Residential Heat Pump Adoption and Nocturnal Atmospheric Cooling in the Las Vegas Valley
A First-Order Engineering Assessment of Heat Extraction, Emissions Reduction, and Spatial Distribution

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Abstract

This paper extends the control-volume framework developed in the companion EV/UHI paper [6] to estimate the nocturnal atmospheric cooling potential of widespread residential heat pump adoption in the Las Vegas valley. Heat pumps operating in heating mode extract thermal energy from outdoor air and deliver it indoors, producing a net cooling effect on the ambient environment. Using Clark County housing stock data (approximately 958,700 total units, of which an estimated 556,000 use natural gas for space heating), representative winter heating loads, and heat pump performance characteristics appropriate to Las Vegas's mild winter climate (COP 3.0–4.0 at typical winter temperatures of 35–50°F), the analysis estimates that full conversion from gas furnaces to heat pumps could extract approximately 2.0 GW of heat from the lower urban atmosphere on a representative cold winter night.

Under the same 15 mi × 15 mi × 100 ft control volume, this corresponds to an avoided warming (or net cooling contribution) of approximately 0.8°F at valley scale, with larger effects under calmer conditions. When integrated with observed chill-hour data showing that Las Vegas has declined from approximately 550 chill hours (below 45°F, November–February) in 1970 to approximately 310 in 2025—a 44% decline—the wind-speed-weighted analysis estimates that combined transport and building electrification could restore approximately 90–135 chill hours at valley scale, equivalent to rolling conditions back to the late 1990s level. A grid-aware emissions analysis accounting for the nighttime generation mix (approximately 75% natural gas when solar is absent) estimates a net CO_2 reduction of approximately 305,000 metric tons per year (52% reduction versus gas furnaces) and a net NO_x reduction of approximately 407 metric tons per year (88% reduction).

1. Introduction

The companion paper [6] established that direct anthropogenic heat from the internal-combustion vehicle fleet in the Las Vegas valley contributes a physically meaningful nocturnal warming increment—approximately 1.07°F in the representative 5 m/s ventilation case—and that broad electrification of the fleet could reduce this by roughly 75%. This paper addresses the building heating sector, which presents a thermodynamically distinct and complementary opportunity.

The key physical distinction is directional. During summer, air conditioners add waste heat to the outdoor atmosphere. During winter, heat pumps do the reverse: they extract heat from outdoor air and deliver it indoors. Las Vegas is particularly well suited for heat pump heating: winter temperatures are mild (average lows 34–40°F, December–February), the heating season is short (four to five months), and the existing residential building stock has forced-air ductwork from air conditioning systems, making retrofits straightforward.

2. Heat Pump Thermodynamics in Heating Mode

$Q_{hot} = Q_{cold} + W$, where Q_{hot} is heat delivered indoors, Q_{cold} is heat extracted from outdoor air, and W is compressor work. $COP_{heat} = Q_{hot} / W$. At COP = 3.5 (representative of Las Vegas at 38°F), a heat pump delivering 20,000 BTU/hr indoors extracts approximately 14,286 BTU/hr from outdoor air. A gas furnace (90% AFUE) producing the same output adds +2,222 BTU/hr waste heat outdoors through the flue. The net thermal swing per home is approximately 12,381 BTU/hr (3.63 kW)—elimination of flue waste heat plus active atmospheric extraction.

3. Data and Methods

Clark County's 2024 housing estimates report 958,705 total units (580,839 single-family, 201,476 apartments, 78,707 condos, 52,031 townhomes, 22,569 duplexes/triplexes, 23,083 mobile homes). Approximately 58% of Nevada homes use natural gas for heating (ACS/EIA), yielding an estimated 556,000 gas-heated dwellings. Average nighttime heating load: 15,000 BTU/hr per home at 38°F outdoor / 68°F indoor. Central COP: 3.5.

Outdoor Temp (°F)	Representative COP	Las Vegas Occurrence
50–60	3.5–4.0	Typical Nov, Mar nights
40–50	3.0–3.5	Typical Dec–Feb nights
30–40	2.5–3.0	Cold Dec–Jan nights
Below 30	2.0–2.5	Rare; ~10 nights/year

Table 1. Representative heat pump COP values by outdoor temperature for Las Vegas conditions.

4. Results

4.1 Valley-Scale Thermal Extraction

Total net heat extraction = 556,000 × 12,381 BTU/hr = 6.88×10^9 BTU/hr ≈ 2.02 GW. Plan-area heat flux: 3.47 W/m²—comparable in magnitude to the gasoline fleet transport heat flux (4.54 W/m²) but in the opposite direction: cooling rather than warming.

4.2 Near-Surface Temperature Effect

Wind Speed	Gas Furnace Fleet	Heat Pump Fleet	Net Temperature Swing
2 m/s	+0.22°F	−1.83°F	2.05°F cooler
5 m/s	+0.09°F	−0.73°F	0.82°F cooler
10 m/s	+0.04°F	−0.37°F	0.41°F cooler

Table 2. Valley-scale near-surface temperature effect of converting all gas-heated residences to heat pumps.

4.3 Combined Effects with Transport Electrification

Wind Speed	EV Avoided Warming	Heat Pump Cooling	Combined Effect
2 m/s	2.01°F	2.05°F	~4.1°F

5 m/s	0.80°F	0.82°F	~1.6°F
10 m/s	0.40°F	0.41°F	~0.8°F

Table 3. Combined nighttime temperature reduction from transport and building heating electrification.

4.4 Grid-Aware Emissions Analysis

Heat pump electricity is not carbon-free, particularly at night when solar generation is zero. Nevada's nighttime grid shifts to roughly 75% natural gas, 12% geothermal, 5% hydro, 5% coal, with a CO_2 intensity of approximately 780 lbs/MWh. At COP 3.5, each heat pump produces about 0.98 lbs CO_2/hr from grid electricity versus 1.95 lbs CO_2/hr from the gas furnace it replaces—a 50% reduction per unit of heat delivered. Aggregated: net annual CO_2 reduction of approximately 305,000 metric tons (52%). The NO_x reduction is proportionally larger at 407 metric tons/year (88%) because centralized power plants with SCR emission controls replace 556,000 uncontrolled residential furnaces.

5. Wind Rose Analysis and Chill-Hour Restoration

Approximately 55% of winter nighttime hours in residential areas fall in the calm-to-light categories (below 2.5 m/s), where the combined EV and heat pump cooling effect exceeds 2.7°F. Roughly 25% are essentially calm (below 1.5 m/s) where the combined effect exceeds 5°F.

Wind Regime	Speed Range	% Winter Nights	Combined ΔT
Calm	0–1.5 m/s	~25%	~5.4°F
Light	1.5–2.5 m/s	~30%	~2.7°F
Moderate	2.5–4 m/s	~25%	~1.6°F
Breezy	4–7 m/s	~15%	~1.0°F
Windy	>7 m/s	~5%	~0.6°F

Table 4. Estimated residential wind speed distribution and combined temperature effect.

5.1 Chill-Hour Gains by Neighborhood Zone

Neighborhood Zone	Baseline Chill Hrs	Additional Chill Hrs	% Increase	Key Factor
Summerlin / West	380–450	+120 to +180	27–40%	High elev., shelter
Spring Valley / SW	320–380	+100 to +150	26–47%	Residential density
Centennial Hills / NW	340–400	+110 to +160	28–47%	Moderate elevation
Henderson / SE	310–370	+100 to +145	27–47%	Moderate elevation
Central Valley / NE	270–320	+85 to +125	27–46%	Lower elev., warmer
Strip / Downtown	200–260	+20 to +40	8–20%	Casino waste heat

Table 5. Estimated additional annual chill hours from combined electrification by neighborhood zone.

The Summerlin area could gain 120–180 additional chill hours per year, restoring accumulation to approximately 500–630 hours—approaching the valley-wide 1970 baseline of 550 hours. However, a companion analysis [14] identifies an additional ~3°F of warming from upwind California agricultural land use that local electrification cannot address, setting a floor on achievable restoration.

6. Spatial Distribution and Ground-Level Placement

The cooling benefit is concentrated in residential neighborhoods. The Strip/downtown corridor sees only modest gains due to year-round waste heat from casino HVAC. Ground-level heat pump installations (split systems, mini-splits) deliver cooled exhaust air directly into the surface layer where density stratification traps it near the ground—the layer that matters most for plant physiology and ecological thermal thresholds. Rooftop packaged units discharge cooled air at 8–25 feet, where turbulent mixing during descent dilutes the temperature depression.

7. Conclusion

Widespread heat pump adoption would produce a measurable nocturnal cooling effect of approximately 2.0 GW on a representative cold winter night. The wind rose analysis shows conditions favorable to large temperature effects during 55% of winter nighttime hours. Combined with the companion EV analysis, electrification could restore approximately 90–135 chill hours per year at valley scale—offsetting roughly half of the 55-year decline. Beyond thermal benefits, conversion eliminates approximately 305,000 metric tons CO_2/year (52%) and 407 metric tons NO_x/year (88%). These findings argue that transport and building electrification should be evaluated not only as decarbonization strategies but also as ecological conservation measures in hot desert cities.

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