

Heat Pumps and DC Technology: Revolutions in Efficiency and Performance

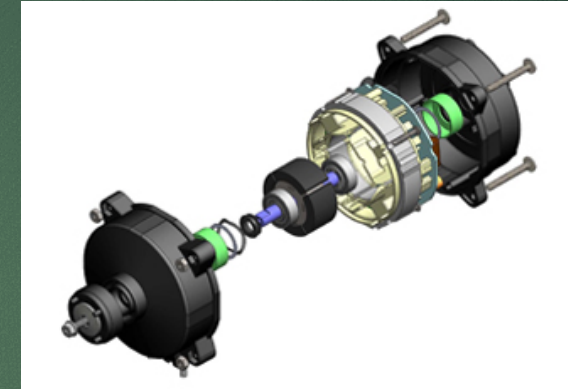
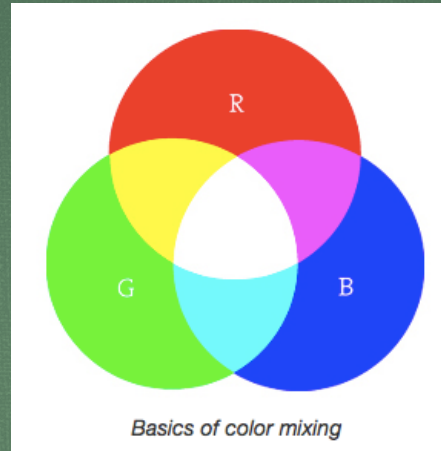
BROUGHT TO YOU BY:



**Cotter & Noson
Consulting Services LLC**

What do we use electricity for?

- ▶ Lighting
- ▶ Entertainment
- ▶ Cooking
- ▶ Ventilation
- ▶ Water heating
- ▶ Heating
- ▶ Cooling



Some basics

Words, principles, practices, and processes

Energy and Power



- ▶ Energy – Kilowatt-hours (kWh)
 - ▶ Utility bills indicate a rate
 - ▶ Cents per kilowatt-hour
 - ▶ In Alaska - \$0.07 - \$0.80 per kWh
- ▶ Power – Watts (W) or Kilowatts (kW)
 - ▶ The rate an appliances uses energy
 - ▶ Snazzy new Panasonic fan = 5 Watts @ 80cfm
 - ▶ Blow dryer = 1300 Watts

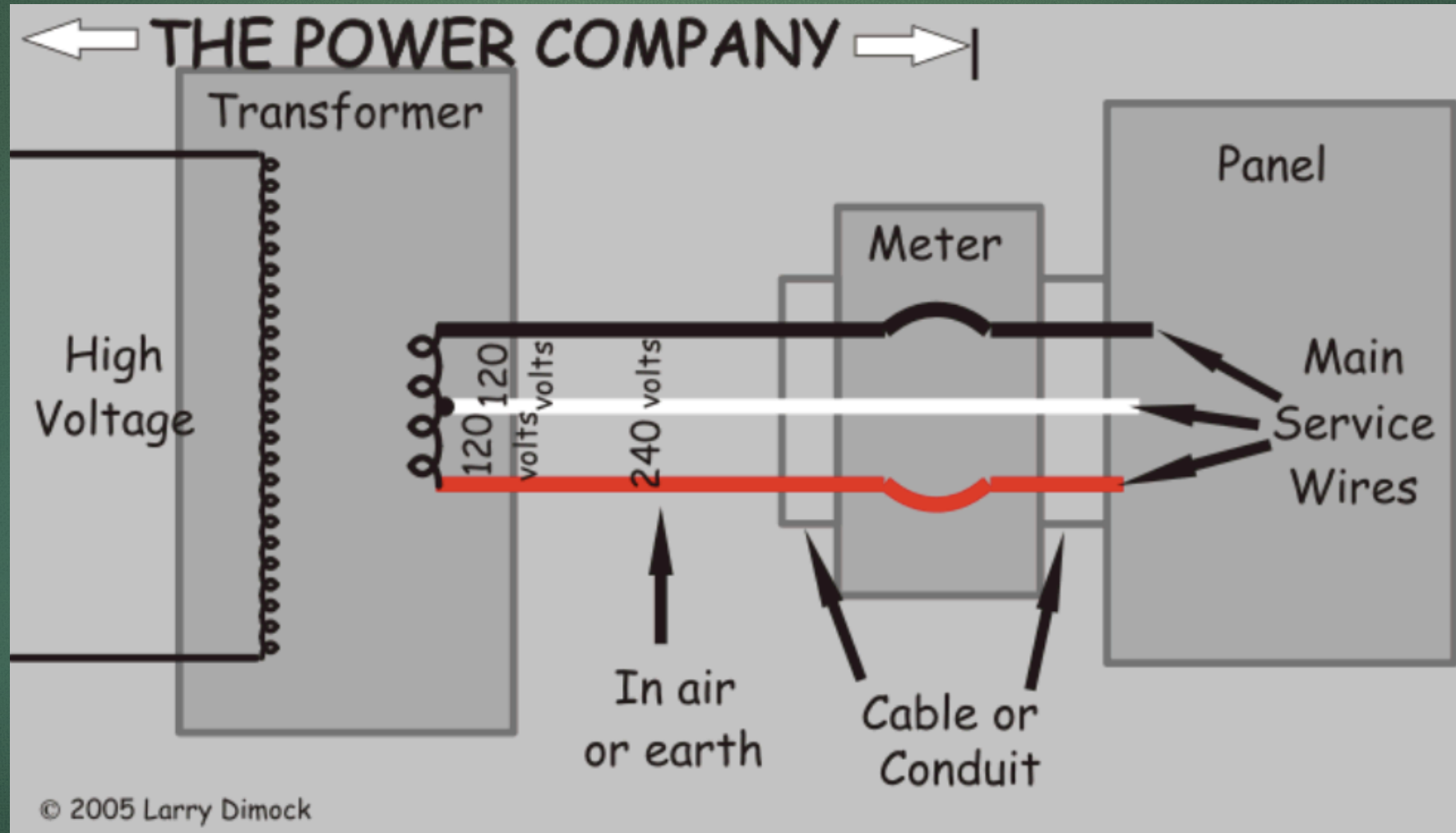
Units – Example



- ▶ If you run your 5 Watt (power) Panasonic fan for 1 hour, you would use 5 Watt-hours of electricity (energy)
- ▶ 5 Watt-hours = 0.005 kiloWatt-hours
- ▶ @ \$0.20/kWh
 - ▶ $0.005 \times \$0.20 = \0.001 or 1/10th of a penny
- ▶ Ventilating is cheap

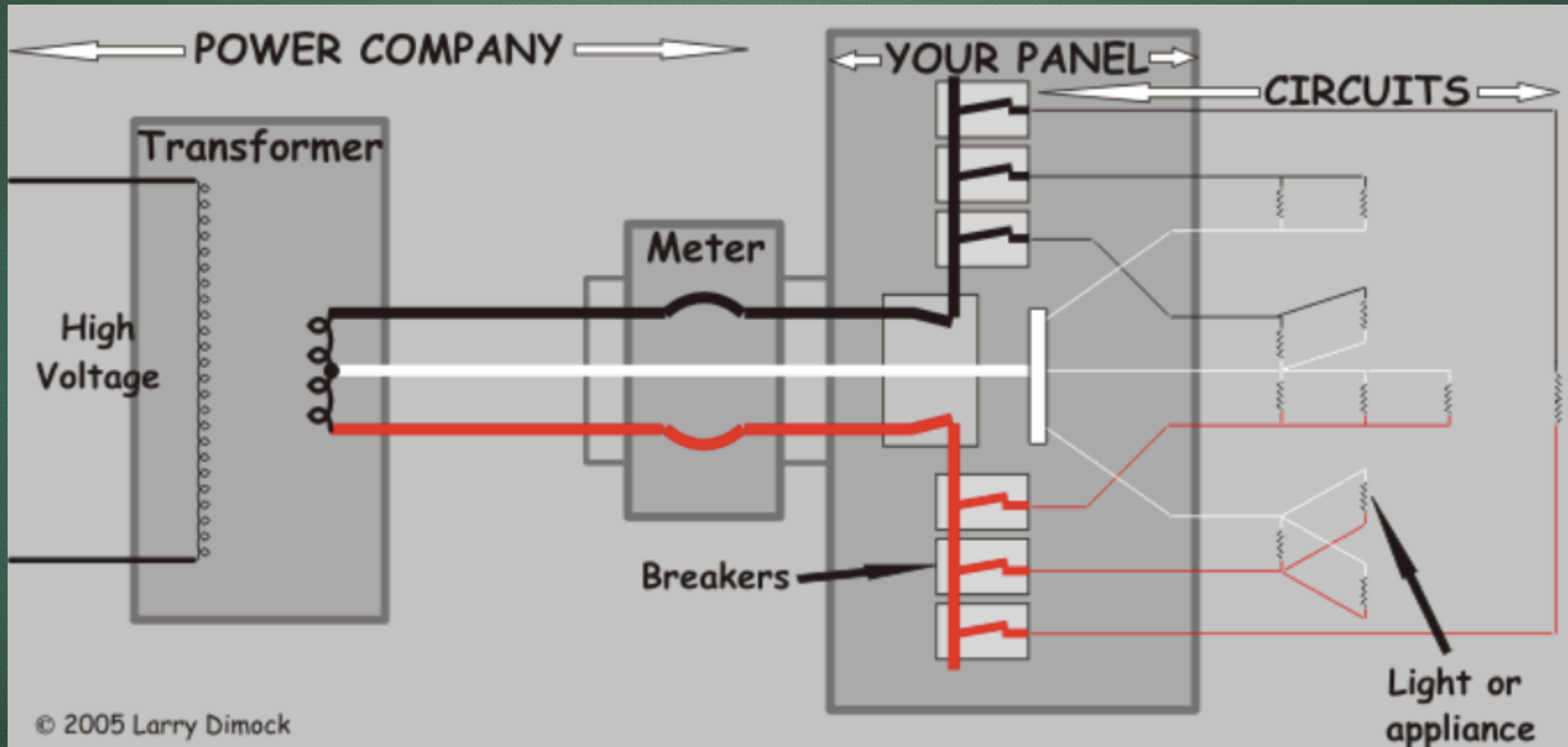
Schematic – Power to House

Generation to transformer to house meter to house panel

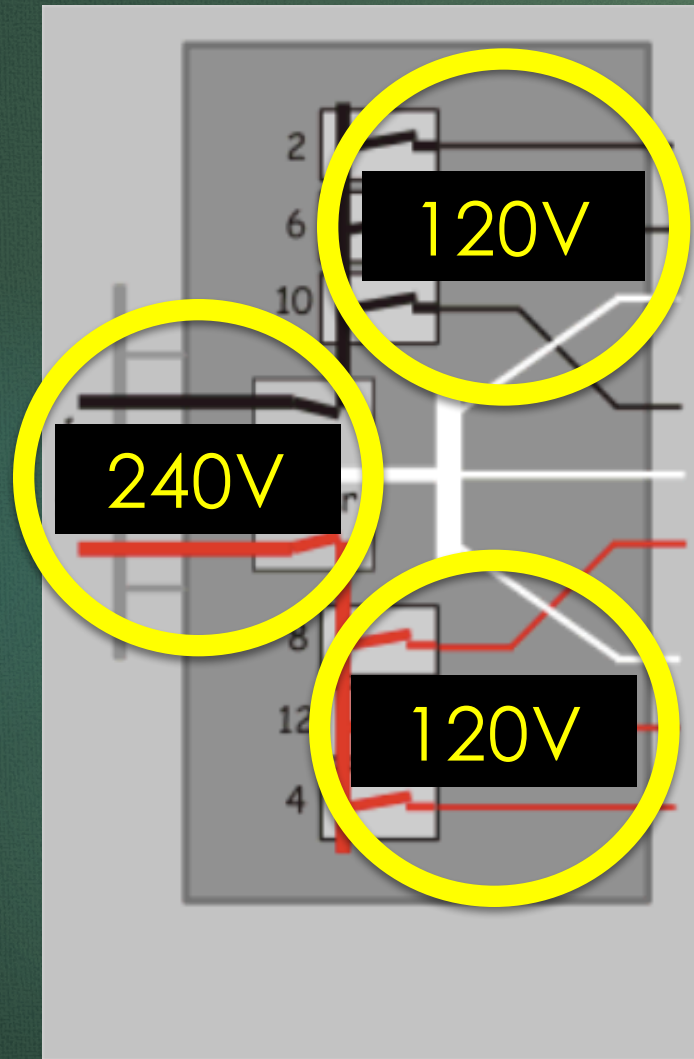


Power Company to Appliance

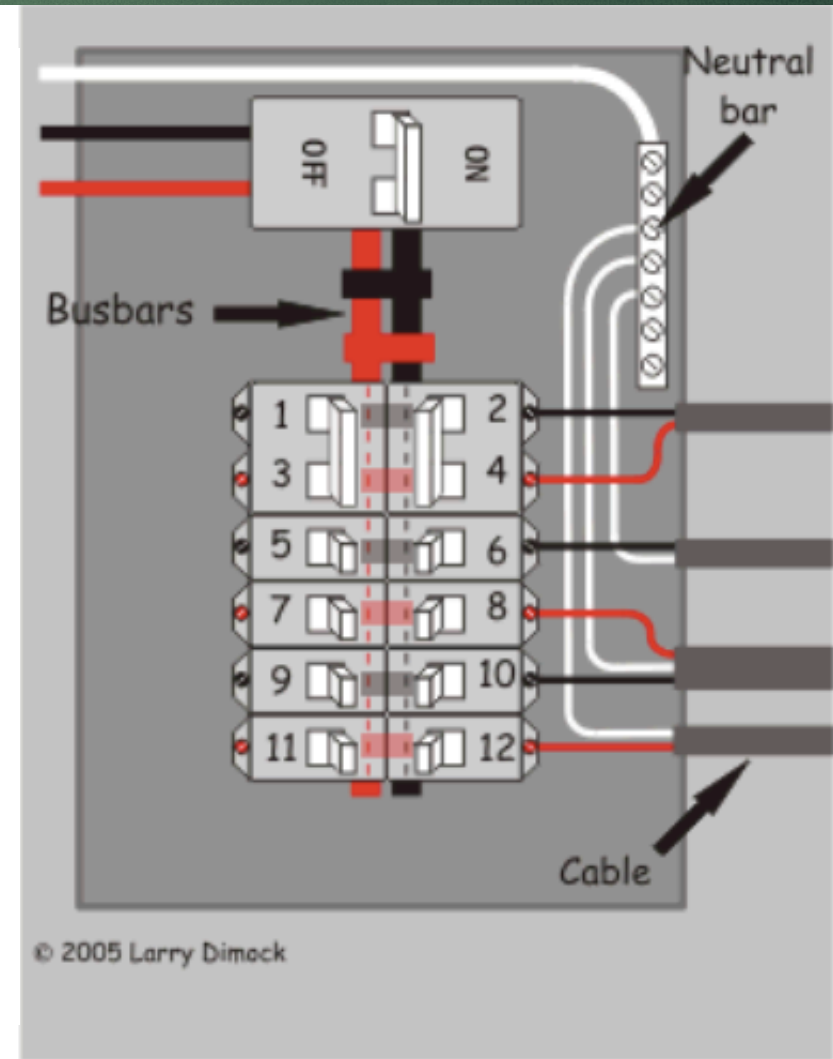
Drop to 120V at panel to deliver to most appliances



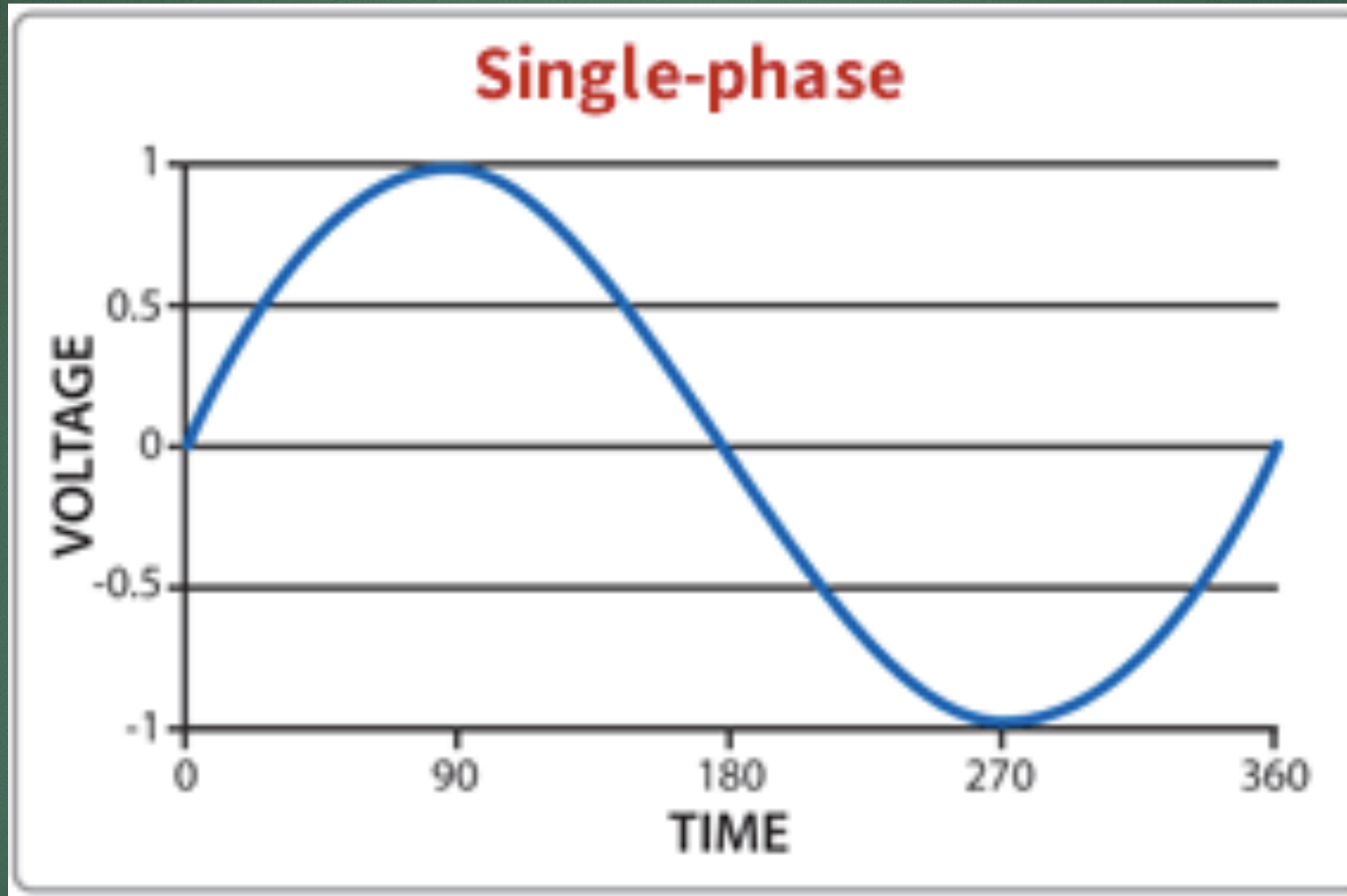
Schematic and Panel Diagrams



Schematic
and real life
views of
electrical
panel



Alternating Current



1 cycle of household current – 60 cycle/second = 60 Hertz

What about DC?

- ▶ Many appliances operate on DC
 - ▶ Fans – bath fan, HRV
 - ▶ Pumps
 - ▶ Compressors
 - ▶ Lighting
- ▶ We are just dishonest about it (Lipstick on the collar)
 - ▶ AC converted to DC at appliance

Why DC?

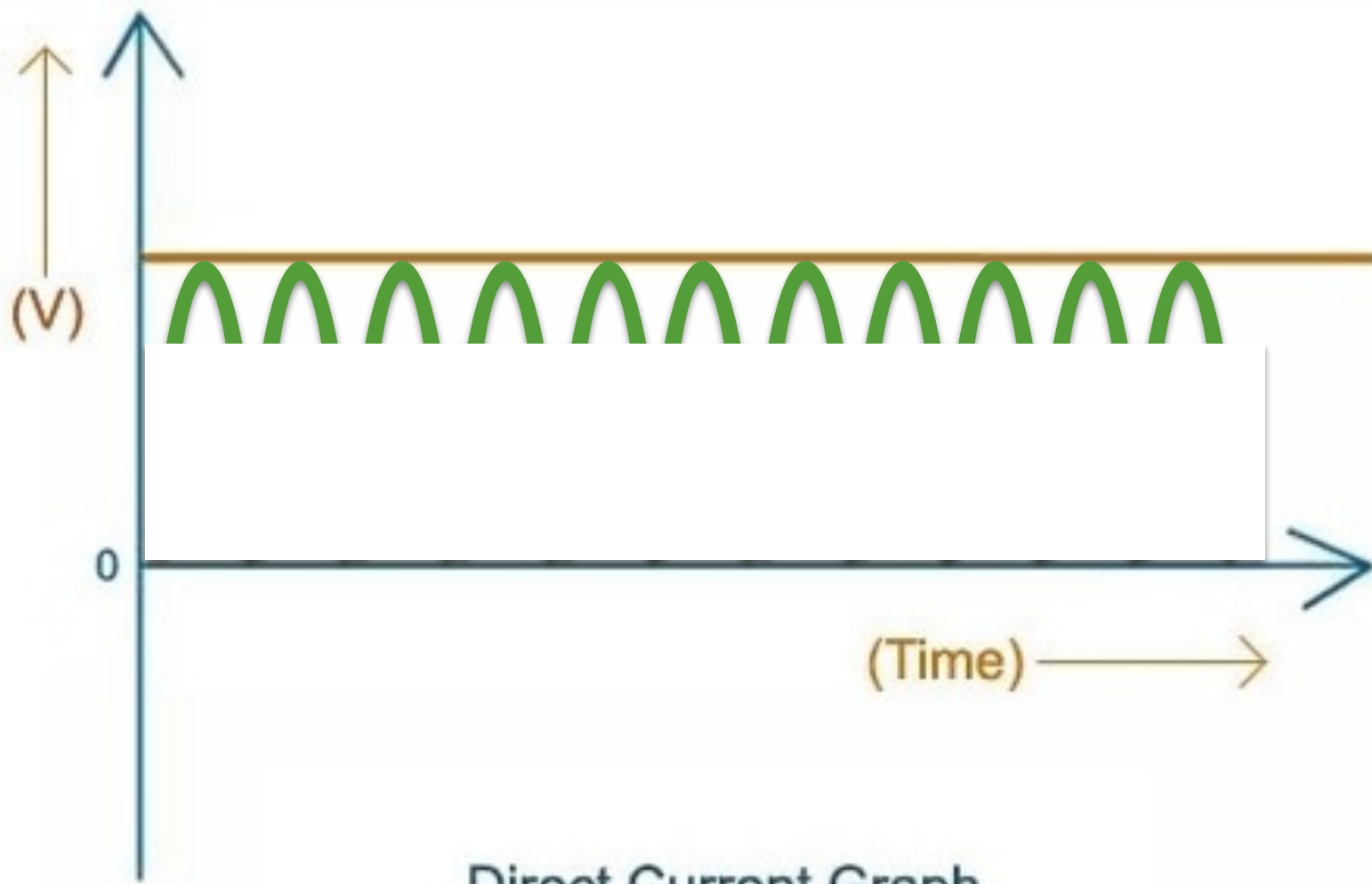
- ▶ Higher Efficiency
 - ▶ Less power requirements for outputs
- ▶ Finer Control
 - ▶ Modulation
 - ▶ Not just "On" and "Off"
- ▶ More Reliable

Direct Current



Direct Current Graph

Direct Current



Direct Current Graph

This can sometimes be "lumpy" or "dirty" after being converted from AC – many appliances don't care

How does stuff run?



Appliance	Good old days	Good new days
Lights	AC	AC/DC
Ventilation Fans	AC	AC/DC >>> DC
Blowers/Pumps (Distribution)	AC	AC/DC >>> DC
Electric Heat	AC	AC/DC (?)

Some appliances are “both” AC/DC – more later

New electrical efficiencies make for many possibilities

But first, a few reminders...

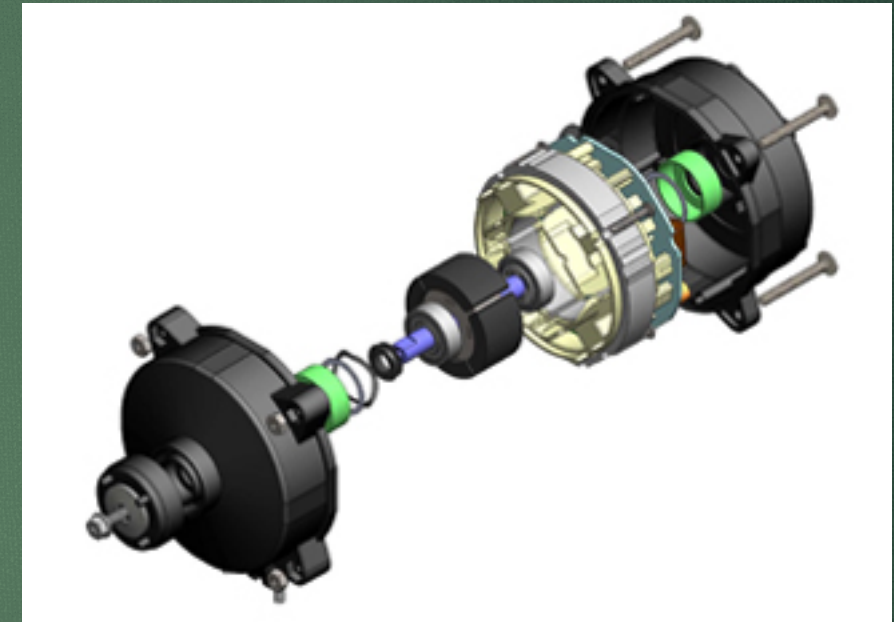
Electrical Efficiency/Performance



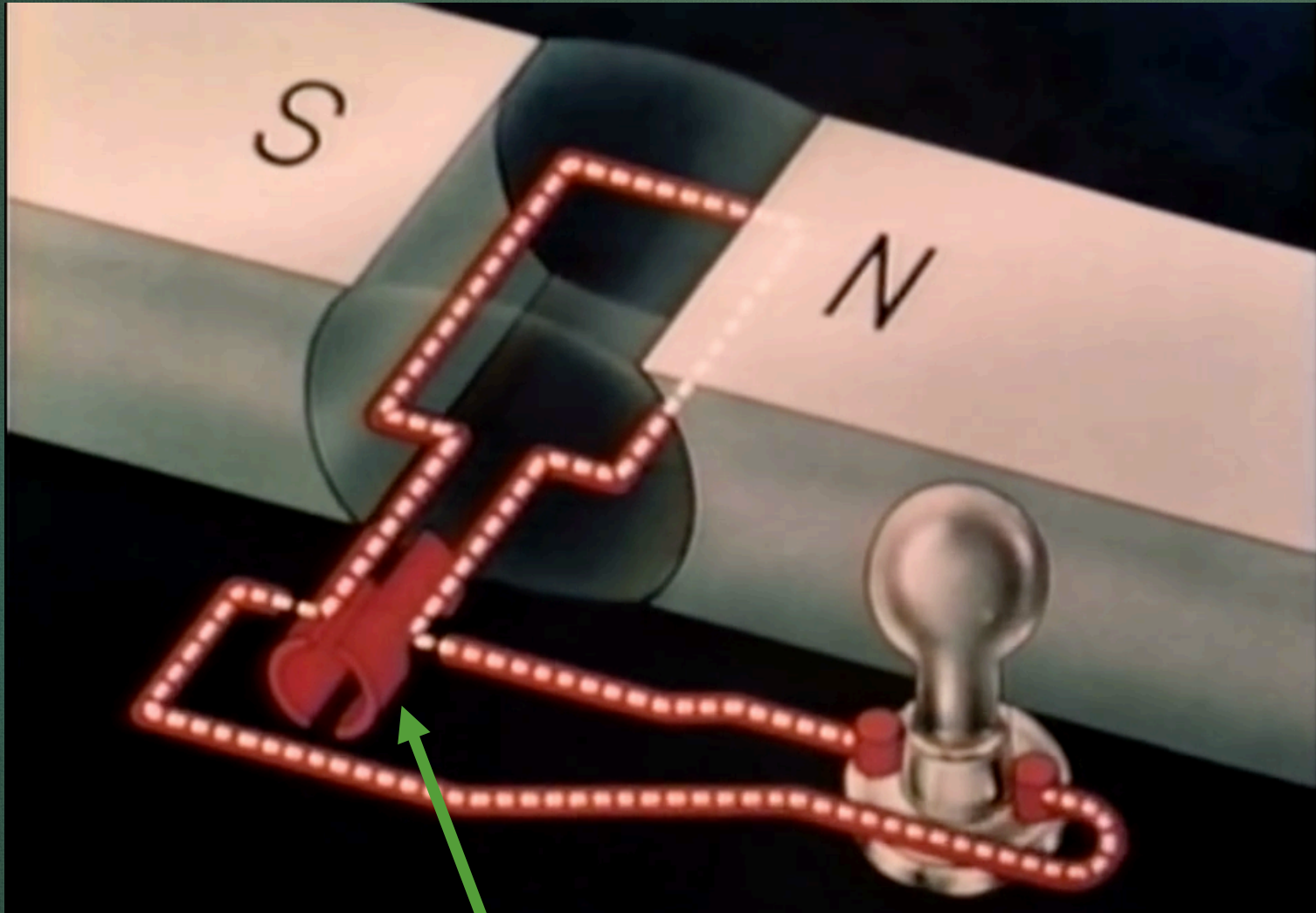
- ▶ Electronic commutation (ECMs)
 - ▶ Brushless motors
 - ▶ Pulsed wave modulation (PWM)
 - ▶ LEDs – lighting and entertainment
 - ▶ “Inverter technology”
-
- ▶ These, and others, have revolutionized home efficiency directly and indirectly
 - ▶ Allow decentralized systems

Fan motors have changed

- ▶ Both Indoor and Outdoor fans use
 - ▶ Electronically commutated Motors (ECMs)
 - ▶ More operability choices
 - ▶ DC
 - ▶ Quieter
 - ▶ Ball bearing durability
 - ▶ High efficiency (65-75%) across speeds
 - ▶ Varied start-up speeds = low stress
 - ▶ Old style Permanent Split Capacitor motors (PSC) are getting rare
 - ▶ Single, full speed; low efficiency (narrow efficiency range)



Commutators?



Commutator

Convert AC to DC

Traditionally a moving piece that we connect in a circuit – less durable

Now, we commutate electronically – efficient, variable, durable

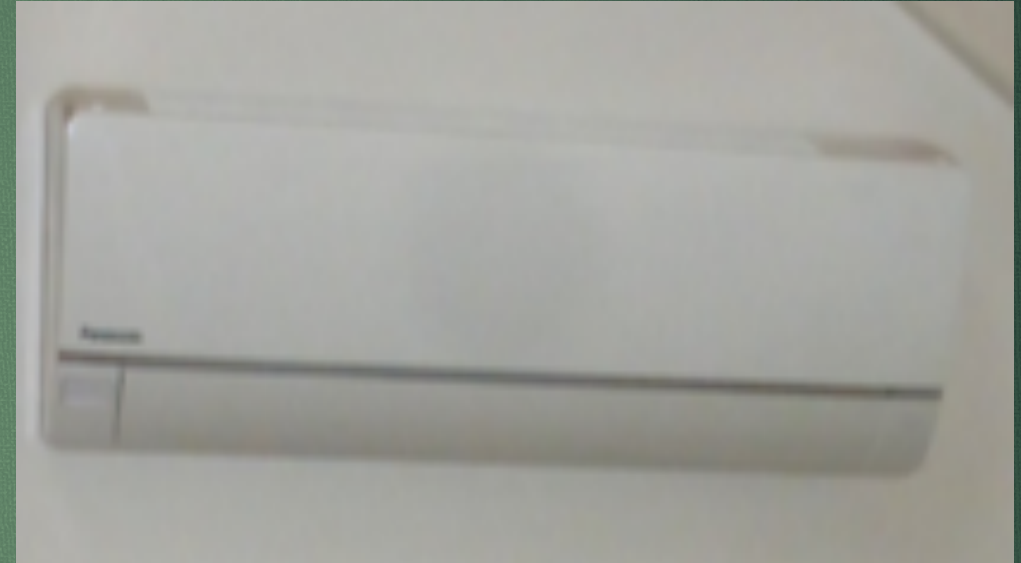
An Example – Double whammy of efficiency, control, and comfort – Air Source Heat Pump



Outdoor unit has “DC” compressor
Variable speed
Efficient across speeds
Fine Control

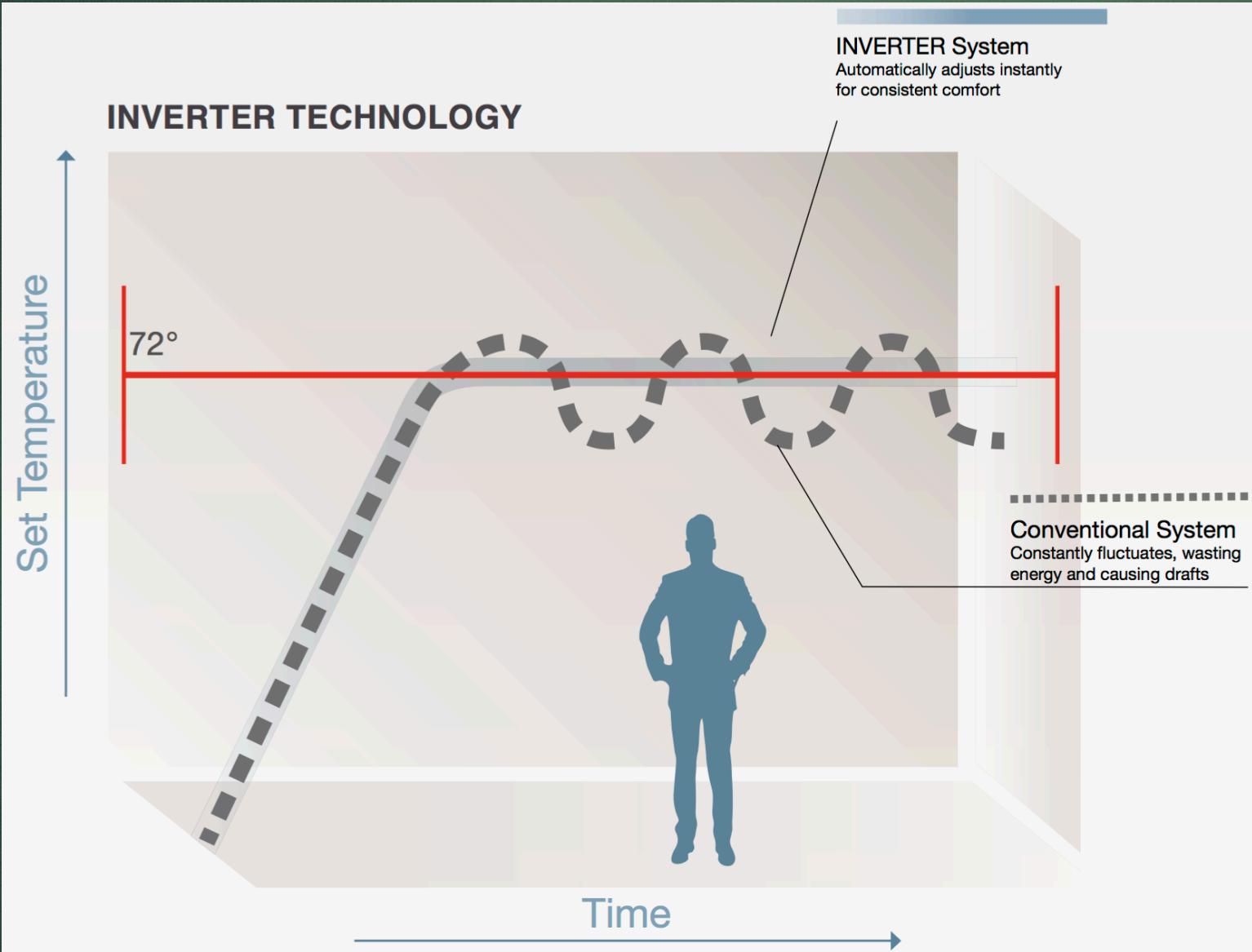


Also control expansion valve



Indoor unit has DC fan motor
Variable speed
Efficient across speeds
Fine Control

More comfort



Inverter compressors are variable speed.

- more efficient
- less stopping/starting
- consistent heating/cooling

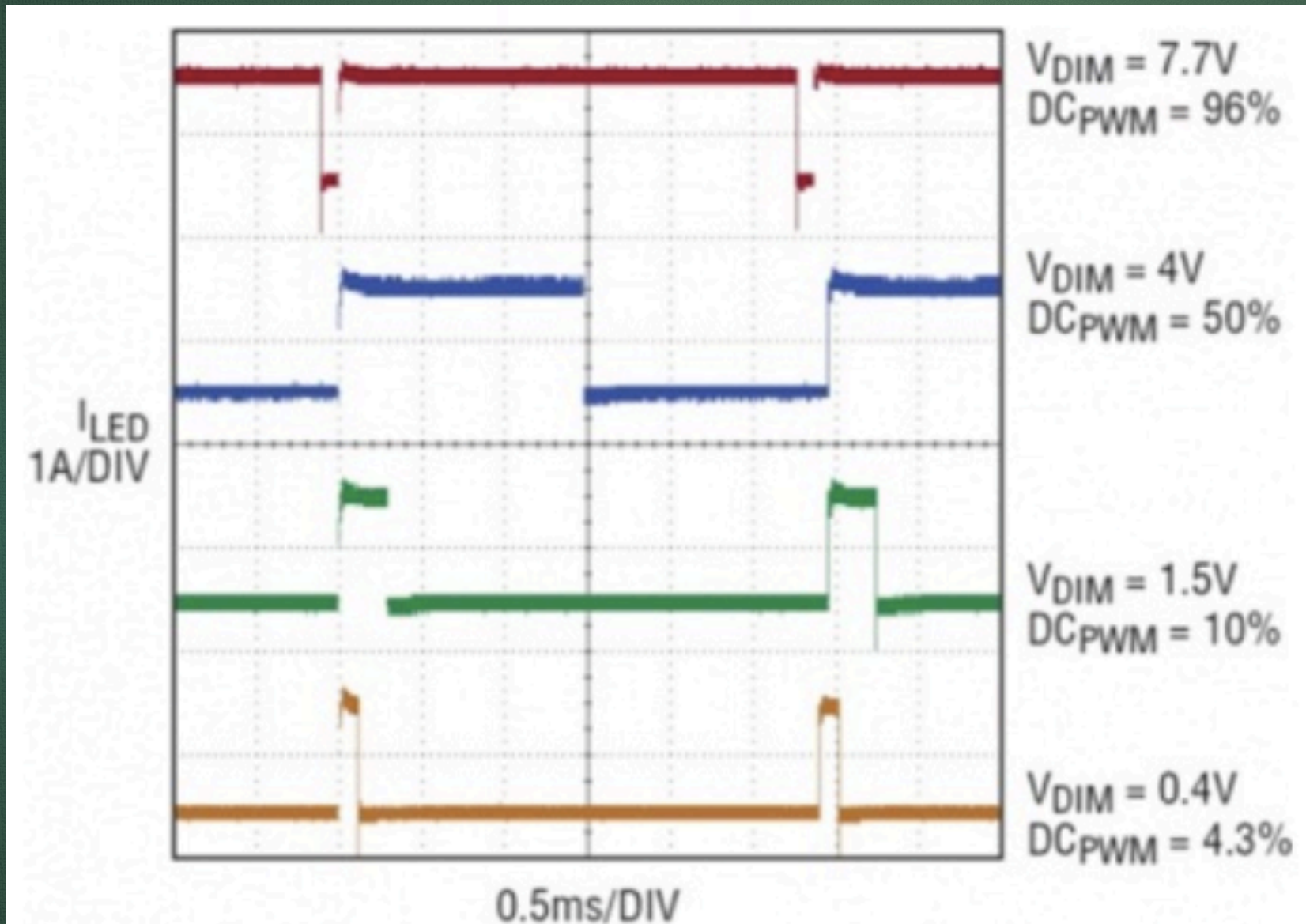
Modulating control versus start/stop and negative feedback strategies

Pulse Width Modulation



- ▶ Controls amplitude of output via rapid switching on/off
- ▶ Duration of pulse = intensity/amplitude
- ▶ Efficient – Why?
 - ▶ Power loss = voltage drop X current in the switch
 - ▶ Switch off, no current
 - ▶ Switch on, power is transferred directly to load – very little voltage drop across switch
 - ▶ Each scenario = very little power loss

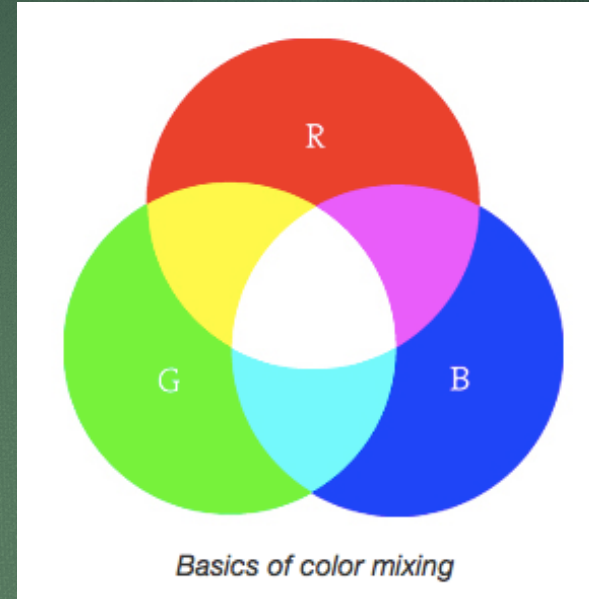
The longer the pulse, the higher the intensity <#>



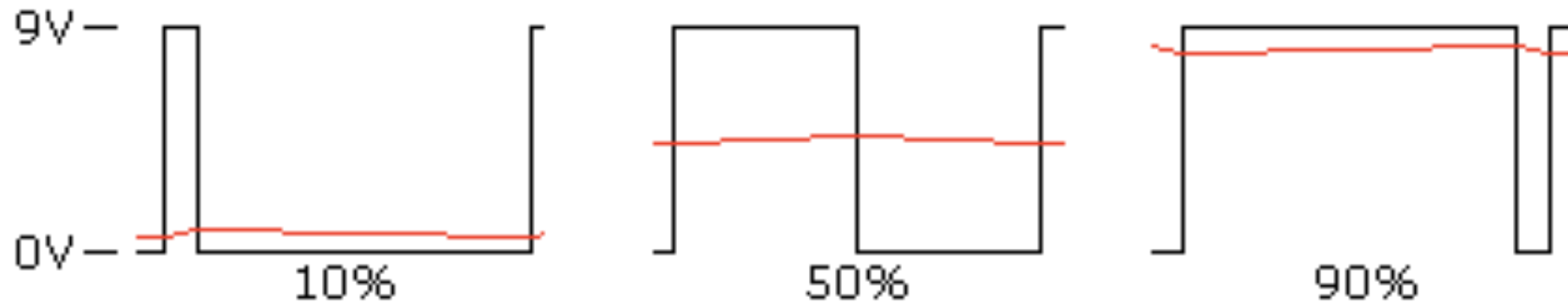
Compare these

PWM in LEDs

- ▶ Dimming LEDs – 2 ways
 - ▶ 1) Analog - adjust DC current
 - ▶ Changes light color
 - ▶ Poor dimming accuracy
 - ▶ 2) PWM – vary duty cycle (PWM) of constant current
 - ▶ Changes average current
 - ▶ Maintains light color
 - ▶ Dimming accuracy
- ▶ PWM also used to make different colors

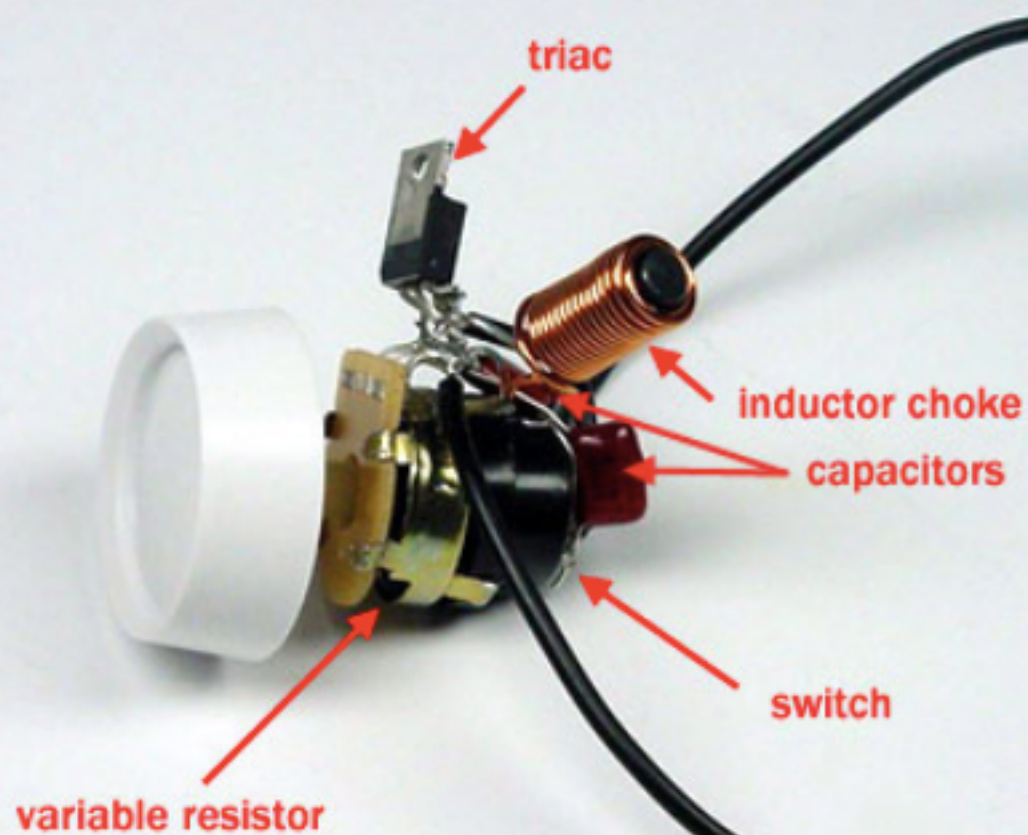


The longer the pulse, the higher the intensity (#)



Examples of PWM Waveforms

Goodbye rheostat



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The guts of a basic dimmer switch

Hot and inefficient

How do appliances run on DC?



- ▶ Depends...
- ▶ AC > DC at/near appliance
 - ▶ Ex. New generation ventilation fans
 - ▶ Connected to AC
 - ▶ Appliance “sees” DC due to conversion
 - ▶ DC signal modified to control appliance
- ▶ Sometimes...
 - ▶ DC signal modified, converted back to AC, then to appliance
 - ▶ Is it AC or DC?

What about these Heat Pumps?



Heat pumps: What are they?

A devices that move heat energy from a SOURCE* of heat to a SINK".

Absorb heat from a cold space and release it to a warmer one - Yup, weird

Use external power to do this.

* Source can be air, water, ground

Reasons to use them



Efficiency (?)

Performance (?)

Cost (?)

- Installation (?)

- Operation (?)

Few penetrations

- Especially up high

- Tighter structures

No combustion appliances

No excessive negative pressure consequences

What can they do?



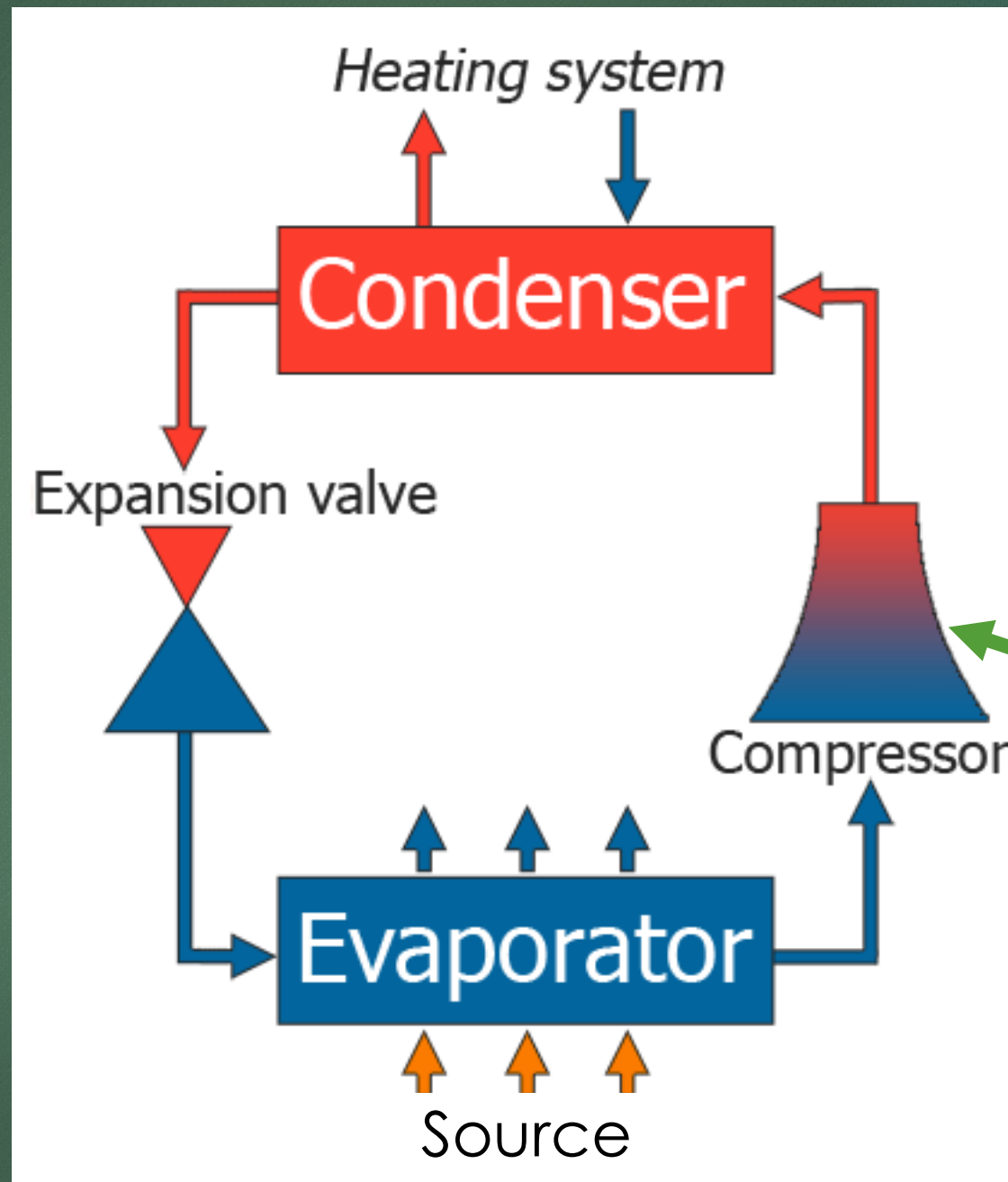
Space Heating

Domestic water heating

Space cooling

How heat pumps work

Its just magic,
really



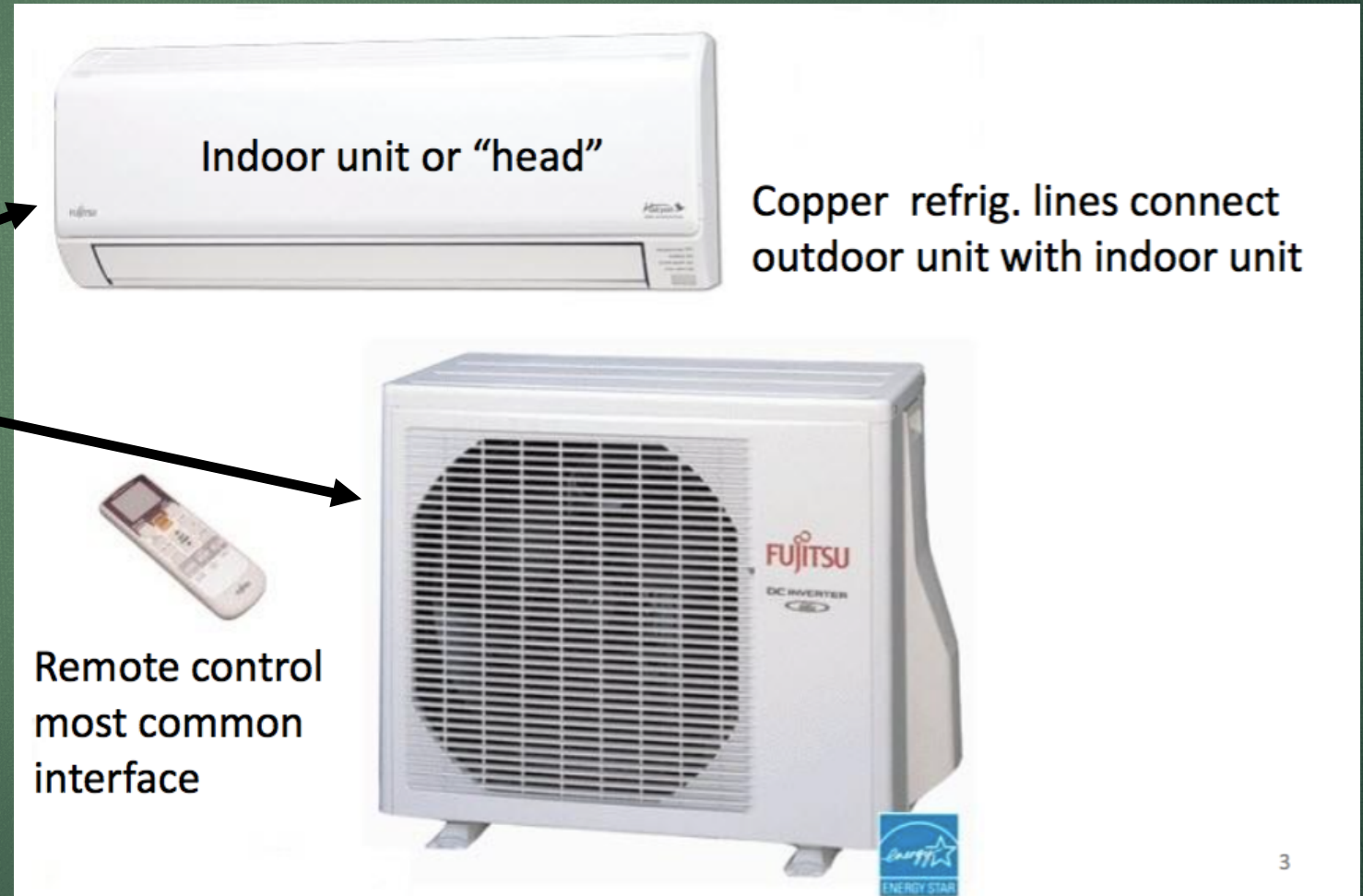
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Just add electricity

The parts - an air source heat pump or DHP

Both fans have
ECMs in
modern,
efficient heat
pumps



Different heads

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Heat pump sizes



- ▶ For the common air source heat pumps
 - ▶ 9,000btu (3/4-ton) and 12,000btu (1-ton)
- ▶ This is typically cooling capacity
 - ▶ Heating capacity ~ 20% greater (see pic)

Size (heating)

The Unit



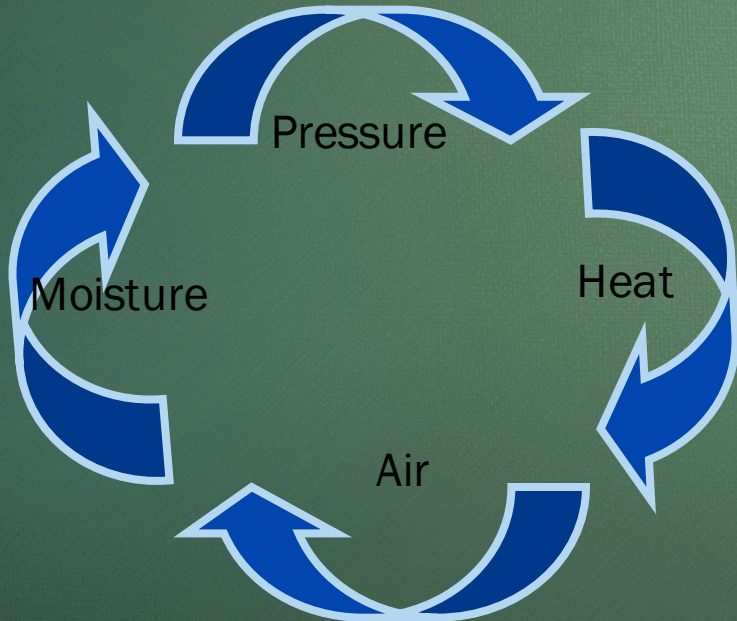
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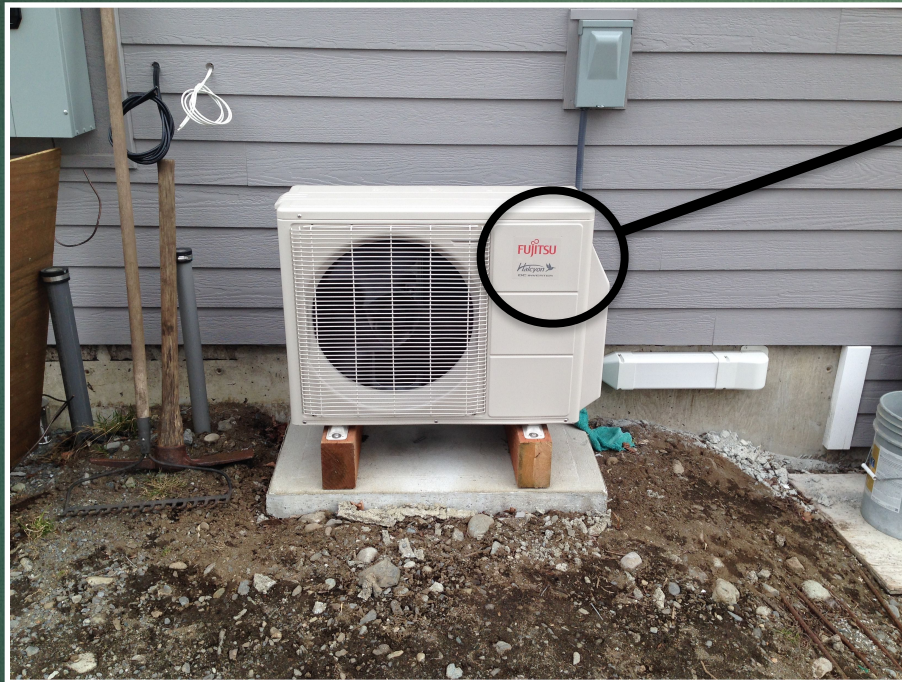
The Specs

Heat pumps: Why now?

Better Shells



Heat pumps: Why now?



Fujitsu
Mitsubishi
Daikin
Panasonic

Better Technology and
Higher Performance

Air Source Heat Pump

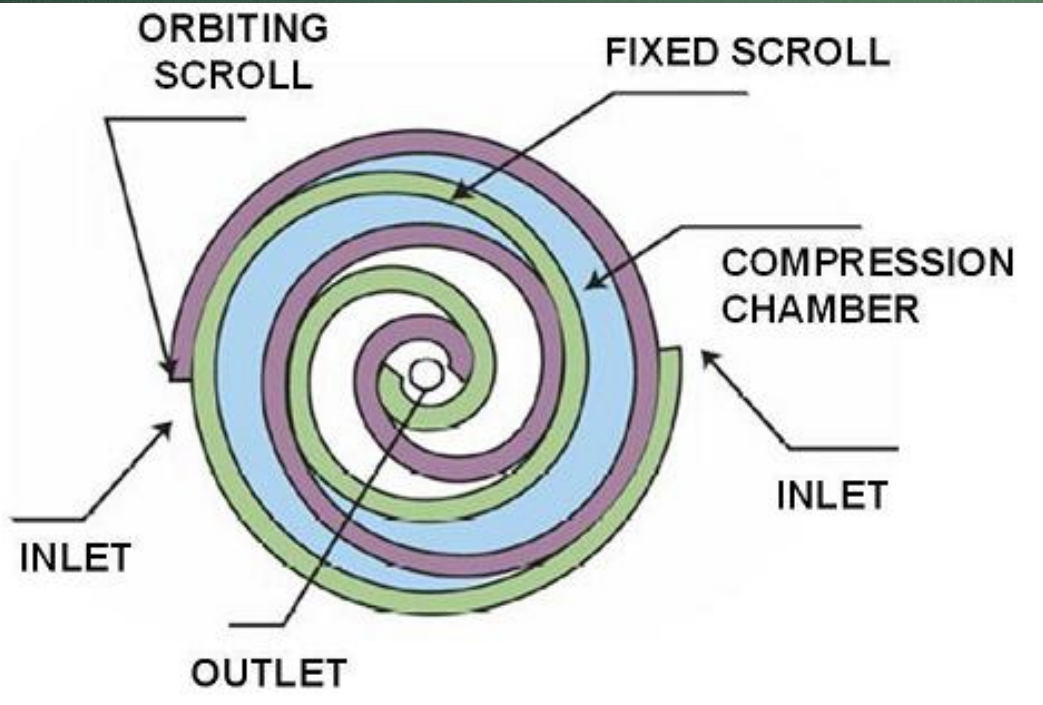
More reasons heat pumps are getting famous

Technology, comfort, efficiency

(Every part of the system has improved performance/efficiency)

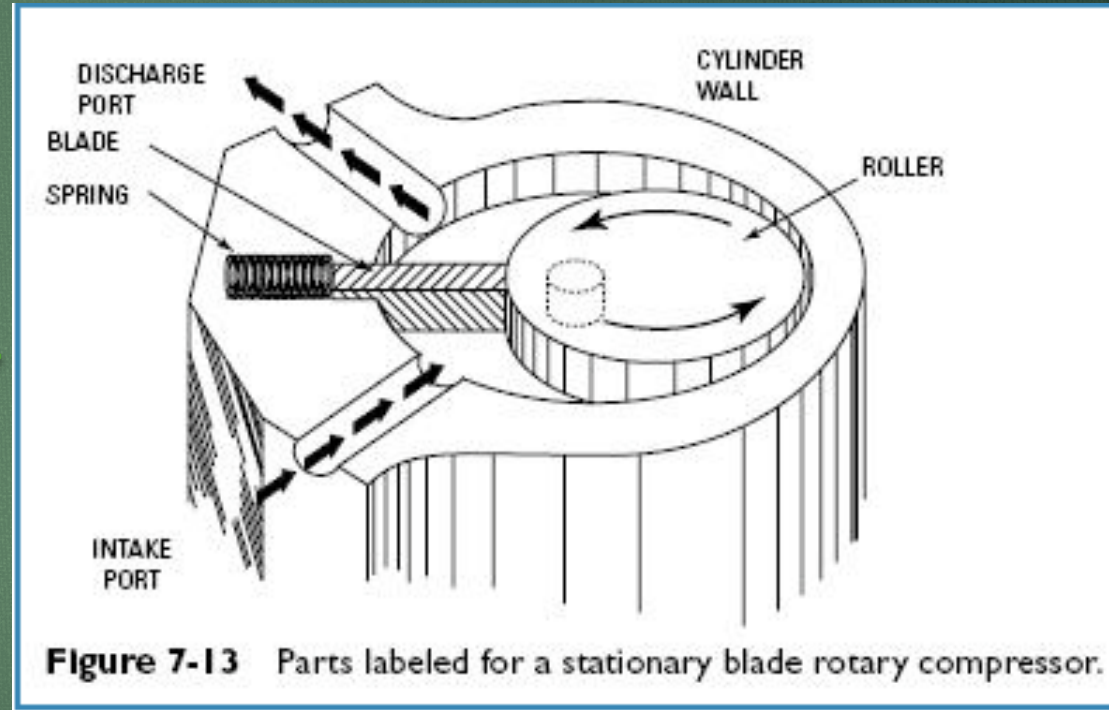
Not the same old Compressors

Scroll



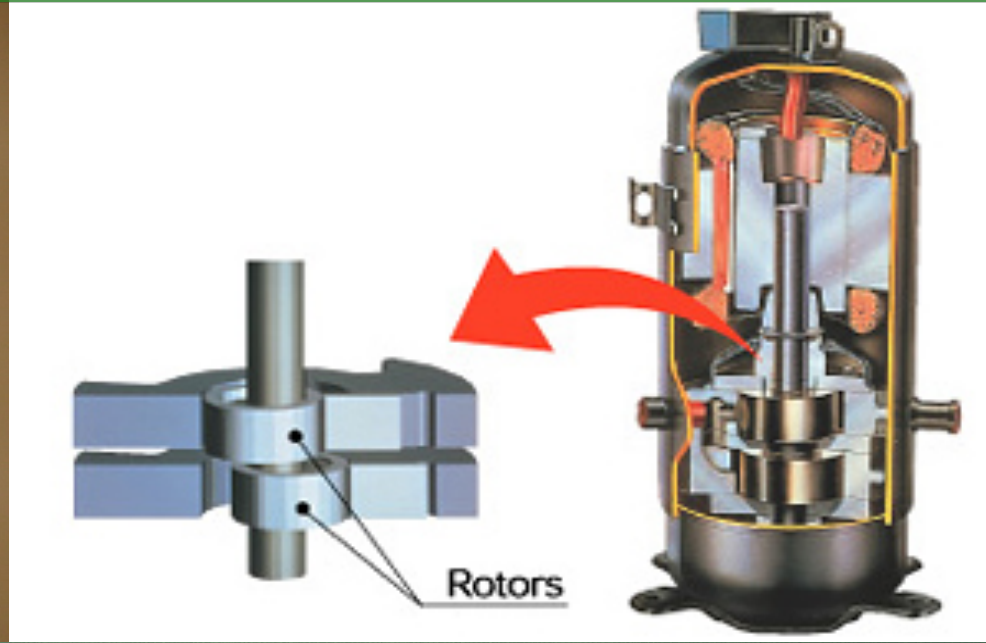
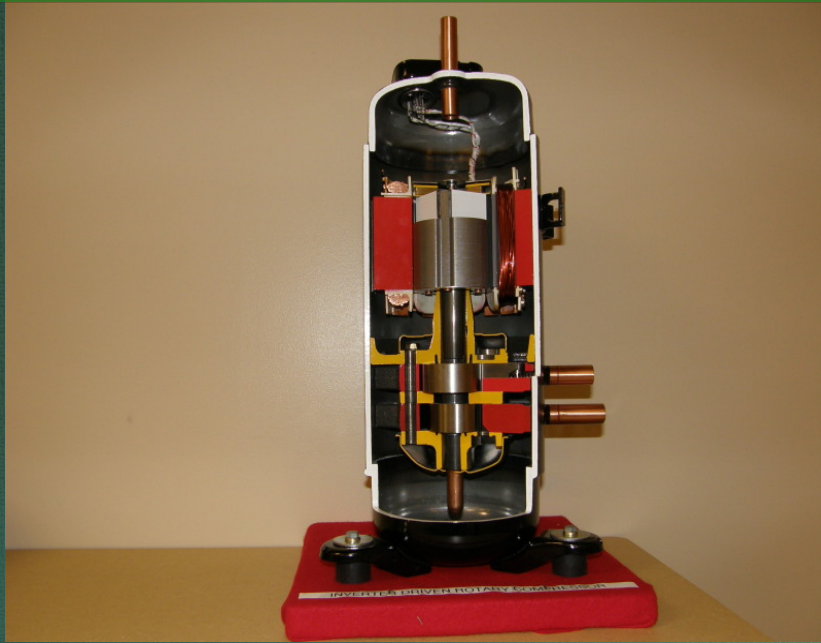
THEN

Rotary



NOW

Twin Rotor DC Compressor



**Digitally Commutated
Compressor**

- Compressor starts at a minimum frequency of 23% of maximum capacity
- Variable speed, based on demand level and ambient conditions
- Soft start operation (< 1 amp on startup)
- Three phase, nearly equal ohm windings
- Etc...

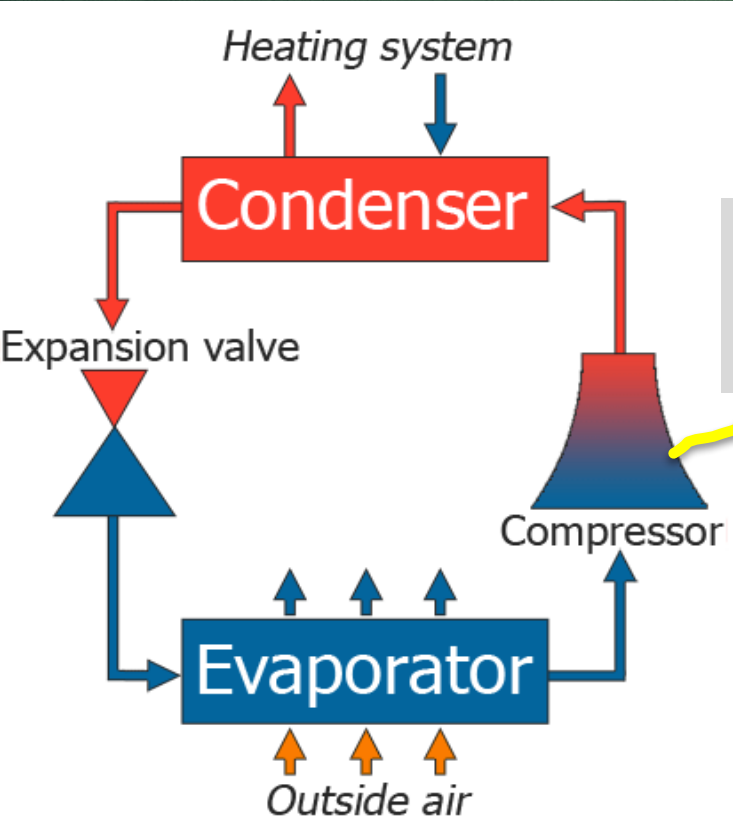
Inverter Technology



- ▶ Allows speed control of compressor
 - ▶ Changes flow of refrigerant
 - ▶ Can modulate between ~ 12 – 100%
- ▶ Strategies differ between manufacturers
- ▶ AC into unit
 - ▶ Rectified to DC
 - ▶ Pulse width modulation (PWM)* makes AC of differing frequency
 - ▶ Allows variable speed control of compressor
- ▶ Cool, huh?

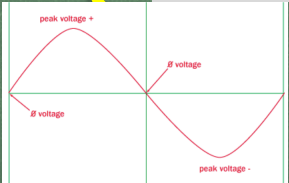


Inverter Technology



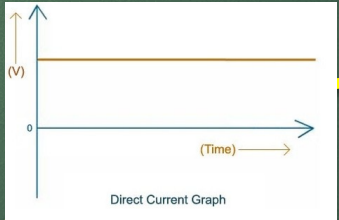
Control
Compressor
Speed

AC
Variable Freq.

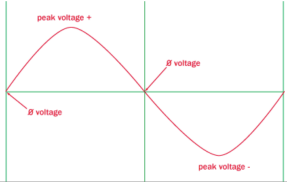


PWM
(Inverter)

DC
Signal



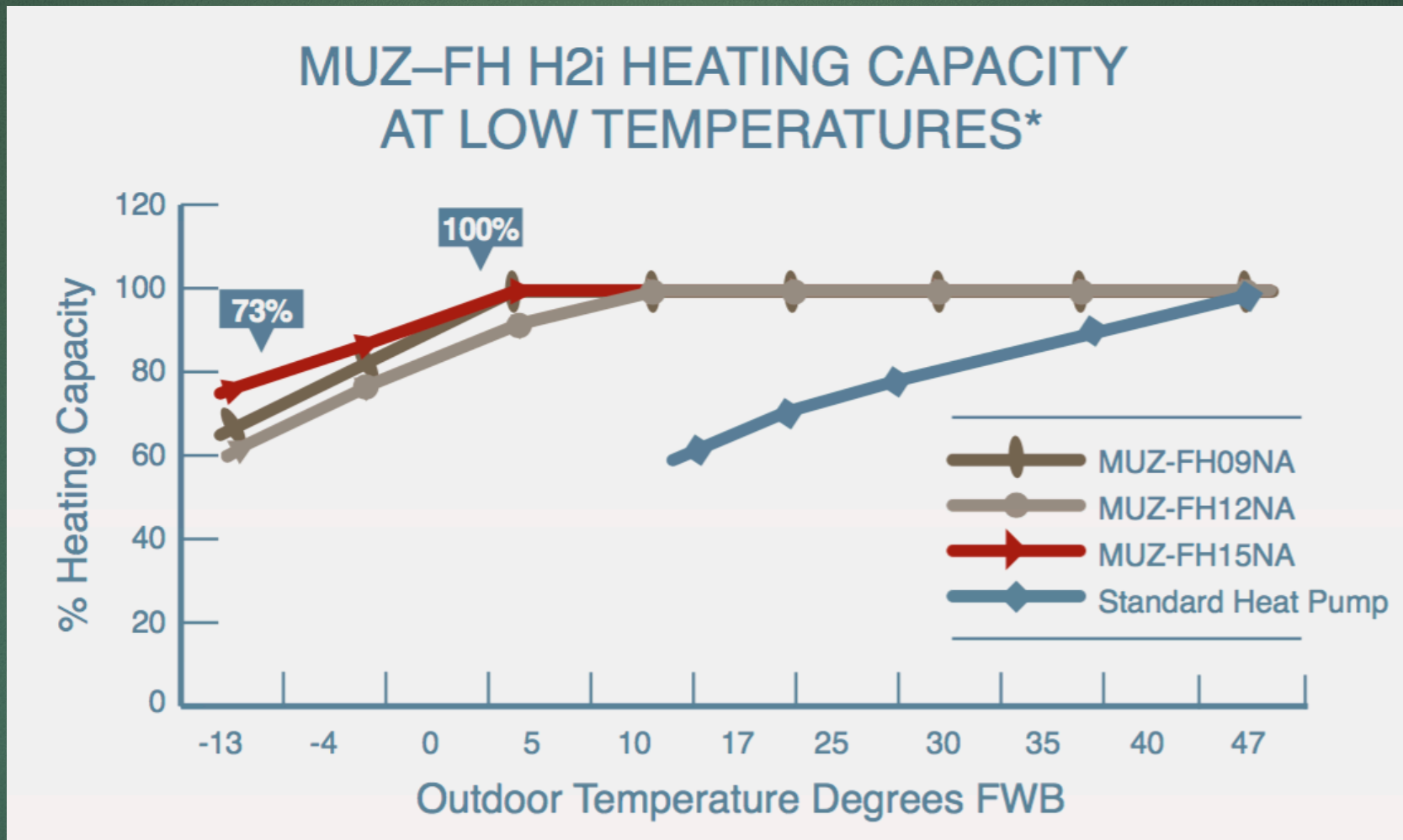
AC from outlet
(60 Hz)



Change
to DC

Mitsubishi says...

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Everything is shifting left.....rapidly....

Some Mitsubishi Numbers and Letters



Indoor Unit:

Blower Motor (ECM)	F.L.A.
--------------------	--------

Outdoor Unit:

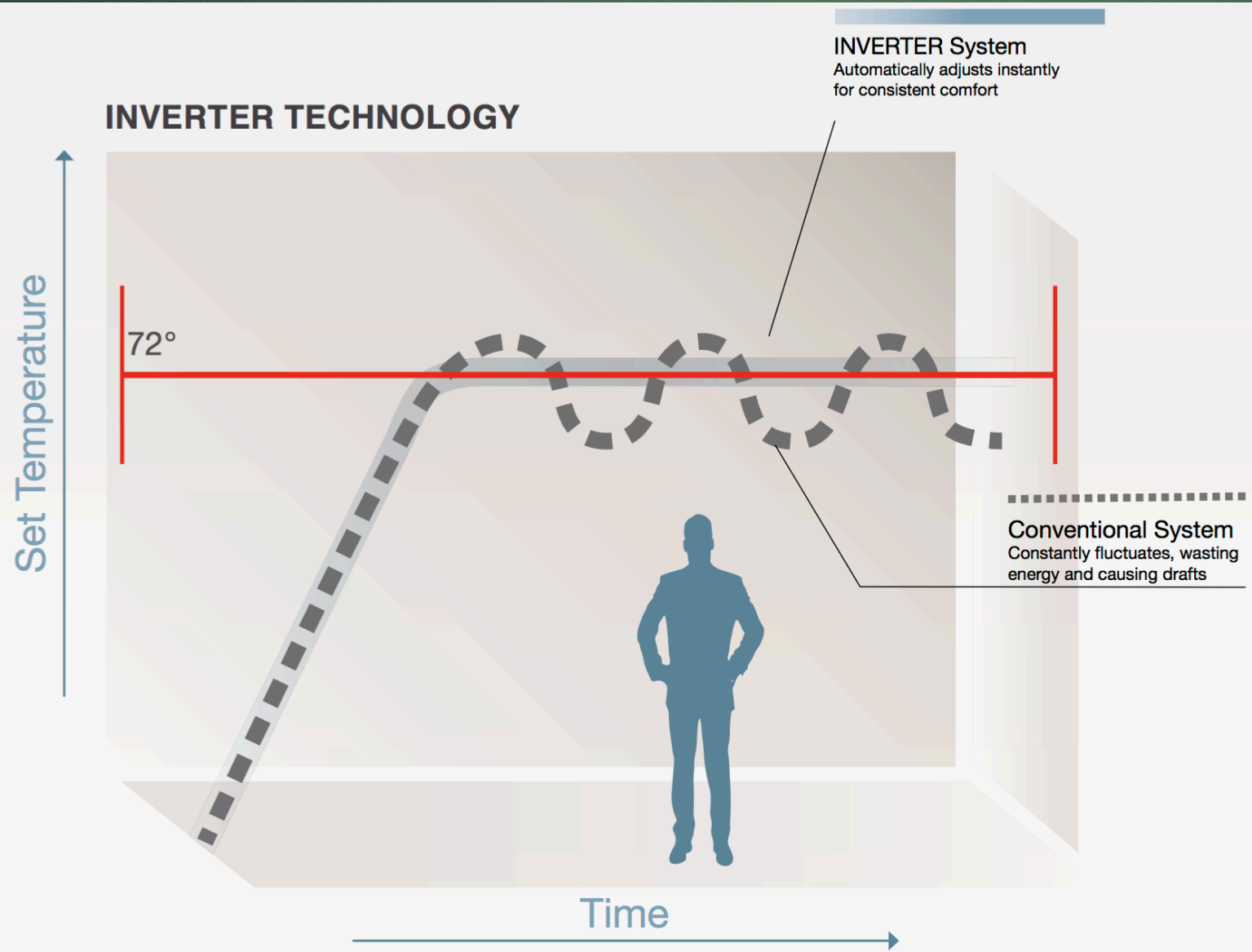
Compressor	Model (Type)	DC INVERTER-driven Twin Rotary			
	R.L.A.	8.2	12.0		
	L.R.A.	10.3	15.0		
Heating at 47° F *2	Rated Capacity	Btu/h	10,900	13,600	18,000
	Capacity Range	Btu/h	1,600 - 18,000	3,700 - 21,000	5,150 - 24,000
	Rated Total Input	W	710	950	1,300
	HSPF (IV)	Btu/h/W	13.5	12.5	12.0
Heating at 17° F *3	Rated Capacity	Btu/h	6,700	8,000	11,000
	Rated Total Input	W	600	720	1,020
	Maximum Capacity	Btu/h	12,200	13,600	18,000
Heating at 5° F	Maximum Capacity	Btu/h	10,900	13,600	18,000

A heat pump isn't a forced
air furnace

Don't treat it or use it like one

Perform best when you set it
and leave it

More comfort

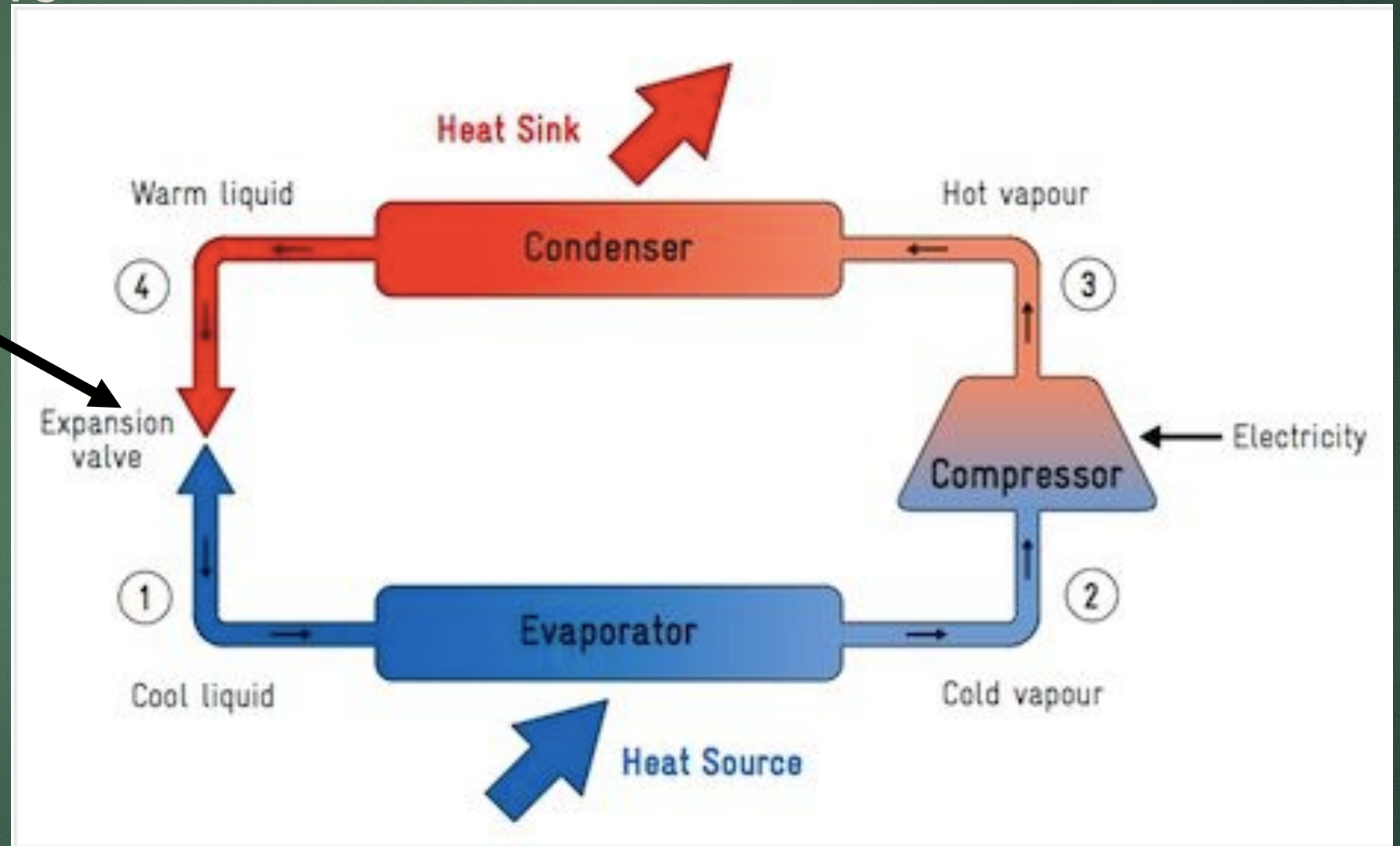


Inverter compressors are variable speed.

- most efficient
- less stopping/starting
- consistent heating/cooling

Further performance improvements

Electronic expansion valve allows precise refrigerant control



Speaking of expansion valves

- ▶ Refrigerants have changed
- ▶ Mostly from R-22 to R-410A
- ▶ R-410A is more environmentally friendly – no chlorine
- ▶ Other proprietary concoctions



Can also provide distribution (HRV)

An option for heat pumps

Satisfy picky code officials?



Additional Factors



- ▶ Many coastal AK communities have
 - ▶ mild temperatures
 - ▶ Renewable electricity generation (hydro/wind)
 - ▶ cheap electricity (\$0.08 - \$0.14/kWh)
- ▶ Easy and cheap installation
 - ▶ Unit + Installation + Commissioning = Less than \$6000.00
- ▶ Performance is improving rapidly
 - ▶ Strong performance down to -15F

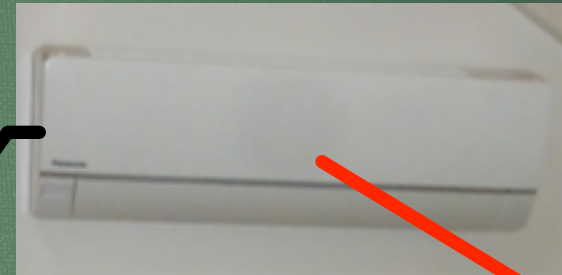
200 - 400% Efficiency
(sometime less)

and I'm not blowing hot air!!

200% - 400% Efficiency?

- ▶ Coefficient of Performance (COP)
 - ▶ ratio of energy output to energy input (usually 1 - 5)

Energy Input
(Watt-hours)



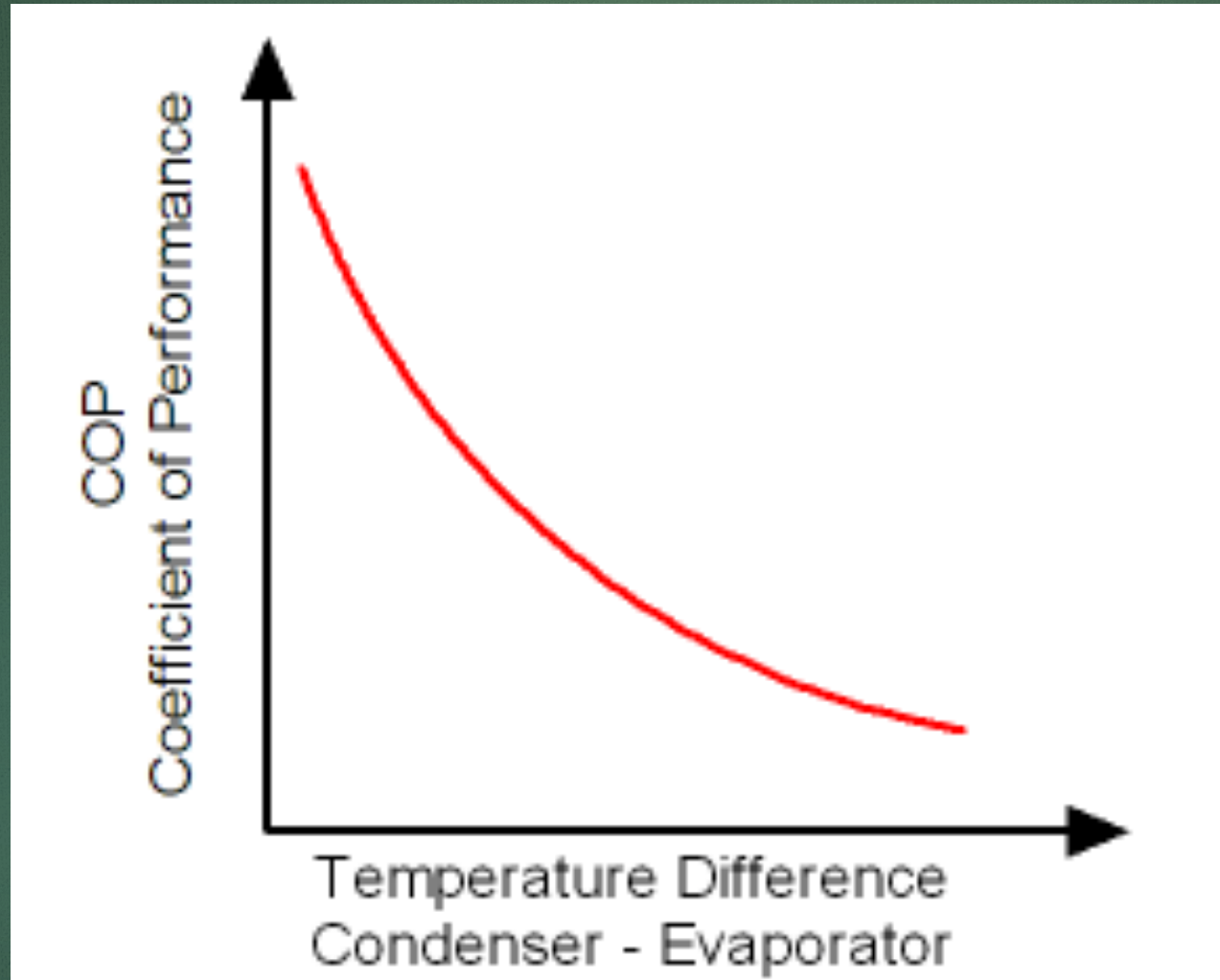
Energy Output
(Watt-hours)

Need to use same units, of course
1 Watt-hour = 3.4 Btu

COP

- ▶ $COP = 2$
 - ▶ 2 units of energy out for each unit of energy (electricity) you put in
 - ▶ same as 200% efficiency
- ▶ $COP = 1$
 - ▶ Same as resistance heat or toaster (not including toast)

COP and Temperature



The Point:
The greater the
temperature
difference, the
lower efficiency

Heating Season Performance Factor



- ▶ HSPF
- ▶ Somewhat analogous to AFUE – kinda sorta
- ▶ Overall heating efficiency over a heating season (Btu/kWh)
 - ▶ Usually ~8-14

Only in America



A couple others

- ▶ SEER

- ▶ Seasonal Energy Efficiency Ratio (minimum 13 in U.S.)

- ▶ Cooling efficiency

- ▶ Cooling output/electrical energy input

- ▶ Btu/hr/watts

- ▶ EER

- ▶ Energy Efficiency Ratio

- ▶ Cooling efficiency – point in time

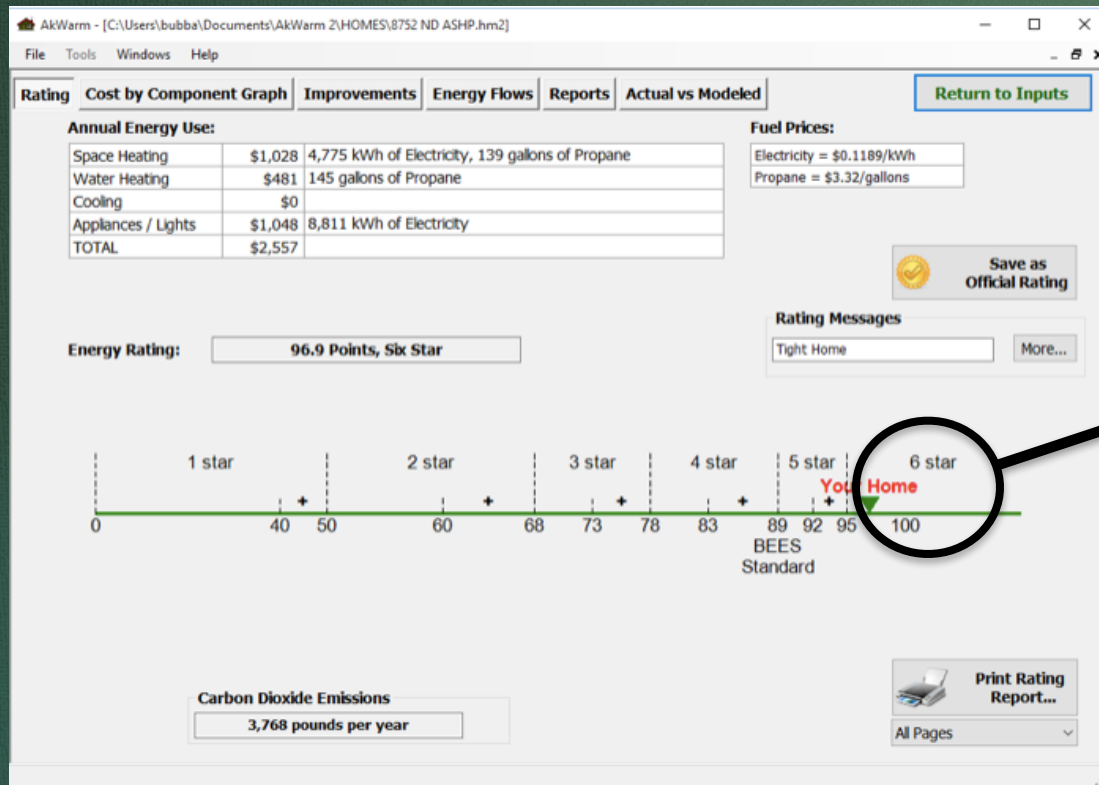
- ▶ (Btu/hr)/watts

So, do these really work?

Some Data from North Douglas, Wrangell, and Juneau

Some Numbers

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6 Star

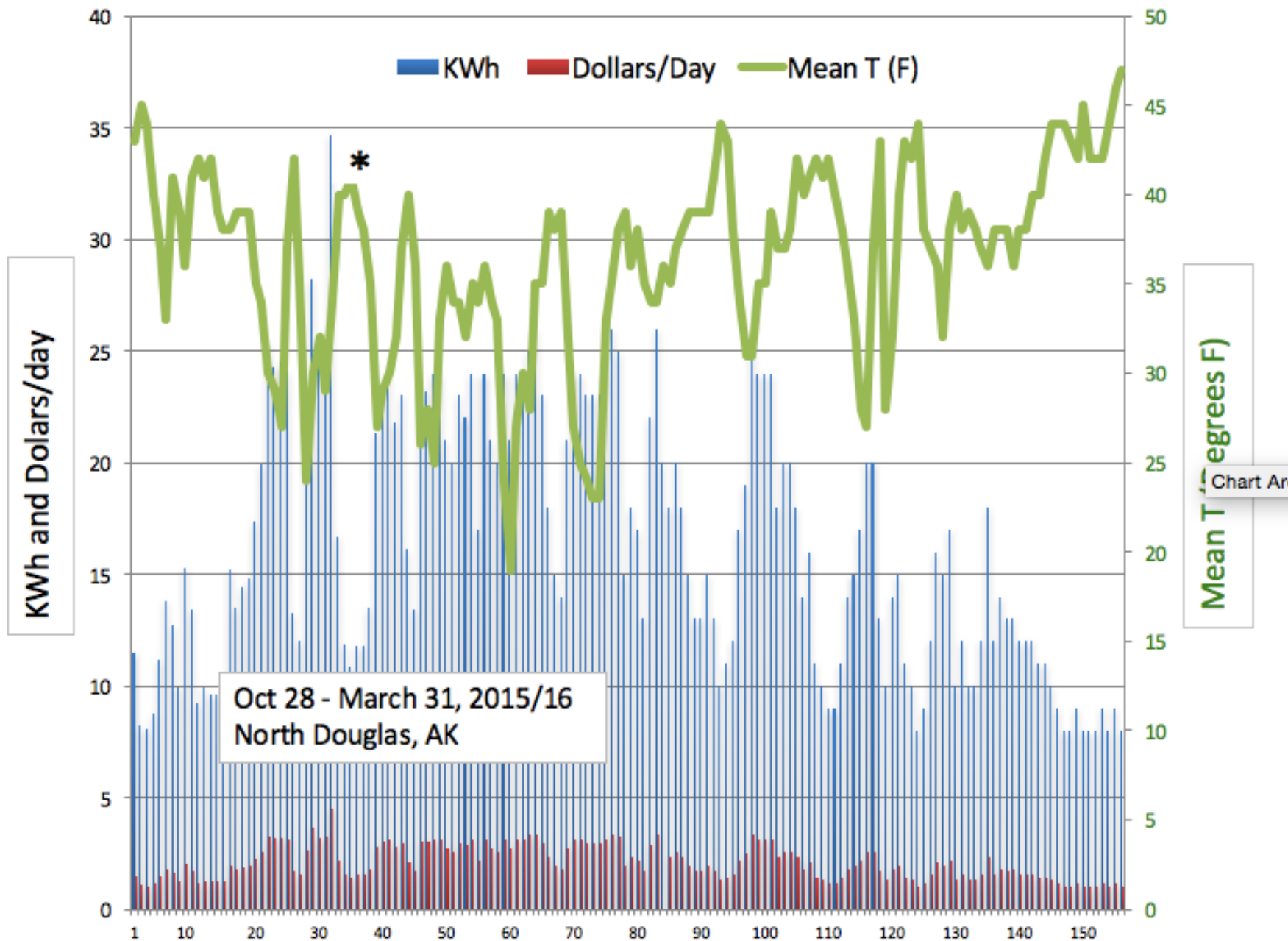
Home Details

Built 1989, N. Douglas

1400 ft²; 13,000 ft³

$ACH_{50} = 0.36$





DHP
Douglas, AK
~8500 HDD

At \$0.13/kWh

~\$360 in 10
months

Another example (Helena, Mt - 8100HDD)

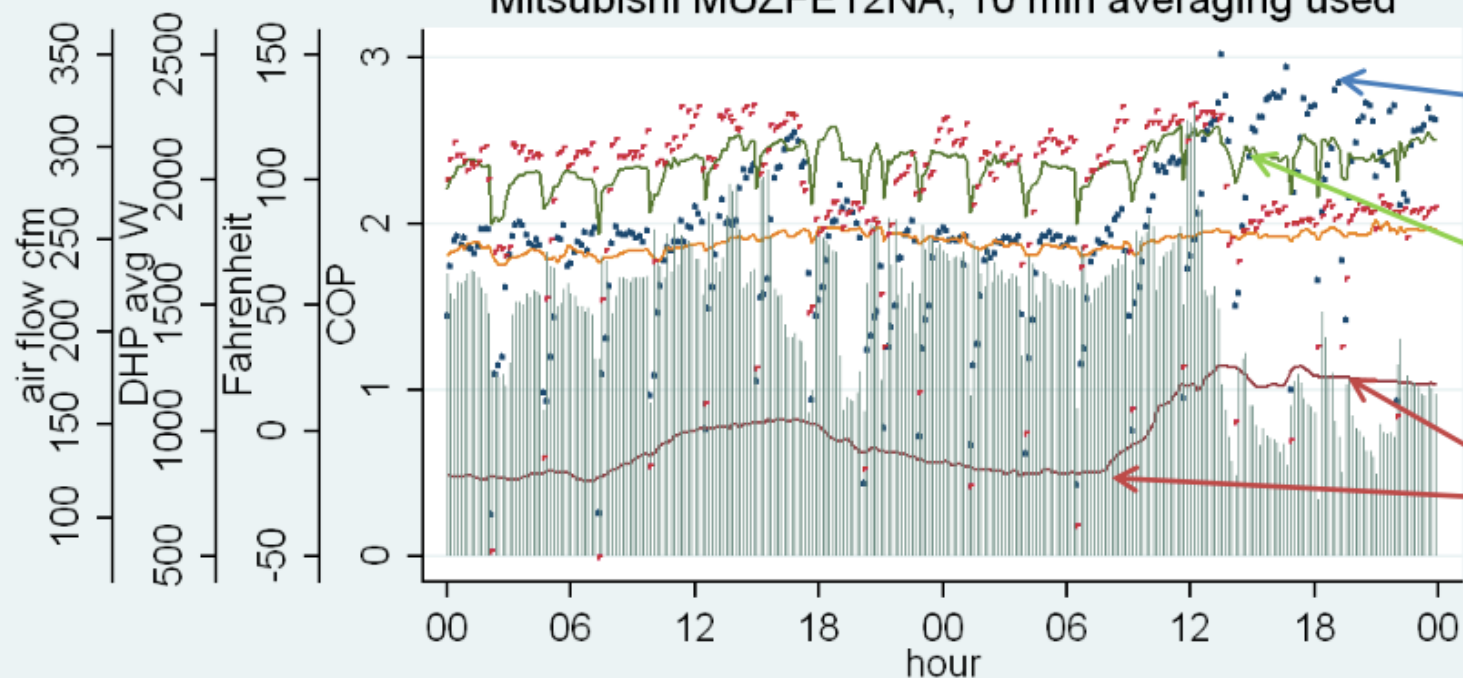
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DHP data for 48 hrs from Feb 25, 2011 0:00

site 20006 (2329721) East Helena, MT

Mitsubishi MUZFE12NA, 10 min averaging used



COP: 1.8 to 2.8

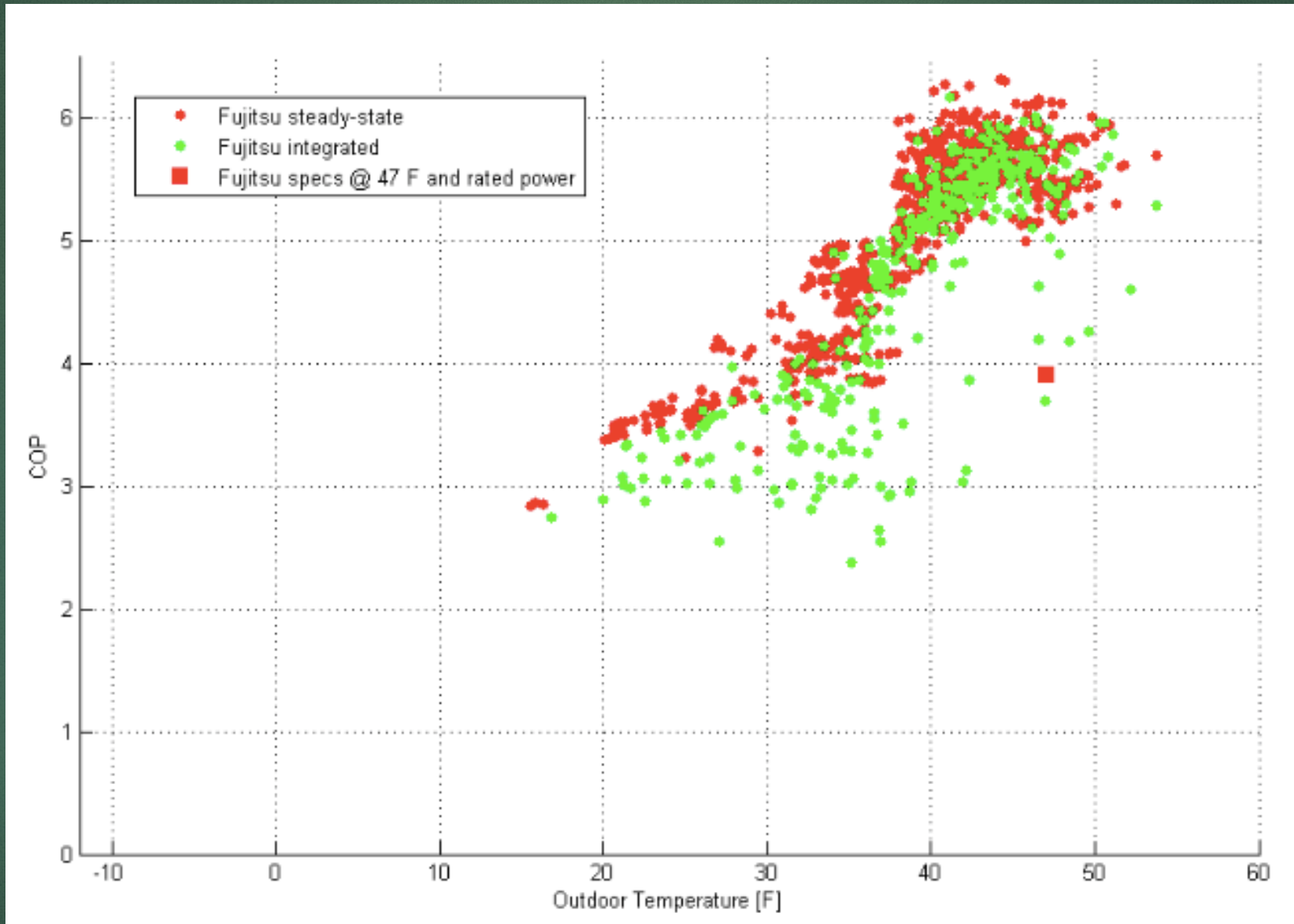
Supply Air T: 100F to 120F

Outdoor T: -15F to 15F



Wrangell Ductless Heatpump COP

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Wrangell DHP - 21 Degrees F

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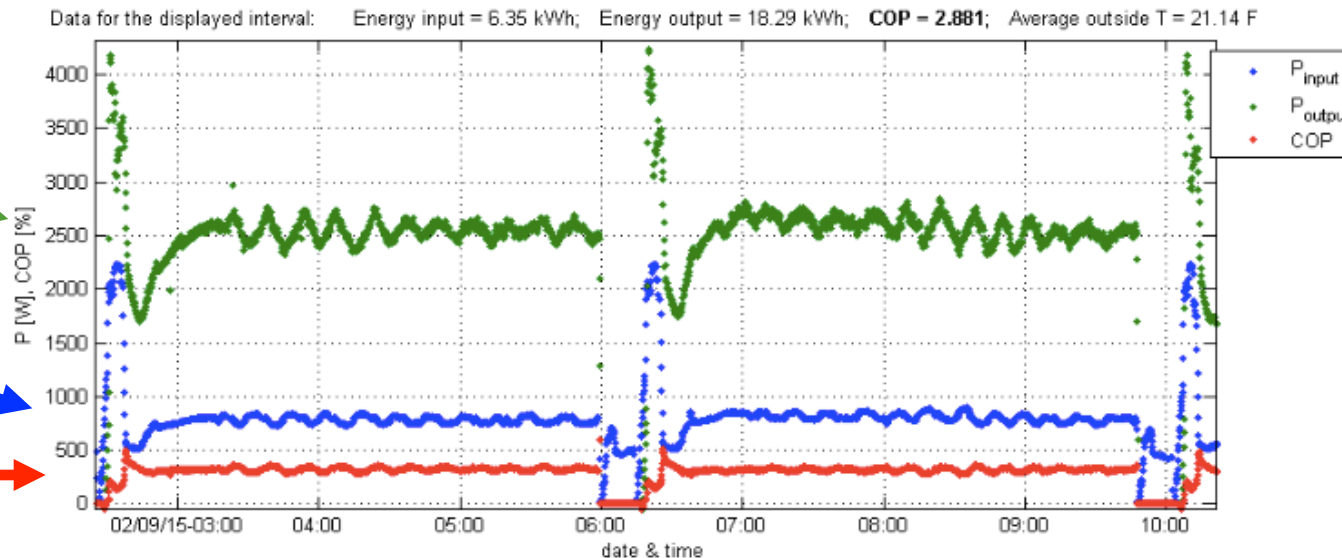
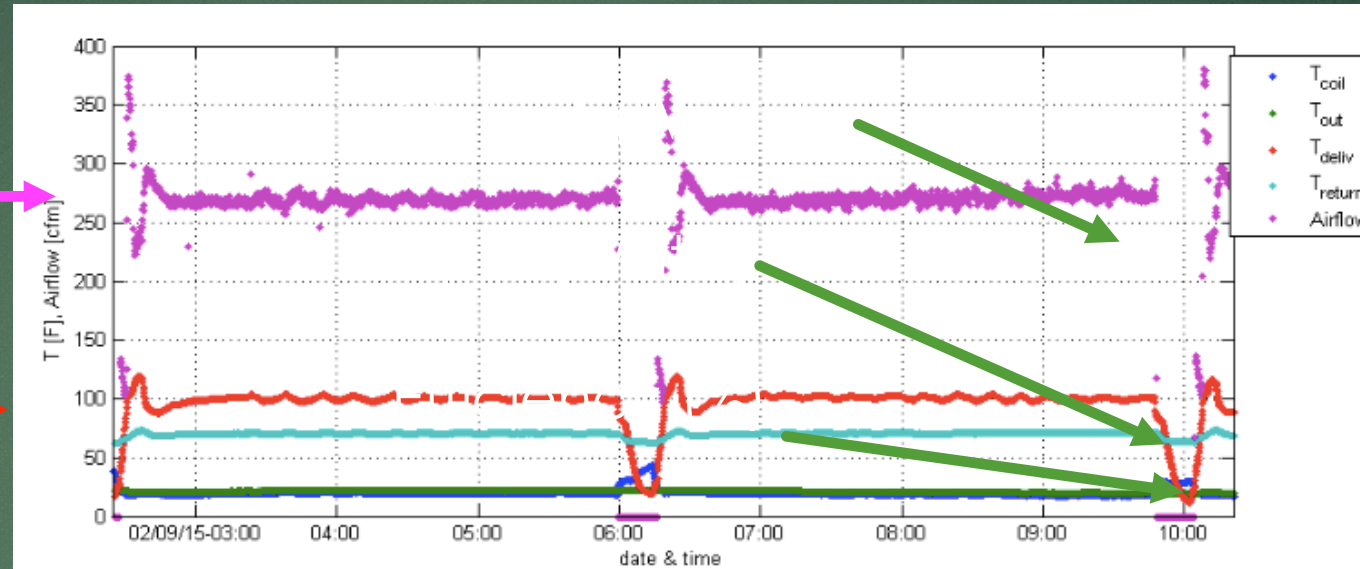
Airflow (cfm)

Delivered
temperature
(F)

Output (Watts)

Input (Watts)

Efficiency (%)



Wrangell DHP - 49 Degrees F

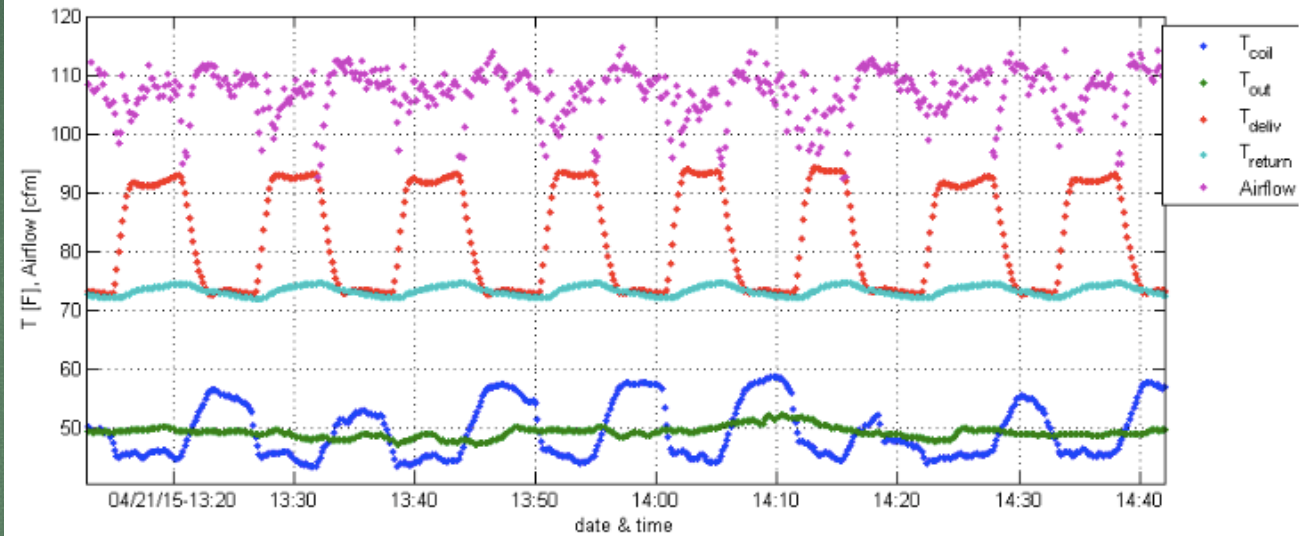
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Airflow (cfm)



Delivered
temperature (F)



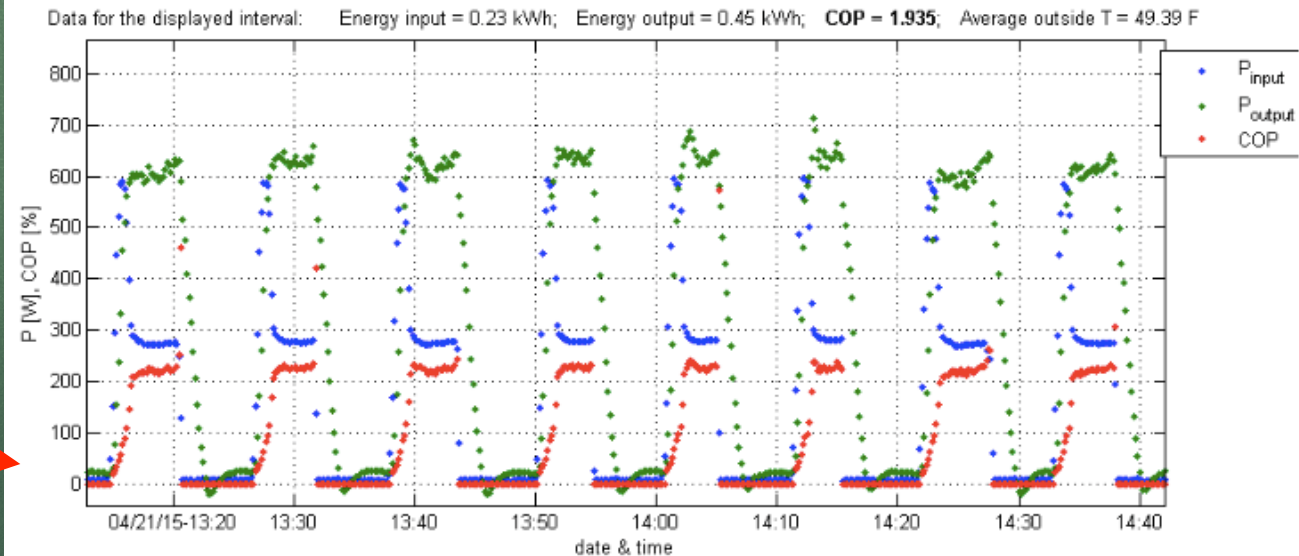
Output (Watts)



Input (Watts)



Efficiency (%)



Juneau - Hot Water and Space Heating

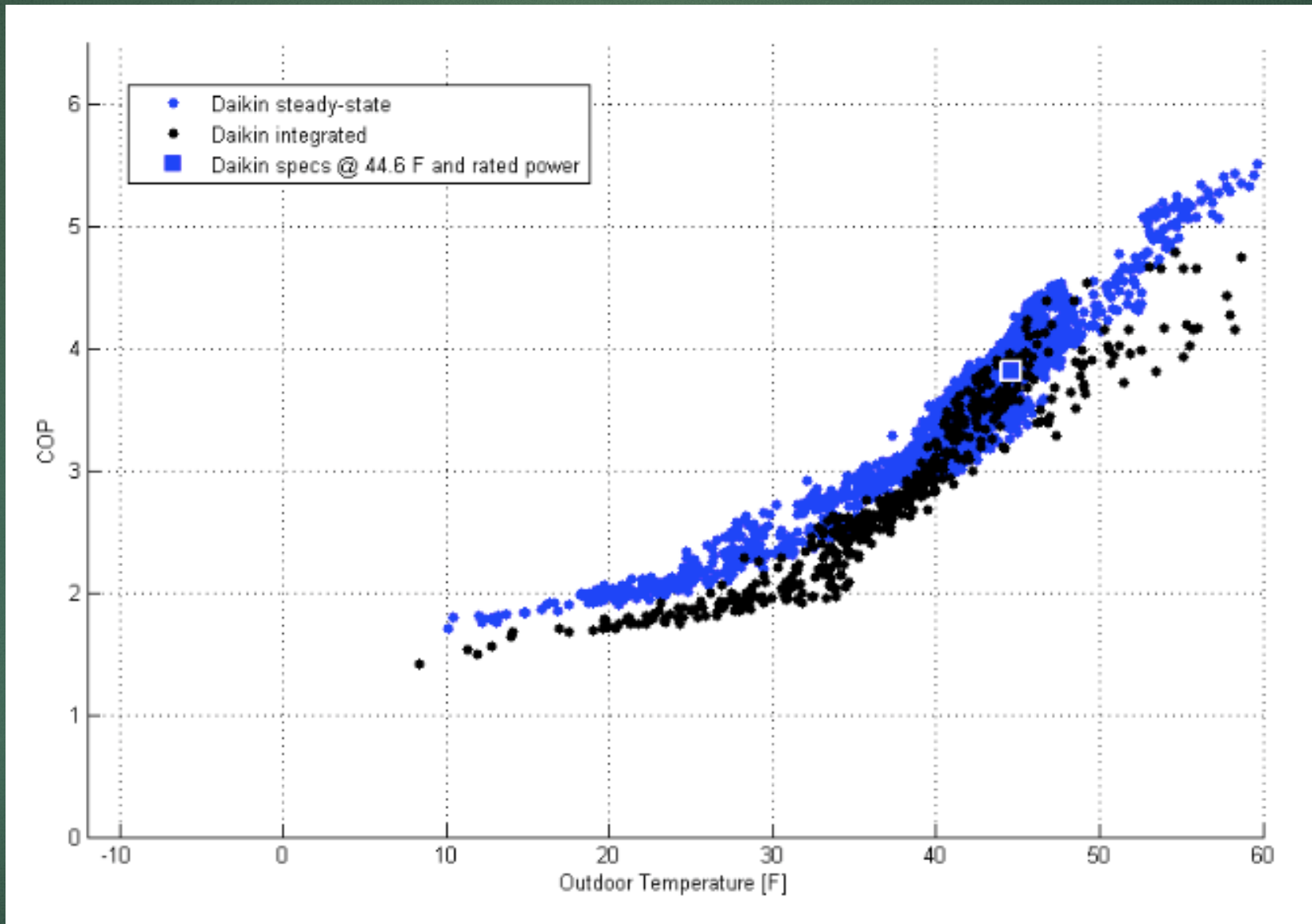
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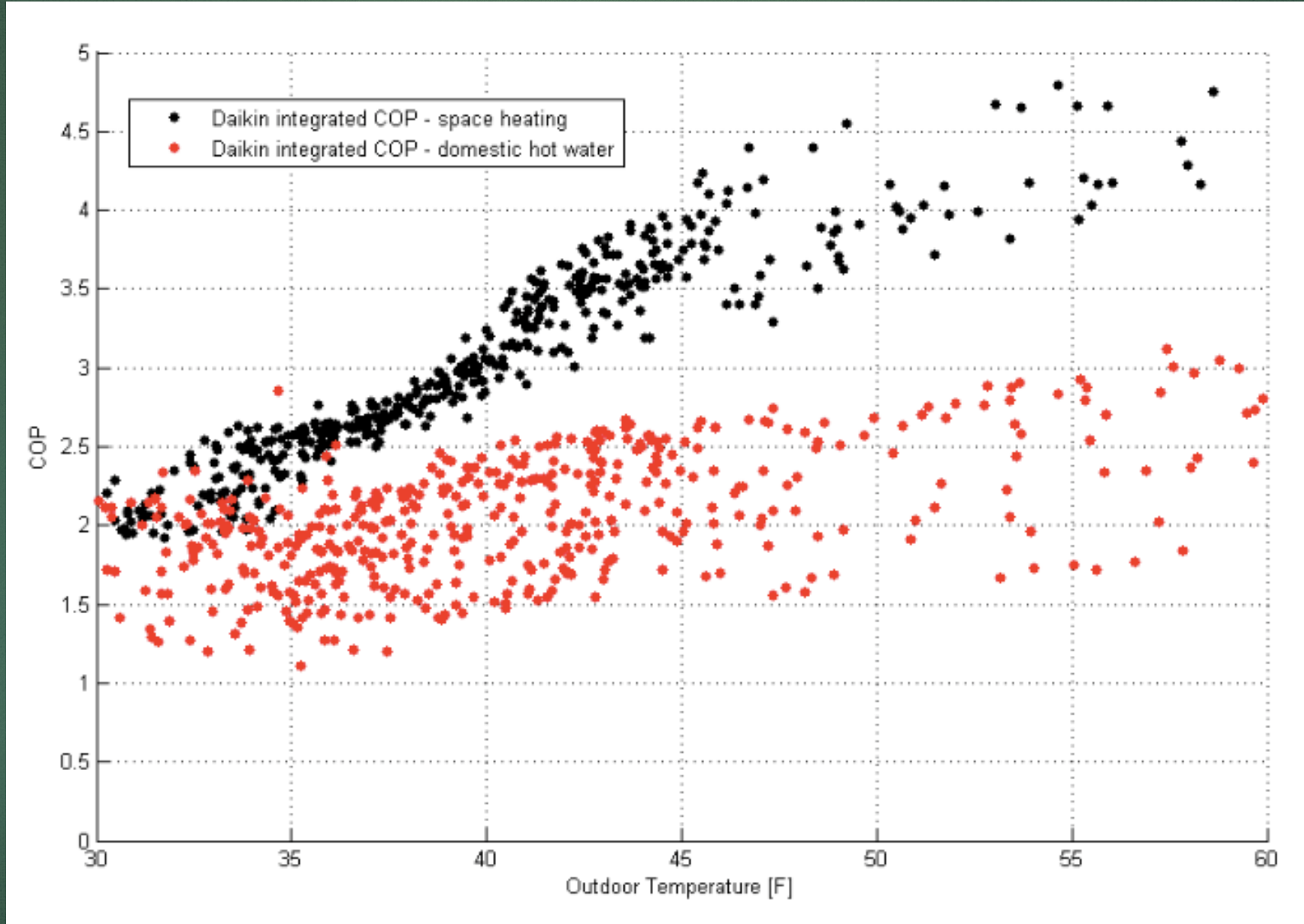
Air to Water System



Juneau - Space heating COP



Juneau - Space heating & DHW COP



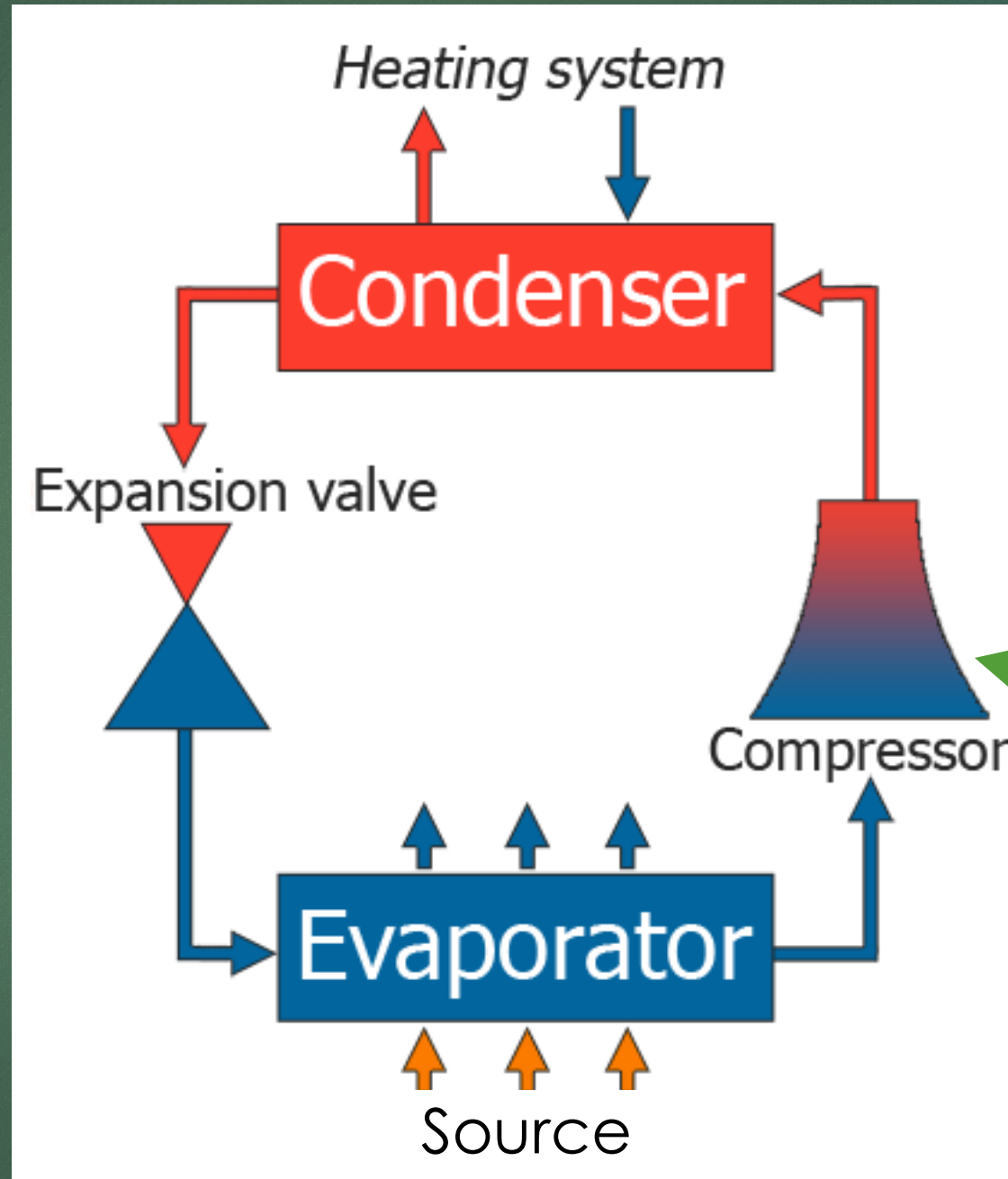
Considerations for installing a ductless heat pump

- ▶ Shell performance
- ▶ Thermal environment
- ▶ Electrical rates
- ▶ Electrical supply
- ▶ Condensate drains?
- ▶ Expectations
- ▶ Heating vs. Cooling
- ▶ Sizing
- ▶ Installation Cost
- ▶ Operating Cost
- ▶ Maintenance
- ▶ Lifespan

Why so Efficient?

Heat pumps expend energy moving heat, not “creating” heat

“Energy Concentrators”



Just add electricity

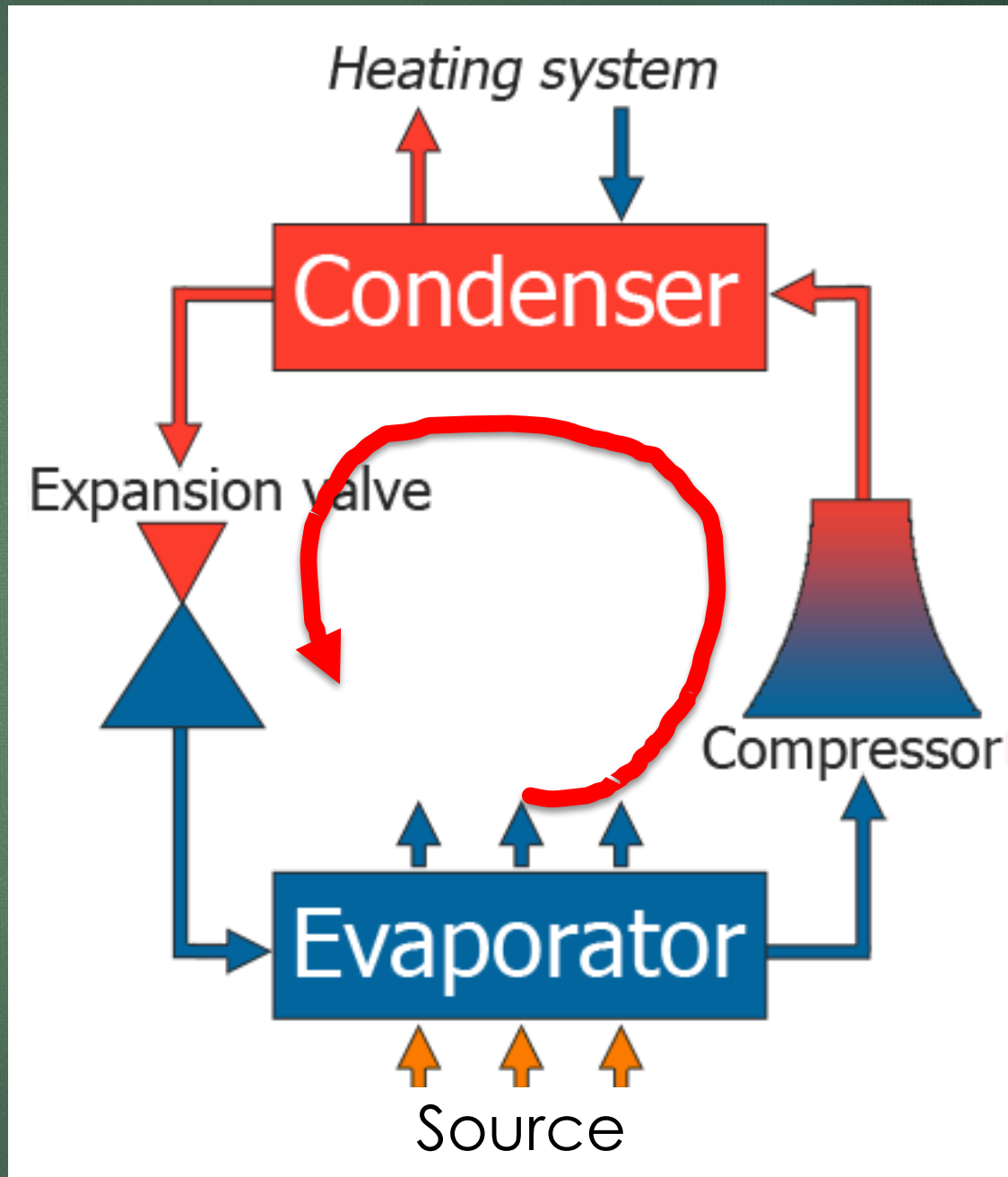
Ice happens - plan accordingly



Still heating
for \$1.70/day

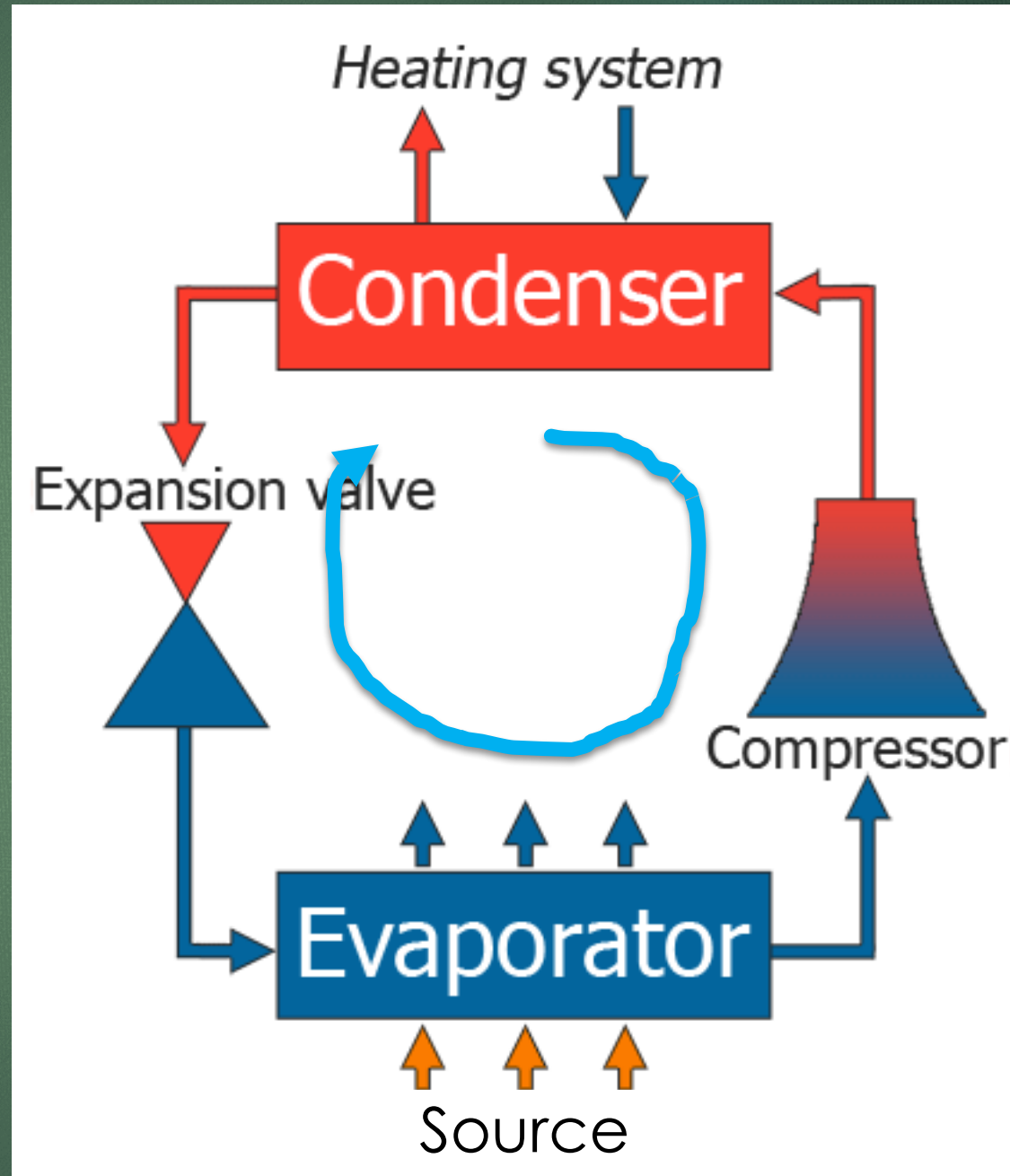
Heating

Dumps heat into interior



Cooling/Defrosting

Pulls heat from interior



Placement is critical

74



Glaciers
happen