Next Gen Rooftop Units

Savings potential of dual fuel heat pump rooftop units and energy recovery ventilators in Minnesota

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BACKGROUND AND SUMMARY

Next Gen Rooftop Units

Next Gen Rooftop Units (RTUs) is a statewide program that strives to advance the performance of next gen rooftop units to meet the growing demand for energy efficient and sustainable building solutions. The program is funded under Minnesota's Efficient Technology Accelerator (ETA), a statewide market transformation program accelerating the deployment and reducing the cost of emerging and innovative efficient technologies, bringing lower energy bills and environmental benefits to Minnesotans. ETA is funded by the state's investor-owned utilities (IOUs), administered by the Minnesota Department of Commerce, Division of Energy Resources (DER), and implemented by Center for Energy and Environment (CEE).

Summary of report

This report provides an analysis of energy and bill savings achievable through the use of dual fuel heat pump RTUs and energy recovery ventilators (ERVs) in Minnesota's commercial buildings. The primary goal is to quantify the potential savings across eight common commercial building types, which represent 72% of the commercial buildings in the state. By focusing on Minnesota's cold climate and building stock, the study evaluates the performance of these technologies both individually and as a combined system.

The model developed by CEE examines how dual fuel heat pump RTUs and ERVs can reduce energy consumption and utility bills. It assumes RTUs have a switchover temperature of 30ºF as recommended by manufacturers.

Scope and results

- The analysis covers eight commercial building types that represent a significant portion of the Minnesota commercial building stock.
- It evaluates the performance of dual fuel heat pump RTUs and ERVs both individually and as a combined system.
- Heat pump RTUs deliver 20% energy savings compared to standard units.
- ERVs deliver 20% energy savings at and below 30% outdoor air.
- Together, heat pump RTUS and ERVs can achieve a total of 40% energy savings.
- Heat pumps do not increase energy bills at 30ºF switchover temperature, in these cases.
- ERVs offer a 10% reduction in bills when outdoor air ventilation is at or below 30%.

In summary, dual fuel heat pump RTUs and ERVs offer substantial energy savings and consistently reduce energy by over 20% compared to standard units. Dual fuel heat pump RTUs and ERVs should be key considerations for any strategy focused on energy efficiency and bill reduction in Minnesota's commercial building sector.

MODEL GOALS AND METHODOLOGY

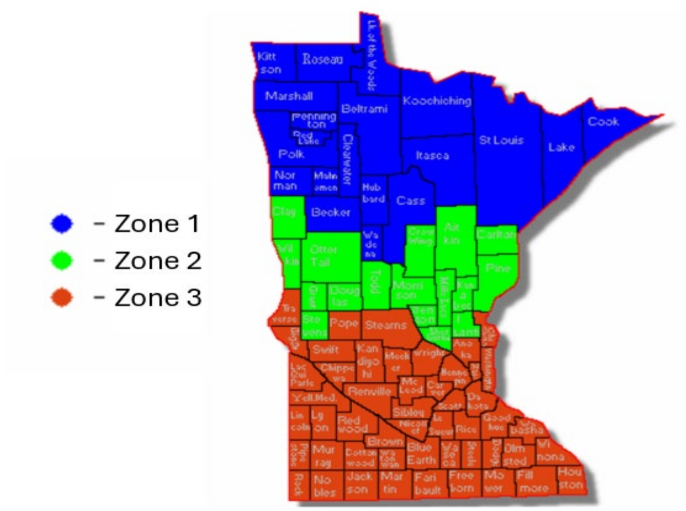
This model developed by Center for Energy and Environment (CEE) demonstrates the energy and bill savings potential of dual fuel heat pump rooftop units (RTUs) and energy recovery ventilators (ERVs). The model focuses on common building types in Minnesota that use RTUs as their primary heating and cooling systems.

The model examines eight cases, each representing a building type in the Minnesota market. These cases vary by buildings with different usage, age, size, location, and RTU distribution.

Climate

Three climate zones aligned with the zones defined in the Minnesota Technical Reference Manual (TRM)[1] were considered for this model. These zones are illustrated in Figure 1. Most cases were modeled in climate zone three, which represents the highest population of the three climate zones. Small offices were modeled in all three climate zones.

Figure 1: Minnesota Technical Reference Manual Climate Zone Map



Billing rates

To establish bill savings, Xcel Energy rates[2] were used for both gas and electric bills. Xcel Energy Small 102 & 108, Large 118 & 125 rate codes were used for gas rates, capturing

[1] TRM version 4.1 available from https://mn.gov/commerce-stat/trm/releases/4.1.pdf

[2] Xcel Energy MN electric and gas rate books available from https://www.xcelenergy.com/company/rates_and_regulations/rates/rate_books

seasonal changes to rates. Xcel Energy A-14 commercial rates were used for electric rates and include a potential per-kWh energy charge credit. All rate assumptions include riders, surcharges, and taxes, but monthly fees not impacted by RTU energy use are excluded. Rates are as of May 2024.

Heat pump performance

This model assumes that dual fuel heat pump RTUs will be less efficient in real-world installations compared to a lab setting where ratings are set. Based on previous research on residential air source heat pump systems, a 30% efficiency reduction for heat pump RTUs is assumed. This derating is being field evaluated.

Baseline

Each case had a baseline model representing a standard efficiency AC and gas furnace rooftop unit. The baseline RTU is a gas furnace and AC RTU with standard efficiency. Standard efficiency was defined as 80% heating efficiency and a SEER of 12.9. The tonnage of each case varied, with RTUs ranging from 3–25-ton.

ERV

Each case also modeled a standard efficiency AC and gas furnace RTU with an ERV. The ERV is modeled to have 60% latent and 68% sensible effectiveness. The RTU is assumed to have the same efficiency as the baseline RTU.

Dual fuel heat pump RTU

Each case also had a model with a dual fuel heat pump RTU. The performance of the dual fuel heat pump RTU is an average performance of four dual fuel heat pump RTUs currently on the market: the Lennox Enlight, the Trane Precedent PRC013AA, the Trane Precedent PRC019C, and the Trane Precedent PRC021C. The average was taken in four bins based on the size of the unit. The bins were 3–5-ton, 6–9-ton, 10–15-ton, and 15–25-ton. A 30°F switchover temperature was assumed.

ERV and dual fuel heat pump RTU

Dual fuel heat pump RTUs with an ERV were also modeled. The dual fuel heat pump RTUs with ERVs share the same performance metrics as the dual fuel heat pump RTU, with the added efficiency of an ERV with 60% latent and 68% sensible effectiveness.

RESULTS BY CASE

Small offices

Three small offices, two stories or less, built before 1946 were considered. Small offices make up 32% of commercial buildings in Minnesota. The three cases examine varied outdoor air percentage (OA), tonnage, and square footage. All three Minnesota climate zones are represented, with one office in each zone. This model found significant energy savings with both dual fuel heat pump RTUs and the combination of dual fuel heat pump RTUs and ERVs. Energy savings and bill savings found from the small office model are shown in Table 1.

Table 1. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on small office buildings

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Small office, climate zone 3	22%	2%	6%	4%	27%	7%
Small office, climate zone 2	21%	-1%	19%	12%	38%	13%
Small office, climate zone 1	13%	4%	26%	13%	39%	18%

Energy savings can reach up to 22% for dual fuel heat pump RTUs and up to 39% for systems combining dual fuel heat pump RTUs and ERVs. ERVs also contribute to bill savings in these small office models. Baseline units with ERVs save 13% of energy bills, while ERVs combined with dual fuel heat pump RTUs can result in 18% savings. The charts below show energy savings when compared to a baseline system, as well as bill savings when compared to a baseline system.

Chart 1. Annual bill savings over baseline vs. switchover temperature for the small office in climate zone 3 model

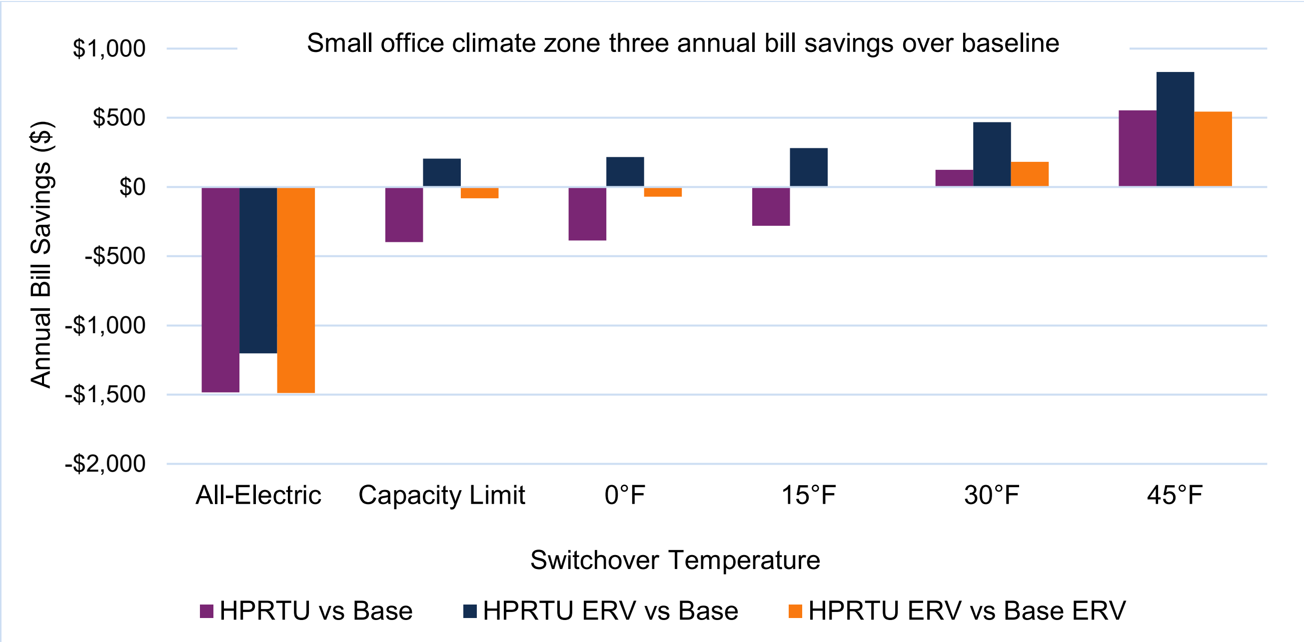


Chart 2. Annual energy savings over baseline vs. switchover temperature for the small office in climate zone 3 model

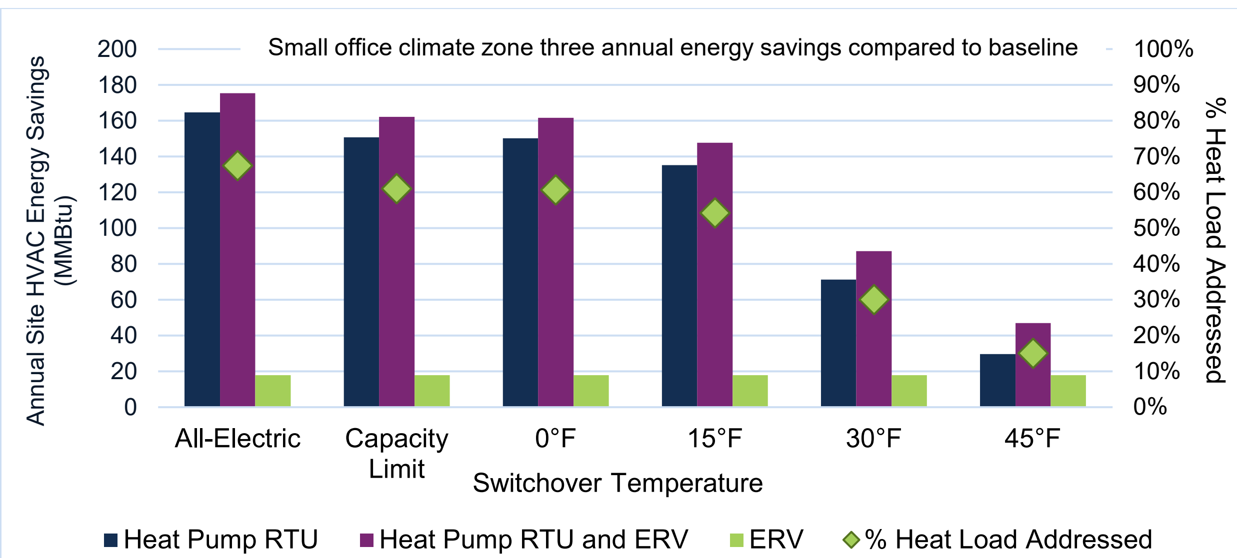


Chart 3. Annual bill savings over baseline vs. switchover temperature for the small office in climate zone 2 model

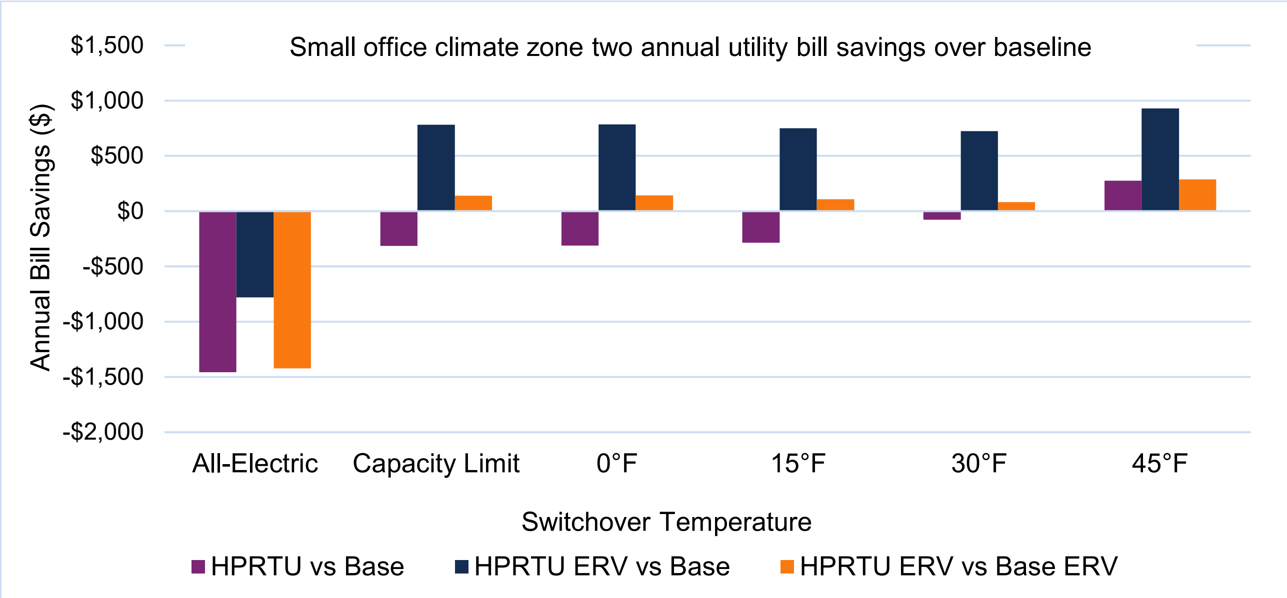


Chart 4. Annual energy savings over baseline vs. switchover temperature for the small office in climate zone 2 model

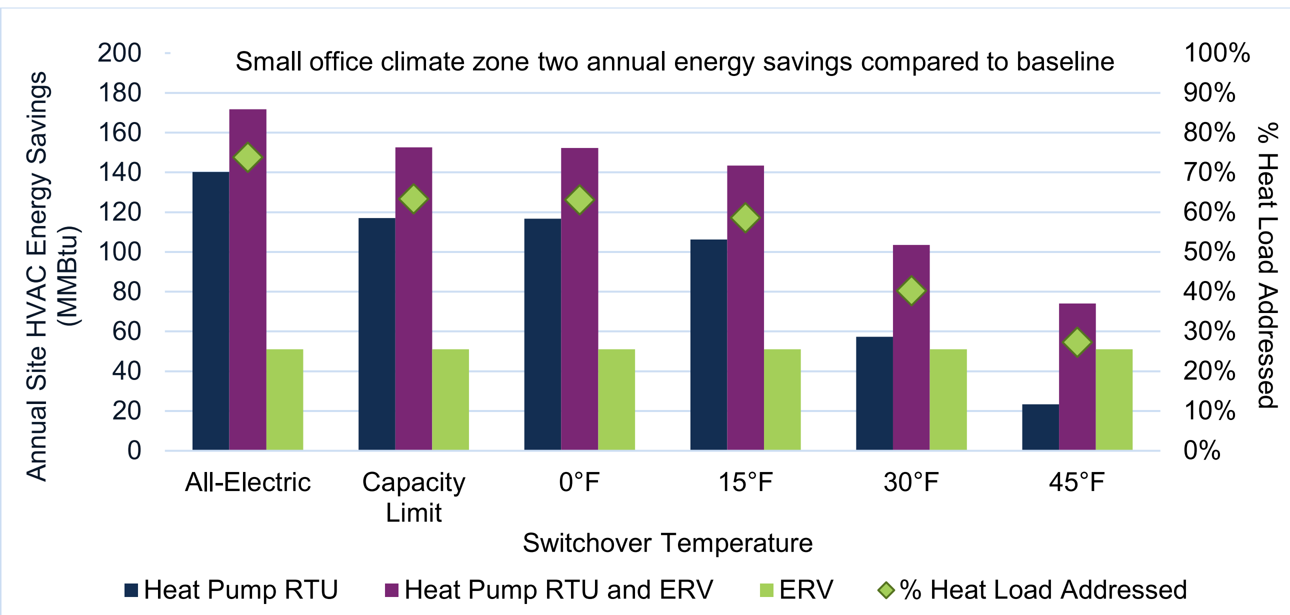


Chart 5. Annual bill savings over baseline vs. switchover temperature for the small office in climate zone 1 model

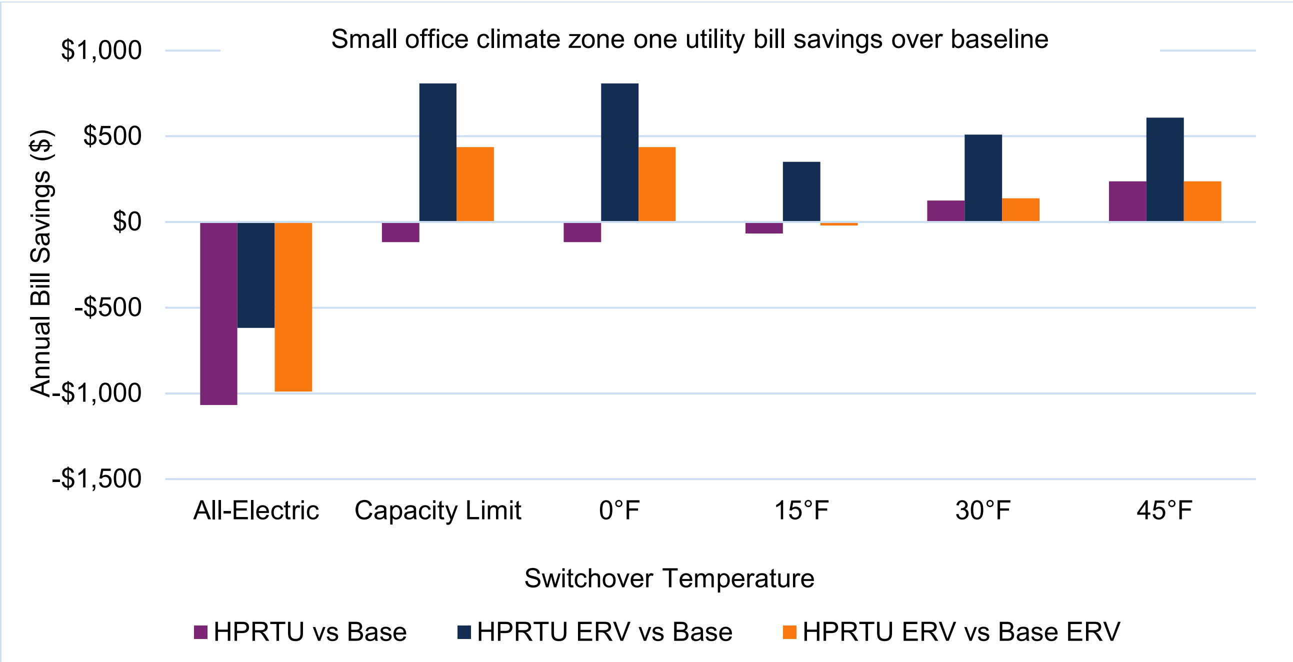
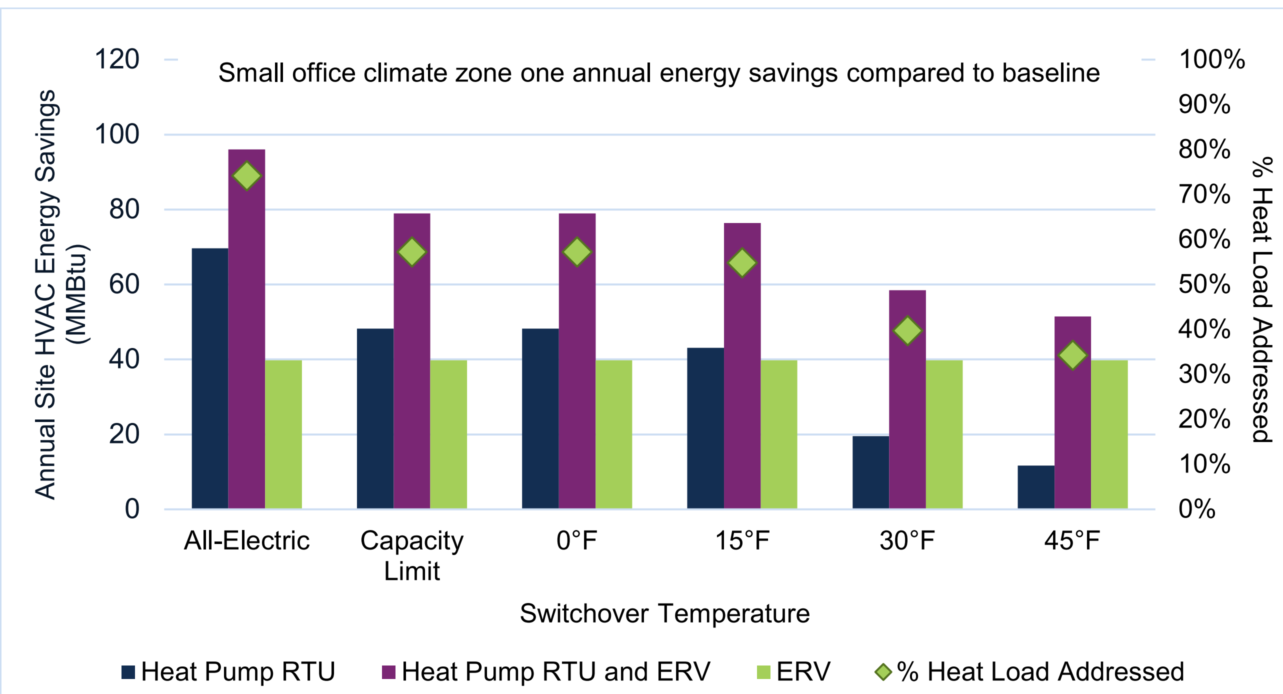


Chart 6. Annual bill savings over baseline vs. switchover temperature for the small office in climate zone 1 model



These charts display annual bill and energy savings outcomes compared to a baseline RTU at a variety of switchover temperatures between 0°F and 45°F. Negative savings represent cases where energy bills with the new system are higher than the previous system. This chart also displays results for a system operated to its capacity limit and in an all-electric scenario. The capacity limit case describes a dual fuel system that operates the heat pump while it can provide the whole heating load without backup. If backup is needed, the heat pump is locked out and the backup gas system provides the entire heating load. Conversely, the all-electric scenario is not a dual fuel system. The heat pump runs as much as possible, with a backup electric heating system supplementing it when the load exceeds the capacity provided by the heat pump alone. This results in better energy savings, but negative bill impacts as no gas is used and peak electric demand is high.

Primary school

The next building modeled is a single-story primary school built between 2000 and 2012. The school is equipped with rooftop units with capacities ranging from 10- and 15-ton with a total of 25-ton capacity. Primary schools make up 5% of commercial buildings in Minnesota and exhibit the highest energy savings when using a dual fuel heat pump RTU. The energy savings and bill savings for this model are shown in Table 2.

Table 2. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on the primary school model

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Primary School	27%	0%	14%	9%	39%	10%

Energy savings can reach up to 27% for dual fuel heat pump RTUs, 14% energy savings from ERVs, and up to 29% for systems combining dual fuel heat pump RTUs and ERVs. ERVs also continue to show bill savings in this model. ERVs on baseline units save 9% of energy bills while ERVs combined with dual fuel heat pump RTUs save 10% of energy bills. When switchover temperature is set to optimize bill savings, dual fuel heat pump RTUs save 13% of energy bills, and ERVs combined with dual fuel heat pump RTUs can save 22% of energy bills. The effect of switchover temperature on bill savings compared to a baseline unit is shown in Chart 7, and energy savings compared to a baseline unit are shown in Chart 8.

Chart 7. Annual bill savings over baseline vs. switchover temperature for the primary school model

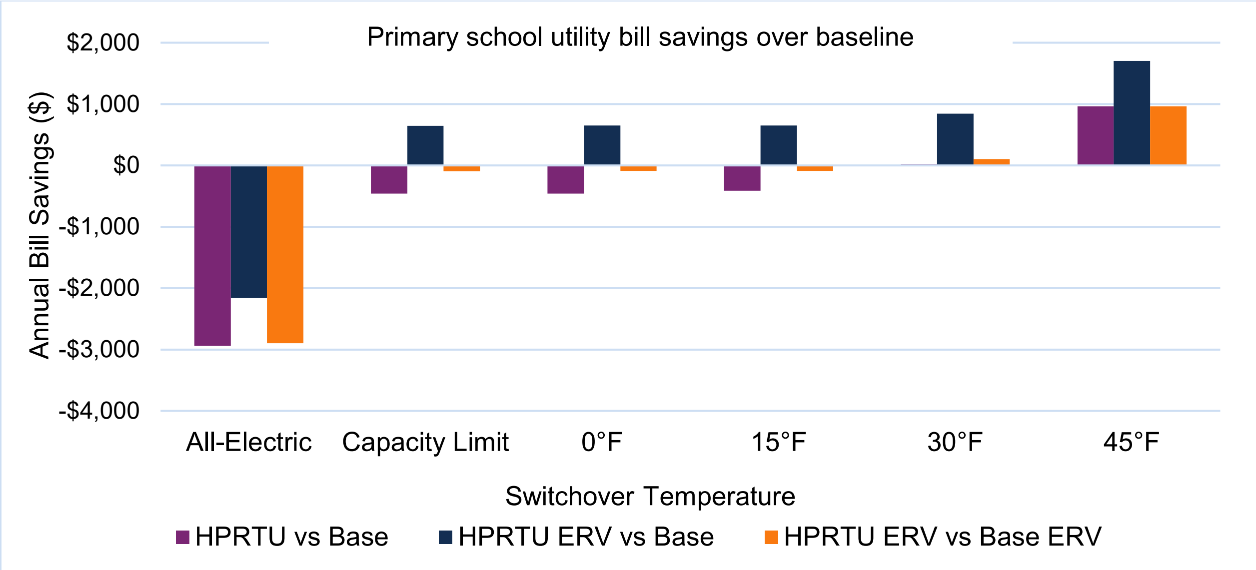
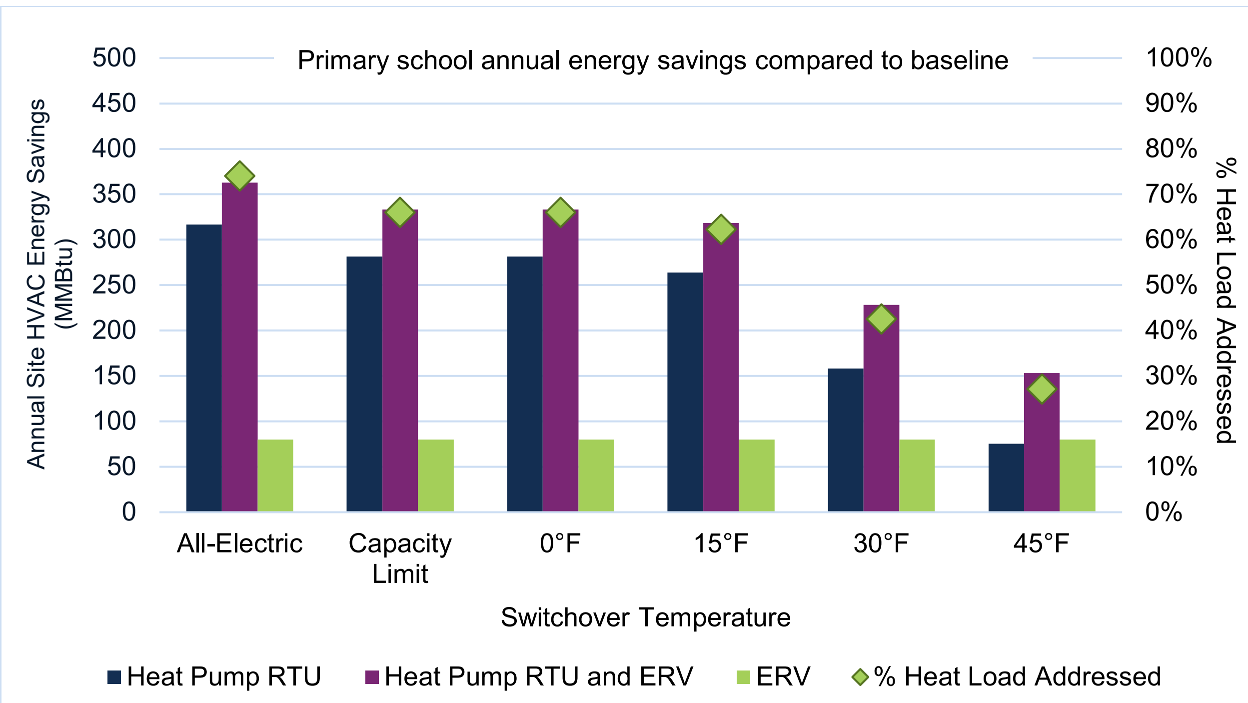


Chart 8. Annual energy savings over baseline vs. switchover temperature for the primary school model



Retail store in strip mall

The next modeled building is a retail store in a strip mall built before 1946. The retail store is equipped with units between 3-ton and 5-ton with a total heat capacity of 20-ton. Retail in strip malls make up 10% of commercial buildings in Minnesota. This model found significant energy savings with dual fuel heat pump RTUs, ERVs, and the combination of dual fuel heat pump RTUs and ERVs. Energy savings and bill savings found from the retail store in a strip mall are shown in Table 3.

Table 3. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on the retail store in strip mall model

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Retail store in strip mall	24%	1%	19%	16%	41%	17%

Energy savings can reach up to 24% for dual fuel heat pump RTUs, ERVs can lead to up to 19% energy savings, and combining the two technologies can realize 41% energy savings. Additionally, ERVs on both gas furnace and dual fuel heat pump RTUs contribute to bill savings. ERVs on baseline units save 16% on energy bills, while dual fuel heat pump RTUs combine with ERVs to save 17% on energy bills. When the switchover temperature is set to optimize bill savings, dual fuel heat pump RTUs save 13% on energy bills, while ERVs combined with dual fuel heat pump RTUs can save 27% on energy bills. The effect of switchover temperature on bill savings compared to baseline units is shown below in Chart 9, and energy savings compared to baseline units is shown in Chart 10.

Chart 9. Annual bill savings over baseline vs. switchover temperature for the retail store in strip mall model

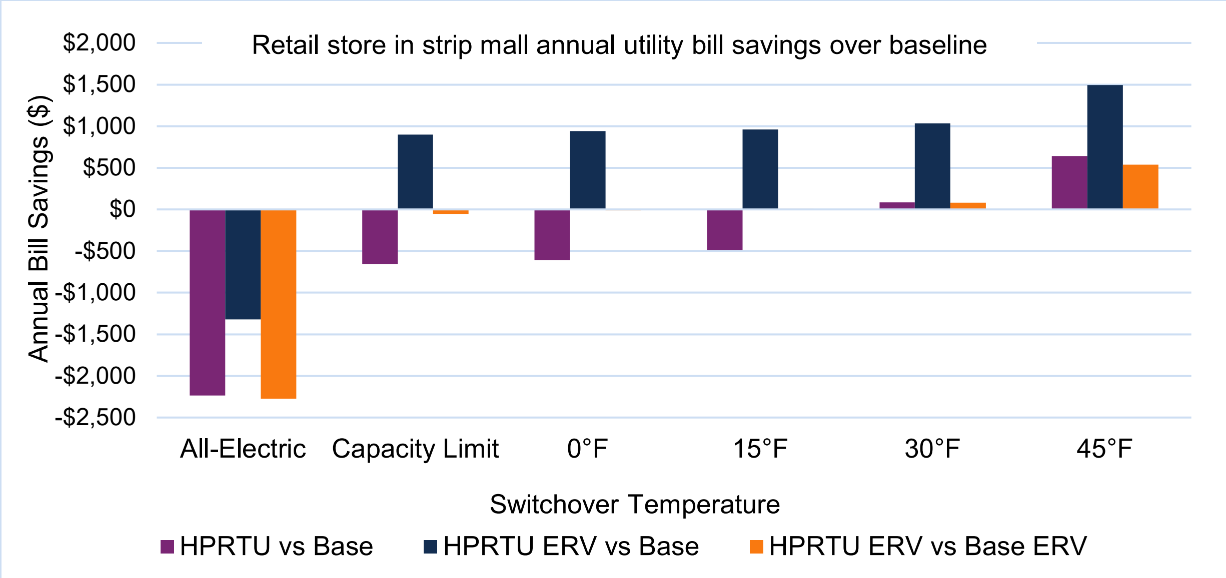
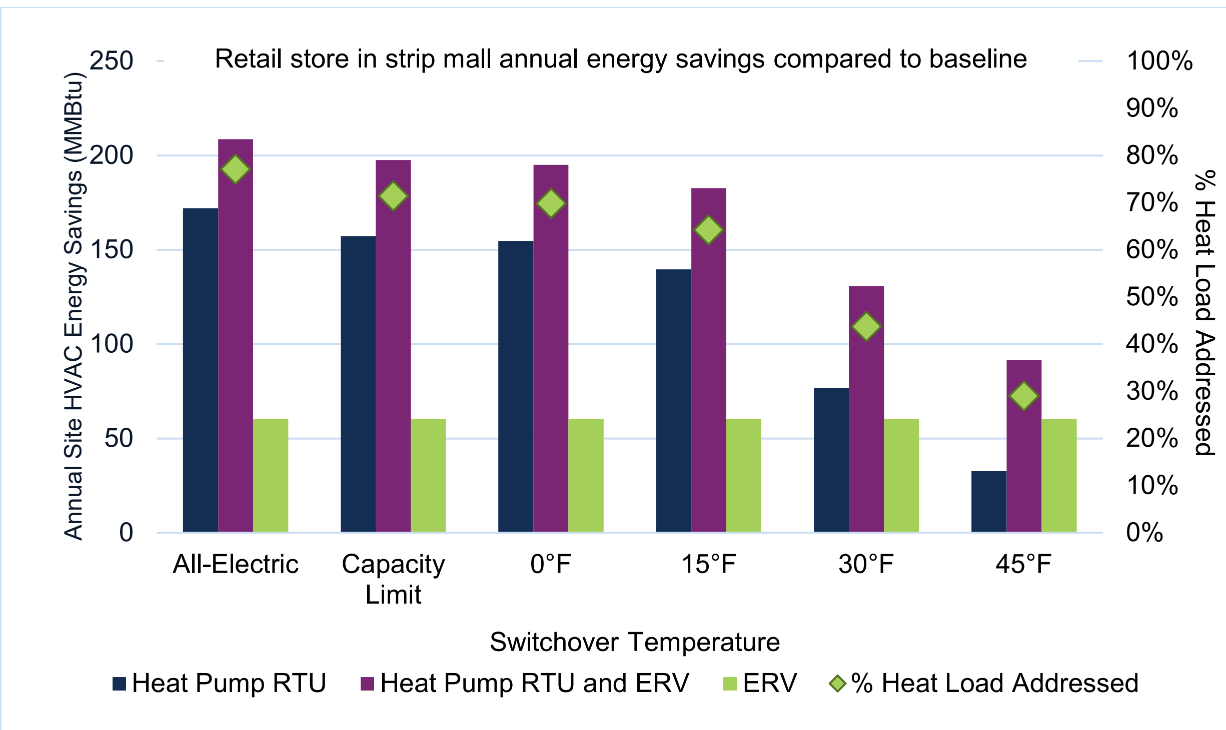


Chart 10. Annual energy savings over baseline vs. switchover temperature for the retail store in strip mall model



Standalone retail

The next building modeled is a single-story, standalone retail store built before 1946. The standalone retail is equipped with RTUs with capacities ranging from 16-ton to 25-ton with a total heat capacity of 170-ton. Standalone retail represents 11% of commercial buildings in Minnesota. The standalone retail store is the case with the highest energy savings with ERVs, and with the combination of ERVs and dual fuel heat pump RTUs. Energy savings and bill savings found from the standalone retail model are shown in Table 4.

Table 4. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on the standalone retail model

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Standalone retail	20%	-6%	27%	18%	45%	16%

Energy savings reach up to 20% for dual fuel heat pump RTUs, 27% energy savings from ERVs, and 45% energy savings for systems combining dual fuel heat pump RTUs and ERVs. Additionally, ERVs on both gas furnace and dual fuel heat pump RTUs contribute to bill savings in standalone retail models. ERVs on baseline units save 18% of energy bills, while dual fuel heat pump RTUs show a savings of 16% on energy bills. When switchover temperature is set to optimize bill savings, ERVs combined with dual fuel heat pump RTUs save 25% on energy bills. The effect of switchover temperature on bill savings compared to a baseline unit is shown in Chart 11, while energy savings compared to a baseline unit is shown in Chart 12.

Chart 11. Annual bill savings over baseline vs. switchover temperature for the standalone retail model

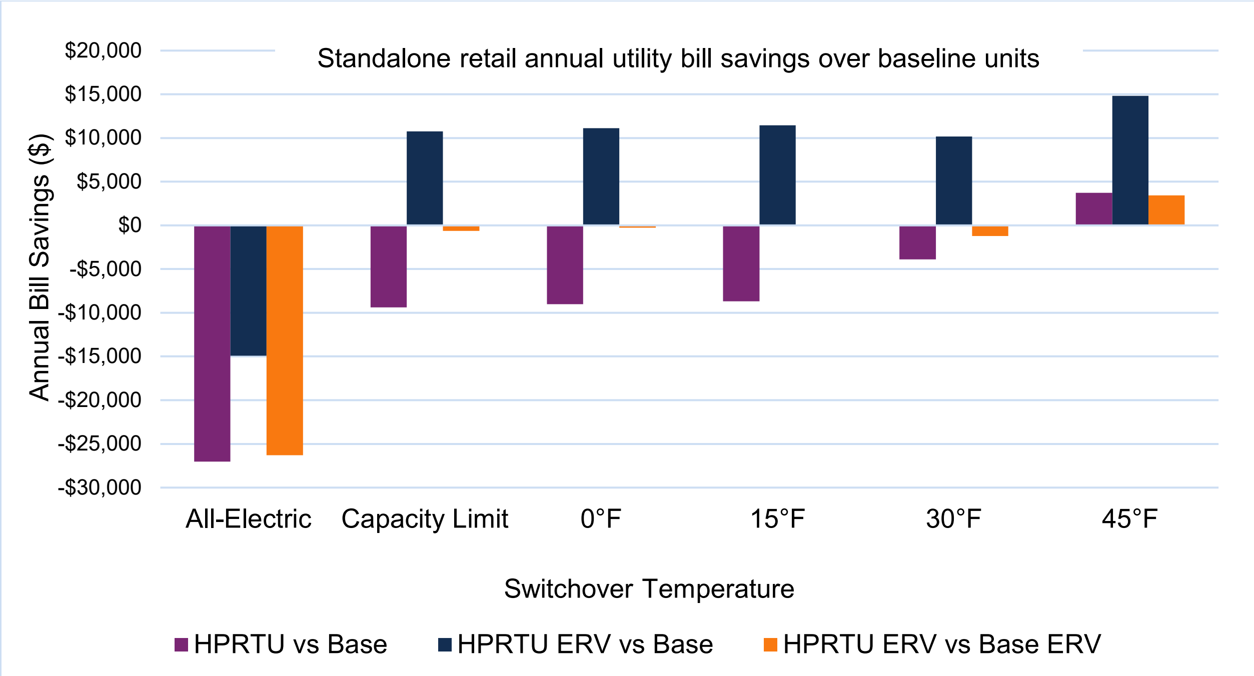
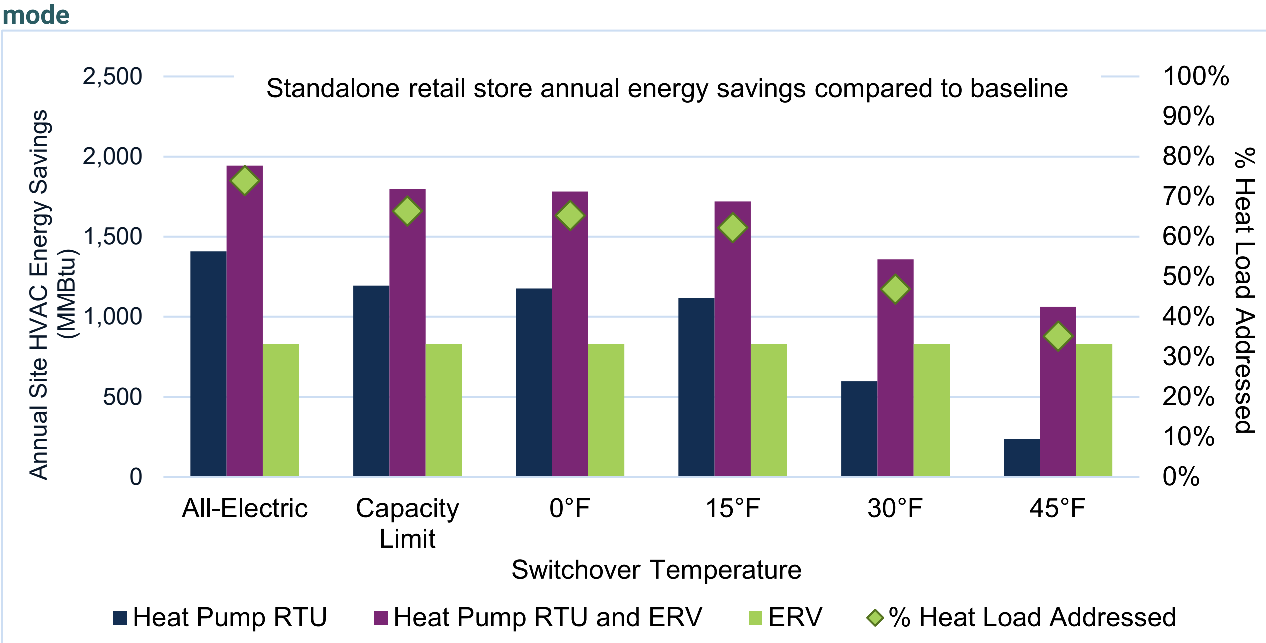


Chart 12. Annual energy savings over baseline vs. switchover temperature for the standalone retail mode



Medium office building

The next modeled building represents a three-story medium office building, built between 1970 and 1979 with units between 16-ton and 25-ton, with a total heat capacity of 100-ton. Medium office buildings represent 4% of commercial buildings in Minnesota. In this case, significant energy savings are found with dual fuel heat pump RTUs, ERVs, and the combination of dual fuel heat pump RTUs and ERVs. Energy savings and bill savings found from the medium office building model are shown in Table 5.

Table 5. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on the medium office building model

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Medium office building	17%	7%	25%	9%	40%	16%

Energy savings can reach up to 17% for dual fuel heat pump RTUs, 25% energy savings from ERVs, and up to 40% energy savings for systems combining dual fuel heat pump RTUs and ERVs. Additionally, ERVs on both gas furnace and dual fuel heat pump RTUs contribute to bill savings. ERVs on baseline units save 9% on energy bills, dual fuel heat pump RTUs save 7% on energy bills, and ERVs combined with dual fuel heat pump RTUs can save 16% on energy bills. Annual bill savings over baseline are shown in Chart 13, and annual energy savings over baseline are shown in Chart 14.

Chart 13. Annual bill savings over baseline vs. switchover temperature for the medium office building model

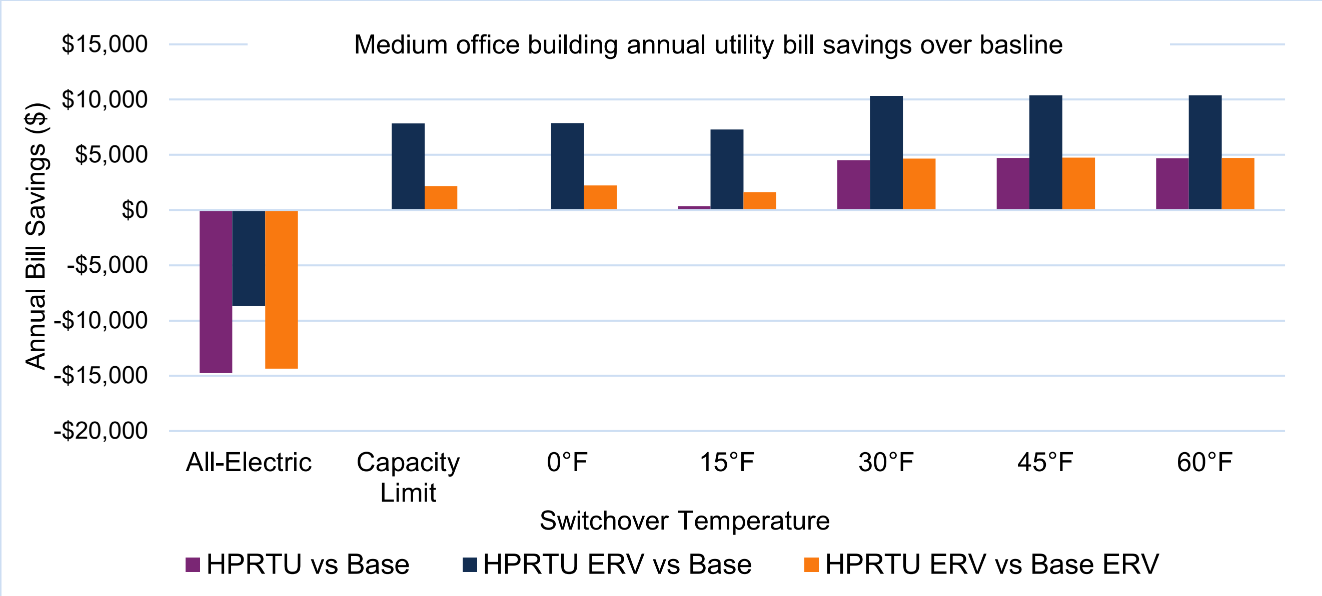
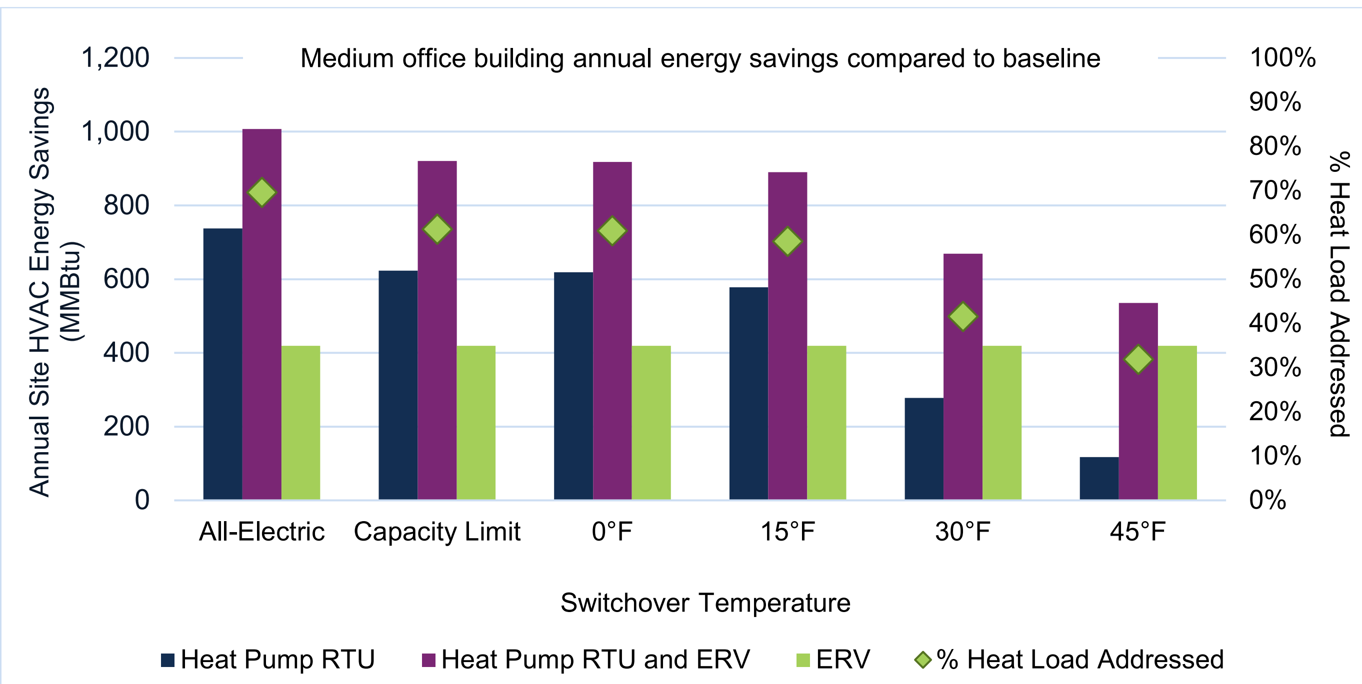


Chart 14. Annual energy savings over baseline vs. switchover temperature for the medium office building model



Outpatient center

The final case modeled represents a one-story outpatient center, built between 2000 and 2012 with RTUs between 10-ton and 15-ton, with a total of 20-ton capacity. Outpatient centers represent 3% of commercial buildings in Minnesota. This model found significant energy savings with dual fuel heat pump RTUs, ERVs, and the combination of dual fuel heat pump RTUs and ERVs. Energy savings and bill savings found from the outpatient center model are shown in Table 6.

Table 6. Energy and bill impacts of dual fuel heat pump RTUs and ERVs on the outpatient center model

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Outpatient center	18%	-1%	9%	5%	27%	7%

Energy savings can reach up to 18% for dual fuel heat pump RTUs, 9% savings from ERVs, and 27% energy savings for systems combining dual fuel heat pump RTUS and ERVs. In addition, bill savings from ERVs are found. ERVs on baseline units save 5% on energy bills, and ERVs combined with dual fuel heat pump RTUs can save 7% on energy bills. Bill savings compared to baseline units is shown in Chart 15 and energy savings compared to baseline savings is shown in Chart 16.

Chart 15. Annual bill savings over baseline vs. switchover temperature for the outpatient center model

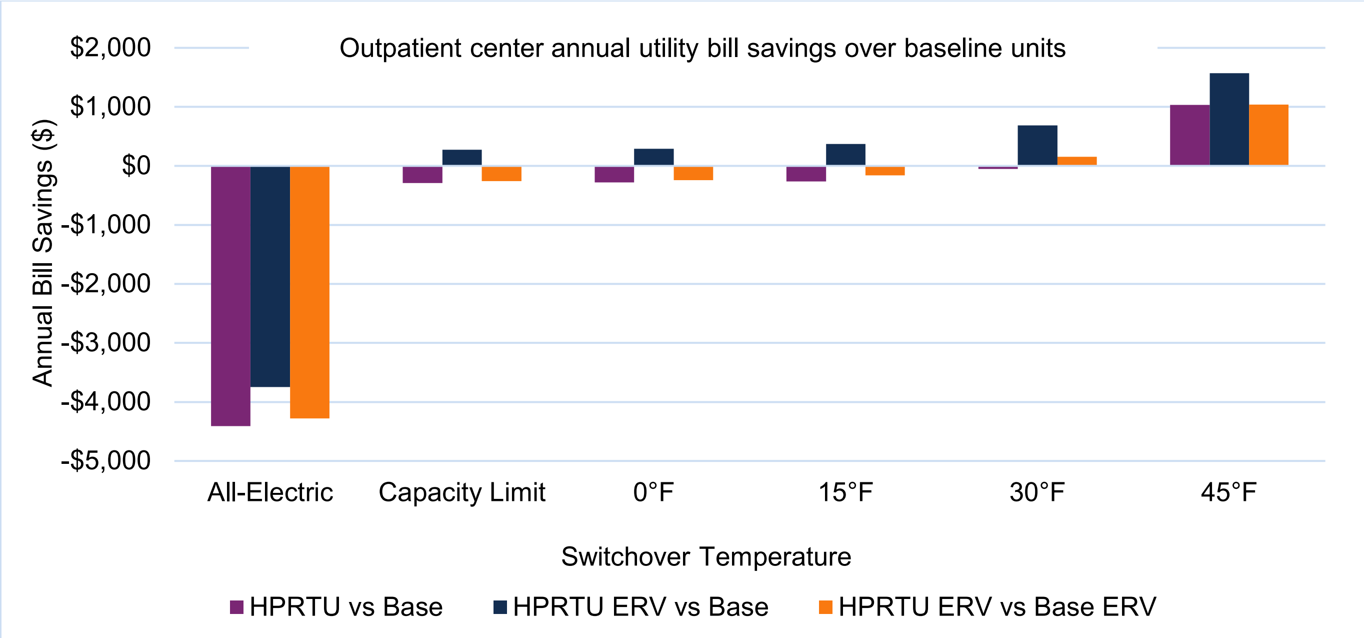
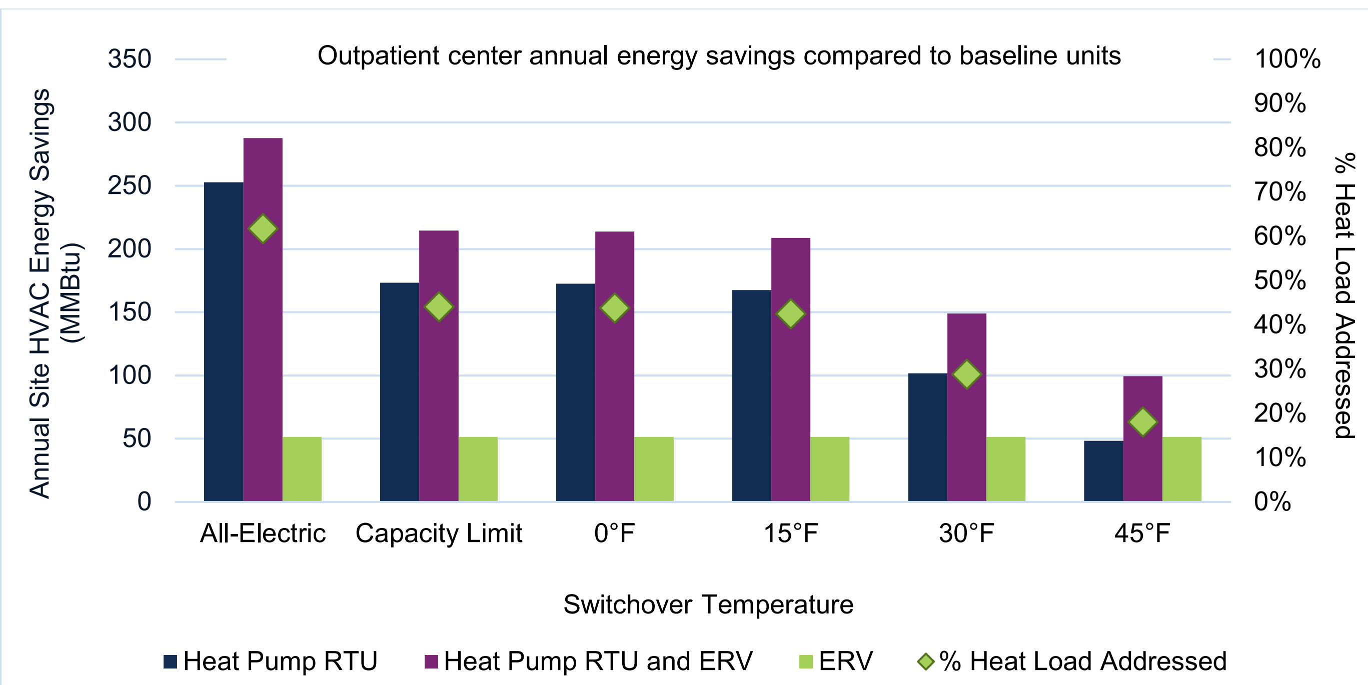


Chart 16. Annual energy savings over baseline vs. switchover temperature for the outpatient center model



OVERALL RESULTS

Overall, both energy savings and bill savings were observed for dual fuel heat pump RTUs and ERVs. When the two technologies were combined, even higher savings were observed. Energy and bill savings are shown in Table 7.

Table 7. Bill and energy savings by building model and technology

	Dual fuel heat pump RTU energy savings	Dual fuel heat pump RTU bill savings	ERV energy savings	ERV bill savings	Dual fuel heat pump RTU and ERV energy savings	Dual fuel heat pump RTU and ERV bill savings
Small office, climate zone 3	22%	2%	6%	4%	27%	7%
Small office, climate zone 2	21%	-1%	19%	12%	38%	13%
Small office, climate zone 1	13%	4%	26%	13%	39%	18%
Primary School	27%	0%	14%	9%	39%	10%
Retail store in strip mall	24%	1%	19%	16%	41%	17%
Standalone retail	20%	-6%	27%	18%	45%	16%
Medium office building	17%	7%	25%	9%	40%	16%
Outpatient center	18%	-1%	9%	5%	27%	7%

Energy savings

These models show consistent energy savings across multiple building types when dual fuel heat pump RTUs and ERVs are utilized**. Consistent energy savings of around 20% are observed when dual fuel heat pump RTUs are modeled in place of a standard unit.** The highest savings come from schools, retail, and small offices, which represent more than 55% of commercial building stock in Minnesota.

When standard units are modeled with ERVs, energy savings of around 20% are typical, though the energy savings vary based on building use. The highest savings are in standalone retail, at 27% savings compared to a standard unit, followed closely by a small office building in climate zone 1 that saw 26% energy savings. Both standalone retail and medium office buildings show 25% energy savings or higher and have an outdoor air (OA) percentage of less than 30%, with medium offices having an OA percentage of 18%. Comstock shows the average OA for buildings in Minnesota is 18%. This is significant because of existing market biases that incorrectly assume ERVs do not provide significant savings at less than 30% OA.

When both dual fuel heat pump RTUs and ERVs are modeled, around 30% energy savings are seen compared to standard units in most cases, and greater than 25% energy savings in all cases with a switchover temperature of 30°F. This represents a significant energy reduction for ERVs and dual fuel heat pump RTUs.

Bill savings

Due to demand charges typically included on commercial electric rates and the current rates of natural gas charges versus electrical charges, energy savings are not always analogous to bill savings for dual fuel heat pump RTUs and ERVs. Demand charges also play a large role in electrical charges, while natural gas relies on volumetric charges. This can increase bills when switchover temperatures are optimized for energy savings, but when switchover temperature is optimized for bill savings, bill impacts are neutral or positive and improve when dual fuel heat pump RTUs and ERVs are combined.

When comparing bill impact between standard units and dual fuel heat pump RTUs, bill impacts are directly related to switchover temperatures. Bill savings as high as 13% are seen when switchover temperatures are higher than 30°F, reducing the units' energy savings. At 30°F switchover temperature, bill impacts are roughly neutral. It is critical to work with building owners to understand their energy saving and bill saving goals to properly set a switchover temperature that aligns with their priorities.

ERVs' impact on bill savings varies based on time of use, ventilation rates, and billing structure. Bill savings can be as high as 18% in standalone retail stores, with most building types seeing savings between 9% and 15%.

When the model considers both ERVs and dual fuel heat pump RTUs, greater savings are achieved. ERVs reduce energy during peak demand, allowing for bill savings at lower switchover temperatures. For example, the standalone retail model shows that dual fuel heat pump RTUs add cost to an energy bill at switchover temperatures of 45°F or less. When an ERV is added to the dual fuel heat pump RTU, bill savings are seen at switchover temperatures as low as 0°F.

Conclusion

When choosing the best HVAC system for a building, decision makers should consider the combined impacts of ERVs and dual fuel heat pump RTUs, on both energy savings and bill savings. This model shows dual fuel heat pump RTUs and ERVs can achieve substantial energy savings, with reductions of over 40% compared to standard units across various building types. Consistent energy savings of around 20% are observed when dual fuel heat pump RTUs are modeled in place of a standard unit, and 20% energy savings are also observed when RTUs with ERVs are modeled in place of a standard RTU. The potential for significant bill savings is notable when the systems are used together, offering greater efficiency even at a lower switchover temperature. The adoption of these technologies does not increase energy bills in these cases and can produce bills savings of up to 18%.

Key factors such as switchover temperature, billing structure, and fluctuating costs of electricity and natural gas play a role in determining bill savings. Energy savings depend on the use and size of the building. Significant bill and energy savings are found on buildings modeled with ERVs with OA percentage as low as 8%, showing the importance of the ERVs on buildings with low ventilation.

Given these findings, dual fuel heat pump RTUs and ERVS should be strongly considered as part of any strategy aimed at reducing energy consumption and minimizing bill costs. For Minnesotan businesses, these technologies present a new solution to save energy and potentially reduce energy bills. By aligning system choices with building-specific characteristics and operation goals, decision makers can maximize energy efficiency and cost savings.