A case study at a brewery

An air-sourced steam-generating heat pump to **decarbonize industrial steam**

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OBJECTIVES

Demonstrate the feasibility and performance of an **air-sourced steam-generating heat pump in** an industrial brewery.

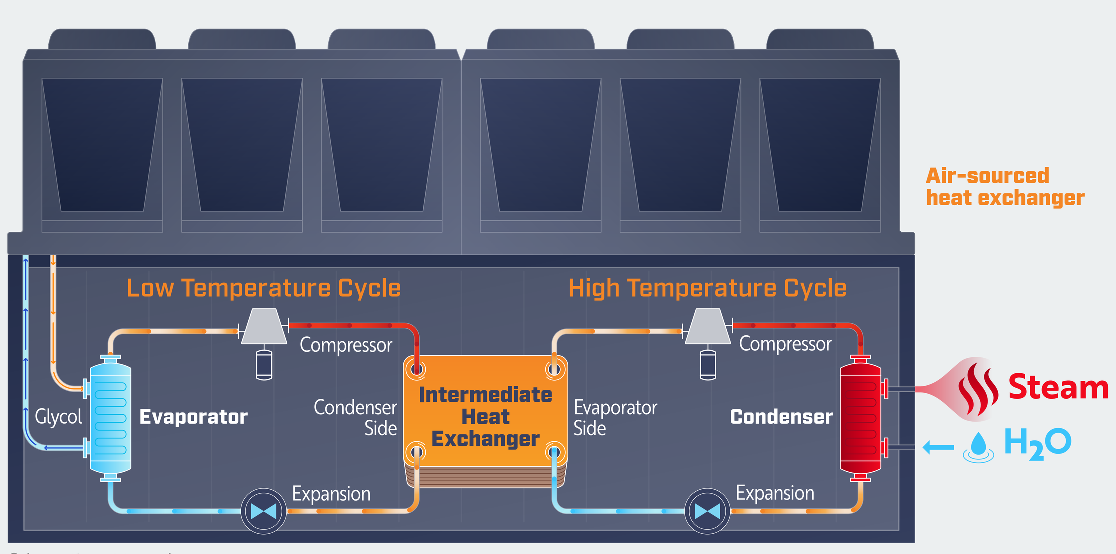
Compare techno-economic outcomes of air-sourced vs. waste heat-driven heat pumps.

Share lessons learned from installation and operation.

PROCEDURES AND METHODS

System overview

- 650 kW air-sourced steam-generating heat pump installed at New Belgium Brewing in Fort Collins, CO.
- Cascaded heat pump cycle delivers steam at up to 150°C (302°F) from ambient air as cold as -20°C (-4°F).
- Integrated with existing natural gas boilers using lead/lag controls and pressure setpoints.



Schematic not to scale

FIGURE 1

Cascaded heat pump cycle to deliver up to 150°C (302°F) steam ambient air as the heat source.

Testing and commissioning

- Factory acceptance testing: cold start, steady-state operation, control validation.
- Site installation completed in one day; commissioning achieved full operation within a month.

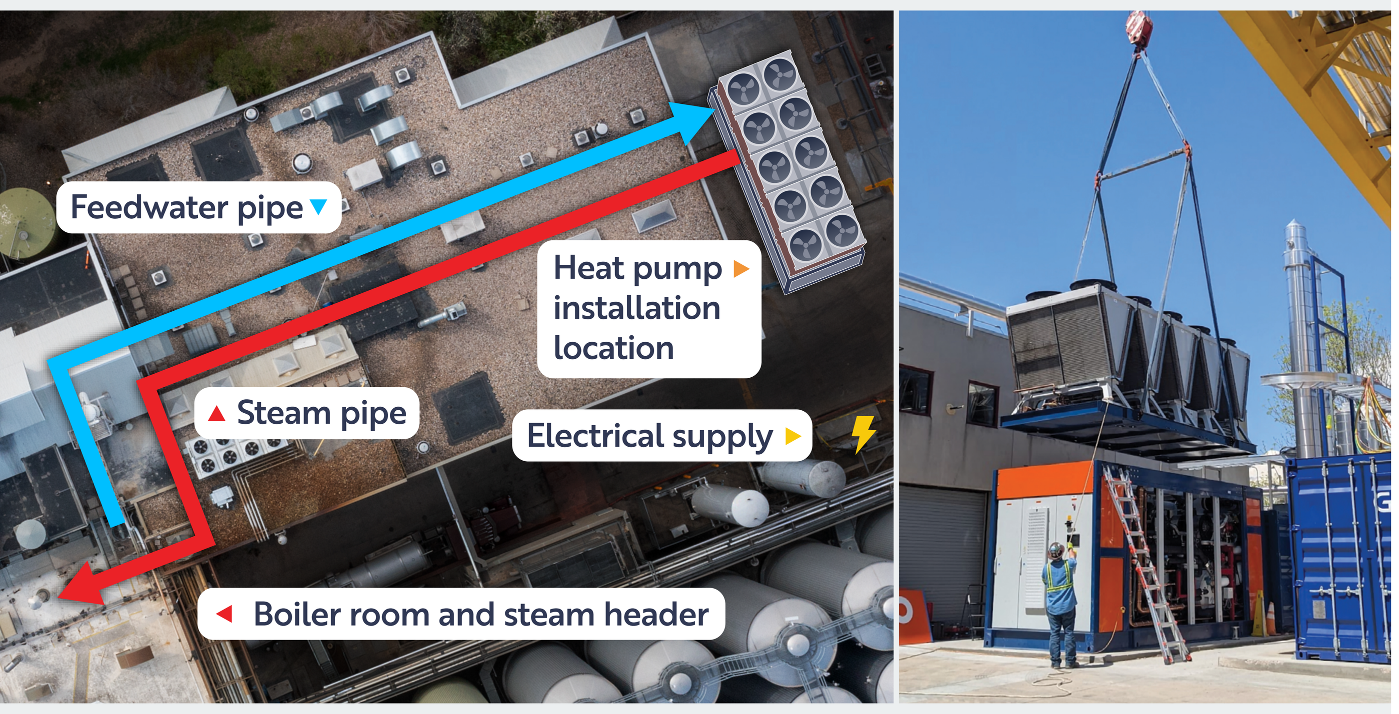


FIGURE 2

(Left) The heat pump installation was located outdoors with only electrical, feedwater, and steam connections required. (Right) The air-sourced heat pump being placed at New Belgium Brewing.

Performance evaluation

- Steady-state and dynamic tests at various ambient temperatures.
- Economic analysis compared installation complexity, operating costs, and payback periods for air-sourced and waste heat-driven systems.

RESULTS

Performance metrics

COP of 1.73

at 11.5°C (52.7°F) ambient air;
tested operation down to -12.6°C (9.3°F).

Up to 150°C (302°F)

of steam generation,
0.25 kg/s (1984 lb/hr) flow rate.

Quick startup

<10 minutes from cold start,
<5 minutes from warm start.

FIGURE 3A

Test data showing 150°C (302°F) steam generation using -13°C (9°F) air as the heat source.

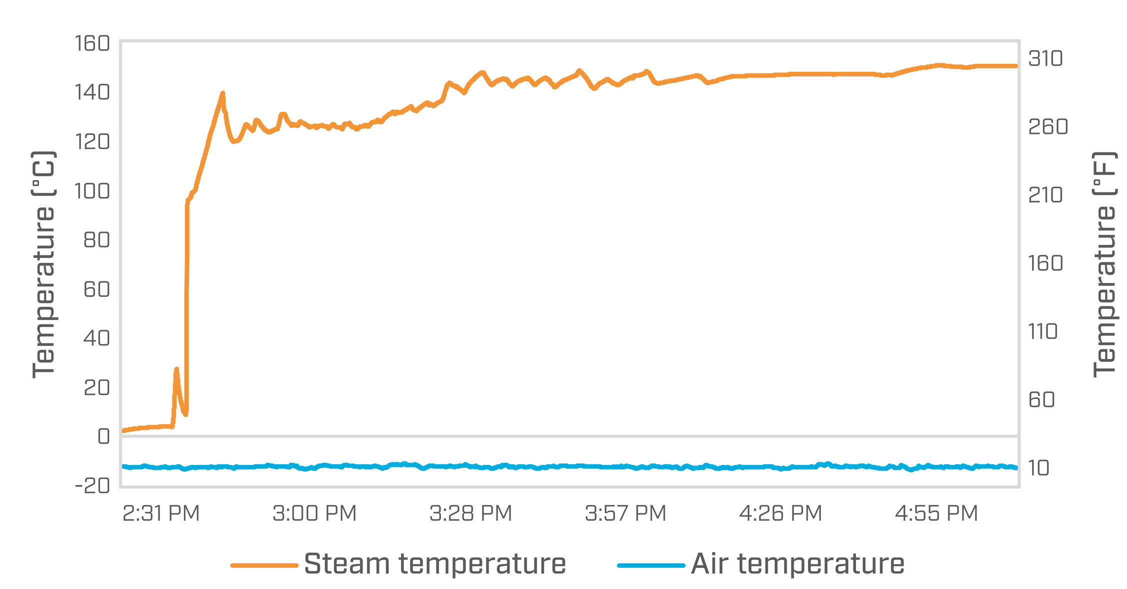


FIGURE 3B

Steam generation performance data from the manufacturer's test facility. Additional data on the tests outlined in orange are provided in Table 1.

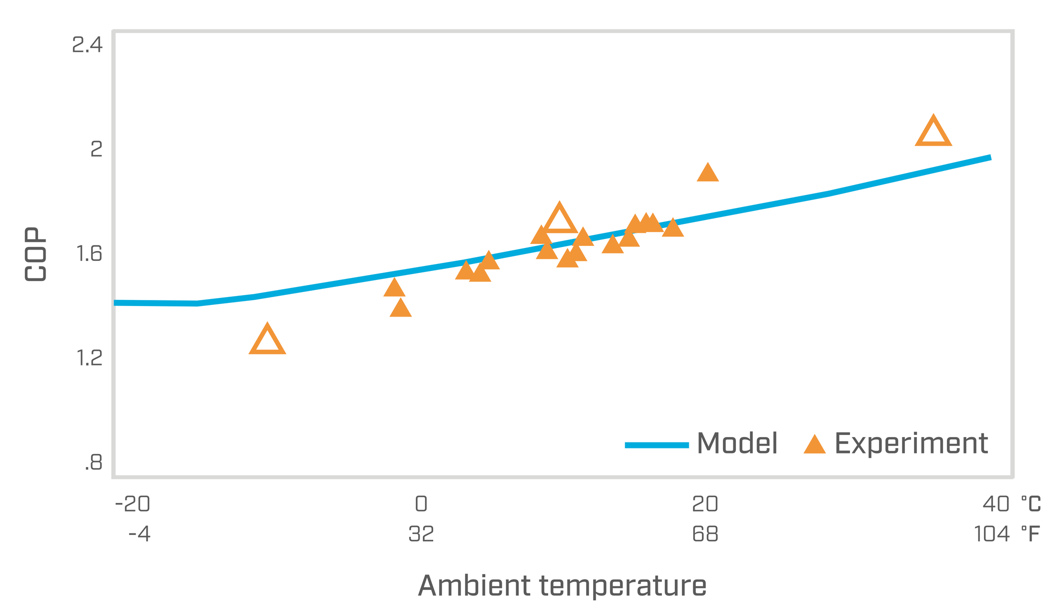


TABLE 1

Key performance metrics at low, medium, and high source temperatures.

△	Air temperature		
	-12.6°C (9.3°F)	11.5°C (52.7°F)	35.0°C (95.0°F)
Steam temperature	150°C (302°F)	149°C (300°F)	149°C (300°F)
Steam heat duty	636 kW (2170 kBtu/hr)	565 kW (1928 kBtu/hr)	589 kW (2010 kBtu/hr)
Calculated steam flow rate	0.25 kg/s (1984 lb/hr)	0.24 kg/s (1905 lb/hr)	0.24 kg/s (1905 lb/hr)
Evaporator heat duty	234 kW (798 kBtu/hr)	244 kW (833 kBtu/hr)	326 kW (1112 kBtu/hr)
Total electrical power	490 kW	327 kW	289 kW
COP	1.30	1.73	2.04

Economic performance

- **Air-sourced heat pump: payback <2 years** vs. electric boilers; **<5 years** vs. waste heat-driven systems (unless high-temperature waste heat is available).
- Installation costs driven by pipe length and location; proximity to steam header **reduces costs by up to 33%.**

TABLE 2

Economic comparison of air-sourced vs. waste heat-driven heat pumps

	Heat source temperature			
	Air at 11.5°C (52.7°F)	35°C (95°F)	60°C (140°F)	90°C (194°F)
Cost increase vs. air-sourced	N/A	$594,980	$754,090	$721,250
COP	1.73	2.04	2.73	4.09
Annual energy cost	$405,470	$343,529	$256,990	$171,330
Payback period vs. air	N/A	9.6 years	5.1 years	3.1 years

Lessons learned

- **Locating the heat pump close to the boiler room minimizes mechanical and plumbing costs.**
- Waste heat recovery systems require complex integration and higher capital costs.
- Optimization opportunities: competitive bidding, improved documentation.

Conclusions

Air-sourced heat pumps are a **practical, scalable solution** for industrial steam decarbonization.

Installation cost optimization is critical for project success.

Reliable, efficient steam generation at industrial scale, **even in cold ambient conditions.**

Techno-economic analysis supports air-sourced heat pumps as a **cost-effective alternative to waste heat-driven systems,** especially where high-temperature waste heat is unavailable.

References

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