Multifamily Domestic Hot Water (DHW) Greenhouse Gas (GHG) and Costs

Gas emerging technologies program (GET)

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Presenter: Cristalle Mauleon, Engineering Manager

August 19, 2025

Our Team

Nicholas Fette

Project Manager, Lincus

Steven Long, P.E.

Director of Engineering, ICF

Nicolas Campbell

Project Manager, Lincus

Cristalle Mauleon

Engineering Manager, Lincus

Agenda

- Introduction
- Background
- Assessment Objectives
- Utility Rate Tariffs and Emission Analysis
- DHW Models, Emissions, and Fuel Costs
- TSB and Simple Payback Analysis
- Conclusions

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Introduction

- Key Focus Areas
  - Energy consumption
  - Operating costs
  - Greenhouse gas (GHG) emissions
- System Comparisons
  - Baseline: 84% efficient gas boiler
  - Condensing Boiler: 97% efficient
  - Electric Heat Pump Water Heater (EHPWH)
  - Gas Absorption Heat Pump (GAHP)
  - Preheats make-up water & reheats recirculation (Case 3)
  - Preheats make-up water only (Case 4)
- GAHP Advantages
  - Lower GHG emissions
  - Improved energy efficiency
  - Cost-effective in California climate

Background

- Key Insights from Prior GET Studies
  - Heat Pump Operating Costs
  - Up to 144% higher than gas furnaces in single-family homes when used in a space heating application (ET23SWG005)
- Impact on Renters
  - Higher DHW costs in multifamily buildings may lead to increased rent burdens
- Capital Cost Challenges
  - EHPWH retrofits often require large storage tanks and may require roof installations due to space constraints (ET23SWG0012).
  - EHPWH retrofits may also be constrained by the existing electric panel capacity leading to expensive retrofits

Assessment Objectives

Modeling study of DHW systems in multifamily buildings using models based upon approved DEER prototypes.

1. Compare metrics for (5) DHW systems:
    - Baseline: 84% efficient gas-fired boiler
    - Measure Case 1: 97% efficient condensing gas-fired boiler
    - Measure Case 2: EHPWH
    - Measure Case 3: GAHP paired w/boiler - preheating city water and reheating of recirculation water
    - Measure Case 4: GAHP paired w/boiler - preheating city water only

2. Metrics to be compared:
    a. Utility capital costs
    b. Return on investment (ROI)
    c. Greenhouse gas (GHG) impacts
    d. Total system benefit (TSB)

Utility Rate Tariffs and Emission Analysis

Climate Zone – Utility Mapping

- Estimating operating costs and GHG emissions using available rate tariffs and the IOU balancing the region.
- One IOU in each climate zone is used.
- This results in one electric tariff per climate zone and service type.
  - Tiered
  - TOU

CA Climate Zone	Electric	Gas	IOU balancing area region
CZ01	PG&E	PG&E	NP-15
CZ02	PG&E	PG&E	NP-15
CZ03	PG&E	PG&E	NP-15
CZ04	PG&E	PG&E	NP-15
CZ05	PG&E	PG&E	NP-15
CZ06	SCE	SCG	SP-15
CZ07	SDG&E	SDG&E	SP-15
CZ08	SCE	SCG	SP-15
CZ09	SCE	SCG	SP-15
CZ10	SCE	SCG	SP-15
CZ11	PG&E	PG&E	NP-15
CZ12	PG&E	PG&E	NP-15
CZ13	PG&E	PG&E	NP-15
CZ14	SCE	SCG	SP-15
CZ15	SCE	SCG	SP-15
CZ16	SCE	SCG	SP-15

Electric Rate Tariffs

- Representative electric rate tariffs were chosen for this analysis from each IOU, both for tiered and time-of-use (TOU) plans.
  - Multifamily eligibility
  - No unique qualifiers such as EV, solar, IOU employment, etc.
  - Most widely applicable from each IOU

Representative Electric Rate Tariffs by IOU

IOU	Type of Service	Electric Rate Tariff
PG&E	Tiered	ES – Multifamily Service
	TOU	TOU – C – Residential Time-of-use
SCE	Tiered	D: Domestic Service
	TOU	TOU – D – 4-9PM
SDG&E	Tiered	DS – Domestic Service
	TOU	TOU – DR – Residential – Time of Use Service

Cost Calculation Methods

- Cost Calculation Approach
  – All tariffs include fixed monthly/daily charges
  – Climate zone, season, and baseline allowances affect costs
  – EnergyPlus models output whole-building and DHW system usage
  – Excel tool automates cost and emissions calculations
    - Inputs: hourly energy data, climate zone, service type, start year
    - Outputs: monthly usage, costs, emissions

Electric Rate Tariffs

Multifamily Model Cost per kWh Analysis with PG&E Schedule ES – Multifamily Service

Month	kWh Usage	Monthly Baseline	Highest Tier this Month	Total	Marginal $/kWh
January	268.31	251.1	Tier 2	$117.17	$0.4367
February	244.70	226.8	Tier 2	$106.98	$0.4372
March	266.37	251.1	Tier 2	$116.23	$0.4363
April	258.09	243	Tier 2	$112.64	$0.4364
May	266.71	251.1	Tier 2	$116.40	$0.4364
June	265.57	213	Tier 2	$119.21	$0.4489
July	268.91	220.1	Tier 2	$120.50	$0.4481
August	273.54	220.1	Tier 2	$122.75	$0.4487
September	260.23	213	Tier 2	$116.61	$0.4481
October	268.20	251.1	Tier 2	$117.12	$0.4367
November	261.11	243	Tier 2	$114.10	$0.4370
December	271.23	251.1	Tier 2	$118.59	$0.4372

Gas Rate Tariffs

- The same sources and methods used for choosing the representative electric tariffs were also applied to choose the gas tariffs.
- There are far fewer options for natural gas rates.

Representative Gas Rate Tariffs by IOU

IOU	Default Electric Rate Tariff
PG&E	G-1: Residential Service
	GS: Multifamily Service
SoCalGas	GS: Multifamily Service
	GM: Master-Metered Multifamily Service
SDG&E	GS: Multifamily Service
	GM: Master-Metered Multifamily Service

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Gas Rate Tariffs

Multifamily Model Cost per Therm Analysis with PG&E Schedule G-1

Month	Therms Usage	Monthly Baseline (Therms)	Highest Tier this Month	Total	Marginal $/Therms
January	38.73	79.98	Baseline	$87.84	$2.2680
February	39.90	62.16	Baseline	$89.98	$2.2551
March	34.52	68.82	Baseline	$78.74	$2.2810
April	36.69	21.6	Excess	$89.98	$2.4524
May	32.71	22.32	Excess	$79.44	$2.4286
June	30.81	21.6	Excess	$74.67	$2.4236
July	31.80	22.32	Excess	$77.06	$2.4233
August	31.88	22.32	Excess	$77.26	$2.4235
September	30.92	21.6	Excess	$74.95	$2.4240
October	32.79	22.32	Excess	$79.63	$2.4285
November	35.66	66.6	Baseline	$81.08	$2.2737
December	41.01	79.98	Baseline	$92.77	$2.2621

GHG Emissions Factors

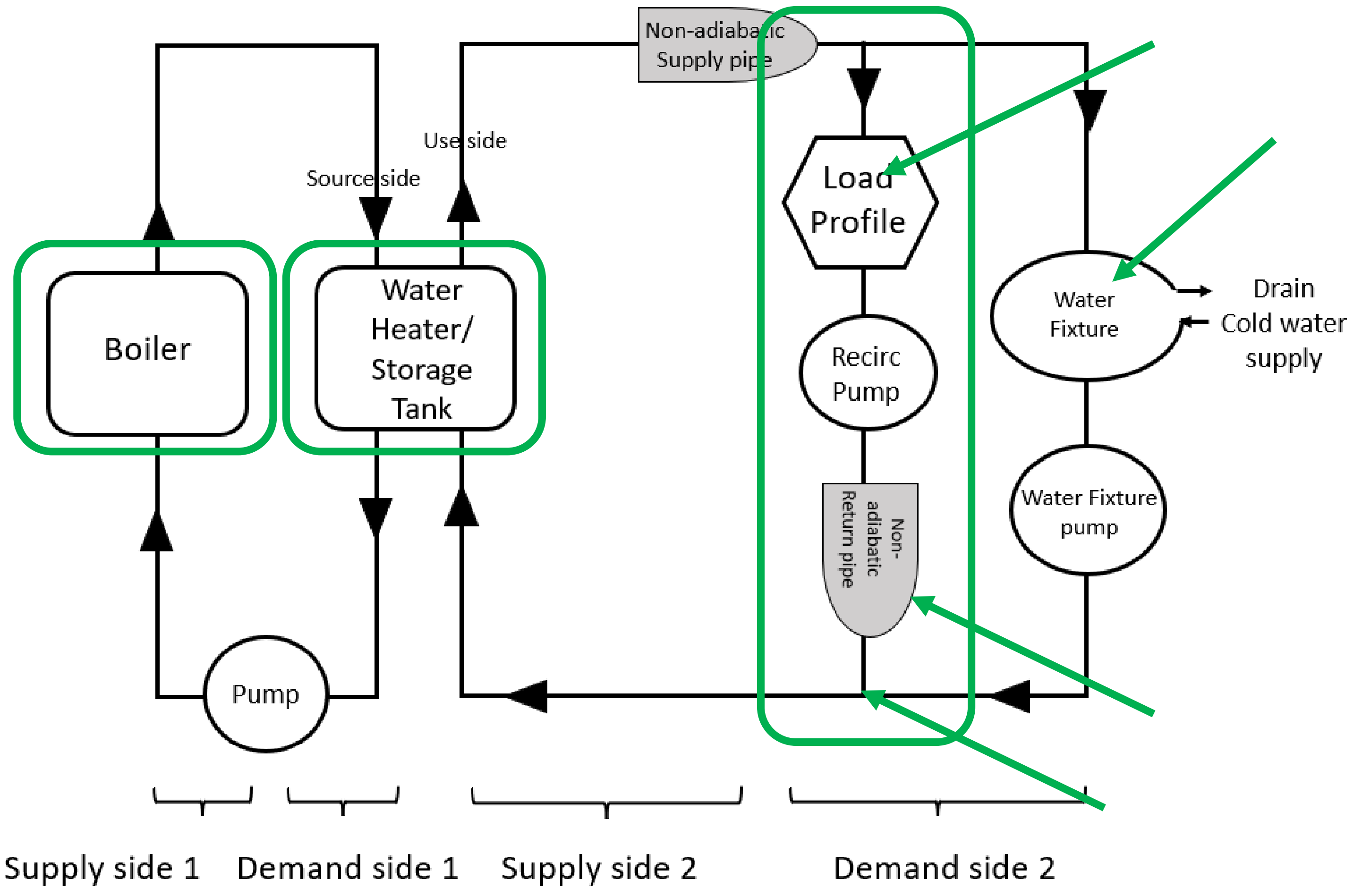
- To evaluate and optimize source fuel usage or greenhouse gas emissions, source fuel and GHG factors from the 2024 CPUC California ACC Electric and Gas models were used.

AC/Gas Furnace Model, Gas Water Heaters Emissions Analysis

Month	System kWh Usage	System Therms Usage	Facility kWh Usage	Facility Therms Usage	System GHG Emissions (kg/CO2/yr)	Facility GHG Emissions (kg/CO2/yr)
January	-	30.37	268.31	38.73	161.17	330.38
February	-	27.47	244.70	39.90	145.80	309.40
March	-	30.30	266.37	34.52	160.81	272.35
April	-	29.34	258.09	36.69	155.71	272.19
May	-	30.29	266.71	32.71	160.77	253.63
June	-	29.15	265.57	30.81	154.71	263.84
July	-	30.09	268.91	31.80	159.67	275.73
August	-	30.15	273.54	31.88	160.01	299.91
September	-	29.21	260.23	30.92	155.00	281.61
October	-	30.25	268.20	32.79	160.53	294.75
November	-	29.40	261.11	35.66	156.05	304.38
December	-	30.35	271.23	41.01	161.06	338.36

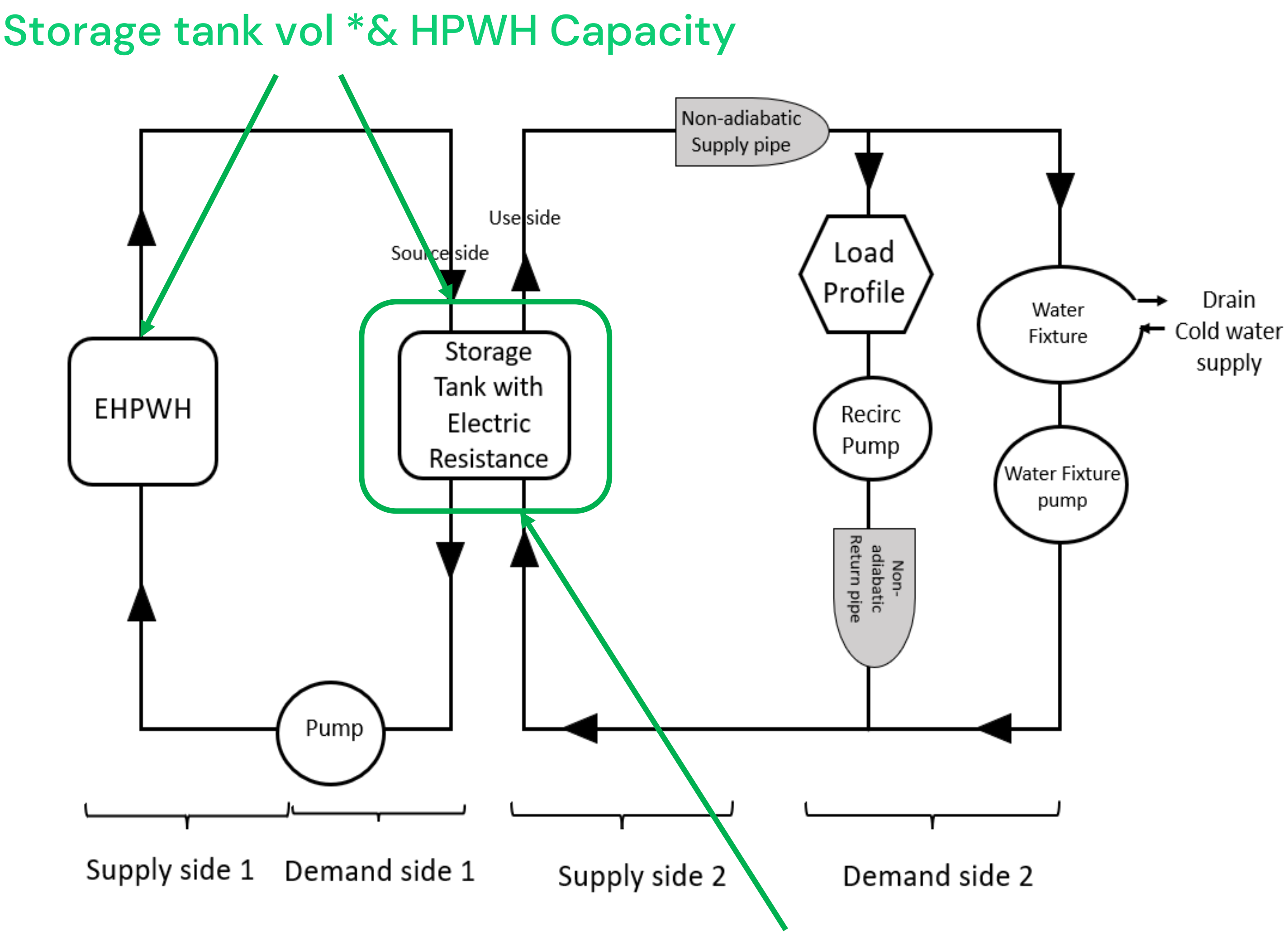
DHW Models, Emissions, and Fuel Costs

Base Case: Boiler with 84% Thermal Efficiency & Measure Case 1: Condensing Boiler with 97% Thermal Efficiency



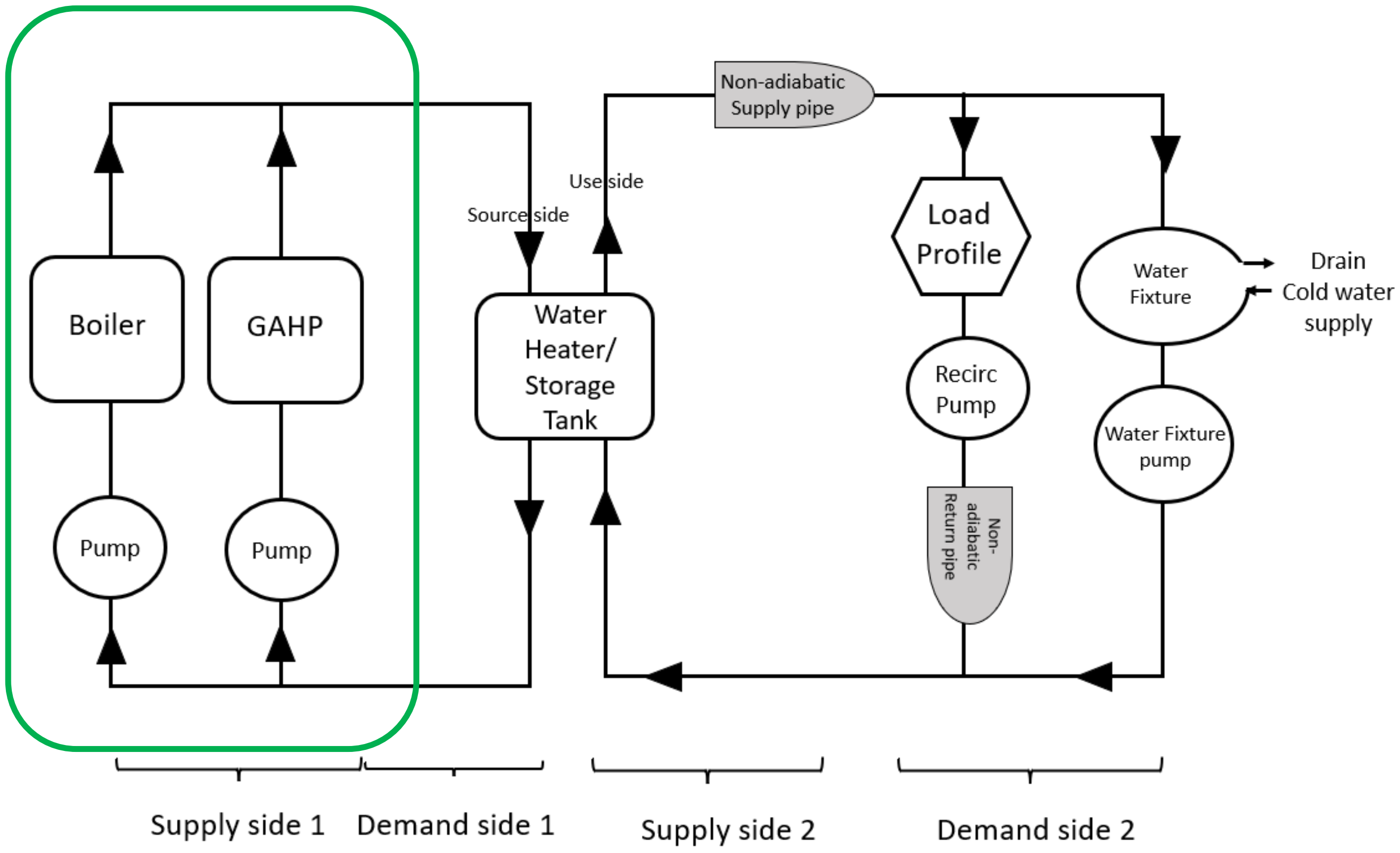
- EnergyPlus translated architecture
- Outlet of the water heater/storage tank on the use side temperature setpoint = 135 °F
- Base case
  - 84% thermal efficiency
  - Non-condensing boiler efficiency curve
- Measure case 1
  - 97% thermal efficiency
  - Condensing boiler efficiency curve

Measure Case 2: Electric Heat Pump Water Heater (EHPWH)



- EnergyPlus translated architecture
- The storage tank includes an electric resistance as a backup to compensate for any temperature drops below a specified threshold.
  - Tank setpoint temperature = 135 °F
  - Deadband = 3.6 °F
- Ecosizer tool
  - Used to determine the appropriate tank volume and heating capacity
  - The curve fit is then hardcoded into EnergyPlus

Measure Case 3: GAHP Acting as Preheat and Reheating Recirc Water



- EnergyPlus translated architecture
- GAHP and boiler operate in parallel to heat the storage tank
  - Load distribution scheme are set to "Optimal" in EnergyPlus
- Outlet of the water heater/storage tank on the use side temperature setpoint = 135 °F
- Robur GAHP with a capacity of 123 kBTU is used
- Boiler and tank capacities are already auto-sized in the base case

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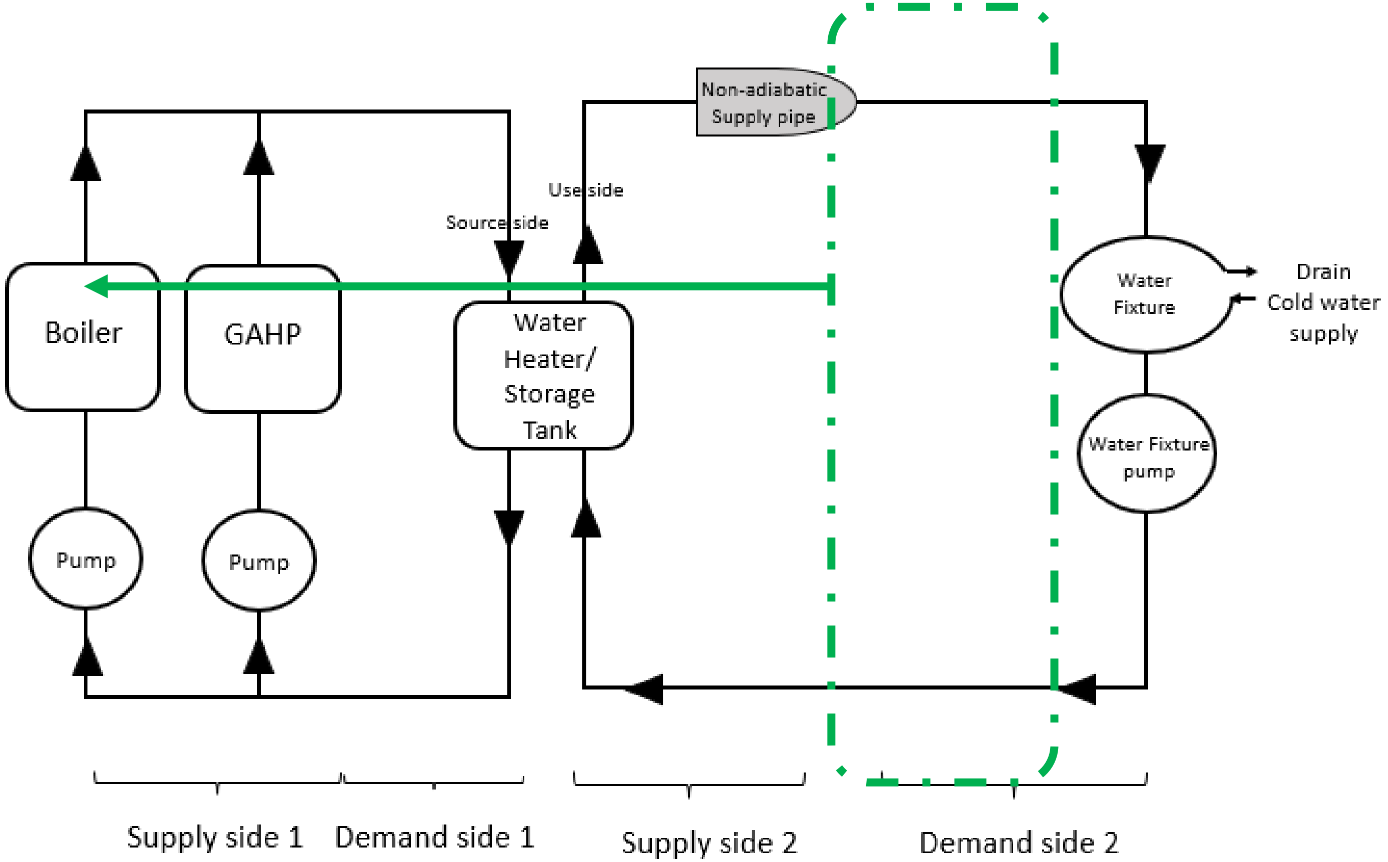
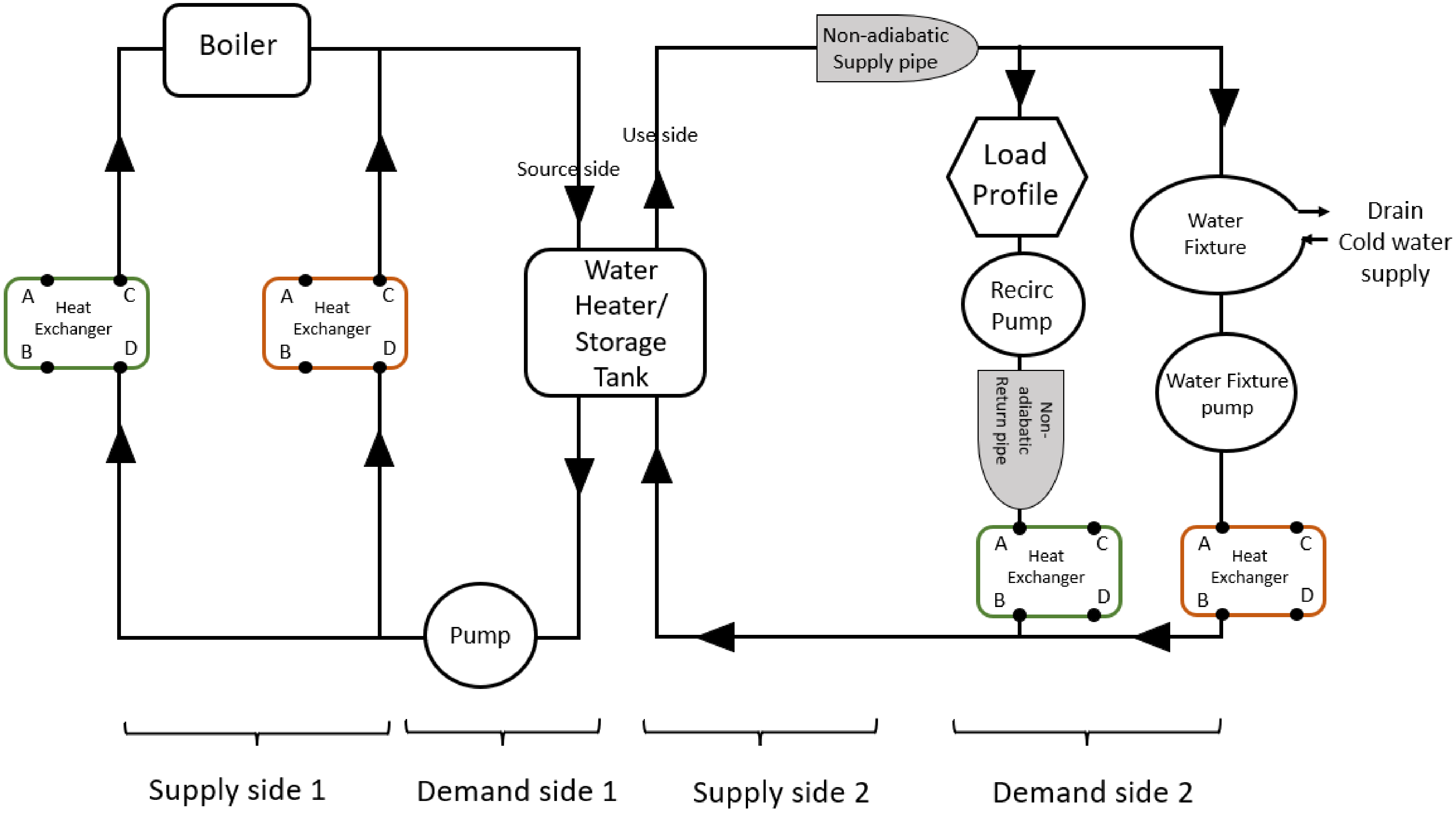
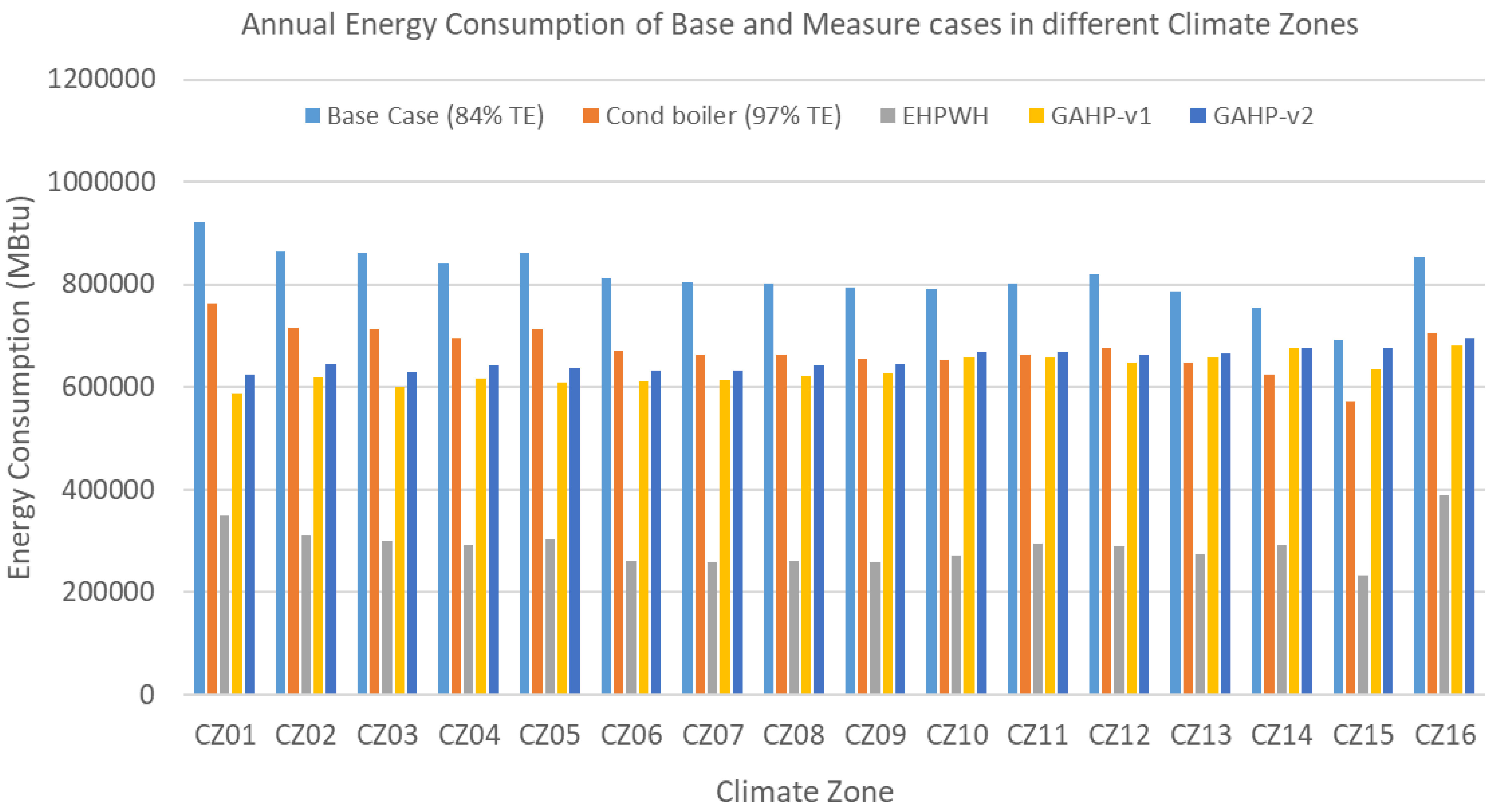
Measure Case 4: GAHP Acting as Preheat

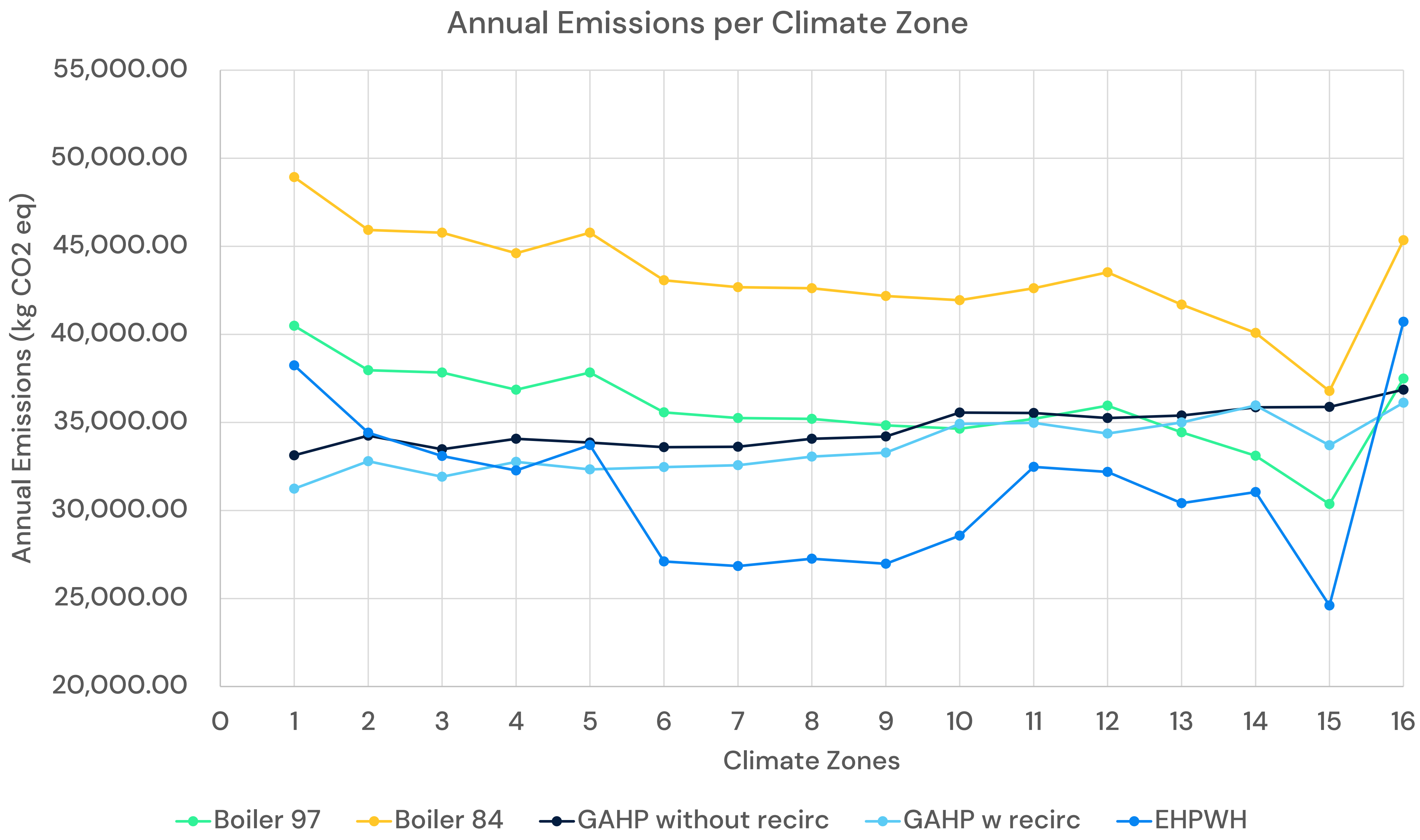


- EnergyPlus translated architecture
- Modified by removing the recirculation branch from the right loop
  - Calculated recirculation energy use is added to the boiler energy consumption in the left loop
  - Makes boiler responsible for heating recirc water rather than GAHP

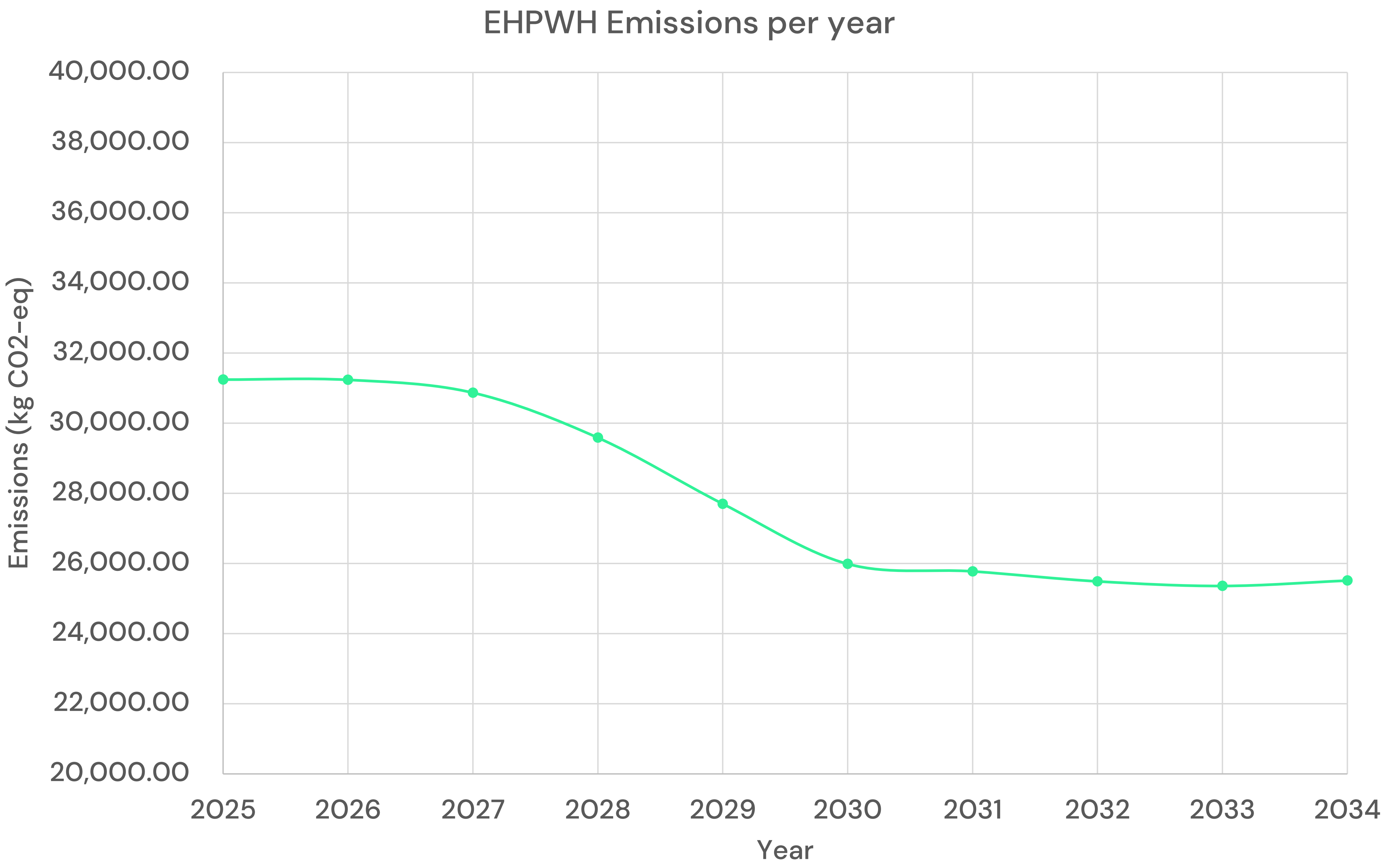
Modeling Challenges

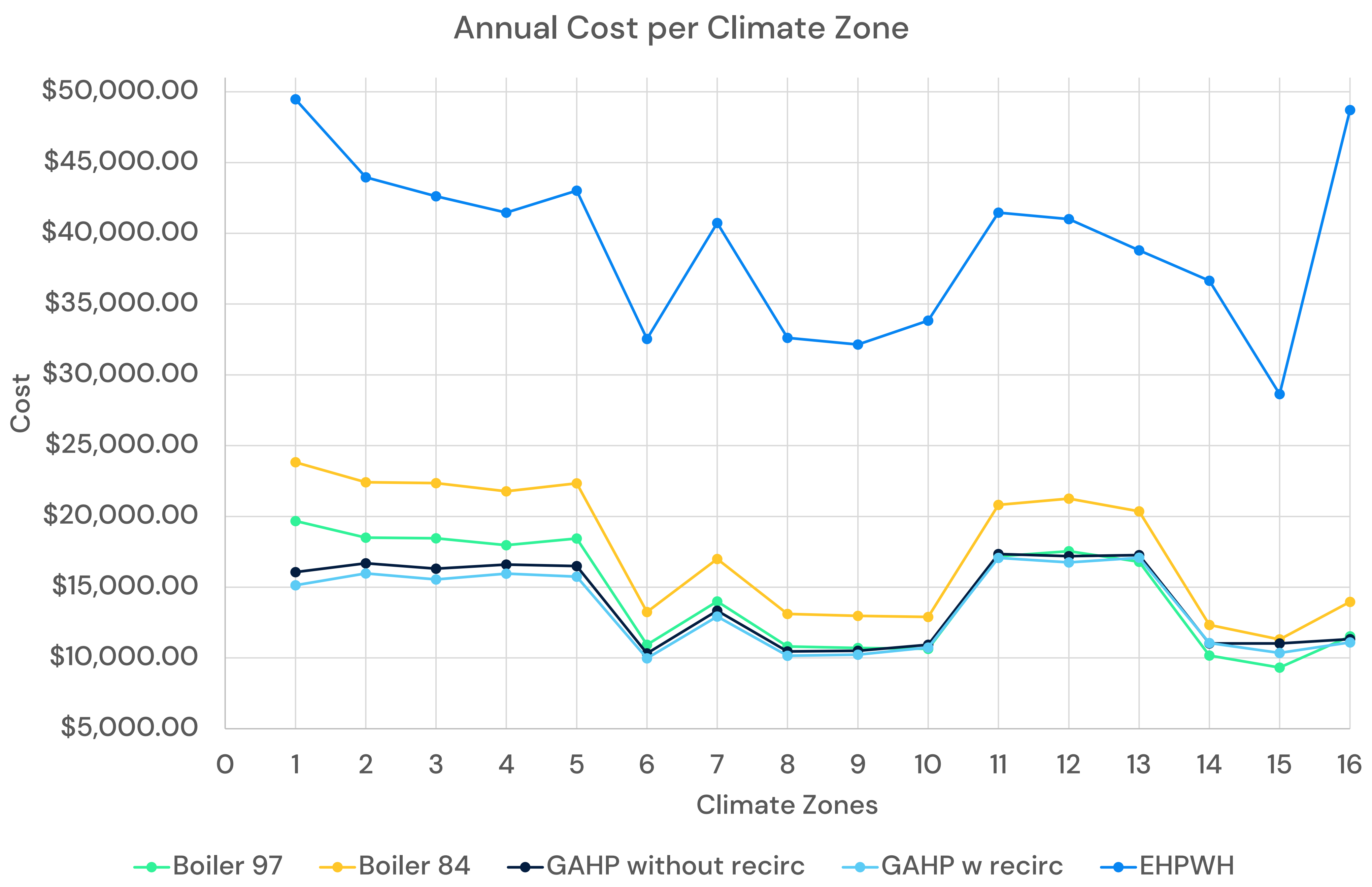


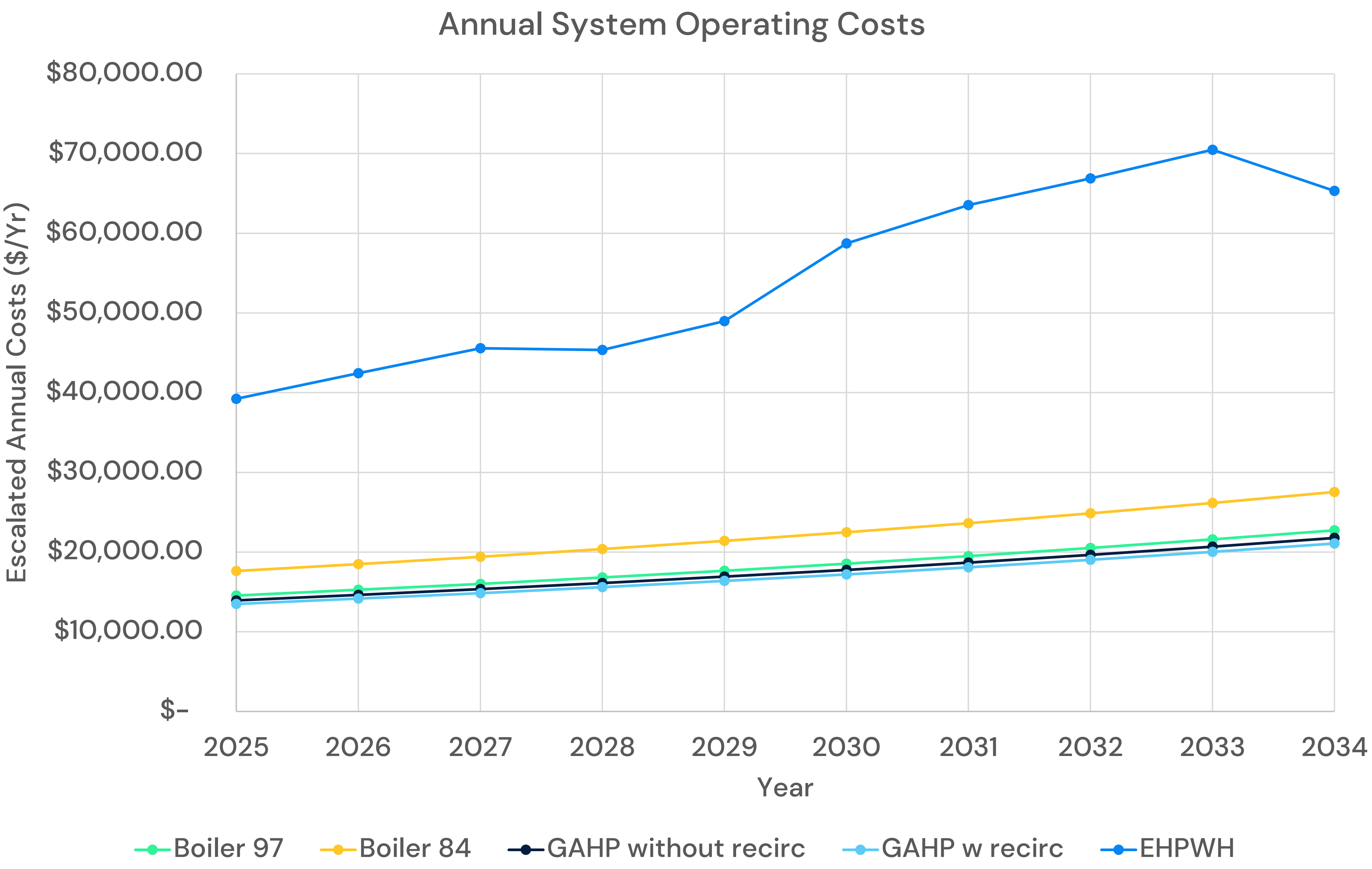

Annual Energy Consumption of Base and Measure cases in different Climate Zones
Base Case (84% TE)
Cond boiler (97% TE)
EHPWH
GAHP-v1
GAHP-v2
Energy Consumption (MBtu)
1200000
1000000
800000
600000
400000
200000
0
CZ01
CZ02
CZ03
CZ04
CZ05
CZ06
CZ07
CZ08
CZ09
CZ10
CZ11
CZ12
CZ13
CZ14
CZ15
CZ16
Climate Zone



Annual Emissions per Climate Zone
Annual Emissions (kg CO2 eq)
55,000.00
50,000.00
45,000.00
40,000.00
35,000.00
30,000.00
25,000.00
20,000.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Climate Zones
Boiler 97
Boiler 84
GAHP without recirc
GAHP w recirc
EHPWH


EHPWH Emissions per year
40,000.00
38,000.00
36,000.00
34,000.00
32,000.00
30,000.00
28,000.00
26,000.00
24,000.00
22,000.00
20,000.00
Emissions (kg CO2-eq)
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
Year


Annual Cost per Climate Zone
Cost
$50,000.00
$45,000.00
$40,000.00
$35,000.00
$30,000.00
$25,000.00
$20,000.00
$15,000.00
$10,000.00
$5,000.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Climate Zones
Boiler 97
Boiler 84
GAHP without recirc
GAHP w recirc
EHPWH



Annual System Operating Costs
$80,000.00
$70,000.00
$60,000.00
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$-
Escalated Annual Costs ($/Yr)
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
Year
Boiler 97
Boiler 84
GAHP without recirc
GAHP w recirc
EHPWH

TSB and Simple Payback Analysis

Measure Cost

- Cost Assumptions for DHW Systems
  - All systems use existing storage due to oversized tanks from EnergyPlus auto-sizing.
  - Condensing Boiler (97%): Costs from 2024 RS Means.
  - EHPWH: Costs from SWWH028 measure package.
  - GAHP: Material costs and labor costs from field study work.

System	Material Cost	Labor Cost	Total Measure Cost
97% Condensing Boiler	$42.99	$8.95	$51.94
EHPWH	$160.44	$23.91	$184.35
GAHP v.1	$150.63	$170.30	$320.92
GAHP v.2	$150.63	$170.30	$320.92

TSB Results

- Total System Benefit (TSB)
  - TSB combines energy savings and refrigerant impacts.
  - EHPWH has refrigerant costs; GAHP does not.
  - Calculated using CET and RACC tools.
-

Climate Zone	97% Condensing Boiler	EHPWH	GAHP v.1	GAHP v.2
CZ01	$183.24	$468.52	$487.09	$434.88
CZ02	$172.95	$457.99	$361.36	$321.38
CZ03	$172.37	$469.81	$381.44	$338.65
CZ04	$168.27	$456.47	$326.15	$290.20
CZ05	$172.34	$454.18	$370.04	$328.16
CZ06	$164.15	$417.62	$291.88	$260.69
CZ07	$167.01	$396.78	$286.16	$256.49
CZ08	$162.53	$408.02	$263.25	$235.61
CZ09	$160.92	$405.66	$244.91	$219.78
CZ10	$159.90	$378.09	$193.57	$175.88
CZ11	$160.90	$414.62	$210.32	$194.83
CZ12	$164.31	$429.61	$252.02	$227.63
CZ13	$157.51	$417.21	$184.14	$173.39
CZ14	$152.79	$297.83	$113.49	$116.52
CZ15	$140.50	$332.03	$84.68	$24.73
CZ16	$172.06	$287.97	$254.19	$233.75

Simple Payback

Climate Zone	97% Condensing Boiler	EHPWH	GAHP v.1	GAHP v.2
CZ01	1.85	N/A	4.56	5.11
CZ02	1.96	N/A	6.15	6.91
CZ03	1.97	N/A	5.83	6.56
CZ04	2.01	N/A	6.81	7.66
CZ05	1.97	N/A	6.01	6.77
CZ06	3.30	N/A	12.09	13.53
CZ07	2.56	N/A	9.74	10.87
CZ08	3.34	N/A	13.40	14.97
CZ09	3.37	N/A	14.40	16.05
CZ10	3.39	N/A	18.22	20.06
CZ11	2.11	N/A	10.57	11.41
CZ12	2.06	N/A	8.82	9.76
CZ13	2.15	N/A	12.07	12.82
CZ14	3.55	N/A	31.08	30.27
CZ15	3.86	N/A	41.66	142.64
CZ16	3.15	N/A	13.88	15.09

- Uses the measure costs and annual operation costs to determine how many years of operational savings it takes to pay off the cost of the system.
- EHPWH has no payback period due to negative cost savings.
- The 97% efficient condensing boiler has the lowest simple payback periods of all the systems.
- Marked yellow indicate payback periods greater than the expected useful life (EUL) of the GAHP.

Conclusion

Key Findings:

- All systems reduced energy consumption and GHG emissions compared to the baseline, but not fuel costs.
- EHPWH consumed the least site energy but had operational costs 3x higher than gas-fueled systems.
- GAHP systems competed with EHPWH in emissions in some climate zones.

Economic Insights:

- Condensing boilers had the shortest payback period due to low initial costs, despite smaller energy savings.
- EHPWH had negative cost savings and no payback period due to high operational costs.
- GAHP systems had short payback periods (as low as 4 years) in favorable zones but were not cost-effective in less favorable climates.

Recommendations

- GAHP systems offer a strong balance of energy efficiency and economic viability, especially in certain climate zones. These systems reduce emissions and provide competitive operational costs compared to EHPWHs. Incentivizing implementation in these areas is recommended.

- Improvement in modeling of domestic hot water systems is necessary, especially surrounding recirculation, due to EnergyPlus' current capabilities and functions.

- Further research on the long-term performance and maintenance costs of GAHP systems is needed to better understand their reliability and overall suitability for multifamily buildings.

Thank you

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