MESM ACADEMY:

Building Systems 101

December 2, 2025

11am

NOTIFICATION OF RECORDING

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MESM ACADEMY:

Building Systems 101

December 2, 2025

11am

Today's Lesson

Lesson Questions

- What are the main forms of heating, ventilation, and air conditioning systems in Massachusetts? What are the most energy efficient systems?

Learning Objectives

- To understand how BTUs/heat are delivered to and removed from a building
- To describe how heat pumps work
- To learn about the "old school" and modern HVAC systems common in residential and commercial buildings in Massachusetts

Introductory Polls

Rate your level of agreement with the following statements:

- I understand how BTUs/heat are delivered to and removed from a building.
- I can describe how heat pumps work.
- I understand how "old school" and modern HVAC systems common in residential and commercial buildings in Massachusetts work.

1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree

Meet the Instructors

Paul Ormond

Engineer
DOER

Becca Edson

Architect
DOER

Training Agenda

Time	Duration	Topic
11:00am	5 mins	**Welcome & Lesson Overview**
11:05am	30 mins	**Building Systems 101 Presentation**
11:35am	20 mins	**Q&A**
11:55am	5 mins	**Next Steps**

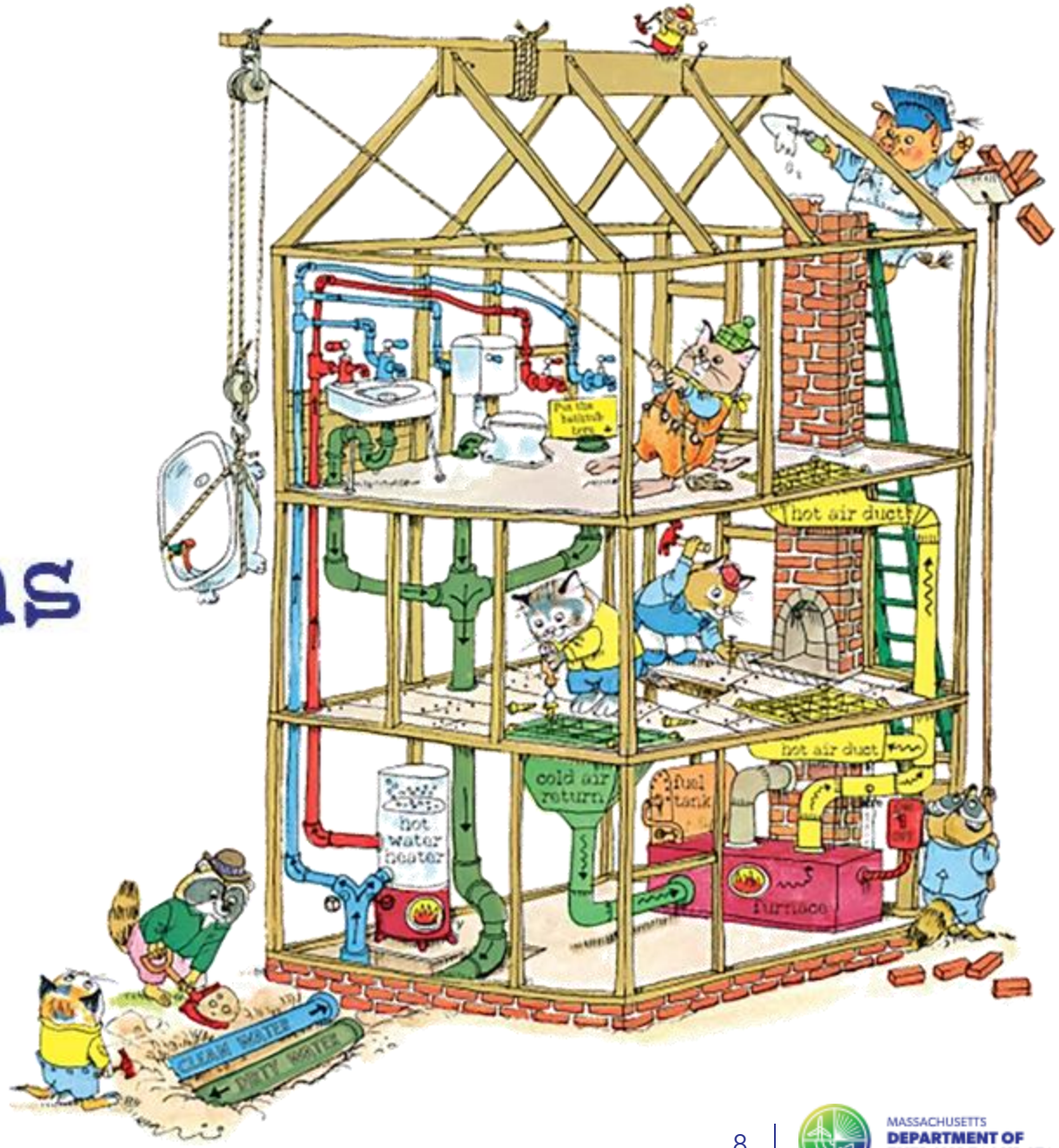
MASSACHUSETTS
DEPARTMENT OF ENERGY RESOURCES

building systems

Heating, Ventilation & Air Conditioning !

Paul Ormond, Engineer

& Becca Edson, Architect



The Mission of the HVAC system :

Comfort

Maintaining a safe interior temperature

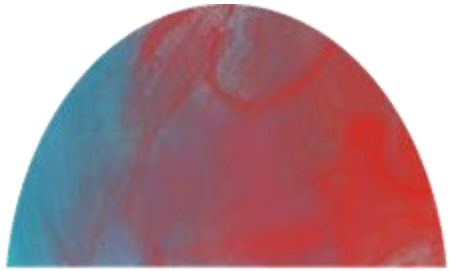
Indoor Air Quality

Energy Efficiency and Decarbonization

The Cast of Characters

The HVAC All-Star Team!

BTU



SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

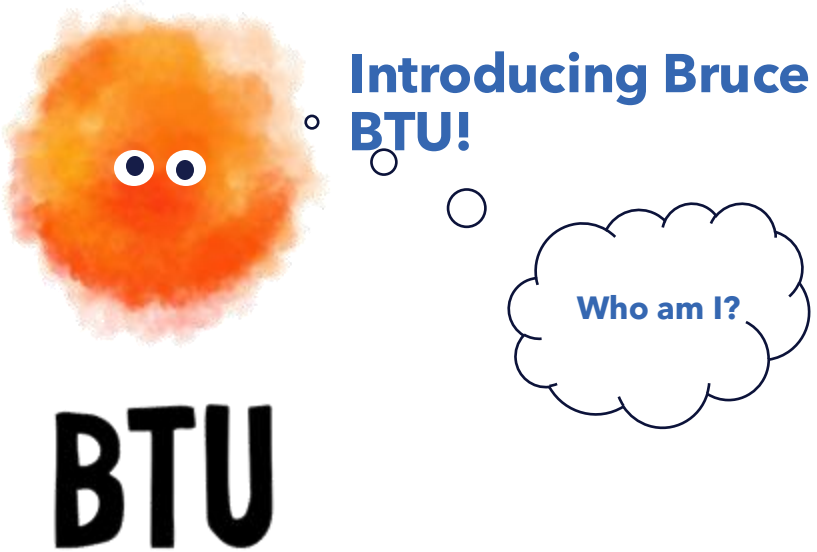
VENTILATION

DOMESTIC
WATER
HEATING

What is a BTU?

A "British Thermal Unit" is a measure of heat.

It defines the amount of heat (energy) required to raise the temperature of one pound of water by one degree Fahrenheit.



One BTU roughly equals the heat produced by burning one wooden match

Bruce the BTU's philosophical angst

Where do I come from?

How do I get there?

Do I live just one life?

To understand HVAC systems, deconstruct these three questions!

Bruce the BTU's philosophical angst

Where do I come from?

Combustion of fossil fuels

Electric Resistance

Electric Heat Pump (moving)

PLUS

Solar Heat Gain (a "New Kid on the Block…")

How do I get there?

Travel by steam

Travel by air (ducted)

Travel by water (hydronic)

Travel by refrigerant (VRF)

Directly!

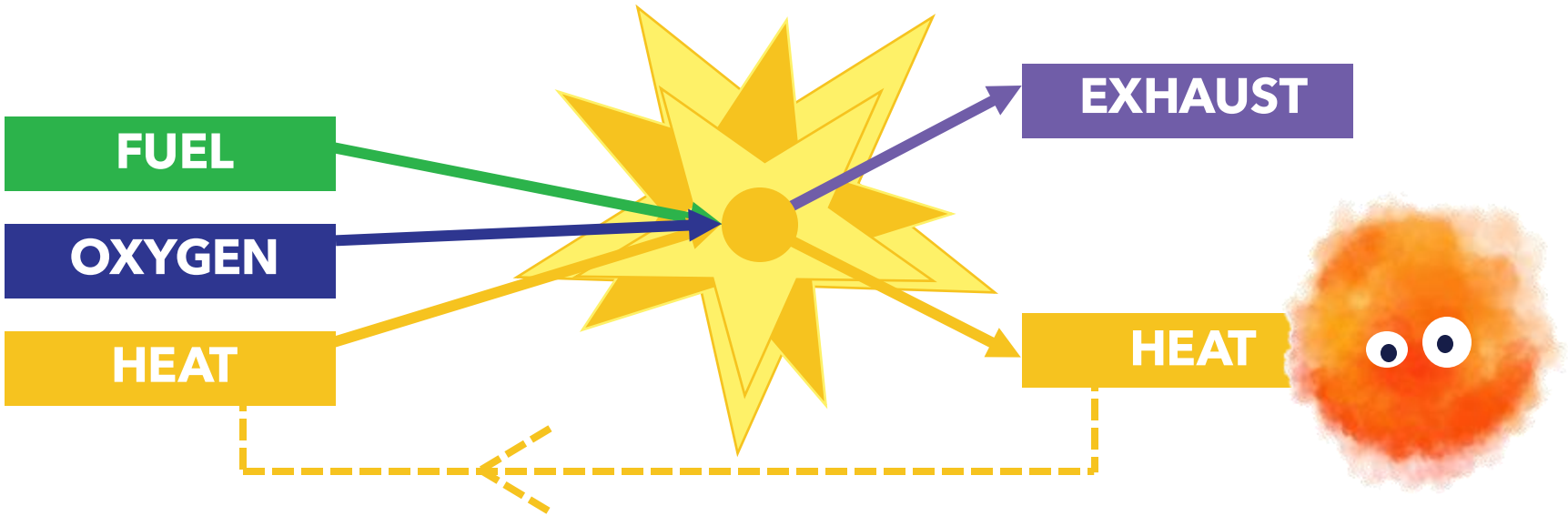
(distributed or "ductless heat pumps)

Do I live just one life?

Energy recovery?

But first……Where do BTUs come from ?!?

1. Combustion:

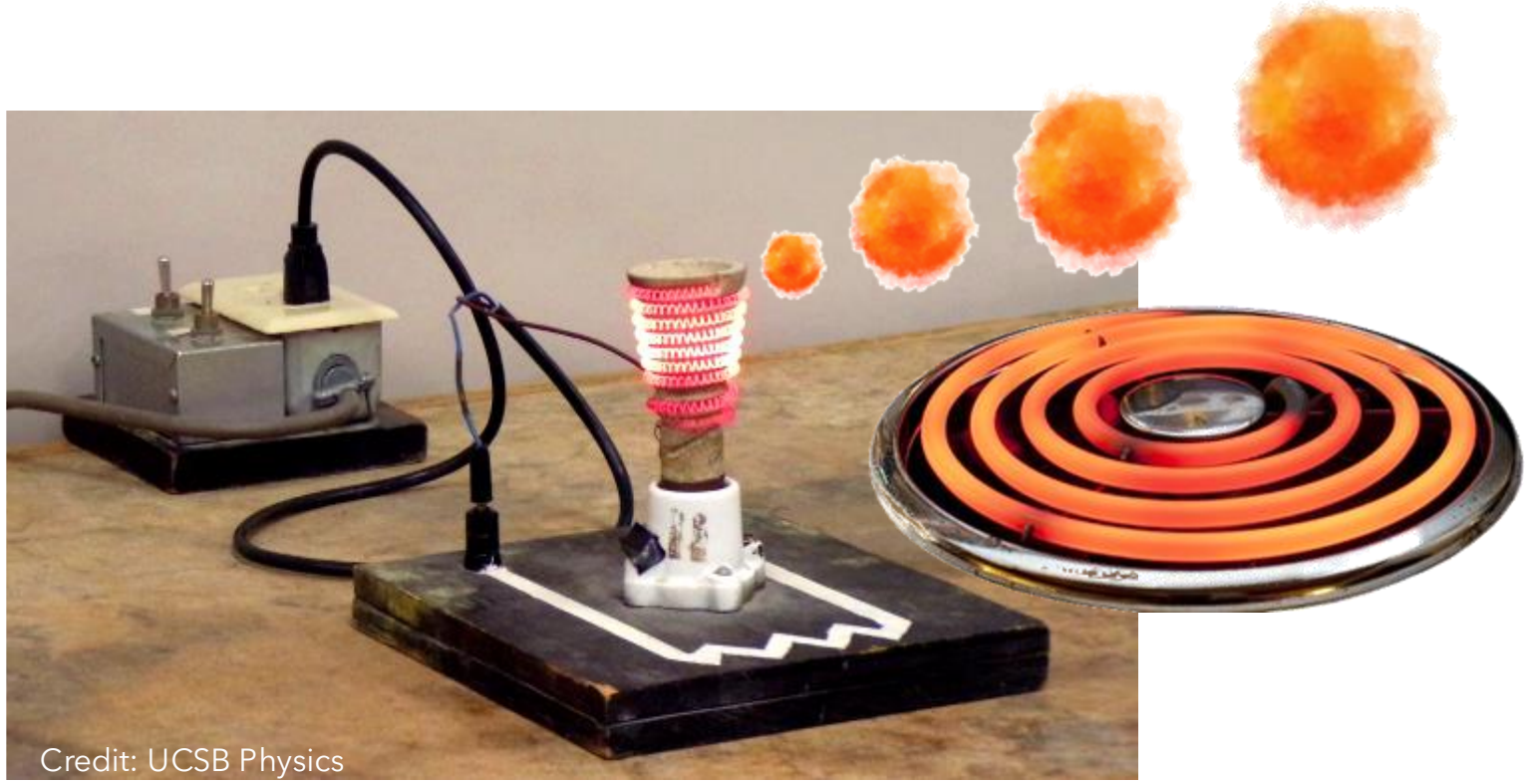


Excepting biomass, combustion involves fossil fuels – and thus emissions – so we want to eliminate it!

Where do BTUs come from ?!?

2. Electric Resistance

Electric current is run through a heating element that has electrical resistance. The heat is produced at a rate of +/- 3.41 BTUs/ watt,



Credit: UCSB Physics

Better than combustion of fossil fuels but horribly inefficient (100%) – use as little as possible!

Where do BTUs come from ?!?

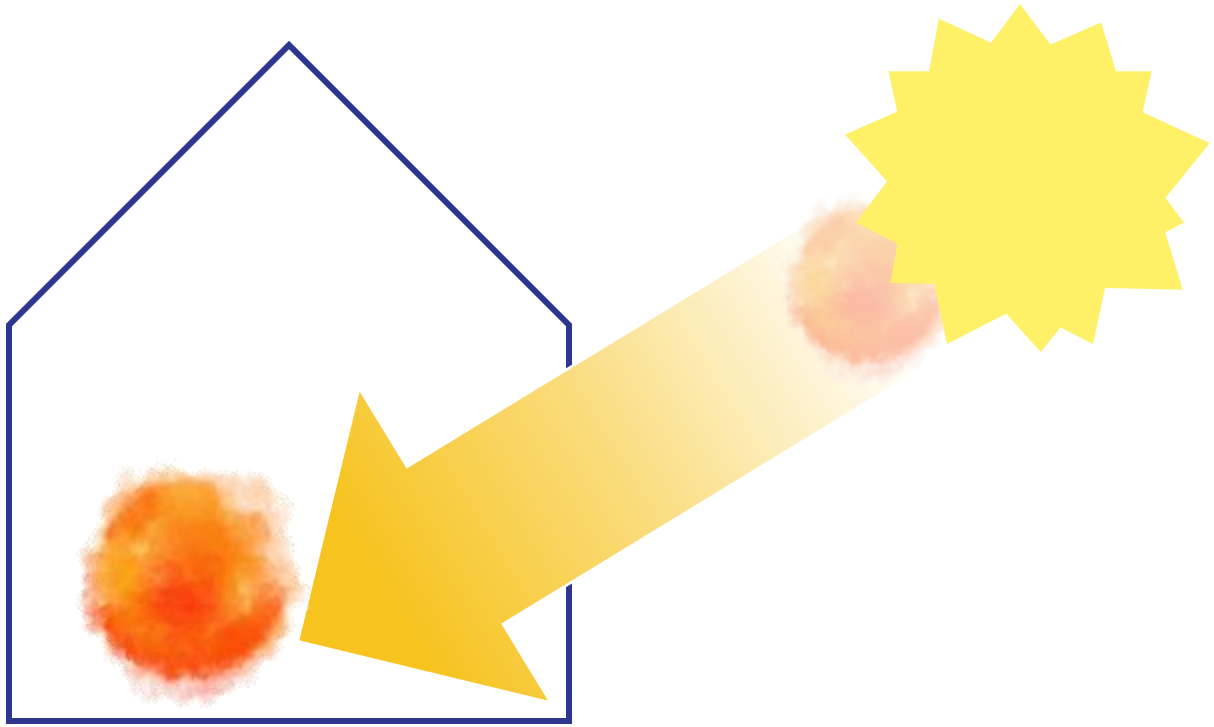
3. Heat Pumps transfer heat from one place to another

Heat pumps (Air Source or Ground Source) move the BTUs from the outside to inside (space heating), or from the inside to outside (space cooling) – and are 300%+ efficient!

Where do BTUs come from ?!?

4.Solar Heat Gain

Passive absorption of solar heat. A quality building envelope helps to keep the heat in.

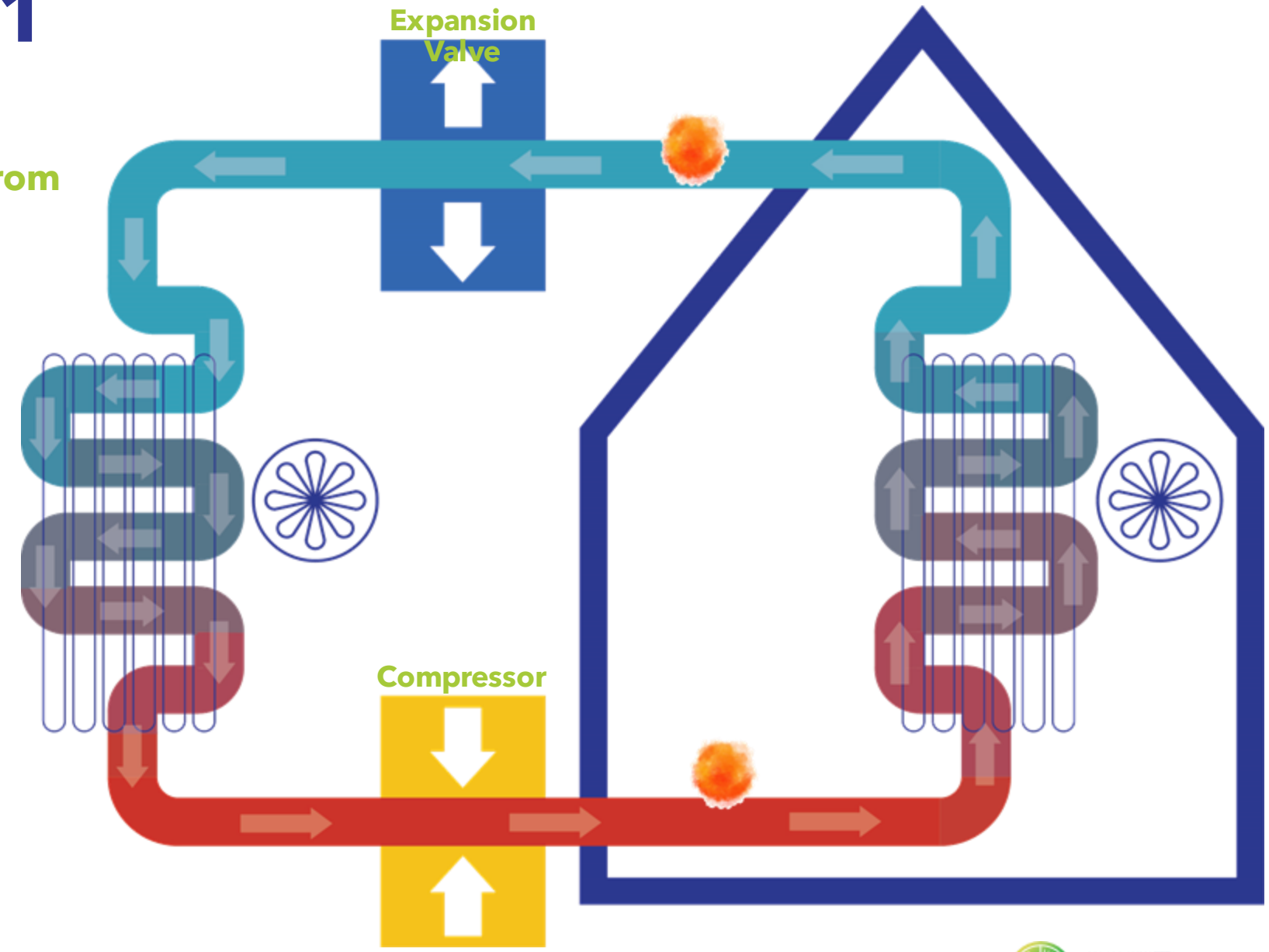


Combustion, resistance, and heat pumps are "active" sources of BTUs while solar gain is "passive" – hence the name "Passive House". Passive House "crushes'" active space heating because solar gains are retained.

Heat Pump 101

It's not about the temperature - it's all about moving the BTUs from inside to outside, or outside to inside.

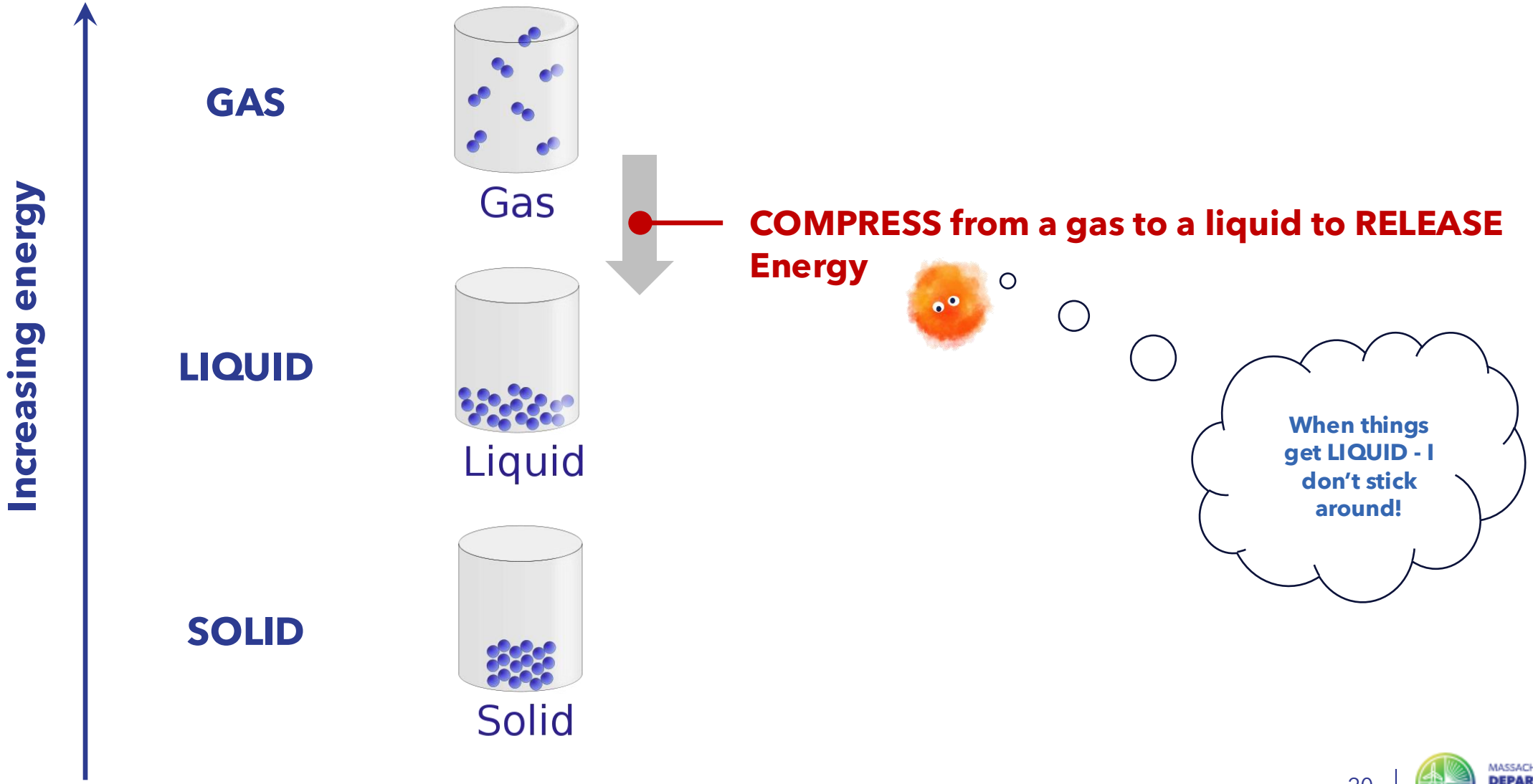
The refrigeration cycle manipulates phase changes to force BTUs to move.



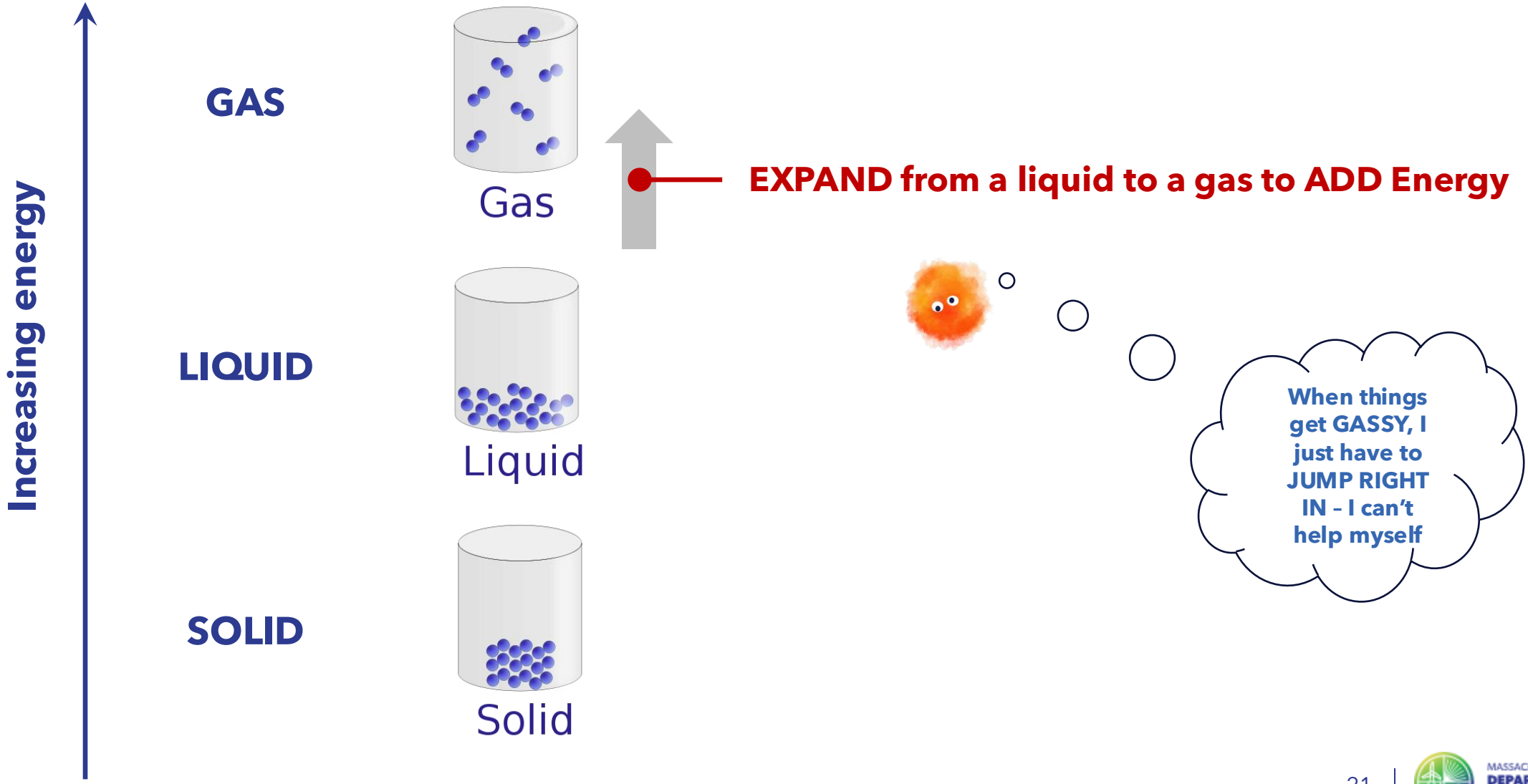
You have a lot of heat pumps in your life

You just didn't know it.....

Bruce enters the refrigerant cycle matrix …….



… to bravely show us how it works ! …..



MASSACHUSETTS DEPARTMENT OF ENERGY RESOURCES

.....Bruce's excellent adventure through a heat pump!.....

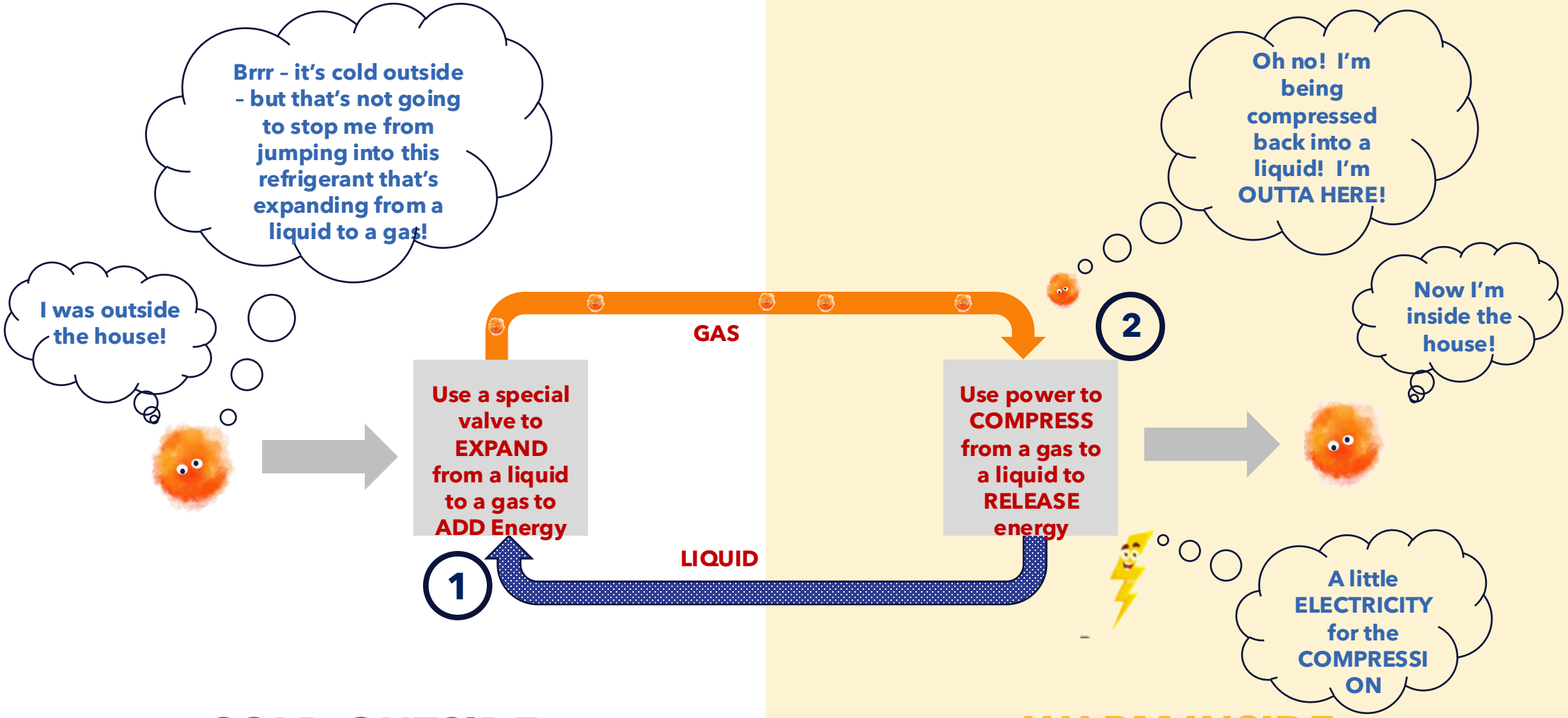


Illustration is simplified, there are several sub-steps not shown

Bruce in the summer!

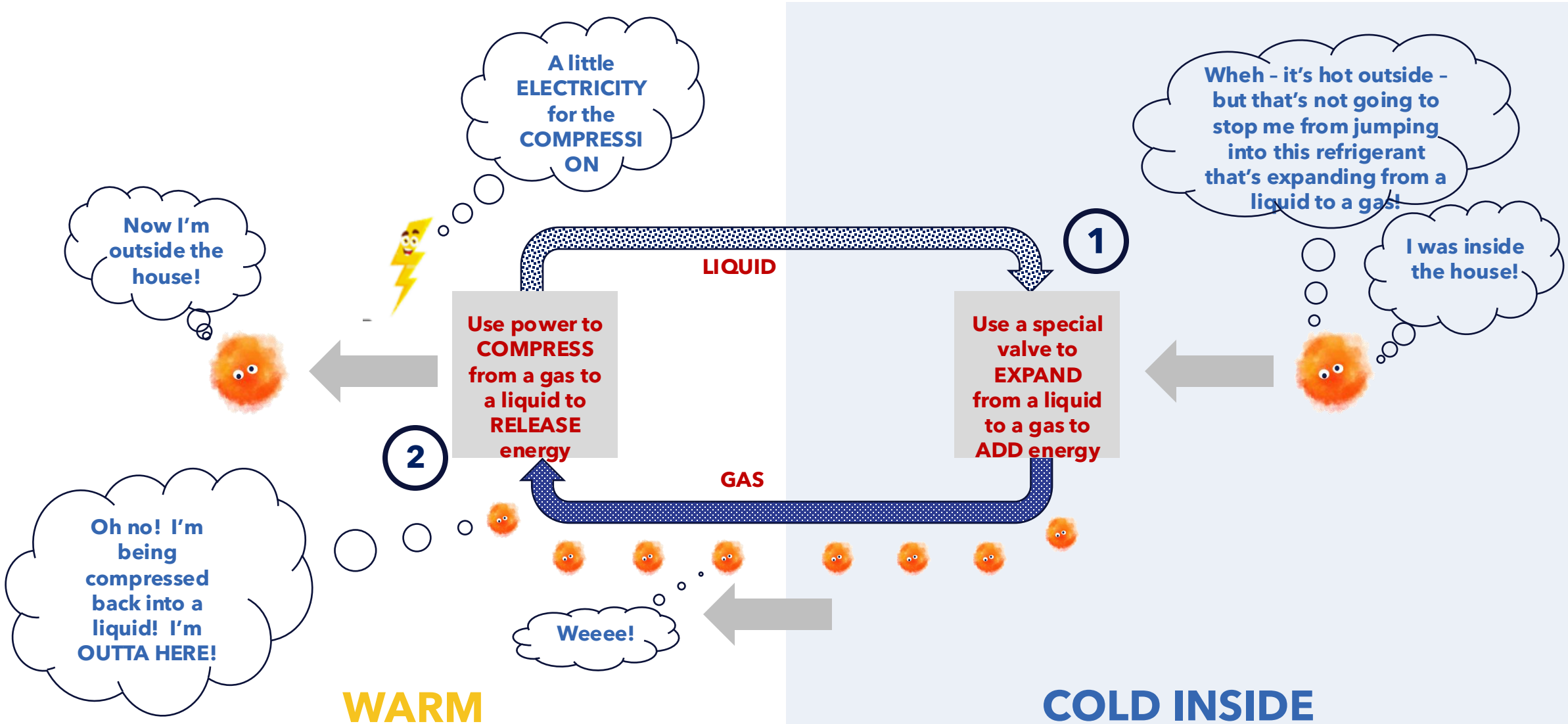


Illustration is simplified, there are several sub-steps not shown

MASSACHUSETTS DEPARTMENT OF ENERGY RESOURCES

And what do heat pumps look like ?

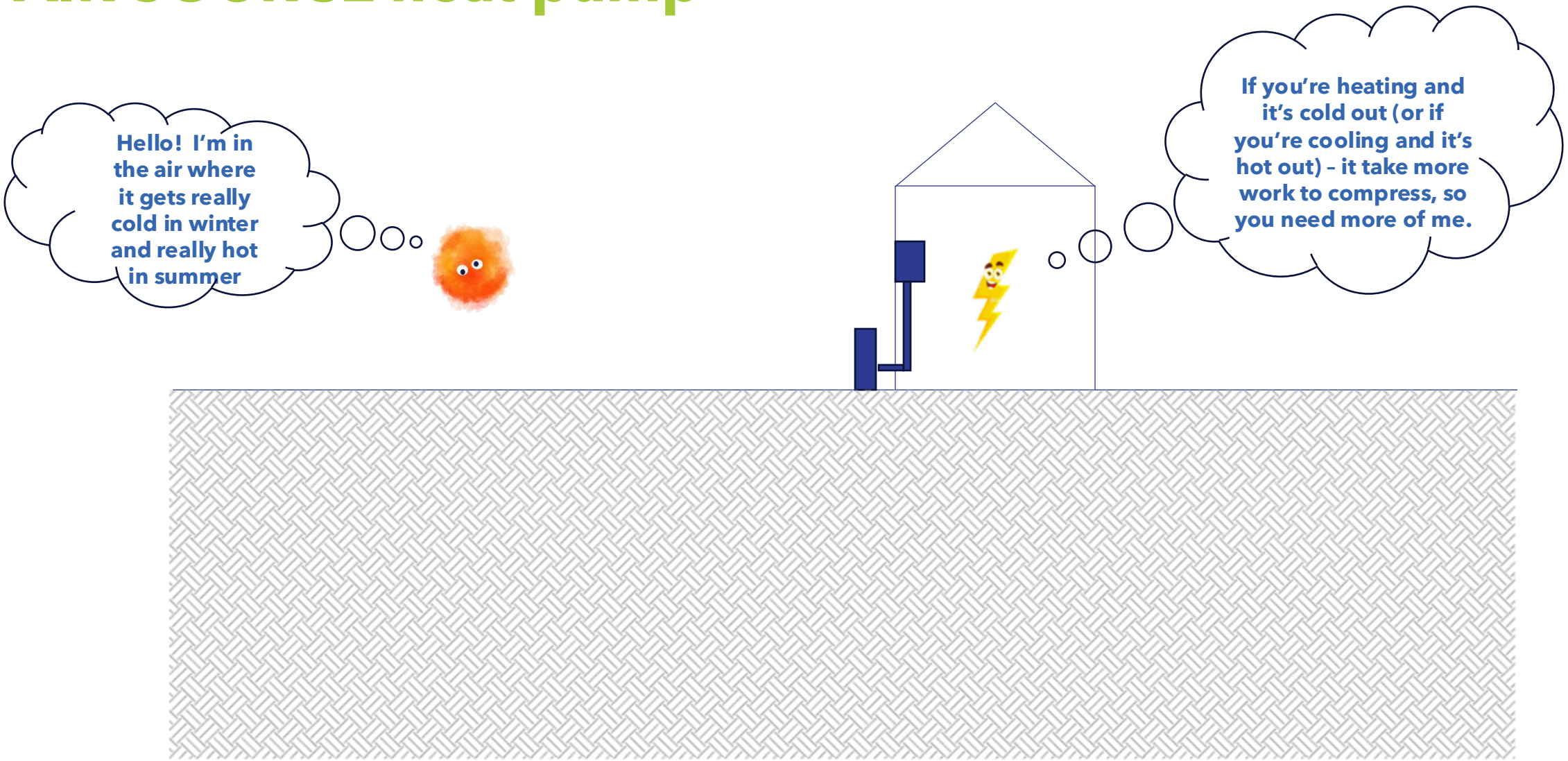
Indoor/outdoor components

Outdoor component on roof

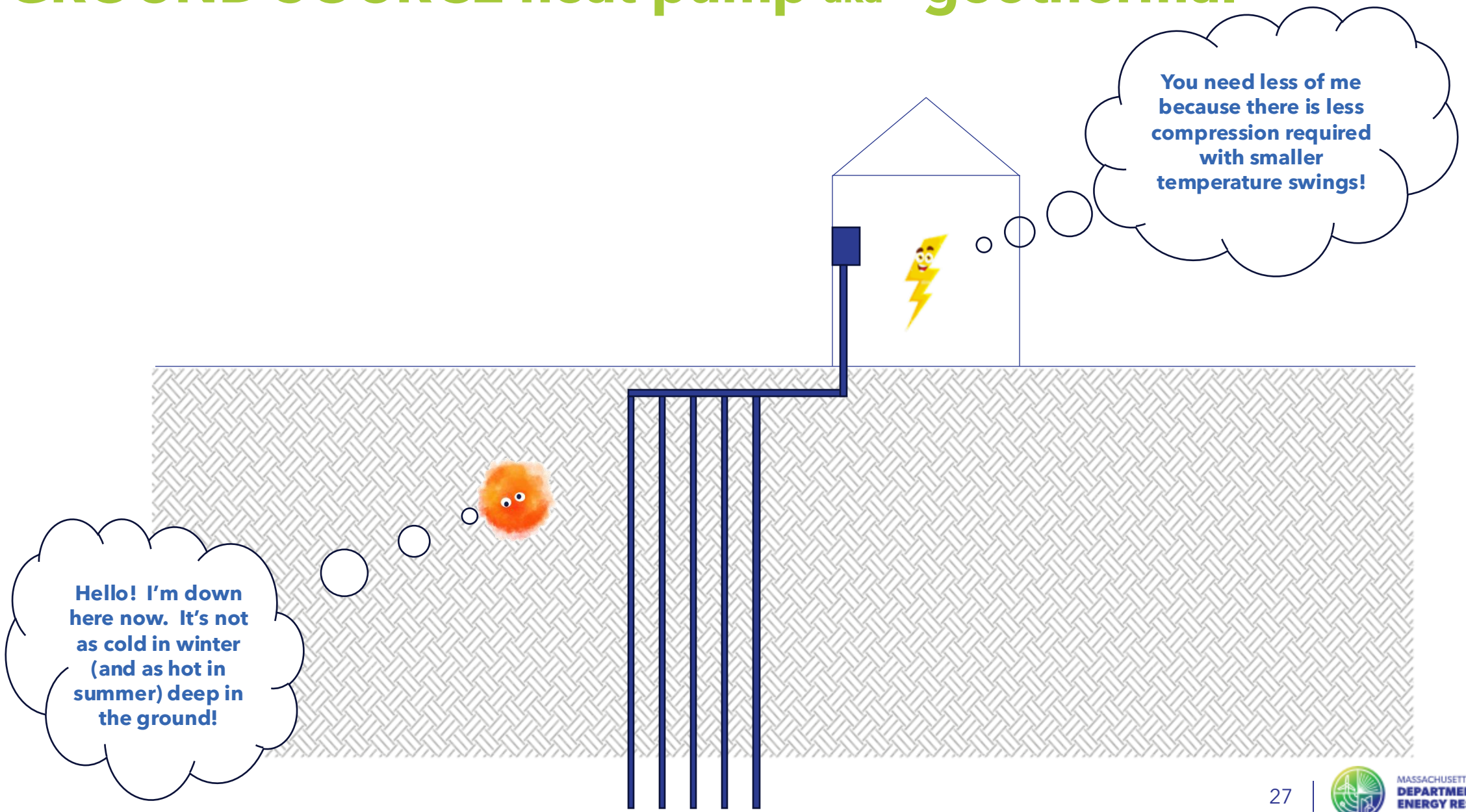
Heat pumps today perform far better than the old school models….
But you still need an insulated and properly sealed building for

If you want them to perform well and efficiently!

AIR SOURCE heat pump



GROUND SOURCE heat pump aka "geothermal"



Now back to the BTU philosophical angst

Where do I come from?

Combustion of fossil fuels

Electric Resistance

Electric Heat Pump (moving)

How do I get there?

Travel by steam

Travel by air (ducted)

Travel by water (hydronic)

Travel by refrigerant (VRF)

Directly!

(distributed or

"ductless heat pumps)

Do I live just one life?

Energy recovery?

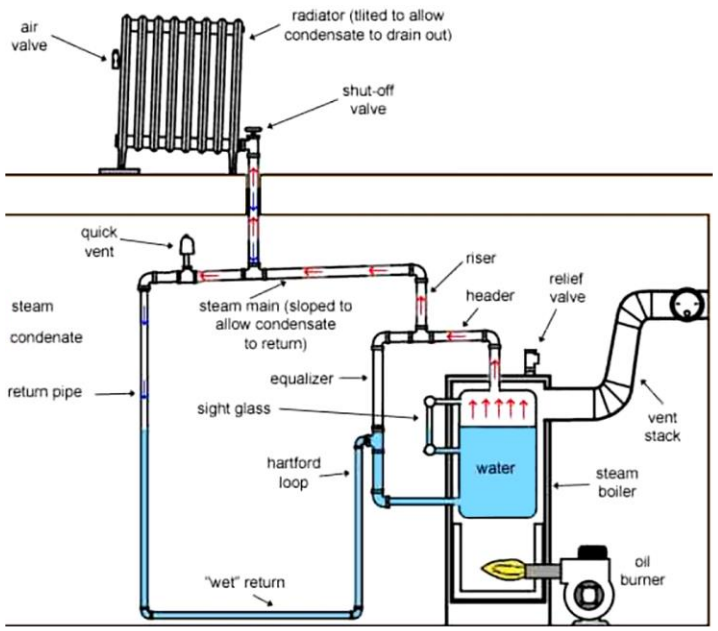
Travel throughout the building by steam

SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

Where do I come from?

Combustion of fossil fuel

How do I get there?



Travel by steam

Credit : Aberdeen Building Consulting

MASSACHUSETTS DEPARTMENT OF ENERGY RESOURCES

Travel throughout the building by air

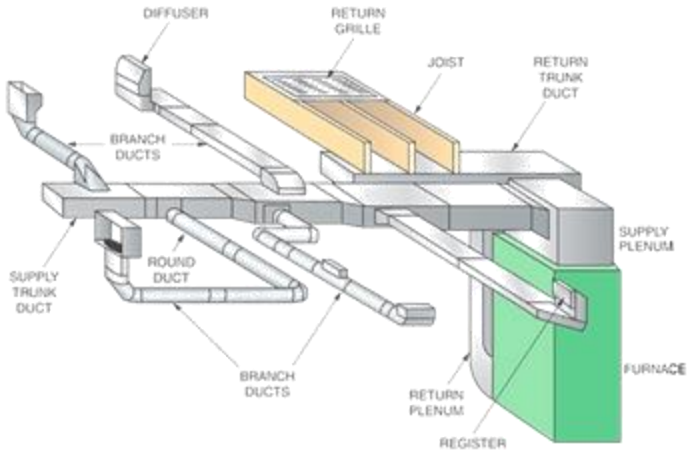
Where do I come from?

Combustion of fossil fuels

Electric Resistance

Electric Heat Pump (moving)

How do I get there?



Travel by air (ducted)

Make the air hot or cold & distribute it throughout the building.

SPACE HEATING AND SPACE COOLING/ DEHUMIDIFICATION

Travel throughout the building by water

SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

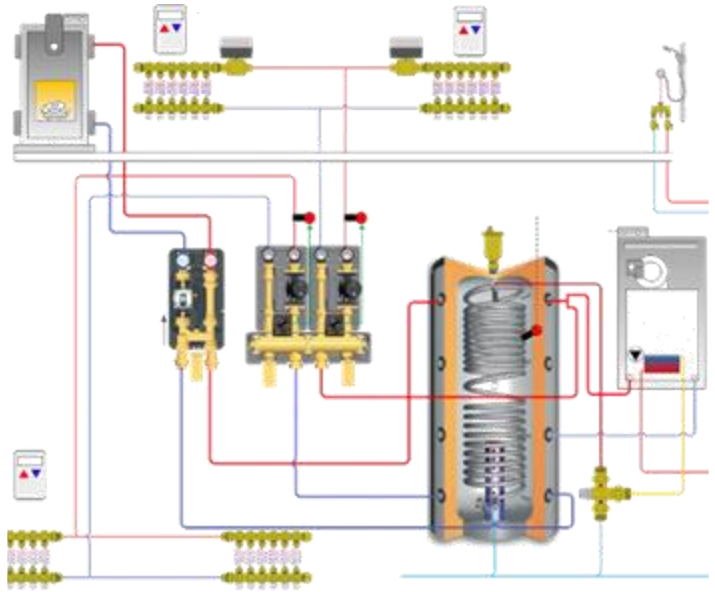
Where do I come from?

Combustion of fossil fuels

Electric Resistance

Electric Heat Pump (moving)

How do I get there?



Travel by water (hydronic)

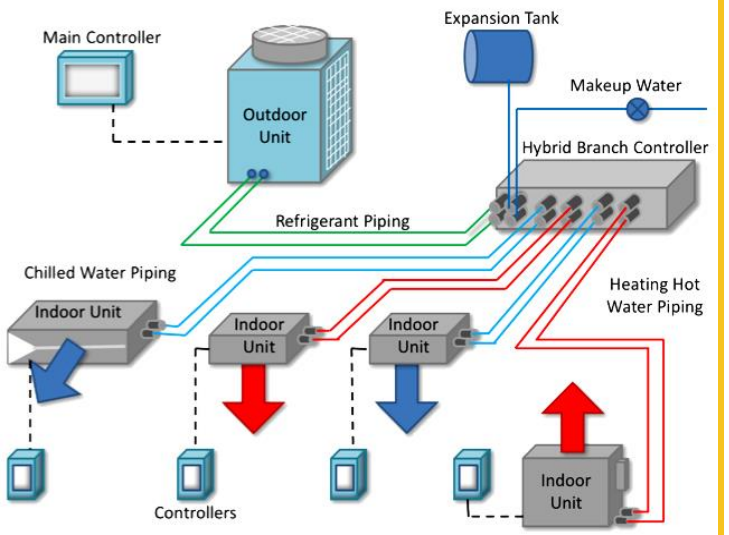
Travel throughout the building by refrigerant

SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

Where do I come from?

Electric Heat Pump (moving)

How do I get there?



Travel by refrigerant (VRF)

Direct (or “ductless”)

SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

Where do I come from?

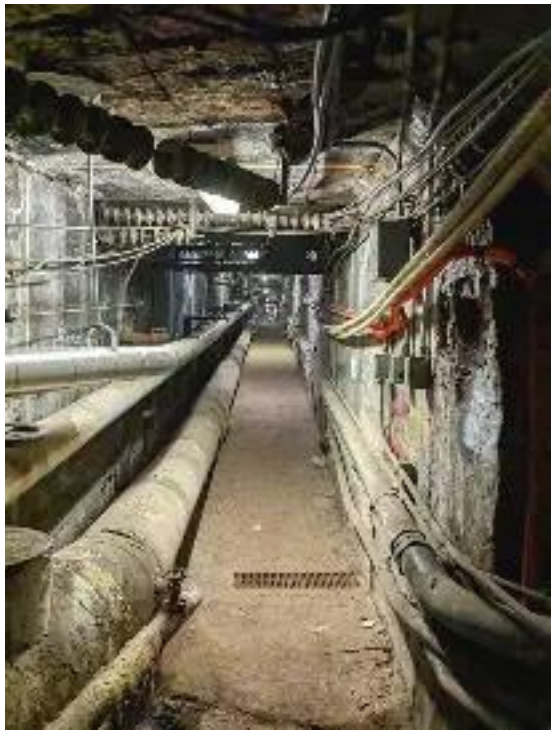
Electric Heat Pump (moving)

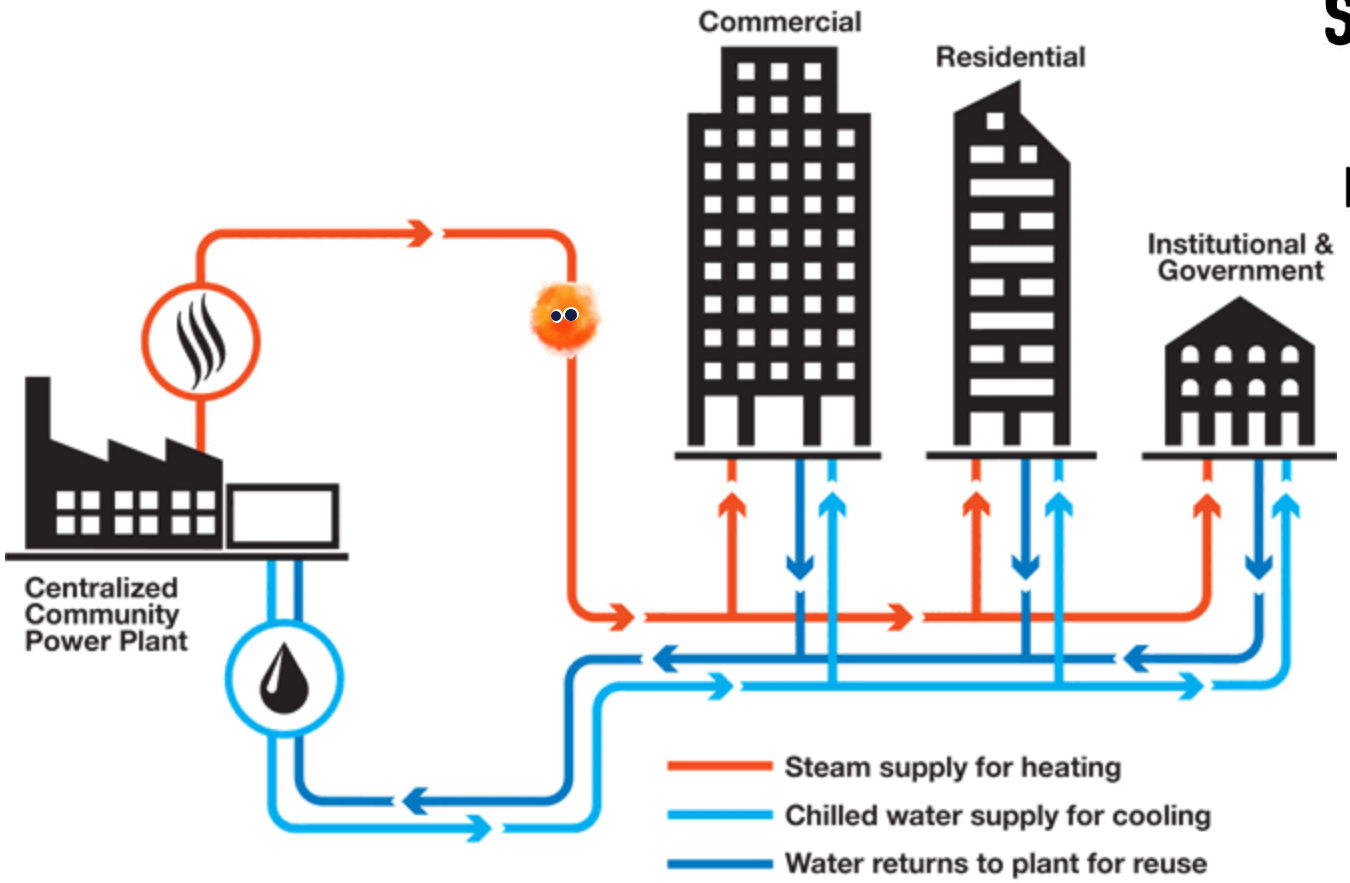
How do I get there?

Ductless heat pumps

District Energy Systems – what is it?

1. Centrally made hot (water or steam) or cold (water)
2. Distributed to multiple buildings through pipes





Credit: Emerald Built Environment

SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

Back again to the BTU philosophical angst

Where do I come from?

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Electric Heat Pump (moving)

How do I get there?

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Directly!

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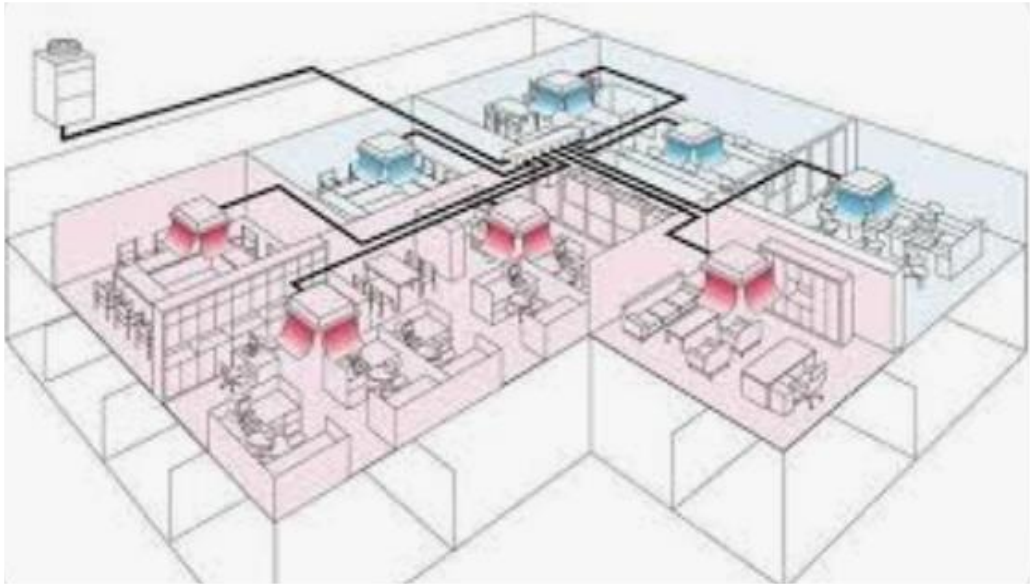
Do I live just one life?

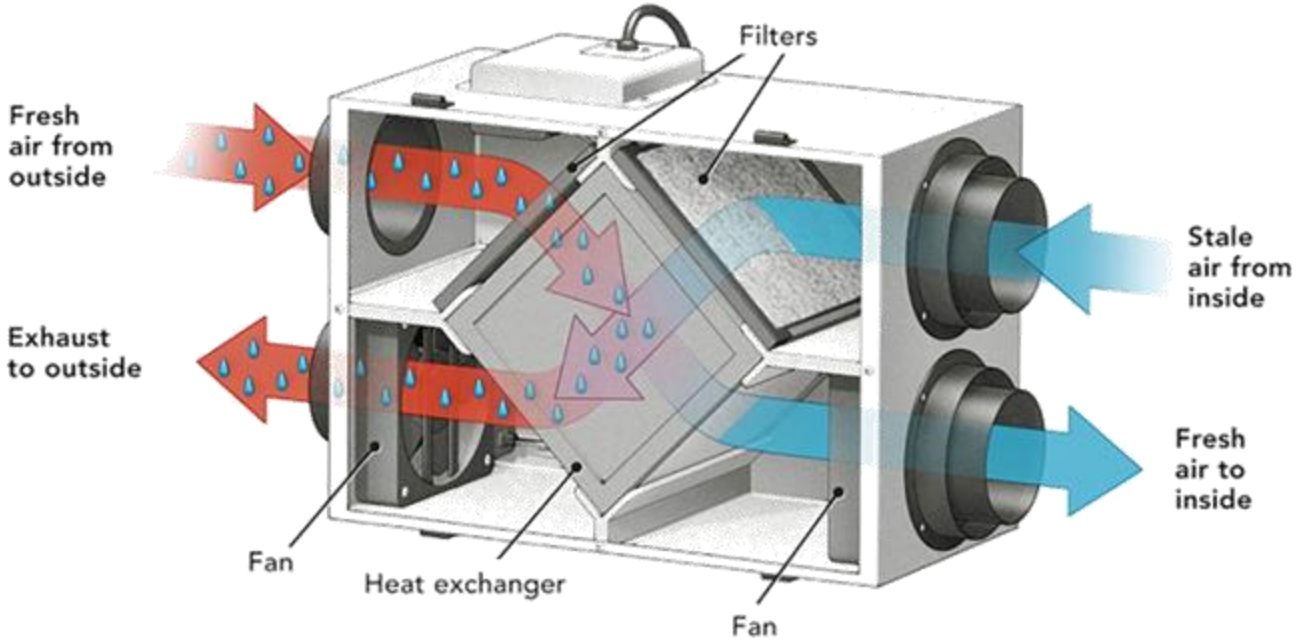
Energy recovery?

Energy Recovery– what is it?

Two ways to do heat recovery



When water or refrigerant is used to distribute the BTU – there can be energy recovery of concurrent heating and cooling



If there is balanced ventilation (more below!) – there can be energy recovery of ventilation air

Ventilation 0.0

Ventilating through walls, ceilings, chimneys, cracks, gaps

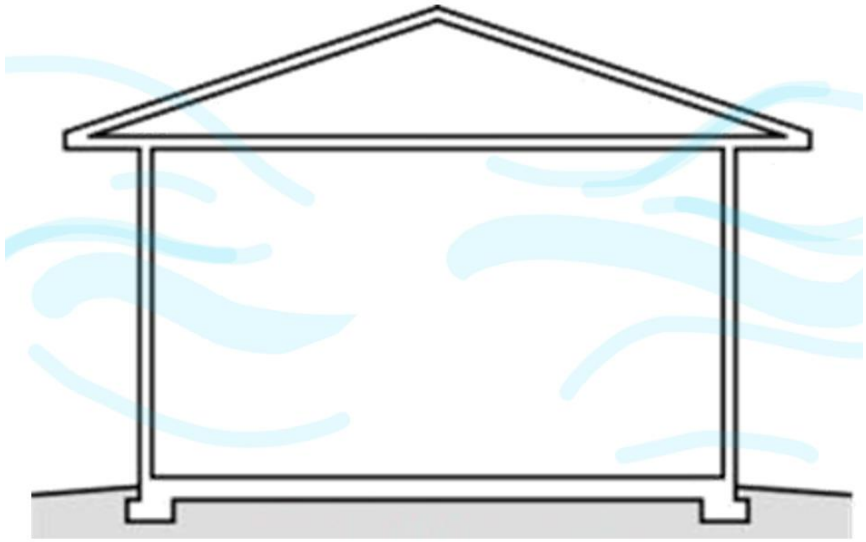
Some older buildings have no official ventilation system!

Once buildings were intentionally built to be leaky - stale indoor air was the culprit of maladies.

Look out for the mouse poo !

Ventilation 0.0b

No intentional exhaust – just leaks



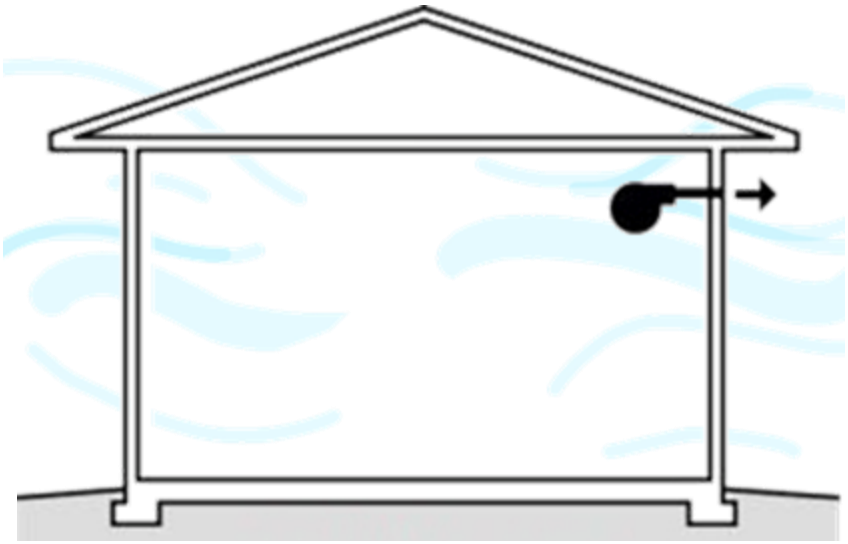
VENTILATION

Ventilation 1.0

Bath and kitchen exhaust only, in one direction

State of practice circa 1989

(The other state of practice in 1989: mullets and "big hair", though mullets are making a comeback….)

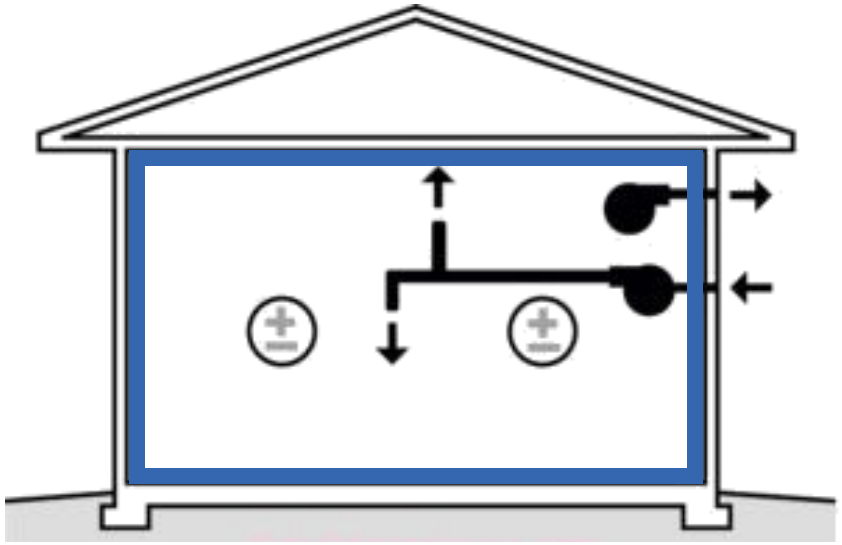


Credit: Building Science Corp

Ventilation 2.0 – Balanced Ventilation

Why does it matter?

- Airtight buildings need to control fresh air
- Filtration improves Indoor Air Quality
- Thermal comfort
- Equal Supply and Exhaust
- Heat and Moisture Recovery



Credit: Building Science Corp

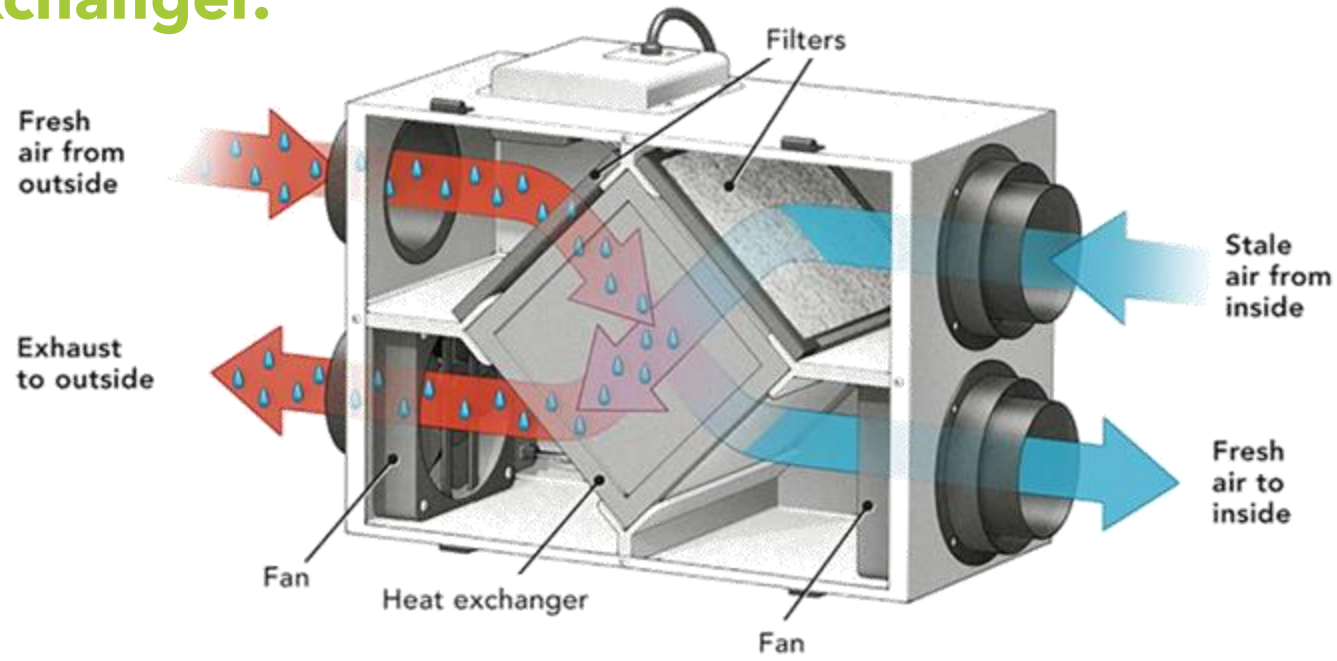
VENTILATION

Ventilation 3.0 – Balanced w/ Ventilation Energy Recovery

How does it work?

Two air streams, supply air and exhaust air pass through the core heat exchanger.

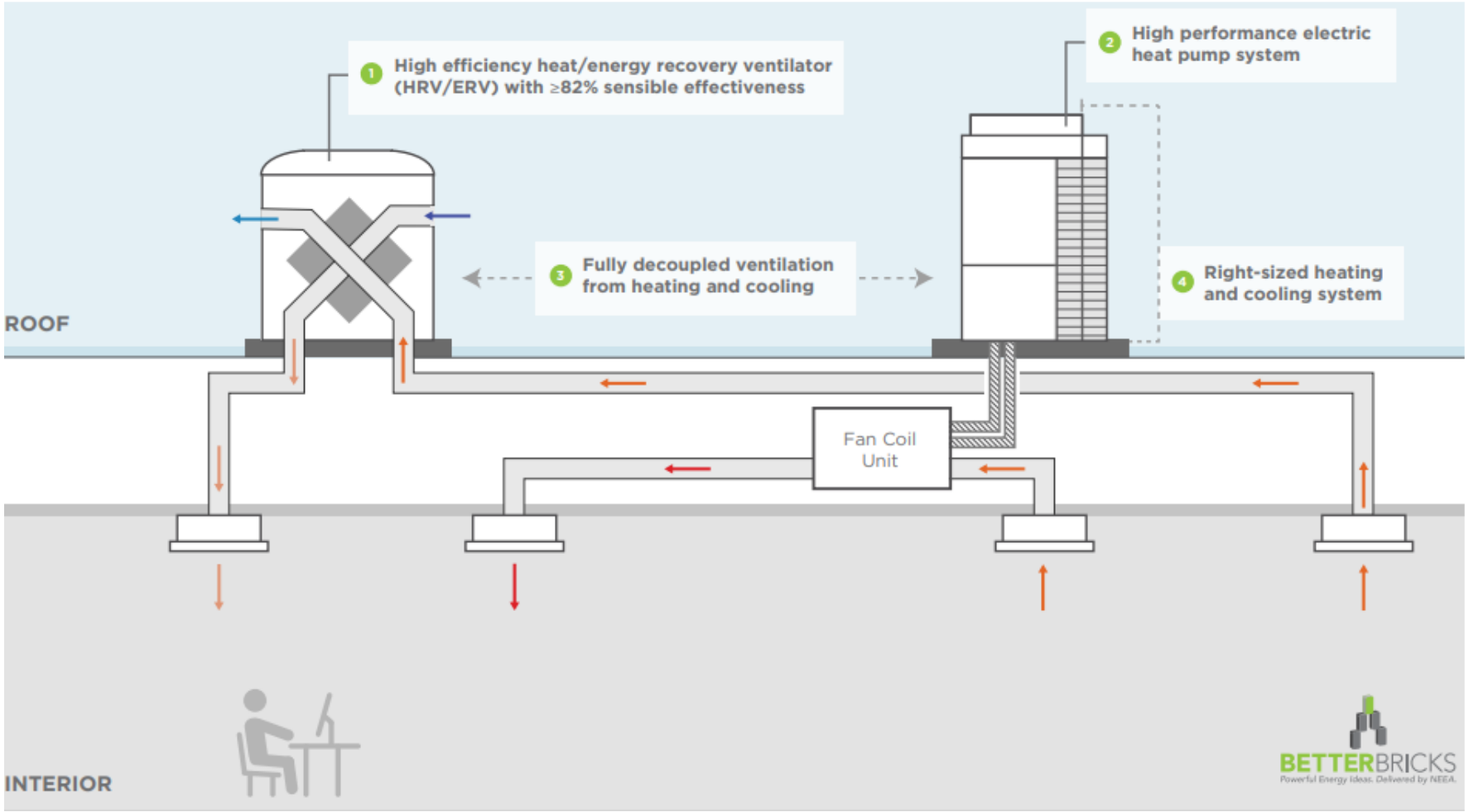
VENTILATION



Credit: David Ponschok

Dedicated Outside Air System

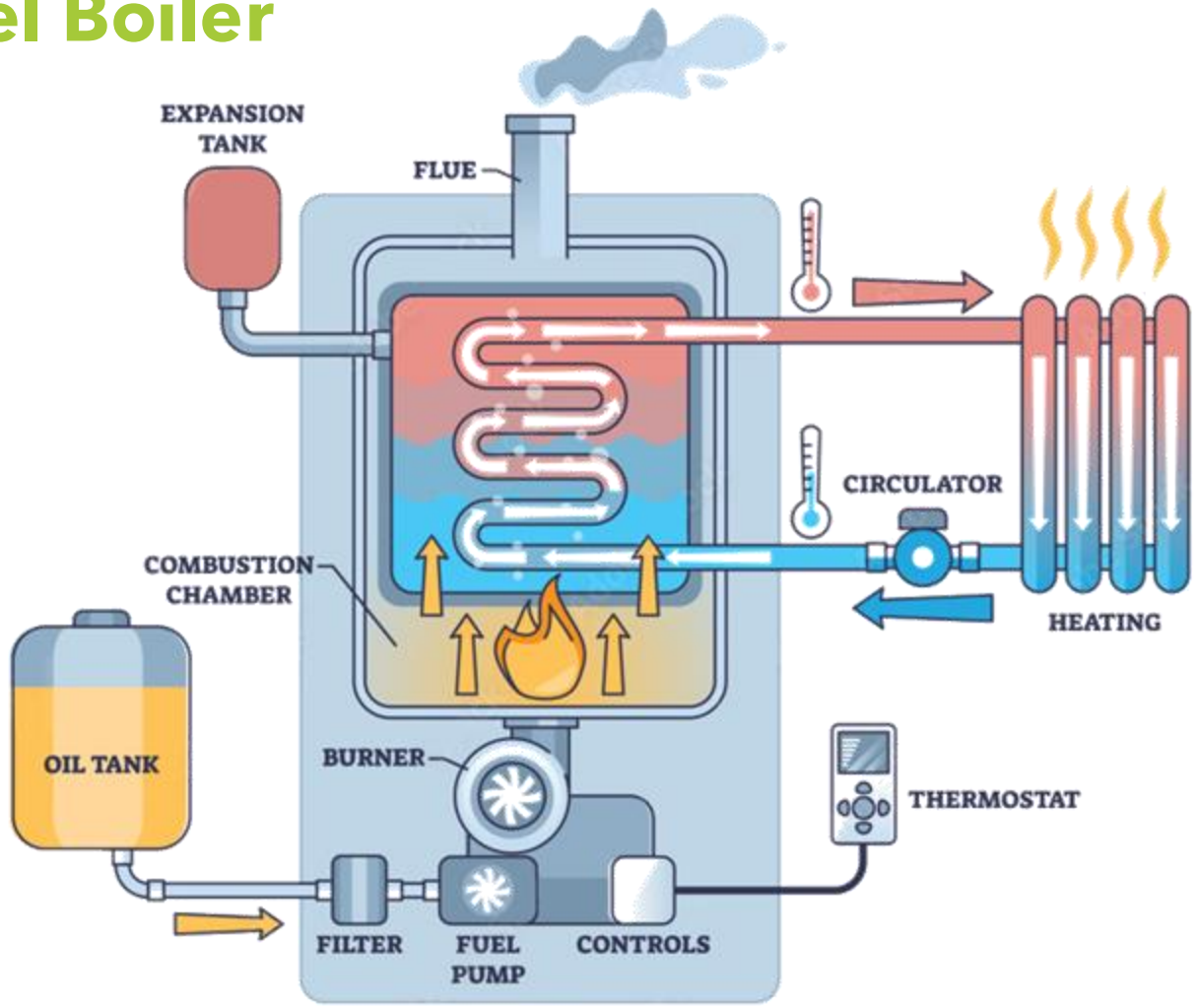
Approach that separates ventilation from heating and cooling system.



VENTILATION

How are BTUs added to the water?

1. Fossil Fuel Boiler



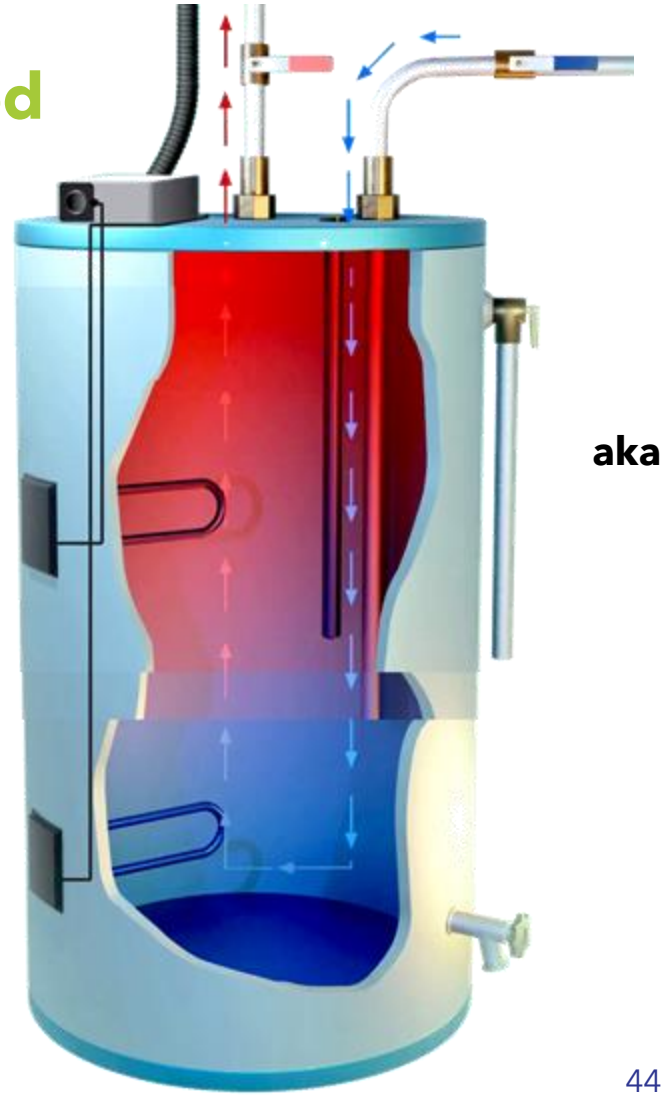
DOMESTIC WATER HEATING

aka **Service Water**

How are BTUs added to the water?

3. Electric Resistance Boiler

Electricity heats up an element immersed in the water, directly heating the water to the desired temperature. The heated water is typically stored in an insulated holding tank.



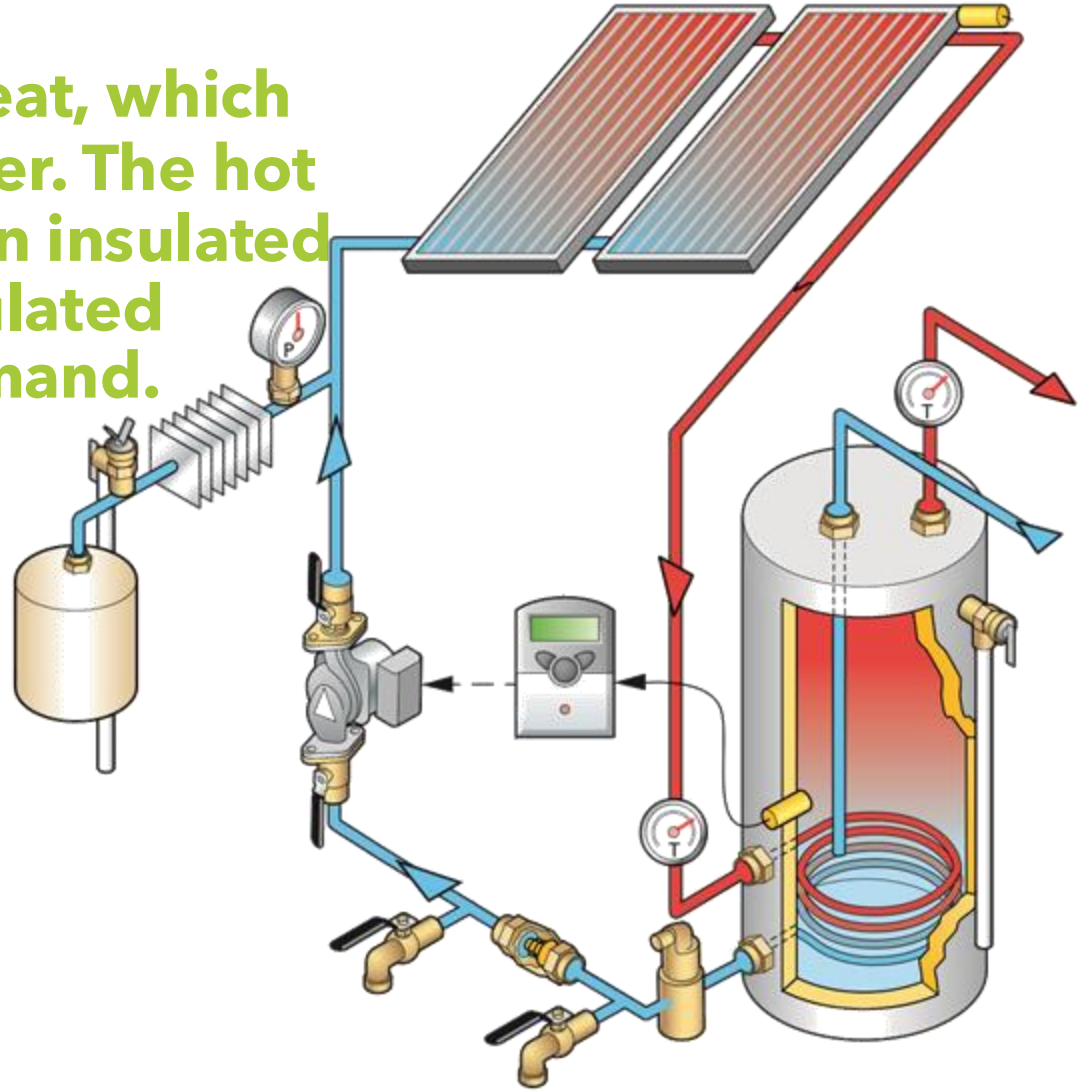
DOMESTIC WATER HEATING

aka **Service Water**

How are BTUs added to the water?

3. Solar Thermal

Solar tubes capture heat, which then heats up the water. The hot water is collected in an insulated storage tank and circulated in the building on demand.



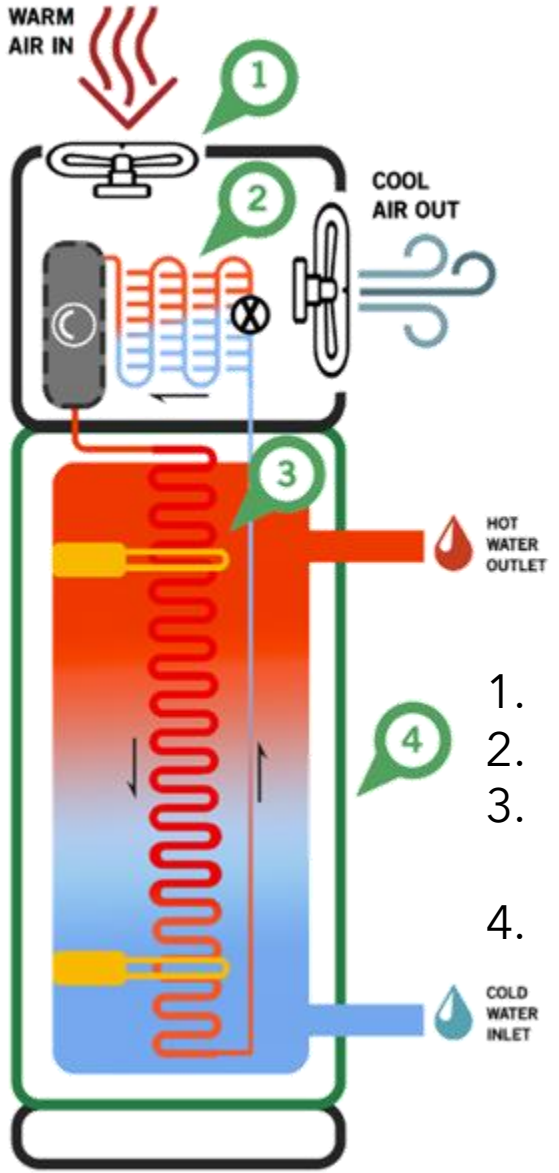
DOMESTIC WATER HEATING

aka **Service Water**

How are BTUs added to the water?

4.Heat Pumps

- Move heat from the surrounding air to heat water
- 3X more efficient than the Electric Resistance Water Heaters



1. Evaporator
2. Compressor
3. Condenser Coils
4. Cool down

DOMESTIC WATER HEATING

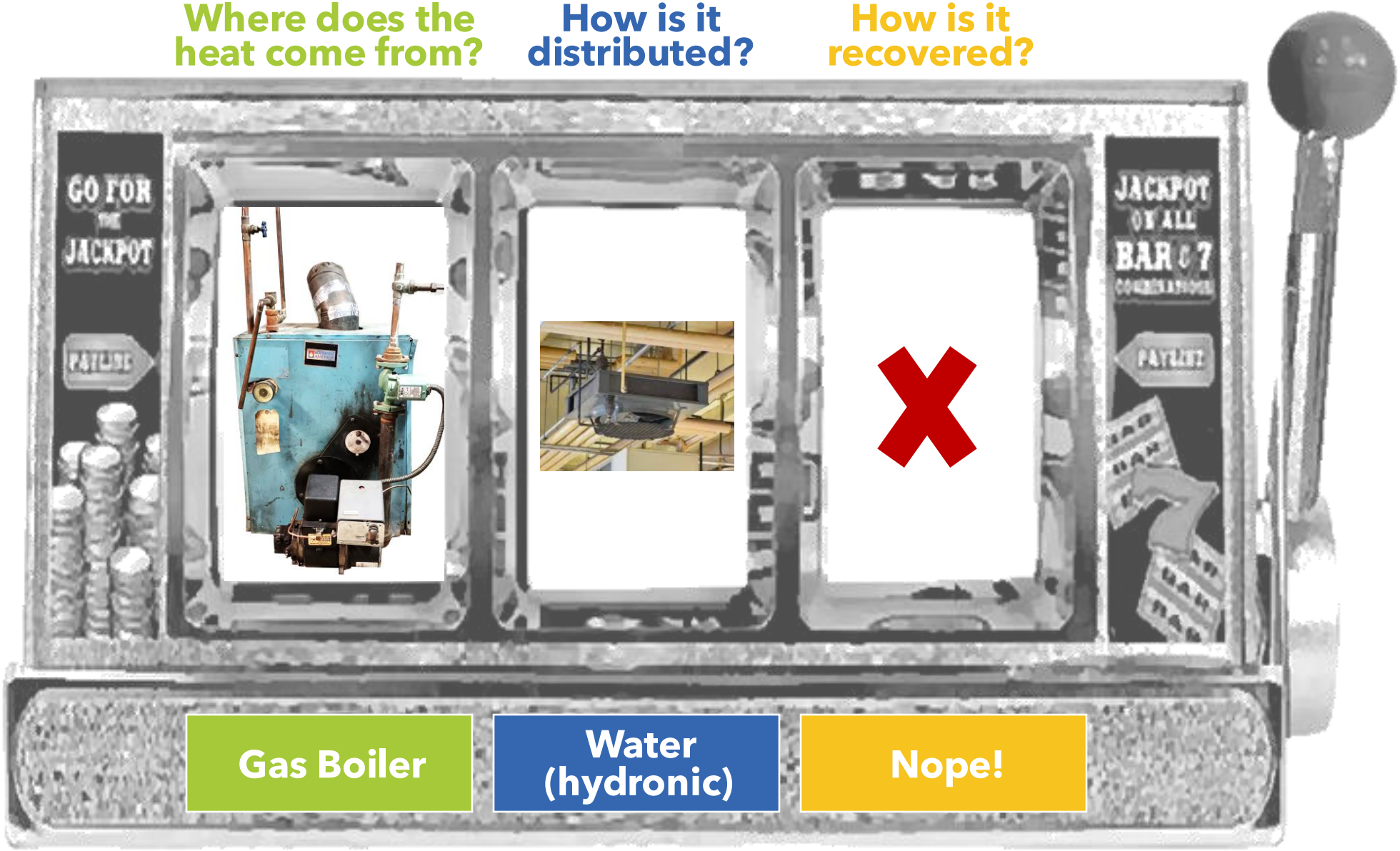
aka **Service Water**

Who's ready to play ?!?

Where does the heat come from?

How is it distributed?

How is it recovered?



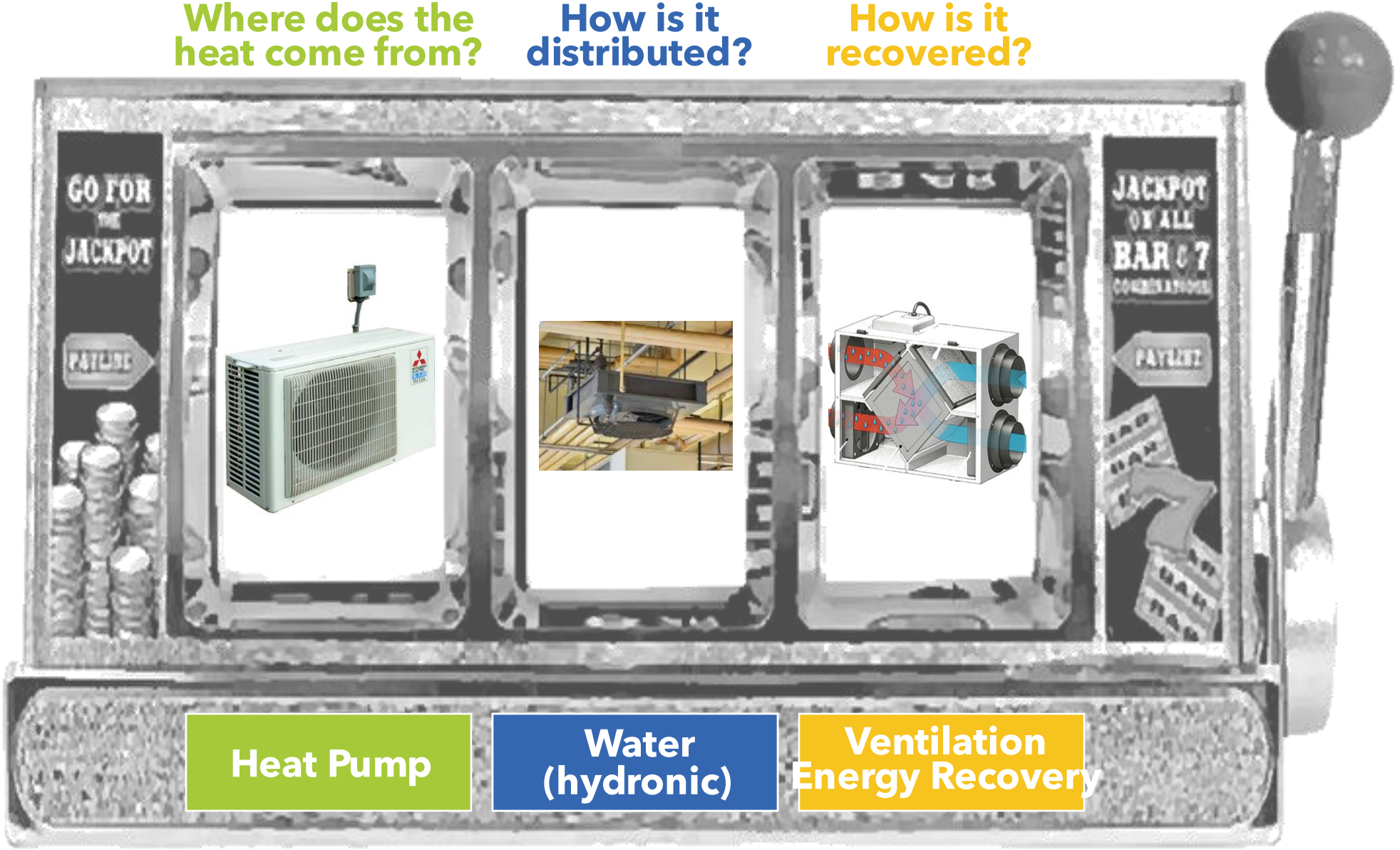
SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

OLD SCHOOL
TOWN HALL
OPTION 1

Where does the heat come from?

How is it distributed?

How is it recovered?



Heat Pump

Water (hydronic)

Ventilation Energy Recovery

VENTILATION

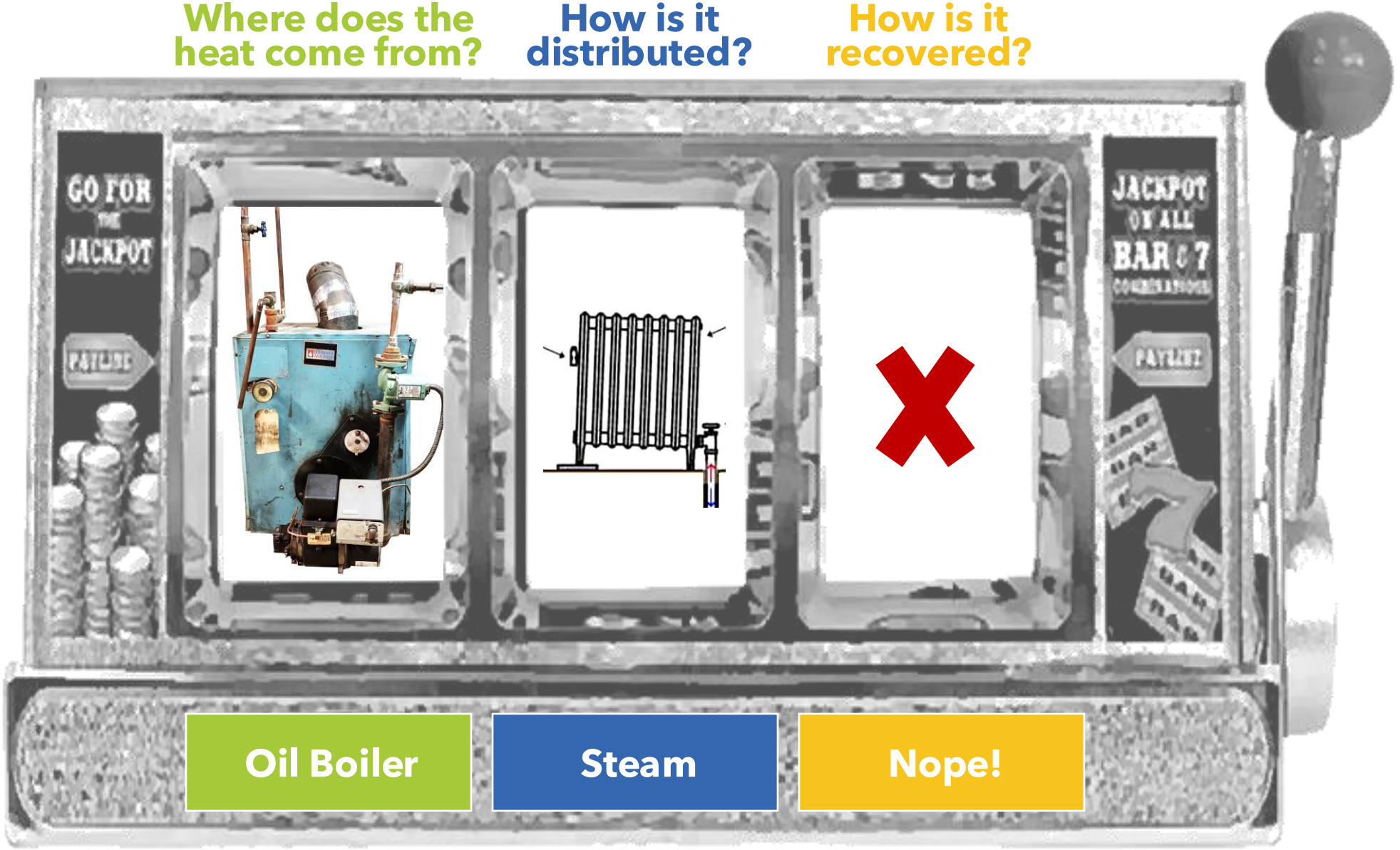
SPACE HEATING AND SPACE COOLING/ DEHUMIDIFICATION

MODERN TOWN HALL OPTION 1

Where does the heat come from?

How is it distributed?

How is it recovered?



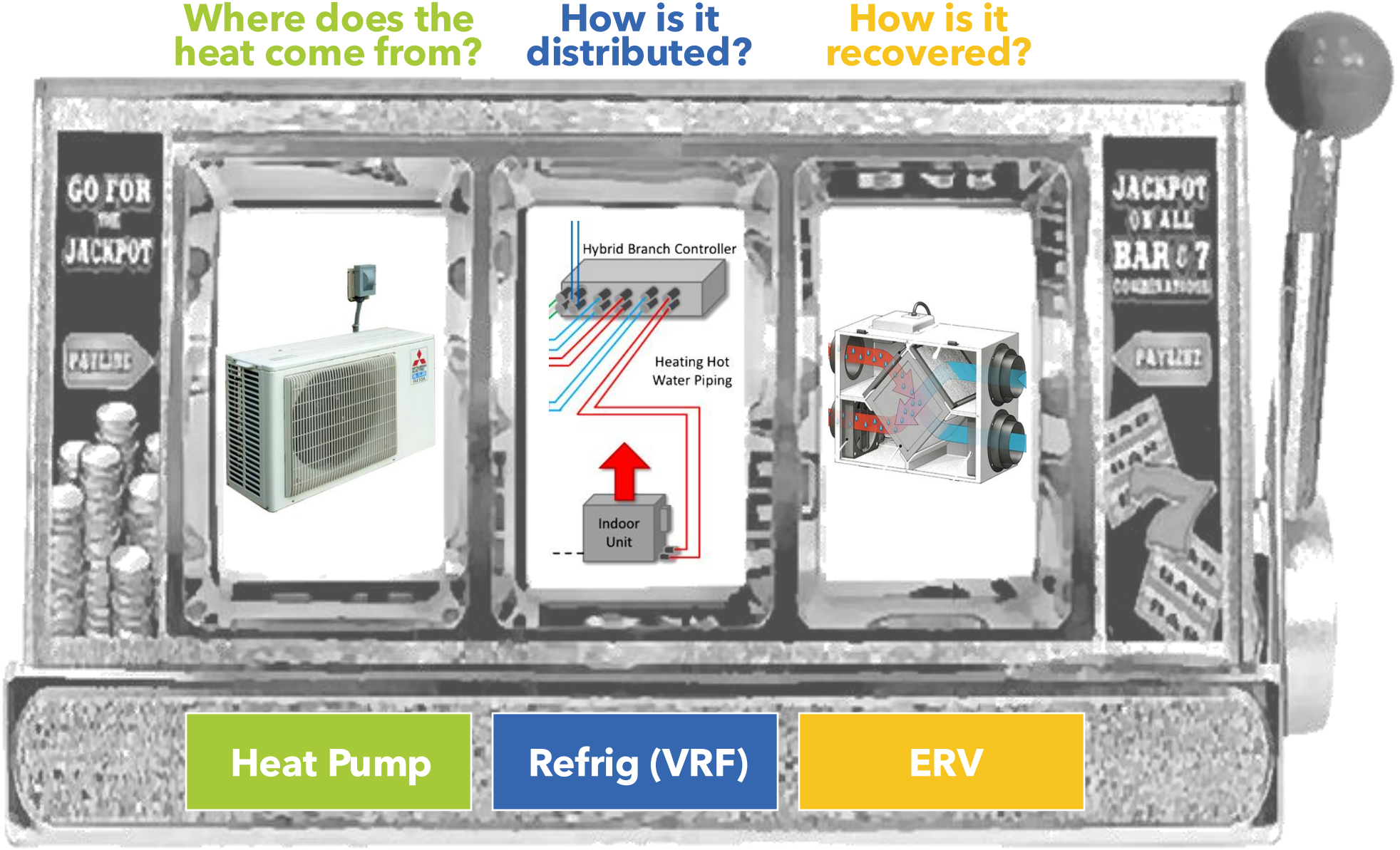
SPACE HEATING
AND
SPACE COOLING/
DEHUMIDIFICATION

OLD SCHOOL TOWN HALL OPTION 2

Where does the heat come from?

How is it distributed?

How is it recovered?



VENTILATION

SPACE HEATING AND SPACE COOLING/ DEHUMIDIFICATION

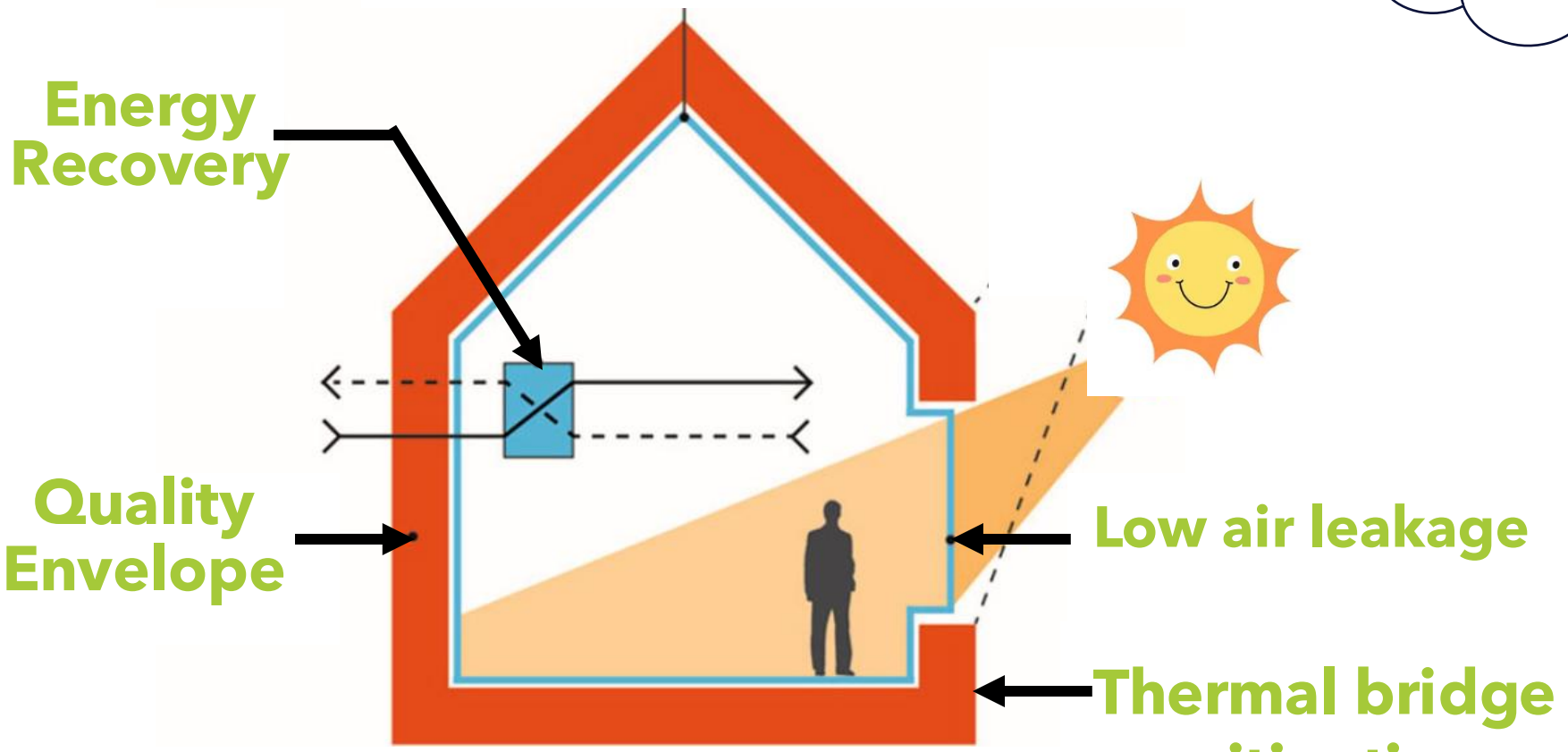
MODERN TOWN HALL OPTION 2

MASSACHUSETTS DEPARTMENT OF ENERGY RESOURCES

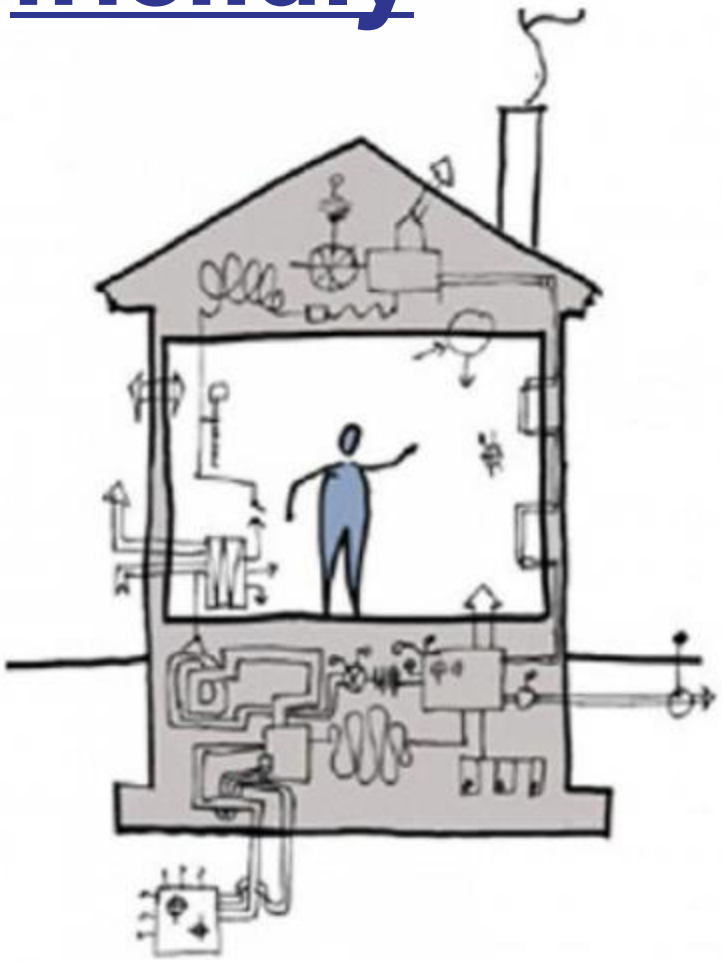
One final philosophical point of angst for Bruce….

How long do I have?

Thermal code – the 4 pillars



Thermal Code – Simpler HVAC and grid friendly



Poor envelope/no ERV
HVAC to "forgive all sins"

Quality envelope + ERV
Very simple HVAC

Less HVAC
Less cost
Lower Maintenance
More reliable
Grid friendly

Fairweather Apartments, Salem, during a panel installation demonstration, prior to starting construction.

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DEPARTMENT OF
ENERGY RESOURCES

Thank You!

Municipal Energy and Sustainability Managers ACADEMY

Questions?

Next Steps

- Please take 3-5 mins to please complete the anonymous evaluation form (link in chat)

Upcoming Events:

- **Optional Office Hour** | 12/03 (1-2pm)
- **Building Decarbonization & Energy Efficiency Strategies for Municipal Buildings** |12/16 (10-11:30am)
- **Peer Learning Network Meeting** | 12/17 (3pm)

Municipal Energy and Sustainability Managers ACADEMY

Thank you!