The Future of Energy at Wesleyan:

Energy Infrastructure Modernization & Our Plan to Achieve Carbon Neutrality

WESLEYAN UNIVERSITY

PHYSICAL PLANT

2024 UPDATE

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The Wesleyan University Campus

- Located in Middletown, CT – Established 1831
- Total of 300+ buildings, totaling 3.2M sf owned by the University on 360 acres
- “Core Campus” comprises 39 buildings with a total area of approximately 1.6M sf
- All core campus facilities fed by campus steam (60 psi) and medium voltage (13.2 kV) distribution system
- Approximately 60% of core campus buildings served by campus chilled water plant
- All facilities outside of core campus served by a variety of local systems

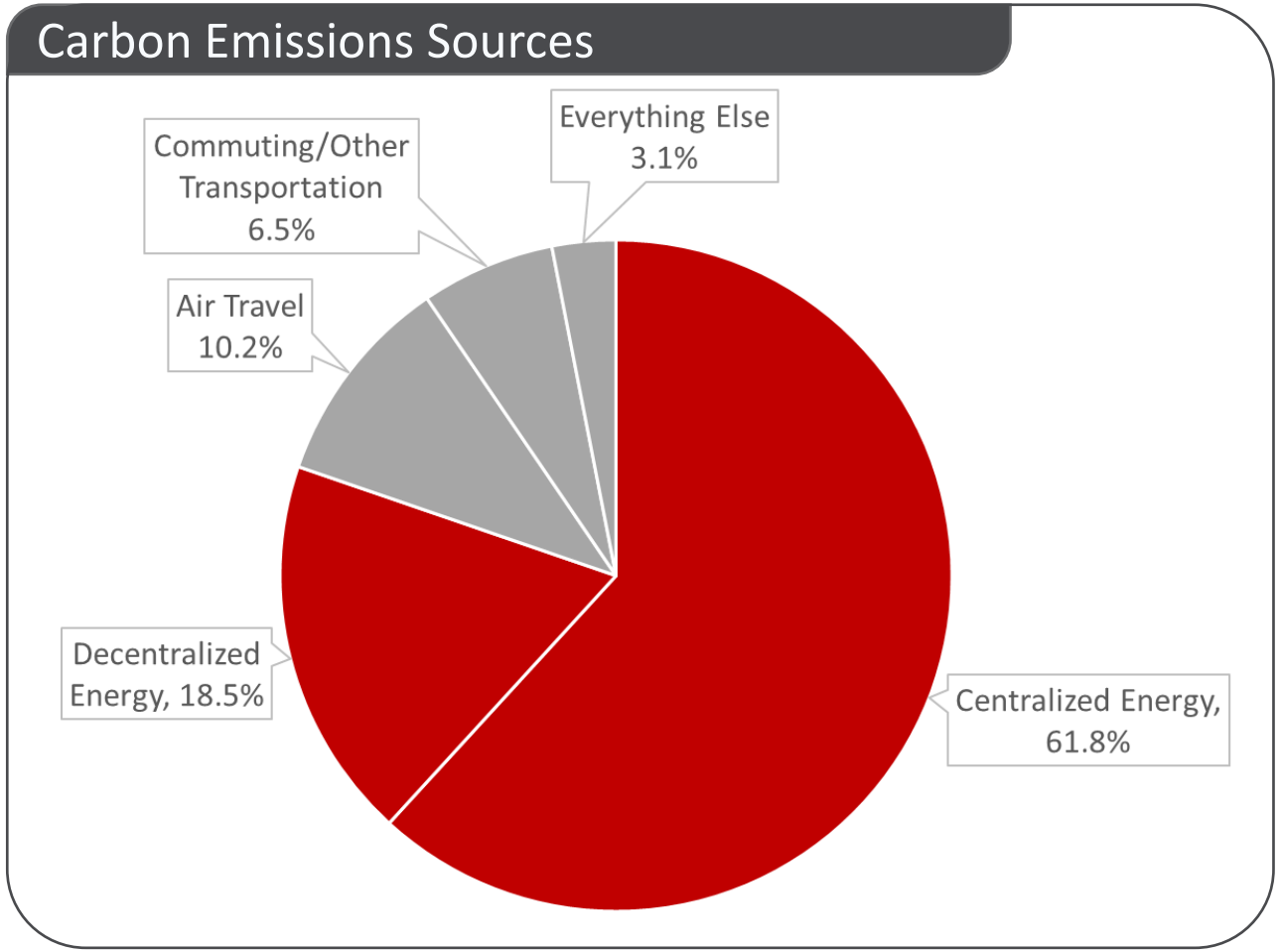
Middletown, CT

Background and Motivation: Carbon Goals

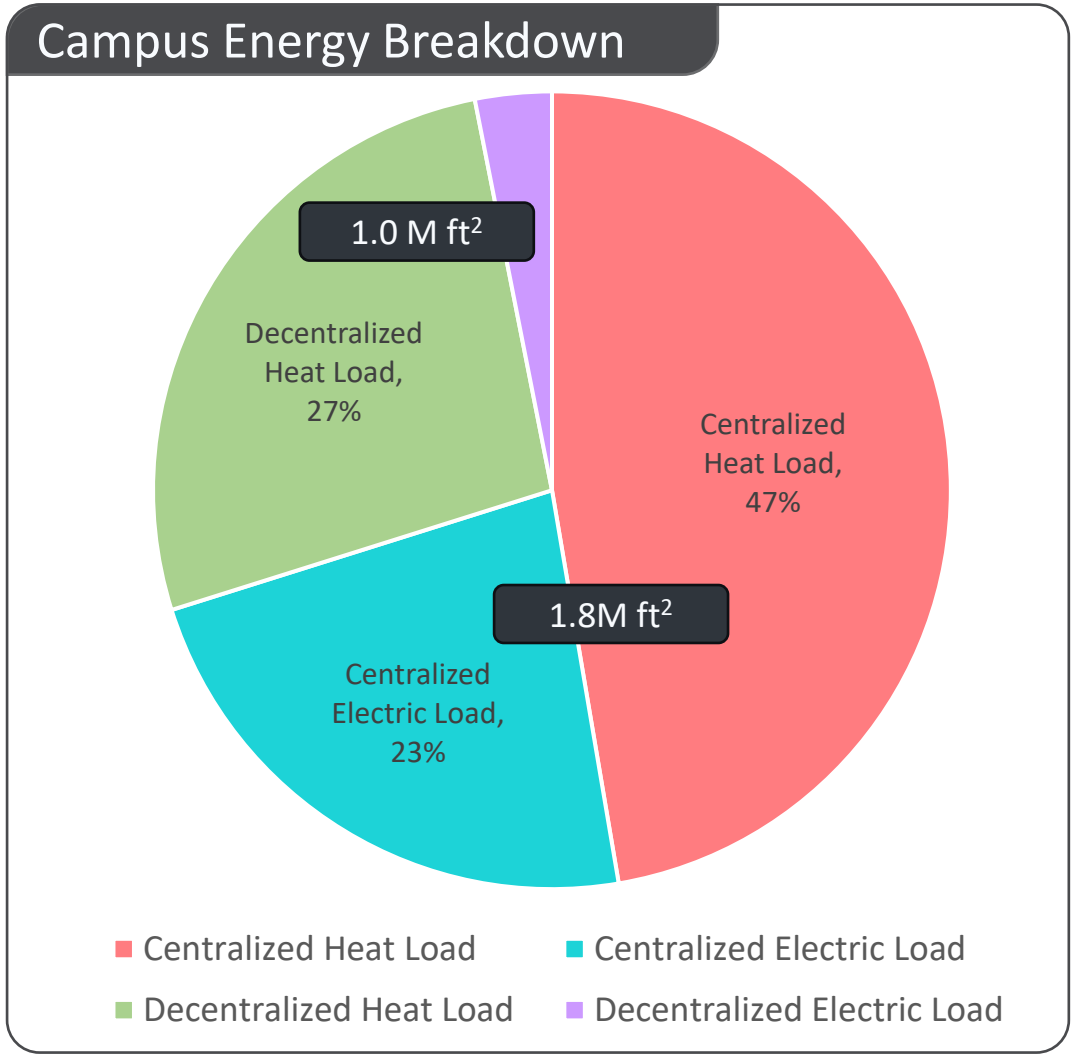
1. **Dramatically reduce fossil fuel usage in campus buildings by 2035**
2. Offset emissions from all Wesleyan employee business and study abroad air travel by 2030
3. Convert 50% of light-duty vehicles in the campus fleet to electric by 2025
4. Encourage decrease in personal use of single-occupancy and fossil-fuel-powered vehicles by employees and students
5. Offset remaining greenhouse gas emissions by 2035
6. Divest from fossil fuels by 2035 and increase investments in renewable energy and climate change solutions

Background and Motivation: Carbon Sources

- Our total Carbon Footprint is ~21,000 MTCDE
- At 80%, The largest source of carbon emissions on campus comes from energy
- Air travel (including business & study abroad travel) accounts for 10% of our carbon footprint
- Commuting, Fleet Vehicles, and everything else accounts for < 10%



Background and Motivation: Fossil Fuel on Campus



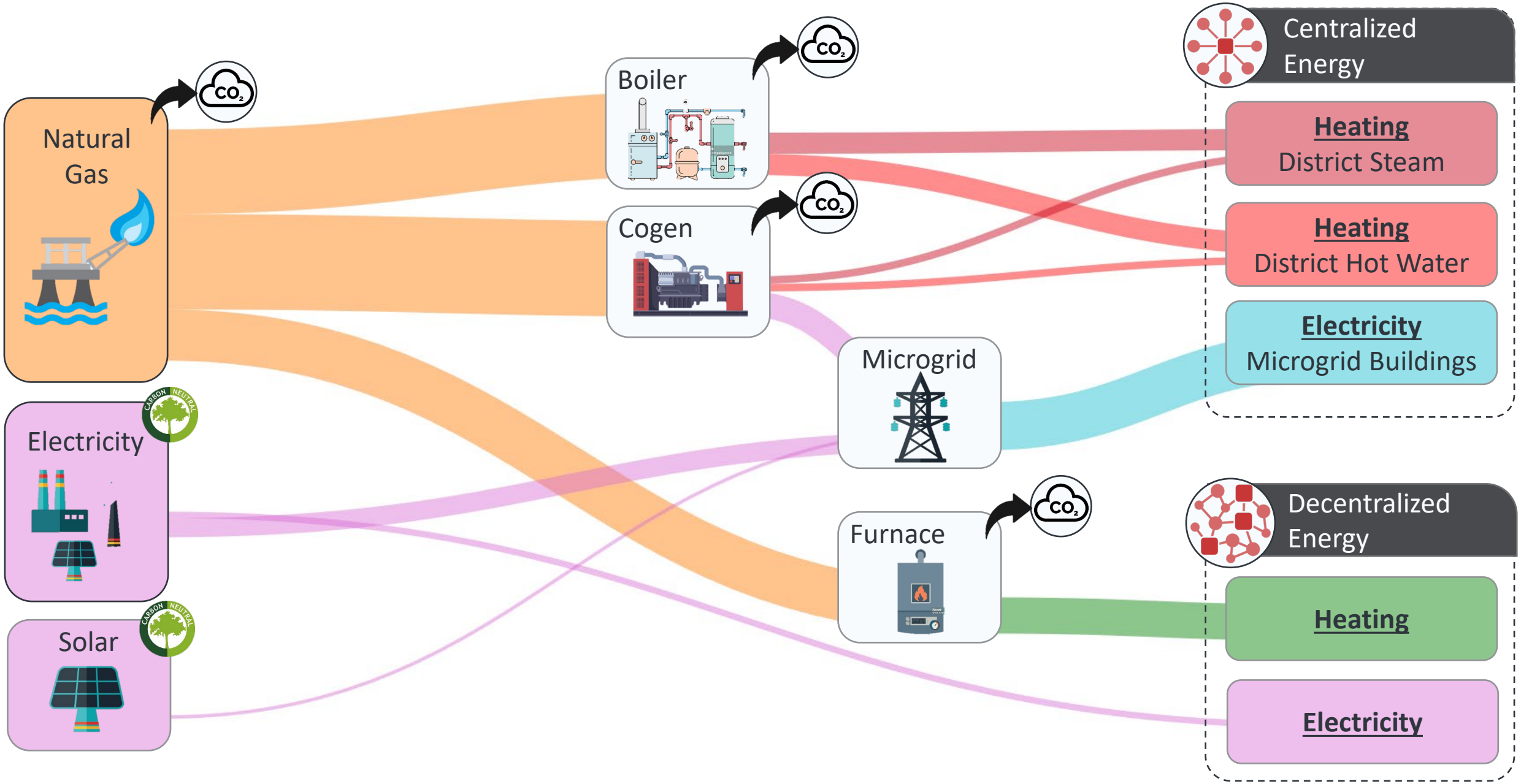
Centralized Energy is 70% of our Energy Consumption

- Boilers at the central power plant generate steam and hot water for heating
- Cogeneration systems at freeman and CPP generate electricity, steam, and hot water
- Electricity is purchased through a main substation at Vine street and distributed through our microgrid

Decentralized Energy is 30% of our Energy Consumption

- 1.0M ft2 of space (35% of our total space)
- Generally, Natural gas is burned in each building for heat (a few properties use heat pumps or bio-diesel)
- Electricity is purchased through a connection at each building

Background and Motivation: Energy at Wesleyan Today



Energy Plan

- Comprehensive Energy
- Building Projects
- Energy Retrofits
- Community Education

Conservation

- Steam to Hot Water Conversion
- Electrification (with Heat Pumps)

Infrastructure

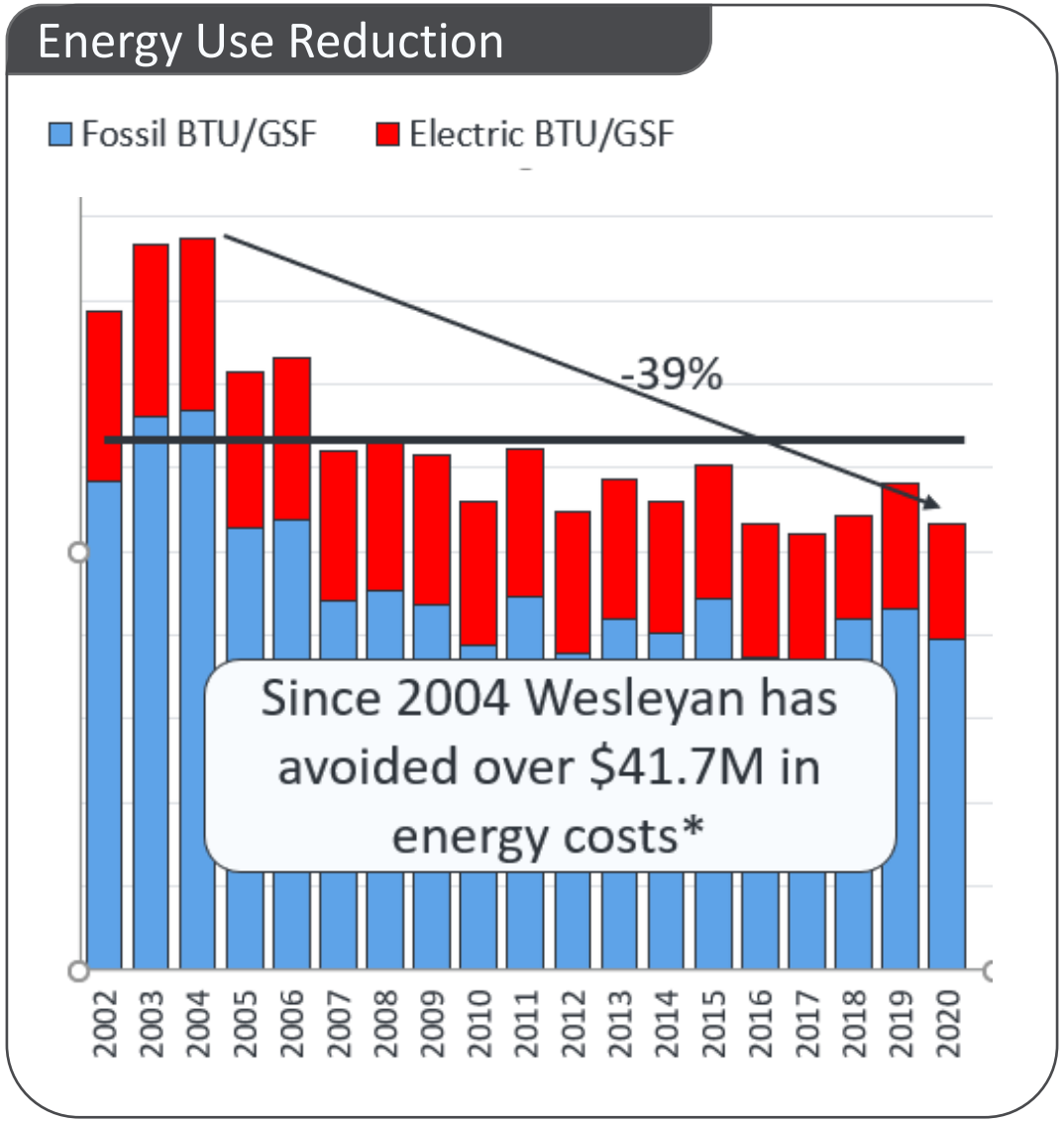
- Renewable Energy Credits
- Carbon Offsets

Offsets

Comprehensive Energy Projects

Conservation | Infrastructure | Offsets

- Any projects that significantly reduce energy or water consumption
- 15 phases of comprehensive energy reductions projects performed
- Offset $2.6M in energy costs annually
  - 12,000 MWh of electricity annually
  - 130,000 therms of natural gas annually
- Reduced our carbon emissions by 9,043 MTCDE annually

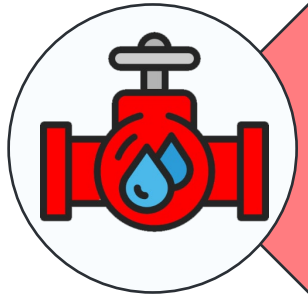


Building Projects and Retrofits

- Design new buildings with a focus on reduction in energy use and for low temperature hot water (130 °F or less)
- Replace or retrofit most energy intense buildings on campus
  - The New Science Building will have an EUI of ~84 kBTU/ft2 and replace Hall Atwater (EUI of ~320 kBTU/ft2)
- Retrocomissioning of existing buildings

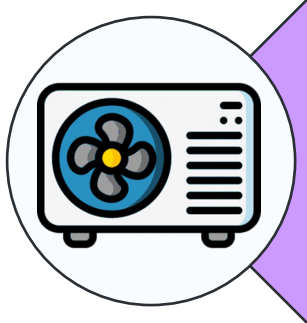
Energy Plan

Conservation | **Infrastructure** | Offsets



Steam to Hot Water Conversion

- Replacement of aging infrastructure (steam pipes, manholes)
- Significant increases in generation and distribution efficiencies
- Flexibility for a variety of current and future renewable energy technologies
- Increased utilization of existing cogeneration waste heat

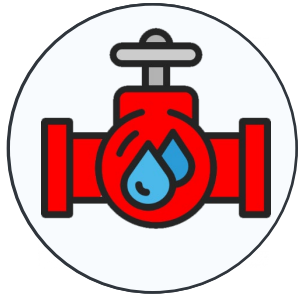


Electrification of Campus (Heat Pumps)

- Eliminates burning of fossil fuels for heating
- Cogen can power heat pumps and provide waste heat until solar is installed
- Heat pumps allow for energy sharing between buildings
- Heat pumps generate hot water, not steam

Renewable Electricity Production

- Renewable energy for electricity, heating, and cooling
- Opportunity for offsite solar projects
- Battery and/or other storage technologies provides microgrid resiliency after cogen is retired



Steam to Hot Water Conversion

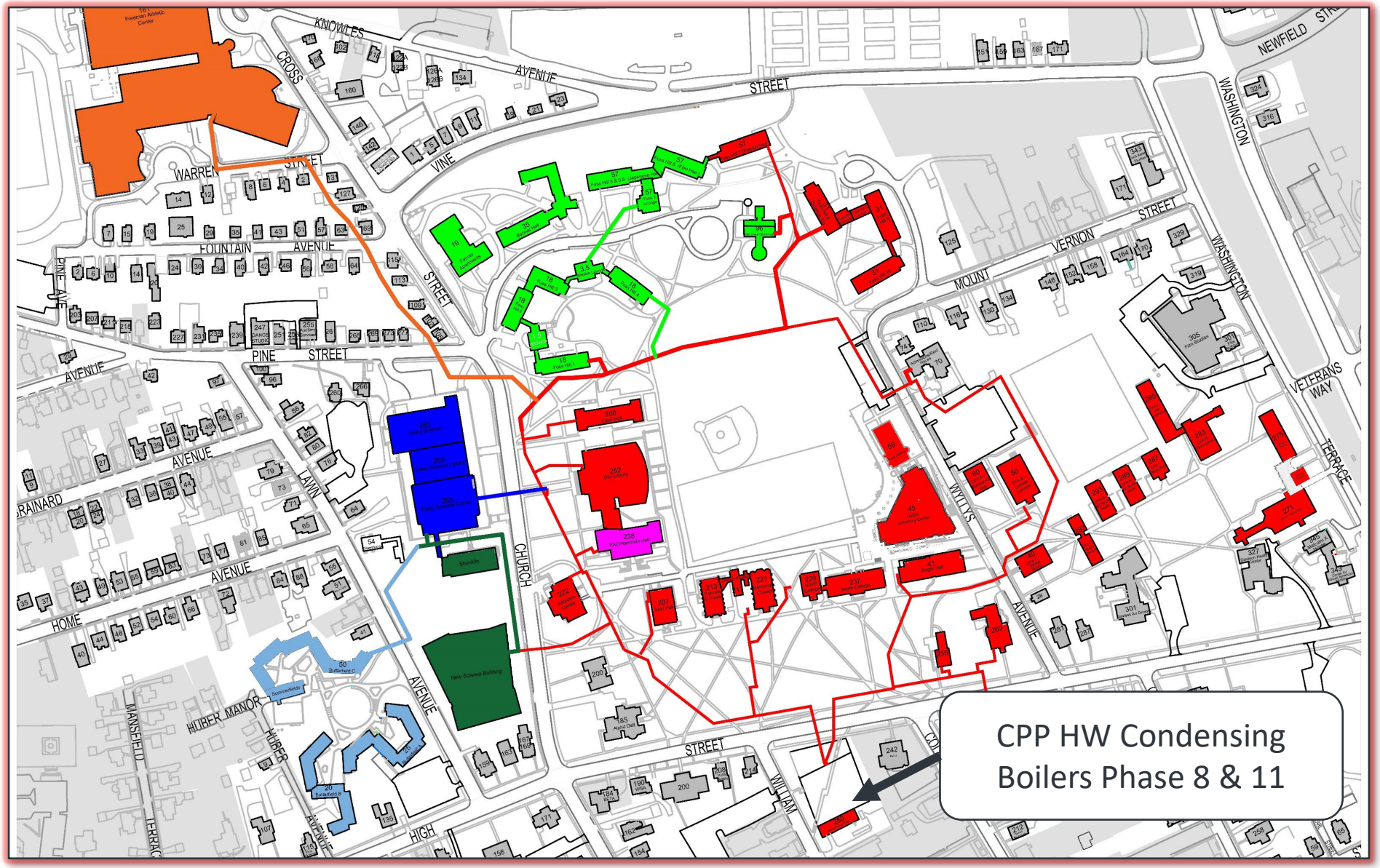
Hot Water Conversion Benefits

Conservation | **Infrastructure** | Offsets

Replacement of Aging Infrastructure	Increased Efficiency	Increased Utilization of Existing Assets	Increased Safety & Reduced Maintenance	Integration of Future Renewables
• Over 10,000 feet of aging steam and condensate pipe on campus • Eliminates failing steam manholes • Boilers at CPP are inefficient and nearly 50 years old • Underground pipe insulation has failed, increasing losses	• Increases distribution efficiency by over 25% • Increase generation efficiency by 15% • Greatly reduces standby losses due to much lower operating temperatures	• Greatly increases utilization of cogen waste heat • Cogen can meet 100% of our summer heat load (reheat & domestic hot water)	• Much lower temperatures increase worker safety • Eliminates high maintenance items such as steam traps	• **Nearly all renewable thermal technologies produce low temp hot water (not steam)** • Unlocks integration of heat pumps, solar thermal, fuel cells, and future renewable technologies

Hot Water Conversion Phasing

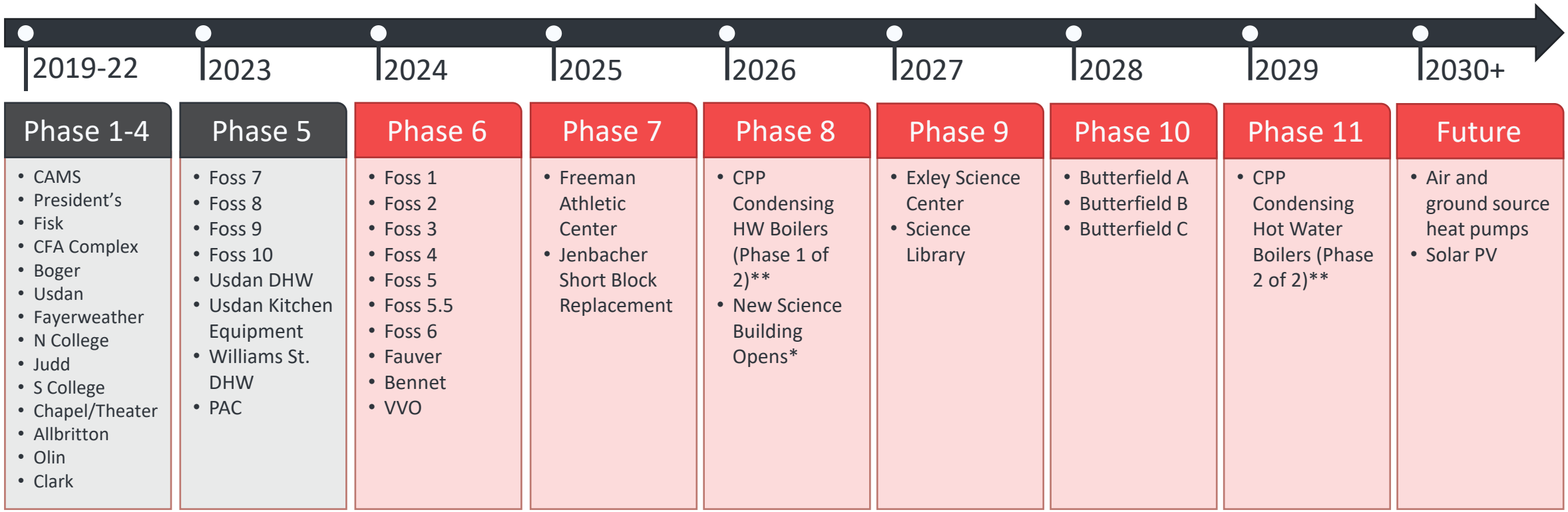
Conservation | **Infrastructure** | Offsets



- Phase 1-5
- Phase 6 (2024)
- Phase 7 (2025)
- Phase 8 (2026)
- Phase 9 (2027)
- Phase 10 (2028)
- Phase 11 (2029)

Hot Water Conversion Phasing

Conservation | **Infrastructure** | Offsets



- *New Science Building and Shanklin open on hot water as part of project; Hall Atwater remains on steam until it is demolished
- **New condensing hot water boilers are installed at CPP for peak load and backup heating

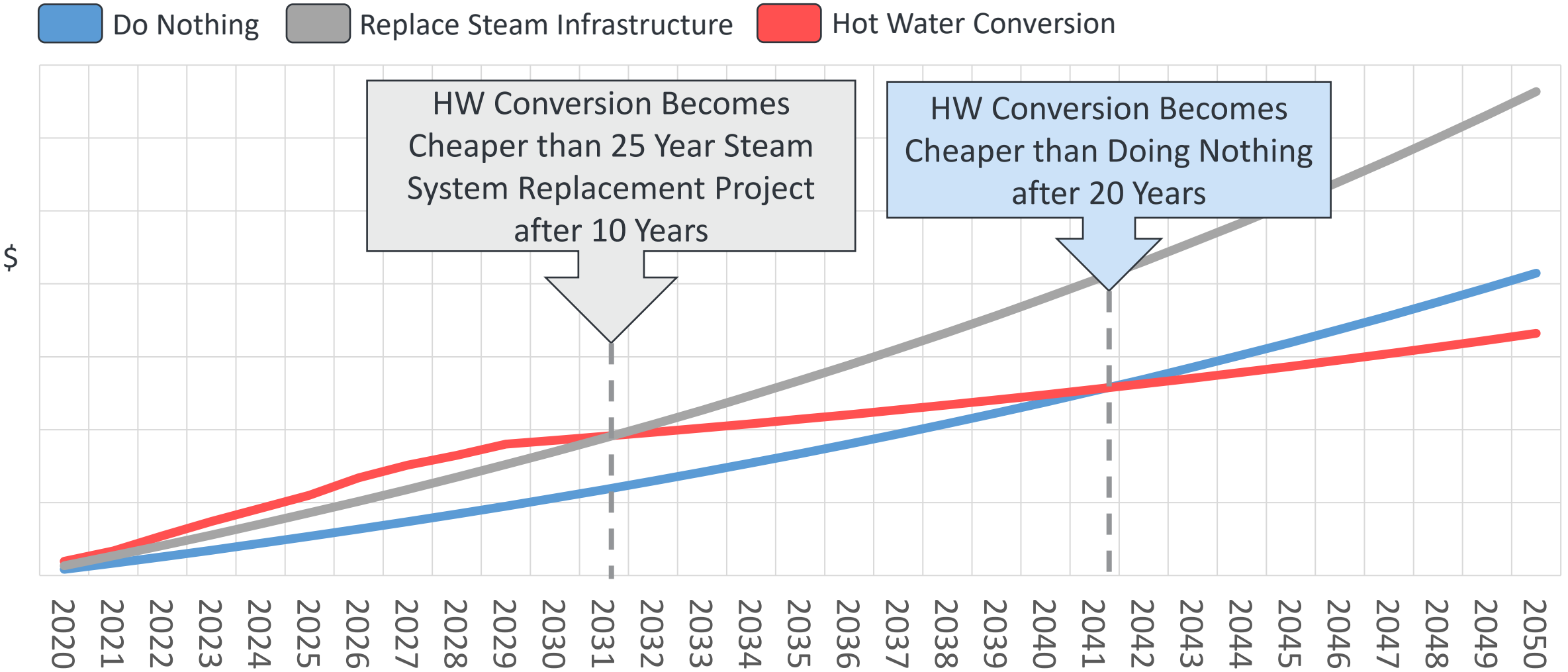
Hot Water Conversion is Messy

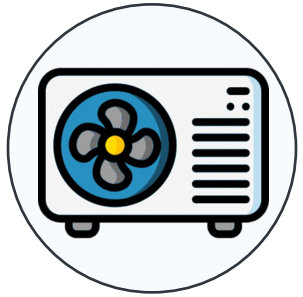
Conservation | **Infrastructure** | Offsets

Wesleyan University

Hot Water Conversion Cash Flow

Conservation | **Infrastructure** | Offsets



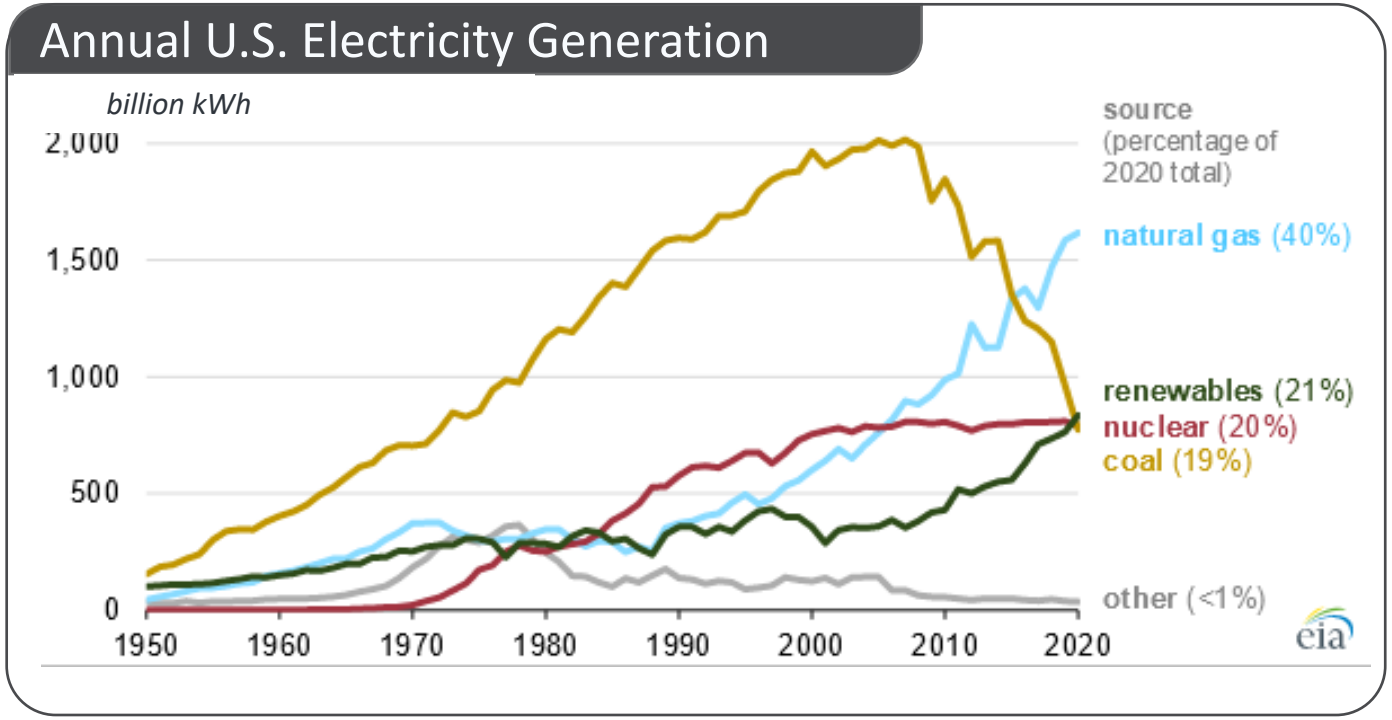


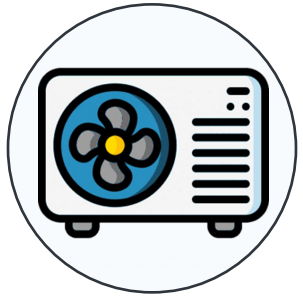
Electrification of Heating System (Heat Pumps)

Electrification Benefits

- To be carbon neutral we need to stop burning fossil fuels

- There are very limited renewable fuels (e.g., biodiesel and hydrogen)
- Renewable electricity has become abundant and relatively inexpensive
- The electric grid is rapidly transitioning to renewables
- Heating with electricity is very efficient (heat pumps)

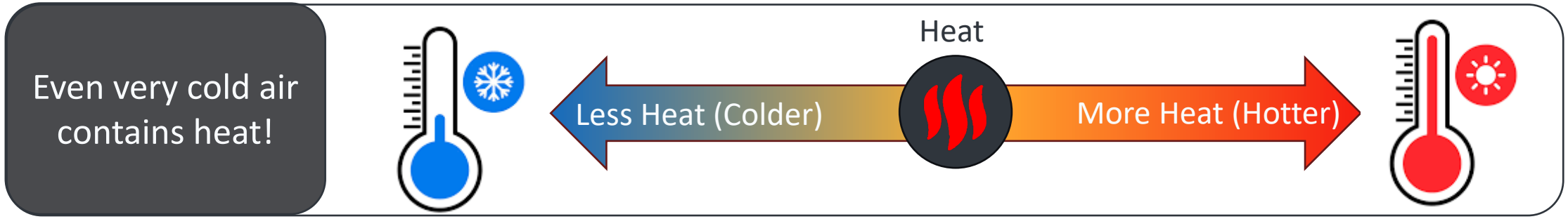




Heat Pump Primer

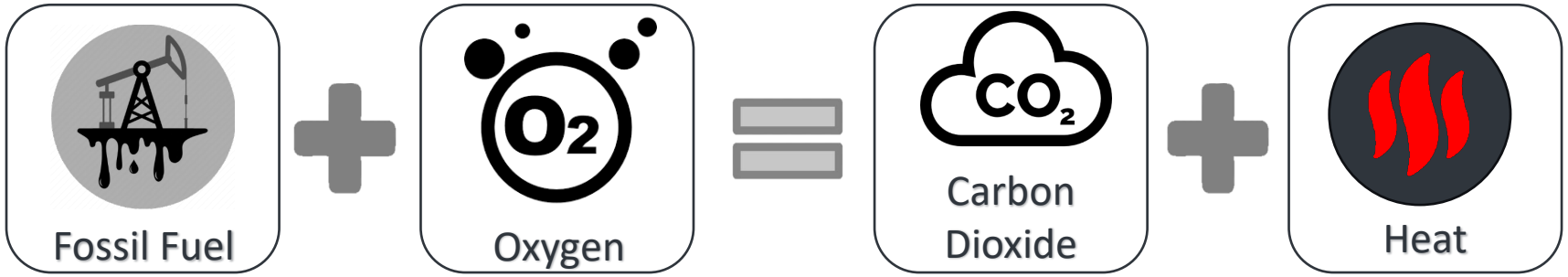
Defining Heat & Energy

- Heat is the amount of thermal energy in a system
- Everything contains heat
- Temperature measures how much heat (energy) is in a system

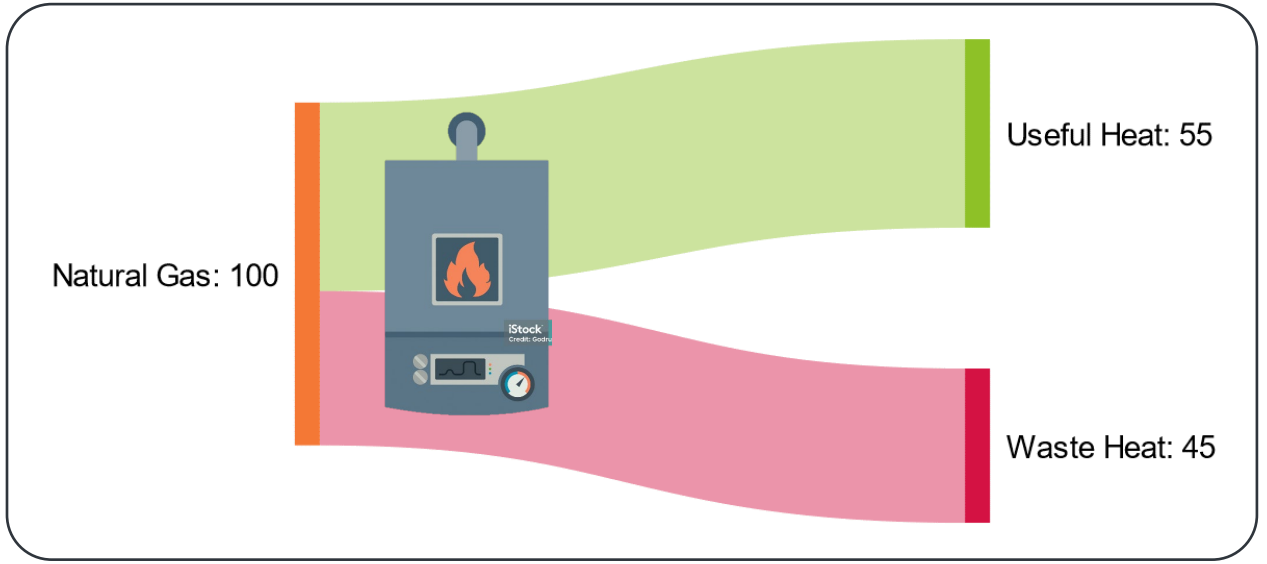


Defining Efficiency

- We can heat something by a chemical reaction (like burning fossil fuels in a furnace)

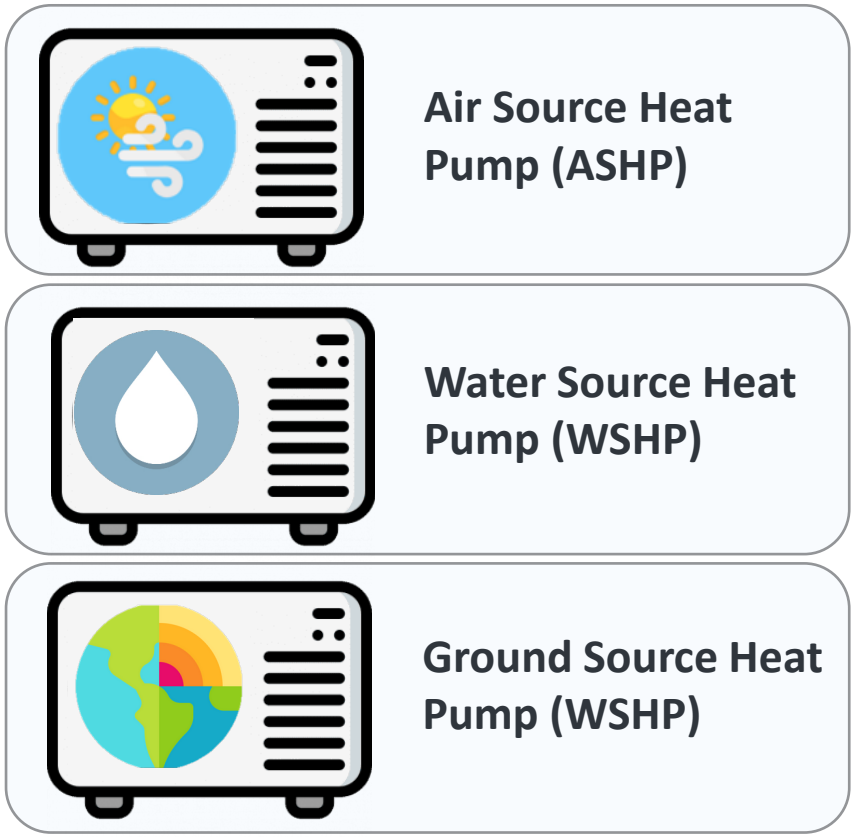


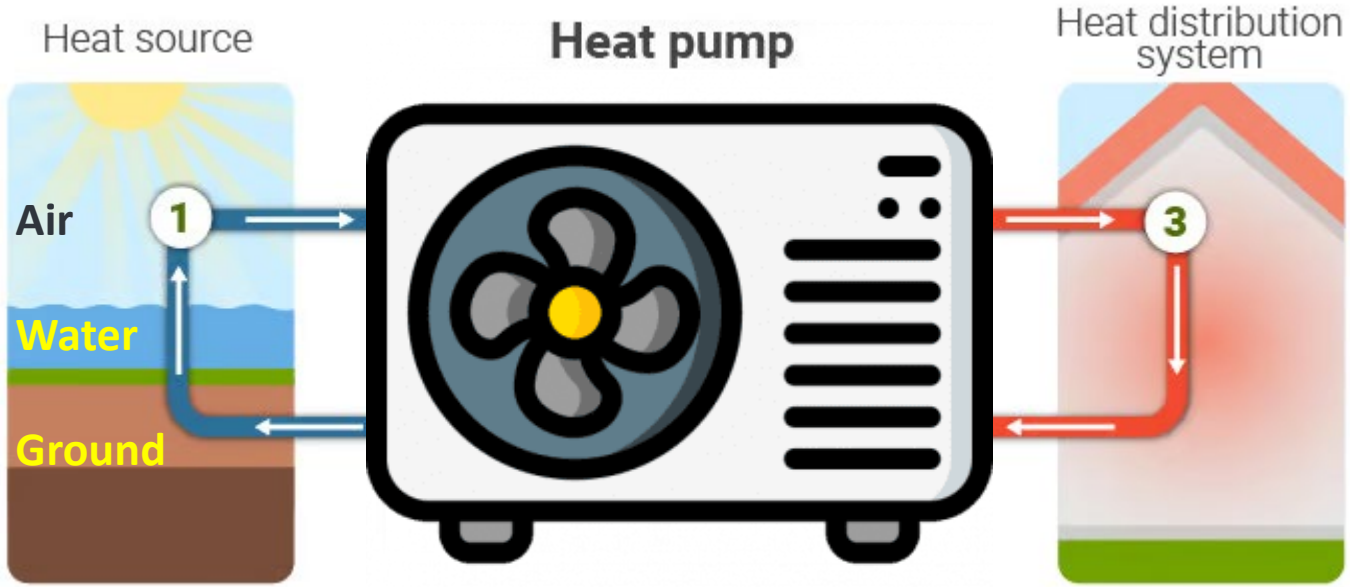
- Creating heat can never be more than 100% efficient (and is typically much less)
- Wesleyan's district steam heating system is about **55% efficient**



Types of Heat Pumps

- We can heat something by **moving existing heat** from one place to another (i.e., pumping heat from one place to another) using a small amount of electricity

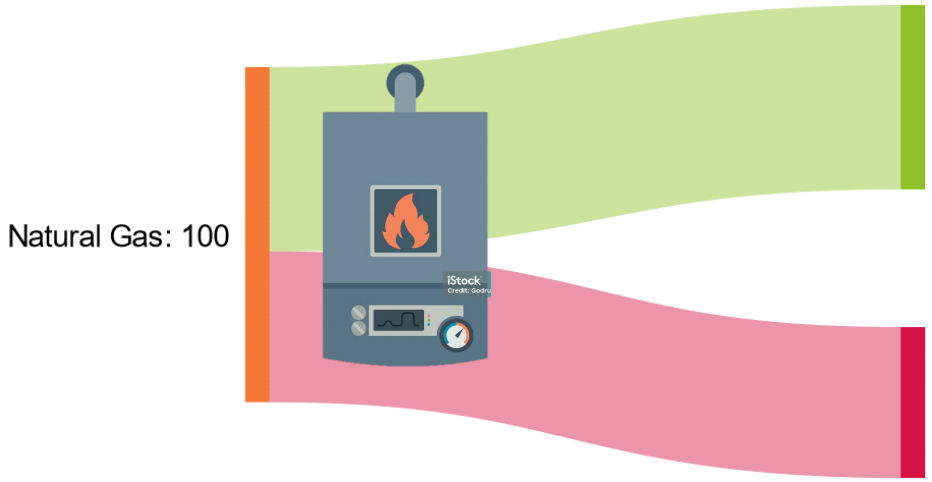




Heat Pump Summary

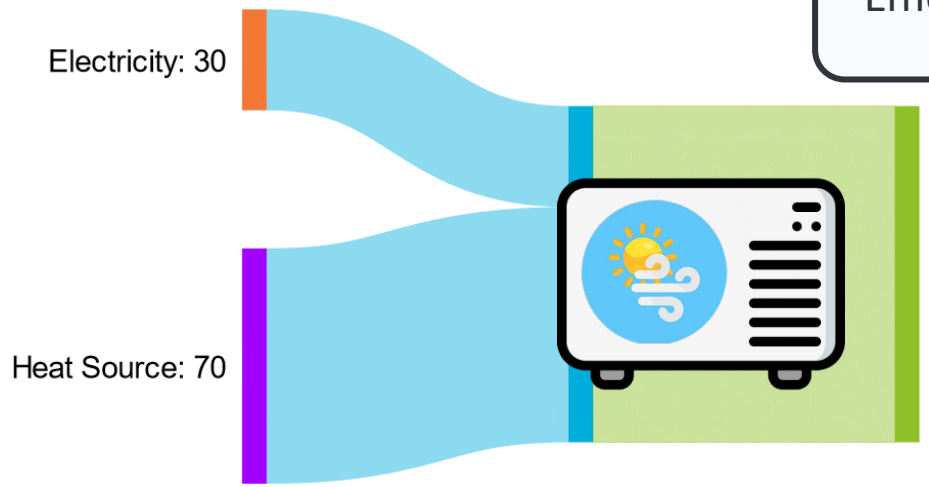
Heat Pump Knowledge Summary

- Boilers and Furnaces Generate Heat (by combustion)
- Heat Pumps Move Heat (Energy)
- It's much more efficient to move heat than to generate it
- Everything contains heat
- Heat pumps use electricity to move heat
- Heat can be moved from the air (air source heat pump) the water (water source heat pump) or the ground (ground source heat pump)



$$\text{Efficiency} = \frac{55}{100} = 55\%$$

$$\text{Efficiency} = \frac{\text{Useful Heat}}{\text{Energy Used}}$$

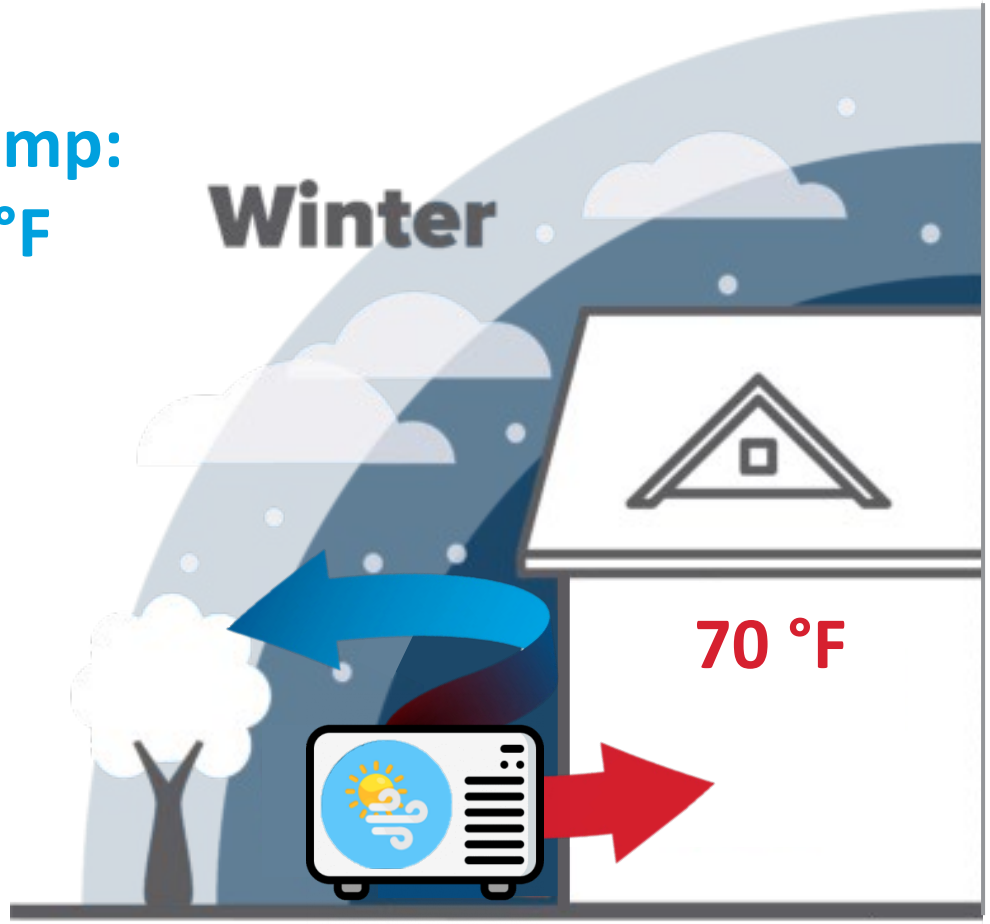


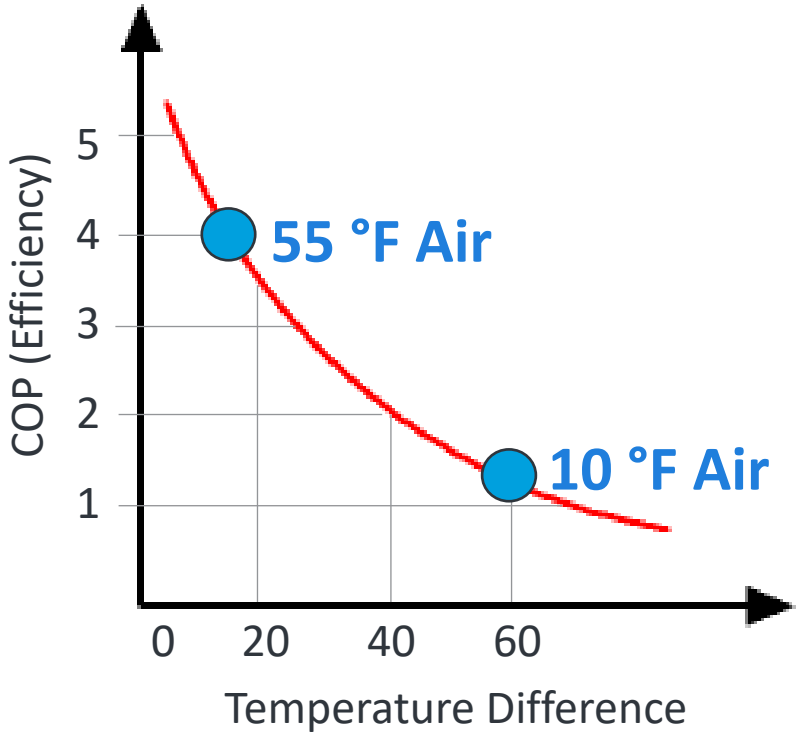
$$\text{Efficiency} = \frac{100}{30} = 333\%$$

COP = 3.33

Air Source Heat Pumps (ASHPs)

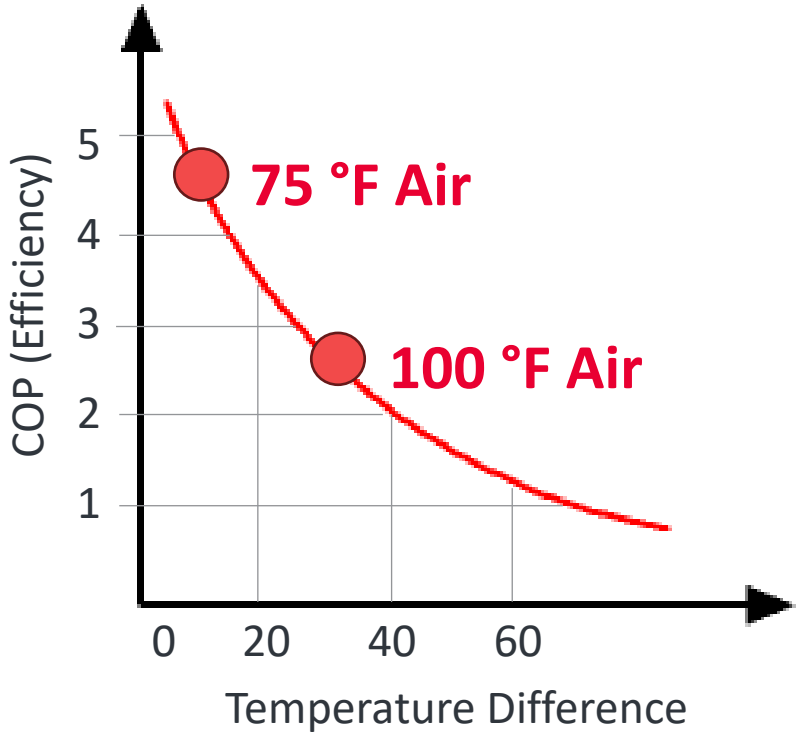
Air Temp:
10 °F

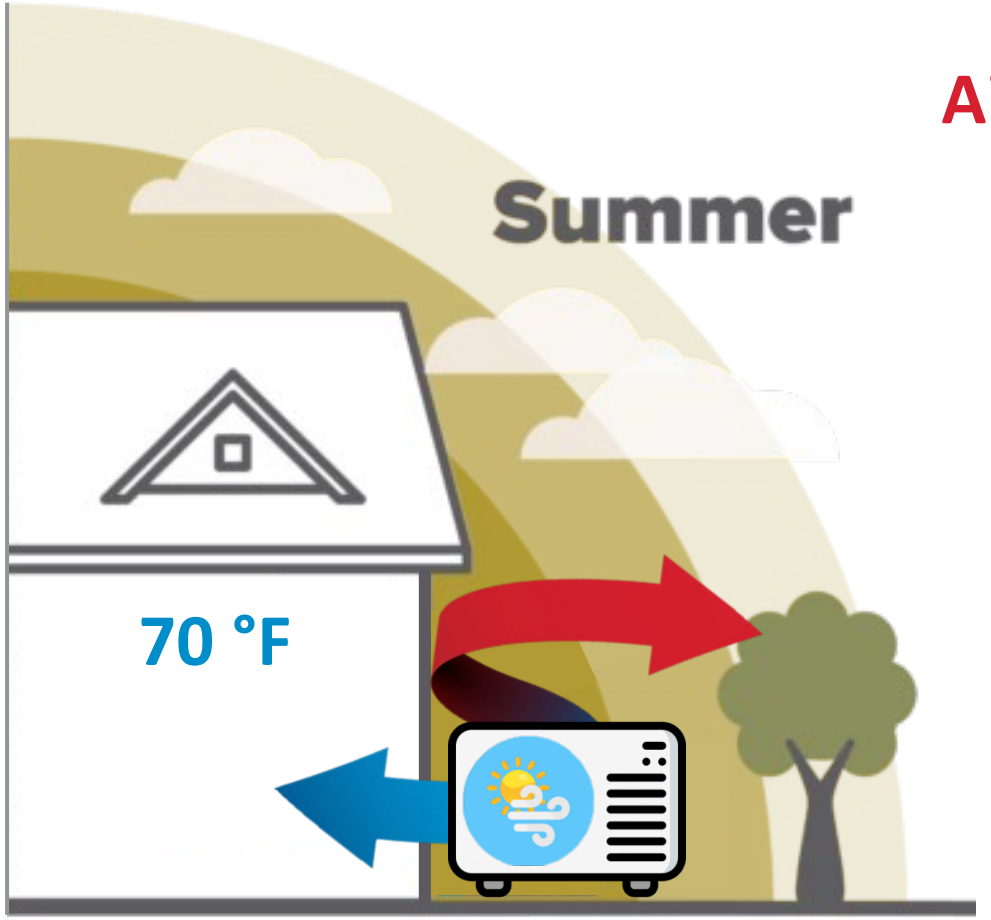




In Winter, the heat pump absorbs heat from outside and transfers it inside (heating the interior)

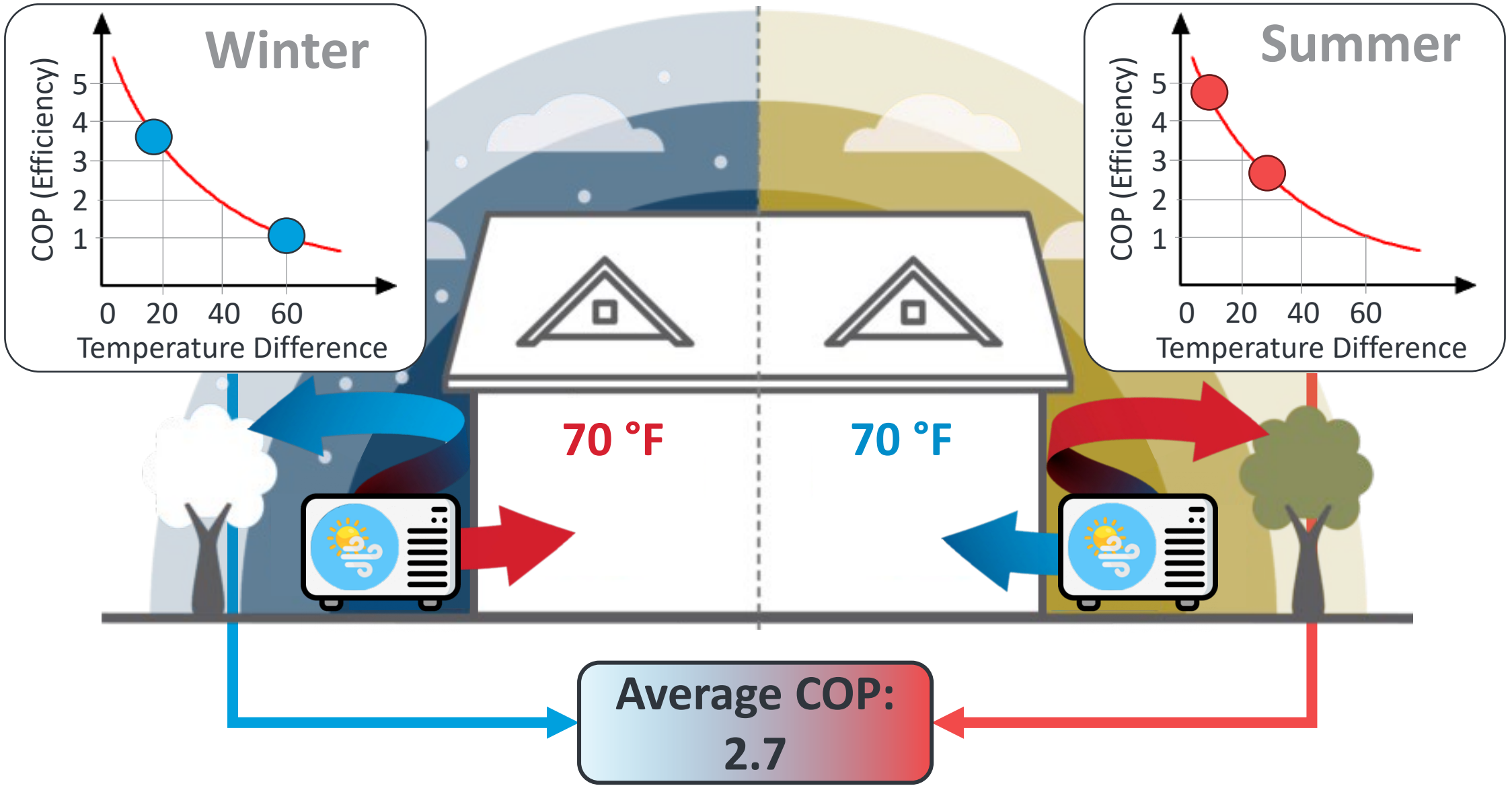
Air Source Heat Pumps (ASHPs)





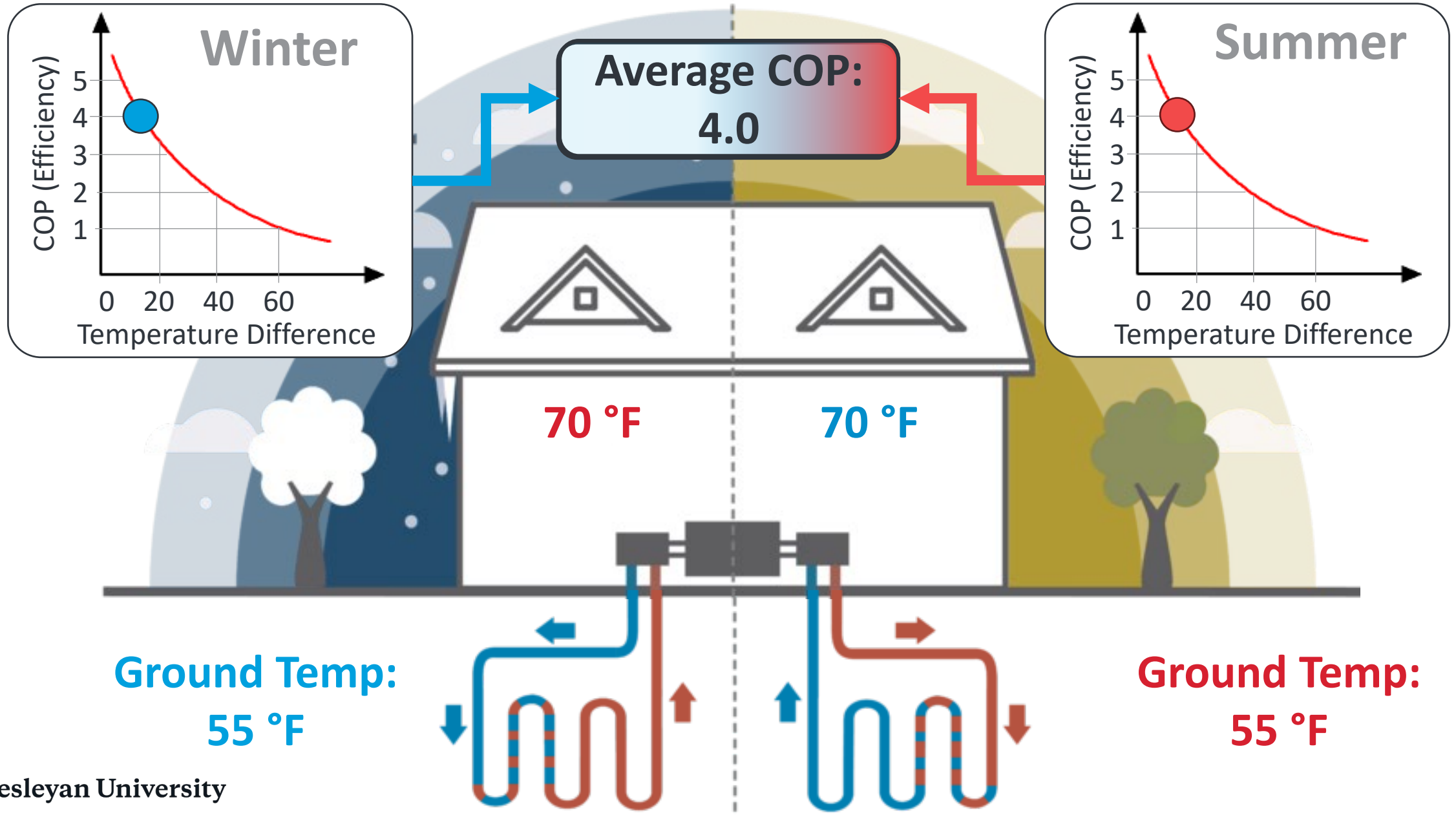
In Summer, the heat pump acts like an air conditioner and moves heat from the air inside to outside (cooling the interior)

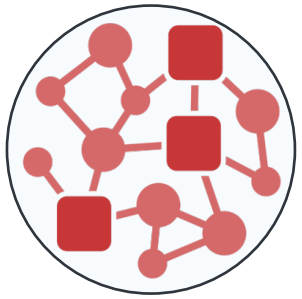
Air Source Heat Pumps (ASHPs)



Ground Source Heat Pumps (GSHPs)

Conservation | **Infrastructure** | Offsets



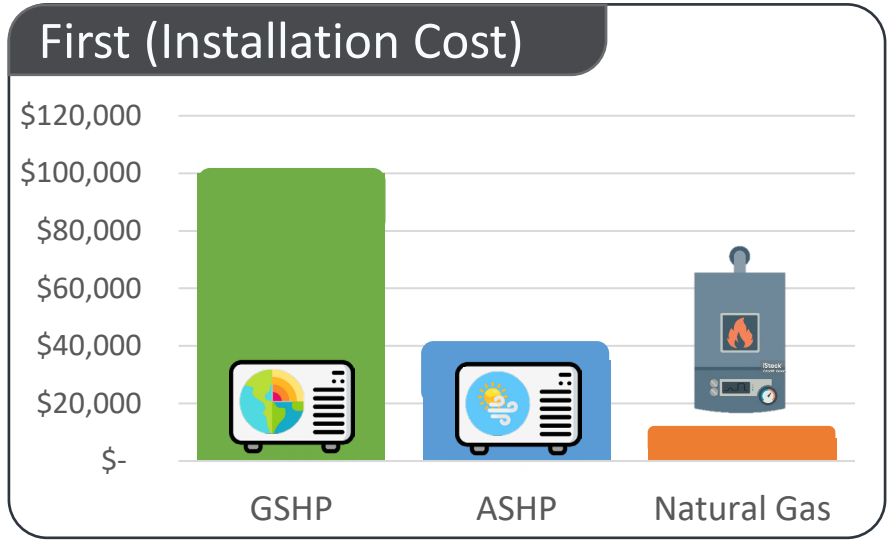


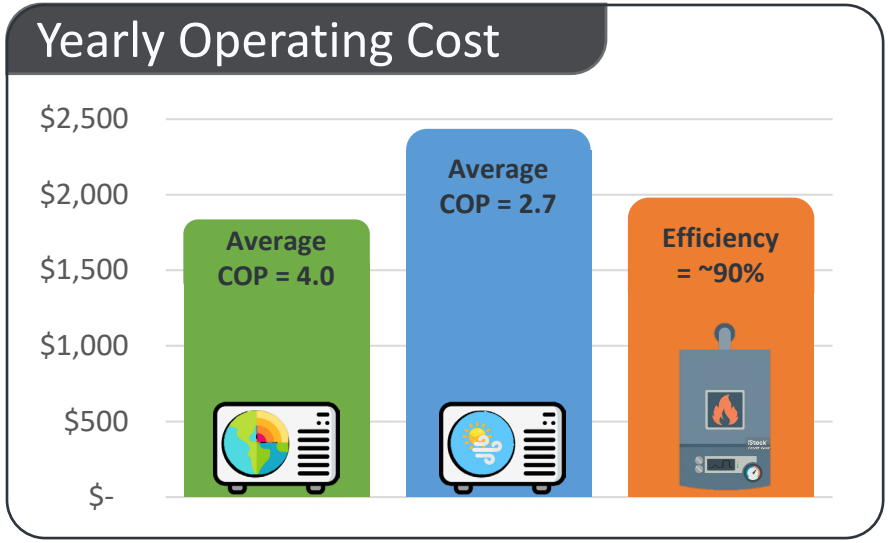
Electrification of Decentralized Heating Systems

Decentralized Heat Pumps

Heat Pump Conversion Challenges

- Ground Source Heat Pumps (GSHPs) are prohibitively expensive for decentralized heating applications
- Gas burning equipment is still much cheaper to install than heat pumps (rebates offset some of this difference)
- Adding heat pumps to existing buildings often require additional expensive electrical infrastructure upgrades
- Converting our existing gas burning equipment to ASHPs will increase our operating costs
- Converting to ASHPs is only carbon free if the electricity we produce on campus is carbon free





Decentralized Heat Pumps

Conservation | **Infrastructure** | Offsets

Heat Pump Strengths & Opportunities

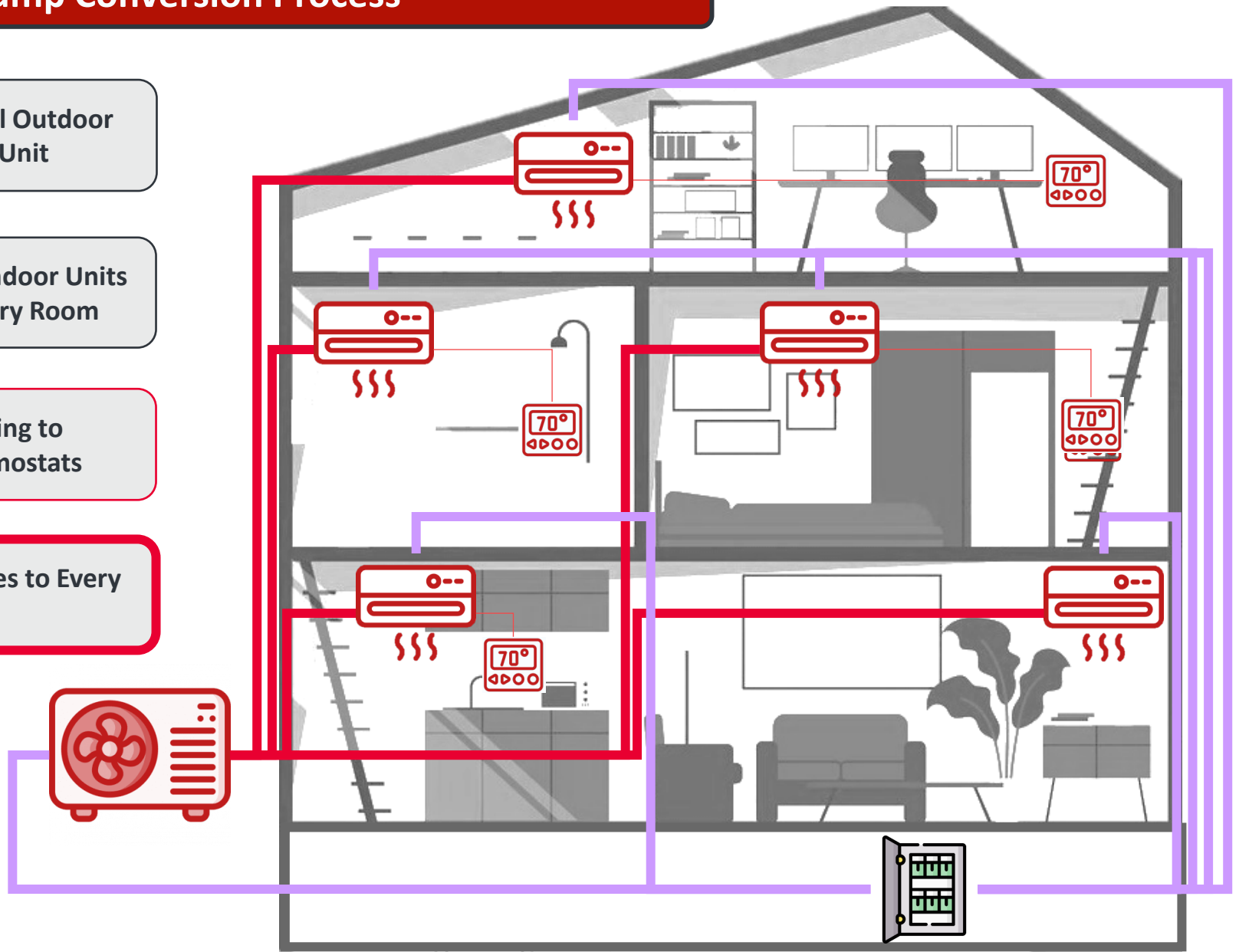
- Air Source Heat Pumps (ASHPs) are the preferred technology for **carbon free** decentralized heating systems
- ASHP technology will get more efficient with time
- ASHP rebates from the utility are increasing
- ASHPs provide the potential to add cooling to our buildings
- Natural gas pricing can be volatile and may increase
- Solar panels on roofs can help lower electric costs, but comes with its own challenges
- Converting our existing oil burning equipment to ASHPs will lower our operating costs

Decentralized Heat Pumps

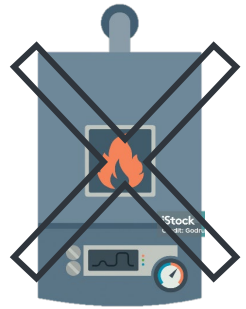
Conservation | **Infrastructure** | Offsets

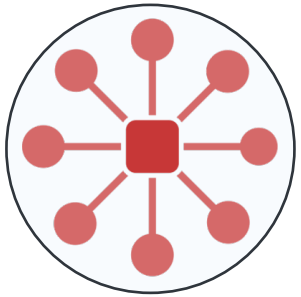
Heat Pump Conversion Process

- Install Outdoor Unit
- Install Indoor Units in Every Room
- Wiring to Thermostats
- Refrigerant Lines to Every Unit



- Upgrade Electric Service
- Electrical Power to Every Unit
- Eliminate Old Gas Equipment & Service





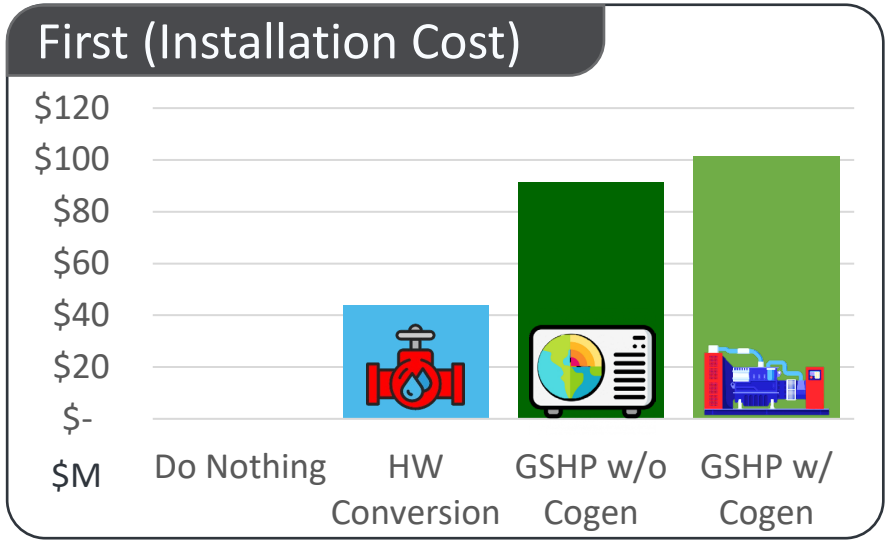
Electrification of Centralized Heating Systems

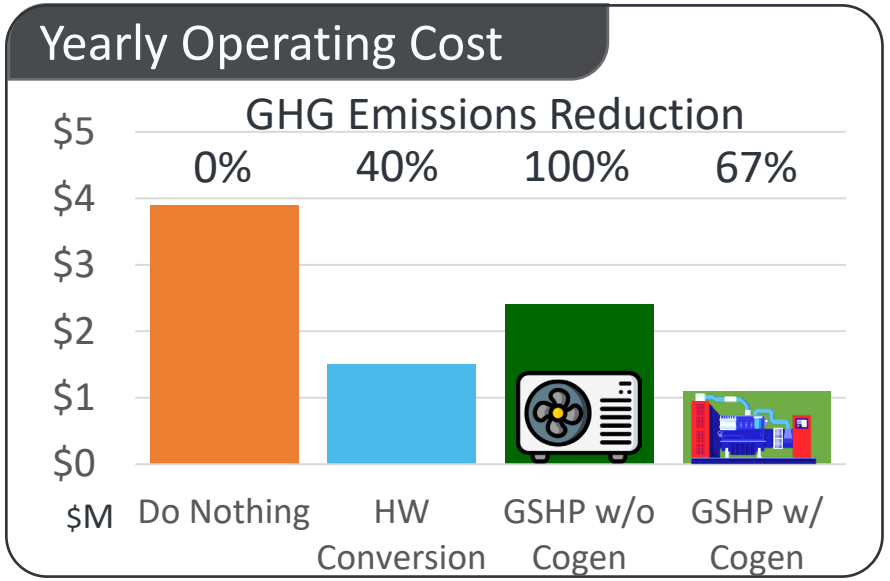
Centralized Heat Pumps

Conservation | **Infrastructure** | Offsets

Heat Pump Conversion Challenges

- Air source heat pump technology doesn't scale well
- Many buildings require hotter water temperature to heat, greatly reducing heat pump COP (efficiency)
- Gas burning equipment is still much cheaper to install than heat pumps (rebates offset some of this difference)
- Converting our existing gas burning equipment to GSHPs will increase our operating costs (electricity is nearly 4x more expensive than natural gas)
- Converting to GSHPs is only carbon free if the electricity we produce on campus is carbon free





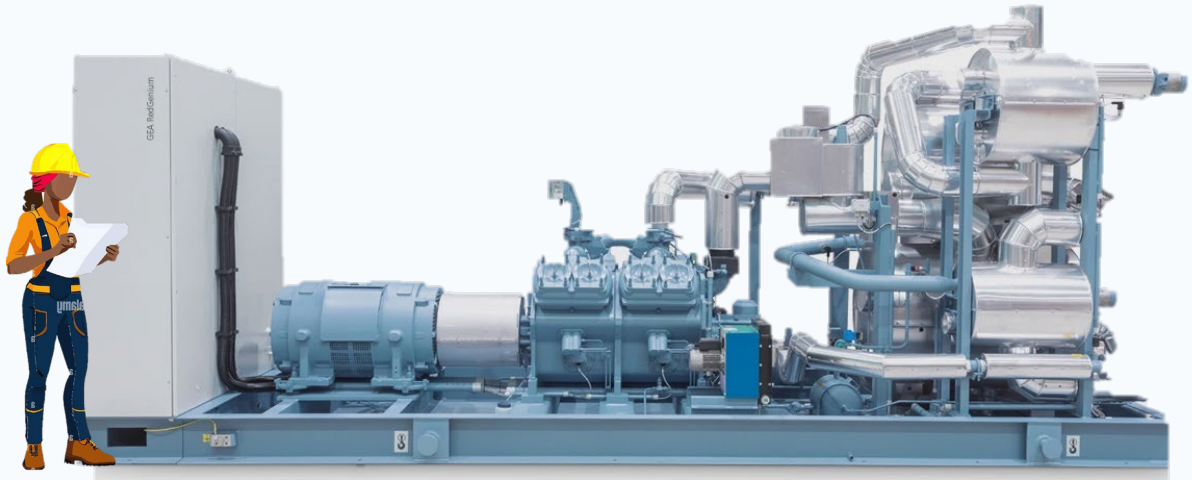
Centralized Heat Pumps

Conservation | **Infrastructure** | Offsets

Heat Pump Strengths & Opportunities

- Ground Source Heat Pumps (GSHPs) are the preferred technology for carbon free centralized (district) heating systems
- GSHP technology will allow for hotter water temperature and will get more efficient with time
- Adding more Cogeneration to campus can greatly reduce operating costs, but would burn natural gas to do so
- Solar panels on campus can help lower electric costs, but comes with its own challenges

GEA RedAstrum Heat Pump: 450 RT



Centralized Heat Pumps

Conservation | **Infrastructure** | Offsets

Heat Pump Conversion Process

- Convert campus from steam to hot water
- Reduce required water temperature in buildings to < 160 °F
- Build local energy transfer (heat pump) plants next to proposed well fields
- Drill wells and connect them to energy transfer plants
- Connect energy transfer plants to campus hot and chill water piping systems

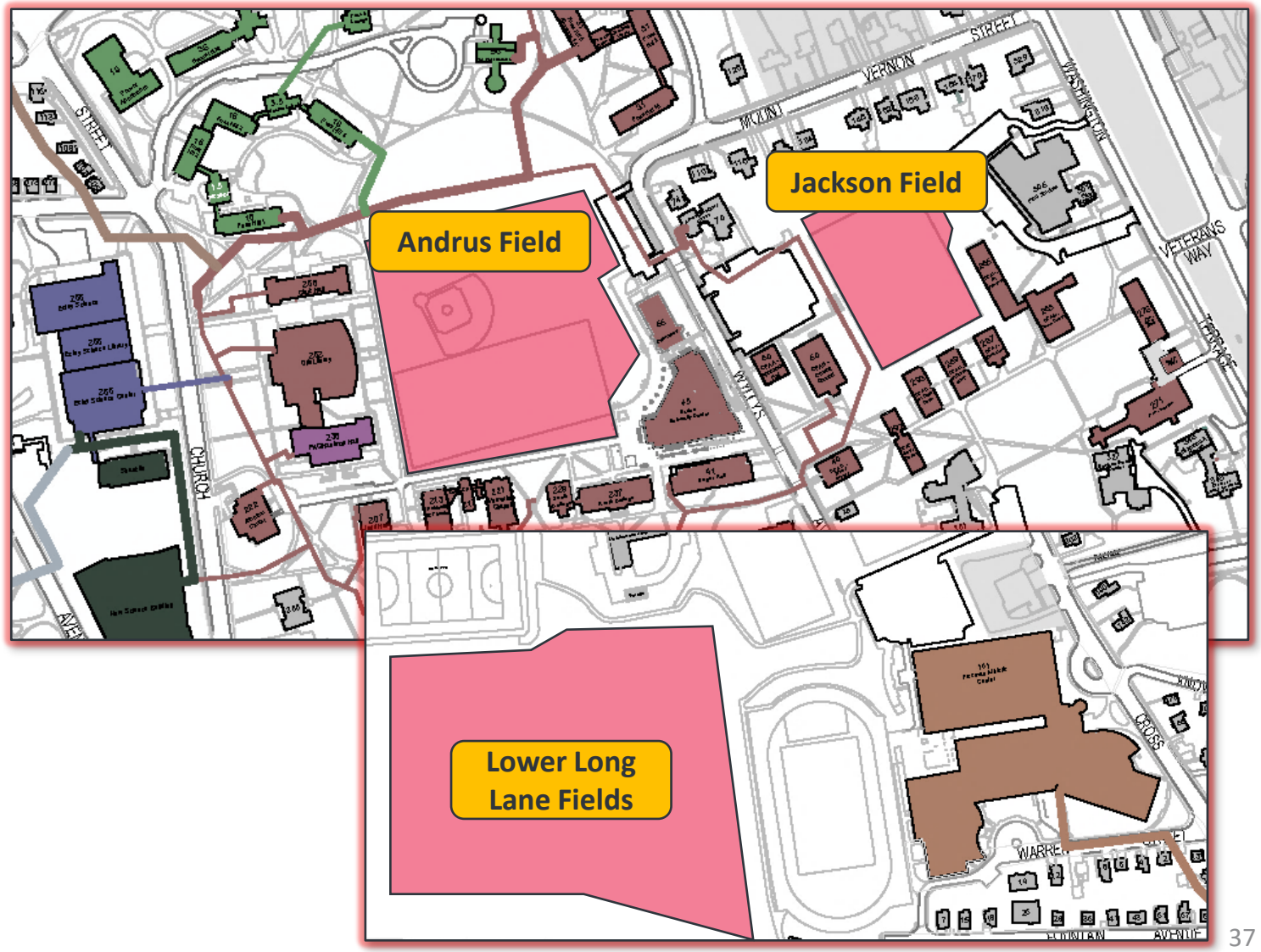
Energy Transfer Plant

Centralized Heat Pumps

Conservation | Infrastructure | Offsets

Heat Pump Conversion Process

- Possible well field locations included Andrus Field, Jackson Field, College Row, and Freeman Athletic Fields
- Approximately 1,680 wells drilled to over 600 feet deep will provide 4,200 tons of heating and cooling capacity
- Natural gas boilers at the power plant will provide redundancy and peaking capabilities



GSHP Well Field

Conservation | **Infrastructure** | Offsets

Well Drilling Video

Heat Pump Summary

Conservation | **Infrastructure** | Offsets

Heat Pump Technology

- ASHPs are preferred for decentralized applications due to their relatively low cost
- GSHPs are preferred for centralized applications due to their significantly higher efficiency
- Condensing hot water boilers will become backup heat sources
- Heat pump technology is constantly improving; allowing hotter operating temperature and increased efficiency

Heat Pump Strengths

- Heat pumps are 2-5 times more efficient than traditional combustion equipment
- A special kind of heat pump will allow energy sharing between simultaneous heating and cooling loads
- Electricity is significantly easier to produce using renewable energy than thermal energy for heating and hot water

Heat Pump Challenges

- Converting our existing gas burning equipment to ASHPs will increase our operating costs
- Many buildings require hotter heating water than a heat pump can currently provide
- Heat pumps are only carbon neutral if the electricity the consume is carbon neutral
- Gas burning equipment is significantly cheaper to install
- Electrification is extremely expensive

Electricity Production

Conservation | **Infrastructure** | Offsets

Challenge

- As more ground source heat pumps are installed, our electric load will increase
- Electricity is 4-6 times more expensive than gas on a per unit of energy basis
- Grid purchased electricity is increasingly green and can be provided with RECs, however it is very expensive
- As the campus electric load increases, we will need to produce cheap renewable electricity to meet our demand

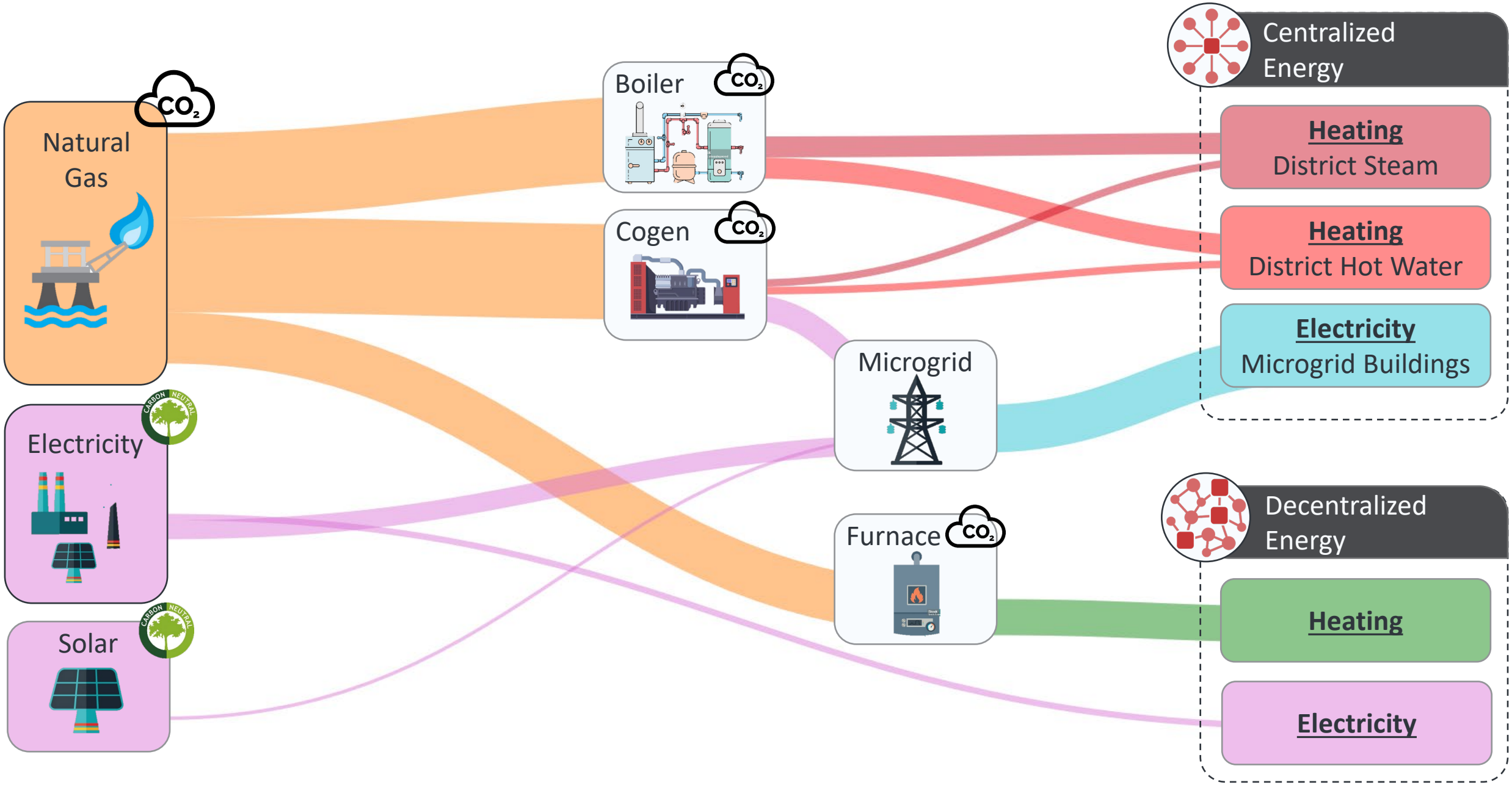
Cogen

- Adding natural gas burning cogen could greatly reduce our electricity costs
- Additional waste heat will provide “free” energy while generating electricity for highly efficient heat pumps
- Even if gas prices double and electricity stays flat, cogen would save upwards of $3.0M dollars/year after the conversion to GSHP is completed

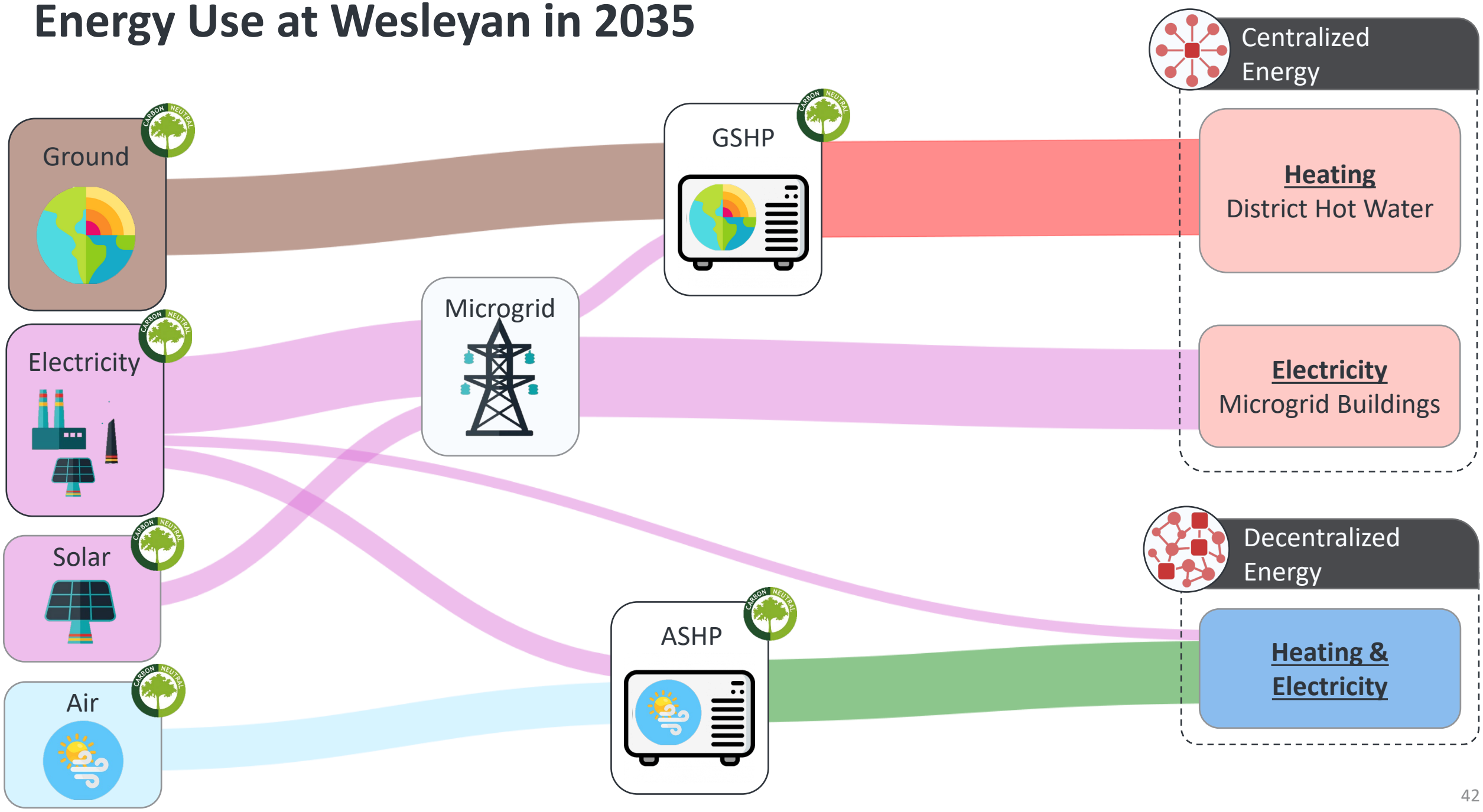
Solar

- Solar on campus is limited due to land space and the amount the utility will allow to connect to their grid
- Must be coupled with some type of battery/energy storage solution as peak heating loads occur outside of peak electricity production times
- Not as inexpensive as it used to be, still more expensive than making electricity with cogen

Energy at Wesleyan Today



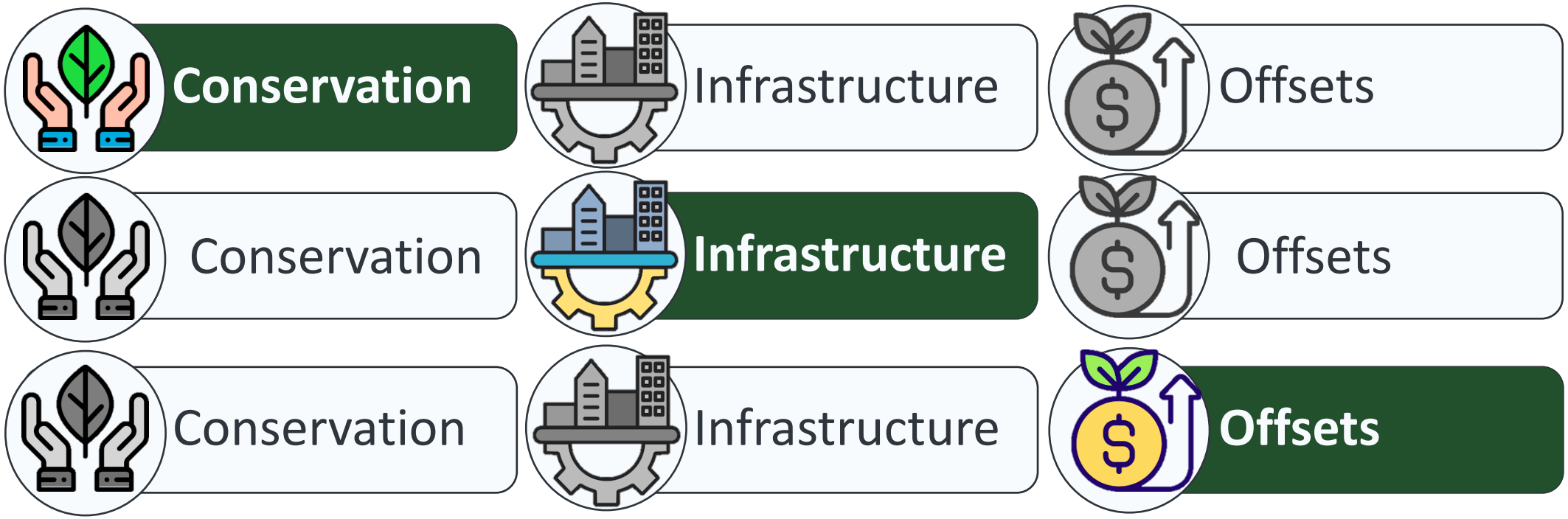
Energy Use at Wesleyan in 2035



Carbon Offsets

- Fossil fuels will have a minor role in our campus energy needs
  - On very cold days, burning of fuel may be needed to supplement heat pumps for heating
  - Emergency and life safety generators will still burn fossil fuels
  - This carbon footprint can be eliminated by buying carbon offsets
- Carbon offsets are not well regulated and their use should be kept to a minimum
- Elimination of fossil fuel use is superior to offsetting use with carbon offsets


Thank You!
Questions?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