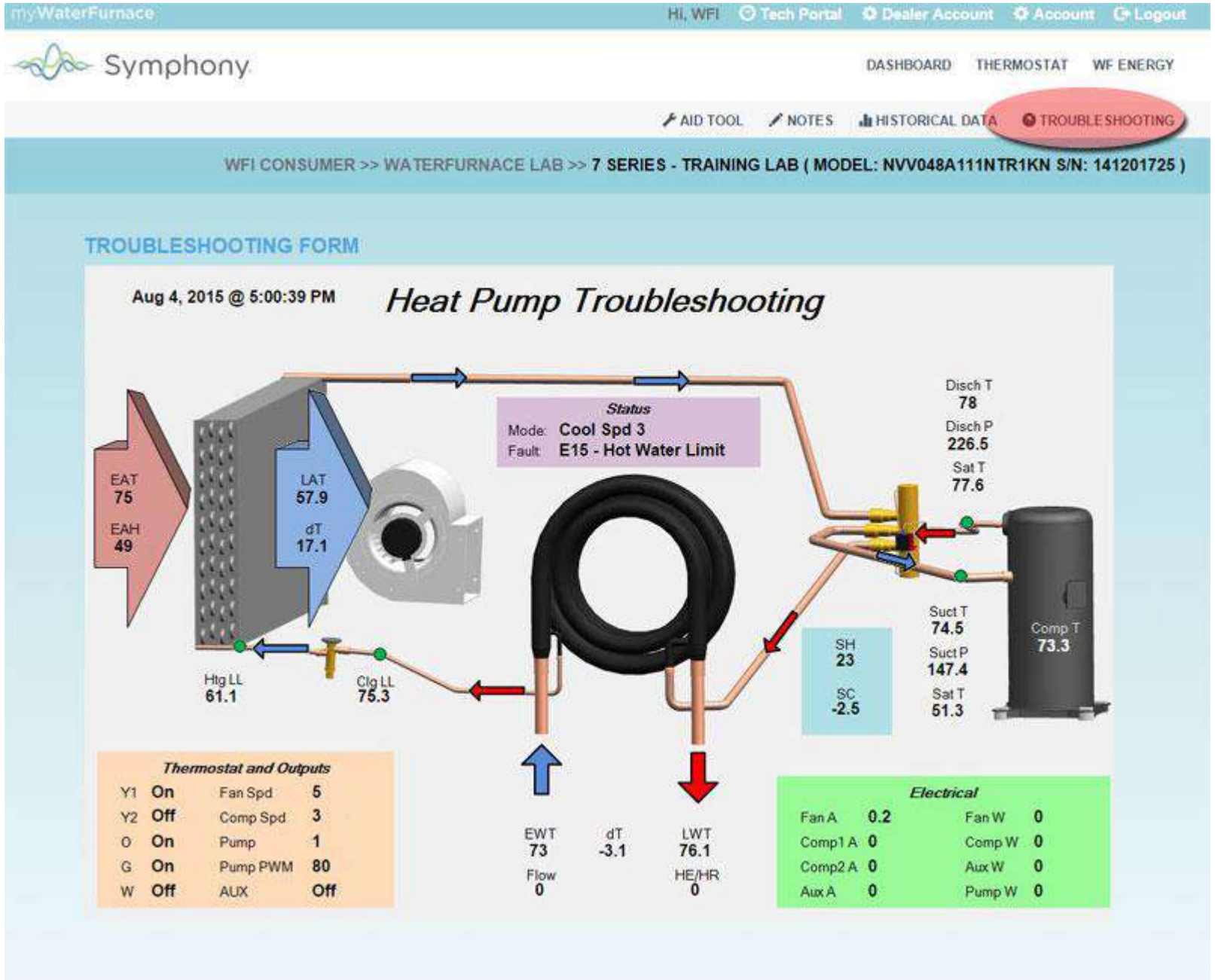
Compressor	Fan Motor	Total Unit Energy
0 W	0 W	0 W

Aux Elect Heat	Loop Pump
0 W	0 W

WaterFurnace
Smarter from the Ground Up™

Complete live access with 12-month history for technical support.

You can find a filter fault from a fjord in Finland or limit a lockout from lounge chair in Lima.



WaterFurnace
Smarter from the Ground Up

Not your grandparents’ heat pump…

Smarter from the Ground Up™

Will Lange
Director of Utility Marketing
will.lange@waterfurnace.com
(260) 442-2814

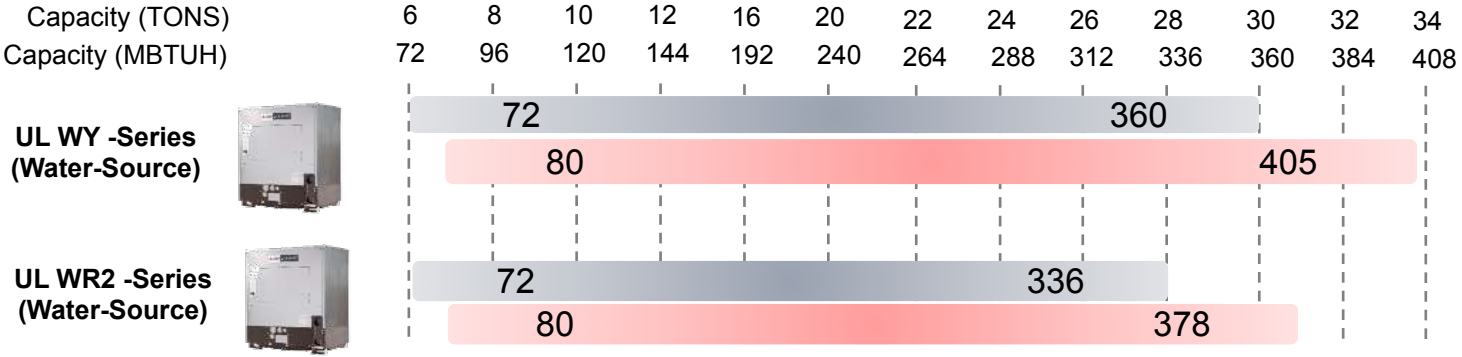
Water Source Considerations

TRANE

MITSUBISHI ELECTRIC

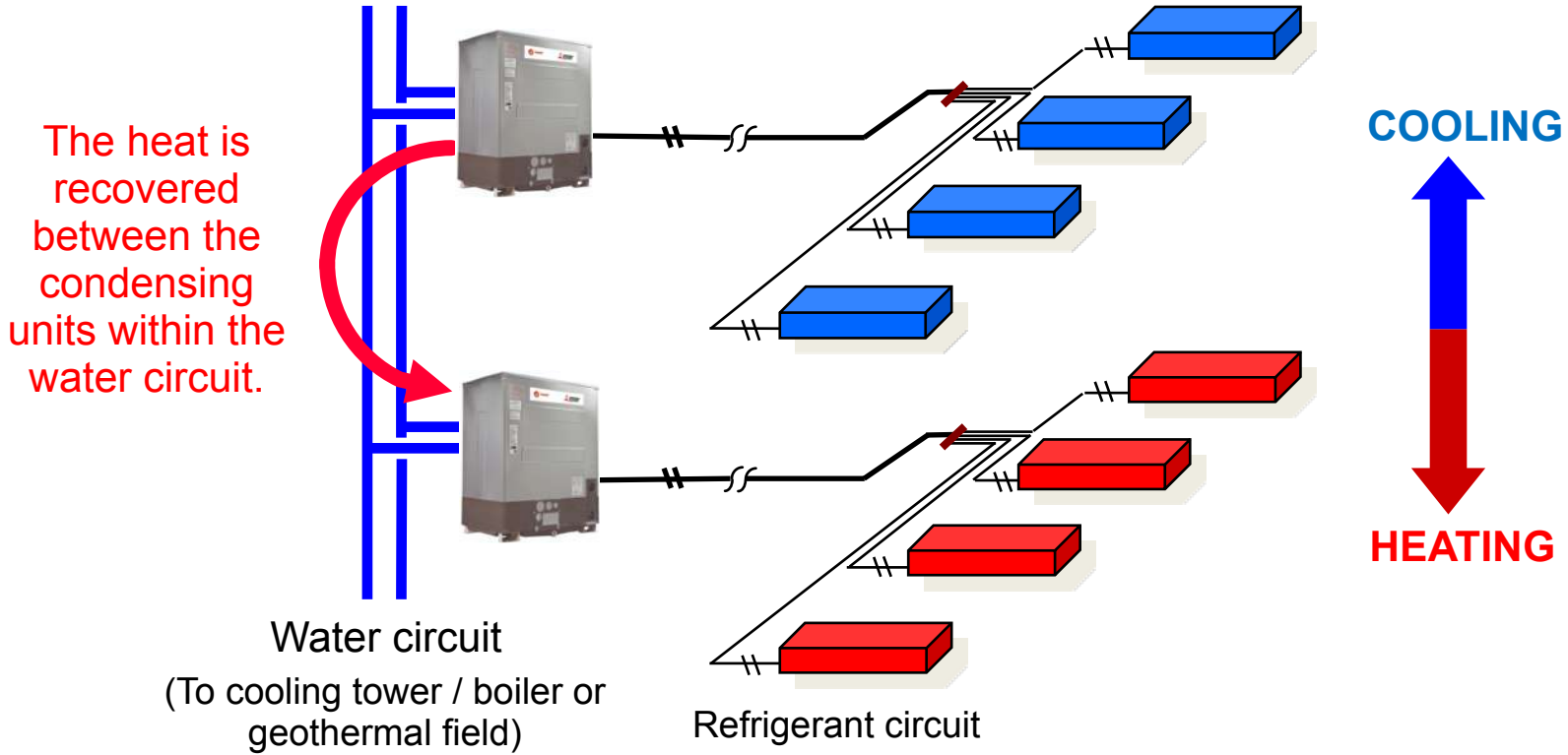
Heat pump and heat pump with heat recovery
Rated capacity:

- WR2 series – up to 28 tons
- WY series – up to 30 tons



WY System Changeover

Water side with WY-Series **Heating** or **Cooling**

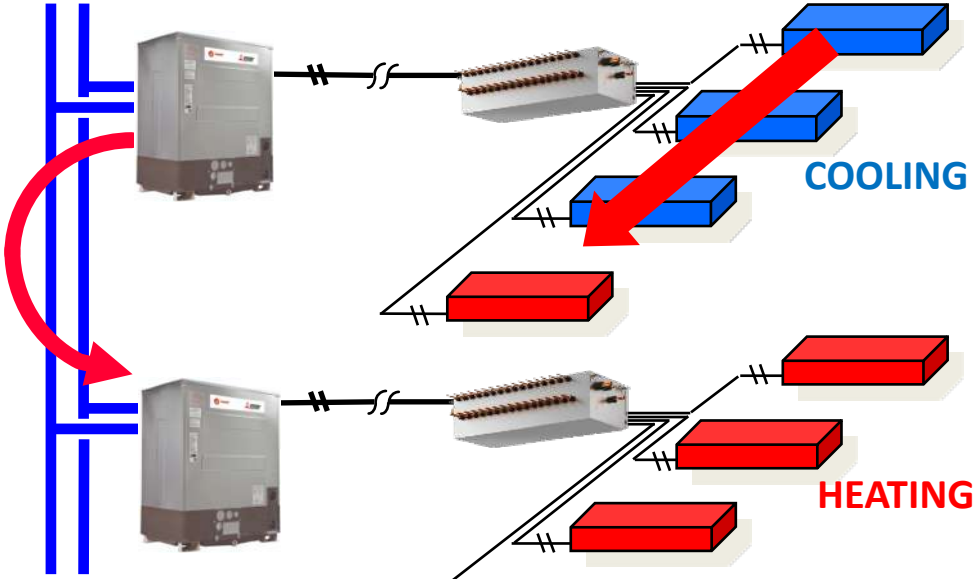


WR2 System Heat Transfer / Heat Recovery

Double heat recovery with the WR2-Series

Heating **and** **Cooling** Simultaneously

The heat is recovered between the condensing units within the water circuit.



Heat is recovered between indoor units within the refrigerant circuit

Water circuit

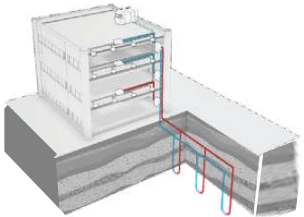
(To cooling tower / boiler or geothermal field)

Refrigerant circuit

Closed Loop Installation

- Consult App Note 2017 and 2031 on www.mylinkdrive.com
- No open tower or direct groundwater applications without a separation heat exchanger

Geothermal



O

Cooling tower

Heat exchanger

Boiler

Water cooled unit

Water-source VRF Systems must be installed in a closed condenser water loop to preserve water quality

Closed Loop Installations

Installations allowed

- Coupled to earth vertical closed loop
- Coupled to earth horizontal closed loop

Installations allowed

- Coupled to a lake or pond closed loop
- Coupled to ground water closed loop

Inlet Water Temperature

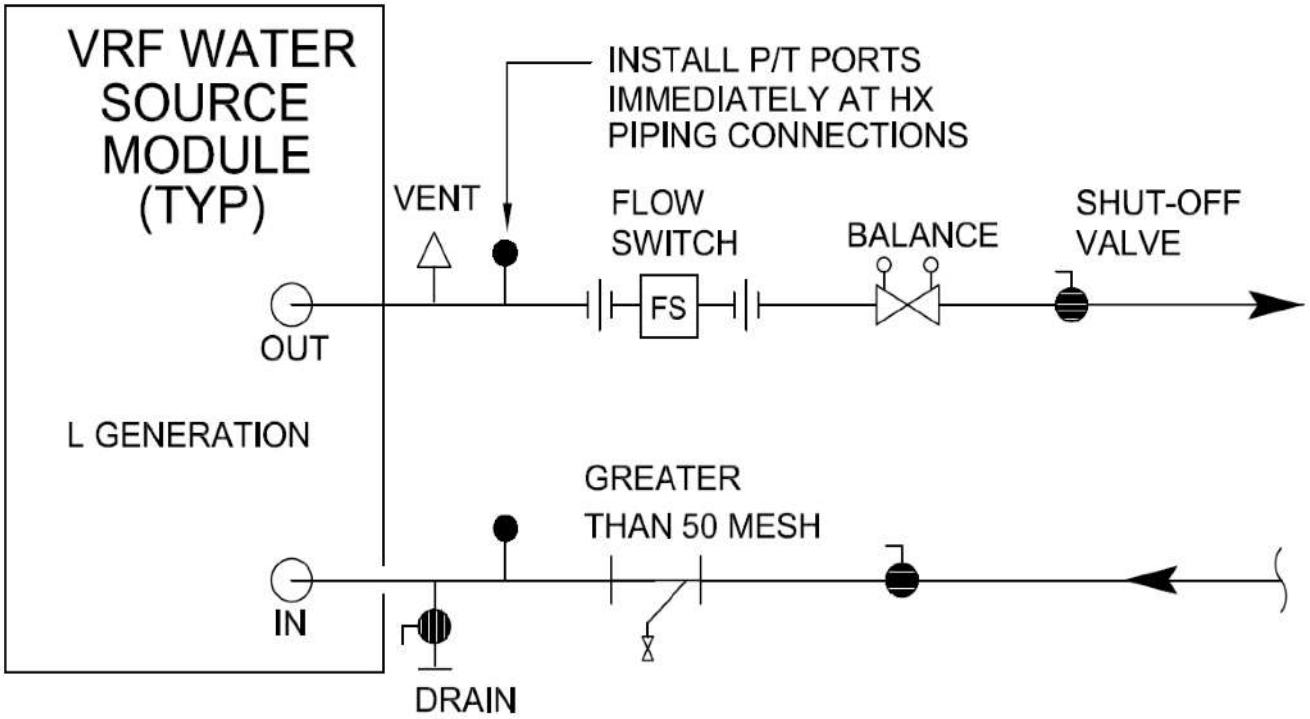
	Cooling Correction Factors					Heating Correction Factors			
Water Temp.	**23º F**	**50º F**	**85º F**	**95º F**	**113º F**	**23º F**	**50º F**	**70º F**	**113º F**
Standard Correction Factor	-	1.00	1.00	.94	.86	-	.84	1.00	1.00
Low Temp. Correction Factor	1.00	1.00	1.00	.94	.86	.65	.93	1.00	1.00

Standard entering water temperature range is 50º F – 113º

Using Low Temperature Correction Factor Requires Glycol

Stacking Water-Source Units

- Twinned water-source modules must be installed at same level
- Field-provided platforms are used to support the upper level of indoor units



All piping specialties shown are FIELD PROVIDED
***Strainer (60 Mesh) Is Critical For HX Protection**

Tower & Boiler Sizing w/ Diversity or Hybrid

Cooling Diversity:

- $$QTower = QBlock + \left(\frac{QBlock}{EER}\right) * 3.412 + Ppump * 2544.43$$
  - $QTower = Tower\ peak\ heat\ rejection$ (btu/hr)
  - $QBlock = Total\ Building\ Block\ Cooling\ Load$ (btu/hr)
  - $Ppump = Pump\ Break\ Horse\ Power$ (HP)

  Use Extreme Caution in Southern Climates with this method!

Heating Diversity:

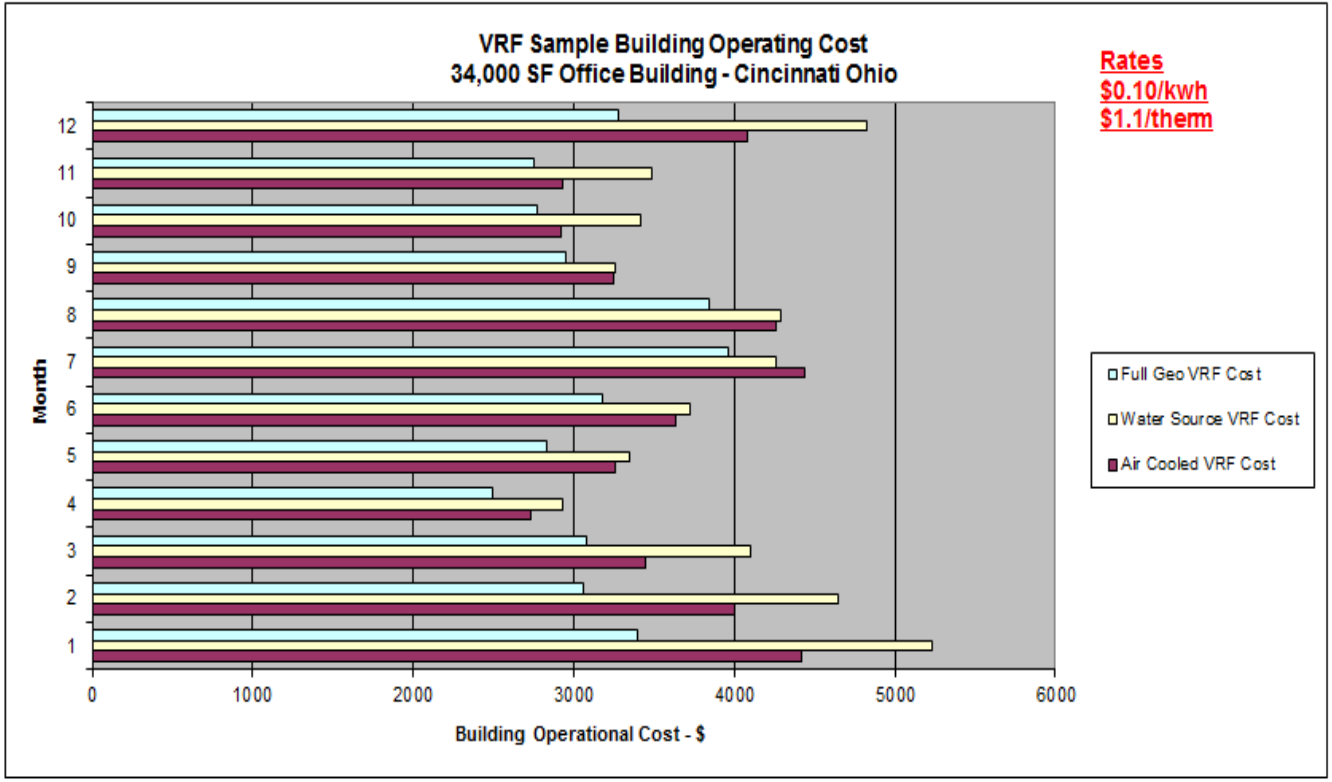
- $$QBoiler = QBlock - \left(\frac{QBlock}{COP}\right)$$
  - $QBoiler = Boiler\ Minimum\ Outpout$ (btu/hr)
  - $QBlock = Total\ Building\ Block\ Heating\ Load$ (btu/hr)

  Use Extreme Caution in Northern Climates with this method!

Why Use WS VRF vs AS VRF?

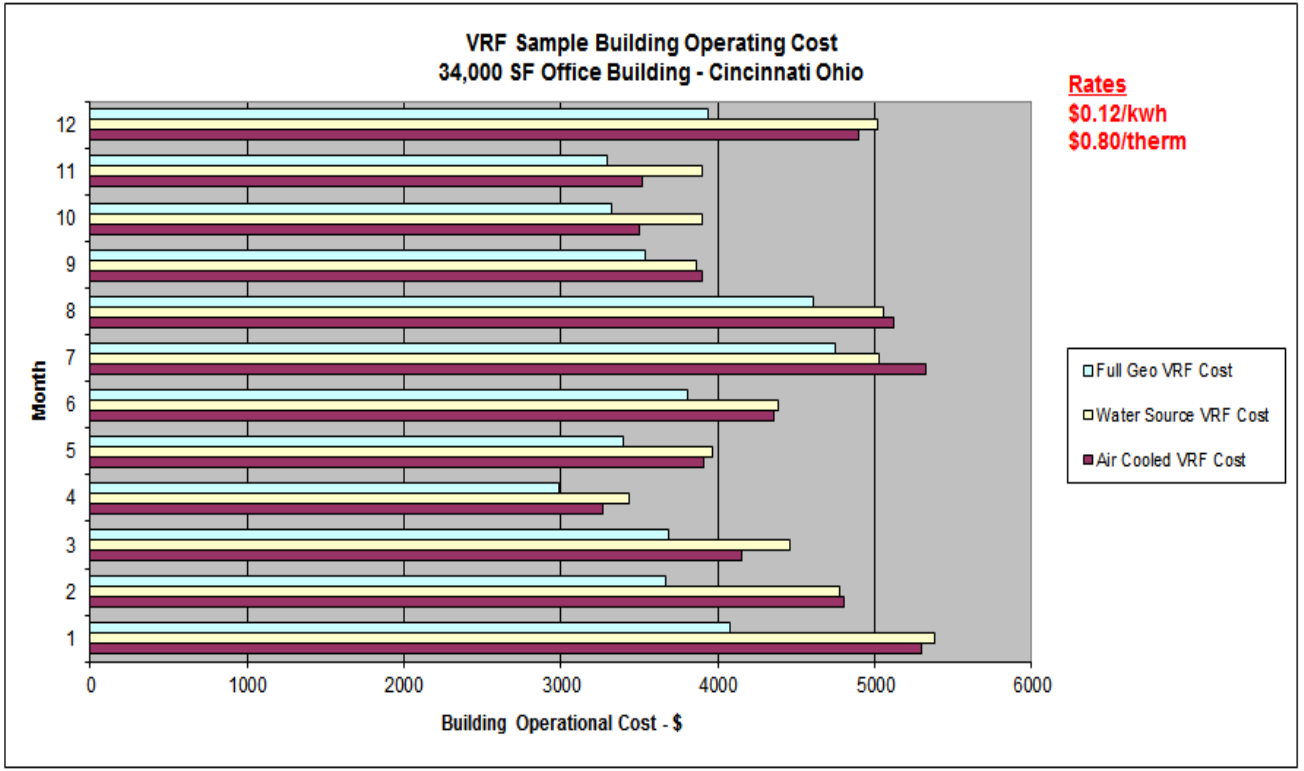
- **High Rise Applications over 130 Ft / 160 Ft mark (OU below/above):**
  - Limited ground/roof space to accommodate all air source modules.
  - Affects on operating range, oil return issues, compressor longevity with Air Source when using extended vertical height (Med Pressure Kits, now built into N gen air source)
- **Cold Climate Applications:**
  - ***Cost of gas vs electric heat ?***
  - **Elimination of ambient de-rates (with boiler / tower designs).**
    - 24-7/Assisted Living / Elderly Care in extreme cold climates.
  - **Requirements for redundant backup heat.**
    - Difficult to do at zone level with air source – easy for boiler / tower WS.
  - No aux. heat control hysteresis with CN24 offsets.
- **Projects driven towards Geothermal:**
  - ***Ultimate efficiency / Highest Cost!***
  - **Hybrid Geo (Cooling Dominant Profiles) with tower to trim peaks can offer significant well field cost reduction!**

How Does Water Source VRF Compare?



Full Geo VRF Yearly Cost	$37,590.00	
Boiler Tower Water Source VRF Yearly Cost	$47,520.00	26% Savings switching to full Geo VRF
Air Cooled VRF Yearly Cost	$43,370.00	13% Savings switching to full Geo VRF

How Does Water Source VRF Compare?



Full Geo VRF Yearly Cost	$45,100.00	
Boiler Tower Water Source VRF Yearly Cost	$53,190.00	18% Savings switching to full Geo VRF
Air Cooled VRF Yearly Cost	$52,060.00	13% Savings switching to full Geo VRF

Water Source VRF /Geothermal Advantages

- Wide Temp Range – Up to 113 deg F inlet water temp – well field sizing !
- Reduced Compressor quantity / maintenance
- Reduced electrical feeds in building distribution vs conventional WSHP systems (modules up to 20 tons)
- Ability to size more for block load vs sum of peaks
  - Less nominal total installed tonnage.
- More flexibility on connected capacity vs air cooled VRF.
- Usually no need for auxiliary heat or large heating de-rates as with air cooled.

Why Are Geothermal Heat Pump Systems Usually Cooling dominated?

Even Balanced buildings (heating load vs cooling load) are net positive with respect to ground…..

Cooling Performance Heat Rejection

1 Ton Cooling + 0.3 Tons Compressor = 1.3 Tons Heat Rejection

Heating Performance Heat Absorption

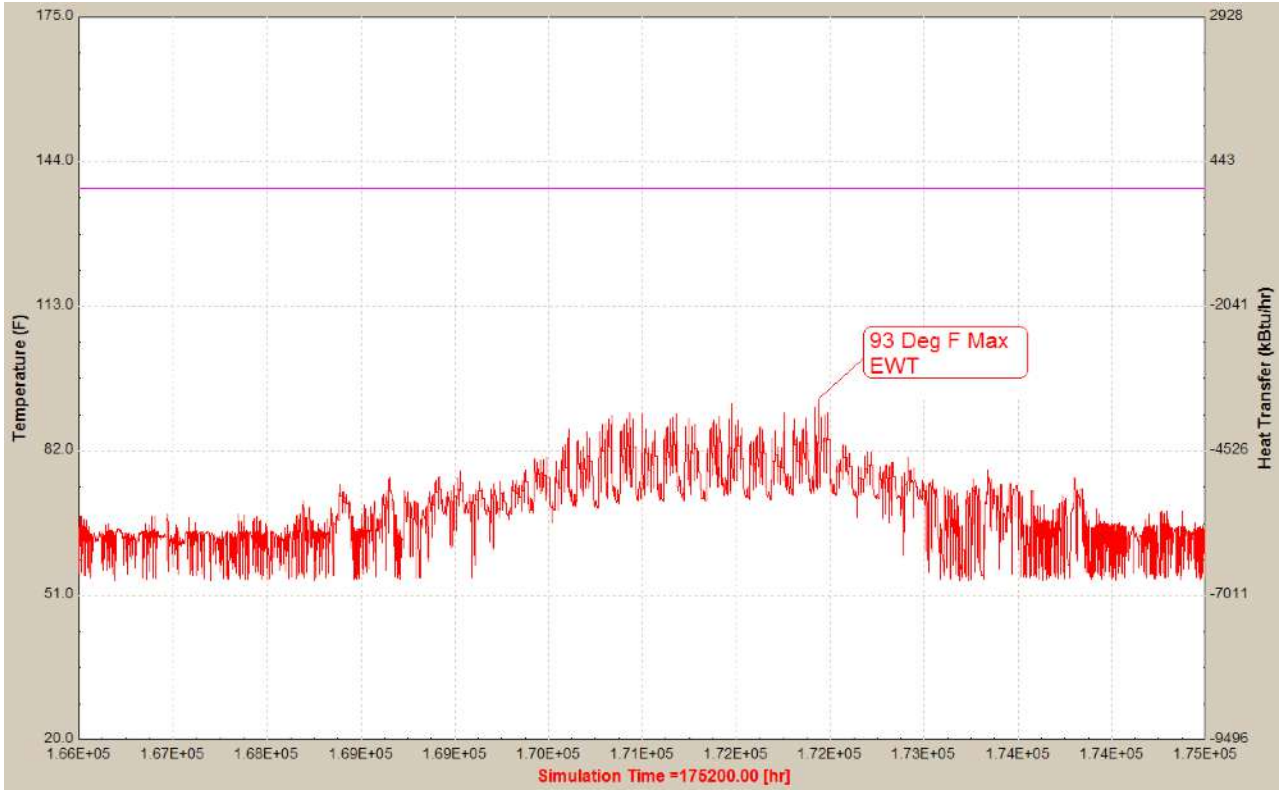
1 Ton Heating = 0.77 Tons Geo Loop + 0.23 Tons compressor Heat

Well Field Profile – Year 20

St. Louis, MO

School, 92,000 ft2, 9 month occupancy (1271/1136 MMbtu/yr of cooling/heating):
Aprox. 200 Tons

117 Wells, 300 ft Deep, 20 ft o.c.



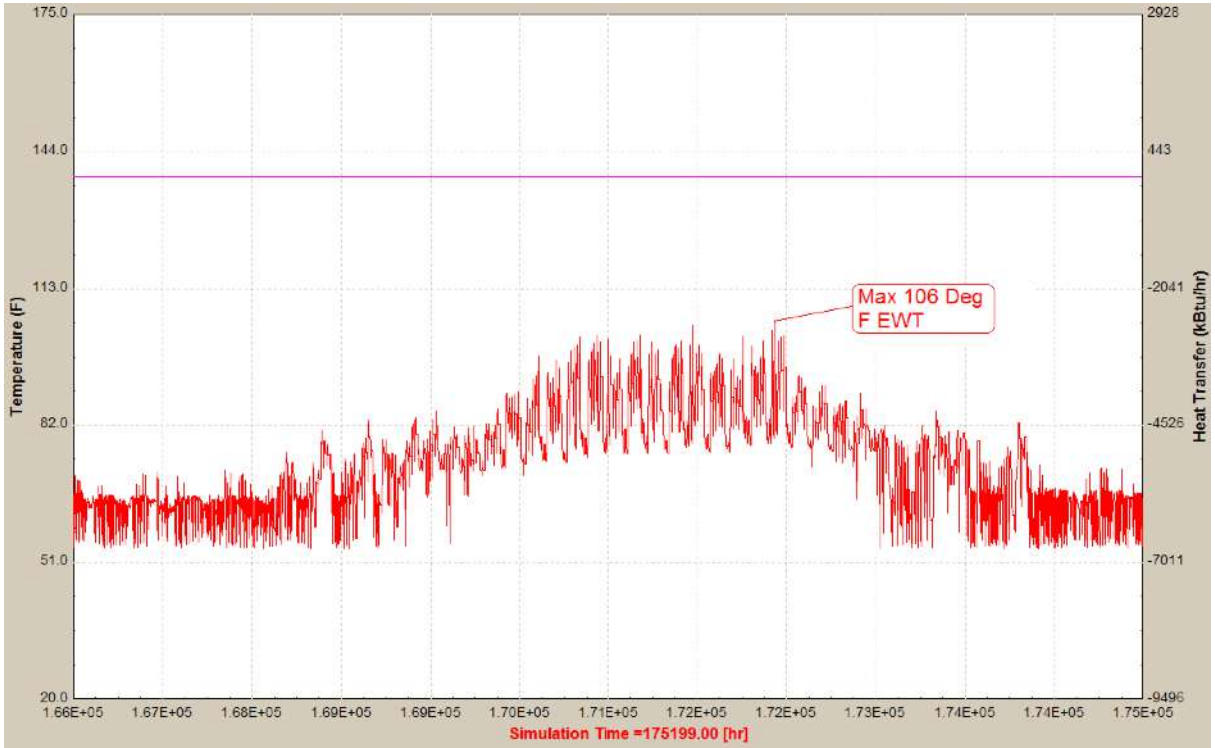
Well Field Profile – Year 20

St. Louis, MO

School, 92,000 ft2, 9 month occupancy (1271/1136 MMbtu/yr of cooling/heating):
Aprox. 200 Tons

85 Wells, 300 ft Deep, 20 ft o.c.

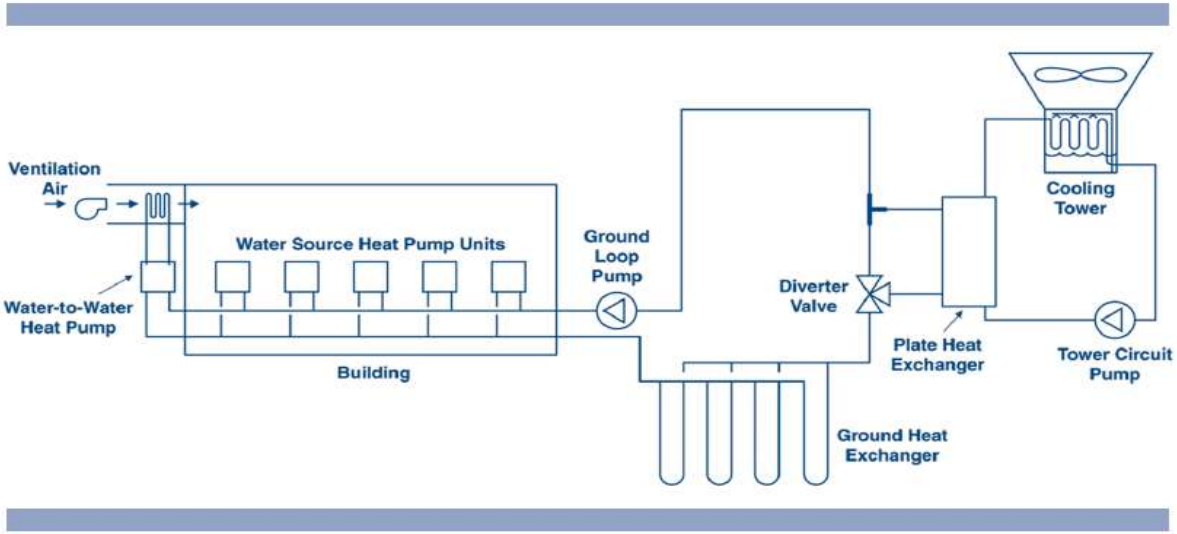
Approximately 9600 Ft of Bore Hole Saved!



Hybrid Geothermal Study Example:

Federal Energy Management / DOE

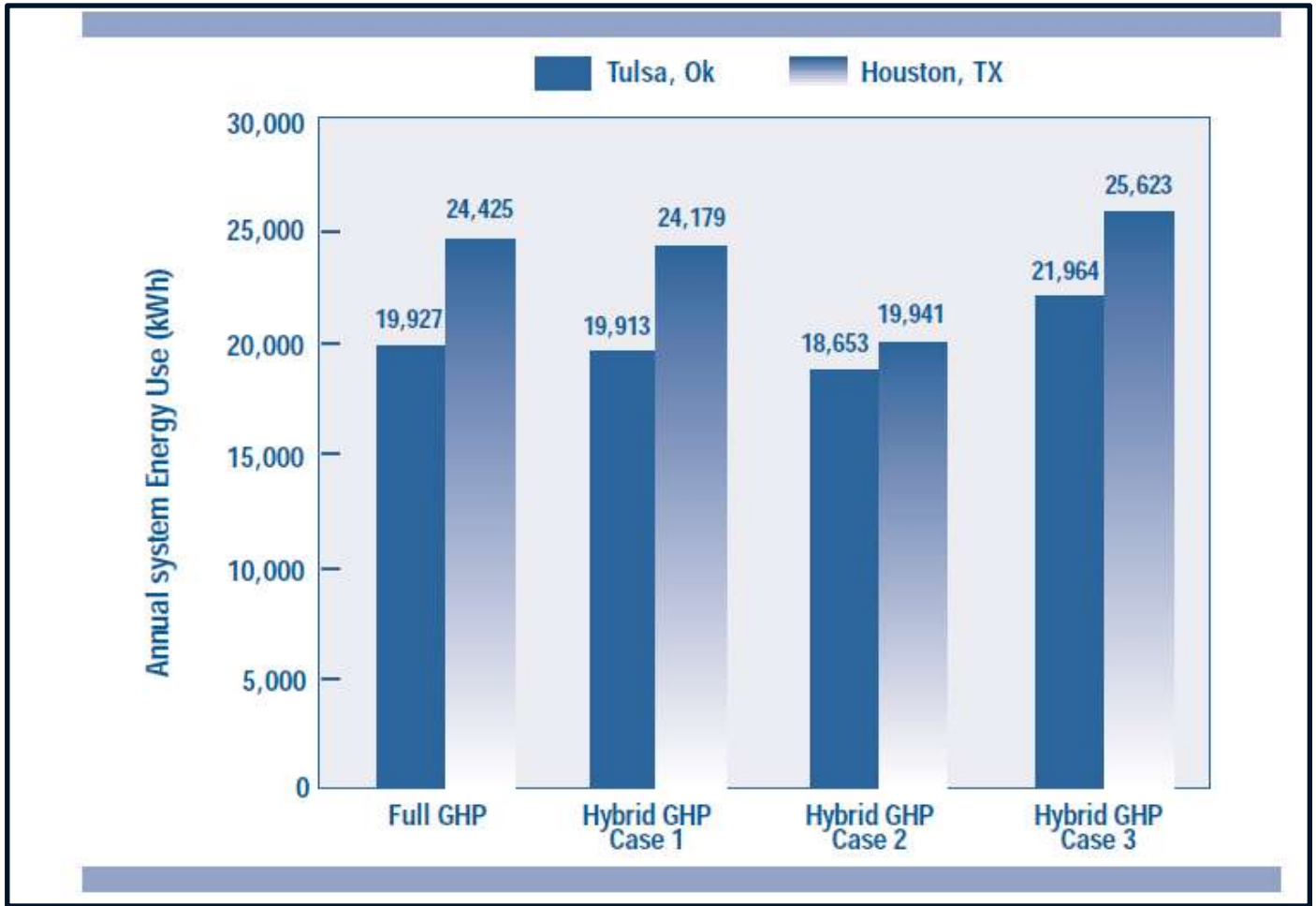
14,000 SF Office Building



Base Case: **Full Geothermal**

Case #1: Tower activated when LWT from building HP's exceeds 96.5 F
Case #2: Tower activated when LWT from building HP's exceeds ambient WB by 3.6F
Case #3: Tower activated on schedule to avoid long term temp rise, 6 hours daily from midnight to 6 am.

Hybrid Geothermal Study Example:



Hybrid Geothermal Study Example Houston Texas:

Table 1. Summary of Hybrid GHP case study for 14,025 ft² office building in Houston, Texas (from Yavuzturk 2000)

Heating degree-days = 1434; Cooling degree-days = 2889 Annual heating load = 7.5 million Btus Annual cooling load = 181.6 million Btus*

	Base case—no cooling tower	Hybrid Case 1[1]	Hybrid Case 2[2]	Hybrid Case 3[3]
Number of boreholes in ground heat exchanger	36 @ 250 ft	12 @ 250 ft	12 @ 250 ft	12 @ 250 ft
Cost of ground heat exchanger[4]	$54,000	$18,000	$18,000	$18,000
Maximum fluid temperature entering heat pumps in 20-year period (°F)	96.6	96.3	80.5	96.0
Minimum fluid temperature entering heat pumps in 20-year period (°F)	71.3	67.3	40.5	54.1
Design capacity of cooling tower (tons)		22.5	11.5	8.5
Cost of cooling tower and plateheat exchanger including controls and auxiliary equipment[5]	-	$8,662	$4,427	$3,272
Total cost of ground heat exchanger and cooling tower equipment	$54,000	$26,662	$22,427	$21,272
Present value of 20 years of electricity costs[6]	$19,611	$19,413	$16,011	$20,573
Present value of total costs	$73,611	$46,075	$38,438	$41,845
Annual energy use (kWh)				
Heat pumps	24,425	23,877	17,792	24,453
Cooling tower fan	-	260	1,847	1,006
Cooling tower pump	-	42	302	164
Total system	24,425	24,179	19,941	25,623

Hybrid Geothermal Study Example
Tulsa Oklahoma:

Table 2. Summary of Hybrid GHP case study for 14,025 ft² office building in Tulsa, Oklahoma (from Yavuzturk 2000)

Heating degree-days = 3680; Cooling degree-days = 1949 Annual heating load = 50.1 million Btus Annual cooling load = 133.8 million Btus*

	Base case—no cooling tower	Hybrid Case 1[1]	Hybrid Case 2[2]	Hybrid Case 3[3]
Number of boreholes in ground heat exchanger	16 @ 240 ft	9 @ 240 ft	9 @ 240 ft	9 @ 240 ft
Cost of ground heat exchanger[4]	$23,040	$12,960	$12,960	$12,960
Maximum fluid temperature entering heat pumps in 20-year period (°F)	96.4	96.9	79.0	97.9
Minimum fluid temperature entering heat pumps in 20-year period (°F)	50.2	39.8	24.2	39.2
Design capacity of cooling tower (tons)	-	17.0	11.0	5.5
Cost of cooling tower and plate heat exchanger including controls and auxiliary equipment[5]	-	$6,545	$4,235	$2,118
Total cost of ground heat exchanger and cooling tower equipment	$23,040	$19,505	$17,195	$15,078
Present value of 20 years of electricity costs[6]	$15,999	$15,988	$14,976	$17,595
Present value of total costs	$39,039	$35,493	$32,171	$32,672
Annual energy use (kWh)				
Heat pumps	19,927	19,813	16,463	20,769
Cooling tower fan	-	86	1,882	984
Cooling tower pump	-	14	308	161
Total system	19,927	19,913	18,653	21,914

Resources

APPLICATION NOTES

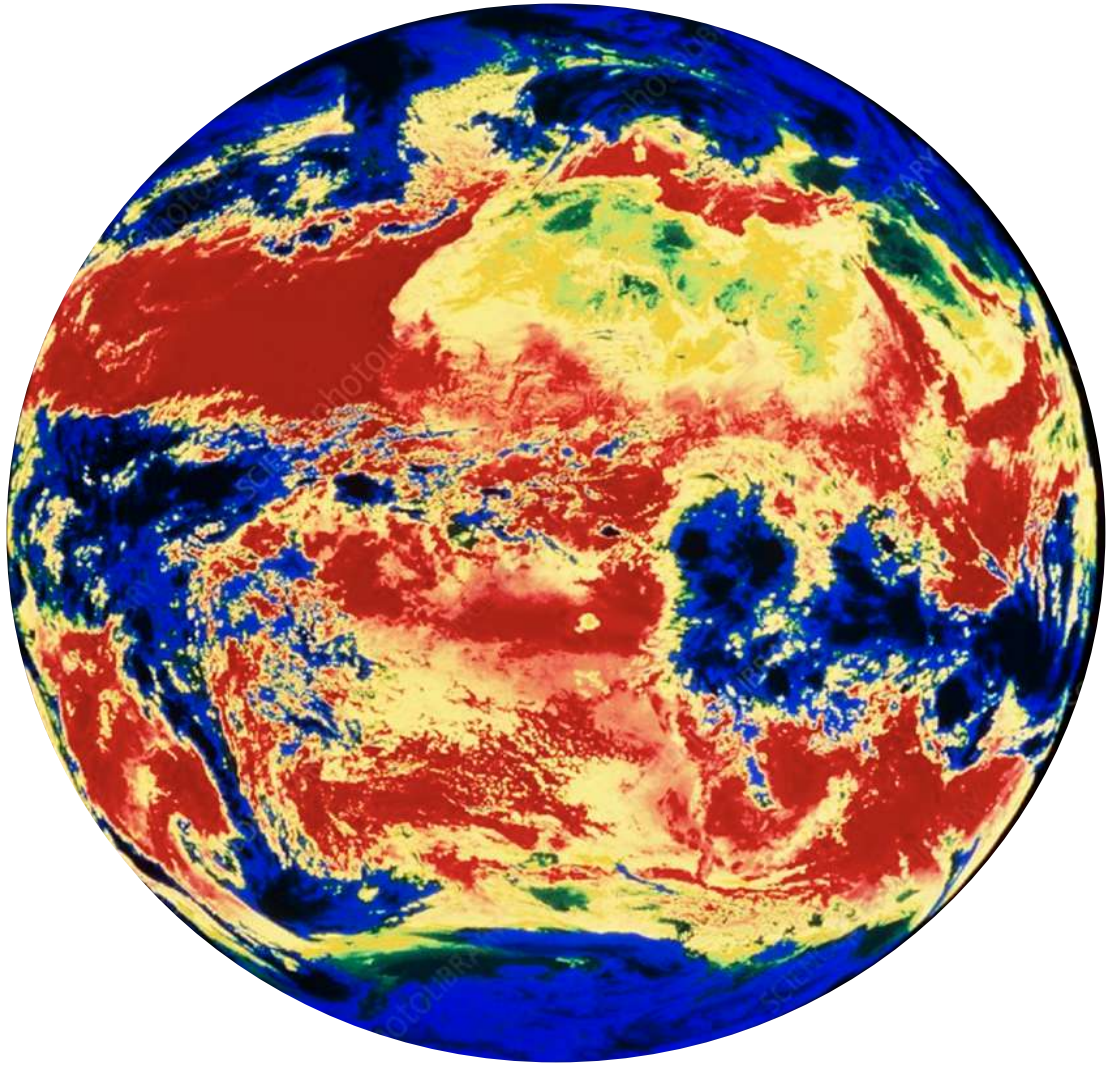
Application Note 2031:
Variable Condenser Water Flow Control
on L Generation Water Source VRF

Application Note 2017:
Water Source VRF Application Guide

heet

THINK THERMAL, TOGETHER

February 2025



THINK THERMAL ?

“The technical potential of geothermal would be more than enough to meet all heat demand in Africa, China, Europe, Southeast Asia, and the United States.”

- IEA December 2024

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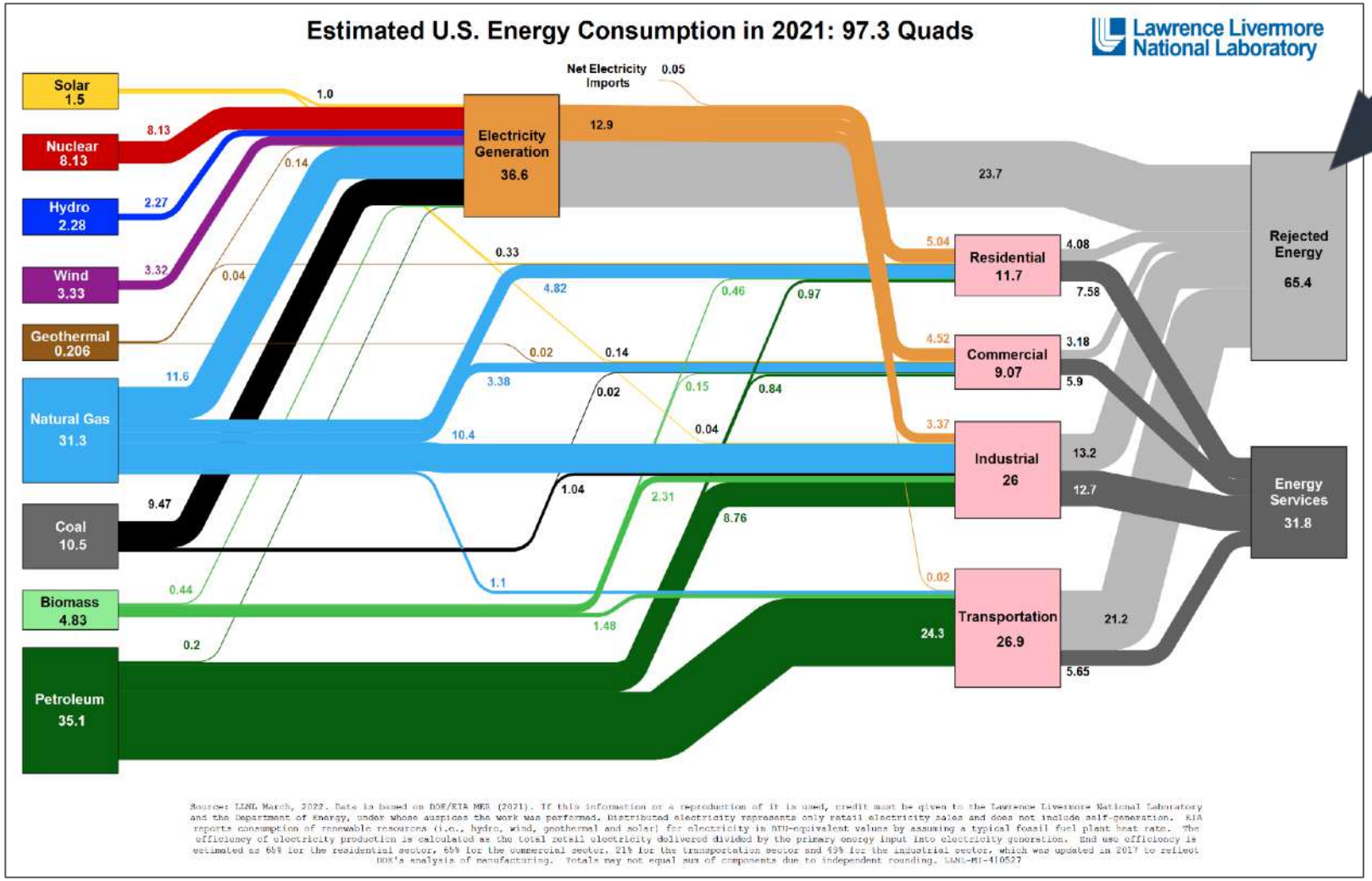
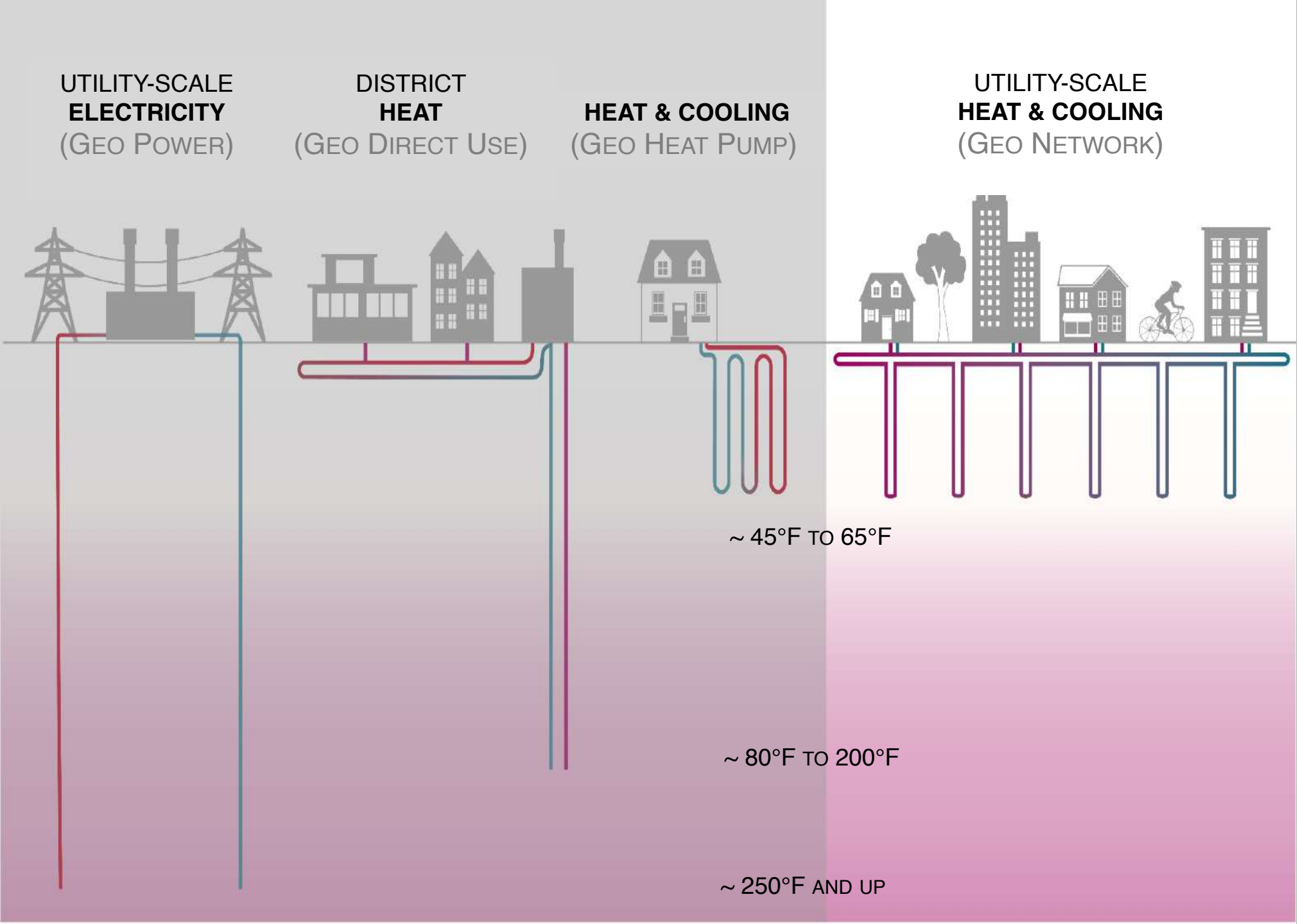


Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

The majority of the energy we use is wasted, much of it is

Thermal energy.

heet



GEOTHERMAL ?

All Geothermal Technologies provide STABLE non-intermittent energy

- Shallow or Deep
- Ambient or Hot
- Everywhere or Not

heet

Engage All Stakeholders

MOVES AT SPEED OF TRUST

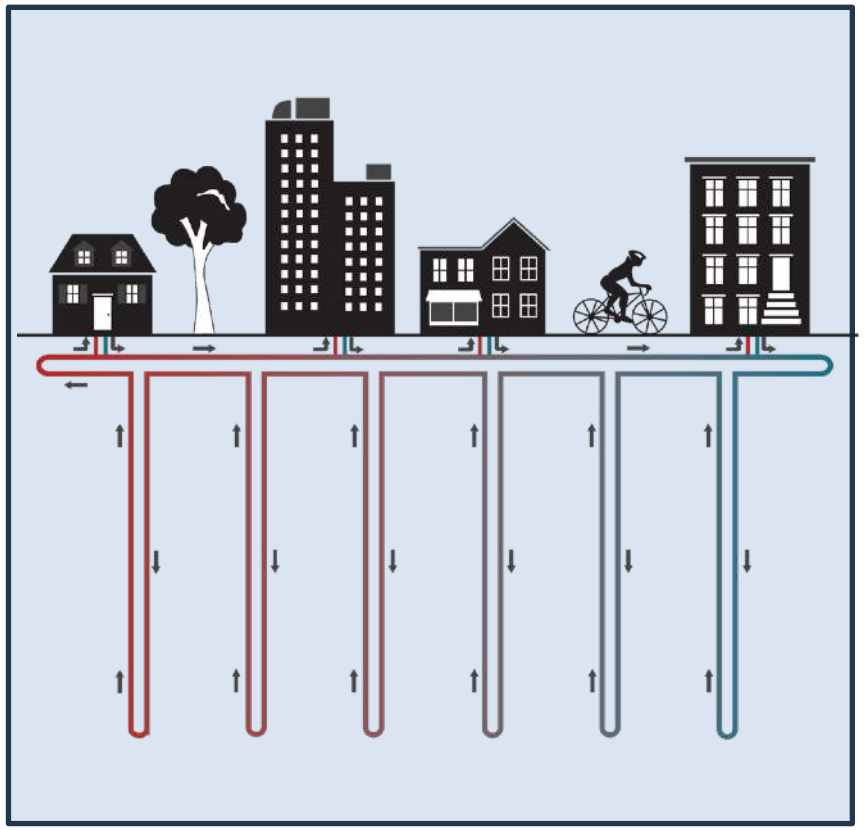
Identify Leverage Points

Innovate & Iterate

HEET's Approach to Designing & Driving Systems Change

Used to develop Geothermal Energy Networks & the Gas to Geo Pathway for gas system decarbonization

heet

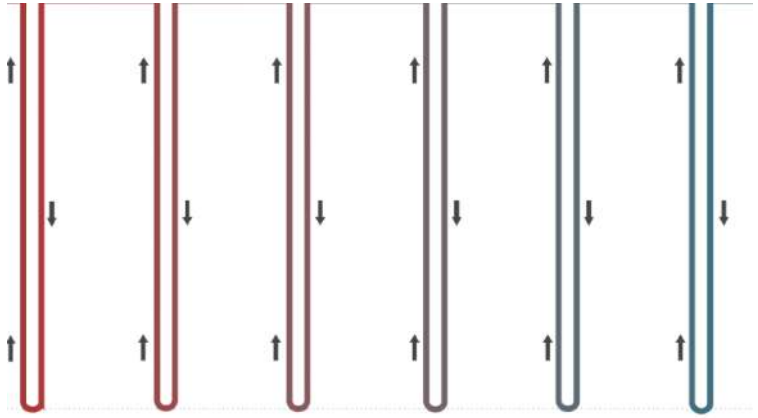


- ☐ High Safety & Security
- ☐ 100% Combustion-Free
- ☐ Reliable & Resilient
- ☐ Scalable & Adaptable
- ☐ Workforce just transition
- ☐ Equitable access
- ☐ Affordable for consumer
- ☐ Economic for utility
- ☐ Speed & Scale needed
- ☐ Benefits Electric Grid
- ☐ Reduces Water Use

heet

BUILDINGS :
(GEOTHERMAL HEAT PUMP)

DISTRIBUTION SYSTEM:
(THERMAL ENERGY NETWORK)



THERMAL ENERGY RESOURCES

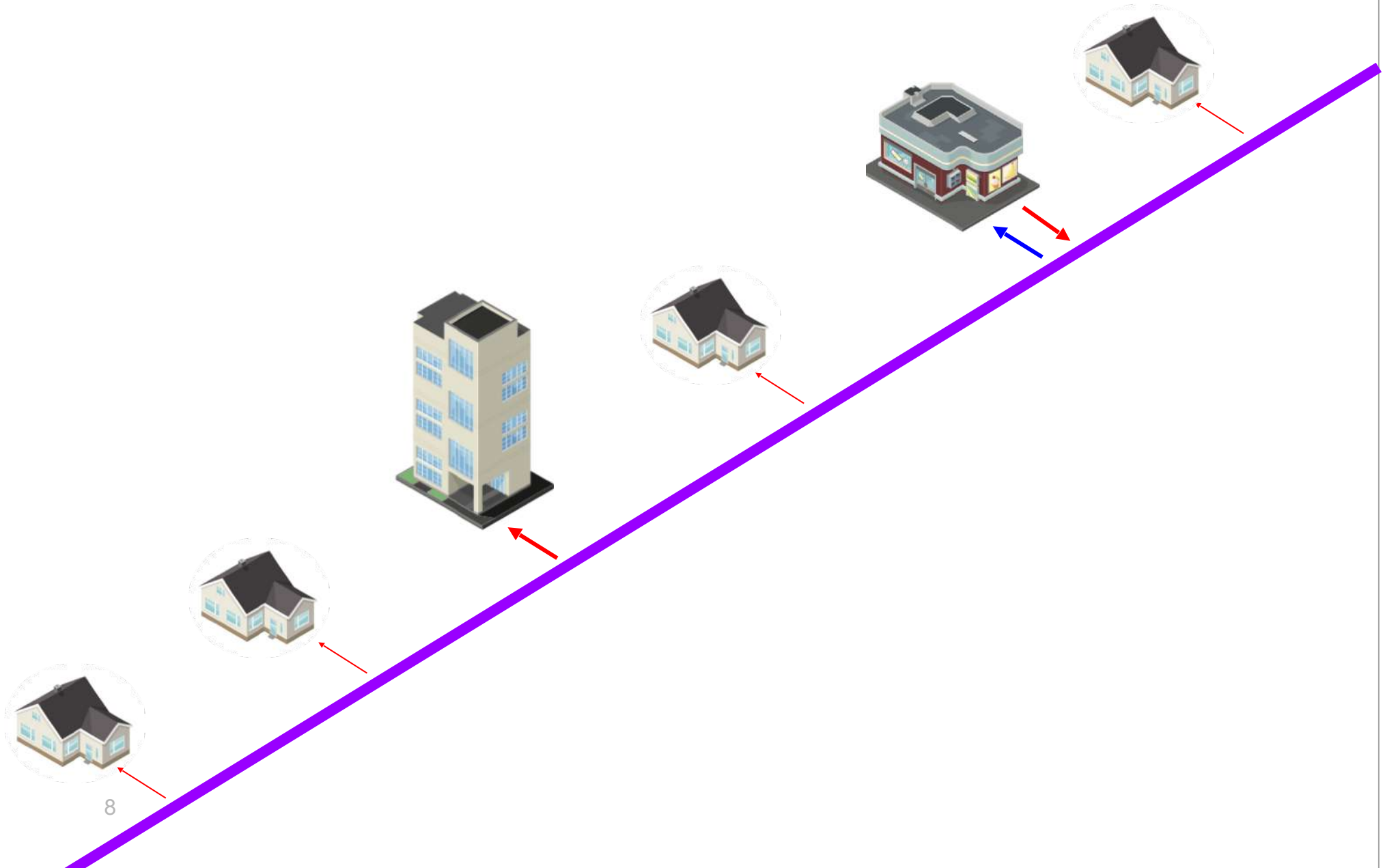
- GEOTHERMAL BOREHOLES
- WASTEWATER EXCHANGE
- INDUSTRIAL WASTE HEAT
- LAKES, RIVERS, PONDS
- A MILLION OTHER THERMAL OPPORTUNITIES . . .

Components of a Thermal Energy Network each contribute efficiencies

Each component is OLD TECH.

Together they are NEW TECH.

heet

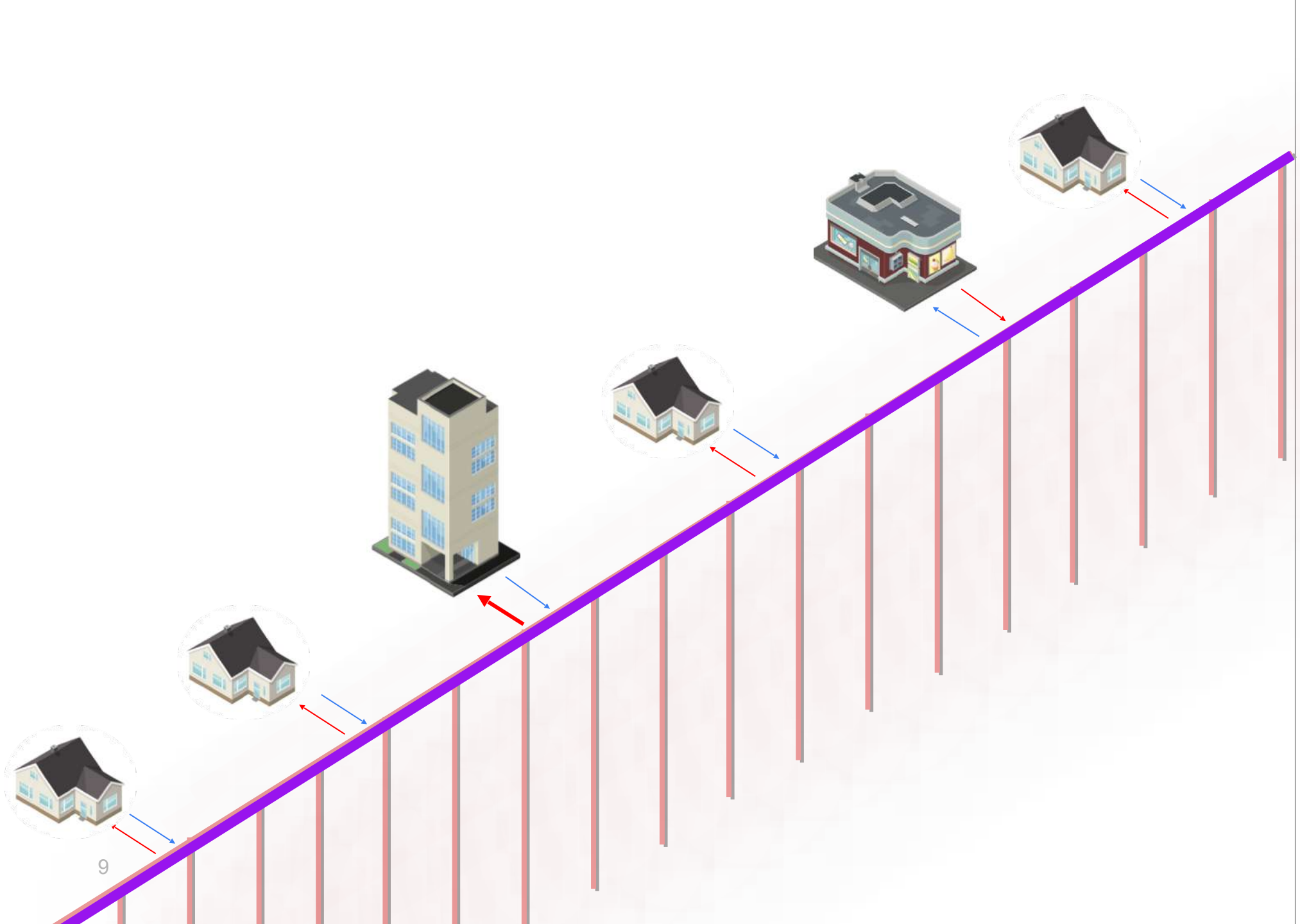


Energy Reuse or
‘Load Cancelling’

(hours)

? Ambient temp

heet



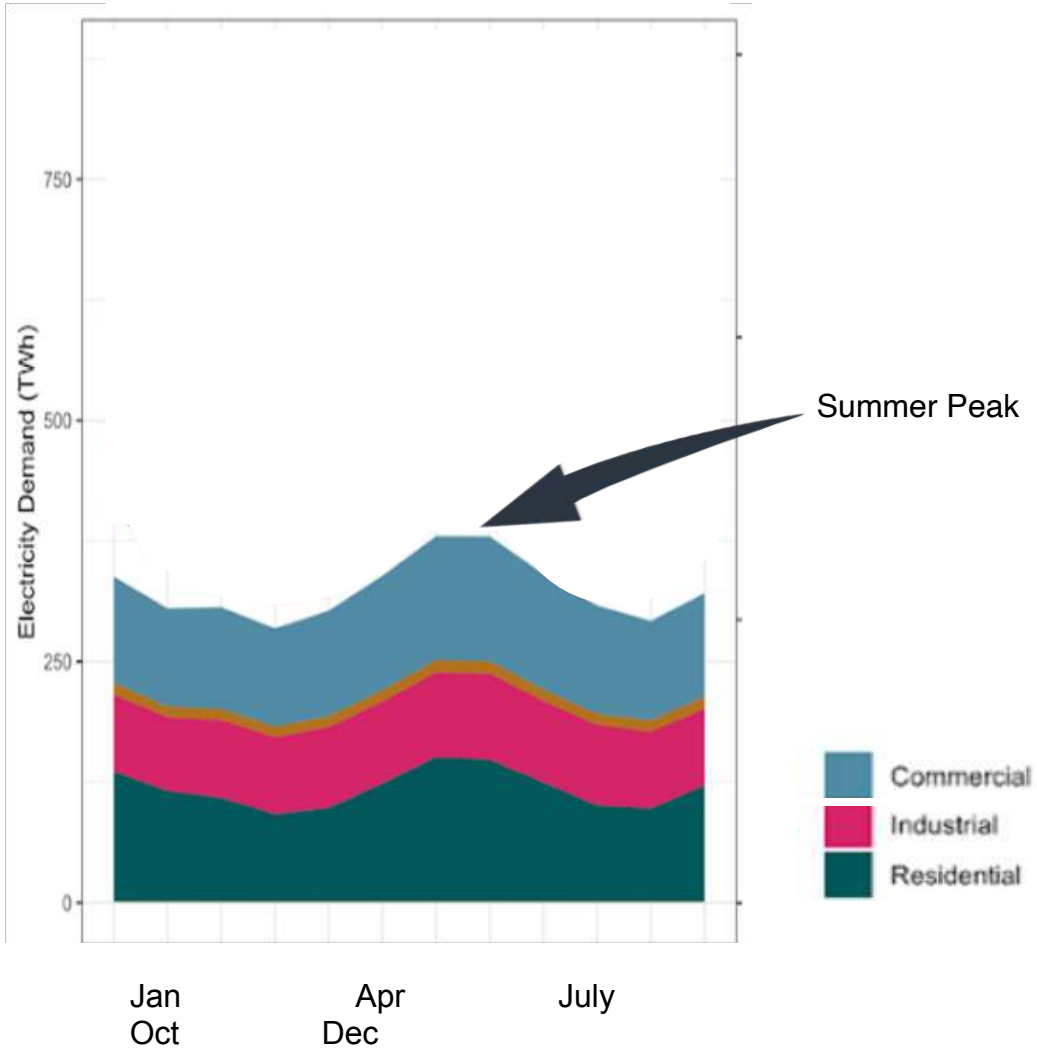
Energy Reuse or ‘Load Cancelling’

(months)

- ? Ambient temp
- ? Geothermal or other thermal storage

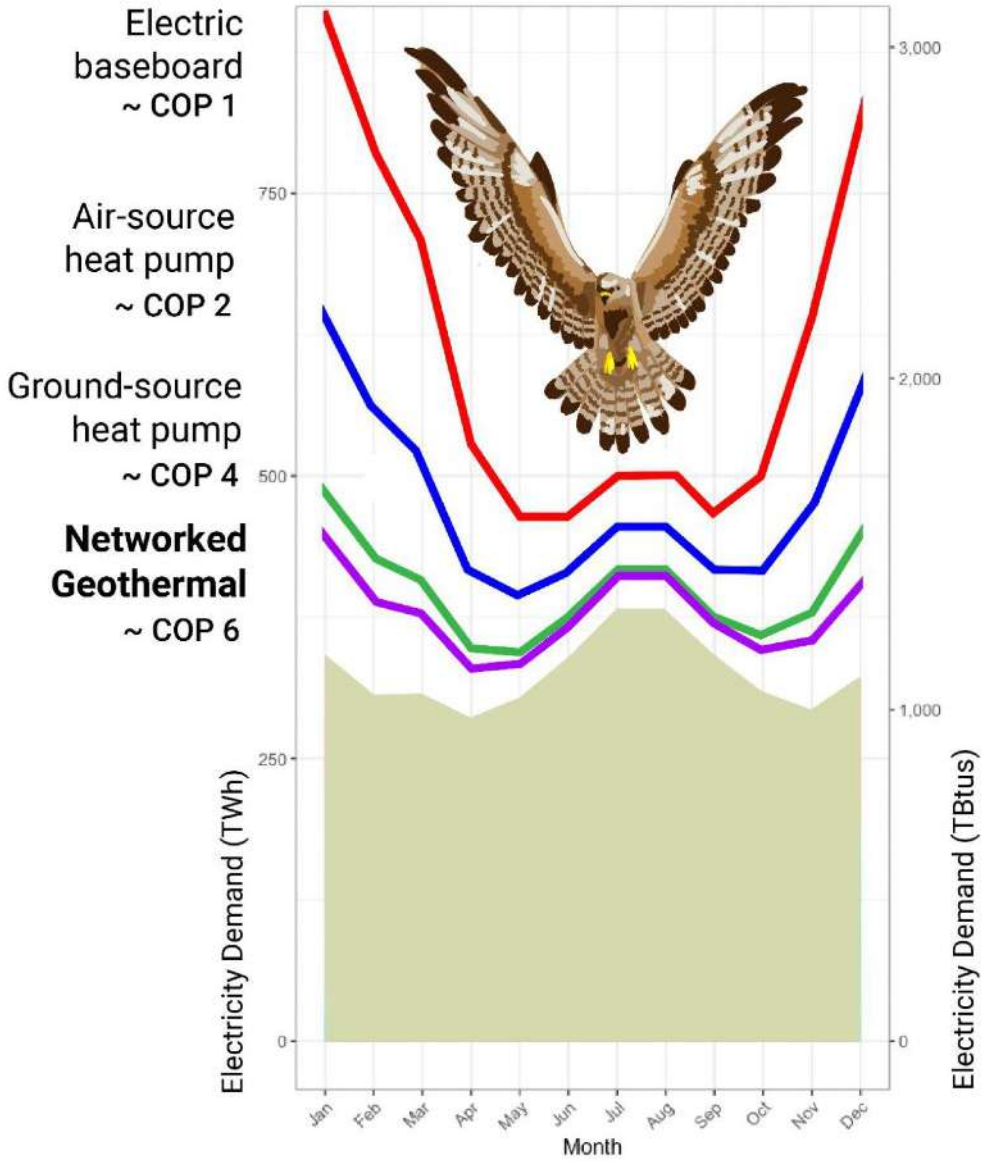
heet

Current US Seasonal Electric Peaks



What effect will electrification have on electric peaks?

Buonocore, J., Salimifard, P., Magavi, Z., Allen, J., "The Falcon Curve: Implications of Seasonal Building Energy Use and Seasonal Energy Storage for Healthy Decarbonization" DOI: 10.21203/rs.3.rs-1054606/v1



The Falcon Curve:

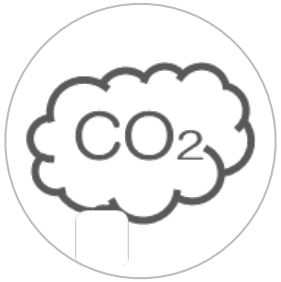
The effect of building electrification on our future electric grid, by technology.

Networked geothermal minimizes the "build-out" of our electric grid

Buonocore, J.J., Salimifard, P., Magavi, Z. *et al.* Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage. *Sci Rep* 12, 11931 (2022).

Cumulative U.S. savings > $1.5 Trillion (NPV)

CO_2E SAVED
7.34 MMTs



FEWER TRANSMISSION LINES
38% reduction

LESS GENERATION NEEDED
13% reduction

FUEL COST SAVINGS
$19 Billion/year

CHEAPER WHOLE SALE ELECTRICITY
12% reduction

ELECTRIC GRID IMPACT of Geothermal Heat Pump 'Mass' Deployment

Liu, X., Ho, J., Winick, J., Porse, S., Lian, J., Wang, X.,, Liu, W.,, Malhotra, M., Li, Y.,, & Anand, J.,. Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States. United States. https://doi.org/10.2172/2224191

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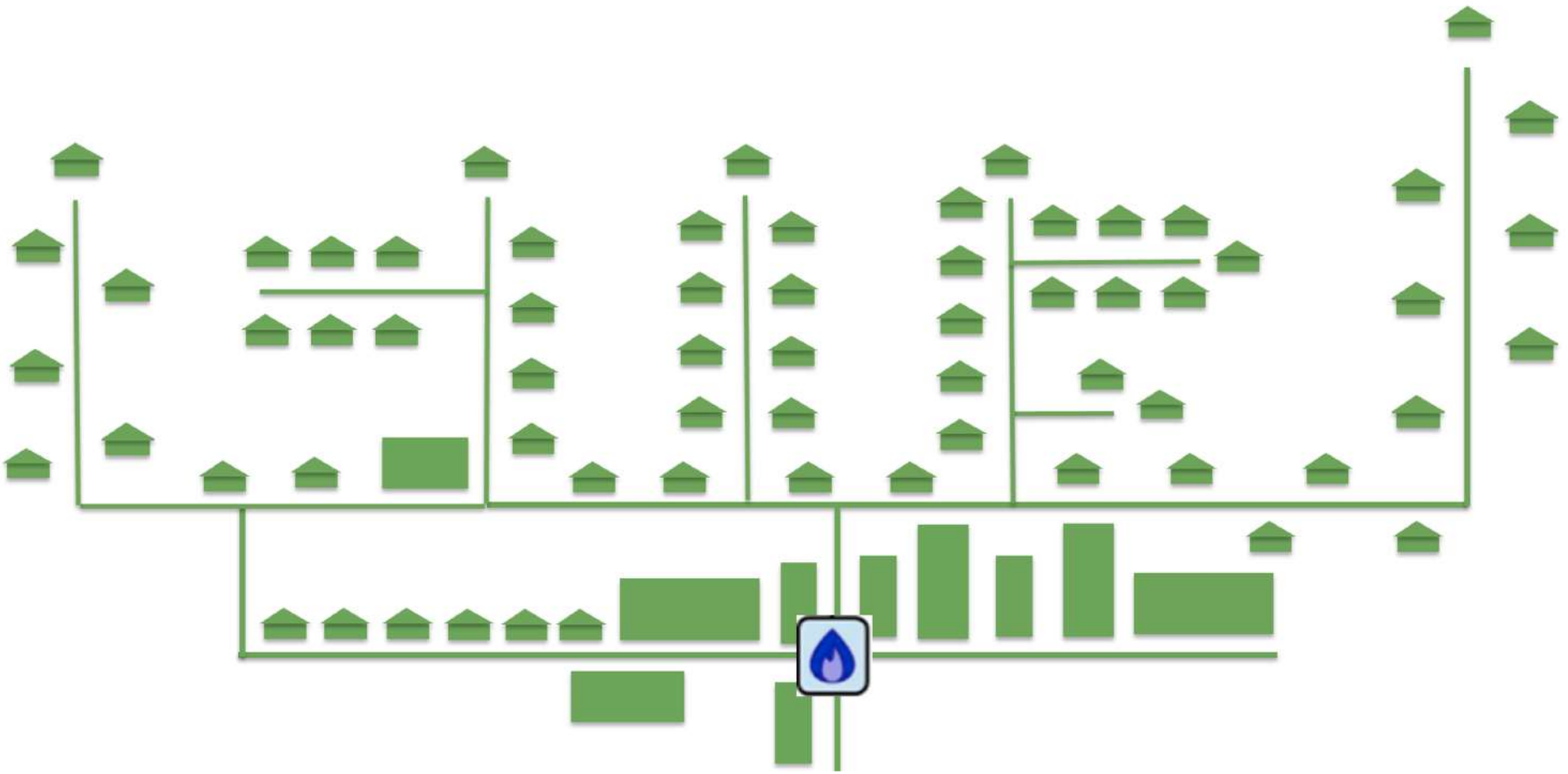
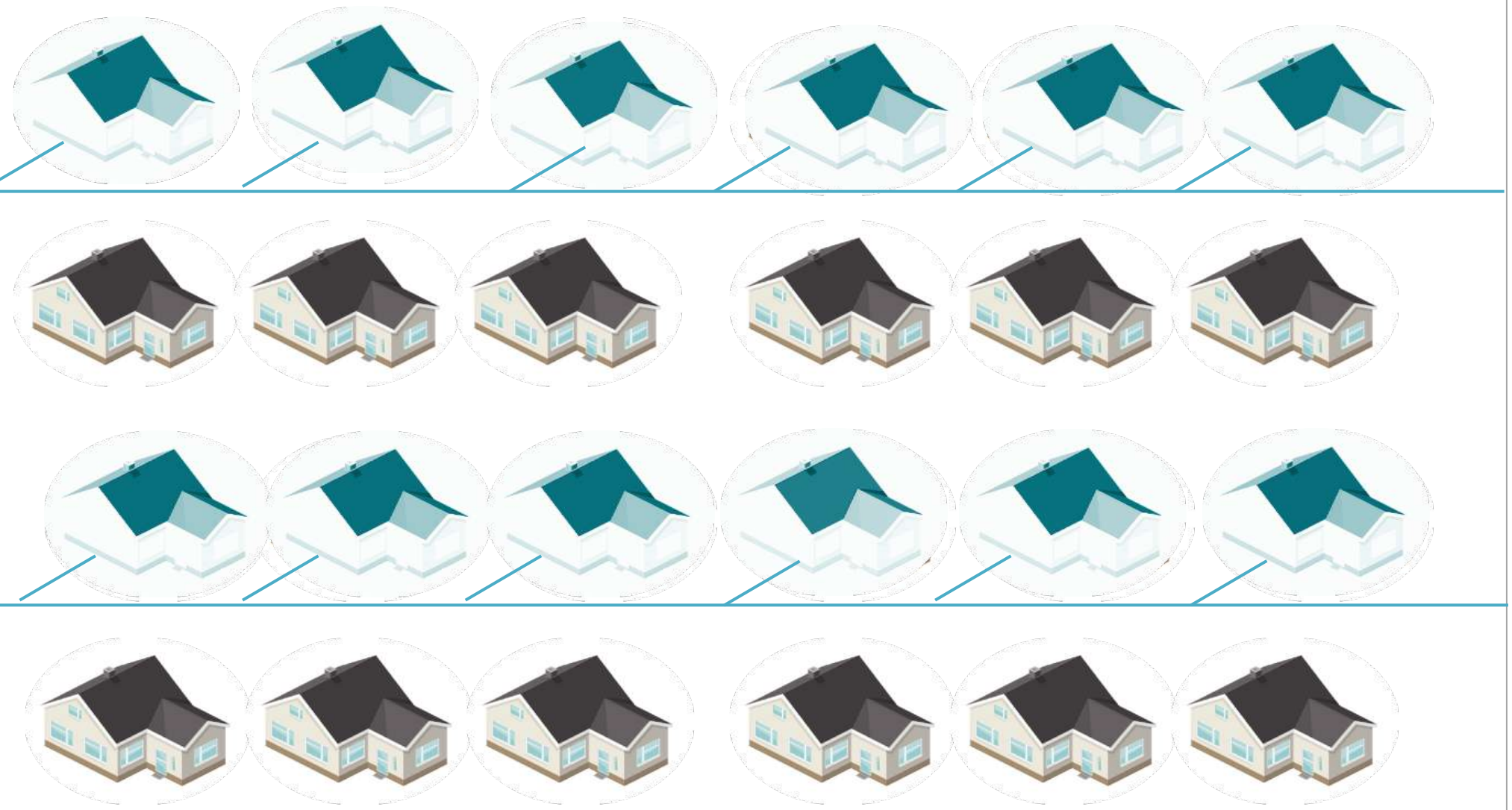


The single pipe ambient loop design HEET supports can grow flexibly; both in extent and in number of customers
AND can adapt to a changing climate

- ? Ambient temp
- ? Geothermal or other thermal storage
- ? Single Pipe

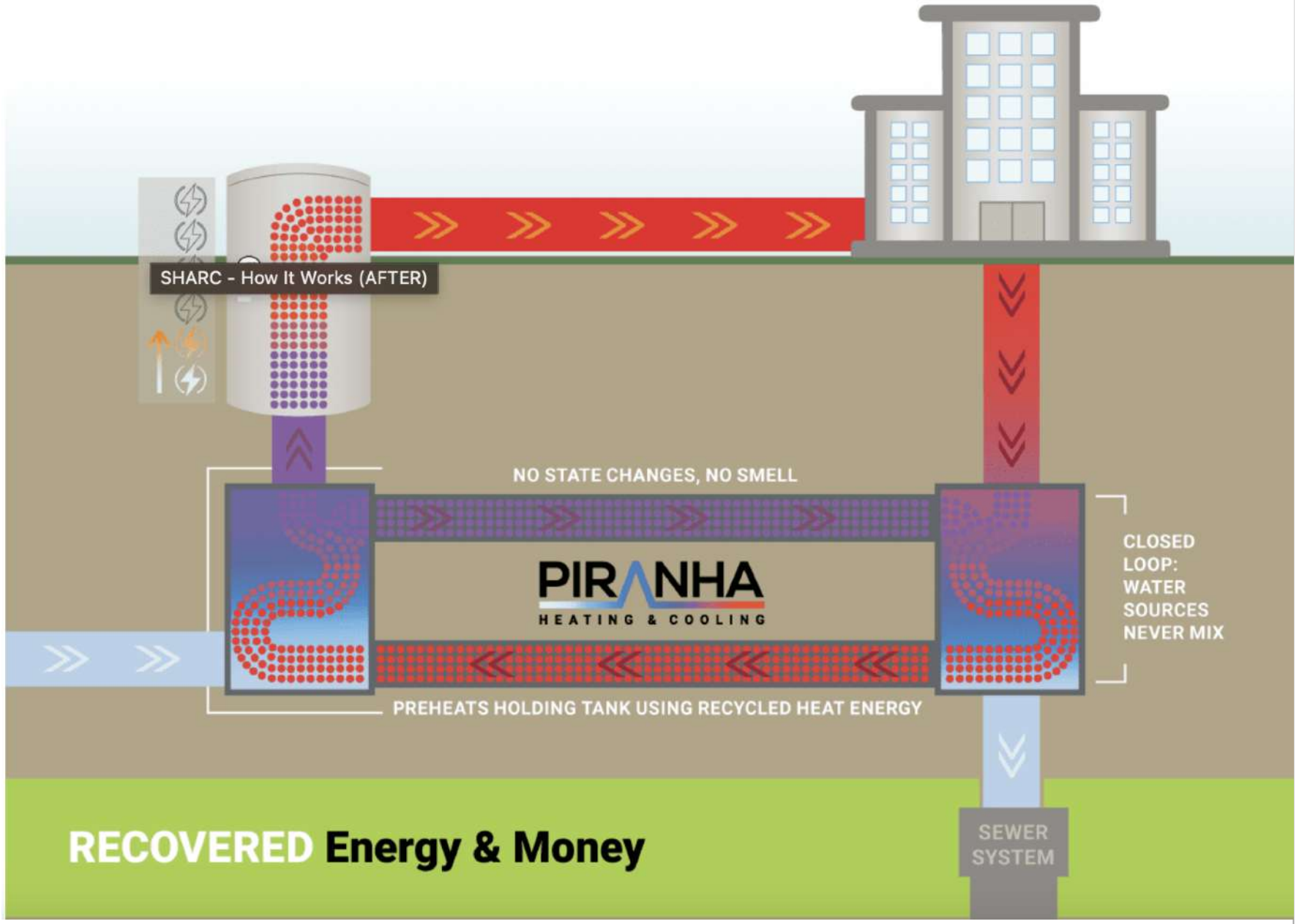
heet



Gas to Geo Decarbonization:

Customers stay with utility in merged ratepayer base to keep energy bills from spiking

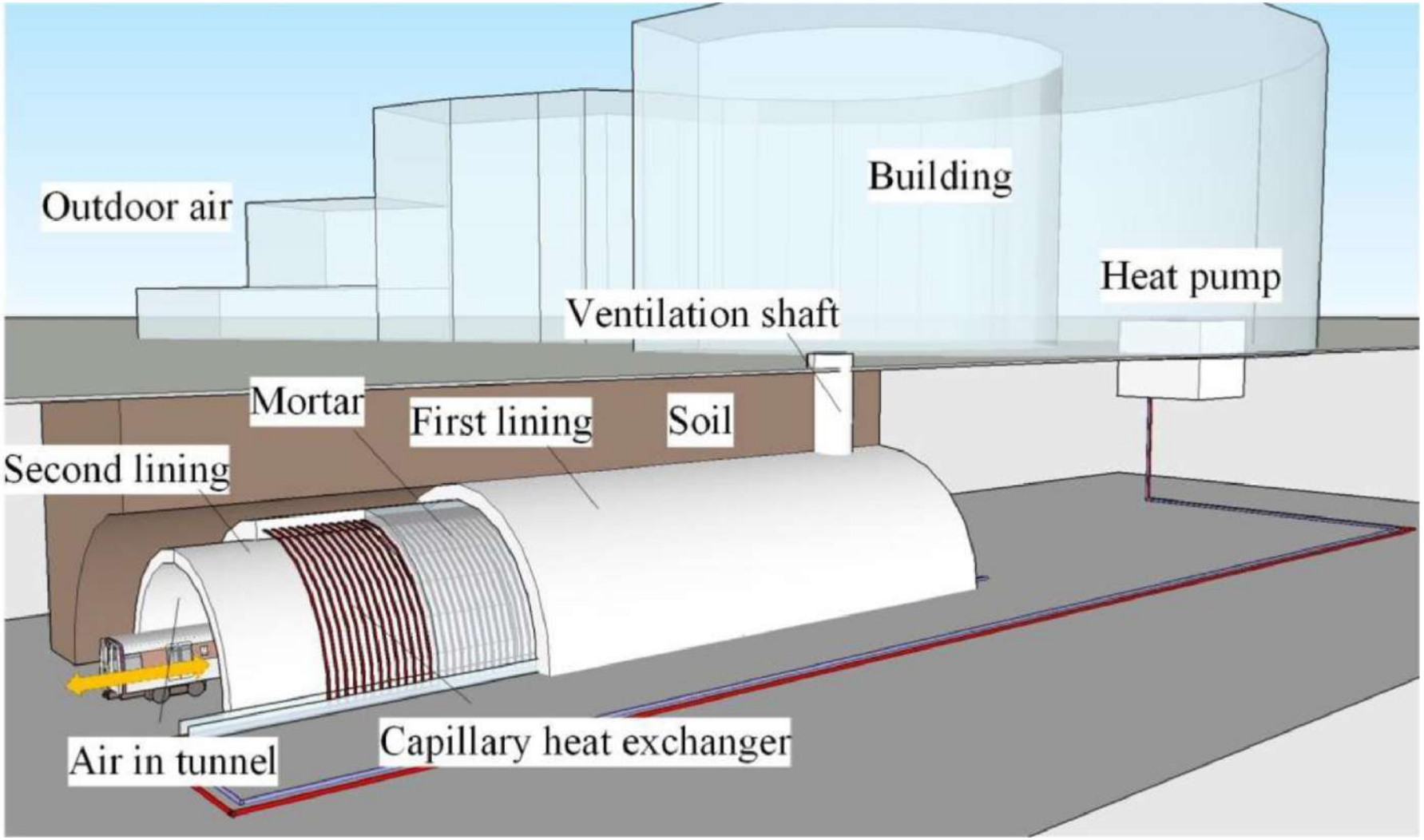
heet



Wastewater Heat Exchange

Can draw heat from wastewater/sewer system, also reject excess thermal energy into wastewater.

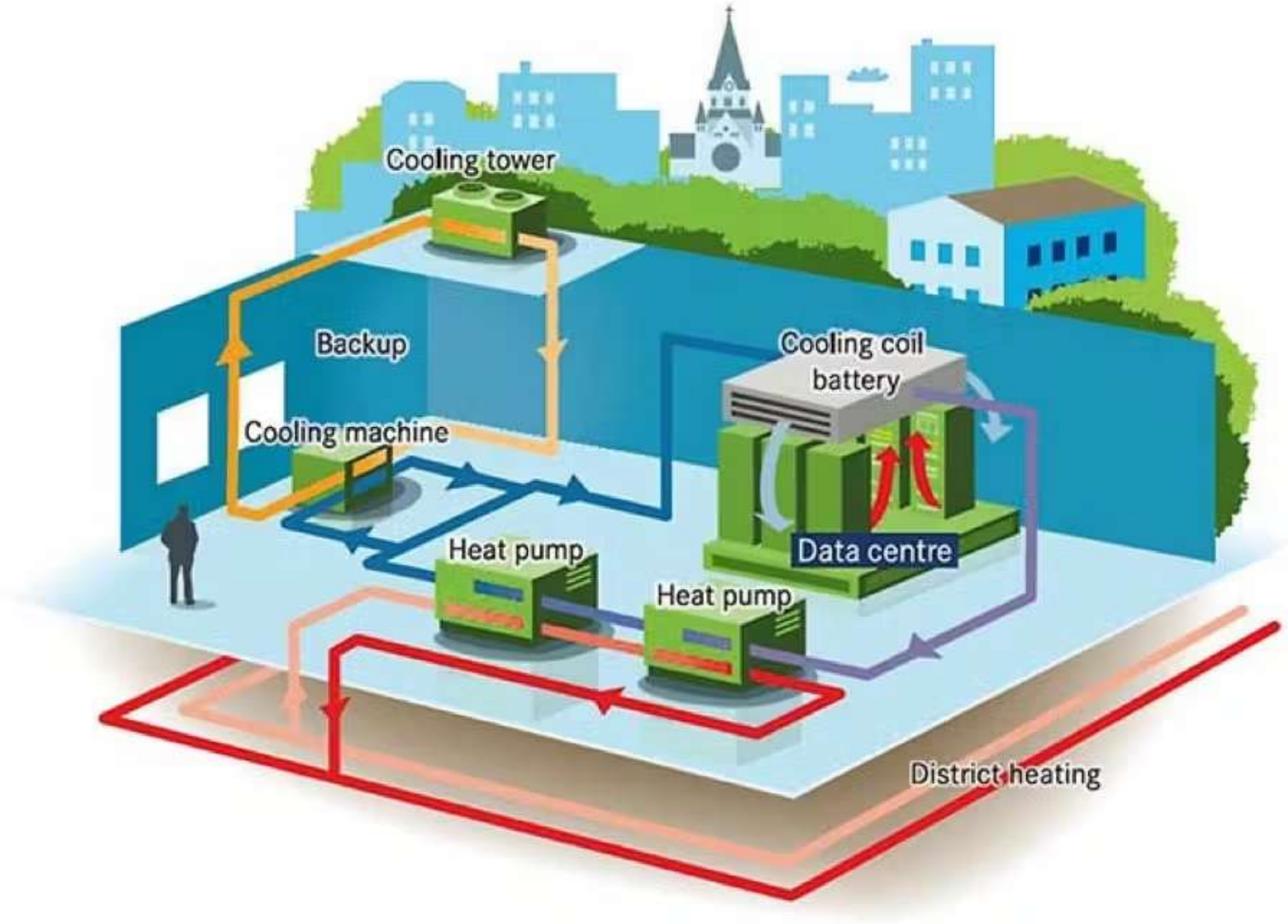
heet



Subway Heat Recovery

Draws thermal energy from subway - through purpose-built tunnel segments or through heat exchangers in ventilation shafts.

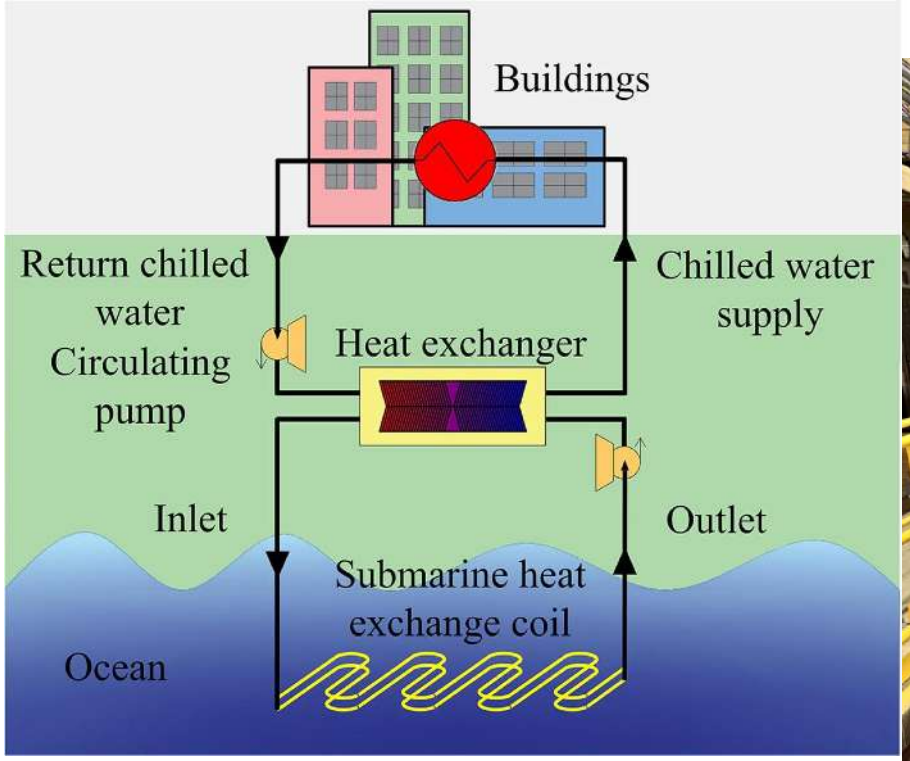
heet

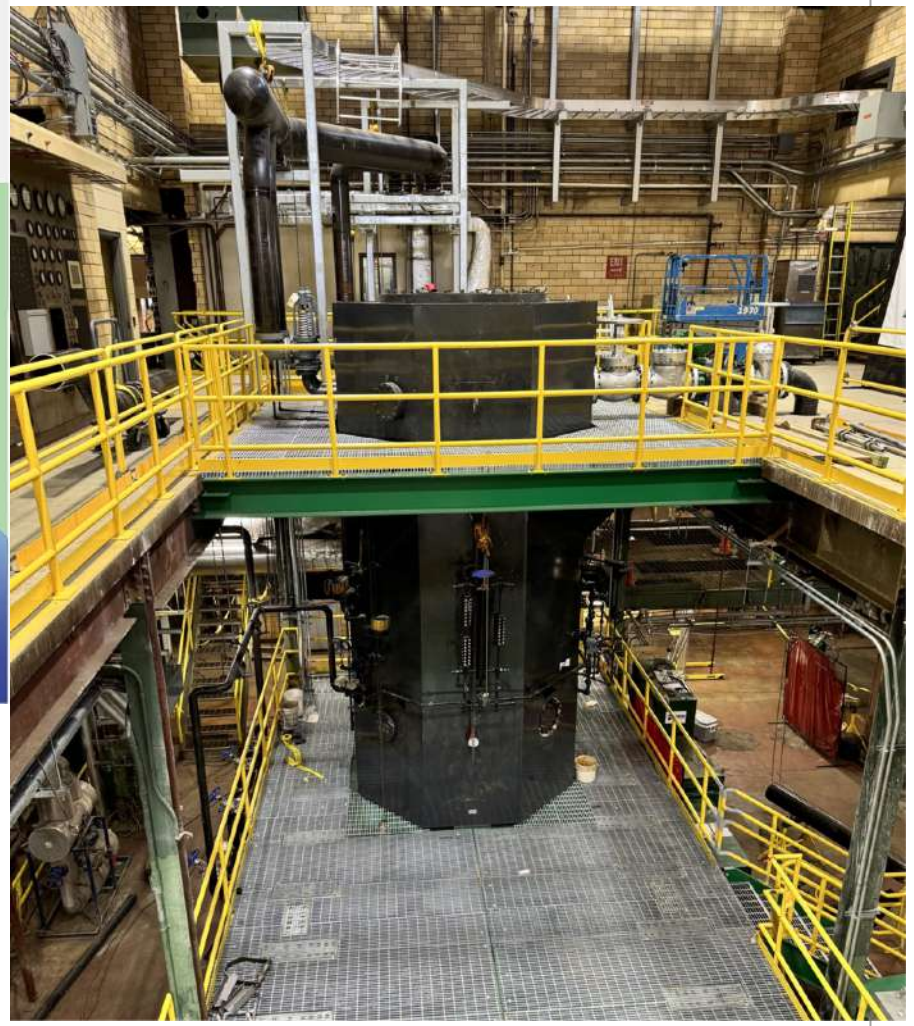


Data Center Heat Recovery

Data centers require large amounts of electricity, almost all of which is converted into heat. This heat is currently vented into the atmosphere, but can be recovered using heat pumps and exchangers (and potentially better thermal media like liquid cooling).
Pilot planned in NYC.

heet

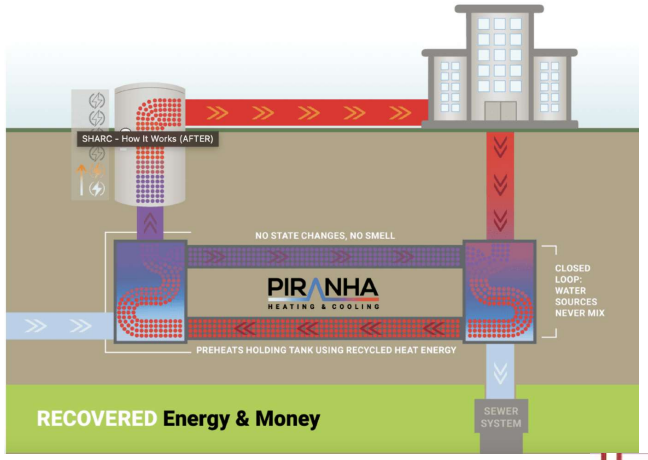


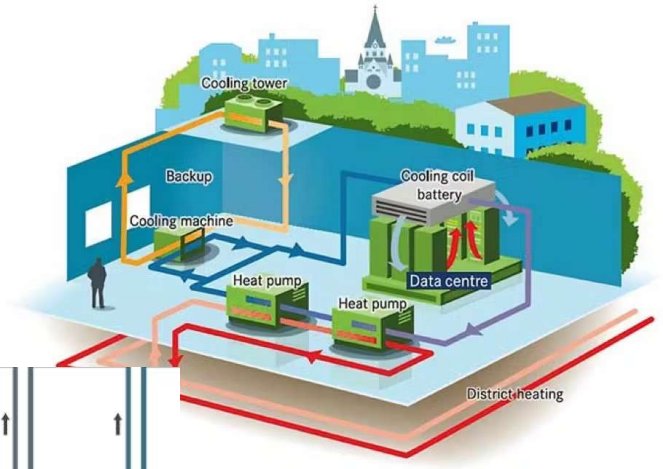


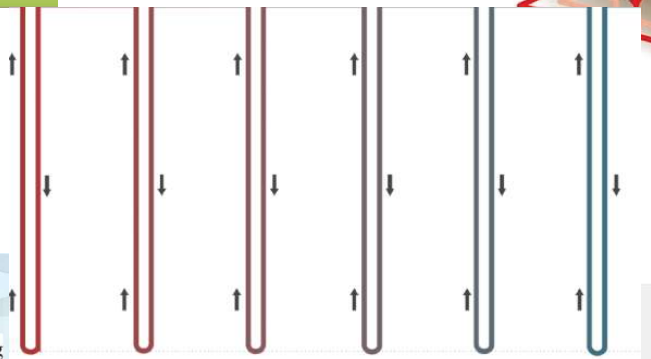
Ocean/River Source Heat Pumps

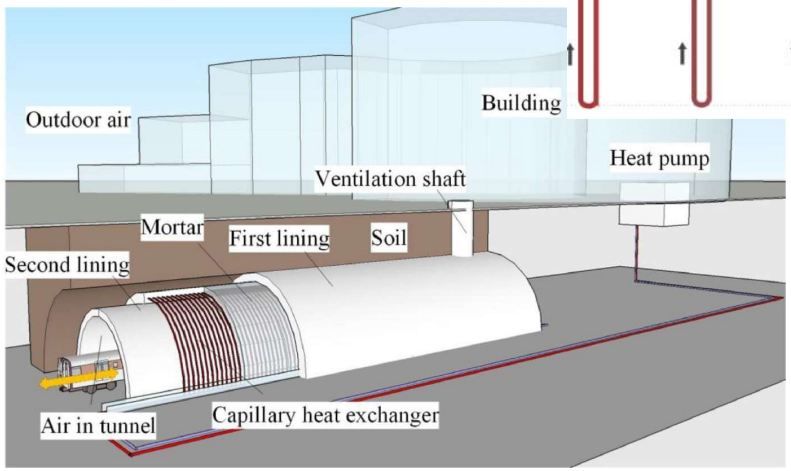
Water a much greater thermal capacity than air (4-3,000x).
Drawing heat from open water sources can help to restore them to historic temperatures.
Vicinity “esteam” project uses multiphase heat pump in Charles River to generate potentially zero emissions steam

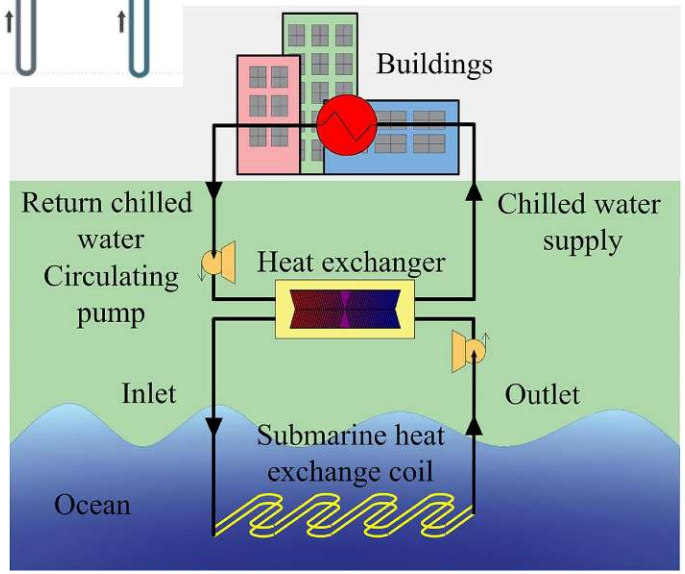
heet









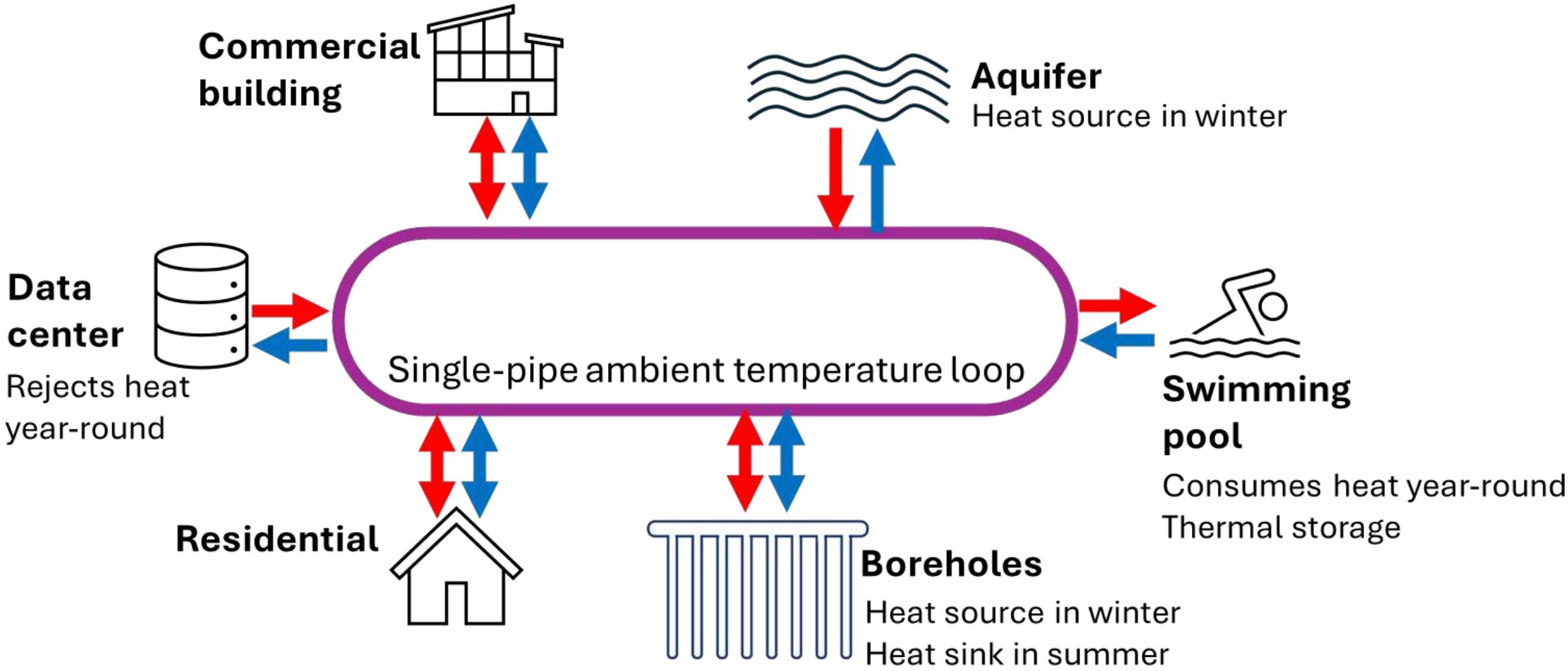


Thermal Mapping

Synergies between these different thermal resources can produce unprecedented efficiencies.

HEET is working to map Boston thermal resources to make this “thermal marketplace” visible and actionable.

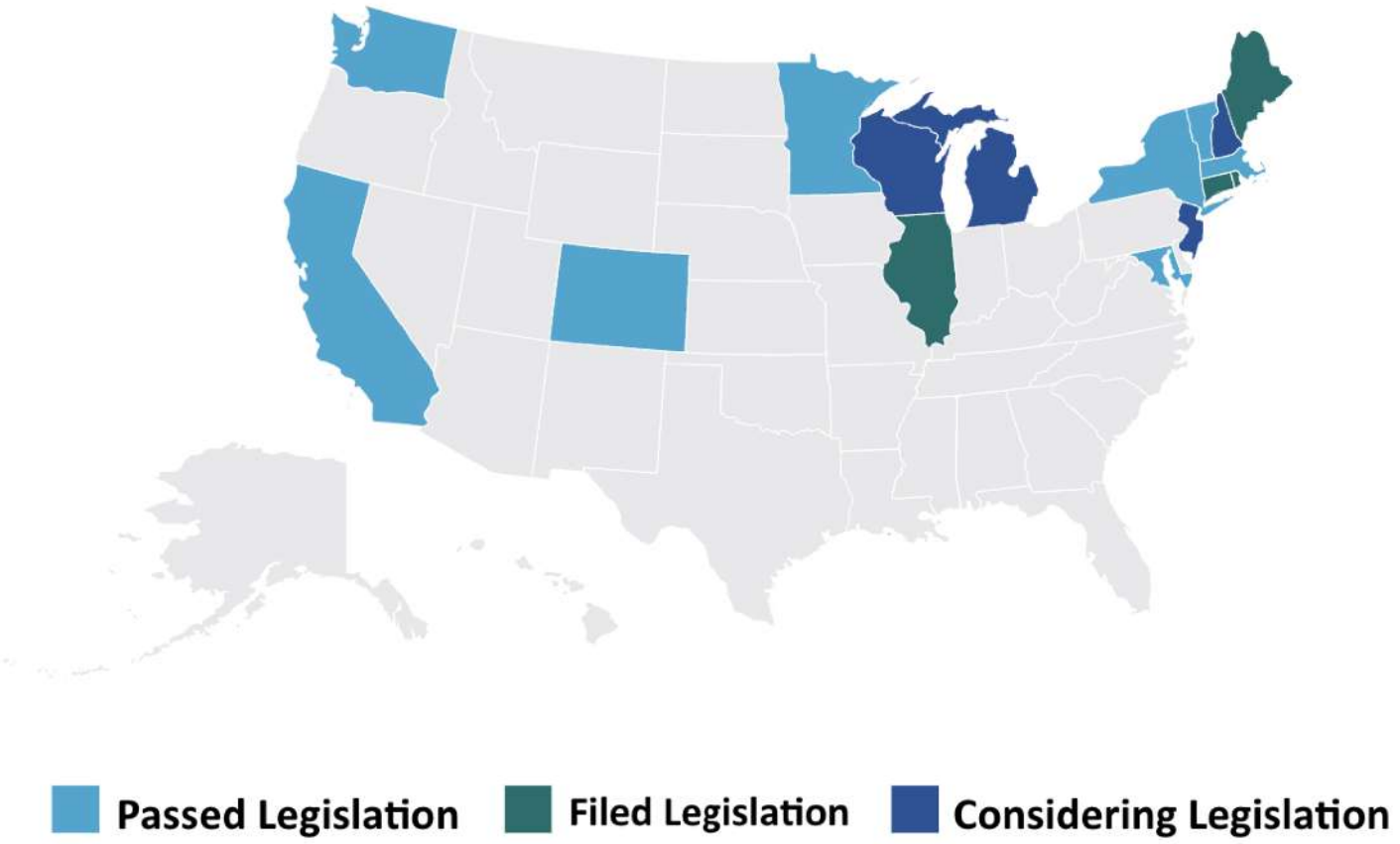
heet


Commercial building
Aquifer
Heat source in winter
Data center
Rejects heat year-round
Single-pipe ambient temperature loop
Swimming pool
Consumes heat year-round
Thermal storage
Residential
Boreholes
Heat source in winter
Heat sink in summer

heet

- ✓ High Safety & Security
- ✓ 100% Combustion-Free
- ✓ Reliable & Resilient
- ✓ Scalable & Adaptable
- ✓ Workforce just transition
- ✓ Equitable access
- ✓ Affordable for consumer
- ✓ Economic for utility
- ✓ Speed & Scale needed
- ✓ Benefits Electric Grid
- ✓ Reduces Water Use

Gas to Geo Legislation in U.S.



MA - An Act Driving Clean Energy (2021-2022)

MN - Natural Gas Innovation Act (2021) + 7 TENs bills in 2024

NY - Utility Thermal Network & Jobs Act (2022)

CO - Thermal Energy Act (2023)

WA - Promoting the Establishment of Thermal Energy Networks (2024)

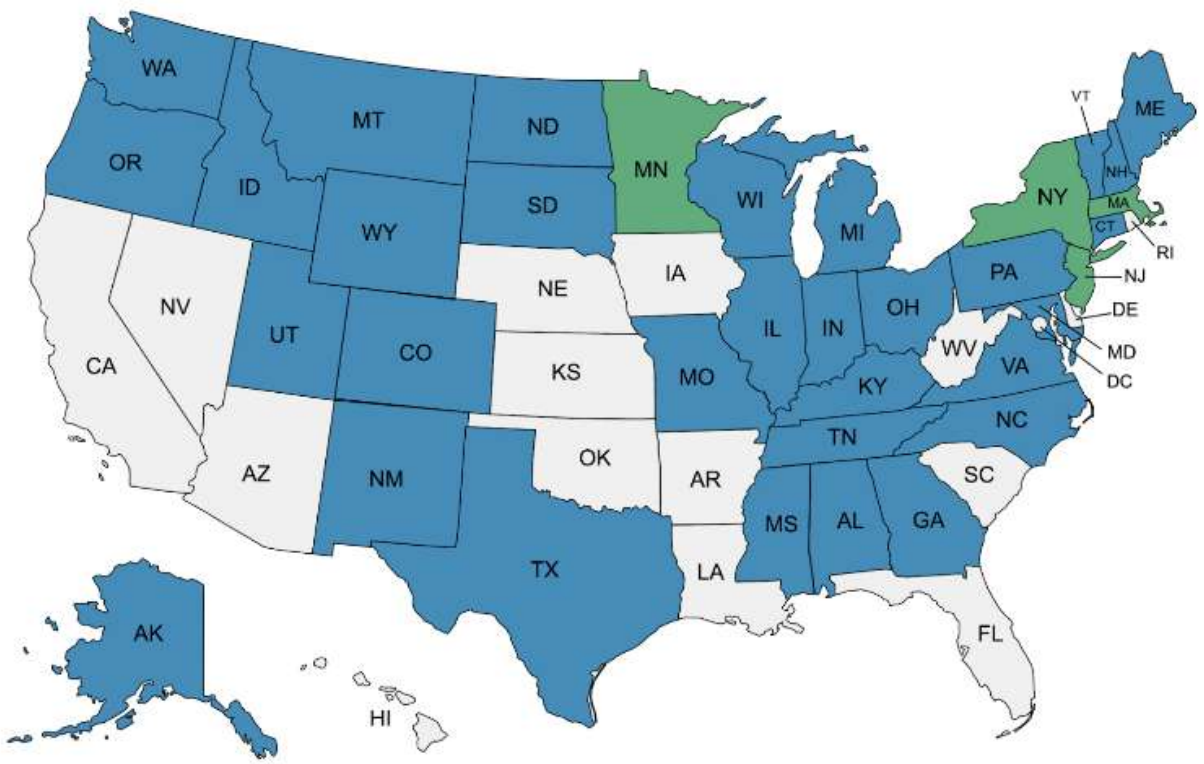
MD - WARMTH Act (2024)

VT - Act relating to Thermal Energy Networks (2024)

CA - Gas corporations: ceasing service: priority neighborhood decarbonization zones (2024)

BDC heet

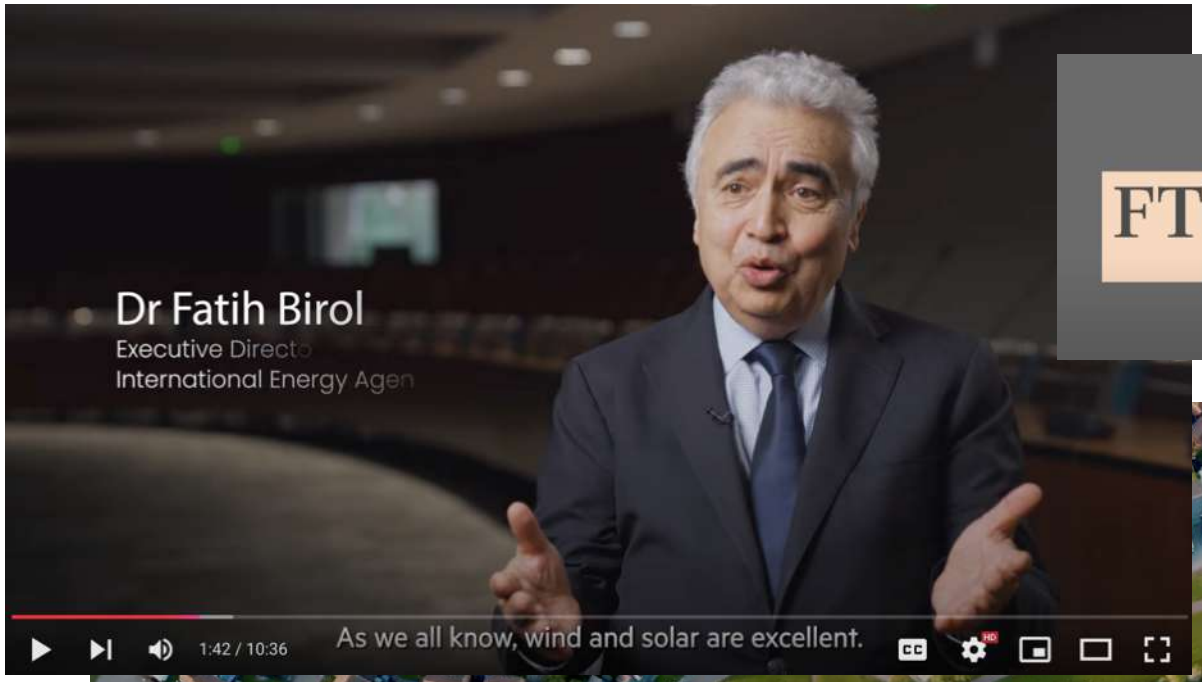
U.S. Gas Utilities in Utility Networked Geothermal Coalition

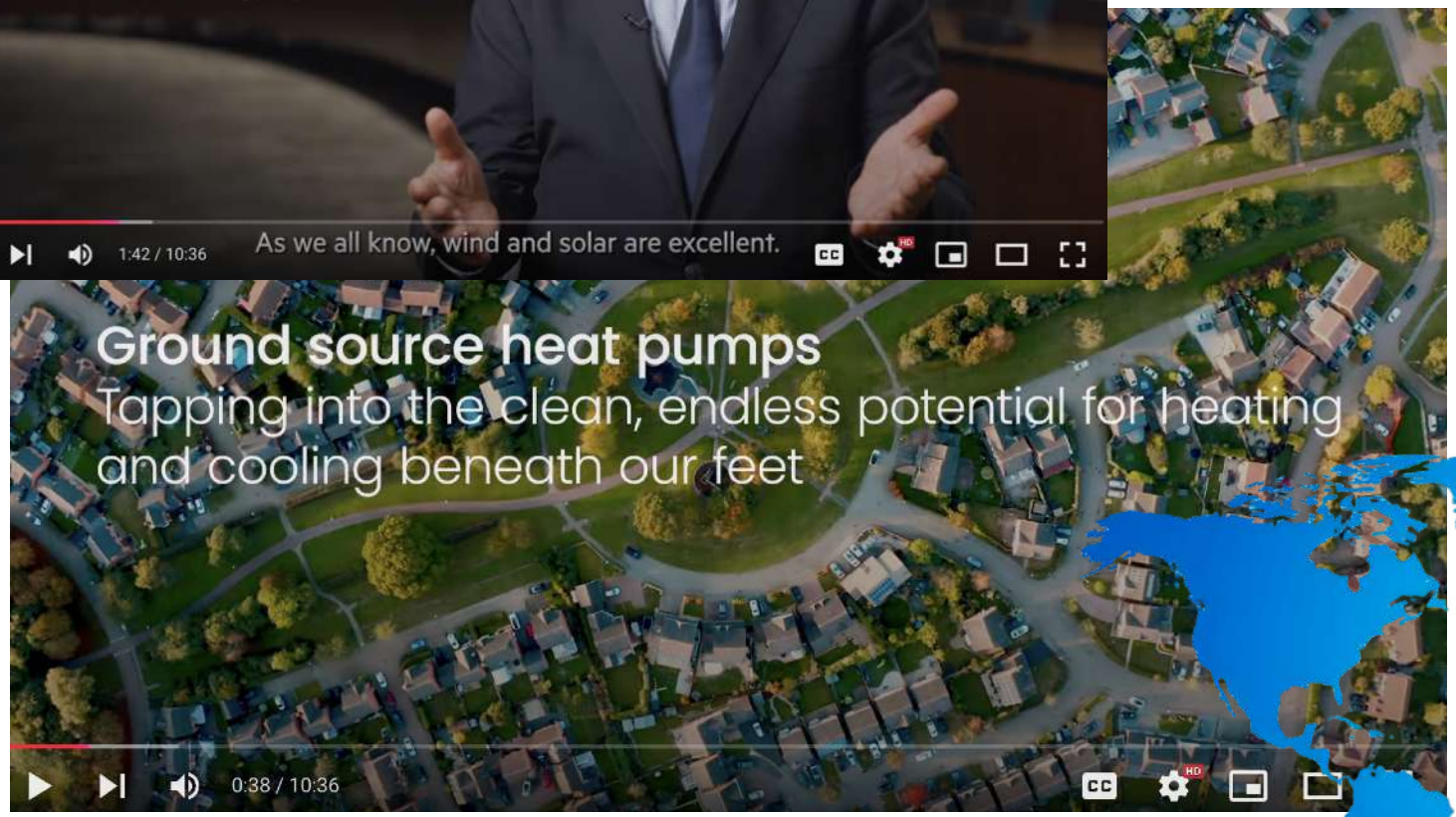


Gas Utility Pilots

Utility Coalition

FORTIS BC
AVANGRID
nationalgrid
National Fuel
spire
AVISTA
PGW
Xcel Energy
CenterPoint Energy
Southern Company Gas
conEdison
BGE
An Exelon Company
NiSource
Consumers Energy
Count on Us
Liberty
PSE
PUGET SOUND ENERGY
Unitil
Washington Gas
CASCADE NATURAL GAS
NW Natural
New Jersey Natural Gas
CMS ENERGY
Nicor Gas
ENBRIDGE
VGS
RICHMOND GAS WORKS
EVERSOURCE ENERGY
BDC
heet





A Financial Times video launched at COP29 with the head of the International Energy Association and leaders from the World Bank Group on the potential of this technology.

heet

#ThinkThermalTogether

heet

First-in-Nation Gas Utility Geothermal Network

Eversource Gas Framingham MA project

- 135 Customers
- Mixed-Use
- 1 mile loop in street
- Retrofits provided
- Bills & Electric Grid load predicted to be lowered
- EJ Community

heet

First-in-Nation Gas to Geo Workforce Transition

The majority of geo jobs were performed by gas workforce

heet

First-in-Nation Geothermal Driller Tech Tutorial

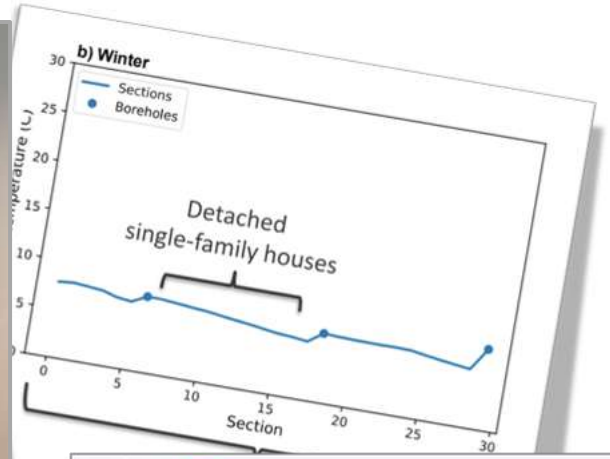
WORKFORCE DEVELOPMENT:

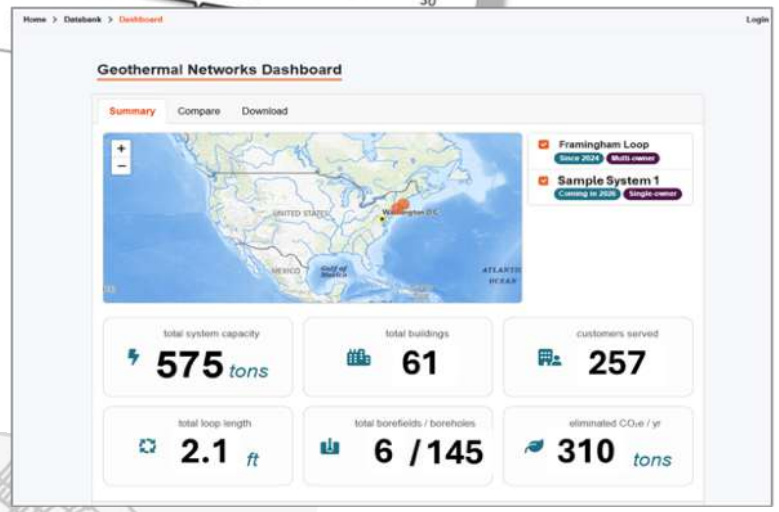
First-in-Nation Geothermal Drilling Technician Tutorial:

- Classroom & Field
- 80-hr curriculum
- 7 graduates, all J40

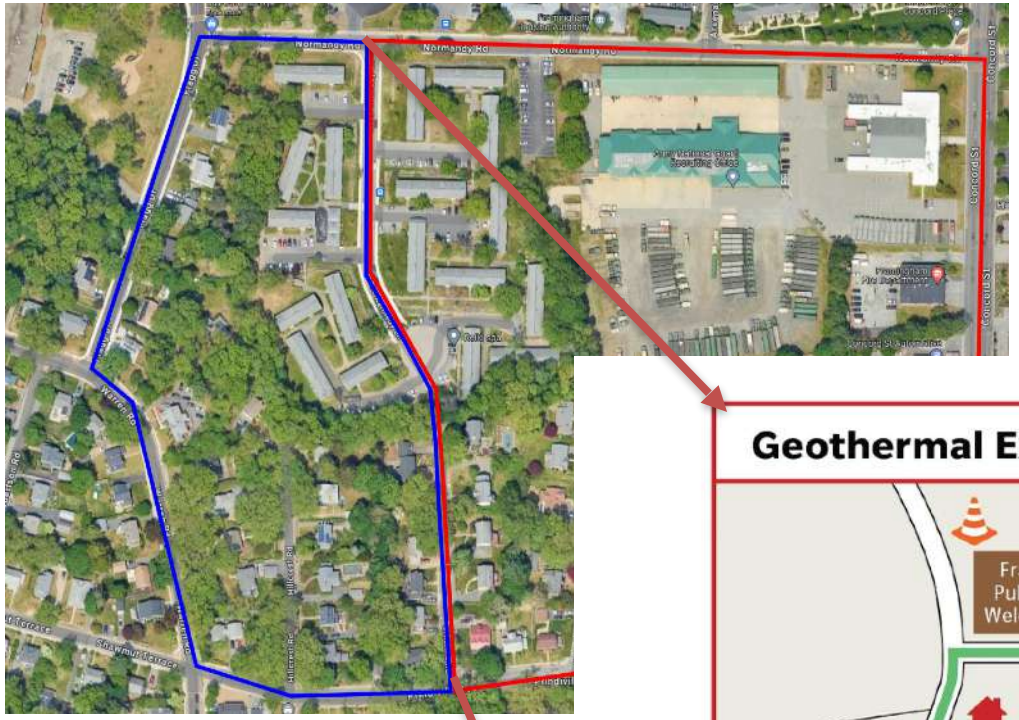
heet

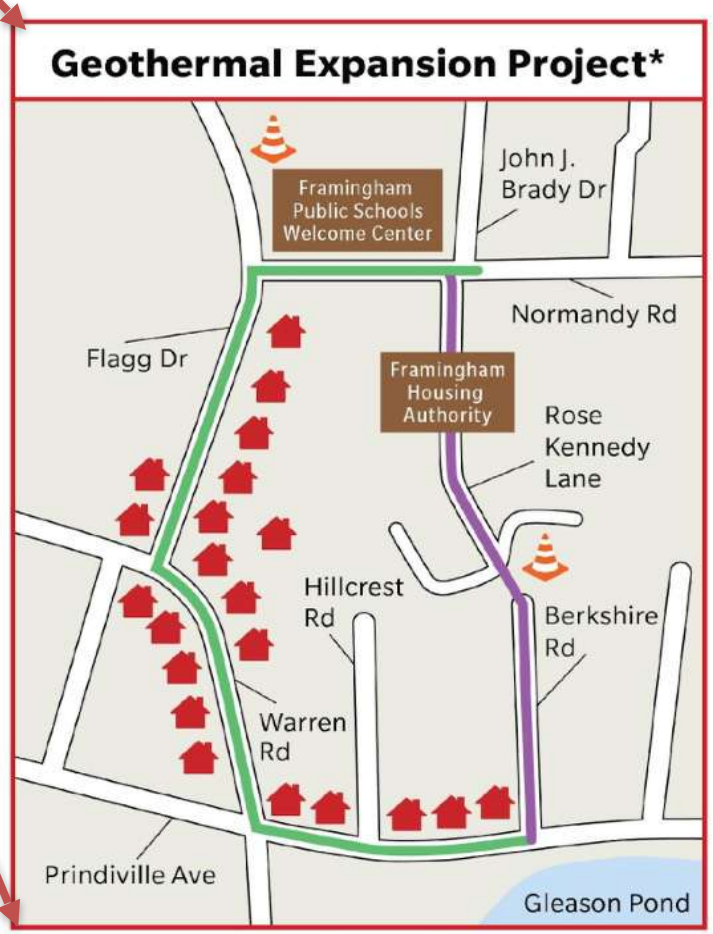
HEET's Geothermal Network Research Team





Framingham Site Expansion: HEET recently awarded DOE funding





Proposed route

Existing Geothermal

Borefield drilling sites

Potential residential customers (representation only)

**Project is in the very preliminary stages and whether it goes forward will depend on the interest level of and support of the residents along the route.*

EVERSOURCE

Salas O'Brien

heet

KICKSTART: Community-led Project Initiation

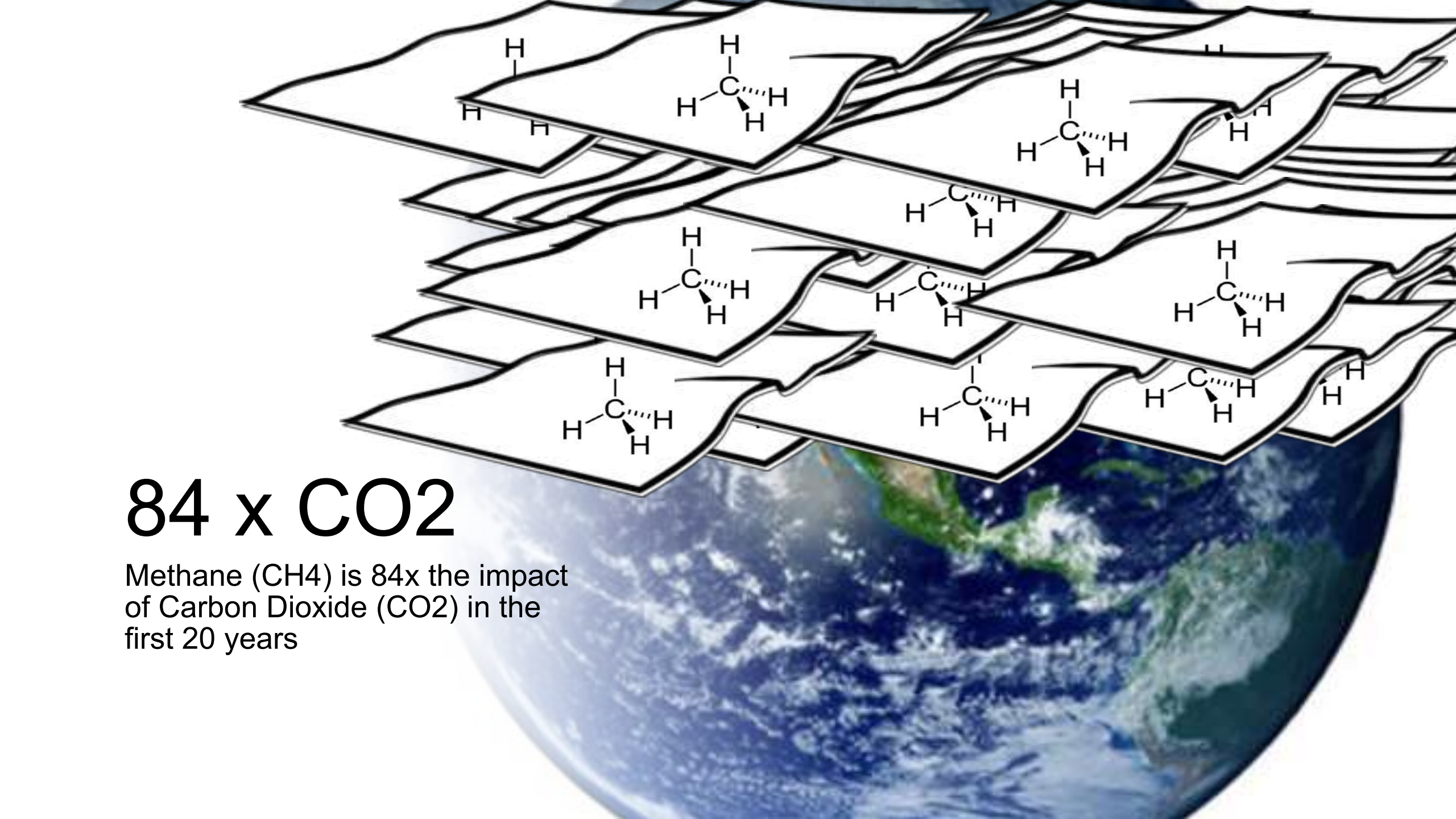
Geothermal networks are a people-centered solution

Prioritize communities with the highest need

Increase access to education about geothermal

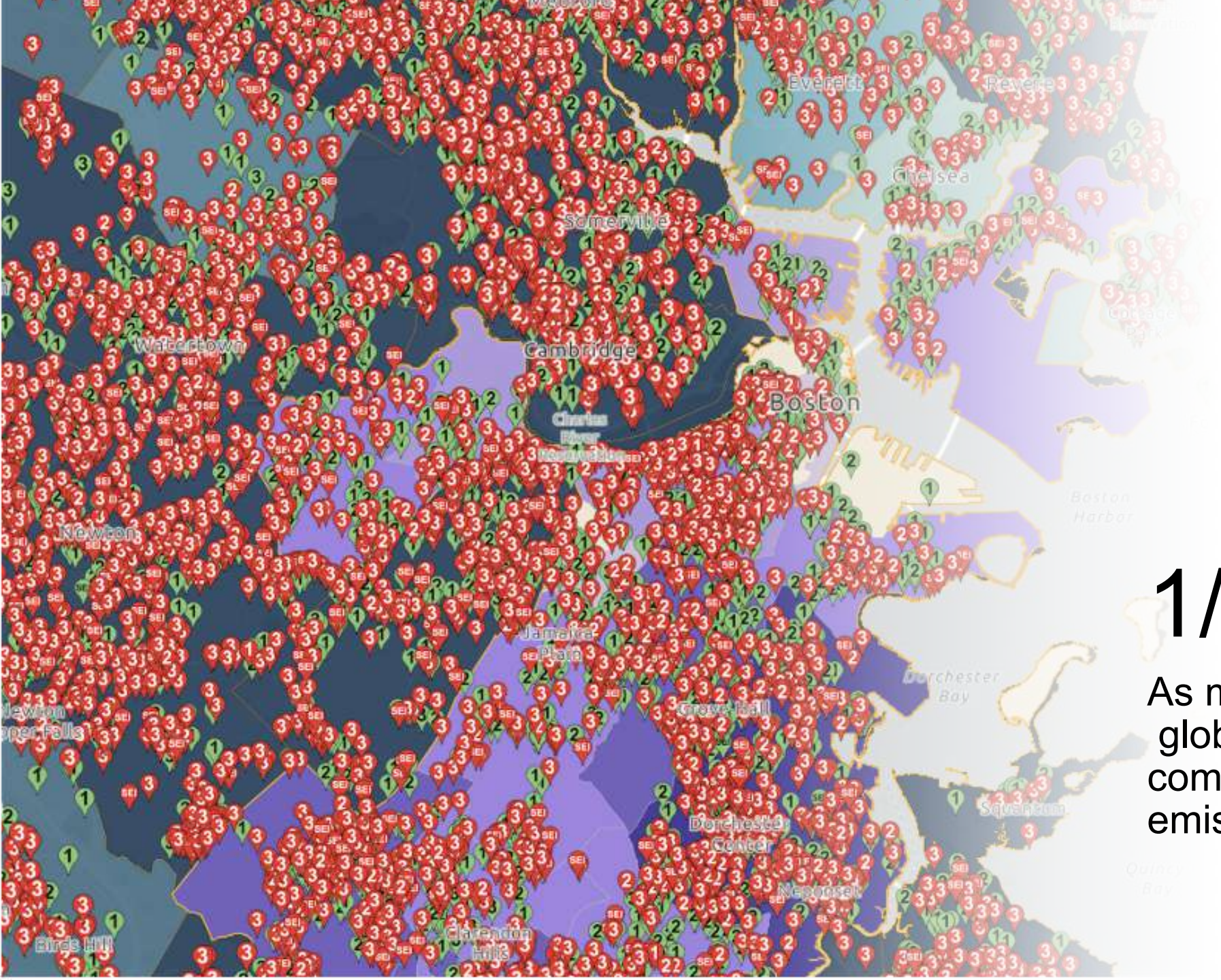
Support communities ready to transition energy at a utility-scale

heet



84 x CO2

Methane (CH4) is 84x the impact of Carbon Dioxide (CO2) in the first 20 years

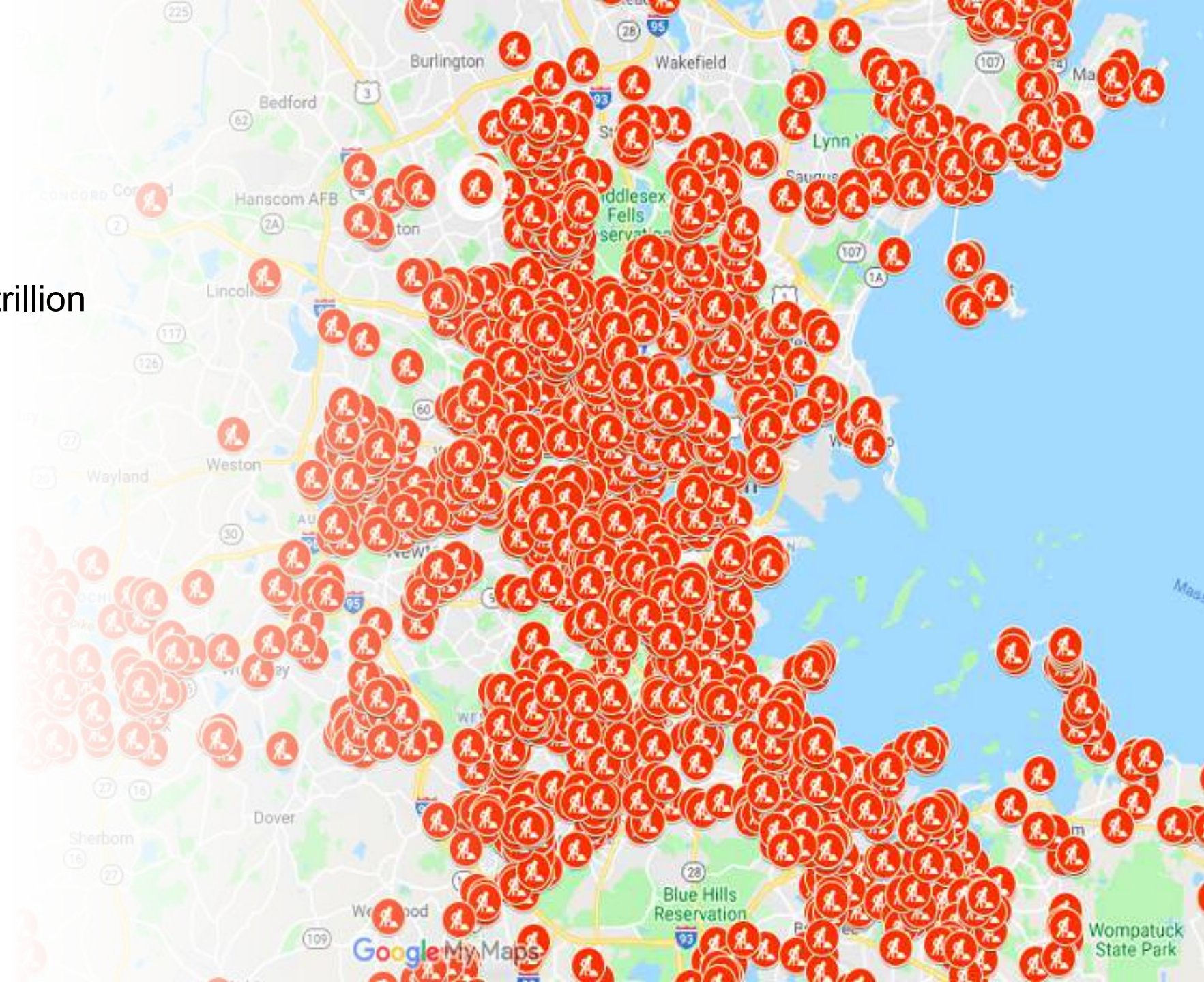


1/3

As much as one-third of global warming today comes from methane emissions of all kinds

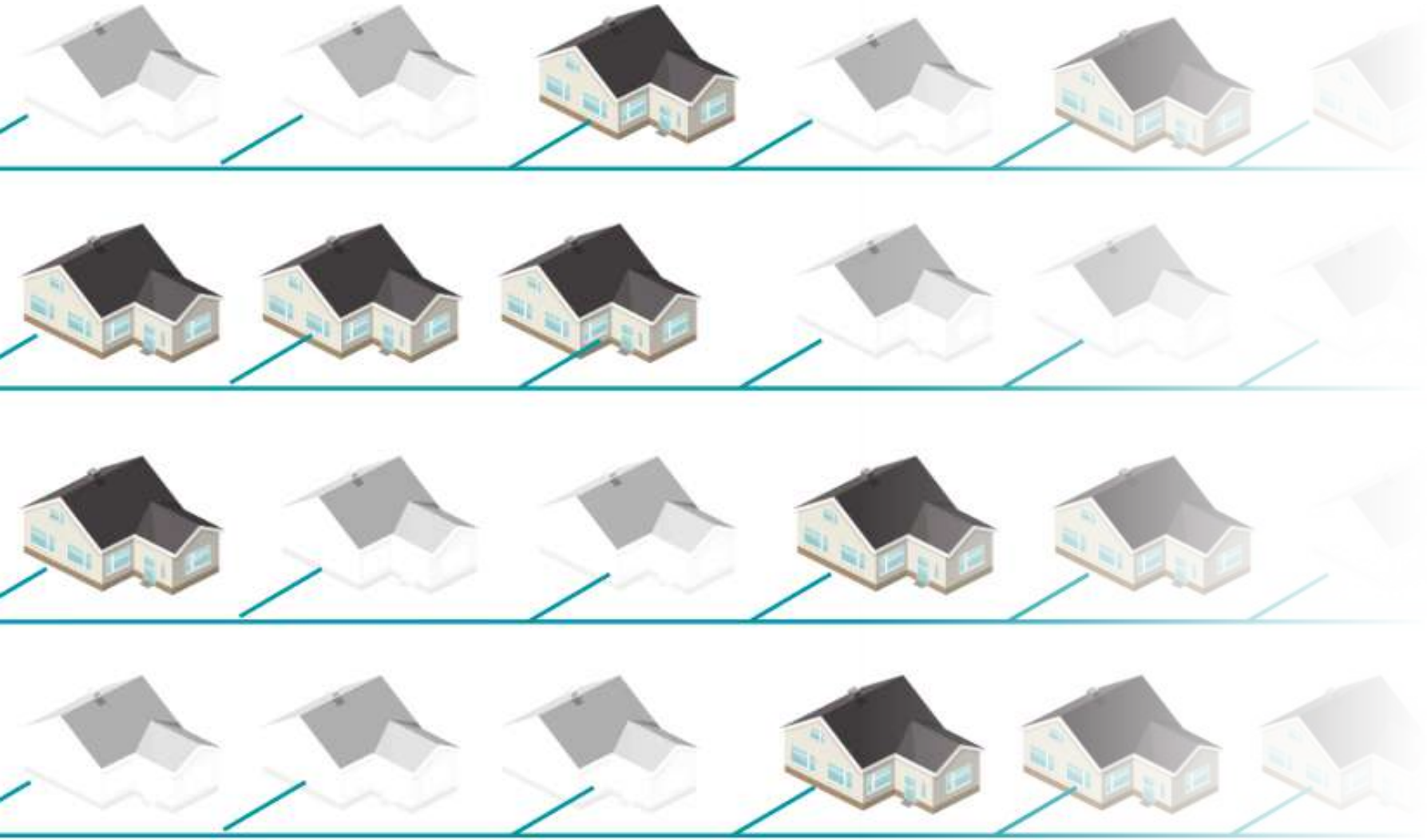
$1.4 trillion

The U.S. will invest $1.4 trillion in new gas infrastructure between now and 2050



$2.5 Trillion

US grid mod costs for by 2035, raising energy costs



27%

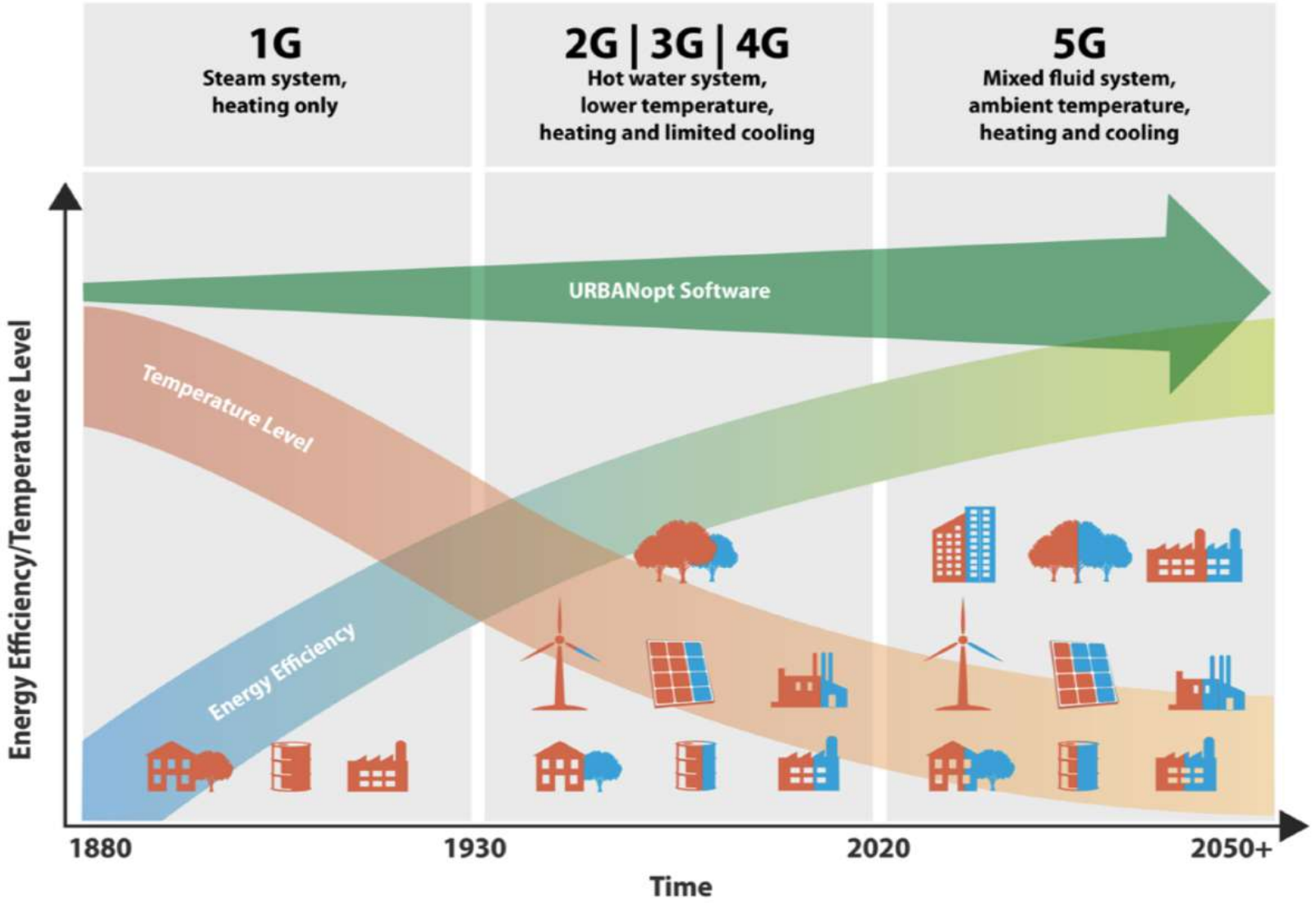
In 2020, 27% of all households reported difficulty paying energy bills or kept their homes at unsafe temperatures because of energy costs.

4.1million

The natural gas industry supports 4.1 million U.S. jobs (according to the gas industry!)

DISTRICT ENERGY ?

A simplified diagram of district energy from NREL (U.S. National Renewable Energy Labs)



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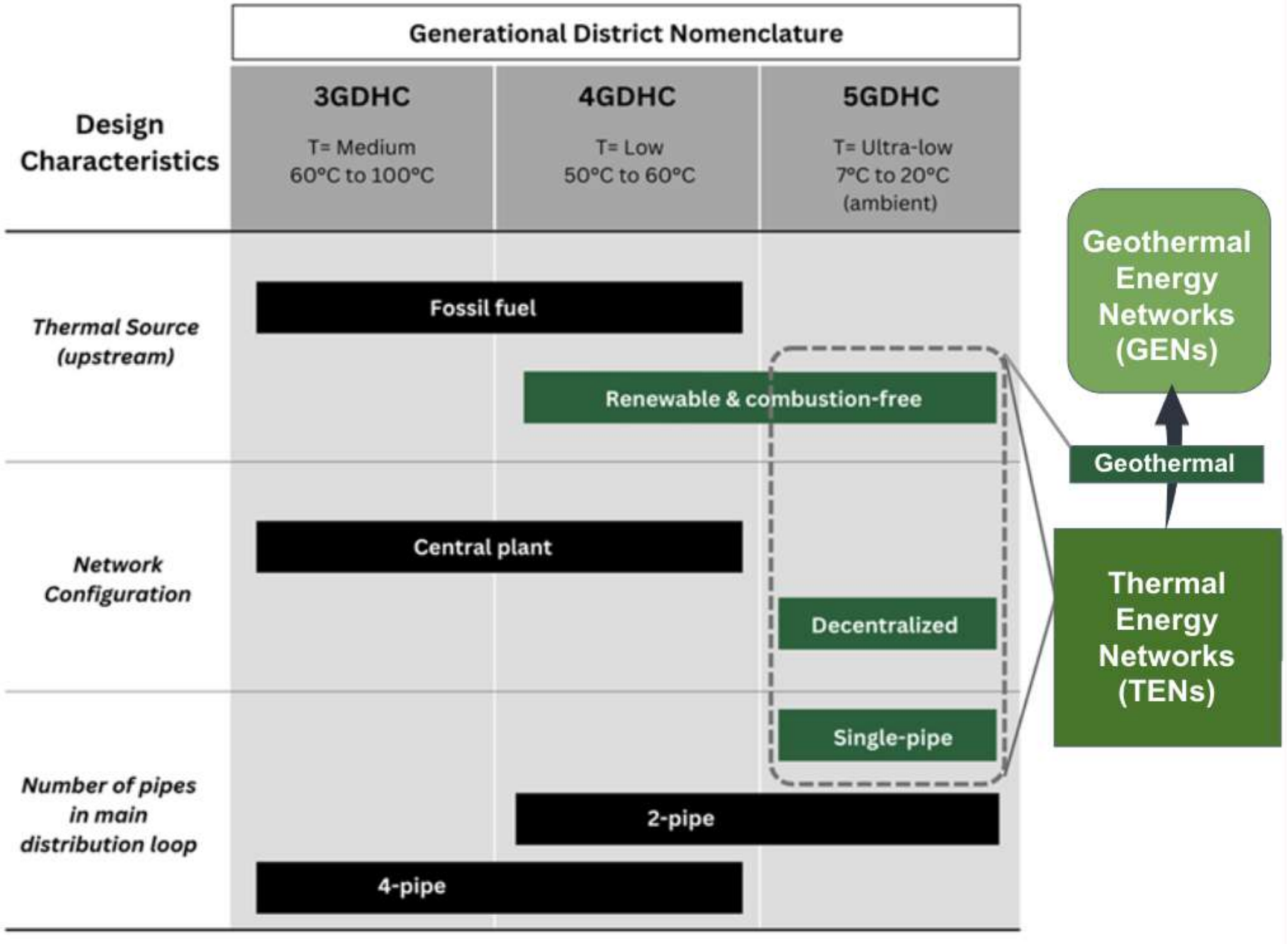


ENERGY NETWORK ?

Geothermal Energy Networks (GENs)

are a subset of

Thermal Energy Networks (TENs)

which are a subset of

5G Districts.

heet

We can move and use thermal energy:

HEAT PUMPs are sponges for heat

Moving it from one place to another

heet

There are lots of HEAT PUMPS:

1. Refrigerator!

2. Air Source

3. Geothermal

(a.k.a. ground source heat pump)

&

4. Industrial Scale!

heet

Värtan Ropsten – The largest sea water heat pump facility worldwide, with 6 Unitop® 50FY and 180 MW total capacity

Client

AB Fortum Värme samägt
med Stockholms stad
11577 Stockholm, Sweden

Stockholm's district heating system

Stockholm, the Royal Capital of Sweden, is situated on 14 islands and is considered as one of the most beautiful cities in the world. Its clean sea and air are the result of stringent environmental care. The district heating system is one vital part of the total

Heat supply for District Heating

Plant	Network	Heat
Värtan	Central	2 600 GWh

The heat pumps (total 420 MW) are used for base load production along with the bio fuel-fired plants (total 200 MW). Oil-fired plants are used in times of high energy demand only.

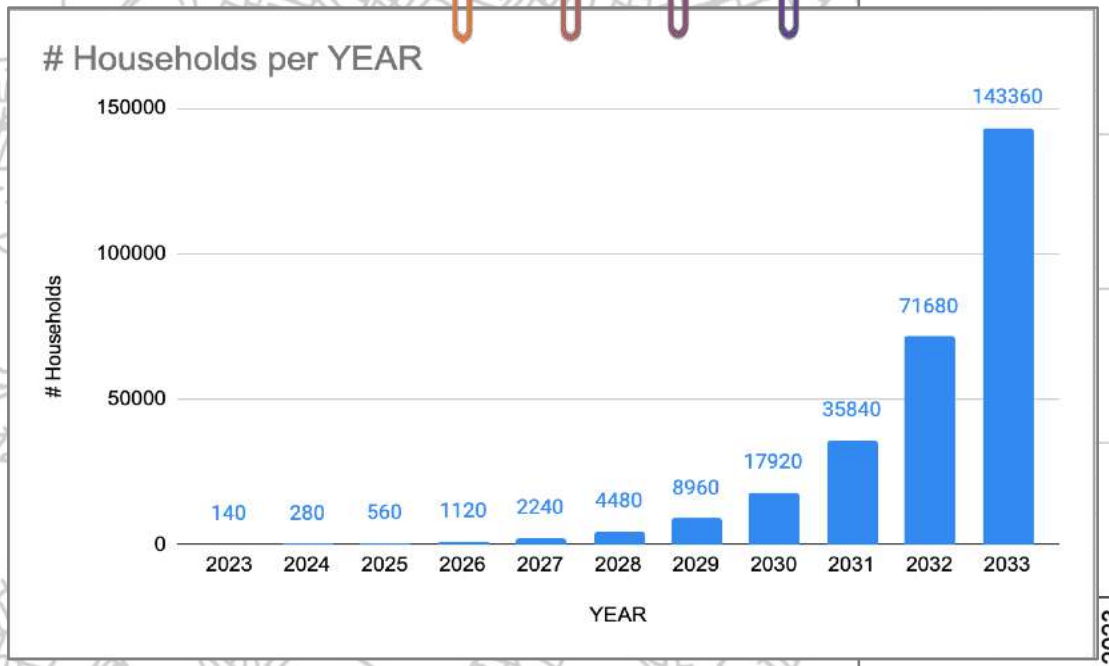
Fortums district heating production system is increasing the use of bio fuels and solar energy sources. In addition, for large heat pumps, hydro-electric power is utilized. All these measures add up to nearly 50% of renewable energy used for the production of district heat.

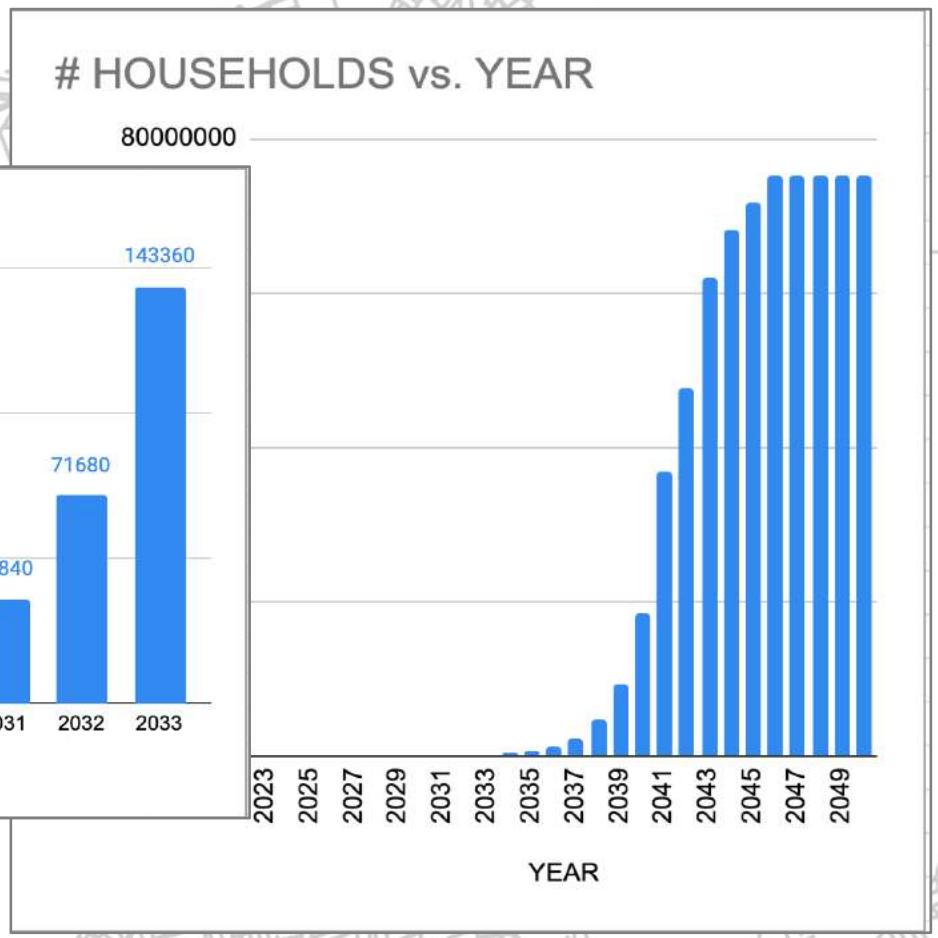
Sea water heat pump program?

heet


Zeynebs

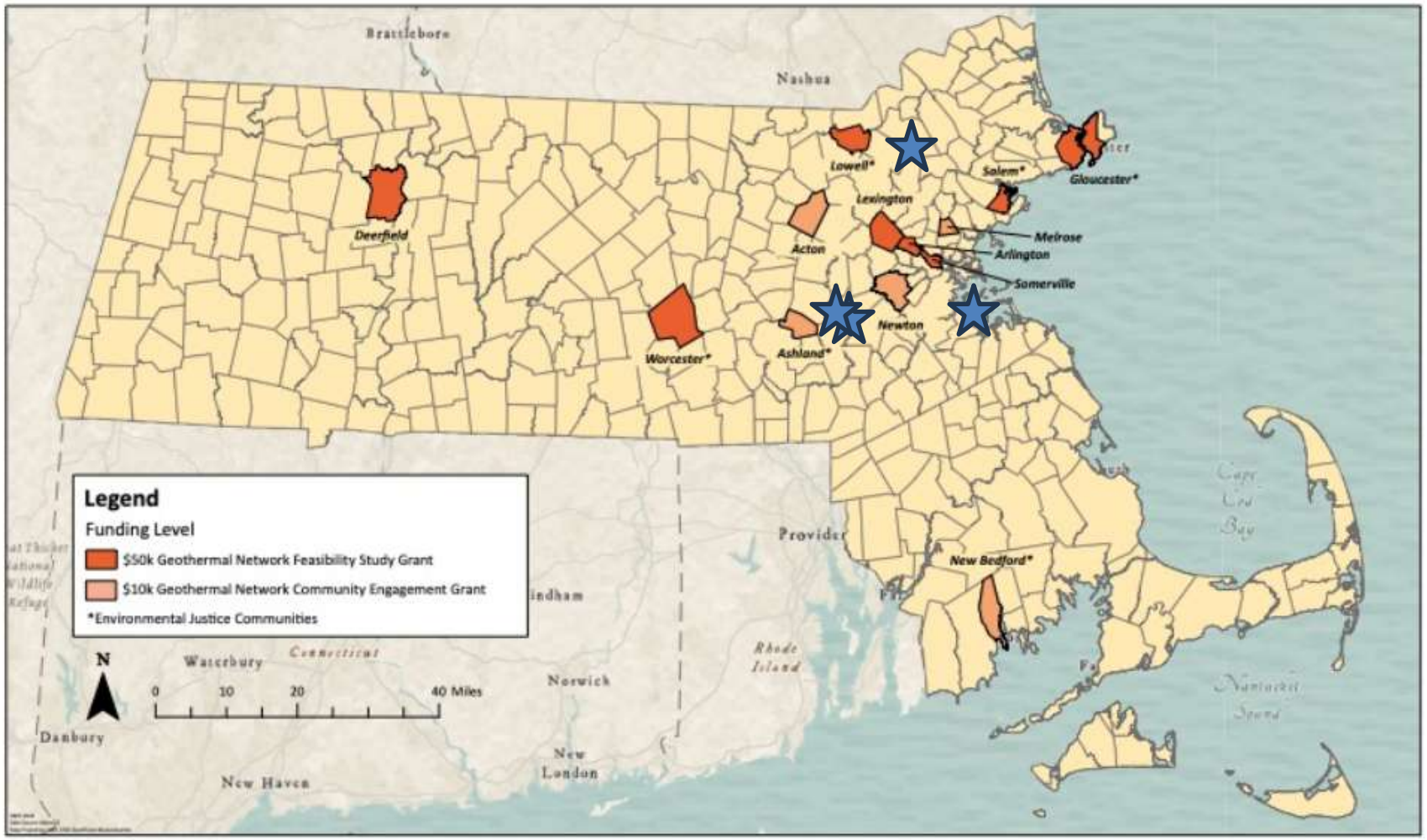
GAS to GEO





To replace our existing 'Thermal Grid' with a non-emitting one requires annual doubling for some time

heet



KICKSTART: Arlington, Deerfield, Gloucester, Lexington, Lowell, Salem, Somerville, Worcester, Acton, Ashland, Melrose, New Bedford, and Newton

Massachusetts:

1 Utility Site operational

2 Utility Sites designed

1 Utility Site in design

13 Sites in Feasibility Stage

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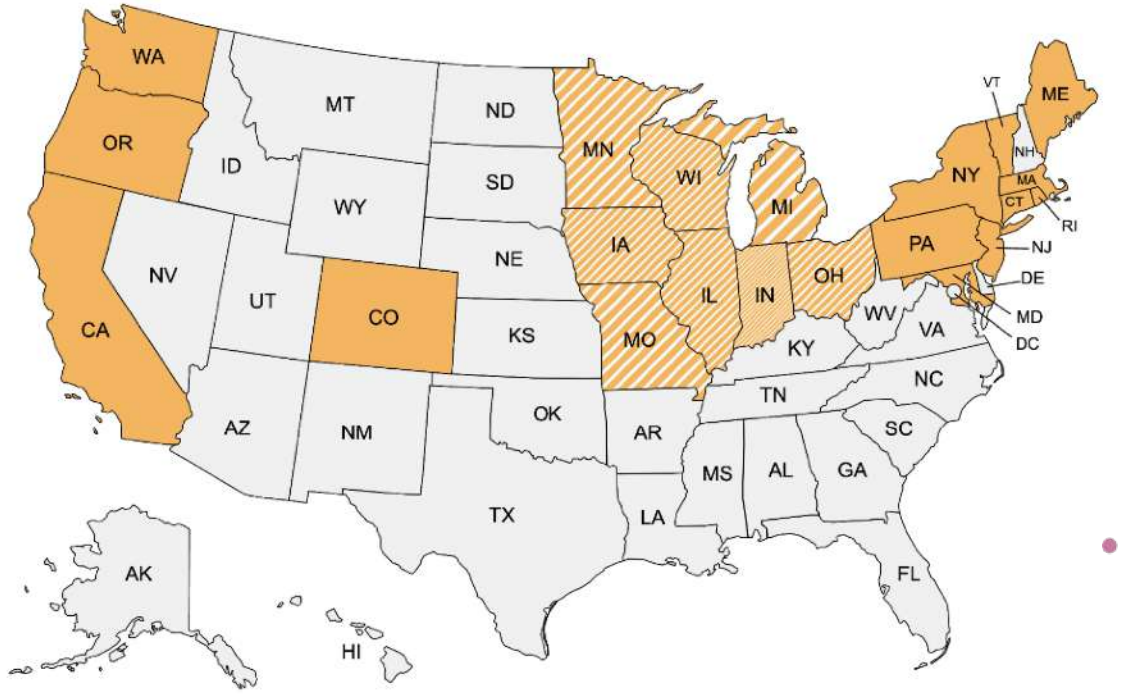
Advocacy Network



ORCAENERGY
GEOTHERMAL UTILITY SERVICES

GEOTILITY
GEOTHERMAL SYSTEMS

Orca Energy

Making Geothermal Easy and Affordable

About Orca Energy & GeoTility

Orca Energy & GeoTility

Construction Company

- Installing Geothermal for 30+ Years
- Over 20,000 tons of systems installed
- Professional engineers on staff
- Canada's largest geothermal contractor
- Largest comprehensive geothermal contractor on US west coast
- Over 4 million feet of pipe installed

Geothermal Utility Company

- Build, own operate & maintain geothermal systems (mostly exterior geo exchange assets)
- Fund 100% of infrastructure costs
- Users pay a monthly fee for geothermal energy
- Utility customers throughout Canada & U.S.
- Experience in working with developers, builders and home-owners
- Operating geothermal utility services for over 15 years

Capabilities

- Engineering
- Feasibility Studies
- Project development
- Project management
- Construction
  - Vertical & Horizontal GHX
  - Energy Piles
  - Open Loop Systems
- Financial modelling
- Drilling
- Fusion services
- Mechanical system installation
- Utility operations
- Marketing expertise
- Implementation of other low carbon technologies (i.e. sewer heat recovery)

Orca Energy Services

Orca Energy is: **A Geothermal Utility Company**

- Orca designs, builds, owns & operates geothermal infrastructure and related systems within masterplanned communities and other development projects
- Orca funds 100% of the infrastructure – **no capital required from developers**
- Users pay Orca a monthly fee for the heating and cooling services received from Orca's geothermal infrastructure
- Orca secures rights, easements and/or covenants similar to any other utility
- Orca is responsible for ongoing O&M of the infrastructure as well as other responsibilities of operating the utility

Why Choose Geothermal?

Homeowner Benefits

Lifestyle & Comfort

- ✓ No outdoor equipment ⇨ ***quieter***
- ✓ Better air flow ⇨ ***better comfort***
- ✓ No fossil fuel combustion ⇨ ***safer***

Financial Benefits

- ✓ No upfront costs
- ✓ Lower long term costs
- ✓ Increased home value
- ✓ Long term energy cost stability
  (Orca fees are fixed to CPI)

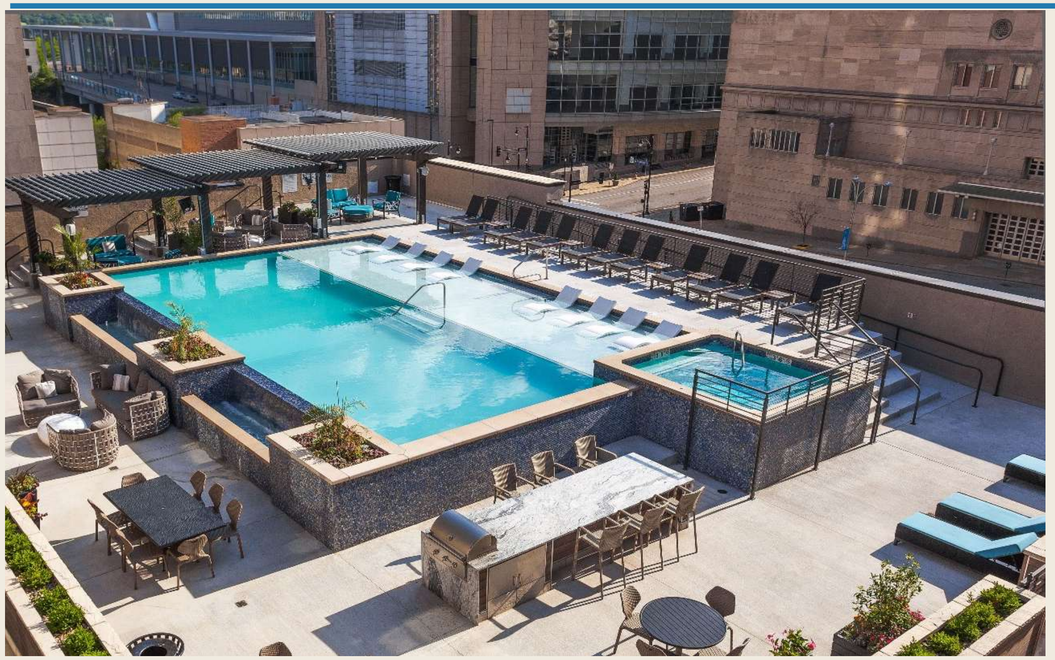
Environmental

- ➢ Renewable energy source for all heating and cooling
- ➢ Eliminates the burning of fossil fuels ⇨ ***eliminates carbon footprint & reduces GHG emissions***
- ➢ Improved indoor air quality
- ➢ More efficient ⇨ ***uses less energy***
- ➢ Equipment lasts longer being indoors

VERSUS

Developer Benefits

- No cost to the developer
- Provide renewable energy for all heating and cooling
- Create a marketing advantage
- Reduce or eliminate carbon footprint
- Partnerships with major geo manufacturers and installers
- Potentially eliminate gas to development and associated costs
- Eliminate outdoor condensers & cooling towers
- Partner with industry leading expert in geothermal design, construction and operations
- Education & training for partners, contractors & team members



VERSUS

Orca & GeoTility Case Studies

Microsoft Campus, Redmond, WA

GeoTility / Orca provided turn-key construction services for the Microsoft campus, including design-assist

THE ASPIRATION

- Microsoft Sets Goal to be Carbon Negative by 2030
- Redevelopment of 100+ acre Redmond Campus Requires Innovative Systems

SOLUTIONS OFFERED

- Campus-wide district energy system featuring a large geothermal field
- 900 boreholes to 550 ft deep
- Up to 16” diameter district wide HDPE mains

RESULT

- Microsoft achieves a zero-carbon heating and cooling solution serving over 3M s.f. of commercial space
- ENR Project of the Year for 2023

Lulu Island District Energy System
Richmond, BC

District System is 100% Owned by the Municipality

THE ASPIRATION

Geotiltiy Helped The City of Richmond Create a Low Carbon District Energy System

SOLUTIONS OFFERED

- 2 pipe low temperature system
- Central plant featuring large geoexchange field with cooling towers and backup boilers
- Geothermal fields installed in phases
- Over 1,000 boreholes installed to 250ft each
- Buildings have a variety of mechanical systems including distributed heat pumps and central chillers
- Capable of service both residential and commercial building for both heating and cooling

RESULT

- First municipally owned geothermal based low carbon energy solution

Oakridge Redevelopment
Vancouver, BC

Low Carbon Energy System Serving 4.5M ft^2

THE ASPIRATION

Oakridge Development in Vancouver Needs

Low Carbon Energy Solution to Serve 4.5M ft^2

SOLUTIONS OFFERED

- Large scale district geothermal system serving 13 residential towers between 10 and 44 stories tall
- 4.5M s.f. of developed space including commercial, civic and residential served by central utility plant
- GeoTility engaged as construction contractor and design/assist role

RESULT

- Central geothermal borefield anchors this district energy system of the future

Lucas Museum of Narrative Art
Los Angeles, CA

GeoTility was responsible for the installation of the geothermal system

THE ASPIRATION

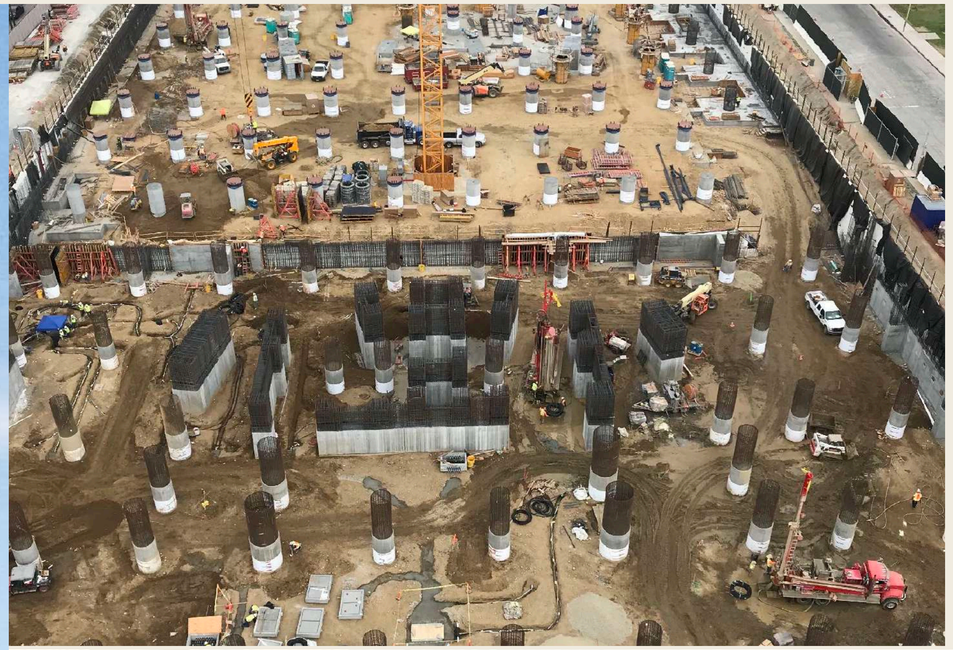
Owner strives to create world class facility using energy efficient solutions

SOLUTIONS OFFERED

- Geothermal based heating and cooling
- Borefield installed beneath building
- 705 bores to 365 ft deep
- Drilled directly within the critical path of construction

RESULT

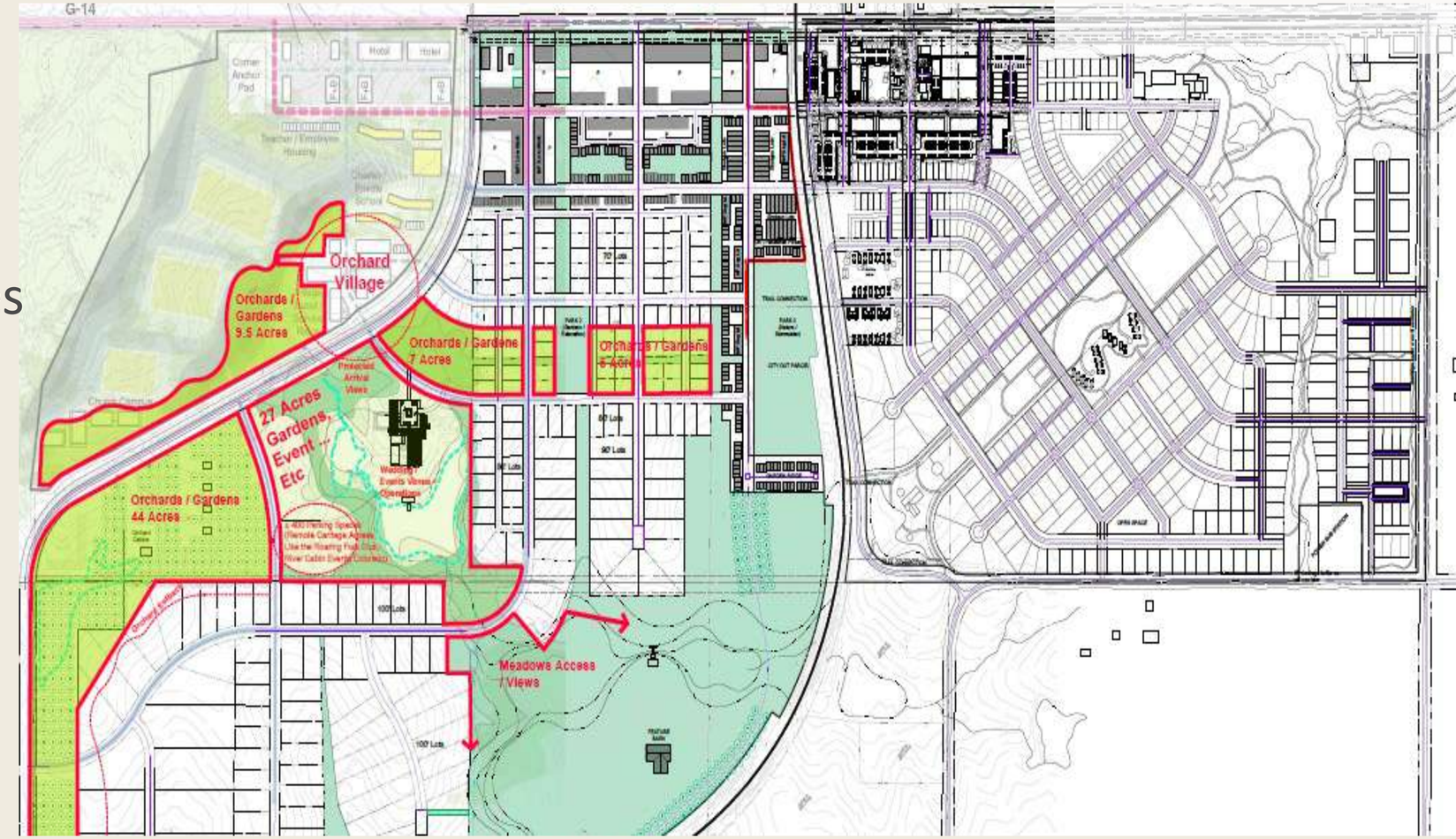
- Largest geothermal installation in California



Orca Energy / TerraSource Projects

Middlebrook Farm, Des Moines, Iowa

- Plans for ~1,700 total homes
- 400,000 s.f. commercial
- Sports complex and open spaces
- Wilson’s Orchard & Farm
- Agricultural community



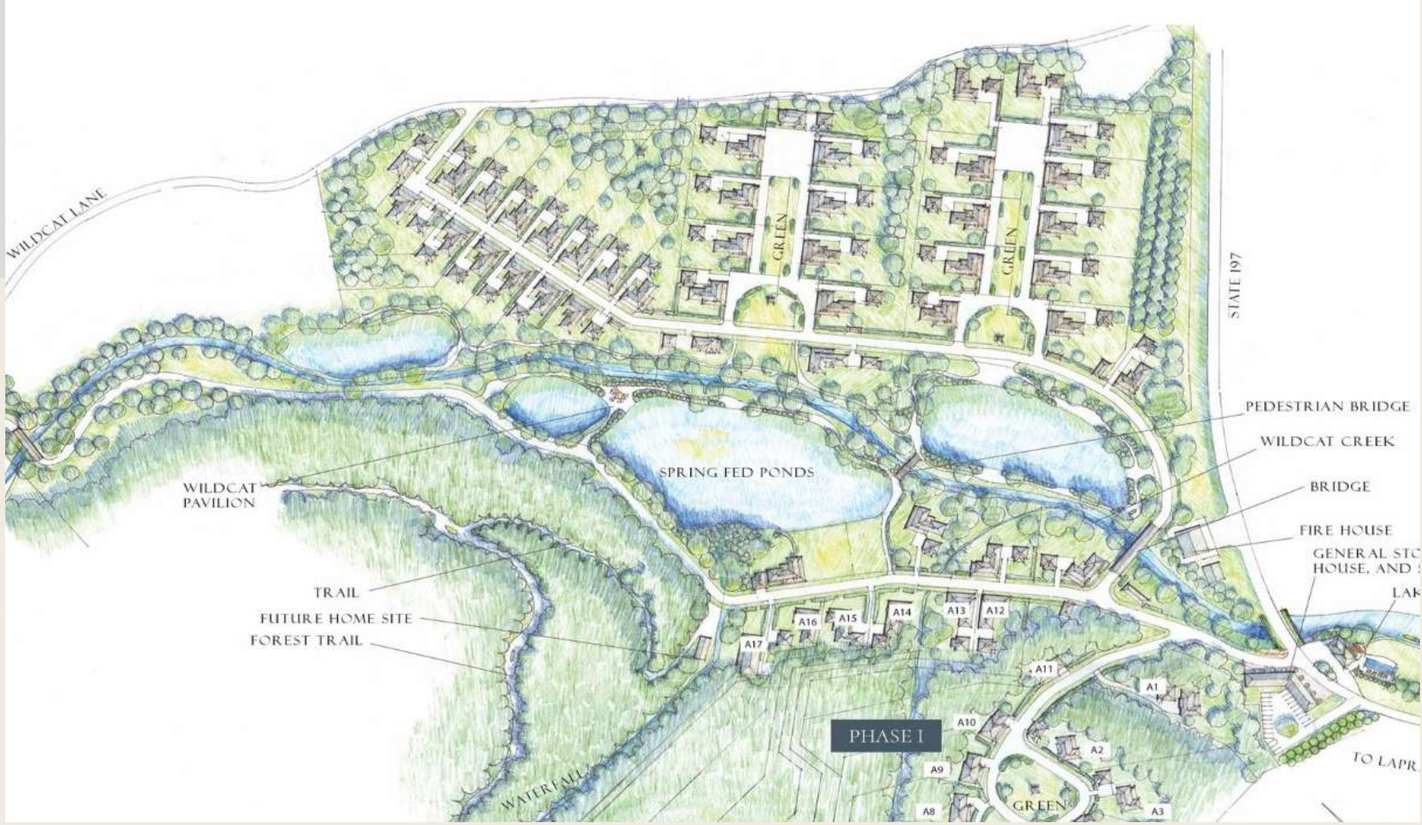
Veridian, Ann Arbor, Michigan

VERIDIAN
AT COUNTY FARM

- 13.59 acres
- 70 to 90 Units
- Townhomes, Apartments, SF Homes, Lofts
- Small retail & community center
- Sustainability focused
- Targeting Net Zero Energy

Lake Burton, Rabun County, GA

- 76 Homes, 13 estate lots
- Pristine lake in North GA
- Hiking, Fishing, Boating
- Developer did not want noise of A/C



Chattahoochee Hills Charter School

- Charter school in Chattahoochee Georgia
- One geothermal heat pump per classroom
- Zero fossil fuel heating and cooling
- Orca provides geothermal utility services

Cadence at the Lakes

- 162 Single Family Homes
- Average 3.5 Ton Heat Pumps
- Retirement Community
- Entry Level Price Point
- Orca/TerraSource provides geothermal utility services

Thank You

Stuart Yanow, P.Eng.
250-870-1213
syanow@geotility.com

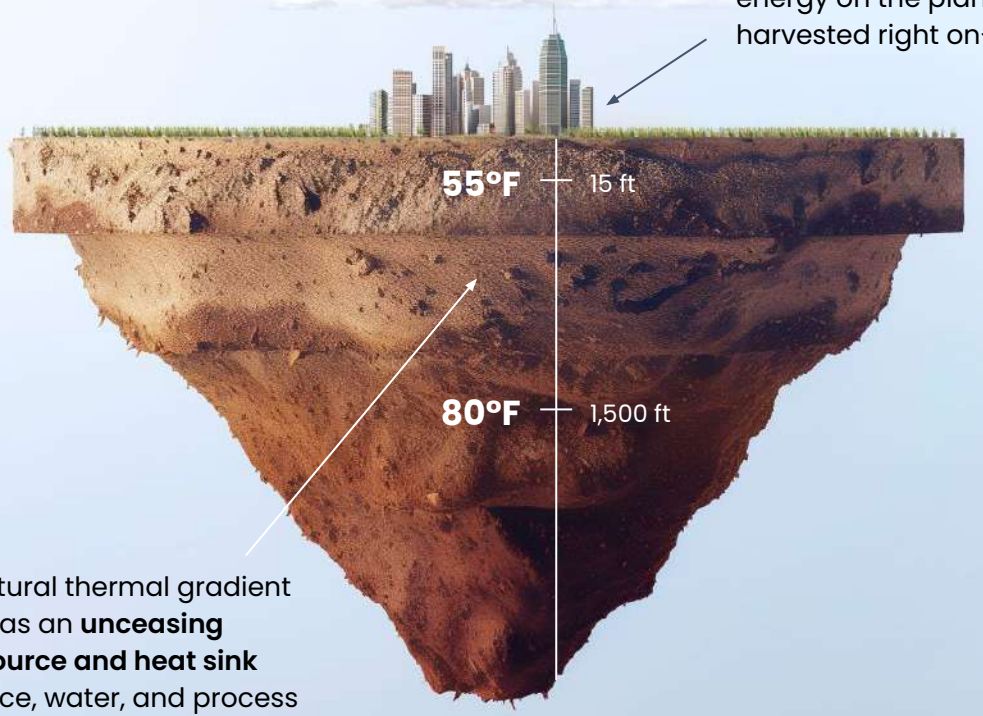
Bedrock Energy

Decarbonizing buildings everywhere

Electrification and energy savings with geothermal heating & cooling

Everywhere in the world, the first kilometer of the earth's subsurface provides **24/7 clean heating & cooling**

The most **consistent, sustainable, and efficient** thermal energy on the planet, harvested right on-site



The natural thermal gradient serves as an **unceasing heat source and heat sink** for space, water, and process conditioning in buildings

Four **barriers to scale** have impeded geo adoption for decades

High upfront cost	Limited space	Drilling error	Uncertain performance
10–25 year payback periods	**1:1 space requirements**	**5%–10% drilling deviation**	**10%–20% risk of ‘thermal creep’**
Due to expensive and uncertain upfront CapEx for drilling & construction	Due to 500’–850’ driller depth constraints and few design inputs	Due to ‘blind’ drilling and lack of control	Due to limited design data resolution

To scale up geo's value proposition, Bedrock solves the **barriers to scale** that have impeded geo for decades

Affordability

3x speed increase
driven by 3x-6x faster drilling

↓

Time is money, speed is affordability

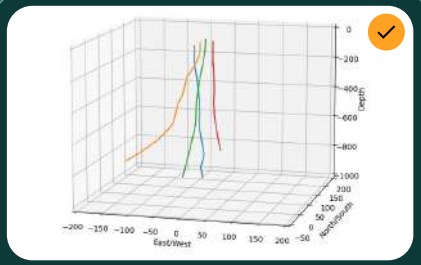
Space-Efficiency

3x load increase
deeper bores for smaller space

↓

Enable geo on smaller urban sites

Risk Reduction

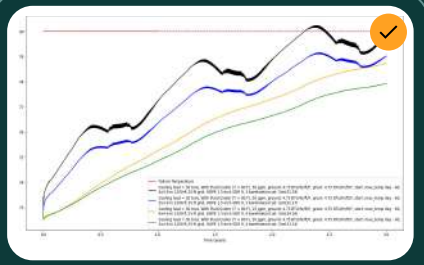


First ever
sensing and mapping of bores while drilling

↓

Real-time drift monitoring

Energy Confidence



First ever
physics-based subsurface energy modeling

↓

Confidence for performance guarantees

Our **Oil & Gas**, **Silicon Valley**, and **Real Estate** expertise creates a unique moat in direct-use geothermal

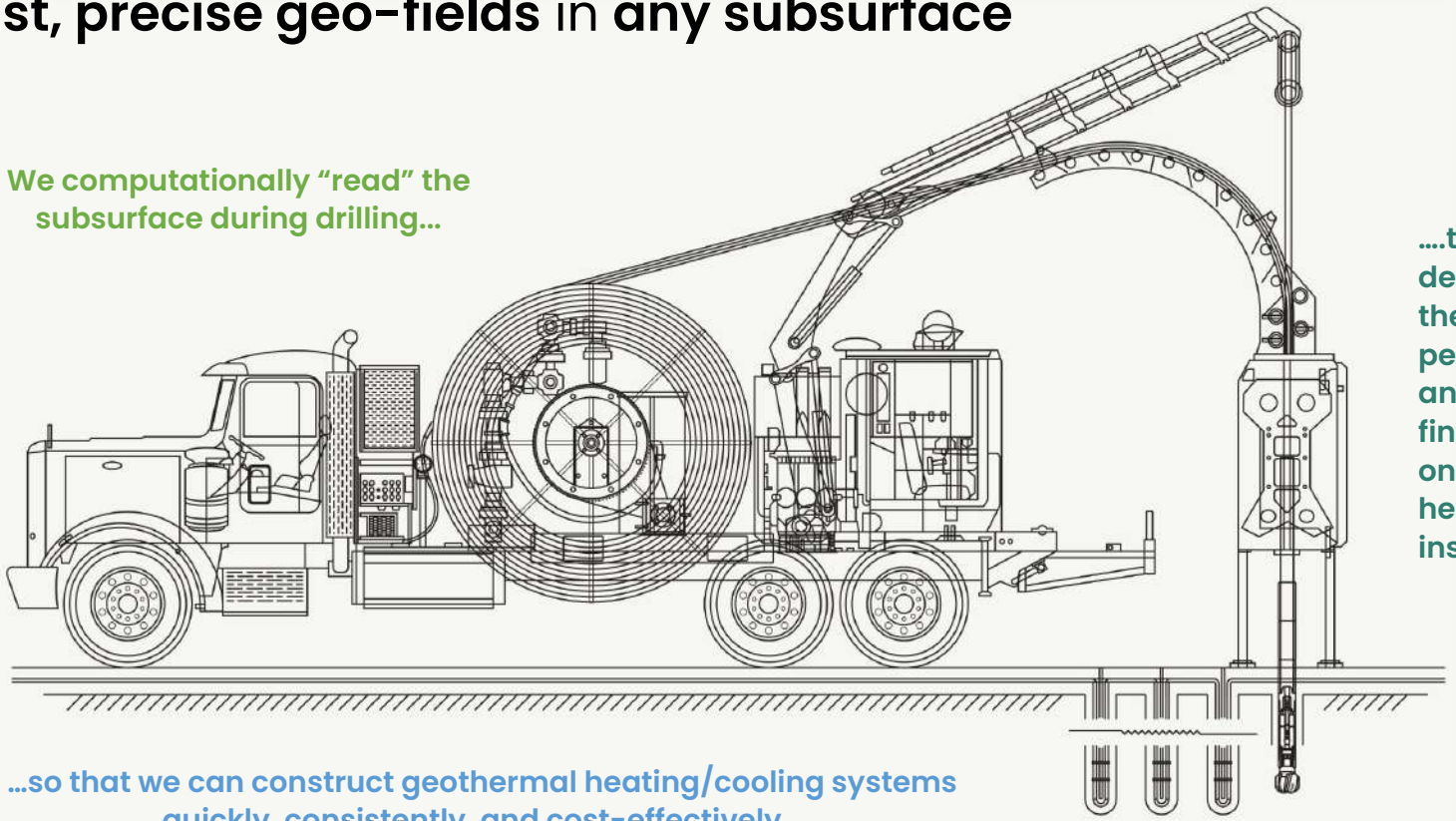
Bedrock's **diverse specializations** introduce the technical sophistication of the oilfield, with the price points needed in real estate construction, achieved at start-up speeds

Silviu Livescu
CTO
Former Chief Scientist of Pressure Pumping at Baker Hughes

Joselyn Lai
CEO
Former Bain & Company and sustainability start-ups

Bedrock's integrated, intelligent design-construction platform builds **fast, precise geo-fields** in **any subsurface**

We computationally "read" the subsurface during drilling...



....to give developers the highest energy performance and strongest financial return on a geothermal heating/cooling installation!

...so that we can construct geothermal heating/cooling systems quickly, consistently, and cost-effectively...

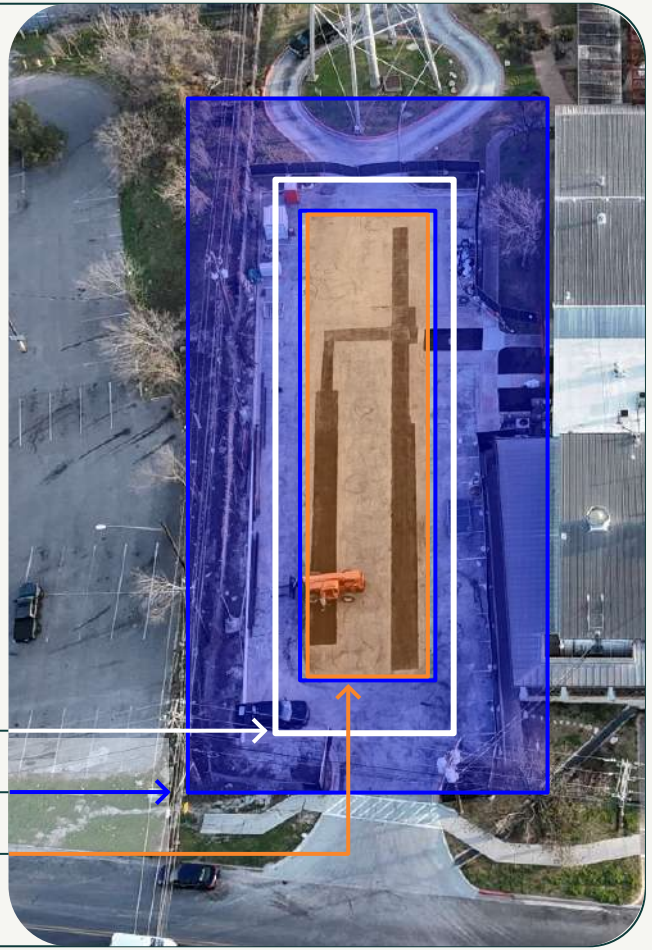
We've already demonstrated how we expand the market for geo HVAC - new or retrofit

CIM

Supported emissions reductions goals of a $30B AUM real estate owner

Deployed geothermal under a tight parking lot in urban Austin, TX, without disrupting office tenants

- Space available for geo-field
- Space required with legacy practice
- Bedrock geo-field footprint

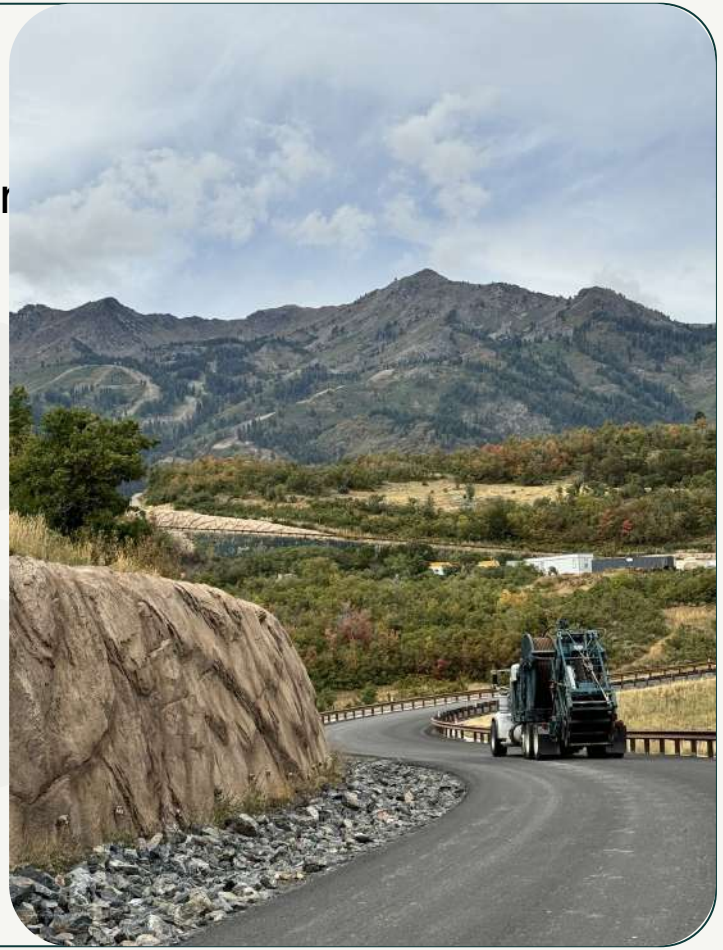


7

We are now proving out our **speed** and **depth** advantages in the Mountain region

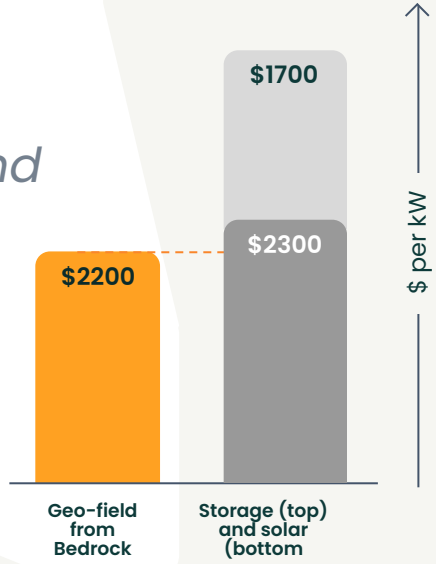
Supporting sustainability goals for a hospitality project in Morgan, UT

- Drilling through difficult unconsolidated boulders
- Experienced local driller = 4-5 days to drill 500'
- Bedrock = 1 day to drill a 1000' bore



8

Bedrock turns **geo-fields** into the **most affordable** *and* **resilient** form of distributed energy



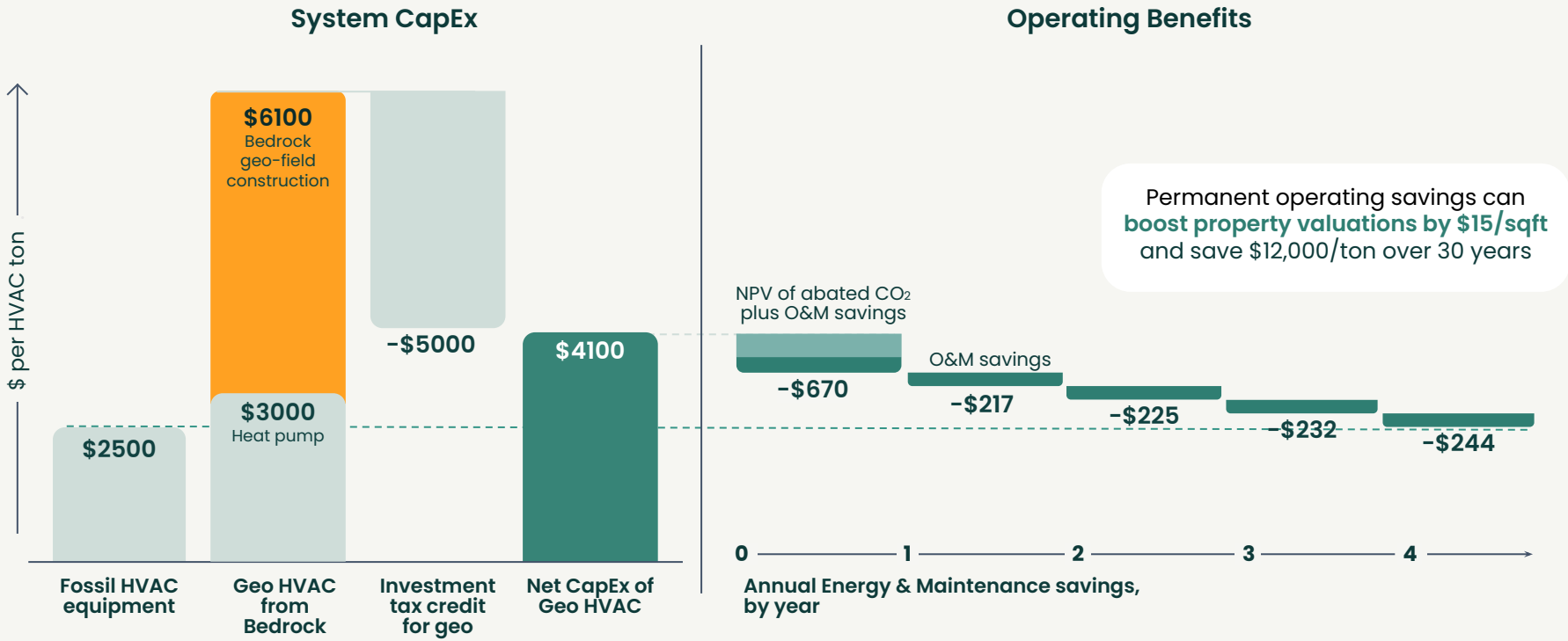
Clean energy installation CapEx
$ per kW produced, stored, or reduced

Geo-fields are the underground thermal energy asset that connects to the heat pump, central plant, or district system; the geo-field *reduces* peak power demand in lieu of providing power capacity

- Viable anywhere, 24/7/365
- Asset life of 50+ years
- Common, domestic materials
- No utility charges or interconnect fees
- Zero price volatility
- Easy to permit

Sources: Wood Mackenzie, US DOE, US NREL

Bedrock deploys geo to electrify real estate HVAC with ~**5yr payback**




info@BedrockEnergy.com