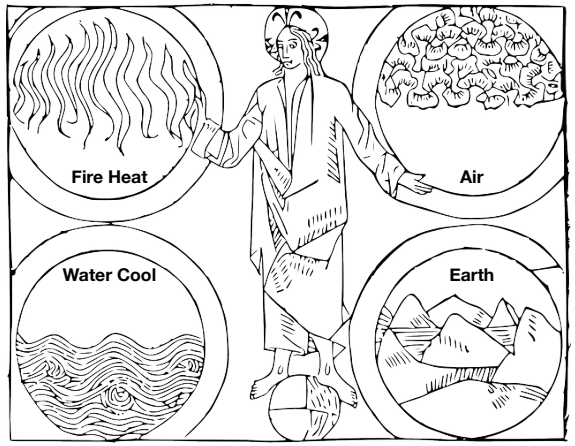


Heat and Cool Your Home Renewably and Get Off Natural Gas Cost Effectively.

Ken Regelson
12/6/2022

Image: pixabay.com

Energy ShouldBe.org

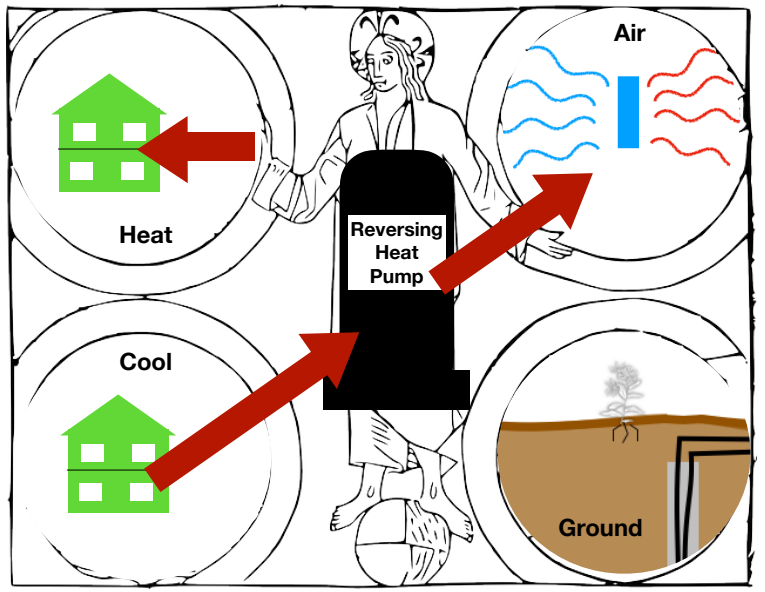


Image: pixabay.com and EnergyShouldBe.org

I skate to where the puck is going to be, not where it has been.

- Wayne Gretzky

Don't Believe Everything You Think.

Energy ShouldBe.org

Drive a rapid transition to a reliable, reasonable cost, responsible energy future based on data driven actions.

Gretzky Image: Kris Krüg [CC BY-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0)] source: https://commons.wikimedia.org/wiki/File:Wayne_Gretzky_2006-02-18_Turin_001.jpg

Getting Off Gas

2022

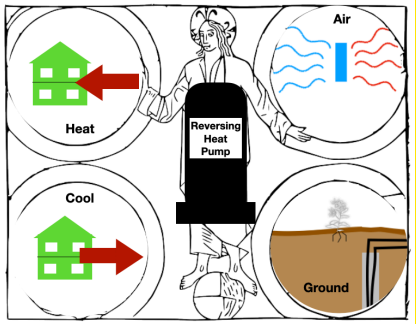
Image: EnergyShouldBe.org

Energy ShouldBe.org

Getting Off Gas

2022

Image:EnergyShouldBe.org



Topics:

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- **What is a heat pump?**
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- **Air Heat Pump.**
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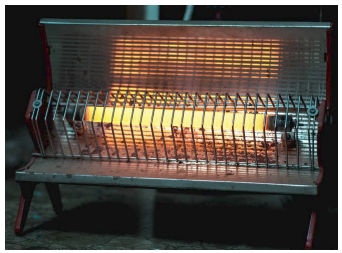
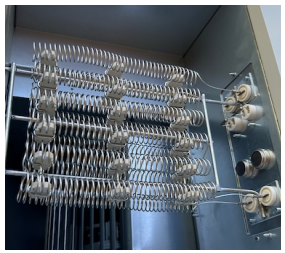
- **Energy Audit and Action First**

Image: pixabay.com

Electric Resistance Heat



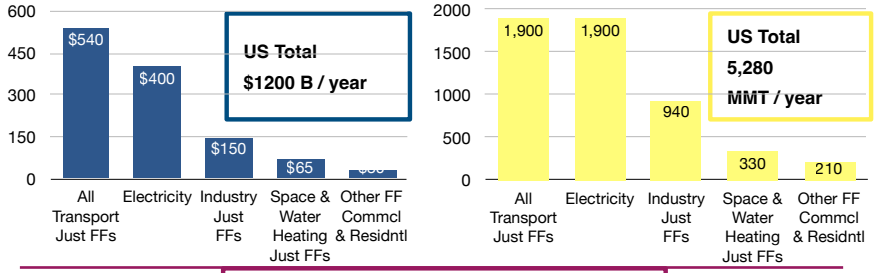


Images:pixabay.com and EnergyShouldBe.org

US Energy Cost Billion $ Per Year

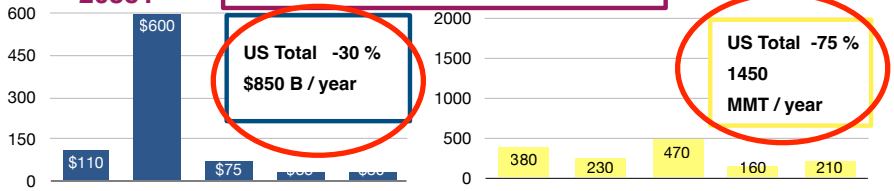
2015

US Energy GHGs Million MT CO2*e*



2035?

90% Renewable Electricity. 80% EVs. Electrify 50% of industry and Heating.



Images: EnergyShouldBe.org Data analysis EnergyShouldBe.org based on EIA 2015 US data.

US Energy Cost
Billion $ Per Year

US Energy GHGs
Million MT CO2*e*

US Total
$1200 B / year

US Total
5,280
MMT / year

SAVE
$350 B / year

2035?

US Total -30 %
$850 B / year

US Total -75 %
1450
MMT / year

Images: EnergyShouldBe.org Data analysis EnergyShouldBe.org based on EIA 2015 US data.

US Energy Cost

US Energy GHGs

Empower Our Future presents

EMPOWER HOUR

Making Miles While the Sun Shines.

Why charging EVs for cheap is good for everyone's electric bill.

$850 B / year

1450
MMT / year

Images: EnergyShouldBe.org Data analysis EnergyShouldBe.org based on EIA 2015 US data.

My Daughter Bakes Really Great Cakes!

Like most bakers, she follows a recipe.

Colorado Energy Recipe

1 part 90 -100% Renewable Electricity

1 part *Electrify All* - Everything Else

Cold Climate, Getting Off Gas Recipe - Electrify All

Cooktop.	**Induction** **I Believe**
Water heater.	**Resistance or Heat Pump** **I Believe**
Clothes dryer.	**Resistance or Heat Pump** **I Think**
Home heating.	**Ground or Air Heat Pump** **I Think**

Goal: Cost-Effective and Responsible Comfort

Images:EnergyShouldBe.org and pixabay.com

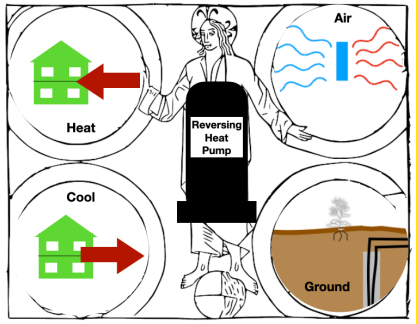


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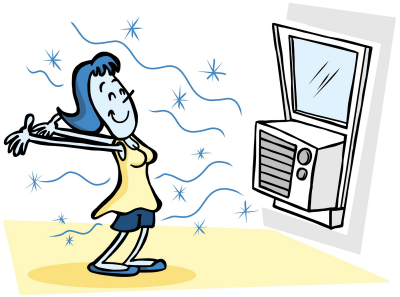
Image: pixabay.com

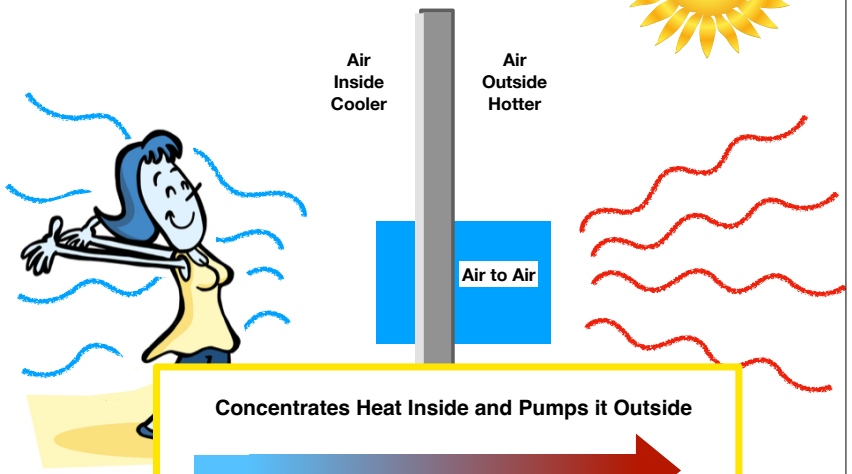
Heat Pumps: You've Got Some



Use electricity to run a pump that moves heat from one place to another.

Images: pixabay.com

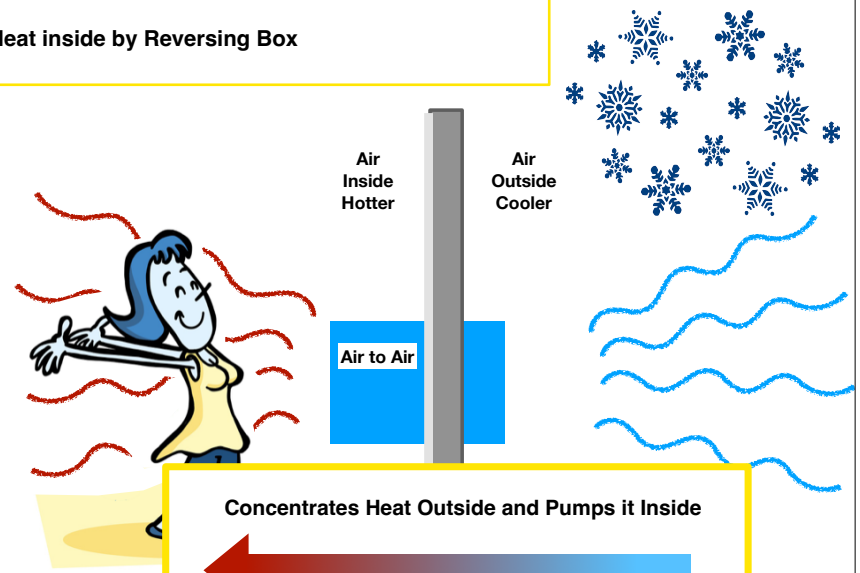
Air Conditioner: a Cooling only Heat Pump



Concentrates Heat Inside and Pumps it Outside

Images: pixabay.com and EnergyShouldBe.org

Heat inside by Reversing Box



Concentrates Heat Outside and Pumps it Inside

Images: pixabay.com and EnergyShouldBe.org

About That Name

Heat Pump

Air Source Heat Pump

Geothermal or Geo Heat Pump

Ground Source Heat Pump

Air to Air Heat and Cool Pump

Air to Ground …

Air Heat Pump

Ground Heat Pump

Image: pixabay.com

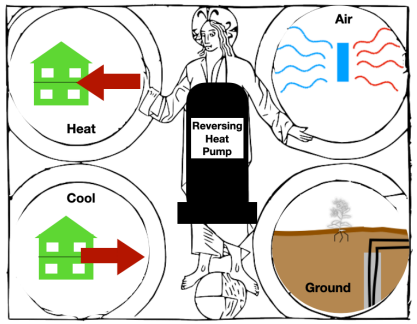


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Image: pixabay.com

Ground Heat Pump

Also known as

- Geothermal or Geo
- Ground Source Heat Pump
- Ground to Air Heat or Cool Pump
- GeoExchange …
- Brine …

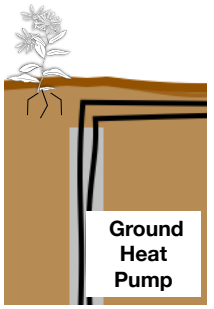
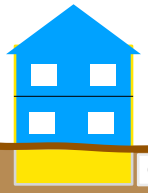


Image: pixabay.com

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.



Average about 50° F

Not to Scale

400' deep

Image: EnergyShouldBe.org

Ground Heat Pump Installatio
Loop, Heat Pump, & Air Hand

Average about 50° F

Not to Scale

400' deep

Image: EnergyShouldBe.org

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.

Crawlspace

Average about 50° F

Not to Scale

400' deep

Image: EnergyShouldBe.org

21

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.

Crawlspace

Average about 50° F

Not to Scale

400' deep

Image: EnergyShouldBe.org

22

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.

3' deep

Crawlspace

Heat Pump & Air Handler

Average about 50° F

Not to Scale

400' deep

Image: EnergyShouldBe.org

23

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.

Crawlspace

Heat Pump & Air Handler

wells about 20' apart

Not to Scale

Image: EnergyShouldBe.org

24

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.

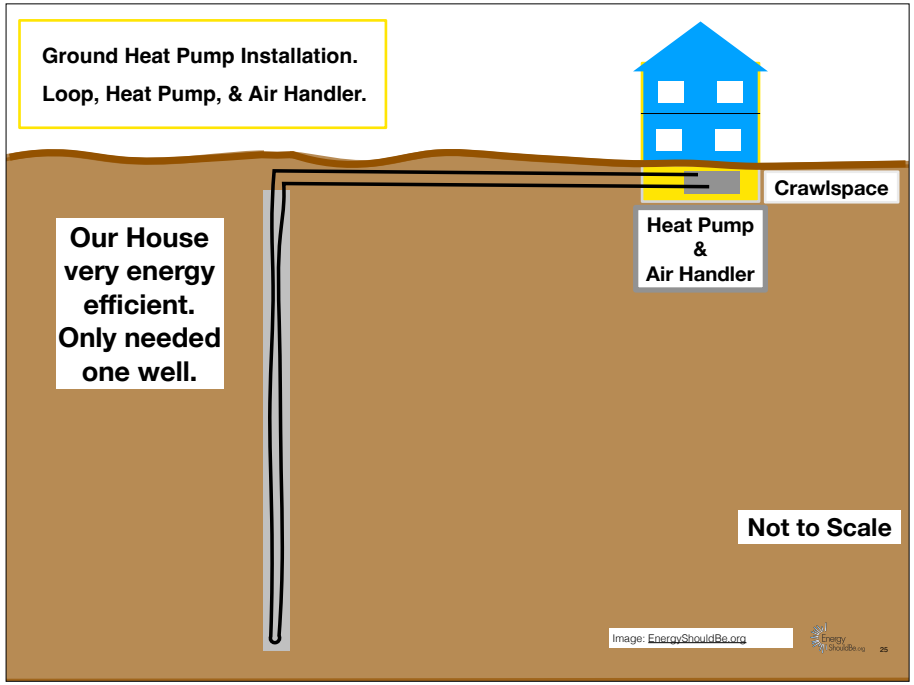


Image: EnergyShouldBe.org

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Loop, Heat Pump, & Air Handler.

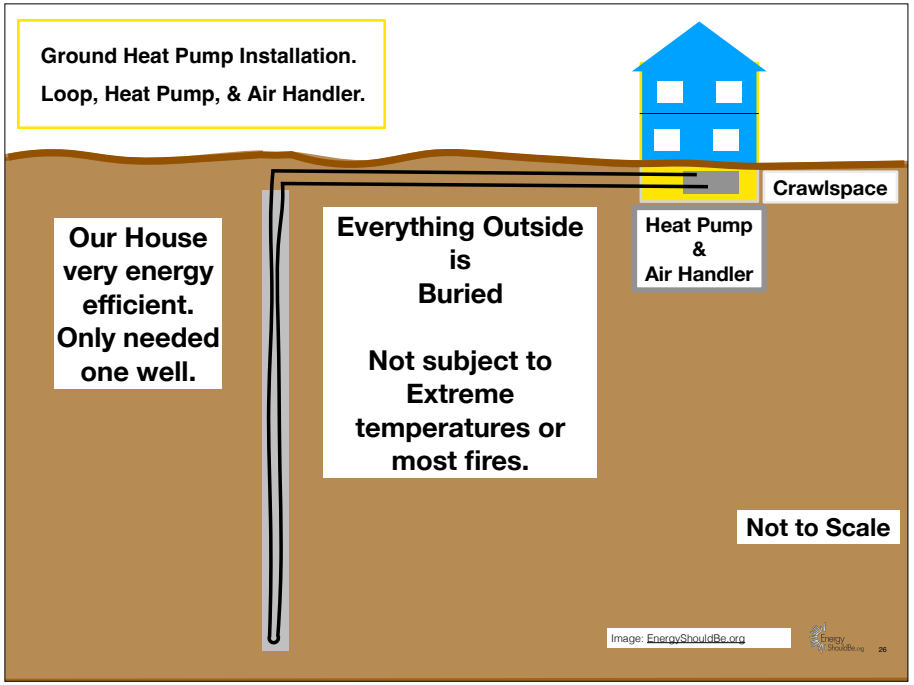


Image: EnergyShouldBe.org

Front Yard Before & After

Images: EnergyShouldBe.org

Heavy Equipment for Loop Well

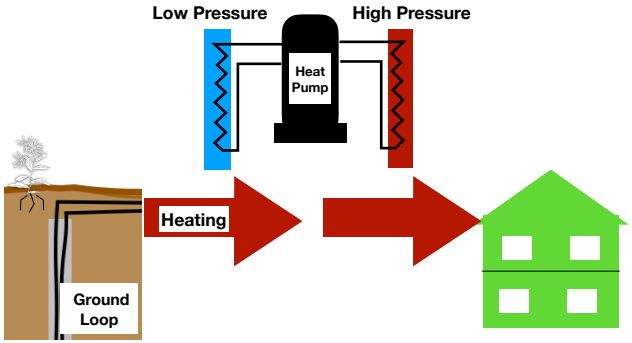
- Drilling Rig
- Sucker Truck
- Compressor
- Excavator
- Grout Mixer

Image: EnergyShouldBe.org

How Does Ground Work?

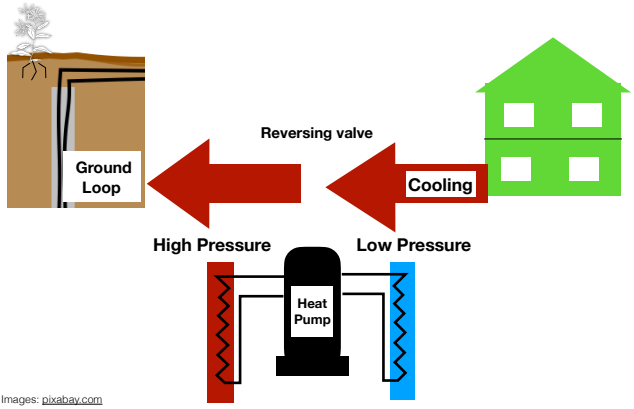
Image: EnergyShouldBe.org

Heat and Cool Pump



Images: pixabay.com

Heat and Cool Pump



Images: pixabay.com

How does it work?

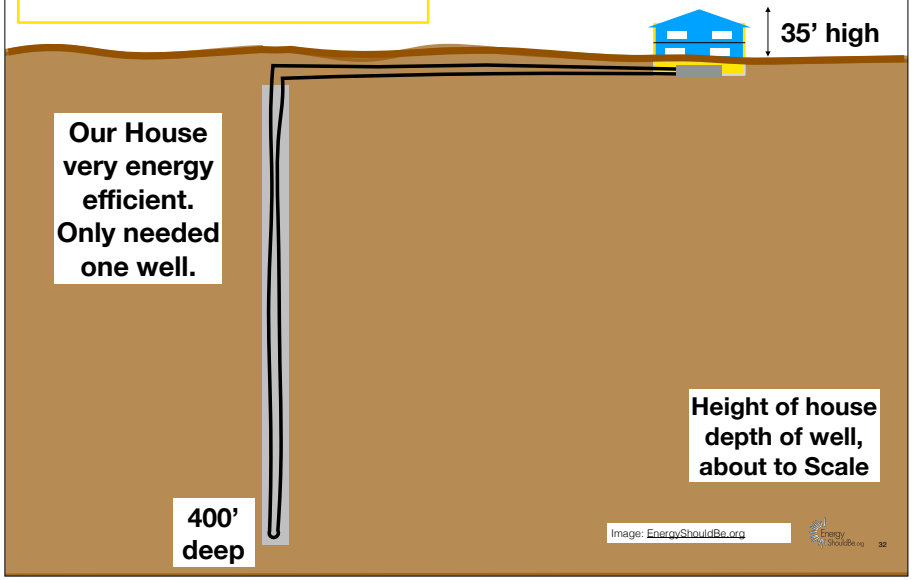
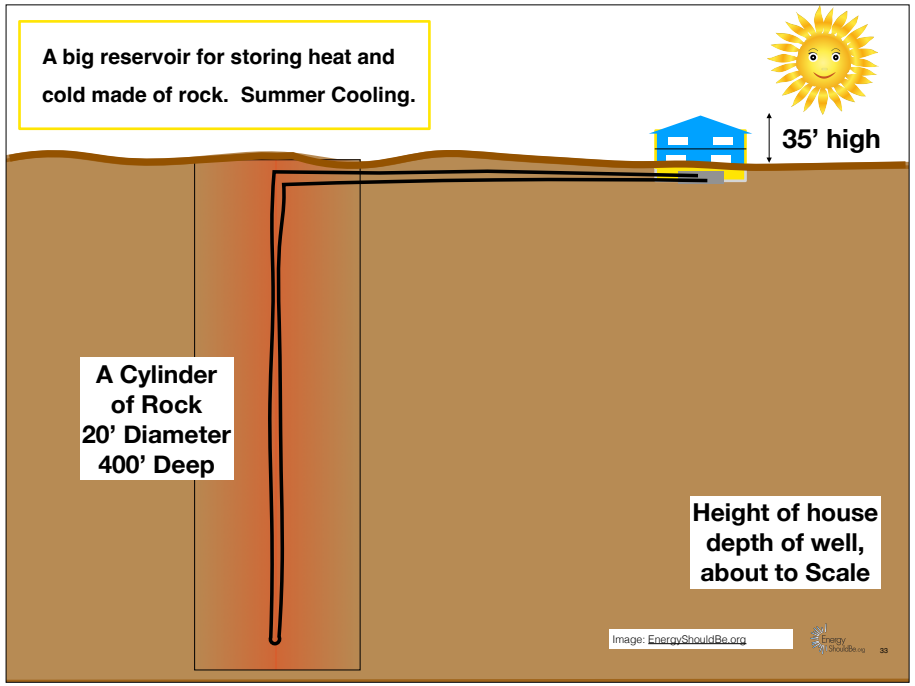


Image: EnergyShouldBe.org

A big reservoir for storing heat and cold made of rock. Summer Cooling.



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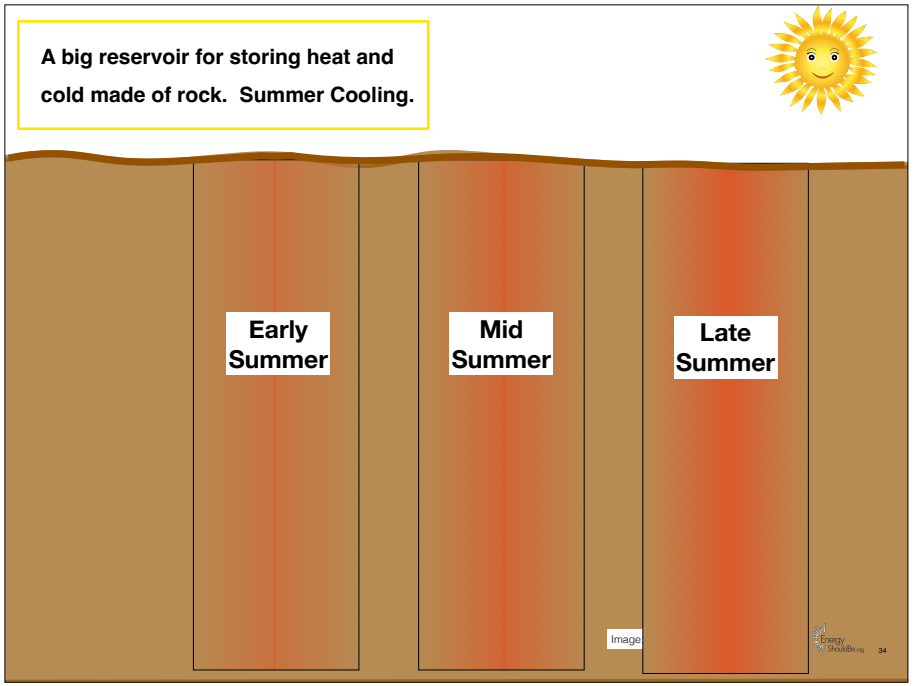

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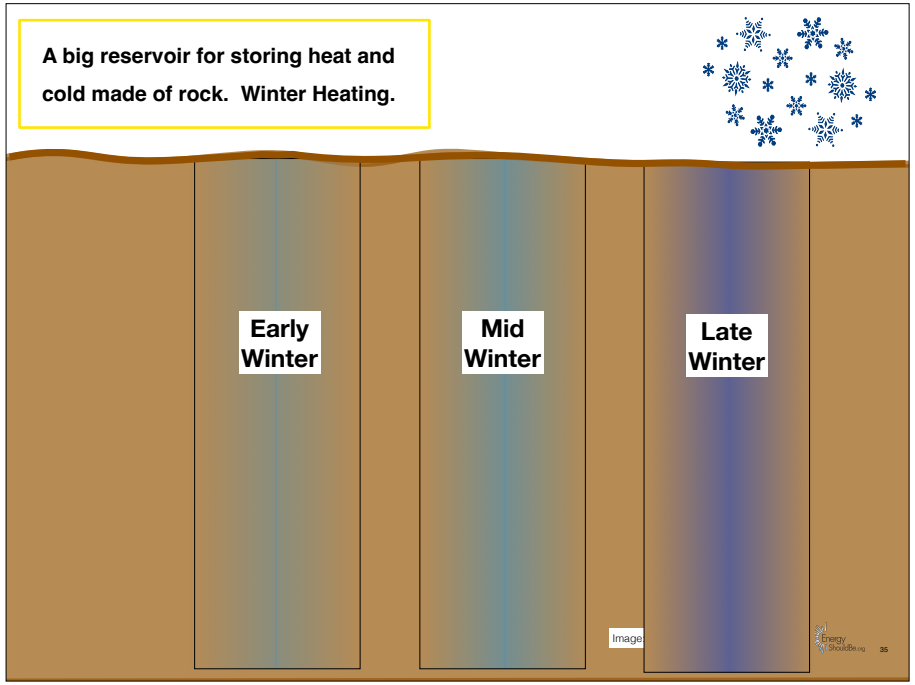

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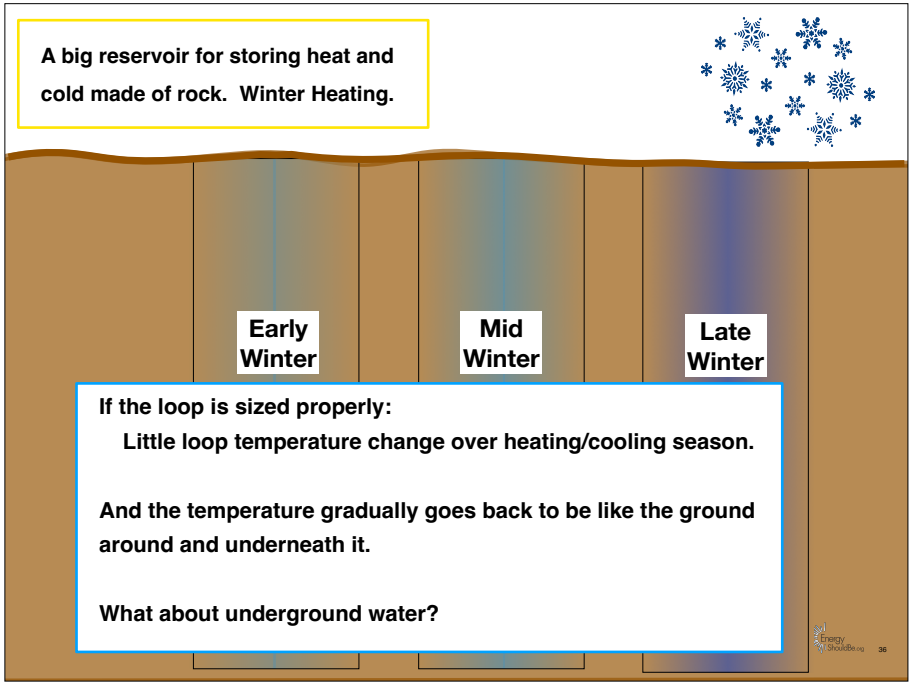


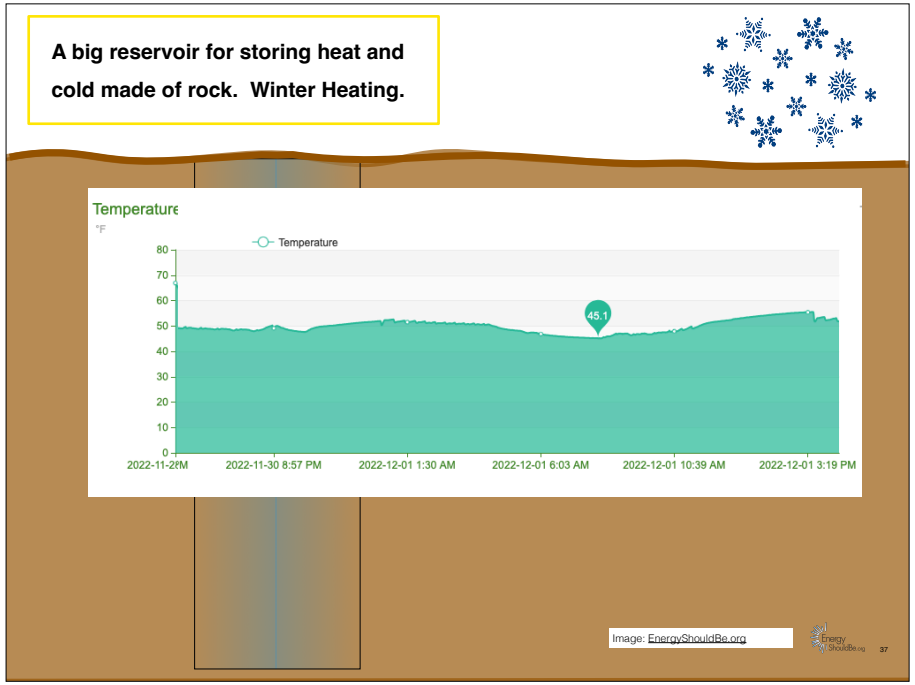
If the loop is sized properly:

Little loop temperature change over heating/cooling season.

And the temperature gradually goes back to be like the ground around and underneath it.

What about underground water?

A big reservoir for storing heat and cold made of rock. Winter Heating.



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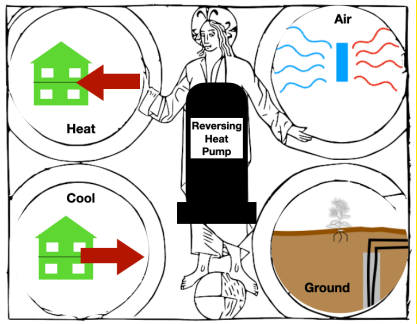

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Image: pixabay.com

Air Heat Pump

Also known as

- Air Source Heat Pump
- Air to Air Heat or Cool Pump

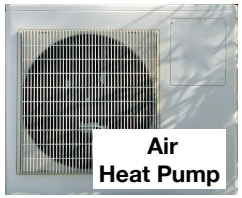


Image: pixabay.com

Air Heat Pump Installation.
Outside and Inside Units.

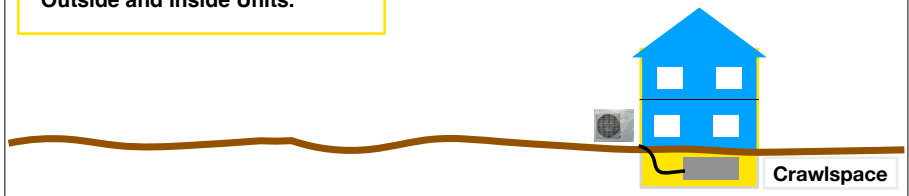


Image: EnergyShouldBe.org

Air Heat Pump Installation.

Outside When 110.

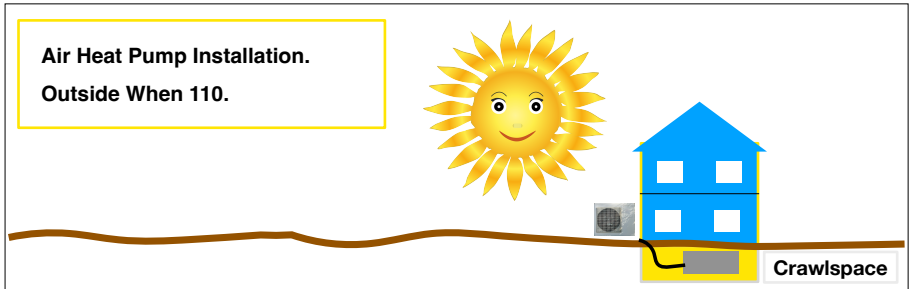
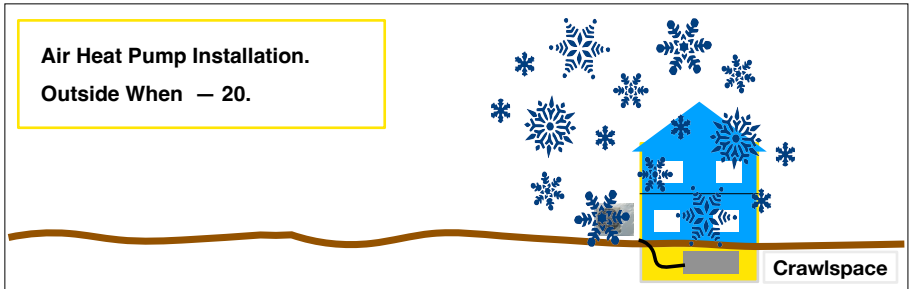


Image: EnergyShouldBe.org

Air Heat Pump Installation.

Outside When — 20.



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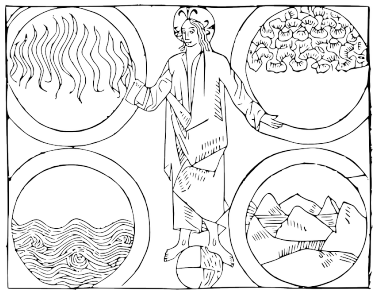

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Ground vs Air

Both:

Cooling

Much more energy efficient than traditional air conditioners.

Ground more efficient cooling than air.

Heating

On an annual basis, very likely to save money over electrical resistance, propane, and fuel oil heat. Possibly annual savings over gas.

Image: EnergyShouldBe.org

Ground vs Air

Both:

Available in different sizes.

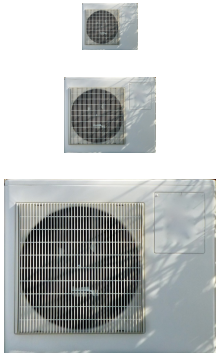


Image: EnergyShouldBe.org

Ground vs Air

Both:

Single Stage

Two Stage

Inverter or Modulating

Image: EnergyShouldBe.org

Ground vs Air

Both:

Short Cycling.

When temperatures are mild, one-stage HPs may cycle on and off quickly. This increases maintenance and decreases efficiency.

Two-stage HPs are less prone to short-cycle, and modulating HPs are even less likely to short-cycle.

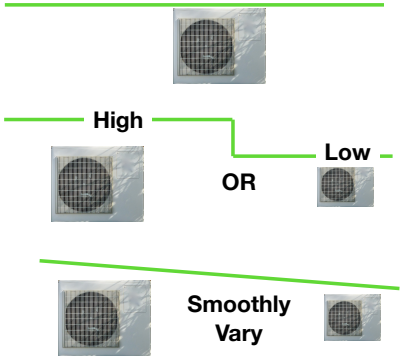
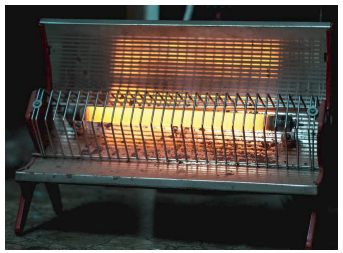
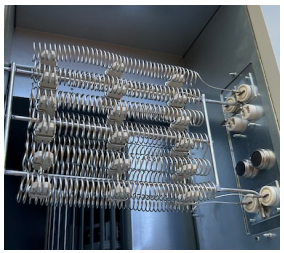


Image: EnergyShouldBe.org

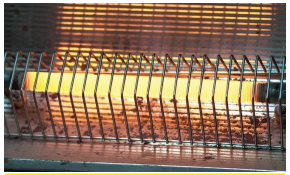
Electric Resistance Heat





Images:pixabay.com and EnergyShouldBe.org

Efficiency



Resistance Heat: 1 to 1.
Make 1 kWh of heat from
1 kWh of electricity

Heat and electricity are both forms of energy

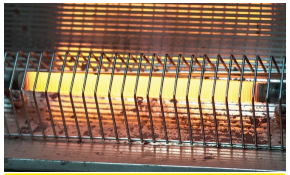
1 kilowatt-hour of electricity is 3213 BTUs

Wouldn't it be great if you could heat your home at 3 to 1 or even 5 to 1?

Breaks laws of thermodynamics? No. Not creating heat, but moving it.

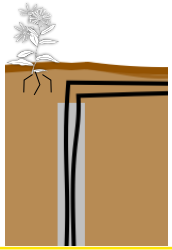
Images:pixabay.com and EnergyShouldBe.org

Efficiency



Resistance Heat: 1 to 1.
Make 1 kWh of heat from
1 kWh of electricity

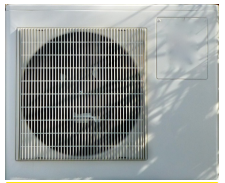
Or 100% Efficient.



Ground Heat Pump:
4 to 1 up to 5 to 1.
If Loop is right-sized.

300 to 500% efficient.

5 to 1 for cooling.



Air Heat Pump:
Up to 3 to 1.
Some 4 to 1.

Up to 300% efficient.

Images:pixabay.com and EnergyShouldBe.org

Air & Ground Heat Pumped as Outside Temp Changes

Comfy 70°

Outside °F

110
90
70
50
30
10
-10

Images: pixabay.com and EnergyShouldBe.org

Energy Needed to Be Moved as Outside Air Changes Temperatures

Comfy 70°

Outside °F

Energy Moved to Cool Home

Energy Moved to Heat Home

Both Air and Ground Heat Pumps

110
90
70
50
30
10
-10

Images: pixabay.com and EnergyShouldBe.org

Water Pump

Comfy 70°

Outside °F

110
90
70
50
30
10
-10

Energy Moved to Cool Home

Energy Moved to Heat Home

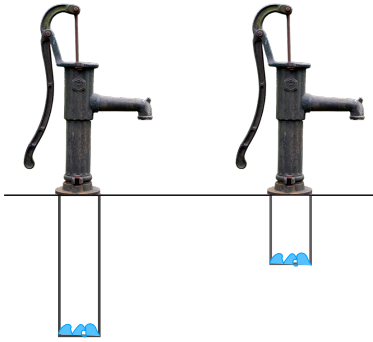
Both Air and Ground Heat Pumps

Pump efficiency:
- How much work for each gallon of water.

Capacity:
- How much can pump per hour.

Images: pixabay.com and EnergyShouldBe.org

Water Pump: Capacity & Efficiency Shrink as Water Depth Falls



Comfy 70°

Outside °F

110
90
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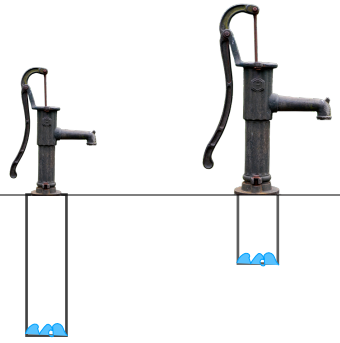
Energy Moved to Cool Home

Energy Moved to Heat Home

Both Air and Ground Heat Pumps

Images: pixabay.com and EnergyShouldBe.org

Water Pump: Capacity & Efficiency Shrink as Water Depth Falls



Comfy 70°

Outside °F

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90
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-10

Energy Moved to Cool Home

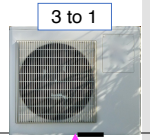
Energy Moved to Heat Home

Both Air and Ground Heat Pumps

Images: pixabay.com and EnergyShouldBe.org

Air Heat Pump: Heating Efficiency and Capacity Shrink as Outside Temp Falls

More Work to Concentrate the Heat.



Comfy 70°

Outside °F

110
90
70
50
30
10
-10

Energy Moved to Cool Home

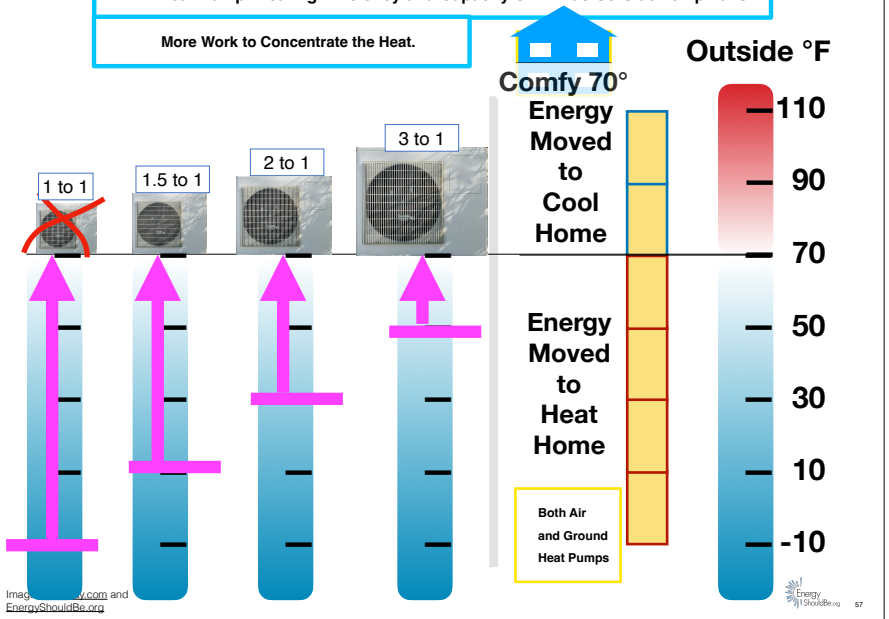
Energy Moved to Heat Home

Both Air and Ground Heat Pumps

Images: pixabay.com and EnergyShouldBe.org

Air Heat Pump: Heating Efficiency and Capacity Shrink as Outside Temp Falls

More Work to Concentrate the Heat.

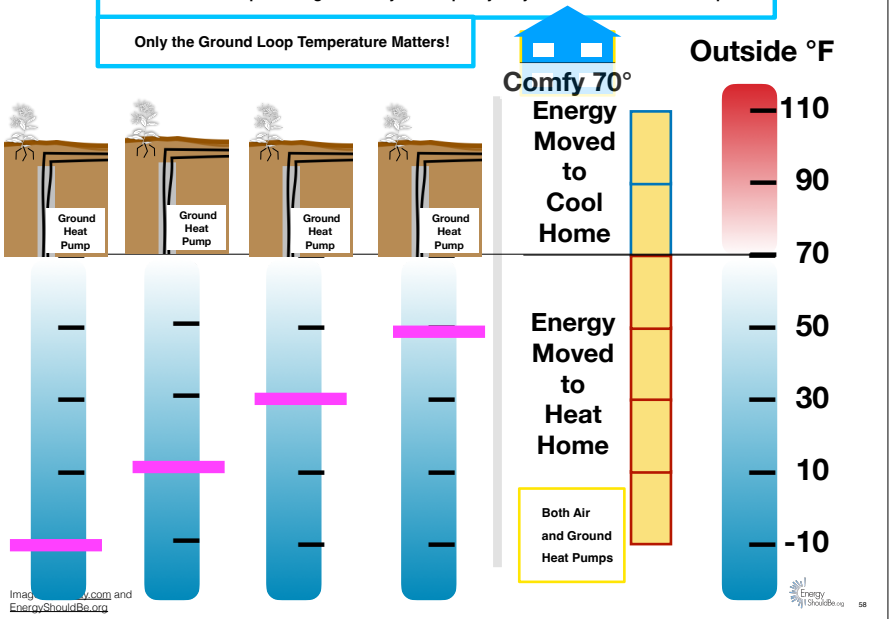


Images: pixabay.com and EnergyShouldBe.org

57

Ground Heat Pump: Heating Efficiency and Capacity Stay the Same as Outside Temp Falls

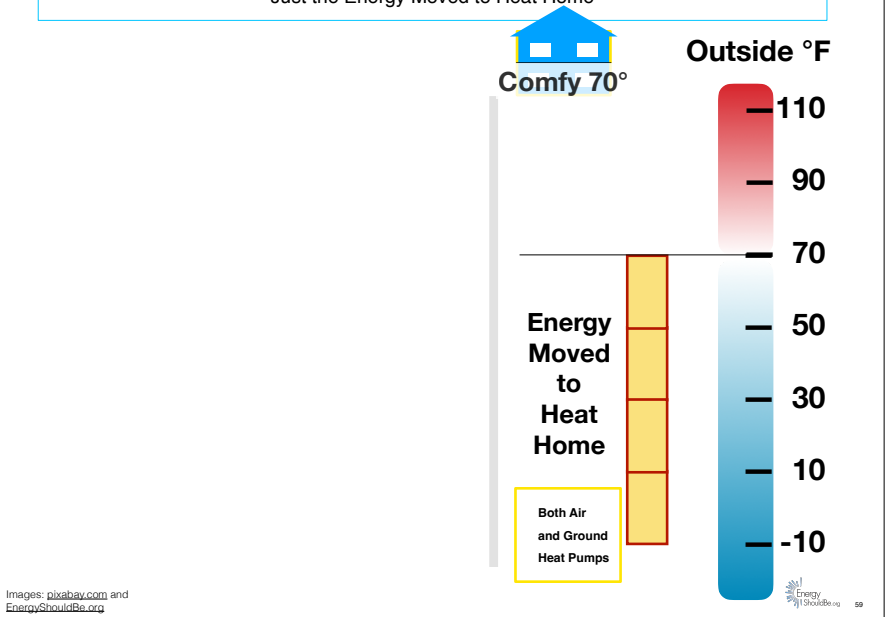
Only the Ground Loop Temperature Matters!



Images: pixabay.com and EnergyShouldBe.org

58

Just the Energy Moved to Heat Home



Images: pixabay.com and EnergyShouldBe.org

59

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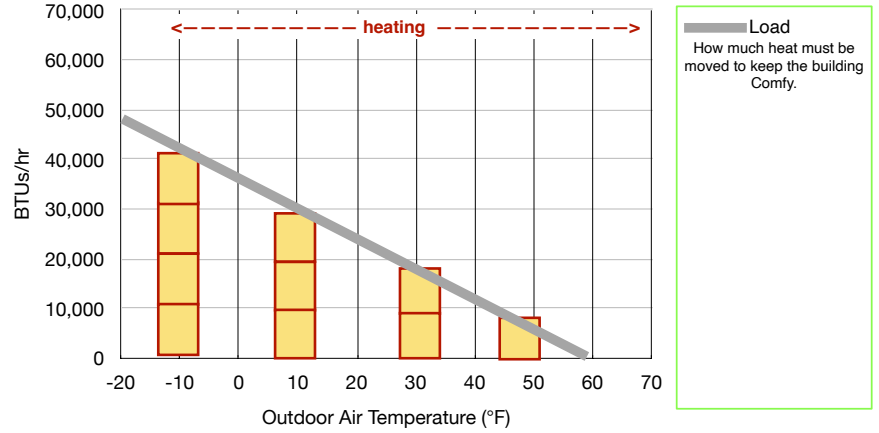
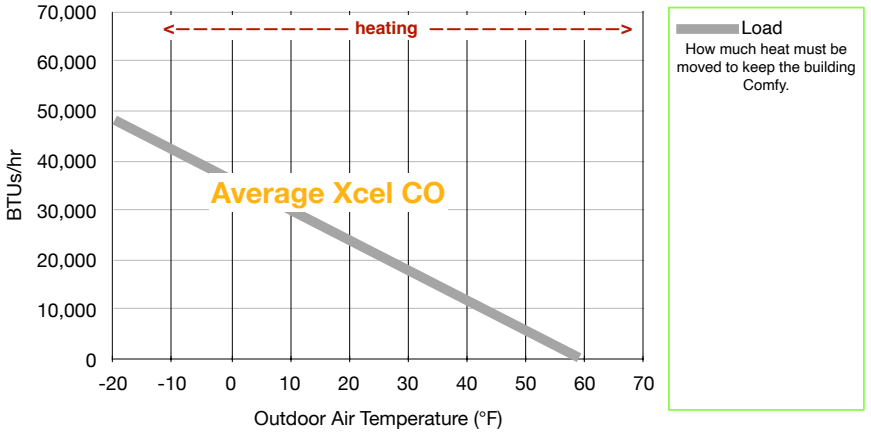


source: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Clean-Energy-Workforce-Development/ASHP-Sizing-Design-Training-Tech.pptx%202021-12-16
Slide 56 major changes for presentation by EnergyShouldBe.org

60

The Average Xcel Gas for Heat Colorado Residence



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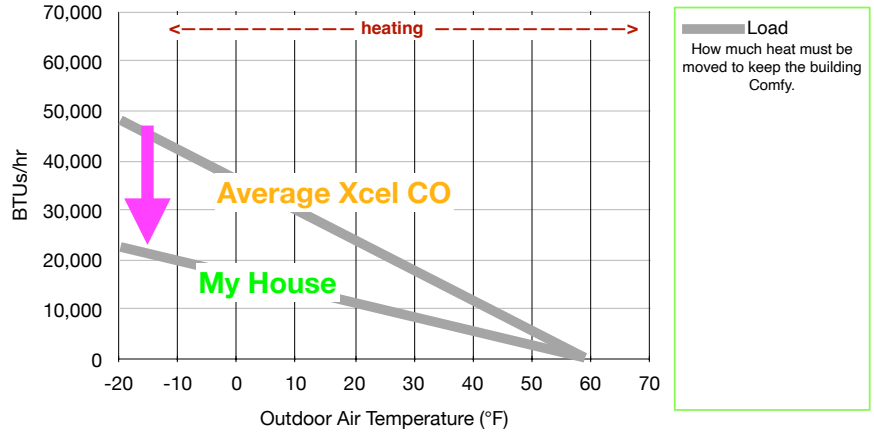
First, Improve Efficiency



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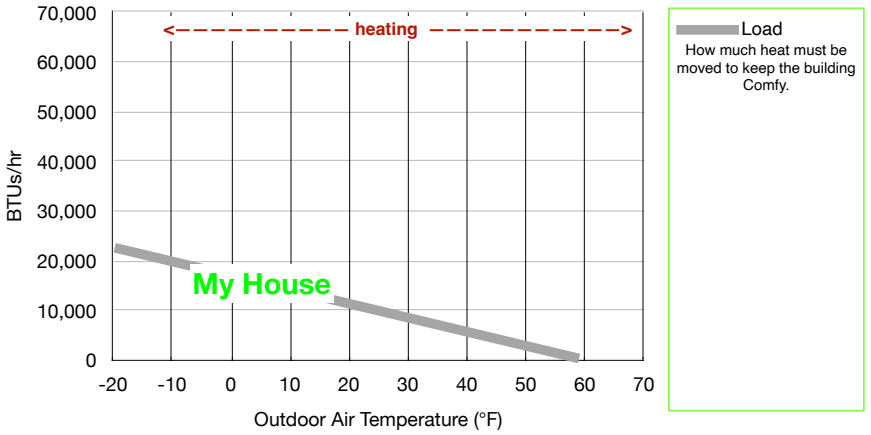

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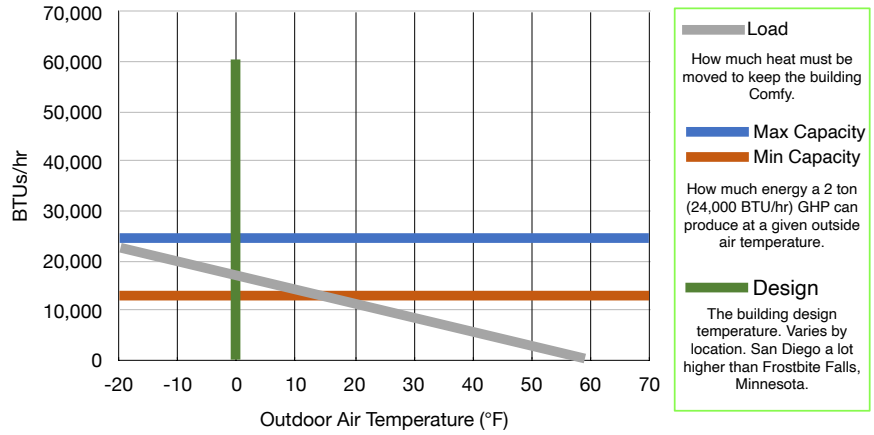
My House and Ground Heat Pump



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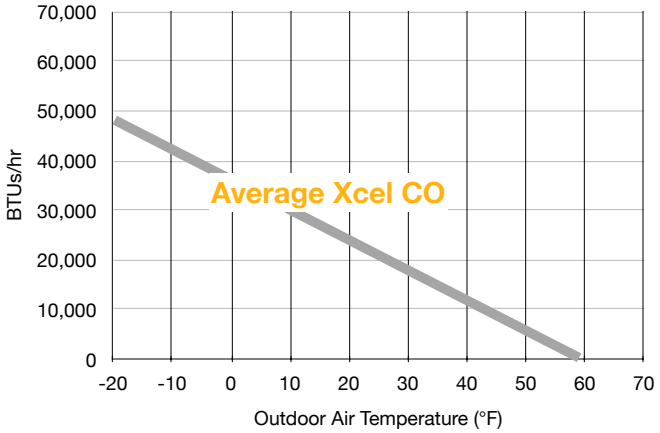
Slide 56 major changes for presentation by EnergyShouldBe.org

for my house based on cold snap of Feb 2021 measured gas usage, average coldest 24 hours at -4 F and used 5.6 therms or 19,800/hour in assumed 85% efficient gas furnace.

Cold Climate Air Heat Pump: As Outside Air Temp Drops, Capacity and Efficiency Shrink



Load

How much heat must be moved to keep the building Comfy.

Max Capacity

Min Capacity

How much energy a 3 ton (36,000 BTU/hr) modulating GHP can produce at a given outside air temperature.

Design

The building design temperature. Varies by location. San Diego a lot higher than Frostbite Falls, Minnesota.

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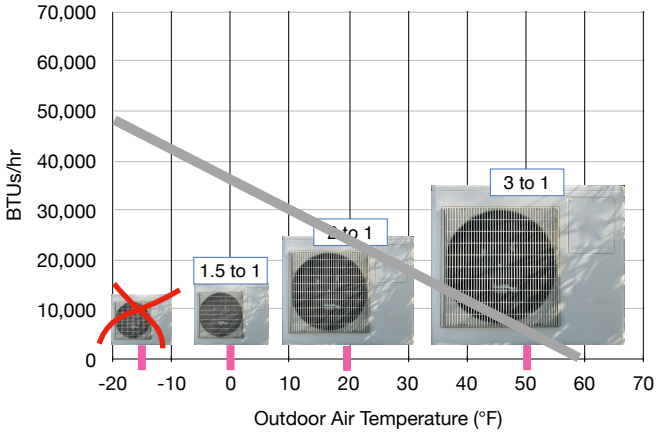

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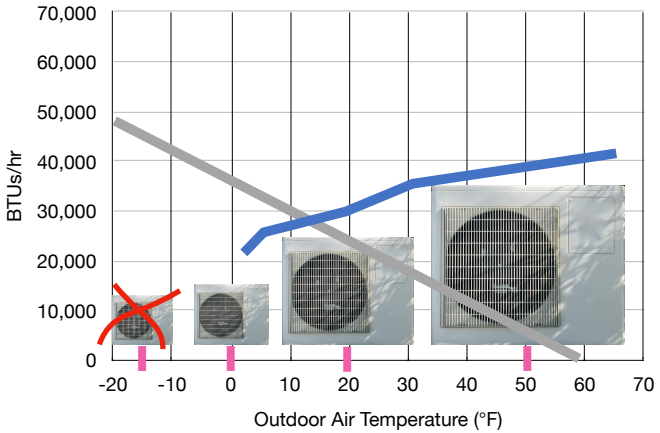

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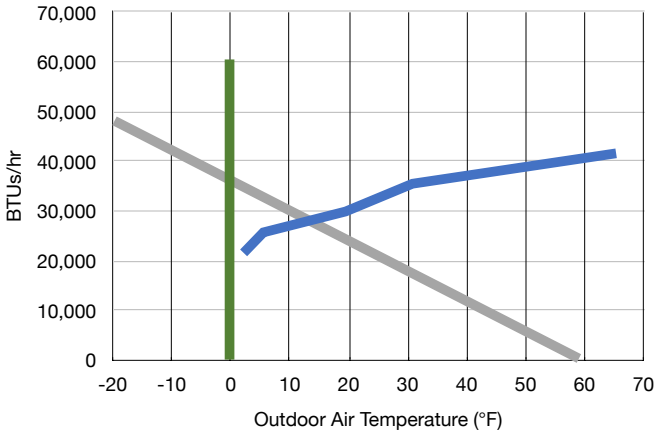

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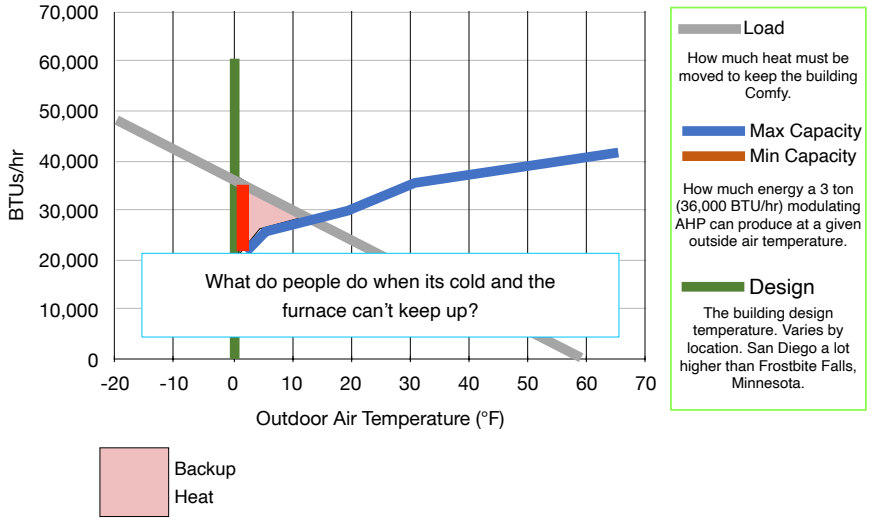

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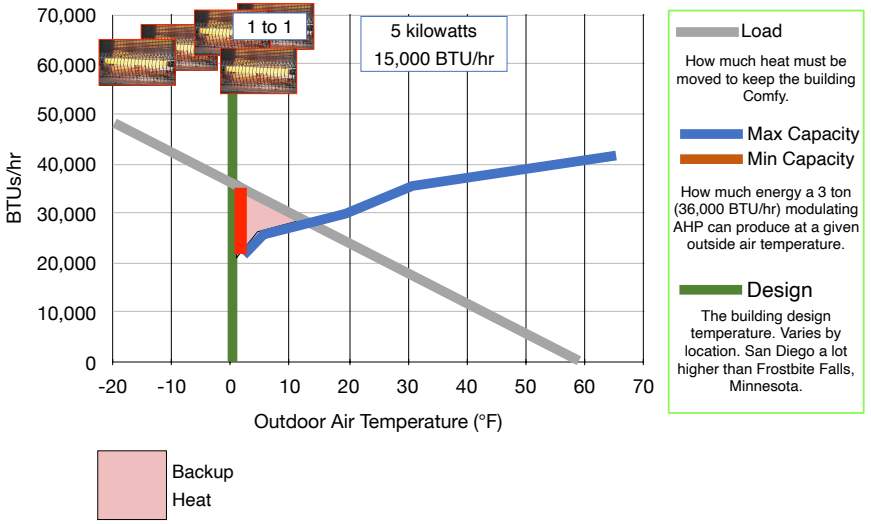

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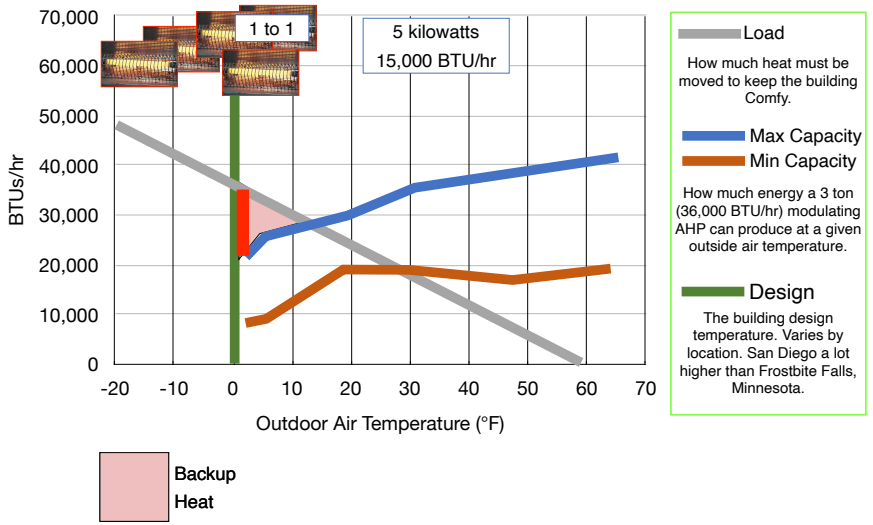

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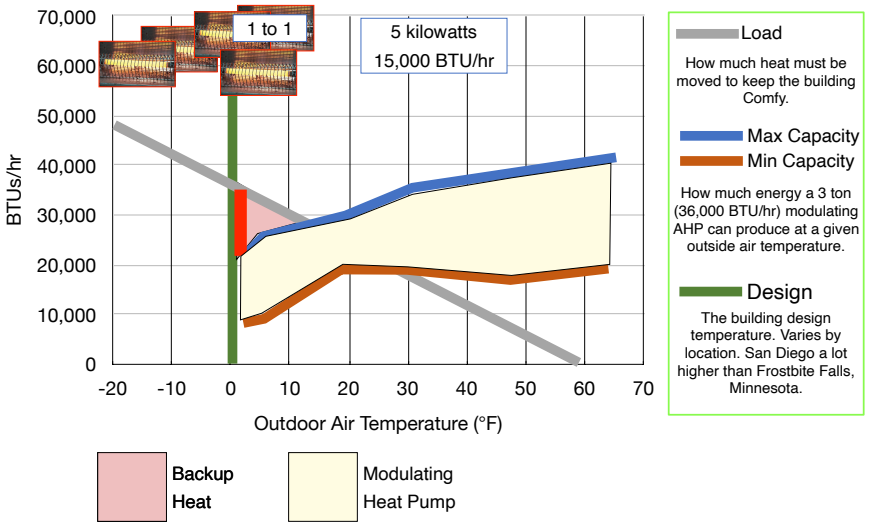

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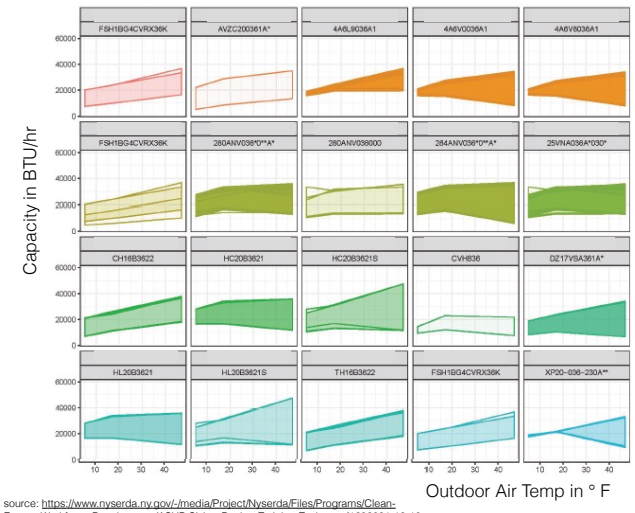
Slide 56 major changes for presentation by EnergyShouldBe.org

Air Heat Pump in cold climates - What happens at -10 °F? -20 °F?

"...data ... from NEEP ccASHP database for a wide variety of nominal **3-ton** products. Products are ... anonymized..." "voluntary" reporting.



More comments from slide 54:

Some products provide minimal modulating rates at lower temperatures (3rd box, top row. And 5th box, bottom row)

Some products provide great low-load modulation (4th box, 2nd row)

Some products lose max-capacity quickly as temperatures decline (1st box, 2nd row, and 1st box 3rd row)

Some products maintain near-nominal capacity even at low ambient (1st box, bottom row)

About NEEP ccASHP database: https://neep.org/sites/default/files/media-files/cold_climate_air_source_heat_pump_specification_-_version_4.0_final.pdf : "voluntary 'Cold Climate Air Source Heat Pump Specification'". Data is provided by manufacturers with no apparent 3rd party verification.

source: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Clean-Energy-Workforce-Development/ASHP-Sizing-Design-Training-Tech.pptx%202021-12-16
Slide 54 minor additional labeling by EnergyShouldBe.org

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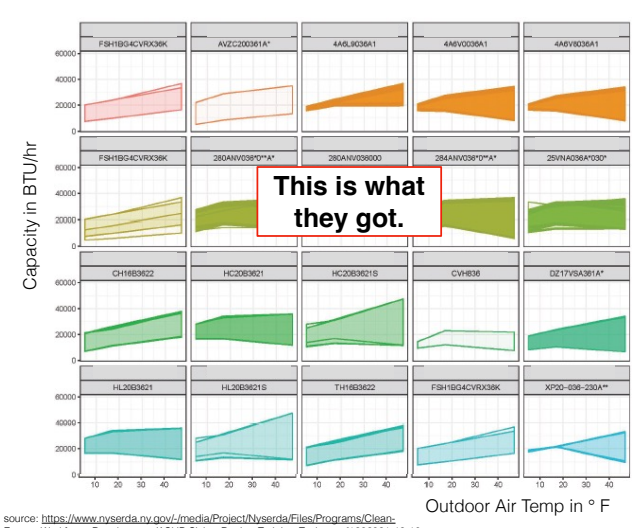
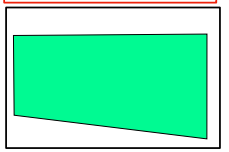
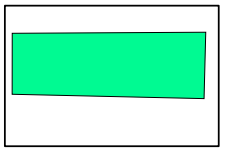


This is what they got.

For Air we want.



What I have (Ground)



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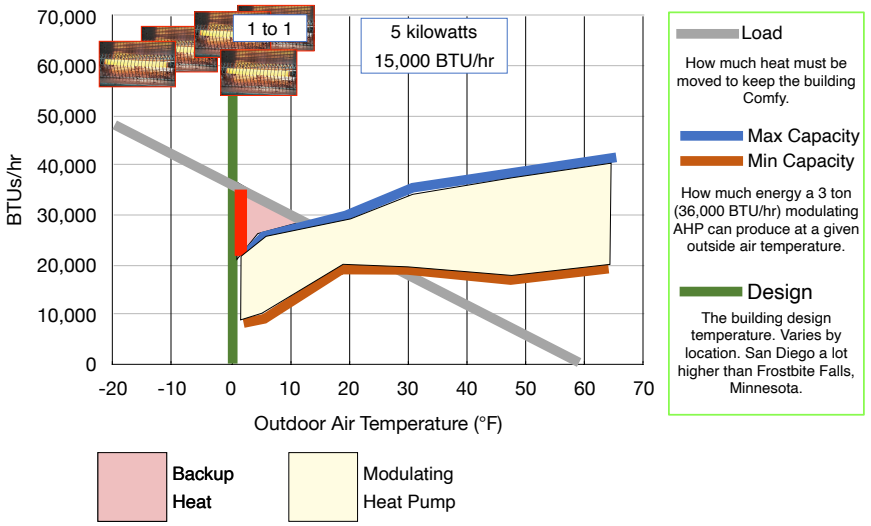

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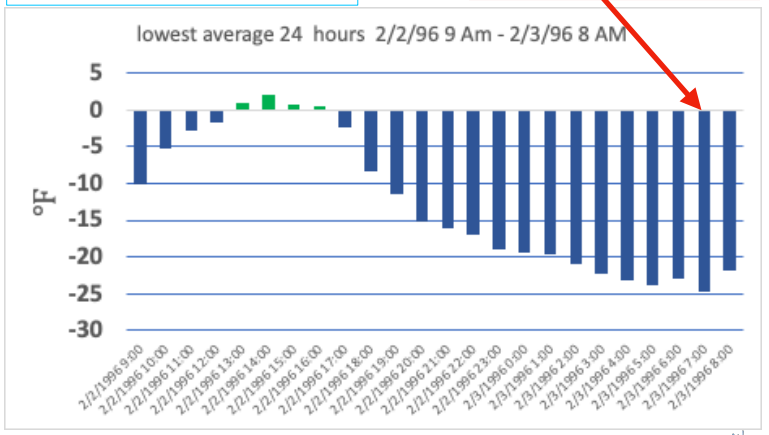
Slide 56 major changes for presentation by EnergyShouldBe.org

How cold does the front range get?

Fort Collins. Coldest 24 hours in last 30 years based on average temp for 24 hours.

Average over 24 hours: **- 13 °F**

Lowest hourly temp in 30 years
2/3/96 7:00 **- 25 °F**



Data from https://coagmet.colostate.edu/data/hourly/ftc01.csv?header=yes&from=1992-01-01&to=2022-03-28&fields=t

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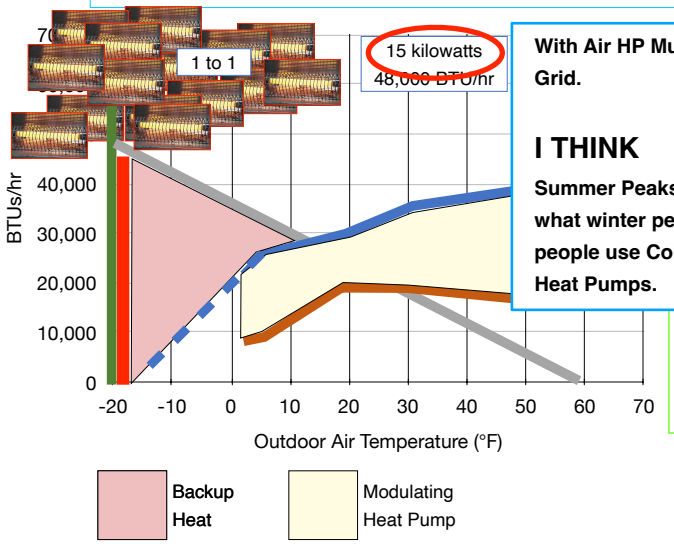

With Air HP Must Build More Grid.

I THINK

Summer Peaks are fraction of what winter peaks will be if most people use Cold Climate Air Heat Pumps.

Design

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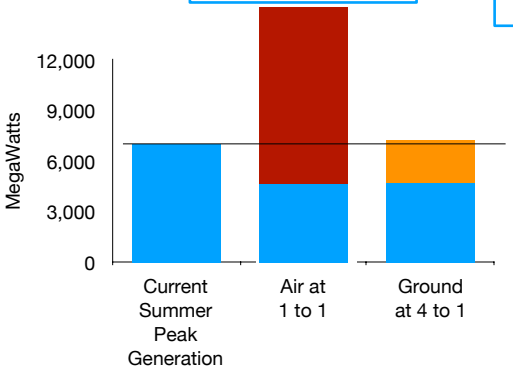
What Will This Take?

Assume - 20 °F

700,000 is 1/2 of Xcel Colorado Residential

64 Therms per month is average

Xcel Colorado



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I THINK

NEW GENERATION

Xcel Colorado Summer Peak Generation: **7,000 MW**

15 kW * 700,000 residences at Air Heat Pump 1 to 1: 10,500

…at Ground 4 to 1: **2,625**

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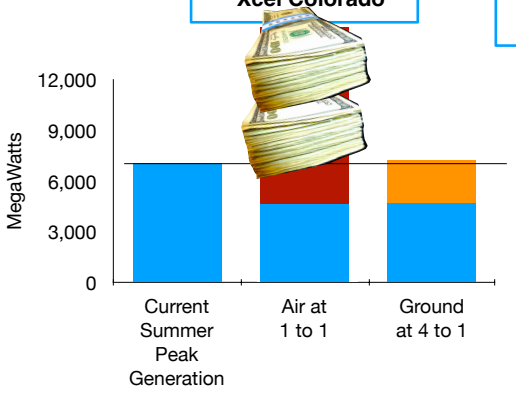

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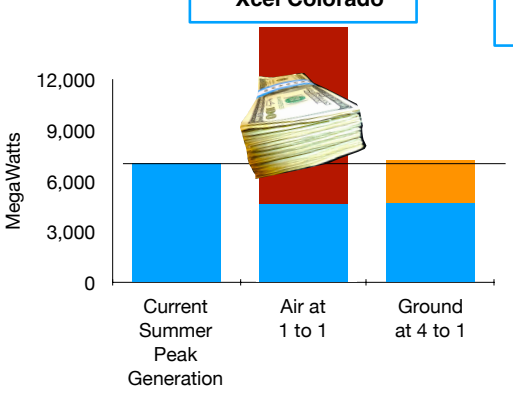


With Air HP Must Build More Grid.

I THINK

Smarter to Use Batteries in Our EVs

Xcel Colorado Summer Peak Generation: **7,000 MW**

For my Ground HP, a 100 kWh battery will run it for 45 hours.

700,000 100 kWh EVs is 70,000 MWhs.

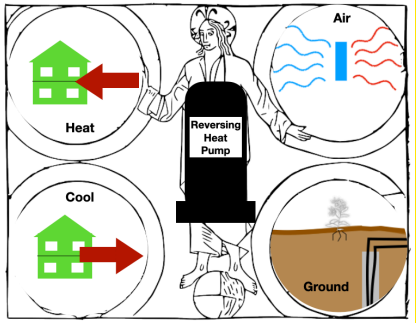
Other Reasons Ground is Better Than Air

Ground has nothing outside.

Outside is quieter than Air.

No weather issues with outside Air unit.

Images: EnergyShouldBe.org

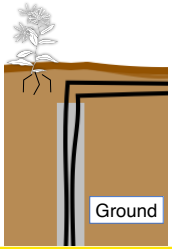


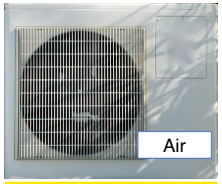
Topics:

- Background.
- What is a heat pump?
- Ground Heat Pump.
- Air Heat Pump.
- Ground vs. Air Heat Pumps
- Cost-Effective Transition.
- Energy Audit and Action First

Image: pixabay.com

Cost Equipment & Install to Retrofit My Home Heating & Cooling





$16,000 **Mass Production Works** **$16,000**

$13,000 for the Ground Loop

Images: EnergyShouldBe.org

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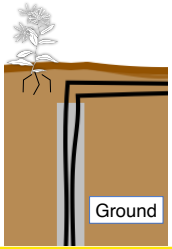
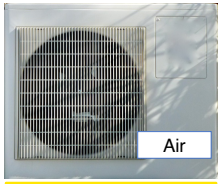




$16,000

$16,000

$13,000 for the Ground Loop

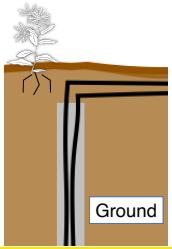
Mass Production and Mass installs Work

Images: EnergyShouldBe.org

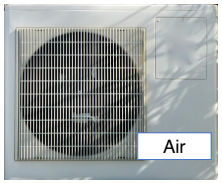
For Ground, the more holes drilled at same time and place the cheaper.

Image: EnergyShouldBe.org

Cost Annual Fuel



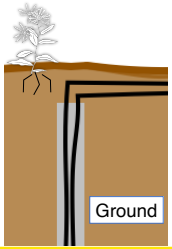
Cheaper than air.



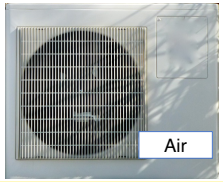
Cheaper than propane, fuel oil, and resistance electricity.
Probably cheaper than gas.
Possibly pay for upfront costs.

Images: EnergyShouldBe.org

Grid Costs

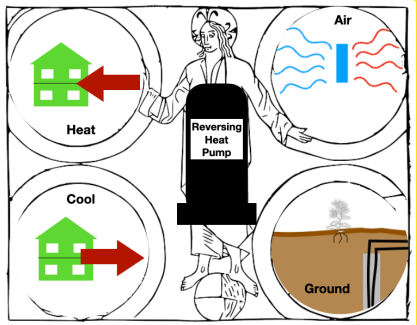


Probably MUCH cheaper than air.



Massively More than Ground Heat Pumps. (I Think)

Images: EnergyShouldBe.org



Topics:

- Background.
- What is a heat pump?
- Ground Heat Pump.
- Air Heat Pump.
- Ground vs. Air Heat Pumps
- Cost-Effective Transition.
- Energy Audit and Action First

Image: pixabay.com

Existing Home: Get an Energy Audit

Blower Door, Infrared Camera, and estimates of Cost-Effective measures.

Your Upgrades Overview

Estimated Totals

Installed Cost
$10,185
This is the estimated cost of your upgrades before incentives. It includes material and labor.

Energy Savings
$206/yr.
That's $17/mo.

This is an estimate of much you could save starting in Year 1. These savings will only increase as energy prices rise over the years.

Rebates & Incentives

All costs and estimates in this report are our best guess but not binding.

Your recommended energy upgrades

Details	Installed Costs	Annual Savings	Rebates	SIR	MIRR	ROI	Comfort	Health & Safety
Replace Freezer	$474	$55	N/A	1.7	9%	✓		
Seal Air Leaks	$1000	$100	N/A	1.5	8%	✓	✓	✓
Upgrade Your Heating System	$350	$23	N/A	1	5%			✓
Insulate Floors	$361	$14	N/A	0.8	4%		✓	
Insulate Walls	$5000	$101	N/A	0.4	0		✓	
Seal Duct Work	$1500	$39	N/A	0.4	-0.01	✓	✓	
Insulate Crawl Space	$1500	$-126	N/A	<0	-1		✓	

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Do the cost-effective measures.

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Images: EnergyShouldBe.org

New Home: Carefully Consider Ground Heat Pump

Clear field lowers cost of loop install.

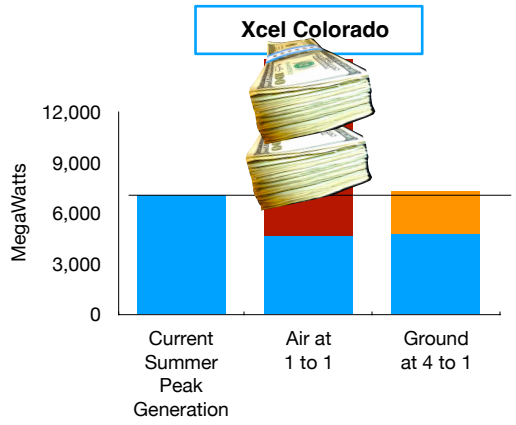
Lots of loops drilled for a housing development significantly lowers cost. Require Ground HPs!

Energy efficient building lowers cost of heat pumps.

Consider ground for fuel savings and grid savings.

Images: EnergyShouldBe.org

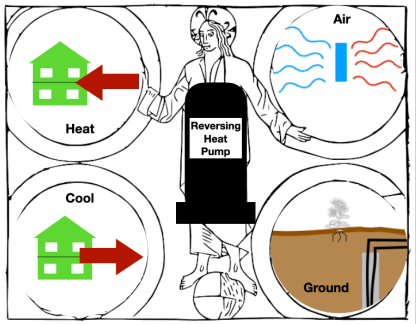
Need RESEARCH on Grid Costs for Mass Transition Air vs Ground in Cold Climates and All Climates.



Images: EnergyShouldBe.org

Require Reversing Valves on All Heat Pumps.

Images: EnergyShouldBe.org



Summary

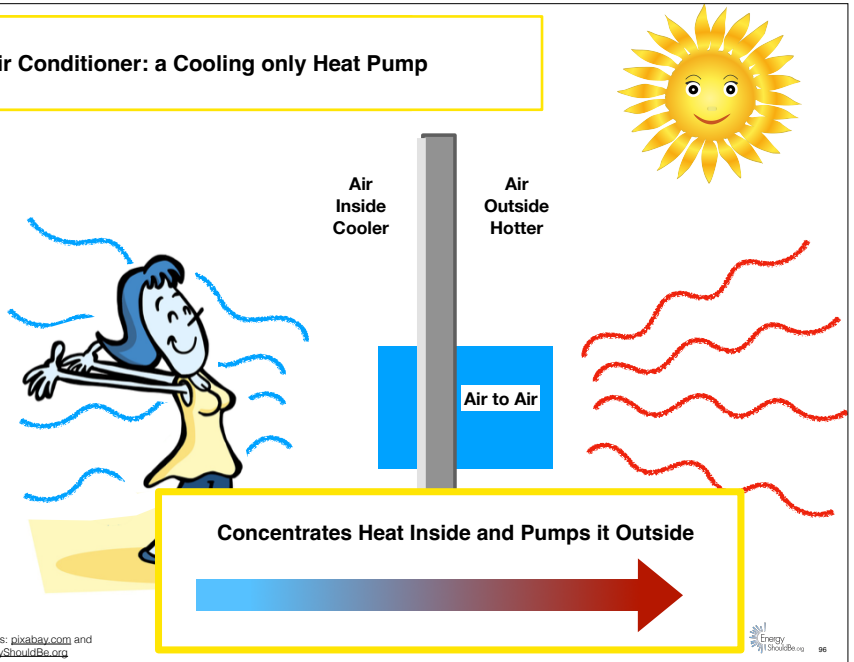
Image: pixabay.com

Getting Off Gas

2022

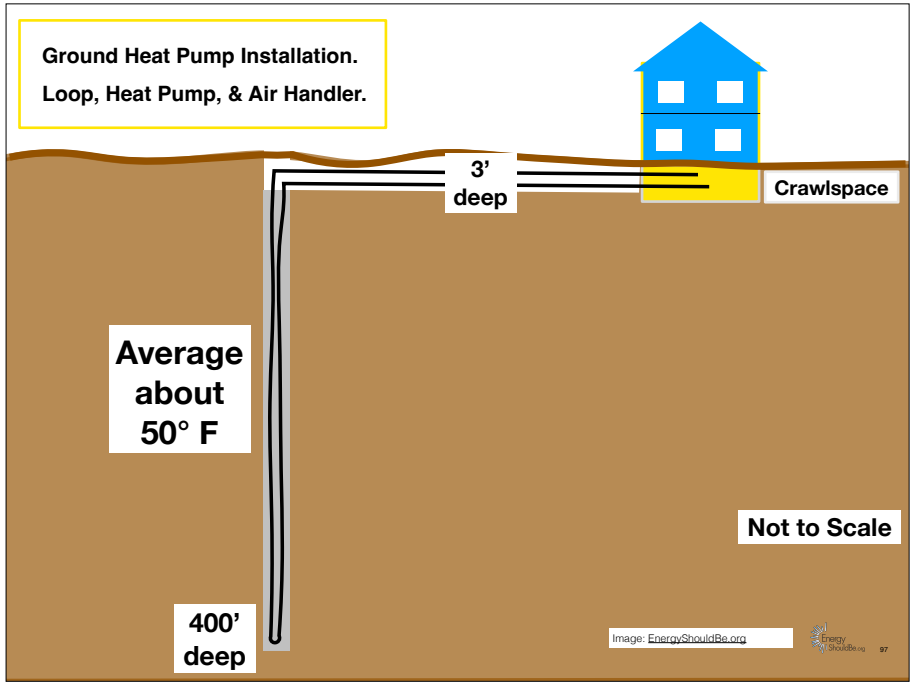
Image: EnergyShouldBe.org

Air Conditioner: a Cooling only Heat Pump



Images: pixabay.com and EnergyShouldBe.org

Ground Heat Pump Installation.
Loop, Heat Pump, & Air Handler.



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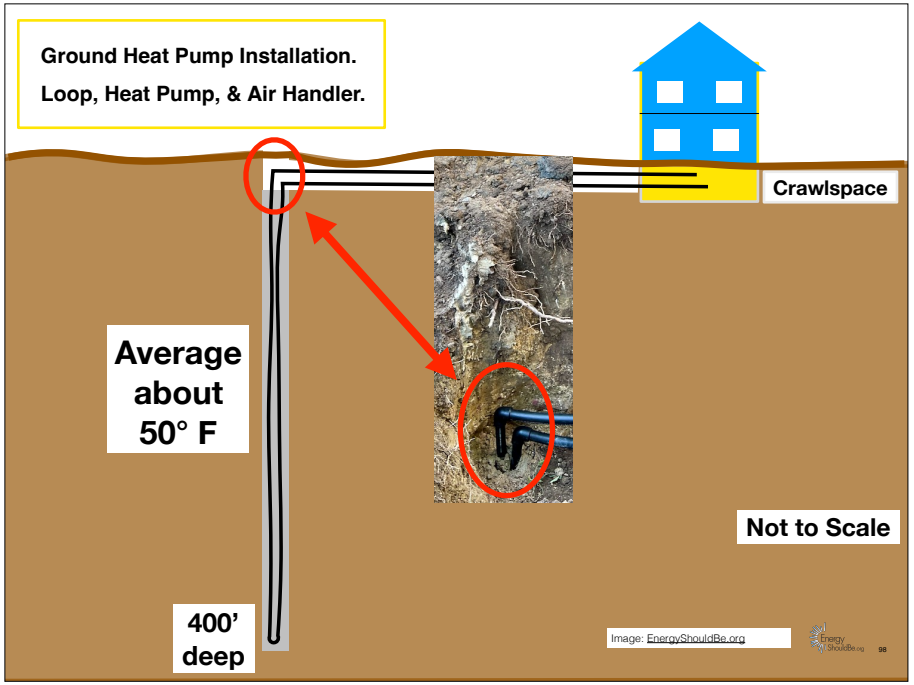

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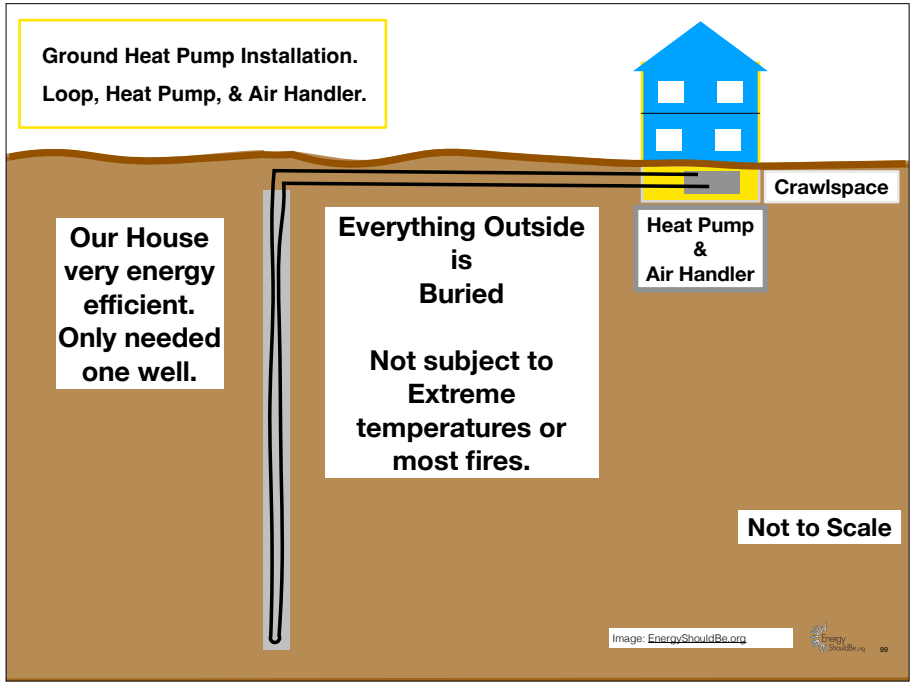


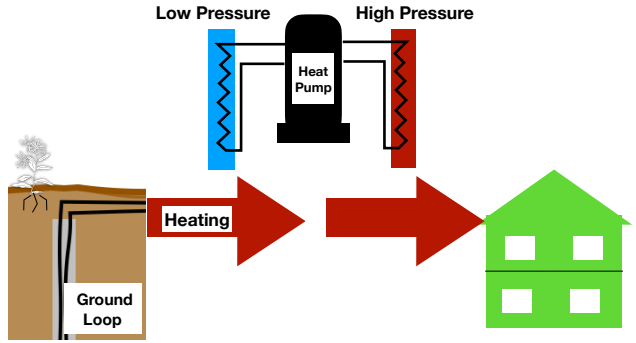
Image: EnergyShouldBe.org

Heavy Equipment for Loop Well

- Drilling Rig
- Sucker Truck
- Compressor
- Excavator
- Grout Mixer

Image: EnergyShouldBe.org

Heat and Cool Pump



Images: pixabay.com

Air Heat Pump Installation.

Outside When — 20.

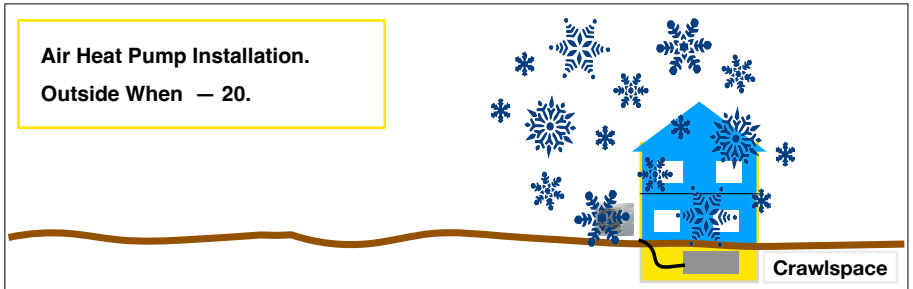
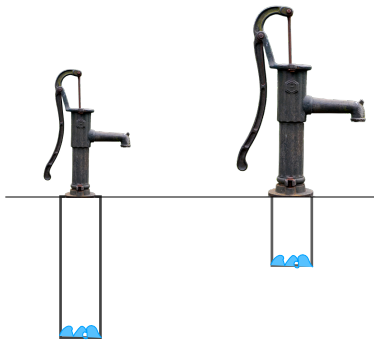
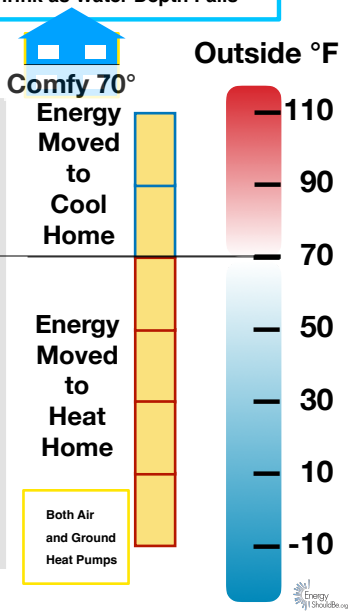


Image: EnergyShouldBe.org

Water Pump: Capacity & Efficiency Shrink as Water Depth Falls

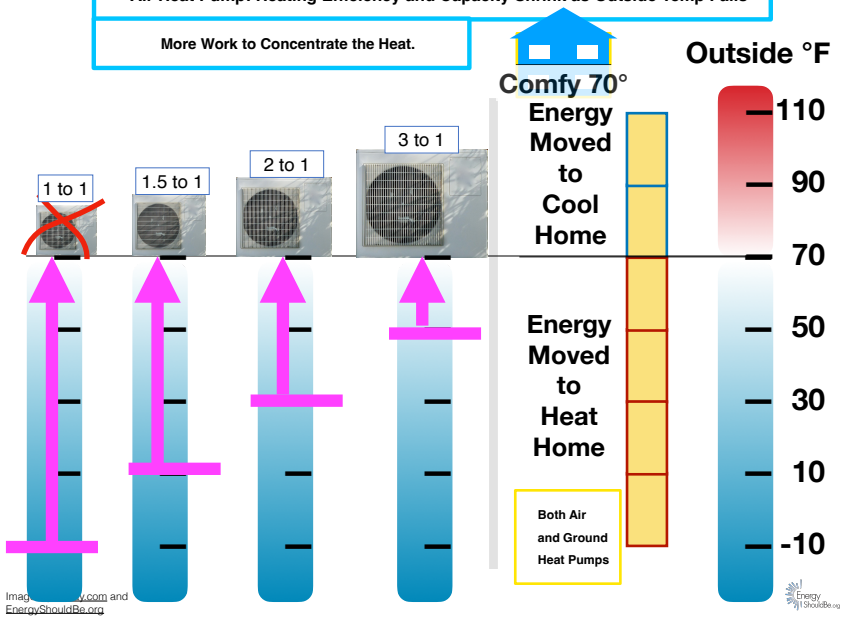




Images: pixabay.com and EnergyShouldBe.org

Air Heat Pump: Heating Efficiency and Capacity Shrink as Outside Temp Falls

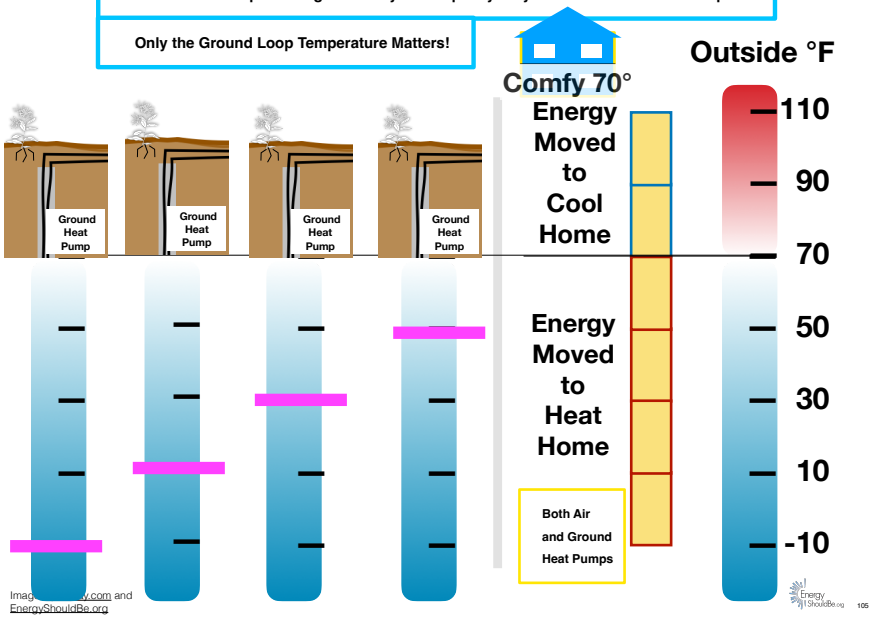
More Work to Concentrate the Heat.



Images: pixabay.com and EnergyShouldBe.org

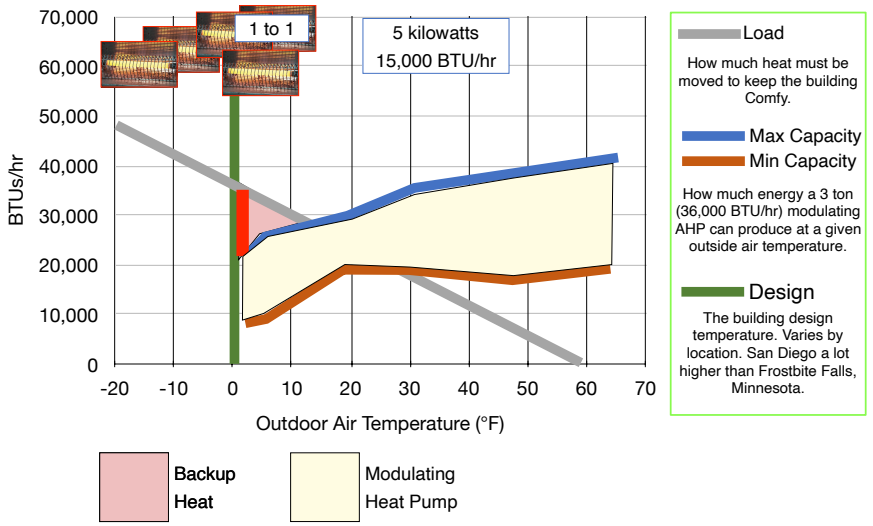
Ground Heat Pump: Heating Efficiency and Capacity Stay the Same as Outside Temp Falls

Only the Ground Loop Temperature Matters!



Imag[illegible].com and EnergyShouldBe.org

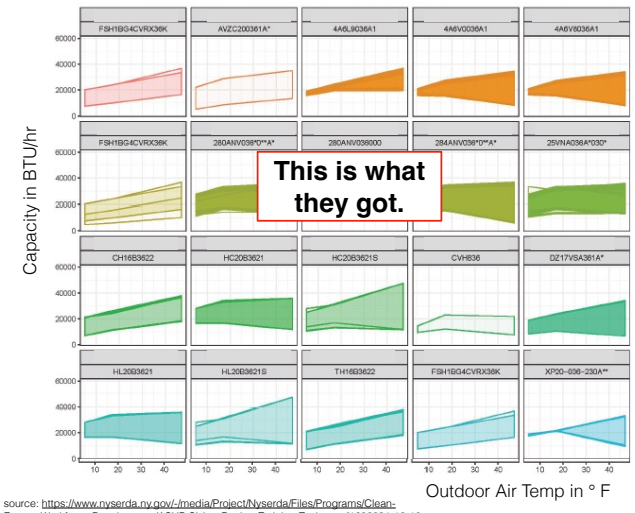
Cold Climate Air Heat Pump: As Outside Air Temp Drops, Capacity and Efficiency Shrink



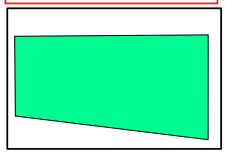
source: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Clean-Energy-Workforce-Development/ASHP-Sizing-Design-Training-Tech.pptx%202021-12-16
Slide 56 major changes for presentation by EnergyShouldBe.org

Air Heat Pump in cold climates - What happens at -10 °F? -20 °F?

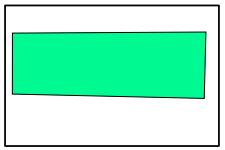
"…data … from NEEP ccASHP database for a wide variety of nominal 3-ton products. Products are … anonymized…" "voluntary" reporting.



For Air we want.



What I have (Ground)



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Slide 54 minor additional labeling by EnergyShouldBe.org

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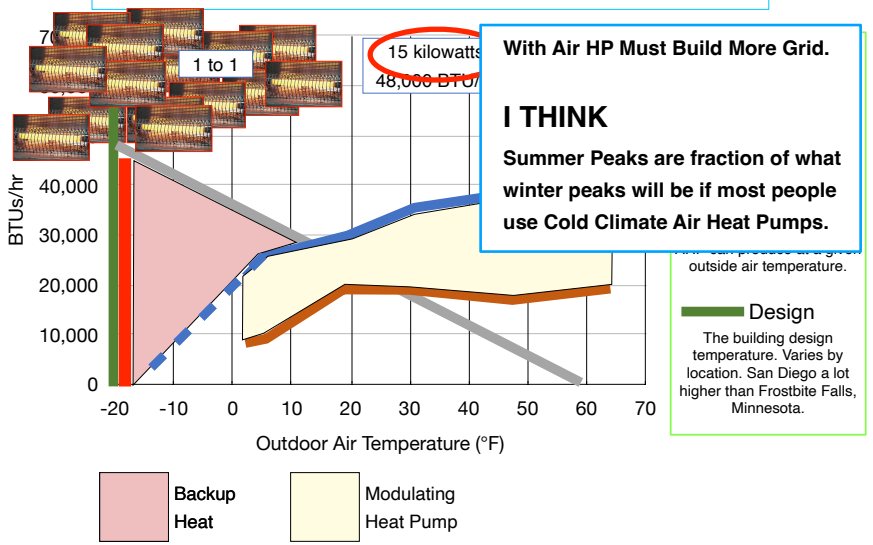


With Air HP Must Build More Grid.

I THINK

Summer Peaks are fraction of what winter peaks will be if most people use Cold Climate Air Heat Pumps.

source: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Clean-Energy-Workforce-Development/ASHP-Sizing-Design-Training-Tech.pptx%202021-12-16
Slide 56 major changes for presentation by EnergyShouldBe.org

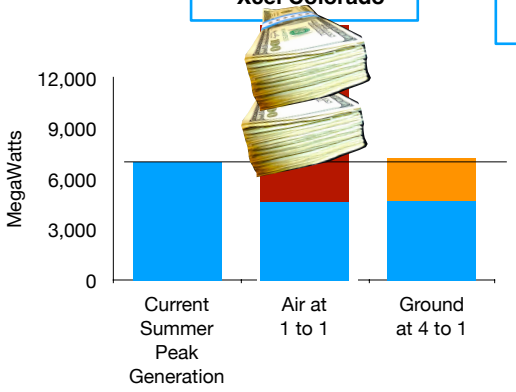
What Will This Take?

Assume - 20 °F

700,000 is 1/2 of Xcel Colorado Residential

64 Therms per month is average

Xcel Colorado



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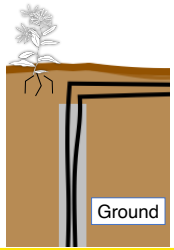
NEW GENERATION

Xcel Colorado Summer Peak Generation: **7,000 MW**

15 kW * 700,000 residences at Air Heat Pump 1 to 1: 10,500

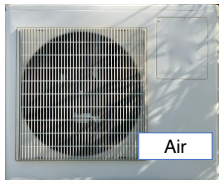
…at Ground 4 to 1: **2,625**

Cost Equipment & Install to Retrofit My Home Heating & Cooling



$16,000

$13,000 for the Ground Loop

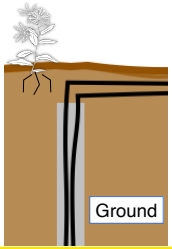


$16,000

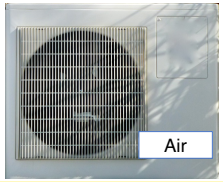
Mass Production and Mass installs Work

Images: EnergyShouldBe.org

Cost Annual Fuel



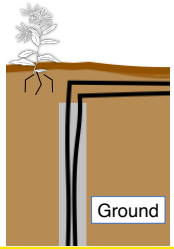
Cheaper than air.



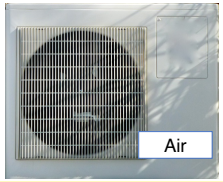
Cheaper than propane, fuel oil, and resistance electricity. Probably cheaper than gas. Possibly pay for upfront costs.

Images: EnergyShouldBe.org

Grid Costs



Probably MUCH cheaper than air.



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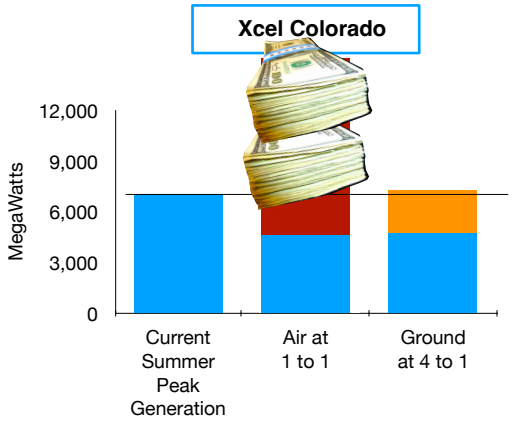

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