Electric Vehicle Adoption and Transport-Related Anthropogenic Heat in the Urban Heat Island: A First-Order Engineering Assessment for Las Vegas, Nevada

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ABSTRACT

Las Vegas combines rapid warming, a strong urban heat island, and a vehicle-dominated transport system, making it a compelling case for studying anthropogenic heat from traffic. This paper develops a first-order engineering estimate of how much near-surface warming could be reduced if the urban light-duty fleet were electrified. Using Clark County vehicle-miles-traveled data, representative gasoline (25 mpg) and battery-electric (34 kWh/100 mi) energy intensities, and a control-volume model for a 15 mi × 15 mi × 100 ft lower atmospheric layer whose depth is supported by field observations of nocturnal smoke-layer behavior, the analysis estimates that direct traffic heat release falls from roughly 2.65 GW (4.54 W/m²) for an internal-combustion fleet to about 0.67 GW (1.15 W/m²) for an all-electric fleet. Under a representative 5 m/s ventilation case, direct avoided warming is approximately 0.80 °F; when a secondary air-conditioning feedback term is included, the avoided warming rises to approximately 0.91 °F. Electrification would not eliminate urban anthropogenic heat—EV energy use also degrades to

heat locally—but it could materially reduce a nocturnal and corridor-scale component of the Las Vegas heat burden, with potential co-benefits for cooling energy demand and nighttime ecological recovery.

1. Introduction

Las Vegas is a useful case study for anthropogenic heat because it combines rapid warming, a strong urban heat island, high summer cooling demand, and a transportation system dominated by private vehicles. The National Weather Service notes that the city's mean low temperature increased from 53.3 °F in the 1970s to 60.3 °F in the 2010s, a rise linked in large part to urbanization and heat-island effects (NWS 2021). Separately, Southern Nevada's 2022 urban heat mapping campaign measured a same-day maximum air-temperature differential of 11.1 °F across a 430 mi² study area, underscoring the magnitude of spatial heat inequality already present in the valley (RTC 2023).

Most urban heat mitigation discussion focuses on surface albedo, vegetation, urban geometry, and long-term regional climate change. Those drivers are rightly central. But a second class of drivers—direct anthropogenic heat releases from engines, buildings, and infrastructure—also matters, especially at night, in calm wind conditions, and in dense corridors. The role of anthropogenic heat in urban climates has been studied through mesoscale modeling (Sailor 2011; Ichinose et al. 1999) and through sector-specific inventories of vehicular waste heat (Esparza-López et al. 2022), yet few analyses have focused specifically on desert cities where the thermal stakes are highest and where building cooling feedback amplifies the signal. In Las Vegas, that question is practically important because the region's thermal burden feeds back into residential and commercial cooling demand, which in turn rejects additional heat to the outdoor environment. There is also a growing ecological dimension: rising nighttime temperatures in the Las Vegas valley have been linked to stress on native desert vegetation and fauna, which depend on overnight thermal recovery that is increasingly compromised by the urban heat island (Devitt and Bird 2026).

This manuscript develops a first-order engineering estimate rather than a full mesoscale simulation. Its contribution is threefold: it applies the analysis to a hot desert city where the practical stakes are highest; it couples the transport heat estimate to an explicit air-conditioning feedback term; and it grounds the control-volume assumptions in local observational evidence from the Las Vegas valley. The aim is to answer a bounded question: if the urban vehicle fleet in Las Vegas were largely electrified, how much direct transport heat might be removed from the lower urban atmosphere, and how much secondary reduction might follow through lower air-conditioning waste heat? The resulting numbers should be interpreted as engineering-order estimates that motivate further measurement and modeling, not as definitive field measurements.

2. Conceptual framework

A key conceptual point is that the paper counts local end-use dissipation within the Las Vegas control volume, not upstream generation heat outside it. Electricity produced at Hoover Dam, a remote fossil plant, or a utility-scale solar facility outside the valley does not add generation-side heat to the modeled Las Vegas box. What is counted is the energy actually used by vehicles while operating inside the box. For internal-combustion vehicles, fuel energy appears first as engine, radiator, exhaust, and driveline heat, and the remaining mechanical work then degrades into heat through rolling resistance, aerodynamic drag, and braking. For EVs, the motor and inverter are much more efficient, but the delivered battery energy for an urban trip is still mostly dissipated by the end of that trip through motor losses, tire-road friction, aerodynamic drag, cabin cooling, and unrecovered braking losses. If a trip begins and ends with similar speed and elevation, and if ordinary regenerative braking is already embedded in the per-mile EV consumption figure, the net storage terms are small and the trip energy is well-approximated as local heat release. The urban heat benefit of electrification therefore arises from lower total energy consumed per mile, not from the complete disappearance of local thermal dissipation (EPA 2025; DOE and EPA 2026; Esparza-López et al. 2022).

A second conceptual point is that building cooling introduces a feedback loop. Air conditioners do not destroy heat; they transfer heat from indoors to outdoors while adding compressor work. As outdoor air becomes warmer, cooling loads rise, and the condenser side of the HVAC system rejects more heat to the urban atmosphere (DOE 2026). This mechanism is especially relevant in a city such as Las Vegas, where summer electricity demand and late-day building cooling loads are already intense.

3. Data and methods

a. Transport activity and energy assumptions

The transport base case uses the Nevada Department of Transportation's 2024 Annual Vehicle Miles of Travel report (derived from 2023 HPMS data). Summing Clark County's urban and small-urban classes yields 17.208 billion vehicle-miles per year, used here as a proxy for urban valley-scale travel (NDOT 2024). A representative gasoline fleet efficiency of 25 miles per gallon is used as the central internal-combustion assumption. The U.S. Environmental Protection Agency defines one gallon of gasoline equivalent as 33.7 kWh (EPA 2025), giving a central energy intensity of 1.348 kWh/mi for the gasoline case.

For the battery-electric counterfactual, the manuscript uses a representative consumption of 34 kWh/100 miles (0.34 kWh/mi), close to the middle of current 2024 model-year all-electric listings on FuelEconomy.gov (DOE and EPA 2026). This value is used here as the per-mile electricity required for urban travel inside the modeled domain; it is not assumed that the electricity is generated inside Las Vegas. This choice is intentionally transparent and easy to stress-test. It can be replaced by a weighted local fleet average if registration-level vehicle-mix data are later introduced.

b. Control volume and ventilation model

To convert annual transport energy to a temperature increment, the paper uses a simplified steady-flow control volume for the lower urban atmosphere. The assumed control volume is a 15 mi × 15 mi plan area and a 100 ft mixing height, representing a shallow near-surface layer during

evening or nighttime conditions. This is an illustrative research assumption, but it is supported by local observational evidence. The Las Vegas urban area is dominated by one- and two-story residential structures, with taller buildings concentrated along the Las Vegas Strip corridor. On calm summer nights, direct visual observation of fireworks smoke during Fourth of July and New Year's Eve events provides a natural tracer of the shallow nocturnal surface layer. The smoke visibly pools and shears at approximately rooftop height of the surrounding one- to two-story homes, and this layered structure can persist for an hour or more before dissipating. These observations suggest that effective nocturnal mixing heights in residential areas are often well below 100 ft, making the assumed layer height a conservative (i.e., warming-understating) choice rather than an aggressive one. The ground-level wind shear observable at Harry Reid International Airport provides a complementary perspective: the abrupt transition from the sheltered residential fabric to the open runway environment produces a notable change in surface wind behavior, illustrating how urban roughness elements suppress ventilation in built-up areas.

Inflow ventilation is represented by an average horizontal wind speed U crossing one face of the control volume. Representative cases of 2, 5, and 10 m/s are used to bracket calm, typical, and breezy conditions. The Las Vegas valley's mean annual wind speed is below 7 mph (approximately 3 m/s), and nighttime conditions in residential neighborhoods are typically calmer still. Formal nocturnal boundary-layer profile data specific to the current Las Vegas urban footprint are limited, in part because the valley's rapid expansion over the past several decades has continuously altered the surface roughness and local wind dynamics. Long-term residents report that ground-level dust storms driven by soil erosion, once common fifty years ago, have essentially ceased as development replaced open desert with impervious surfaces and structures. This ongoing transformation of the valley's aerodynamic character makes historical boundary-layer studies of limited applicability to the present urban form and reinforces the value of direct observational indicators such as the fireworks smoke behavior described above.

The average transport power release is calculated as

$$\dot{Q} = VMT \times e \times 3.6 \times 10^{6} / (365 \times 24 \times 3600)$$

where VMT is annual vehicle-miles traveled and e is vehicle energy intensity in kWh/mi. The corresponding plan-area heat flux is

$$F = \dot{Q} / A$$

with A as the control-volume plan area. The first-order lower-layer air-temperature increase is then estimated from a flow-through energy balance:

$$\Delta T = \dot{Q} / (\rho\, c_p\, U\, H\, L)$$

where $\rho = 1.2$ kg/m³, $c_p = 1005$ J/kg·K, H is the assumed lower-layer height, and L is the cross-wind width of the square control volume. In effect, the model treats trip energy used within the domain as local heat release except for any small net changes in stored kinetic or potential energy over the completed trip. Because the model is linear, the estimate is best interpreted as a near-surface perturbation under specified ventilation assumptions, not as a full urban-climate forecast.

c. Air-conditioning feedback term

To approximate the secondary building feedback, the manuscript uses results from a city-scale building waste-heat study that found an hourly waste-heat sensitivity of 1.72 W/m² per 1 °C increase in outdoor air temperature and that air-conditioning heat rejection contributed 86.5% of building waste heat during heat-wave conditions (Salamanca et al. 2020). Because the Los Angeles study domain and urban form differ from Las Vegas, the present paper applies the coefficient as a sensitivity term rather than a fixed truth. A building-applicability factor f^b of 0.25 to 1.00 scales the area-wide relevance of the coefficient. The physical logic is sequential: direct transport heating raises outdoor air temperature first; that warmer air then increases building sensible load and condenser heat rejection; the added condenser heat slightly raises outdoor temperature again.

The feedback terms are written as

$$\Delta T_direct = \gamma F_transport$$

$$F_AC = \alpha\, f^b\, \Delta T_direct$$

$$\Delta T_{total} = \gamma(F_{transport} + F_{AC}) = \gamma F_{transport} / (1 - \gamma \alpha f^{b})$$

$$\Delta T_{AC\text{-}only} = \Delta T_{total} - \Delta T_{direct}$$

where $\gamma = L / (\rho c_p U H)$ and $\alpha = 1.72$ W/m²/K. The open-loop term $F_{AC} = \alpha f^{b} \Delta T_{direct}$ is useful because it shows the extra building waste heat attributable to the traffic-driven warming increment itself before the feedback loop is closed. In the representative 5 m/s case, γ is approximately 0.131 K m²/W, so a 0.60 K direct warming increment implies roughly 0.51 W/m² of extra AC waste heat when $f^{b} = 0.5$. This is the kind of secondary cooling-load reduction that broad transport electrification could avoid.

4. Results

a. Base-case transport heat release

Under the central assumptions, the urban Clark County light-duty fleet equivalent releases about 2.65 GW of average transport heat in the gasoline case and about 0.67 GW in the all-EV case. Spread over the 225 mi² assumed plan area, that is approximately 4.54 W/m² for the gasoline fleet and 1.15 W/m² for the electric fleet. In other words, the representative EV scenario reduces direct traffic heat by about 75%.

Table 1. Core model inputs and central assumptions.

Input	Value	Units	Basis
Clark County urban + small-urban VMT	17.208	billion mi/yr	NDOT 2024 AVMT report
Gasoline fleet efficiency	25	mi/gal	Central scenario assumption
Gasoline energy equivalence	33.7	kWh/gal	EPA gallon gasoline equivalent
EV energy intensity	34	kWh/100 mi	Representative 2024 EV mid-range
Plan area	15 × 15	mi	Illustrative control volume
Lower-layer height	100	ft	Conservative nocturnal layer estimate
Air density, ρ	1.2	kg/m³	Standard warm-condition approximation
Specific heat, c_p	1005	J/kg·K	Standard atmospheric value
Building feedback sensitivity, α	1.72	W/m²/K	Salamanca et al. (2020)

b. Near-surface temperature implications

The first-order temperature response depends strongly on ventilation. In the 5 m/s representative case, the direct traffic contribution is about 1.07 °F for the gasoline fleet and 0.27 °F for the EV fleet, for an avoided warming of roughly 0.80 °F. In a calmer 2 m/s case, the avoided warming increases to about 2.01 °F. In a breezier 10 m/s case, the avoided warming falls to about 0.40 °F. These results show why anthropogenic heat matters most during weaker ventilation and shallower evening boundary layers.

Table 2. Direct lower-layer temperature contribution of transport energy under the central scenario.

Wind speed	Gasoline fleet	All-EV fleet	Avoided warming	Interpretation
2 m/s	2.69 °F	0.68 °F	2.01 °F	Calm to weakly ventilated evening/night
5 m/s	1.07 °F	0.27 °F	0.80 °F	Representative valley-scale case
10 m/s	0.54 °F	0.14 °F	0.40 °F	Breezy or better-mixed condition

c. Air-conditioning feedback sensitivity

When the building waste-heat sensitivity term is included, the transport signal is amplified modestly because a warmer outdoor environment increases condenser heat rejection. In the representative 5 m/s case, applying the published 1.72 W/m²/K coefficient to 25%, 50%, and 100% of the modeled area raises the avoided warming from 0.80 °F (no feedback) to approximately 0.85 °F, 0.91 °F, and 1.04 °F, respectively. The added AC term is therefore meaningful but still secondary to the direct transport-energy difference. Put differently, the traffic-heating increment slightly increases building cooling load, and reducing that increment through electrification slightly reduces the amount of heat that air-conditioning systems must reject back into the urban canopy layer.

Table 3. Representative 5 m/s case with building cooling feedback.

f^b	Gasoline total	EV total	Avoided warming	Meaning
0.25	1.14 °F	0.29 °F	0.85 °F	Conservative partial-area building response
0.50	1.21 °F	0.31 °F	0.91 °F	Moderate area-wide building

				response
1.00	1.39 °F	0.35 °F	1.04 °F	Upper-bound full-area response

d. Worked feedback-loop calculation for the representative case

The representative 5 m/s case can be shown step by step so the AC-load term is explicit. First, the gasoline fleet energy intensity is $e_g = 33.7/25 = 1.348$ kWh/mi and the EV case is $e_{ev} = 34/100 = 0.34$ kWh/mi. Using 17.208 billion mi/yr, those values imply average transport powers of about 2.65 GW and 0.67 GW, which become plan-area heat fluxes of 4.54 and 1.15 W/m² over the assumed 225 mi² control volume. With $\gamma = L/(\rho\, c_p\, U\, H)$ at $U = 5$ m/s, the corresponding direct temperature increments are 1.07 °F and 0.27 °F. Applying the open-loop AC relation $F_{AC} = \alpha\, f^b\, \Delta T_{direct}$ with $\alpha = 1.72$ W/m²/K and $f^b = 0.5$ gives about 0.51 W/m² of added building waste heat in the gasoline case and 0.13 W/m² in the EV case. Closing the loop raises the total lower-layer warming to 1.21 °F and 0.31 °F, so the feedback itself contributes about 0.14 °F and 0.03 °F, respectively, and the avoided warming increases from 0.80 °F direct-only to about 0.91 °F with feedback.

Table 4. Worked 5 m/s feedback-loop calculation with moderate building applicability ($f^b = 0.5$).

Quantity	**Gasoline fleet**	**All-EV fleet**	**Avoided / difference**
Direct transport heat flux, $F_{transport}$	4.54 W/m²	1.15 W/m²	3.39 W/m² lower
Direct lower-layer warming, ΔT_{direct}	1.07 °F	0.27 °F	0.80 °F lower
Added AC waste heat, $F_{AC} = \alpha\, f^b\, \Delta T_{direct}$	0.51 W/m²	0.13 W/m²	0.38 W/m² lower
Total lower-layer warming, ΔT_{total}	1.21 °F	0.31 °F	0.91 °F lower
Feedback-only increment, $\Delta T_{AC\text{-}only}$	0.14 °F	0.03 °F	0.11 °F lower

5. Discussion

Four findings emerge from the calculations. First, the hypothesis that vehicle heat can produce a measurable lower-atmosphere increment in Las Vegas is physically reasonable. Under calm or typical nighttime conditions, the modeled transport contribution is not trivial. Second, the dominant benefit of electrification is not the elimination of local transport heat, but a large

reduction in total trip energy use per mile inside the valley. Third, the cooling-load feedback is small but explicit: in the representative 5 m/s case with $f^b = 0.5$, the transport increment implies about 0.38 W/m² less AC waste heat in the EV case than in the gasoline case, which adds roughly 0.11 °F to the avoided warming. Fourth, that building term remains secondary to the direct transport term at valley scale.

The results should also be kept in proportion. Southern Nevada's measured urban heat island is much larger than the modeled transport increment alone. The 11.1 °F maximum temperature differential observed in the 2022 mapping campaign reflects the combined effects of land cover, urban form, sparse canopy, thermal storage, surface materials, and anthropogenic heat (RTC 2023). Transport electrification therefore should be viewed as a co-benefit strategy that can trim one component of the nighttime heat burden rather than as a standalone solution to urban overheating.

That said, even a sub-degree valley-scale reduction can matter. Heat risk in desert cities is threshold-driven. Late-evening thermal comfort, overnight cooling, compressor cycling, and building envelope recovery are all sensitive to small changes in outdoor temperature. Any intervention that simultaneously lowers emissions, reduces direct traffic heat, and trims cooling-load feedback deserves attention alongside tree canopy, shade, cool materials, and urban-design strategies.

It is also worth noting that the valley-scale box model produces a spatially averaged estimate, whereas the actual heat burden is concentrated where traffic is dense, ventilation is poor, and mixing is shallow. In sheltered residential corridors dominated by one- and two-story structures, both the effective mixing height and the local wind speed are likely lower than the central-case assumptions, implying that neighborhood-scale temperature perturbations near major arterials could exceed the valley-average values reported here. This spatial heterogeneity connects the transport electrification question to the equity dimension documented in the 2022 Southern Nevada heat mapping campaign, where the 11.1 °F maximum temperature differential was

driven partly by the same neighborhood-scale conditions that concentrate anthropogenic heat (RTC 2023).

Finally, the nocturnal dimension of the heat burden carries ecological consequences beyond human comfort. Rising nighttime minimum temperatures in the Las Vegas valley have been linked to stress on native desert plant and animal species that depend on overnight thermal recovery for metabolic regulation, water retention, and reproductive success (Devitt and Bird 2026). Even fractional reductions in the nighttime anthropogenic heat increment may therefore carry disproportionate ecological value in a system already operating near thermal tolerance limits.

6. Limitations and next research steps

This manuscript is intentionally transparent about its simplifications. The modeled plan area and lower-layer height are assumed research values informed by local smoke-layer observations rather than by formal radiosonde or lidar profiling. Systematic nocturnal boundary-layer measurements for the Las Vegas valley are scarce, in part because the valley's rapid urban expansion over the past several decades has continuously altered the surface roughness, wind dynamics, and thermal character of the basin, rendering older observational data of limited relevance to the current built environment. The use of Clark County urban and small-urban VMT is a practical proxy rather than a precise inventory of travel confined to a 15 mi × 15 mi box. The gasoline and EV energy intensities are representative scenarios rather than observed fleet-weighted means. Upstream electricity-generation heat is outside the control volume unless generation physically occurs inside it. Charging losses are implicitly local only to the extent that charging occurs within the valley. The building feedback coefficient is taken from a Los Angeles study and may not transfer directly to Las Vegas without calibration (Salamanca et al. 2020). Rooftop solar and other roof-surface energy-balance effects are separate urban-climate terms and are not yet included. The model uses annual-average VMT spread uniformly across all hours, which does not capture the mismatch between peak traffic (daytime commute hours) and peak

UHI sensitivity (nighttime); a diurnal traffic profile would refine the nocturnal estimate. Finally, the model does not resolve street canyons, parking-lot heat storage, bus and freight fleets, or the time lag between energy use and heat release.

Those limitations suggest a publishable next phase. A stronger paper would combine (1) an hourly traffic inventory to resolve the diurnal mismatch between peak travel and peak UHI sensitivity, (2) local registration-based fleet-efficiency data, (3) measured or modeled nocturnal boundary-layer depth, potentially using lidar or ceilometer deployments in representative residential and corridor locations, (4) a building-energy model calibrated to Las Vegas land-use classes, (5) fixed-site and mobile temperature observations near major corridors, (6) separate treatment of rooftop PV and other roof-energy-balance modifications, and (7) an assessment of ecological heat-stress thresholds for native desert species to quantify the biological significance of the modeled nighttime temperature reductions. A mesoscale WRF-UCM or CFD-coupled study could then test how much of the first-order estimate survives in a more realistic urban-atmospheric framework.

7. Conclusions

A cautious but useful conclusion is that broad electrification of the Las Vegas urban vehicle fleet could plausibly reduce a lower-layer nighttime anthropogenic heating component by roughly 0.5–1.0 °F in representative valley-scale conditions, with larger benefits in calmer and shallower boundary-layer states. The reduction is not absolute because EV trip energy used within the valley still dissipates there even when the electricity was generated elsewhere, but it is still substantial because EVs use far less energy per mile than internal-combustion vehicles. When the secondary air-conditioning feedback is included, reduced traffic heating lowers the induced building waste-heat increment by about 0.38 W/m² in the representative 5 m/s case, increasing the avoided warming from 0.80 °F direct-only to about 0.91 °F with feedback. Moreover, because the valley-scale estimate averages over neighborhoods with widely varying ventilation and mixing depths, corridor-scale benefits in sheltered residential areas may be larger

than the reported mean. As a result, transport electrification should be treated not only as a decarbonization strategy but also as a local heat-mitigation co-benefit worthy of direct urban-climate study in hot desert cities—one with potential consequences for cooling energy demand, outdoor thermal comfort, and the survival of heat-stressed native ecosystems.

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Data Availability Statement

The Clark County vehicle-miles-traveled data used in this study are publicly available from the Nevada Department of Transportation (NDOT 2024). Gasoline energy equivalence data are from the U.S. Environmental Protection Agency (EPA 2025). Electric vehicle energy consumption data are from FuelEconomy.gov (DOE and EPA 2026). The building waste-heat sensitivity coefficient is from Salamanca et al. (2020). No proprietary data were used in this analysis. The control-volume calculations described in section 3 are fully reproducible from the inputs reported in Table 1.

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