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Seminar 62: The Risk of Decoupling Efficiency and Decarbonization
Presentation #33030 / #33031

Electrification vs. Decarbonization: When does electrification of heat *not* decrease emissions?

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Seminar Learning Objectives

Learning Objectives:

1. Understand the risks associated with incorporating carbon free solutions on end use or primary efficiency.
2. Explain the major factors impacting emissions from electrified heating.
3. Provide examples of how in certain cases electrification of heating can actually increase heating emissions.
4. Offer general guidelines for assessing the best decarbonization strategy for heating systems

Acknowledgements

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Bias disclosure: Employed by Trane Technologies Plc.

Outline/Agenda

1. Background
   1. Finding emissions factors
   2. Scenario & baseline system characteristics
2. Electrification options
   1. Electric boilers
   2. Air-source heat pump
   3. Ground Water heat pump
   4. Air-source heat pump, high efficiency chiller, and heat recovery chiller
3. Conclusions
   1. Emissions comparison
   2. Key takeaways

Background & Baseline System

Emissions Factors

What are they?

$$\boldsymbol{Annual\ emissions = Energy\ Consumed \times Emissions\ factor}$$

Public data source used in this example for fossil fuels:

Carbon Dioxide Emission Coefficients, U.S. Energy Information Administration (2022)

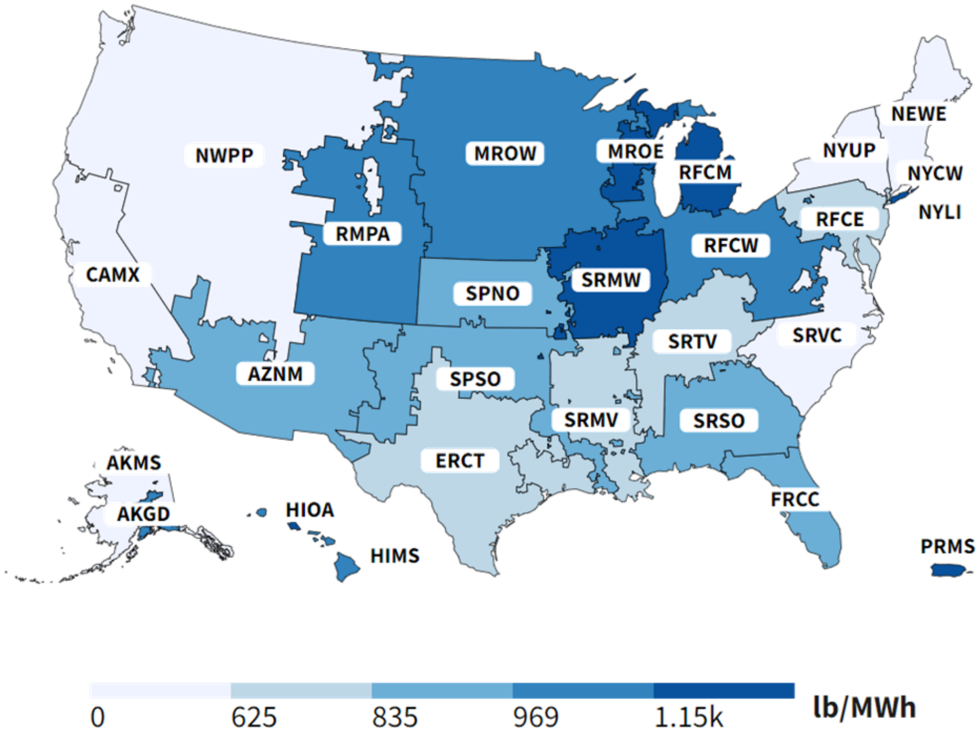
Carbon Dioxide (CO_2) Factors:	Pounds CO_2 Per Unit of Volume or Mass	Kilograms CO_2 Per Unit of Volume or Mass	Pounds CO_2 Per Million Btu	Kilograms CO_2 Per Million Btu
For homes and businesses				
Propane	12.68 gallon	5.75 gallon	138.63	62.88
Diesel and Home Heating Fuel (Distillate Fuel Oil)	22.45 gallon	10.19 gallon	163.45	74.14
Kerosene	21.78 gallon	9.88 gallon	161.35	73.19
Coal (All types)	3,876.61 short ton	1,758.40 short ton	211.87	96.10
Natural Gas	120.96 thousand cubic feet	54.87 thousand cubic feet	116.65	52.91

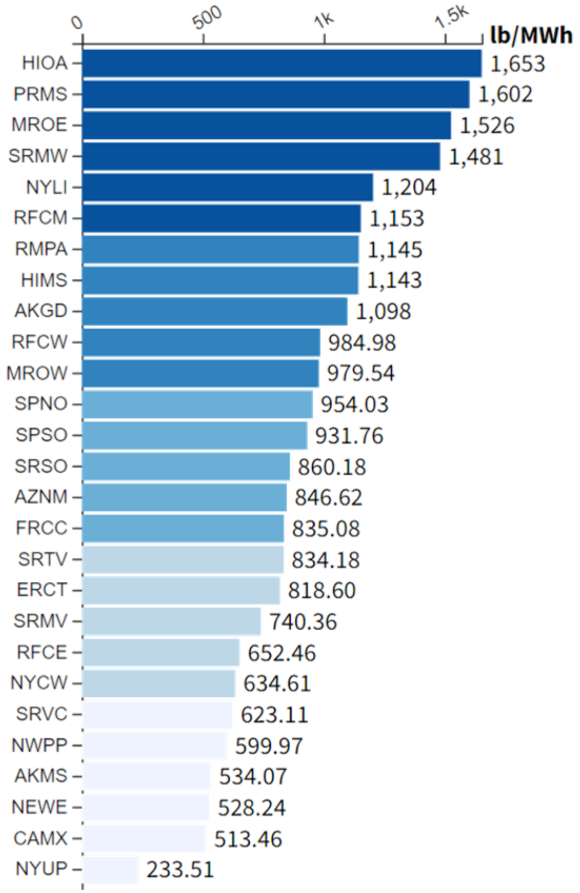
Emissions Factors
Which electricity factor should be used?

- Annual average vs. marginal
- Location-based vs market-based
    - Including renewables

Public data source used in this example for electricity:

eGrid 2020, U.S. Environmental Protection Agency





Scenario & Baseline System Characteristics

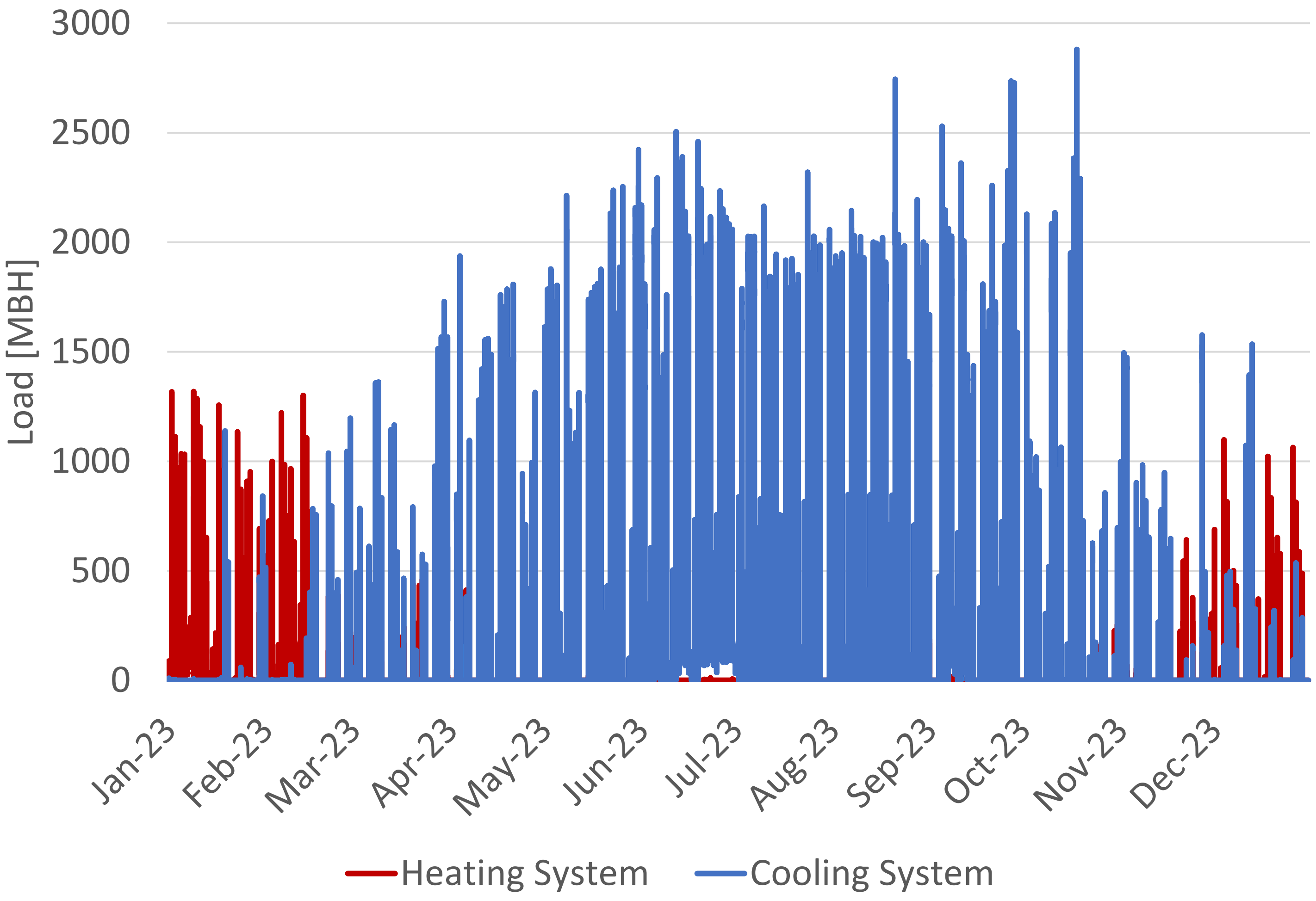
K-12 School in Atlanta

Cooling

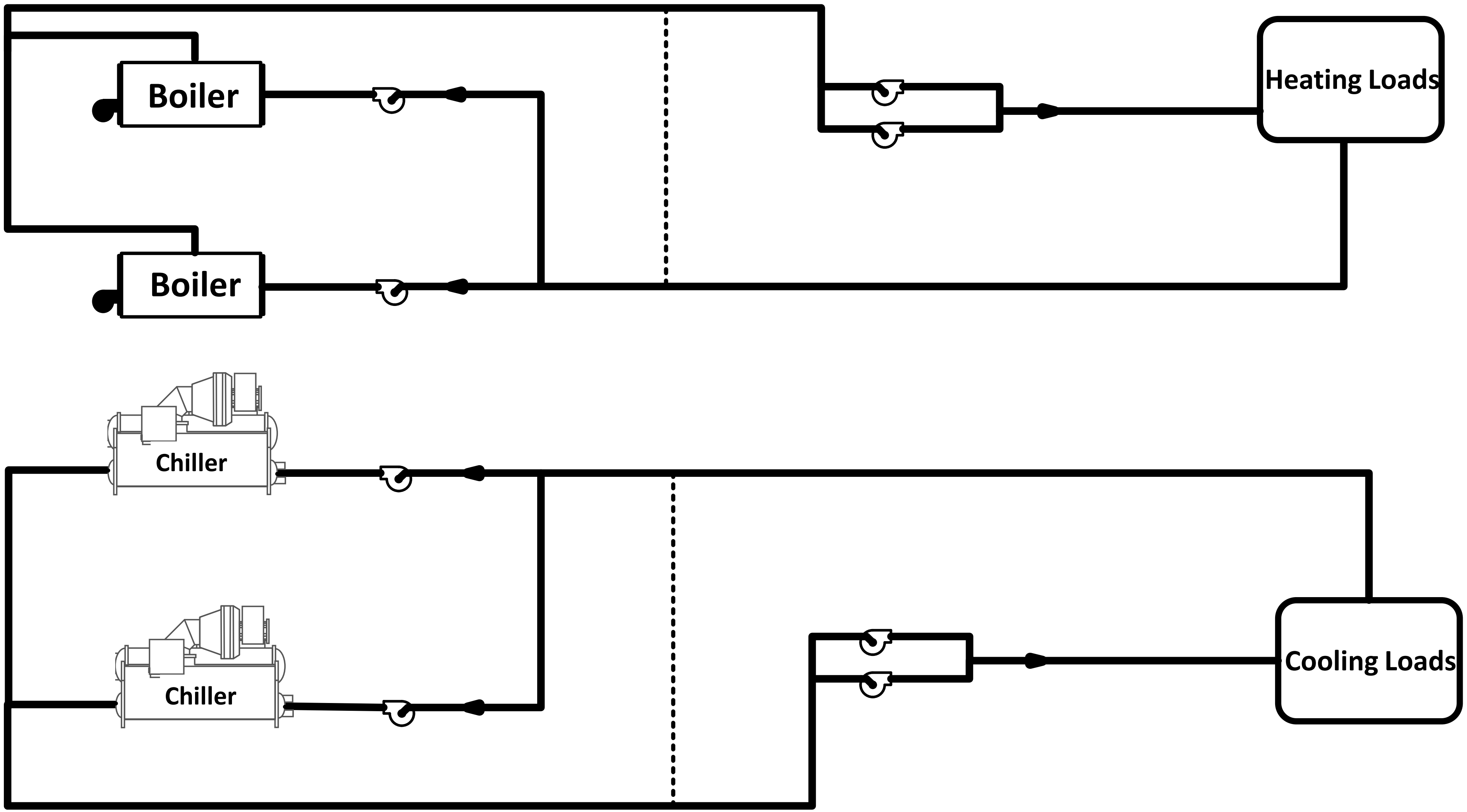
- Design load: 3,709 MBH
- Served by two 160 ton AC chillers
  - 1.19 kW/ton FL, 0.744 kW/ton NPLV

Heating

- Design load: 1,962 MBH
- Served by two 1,250 MBH natural gas boilers
  - 90% AFUE



Scenario & Baseline System Characteristics



Baseline Emissions Calculation

$$Annual\ emissions = \frac{Annual\ load}{Average\ efficiency} \times Average\ emissions\ factor$$

Heating:

$$\frac{294.16\ MMBtu}{0.9\ [efficiency]} \times 116.65\ \frac{lb\ CO_2e}{MMBtu} \left(0.000454\ \frac{metric\ tons}{lb}\right) = 17.29\ metric\ tons\ CO_2e$$

Cooling:

$$\frac{3{,}539.12\ MMBtu}{13.42\ [EER]\ /\ 3.412} \left(293.07\frac{kWh}{MMBtu}\right) \times 0.7198\ \frac{lb\ CO_2e}{kWh} \left(0.000454\ \frac{metric\ tons}{lb}\right) = 86.11\ metric\ tons\ CO_2e$$

Baseline Emissions

	Heating	Cooling
Annual load	294.16 MMBtu	3,539.12 MMBtu
Efficiency	90% (AFUE)	13.42 EER (0.894 kW/ton)
Input energy	326.84 MMBtu	263.76 MWh
Emissions factor	116.65 lb CO_2e/MMBtu	719.77 lb CO_2e/MWh
CO_2e Emissions	17.29 metric tons	86.11 metric tons
	Total Annual System CO_2e Emissions	**103.41 metric tons**

Electrification Options

Electric Boilers with Existing Chillers

Equipment

Retain existing 160 tons air cooled chillers

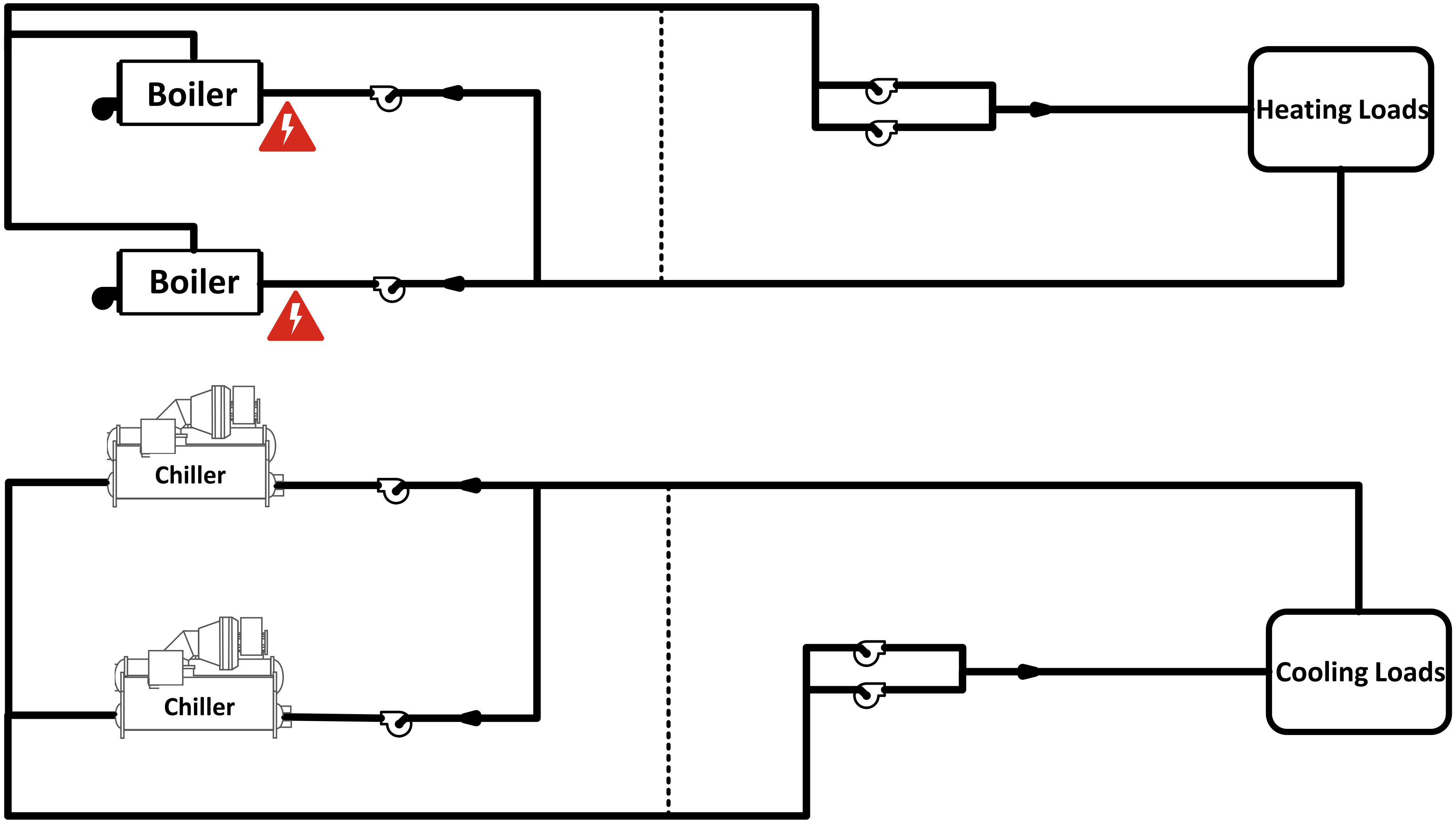
- 1.19 kW/ton FL
- 0.744 kW/ton NPLV
- 42°F CHW

Replace natural gas boilers with electric boilers

- 300 kW electric boilers, 2050 MBH
- Electrical infrastructure consideration
- 110 °F HW

Electric Boilers with Existing Chillers

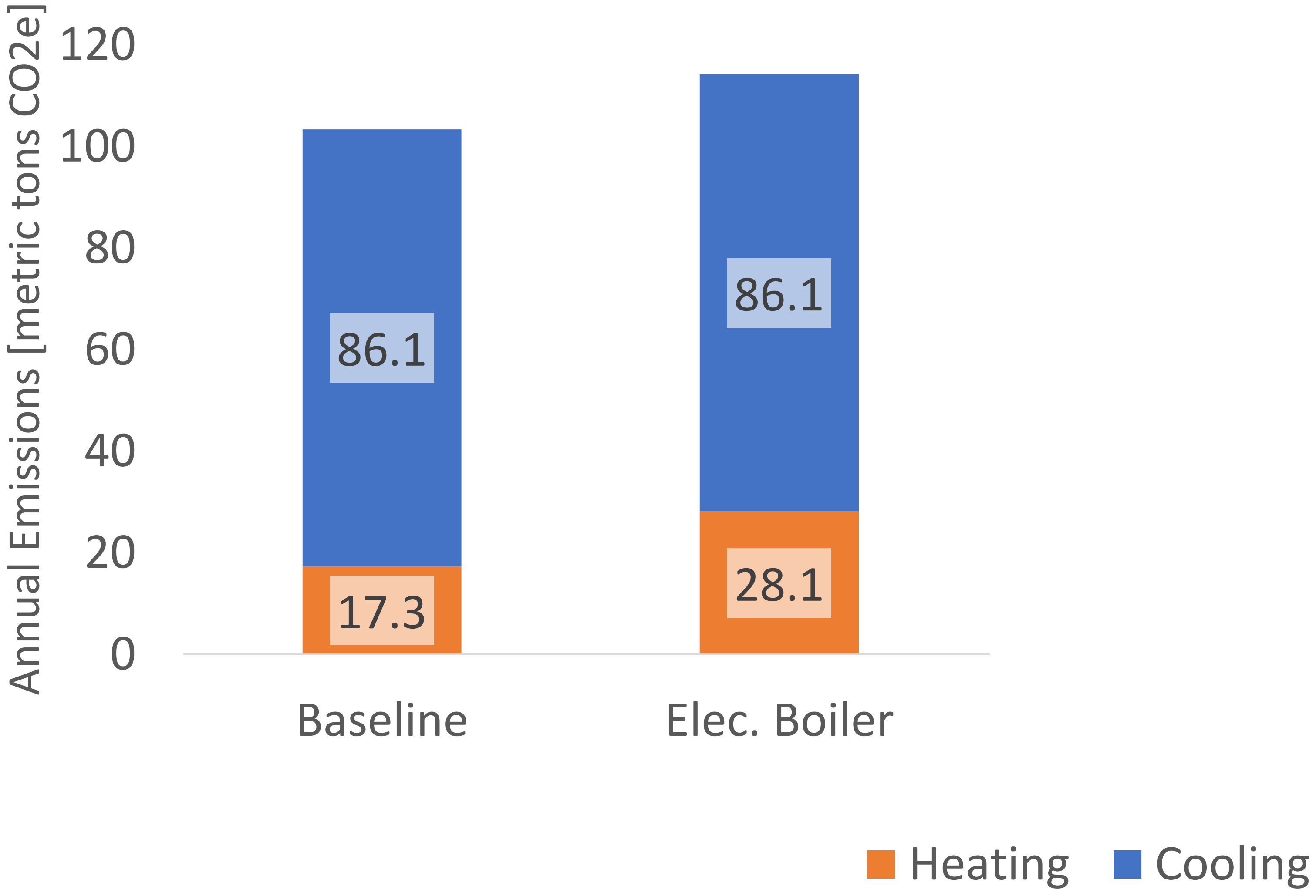
System



Electric Boilers with Existing Chillers
Emission Summary

	Heating	**Cooling**
Annual load	294.16 MMBtu	3,539.12 MMBtu
Efficiency	1 COP	13.42 EER (0.894 kW/ton)
Input energy	86.21 MWh	263.76 MWh
Emissions factor	719.77 lb CO_2e/MWh	719.77 lb CO_2e/MWh
CO_2e Emissions	28.15 metric tons	86.11 metric tons
	Total Annual System CO_2e Emissions	**114.26 metric tons**

Emissions Comparison



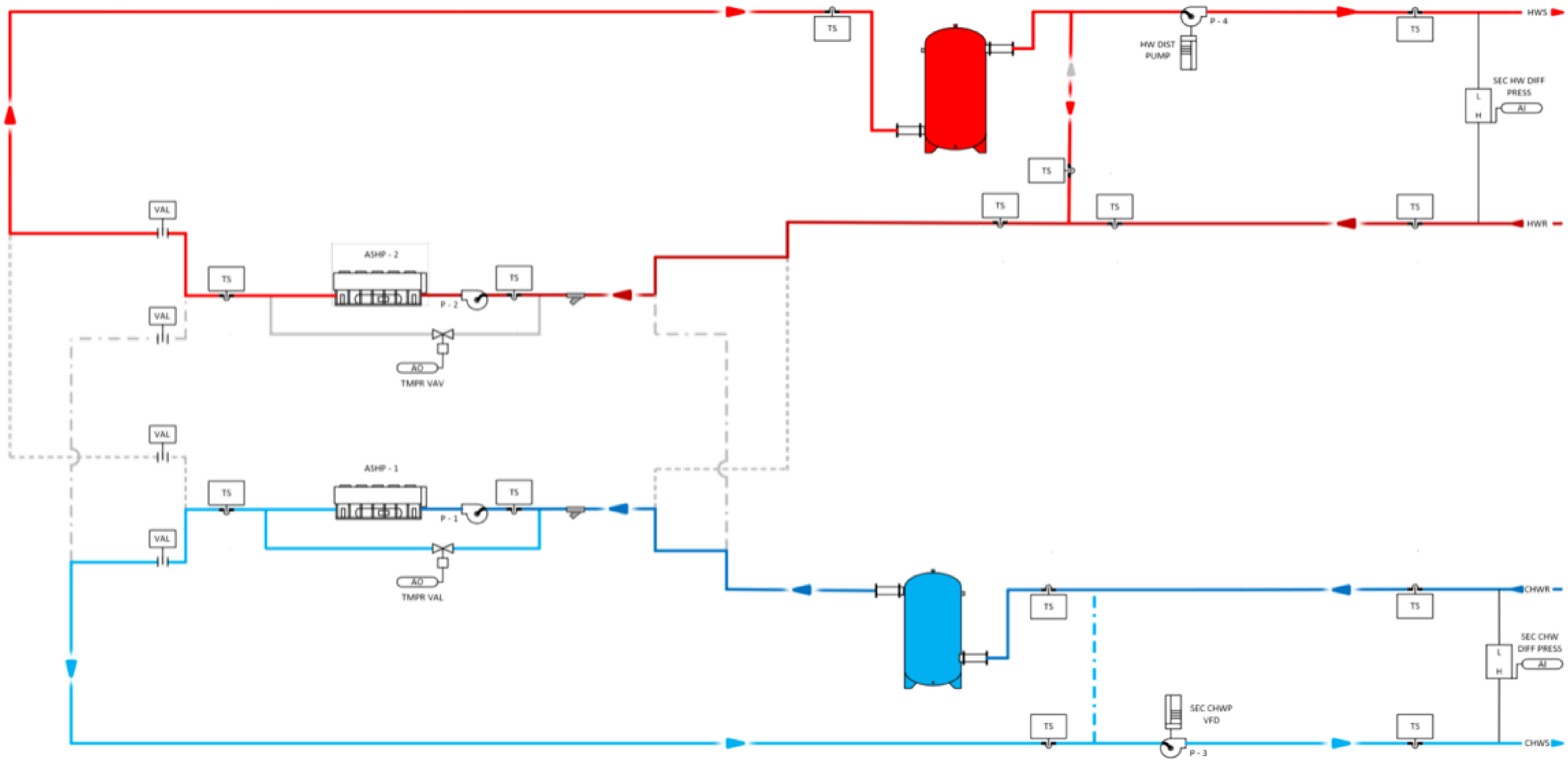
Air Source Heat Pumps with Electric Boiler Backup
Equipment

Two (2) 180 nominal ton packaged ASHPs

- Sized for cooling
- 800 MBH oversized in heating
- 1.22 kW/ton cooling
- 2.45 COP heating

Optional backup boiler for redundancy

Air Source Heat Pumps with Electric Boiler Backup
System

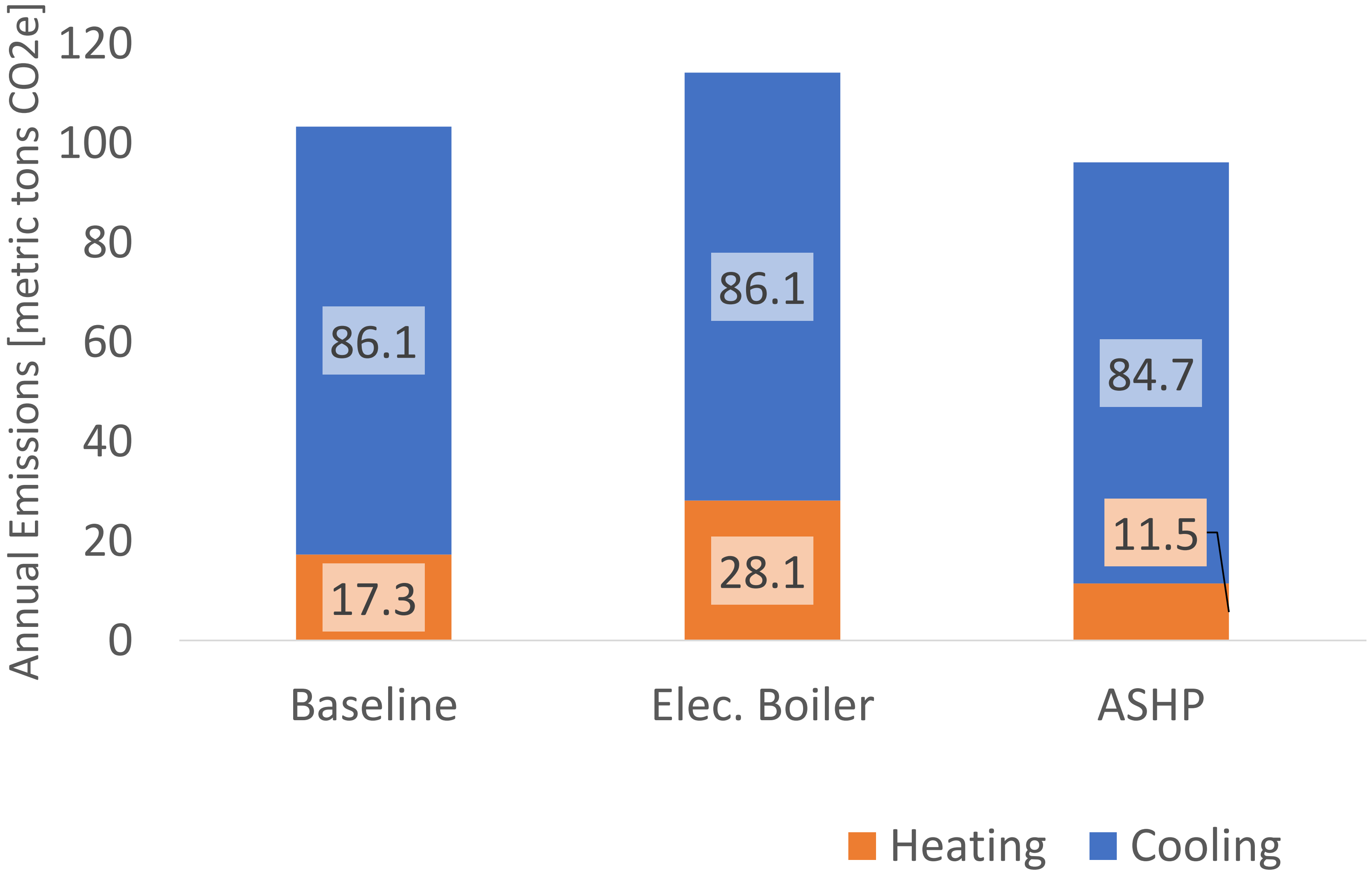


Air Source Heat Pumps with Electric Boiler Backup

Emission Summary

	Heating	Cooling
Annual load	294.16 MMBtu	3,539.12 MMBtu
Efficiency	2.45 COP	13.64 EER (0.880 kW/ton)
Input energy	35.19 MWh	259.41 MWh
Emissions factor	719.77 lb CO_2e/MWh	719.77 lb CO_2e/MWh
CO_2e Emissions	11.49 metric tons	84.69 metric tons
	Total Annual System CO_2e Emissions	**128.91 metric tons**

Emissions Comparison



Ground Water Heat Pump

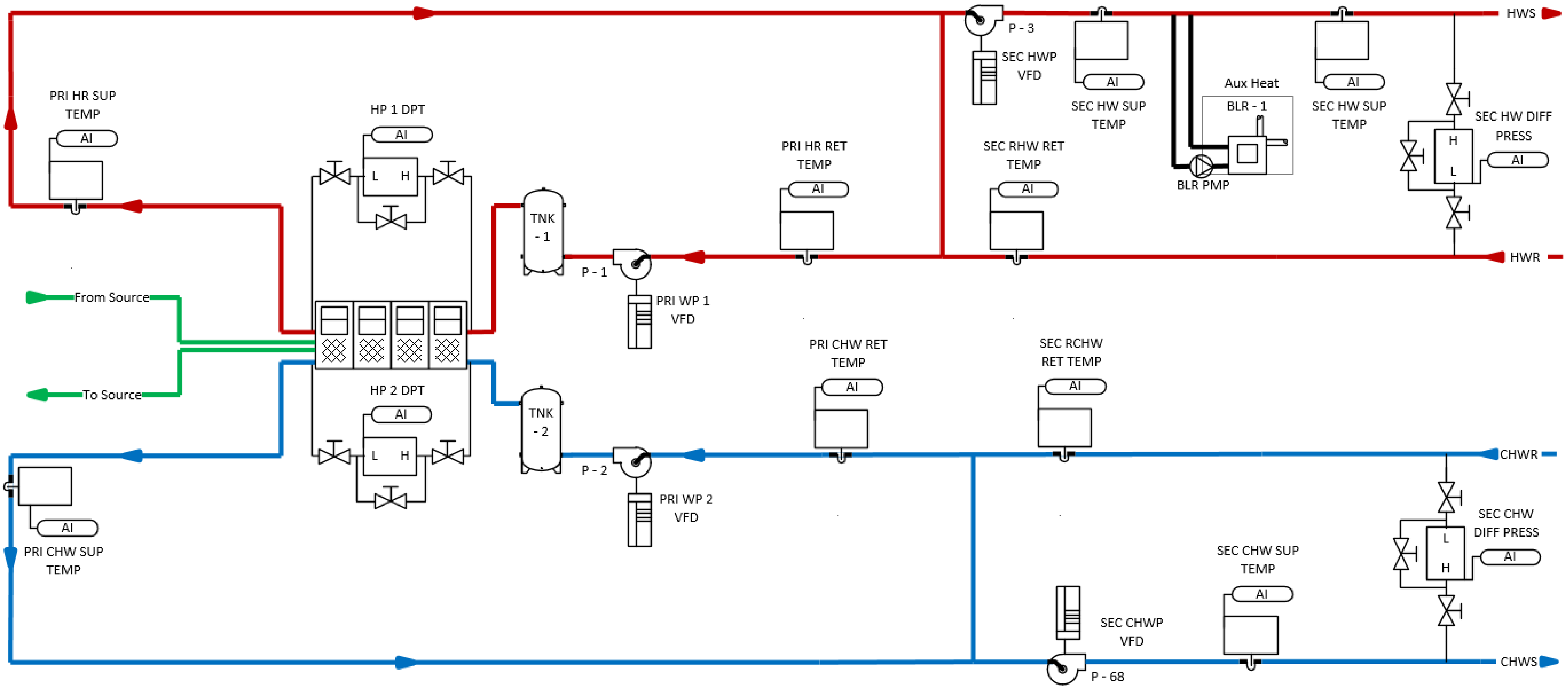
Equipment

6 Pipe Modular heat pump with full heat recovery

- Average ground temp of 67°F
- Cooling - 310 tons, 0.62 kW/ton
- Heating - 4710 MBH, 5.28 COP
- Simultaneous – 267 tons cooling, 4060 MBH heating, 8.45 COP (0.944 kW/ton)

Ground Water Heat Pump

System

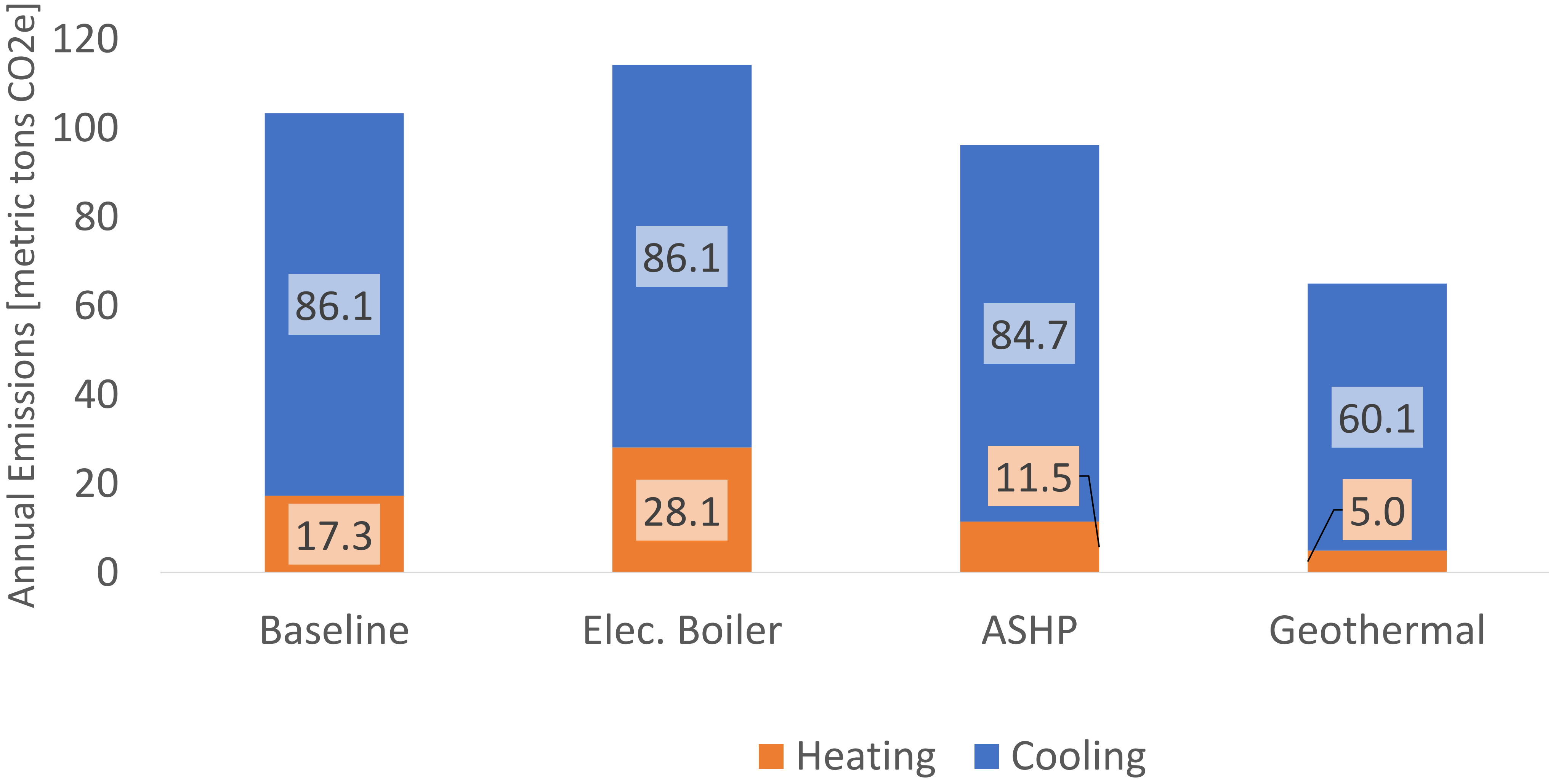


Ground Water Heat Pump

Emission Summary

	Non-Simultaneous		Simultaneous	
	Heating	**Cooling**	**Heating**	**Cooling**
Annual load	243.22 MMBtu	3,486.63 MMBtu	49.62 MMBtu	49.62 MMBtu
Efficiency	5.28 COP	10.35 EER 0.62 kW/ton	8.45 COP	12.71 EER 0.944 kW/ton
Input energy	13.50 MWh	180.14 MWh	1.72 MWh	3.90 MWh
Emissions factor	719.77 lb CO2e/MWh	719.77 lb CO2e/MWh	719.77 lb CO2e/MWh	719.77 lb CO2e/MWh
CO_2e Emissions	4.41 metric tons	58.81 metric tons	0.56 metric tons	1.27 metric tons
			Total Annual System CO_2e Emissions	**65.06 metric tons**

Emissions Comparison



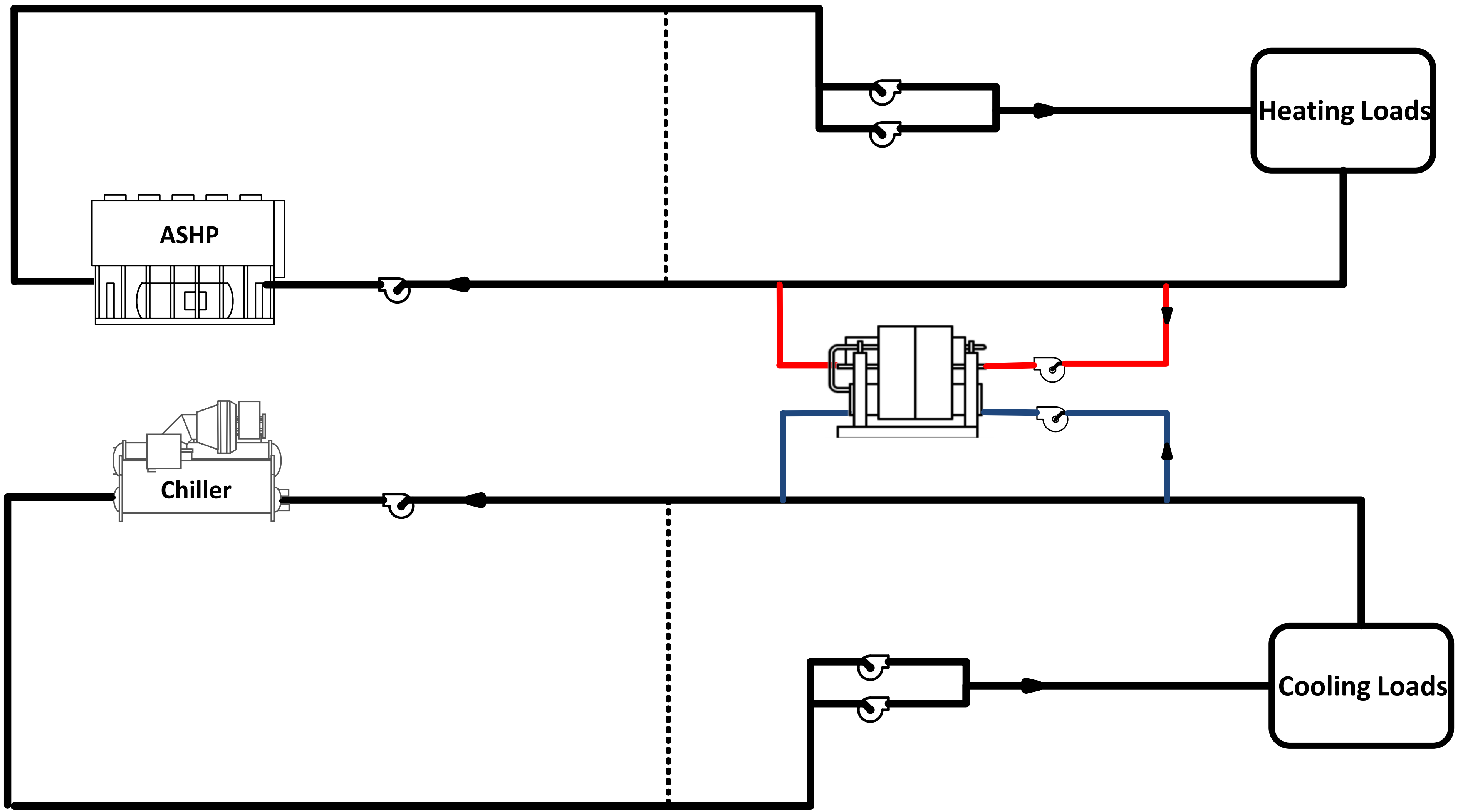
Heat Recovery with High Efficiency AC chiller and ASHP
Equipment

High Efficiency air-cooled chiller
- Sized for peak cooling
- 1.14 kW/ton FL
- 0.63 kW/ton NPLV

Air-source heat pump
- Sized for peak heating
- 2.45 COP

Heat recovery chiller
- Sized shy of peak simultaneous heating & cooling
- 40 tons
- 8.65 combined COP

Heat Recovery with High Efficiency AC chiller and ASHP
System

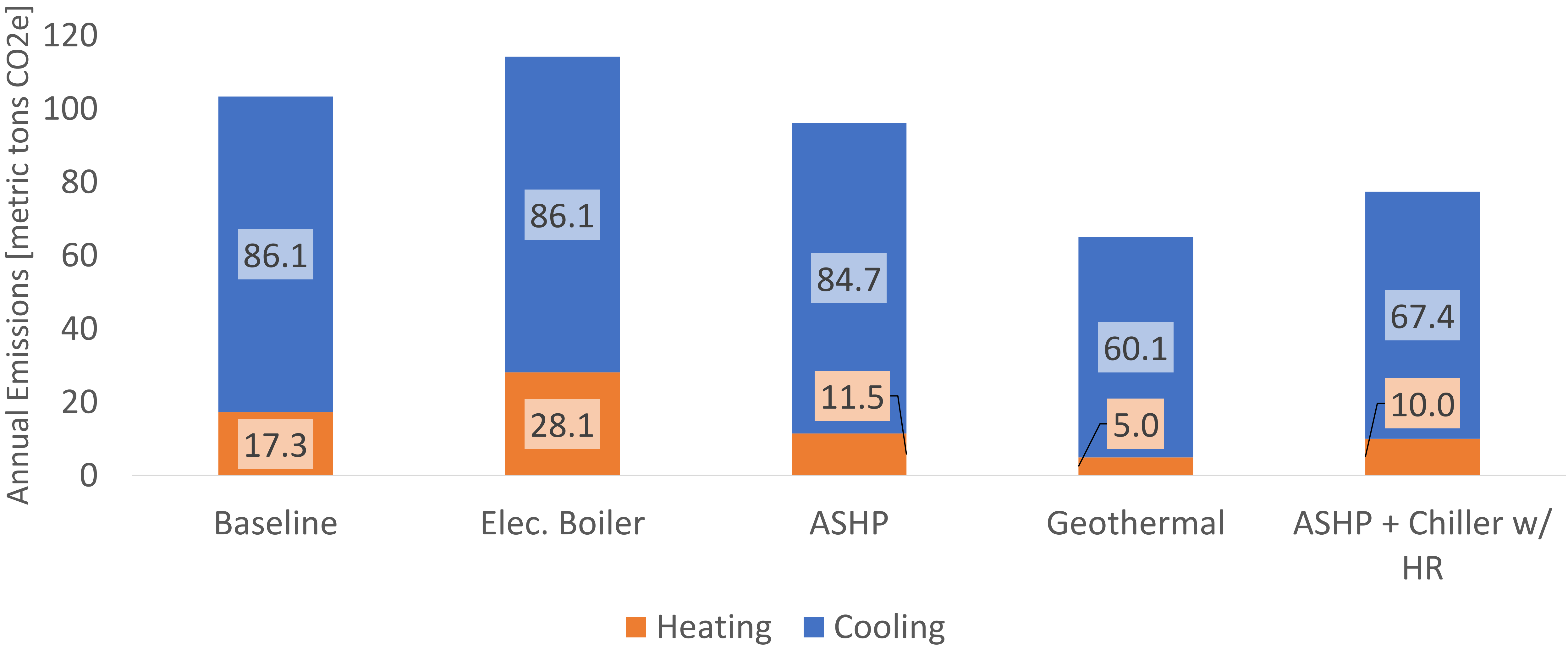


Heat Recovery with High Efficiency AC chiller and ASHP

Emission Summary

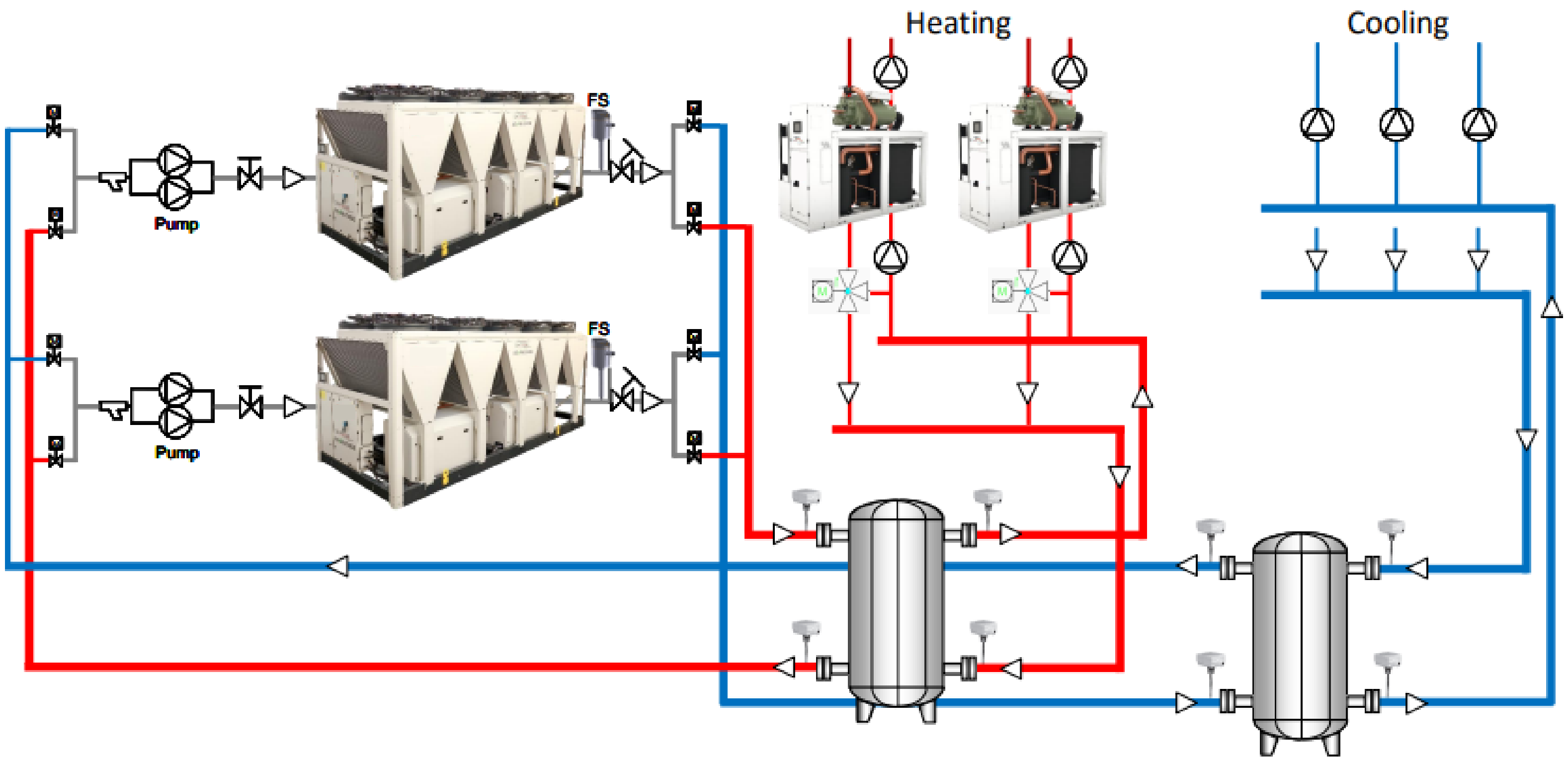
	Non-Simultaneous		Simultaneous	
	Heating only	**Cooling only**	**Simultaneous: Heating**	**Simultaneous: Cooling**
Annual load	243.22 MMBtu	3,486.63 MMBtu	49.62 MMBtu	49.62 MMBtu
Efficiency	2.45 COP	17.22 EER (0.697 kW/ton)	8.65 COP	12.71 EER 0.944 kW/ton
Input energy	29.09 MWh	202.43 MWh	1.68 MWh	3.90 MWh
Emissions factor	719.77 lb CO_2e/MWh	719.77 lb CO_2e/MWh	719.77 lb CO_2e/MWh	719.77 lb CO_2e/MWh
CO_2e Emissions	9.50 metric tons	66.09 metric tons	0.55 metric tons	1.27 metric tons
			Total Annual System CO_2e Emissions	**71.08 metric tons**

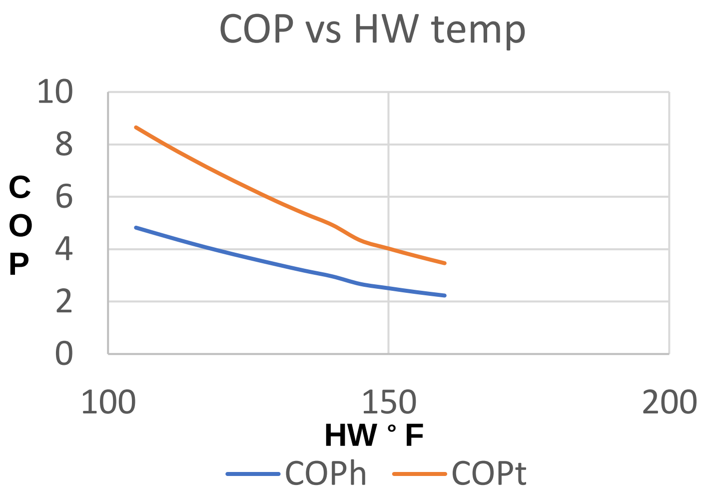
Emissions Comparison



Heat Recovery with High Efficiency AC chiller and ASHP: Cascade for High Temp

Utilize heating loop as source to boost HW temp



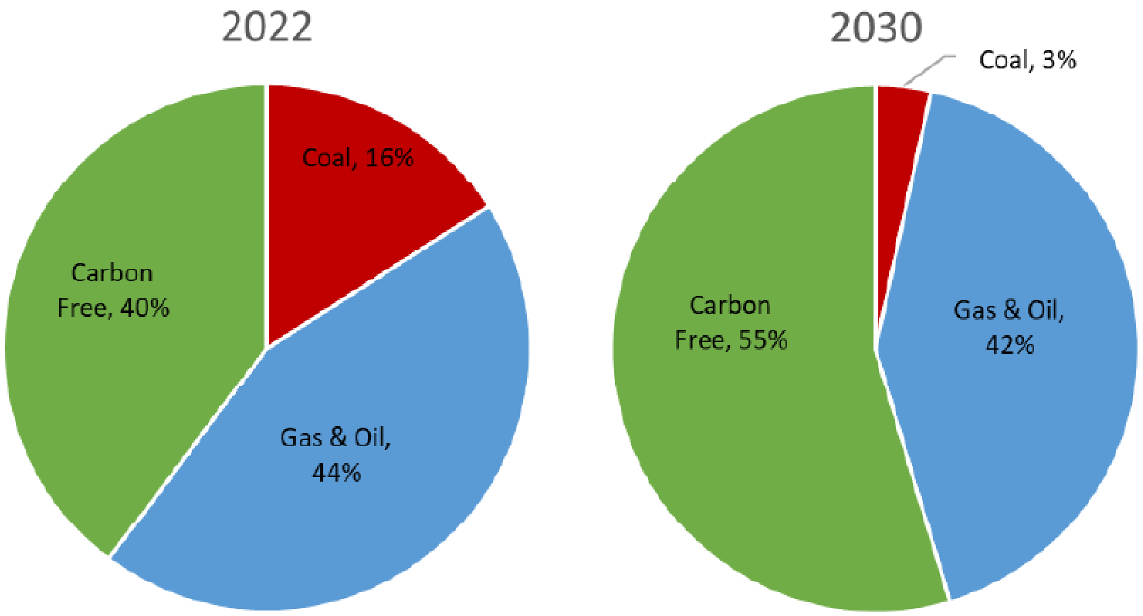


Conclusions

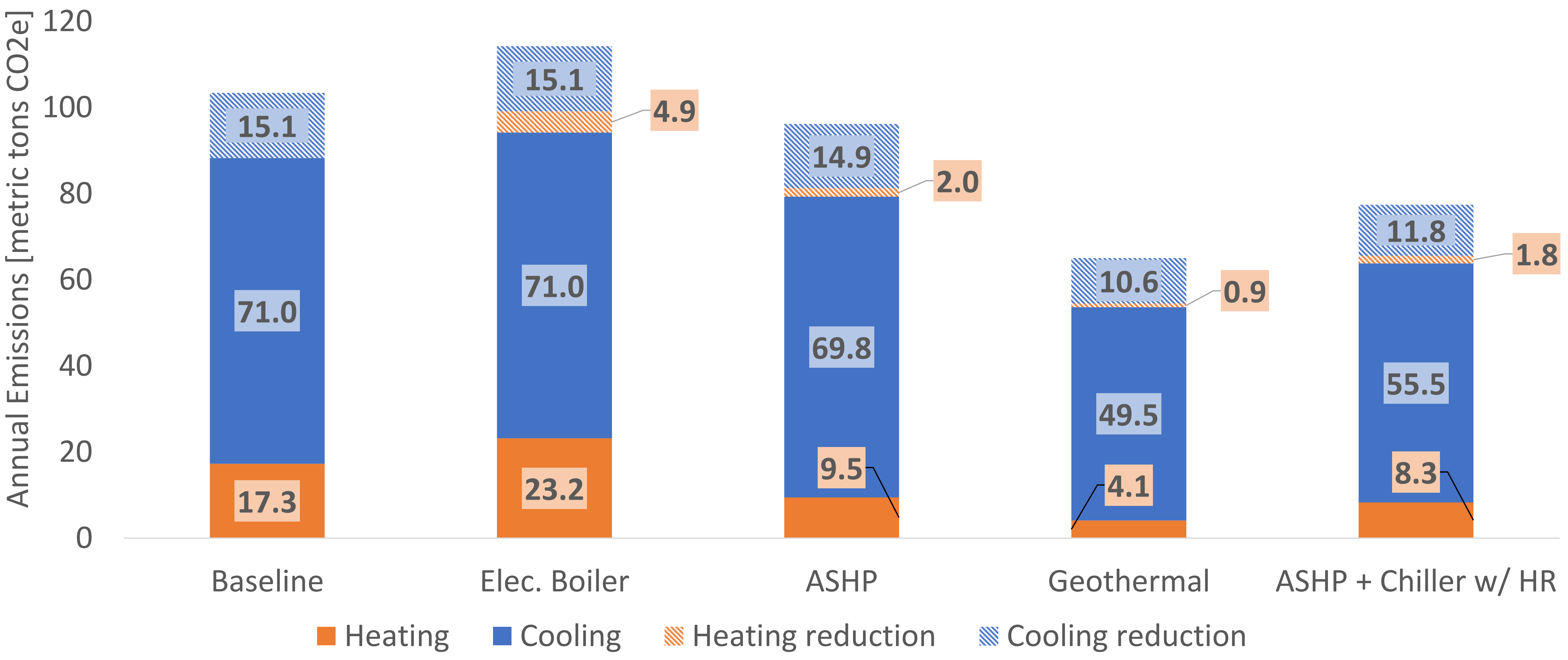
Emissions Comparison – Projected Emissions

Georgia Power Company's 2022 Integrated Resource Plan (IRP) indicates that by 2030 it will rely significantly more on carbon-free energy and less on coal (State of Georgia Public Service Commission, 2022).

Based on the projected source mix in 2030, we can estimate the 2030 average emissions factor to be 593.26 lb CO2e / MWh



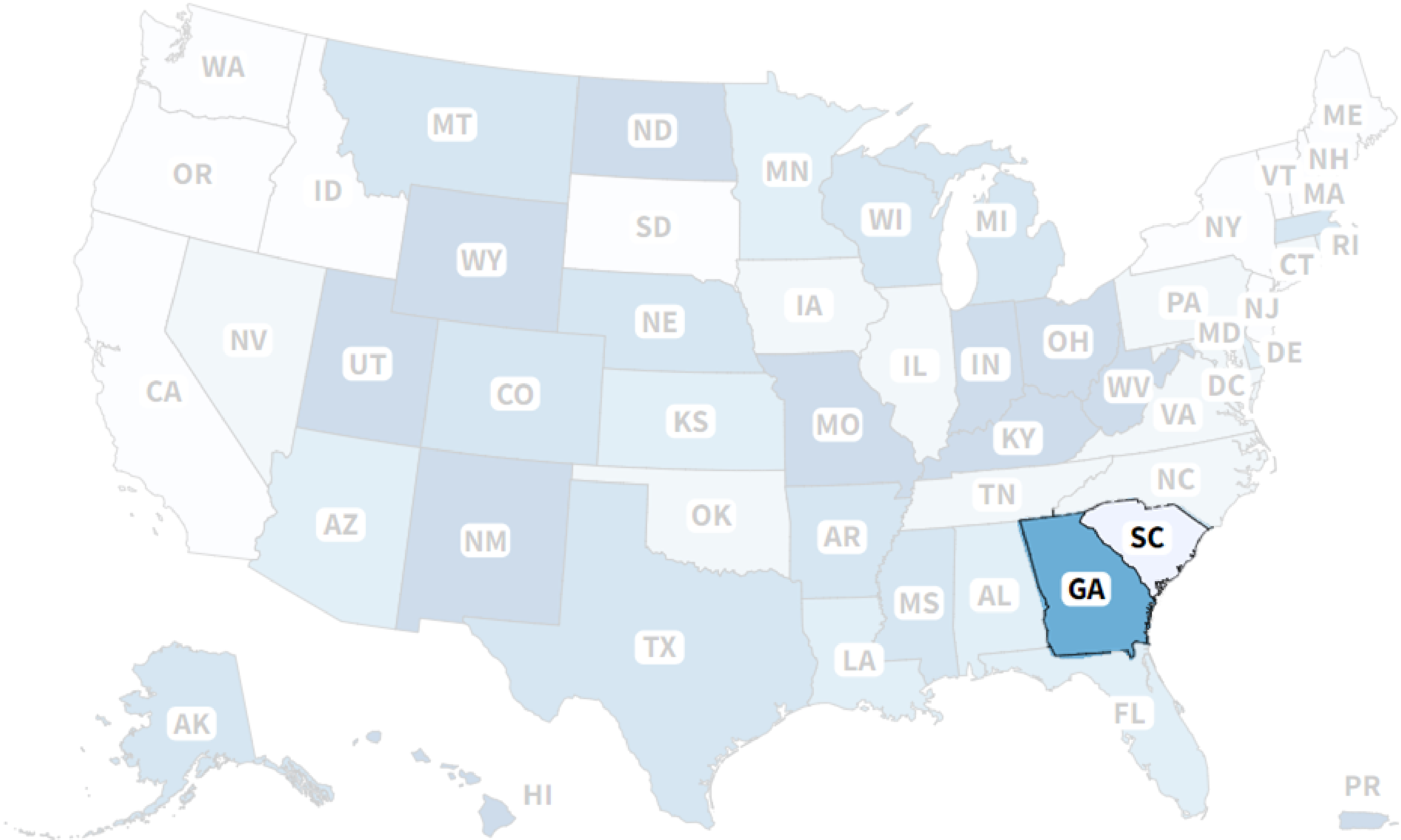
Emissions Comparison – Projected 2030 Emissions



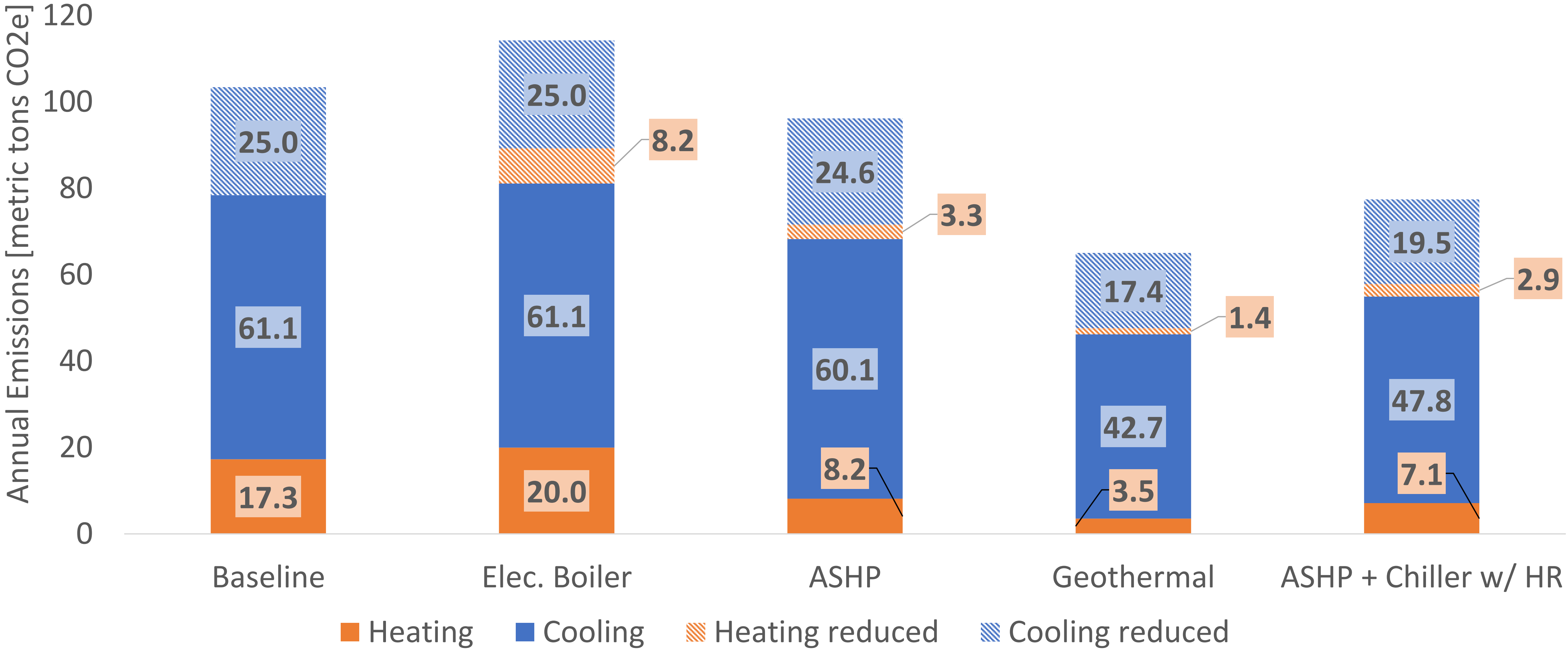
Emissions Comparison – South Carolina

How would emissions change if this project was located in an area served by a less emissions intensive grid?

South Carolina has a 2020 annual emissions factor of 510.19 lb CO_2e / MWh



Emissions Comparison – South Carolina



Conclusion: Key Takeaways

Emissions savings from electrification are highly dependent on a variety of factors:

- Location
  - Emissions factor for purchased electricity
  - Ambient conditions impacting efficiency of the system
- Energy sources
  - Is clean energy available either from the grid or a behind-the-meter source?
  - Design for sustainability: consider grid decarbonization over the lifetime of the system
- System conditions
  - Required supply temperatures
  - Will electrical upgrades be required?

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State of Georgia Public Service Commission, 2022, Document Filing #188519. psc.ga.gov/search/facts-document/?documentId=188519

Electric boiler image:

Laars Heating System Company, Commercial Electric Boiler. laars.com/products/product/commercial-electric-boiler

All images provided courtesy of Trane unless otherwise noted

Questions

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