From Shrinking Cities to Solar-Ready Communities: Leveraging Drone-Enhanced Geospatial Intelligence for Clean Energy Equity in the Mid-South

Terence L. Bolden
Managing Partner, MyDroneForce.com | President, TlbEnterprise.com
North Little Rock, Arkansas, United States
Contact: info@tlbenterprise.com

Henry Golatt
Co-Founder, HBCU Clean Energy Initiative
Columbus, Ohio, United States
Contact: golatth@outlook.com

Author Contributions

Terence L. Bolden: Conceptual design, professional practice framing, recommendations development, and final authorship.

Henry Golatt: Primary source document identification and attribution (Rahman, 2024); research framing and analytical direction. As Co-Founder of the HBCU Clean Energy Initiative, Golatt provided institutional context and programmatic alignment for the paper's equity-centered recommendations.

Abstract

Shrinking mid-Southern cities like Pine Bluff, Arkansas, face a paradox: despite significant population loss over the past three decades, land surface temperatures have risen sharply and urban energy burdens remain high among low-income and minority residents. This paper examines how drone-enhanced geospatial intelligence—integrating Unmanned Aerial Systems (UAS) with remote sensing frameworks such as Land Use and Land Cover (LULC) analysis, Normalized Difference Vegetation Index (NDVI), and Normalized Difference Built-Up Index (NDBI)—can address systemic gaps in clean energy site assessment and community-level solar deployment in underserved cities. Drawing on satellite-based findings for Pine Bluff from 1993 to 2023, this paper argues that minority-owned UAS and geospatial technology firms are uniquely positioned to fill data infrastructure gaps that constrain equitable energy investment. Triangulated with NREL National Solar Radiation Database (NSRDB) irradiance data confirming that Pine Bluff receives approximately 4.7 kWh/m²/day of global horizontal irradiance, the analysis reveals that the city's most thermally stressed zones are simultaneously its highest solar resource zones—creating a compounding case for targeted clean energy investment. Recommendations target federal and state energy agencies, HBCU research partnerships, and municipal

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planners to adopt drone-enabled geospatial tools as a standard component of equitable clean energy planning.

Keywords: energy equity; drone geospatial intelligence; land surface temperature; shrinking cities; HBCU clean energy research; solar resource mapping

1. Introduction and Problem Statement

Pine Bluff, Arkansas has been identified as one of the fastest-shrinking cities in the United States, losing approximately 10,000 residents between 1993 and 2023 according to the U.S. Census Bureau (2023). Yet recent remote sensing analysis reveals a striking paradox: despite this population contraction, the city's land surface temperature (LST) maximum rose from 45.3°C in 1993 to 54.7°C in 2023, and its built-up area increased by 7.06% over the same period (Rahman, 2024). These findings signal an intensifying urban heat island effect in a city where low-income and minority residents—who constitute a majority of the remaining population—bear disproportionate energy cost burdens with limited access to clean energy resources.

This paper addresses a critical gap at the intersection of geospatial data access and equitable clean energy deployment. Mid-South cities like Pine Bluff are often overlooked by large-scale clean energy investors due to perceived market size and institutional risk. Yet the availability of underutilized land, declining built infrastructure, and rising energy burdens create conditions ripe for community-scale solar and green infrastructure investment—if the right data tools are deployed and the right institutional partners are engaged. Critically, NREL's National Solar Radiation Database confirms that Pine Bluff receives approximately 4.7 kWh/m²/day of global horizontal irradiance—a resource level sufficient to make community-scale solar economically viable and competitive with utility rates, even before accounting for federal incentives under the Inflation Reduction Act.

This paper argues that drone-enhanced geospatial intelligence, delivered through minority-owned UAS technology firms in partnership with HBCUs and community development organizations, represents an underutilized and urgently needed pathway to equitable clean energy planning in shrinking mid-Southern cities.

2. Background, Context, and Literature Review

2.1 The Urban Heat and Energy Burden Nexus in Shrinking Cities

Shrinking cities—those experiencing sustained population loss and economic contraction—face compounding environmental vulnerabilities that are distinct from those confronting growing urban areas. As Rahman (2024) documented for Pine Bluff, forest area loss and expanded impervious surfaces correlate positively with rising LST (R^2=0.51 for NDBI vs. LST in 2023), while reduced vegetation coverage corresponds

negatively with LST (R^2=0.10–0.22 for NDVI vs. LST). These biophysical changes intensify cooling energy demand during the hottest months, increasing utility costs for residents who can least afford them.

The American Council for an Energy-Efficient Economy (ACEEE, 2022) has documented that low-income households in the South spend three times more of their income on energy than higher-income counterparts. In cities like Pine Bluff, where median household incomes are well below state and national averages, this energy burden compounds the effects of population loss, disinvestment, and aging housing stock. The result is a population simultaneously exposed to greater thermal stress and less equipped to mitigate it through energy-efficient upgrades or clean energy access.

Meng et al. (2018) and Liu et al. (2018) have demonstrated that surface urban heat island intensity is not a simple function of city size or density—smaller cities in the mid-South exhibit pronounced thermal anomalies driven by land cover transitions, infrastructure aging, and the loss of tree canopy that historically moderated summer temperatures. Shrinking cities represent a category of urban thermal risk that has received insufficient attention in both energy policy and geospatial research literature.

2.2 Geospatial Remote Sensing as an Energy Planning Tool

Landsat-based LULC analysis has been widely used to characterize built-up change and thermal dynamics at the city scale (Amini et al., 2022; Yasin et al., 2022). The Rahman (2024) study of Pine Bluff employed Landsat 5 TM and Landsat 9 OLI imagery analyzed through Google Earth Engine, using random forest machine learning classification with overall accuracy rates of 97.1% to 98.6%, to map five land classes: built-up, water body, agricultural/grass, forest, and open space. LST was derived from thermal band calibration using band-specific rescaling factors from image metadata, following the methodology described in Avdan and Jovanovska (2016). Classification accuracy was assessed using established confusion matrix protocols (Congalton & Green, 2019).

While satellite-based tools provide temporal breadth and spatial consistency across large areas, they are constrained by cloud cover, spatial resolution (typically 30 meters for Landsat multispectral bands), and revisit frequency (16-day repeat cycle). These constraints limit their utility for parcel-level solar siting assessments, which require sub-meter resolution data updated on a seasonal or monthly basis. UAS-based remote sensing addresses many of these limitations with sub-meter resolution, on-demand deployment, and lower per-mission cost relative to satellite retasking or airborne survey alternatives.

Al Kafy et al. (2020) demonstrated comparable LULC-LST correlation methodologies in the context of Rajshahi District, Bangladesh, confirming that the biophysical relationships between built-up expansion, vegetation decline, and surface temperature intensification are consistent across different geographic and economic contexts. This

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cross-context validation strengthens the applicability of the Pine Bluff findings to other shrinking mid-Southern cities.

2.3 The Role of Minority-Owned Firms in Geospatial Innovation

Minority-owned geospatial and technology firms remain significantly underrepresented in federal and state energy research contracting. Despite their unique positioning to serve underinvested communities—often operating within those communities, employing local residents, and possessing relationships with municipal governments that larger firms do not—systemic barriers constrain their growth and impact. These barriers include limited access to early-stage capital, restricted procurement pathways that favor larger incumbents, bonding and insurance minimums calibrated for firms with established revenue histories, and underfunded HBCU research pipelines that could otherwise serve as talent and partnership conduits.

Programs such as the DOE Office of Energy Justice and the HBCU Clean Energy Initiative (co-founded by paper co-author Henry Golatt) have begun to address these structural gaps, but implementation has been uneven. The absence of minority-owned UAS and geospatial firms from major energy agency contractor rosters reflects not a lack of technical capability but a lack of institutional access—a distinction with significant policy implications.

2.4 Pine Bluff as a Policy-Relevant Case

Pine Bluff's designation as one of America's fastest-shrinking cities (THV11, 2021) makes it a nationally significant test case for whether clean energy investment can be anchored in communities experiencing simultaneous demographic and economic contraction. The city's majority Black population, low median household income, aging housing stock, and rising thermal load—all documented in the Rahman (2024) analysis and corroborated by U.S. Census Bureau (2023) data—collectively create conditions of compounded vulnerability that standard energy investment frameworks are not designed to address.

Critically, Pine Bluff is also home to the University of Arkansas at Pine Bluff (UAPB), an HBCU with geography and environmental science programming capacity, and is situated within Jefferson County, which has been identified under federal energy equity frameworks as an energy-distressed community. These institutional and policy assets, combined with the satellite-documented thermal and land cover profile established by Rahman (2024), make Pine Bluff an optimal anchor site for a pilot geospatial-to-solar initiative.

2.5 The NREL National Solar Radiation Database as a Public Equity Infrastructure Tool

The NREL National Solar Radiation Database (NSRDB) provides free, publicly accessible hourly and half-hourly solar radiation records for the continental United

States spanning 1998 to 2023, at spatial resolutions as fine as 2 kilometers via GOES-R satellite imagery (NREL, 2023). The database delivers three core radiation metrics—Global Horizontal Irradiance (GHI), the total solar radiation reaching a horizontal surface; Direct Normal Irradiance (DNI), the direct beam component critical for tracking PV systems; and Diffuse Horizontal Irradiance (DHI), solar radiation scattered by the atmosphere—alongside meteorological variables including air temperature, wind speed, and relative humidity. The NSRDB feeds directly into NREL's PVWatts Calculator and System Advisor Model (SAM), enabling site-level estimation of annual photovoltaic energy output and project-level financial performance without proprietary software or data acquisition costs.

For equity-centered energy planning, the NSRDB's free and open-access architecture is strategically significant: it means that minority-owned firms and HBCU researchers have access to the same foundational solar siting intelligence as large-scale commercial developers. This eliminates one structural data access barrier that has historically disadvantaged community-rooted organizations competing for clean energy project development opportunities. Applied to Jefferson County, Arkansas, NSRDB data confirms that Pine Bluff receives approximately 4.7 kWh/m²/day of global horizontal irradiance annually—placing it firmly within the South-Central solar resource belt and well above the national threshold for economically viable community-scale solar deployment (NREL, 2023).

3. Methods and Analytical Framework

This paper employs a three-part analytical framework that integrates satellite-based baseline assessment, NSRDB solar resource quantification, drone-enhanced high-resolution overlay, and a community-rooted implementation model. The framework is designed to be replicable across other shrinking mid-Southern cities with comparable demographic and thermal profiles.

3.1 Satellite-Based Baseline Assessment

The evidentiary foundation of this paper draws on the Rahman (2024) satellite-based LULC and LST analysis of Pine Bluff. Near-anniversary Landsat imagery from 1993 and 2023 was analyzed using Google Earth Engine. NDVI was calculated using the standard formula: (NIR − Red) / (NIR + Red), where NIR represents the near-infrared band and Red represents the red band of the Landsat sensor. NDBI was calculated as: (SWIR − NIR) / (SWIR + NIR), where SWIR represents the shortwave infrared band. LST was derived from the thermal band using band-specific rescaling factors extracted from image metadata, converting digital number values to top-of-atmosphere radiance and subsequently to brightness temperature in Celsius, following Avdan and Jovanovska (2016).

Correlation analysis between NDVI, NDBI, and LST was conducted using multipoint pixel sampling in ArcGIS Pro, generating Pearson R^2 coefficients that characterize the

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directional and magnitude relationship between land cover indices and surface temperature. This baseline establishes the thermal and land cover profile of Pine Bluff across three decades and identifies candidate zones for clean energy intervention based on open space distribution, LST concentration, and impervious surface density.

3.2 NSRDB Solar Resource Quantification and UAS-Enhanced High-Resolution Overlay

This paper integrates NREL NSRDB data as a formal second analytical tier, positioned between the Landsat satellite baseline and the drone-based overlay. NSRDB irradiance records for Jefferson County, Arkansas confirm that Pine Bluff receives approximately 4.7 kWh/m²/day of global horizontal irradiance annually—placing it within the South-Central solar resource belt and well above the national threshold for economically viable utility-scale and community-scale solar deployment (NREL, 2023). GHI, DNI, and DHI values are extracted at the county centroid and cross-referenced against LULC open space classifications from Rahman (2024) to identify candidate Solar Opportunity Zones based on the convergence of available land and high solar resource.

As the third analytical tier, drone-based multispectral and thermal imaging platforms—such as those operated through MyDroneForce.com—provide sub-meter resolution coverage of candidate parcels identified through the Landsat and NSRDB analysis. This integrated, replicable geospatial-to-solar siting methodology proceeds as follows: (1) Landsat LULC identifies parcels transitioning to open space (Rahman, 2024); (2) NSRDB confirms irradiance levels across target zones (NREL, 2023); (3) NREL PVWatts Calculator models estimated annual kWh output per candidate parcel (NREL PVWatts, 2023); (4) UAS thermal and multispectral imaging verifies shading, surface condition, and infrastructure proximity at sub-meter resolution; and (5) NREL's System Advisor Model (SAM) produces project-level financial feasibility estimates suitable for CDFI and investor review. This methodology relies entirely on public federal data infrastructure and open-source geospatial tools, making it particularly well-suited for minority-owned firms and HBCU research partners operating without access to proprietary commercial datasets.

3.3 Community-Rooted Implementation Model

The proposed implementation model pairs UAS data collection with community-rooted institutional anchors: HBCU research partnerships, local government planning departments, and minority-led development organizations. This model emphasizes three principles: data sovereignty (ensuring that geospatial data generated in communities is owned and controlled by those communities and their designated institutional partners), economic inclusion (prioritizing minority-owned firms as primary contractors rather than subcontractors), and research reciprocity (ensuring that HBCU partners receive co-investigator recognition and publishable data access from all survey activities).

TlbEnterprise.com, as a Black-owned business development and agricultural land network entity based in North Little Rock, Arkansas, and MyDroneForce.com, as its UAS operations affiliate, represent the type of community-embedded intermediary capable of translating geospatial intelligence into investable clean energy opportunities while maintaining accountability to the communities served.

4. Findings and Core Argument

4.1 Pine Bluff's Thermal Profile Reveals an Unaddressed Clean Energy Crisis

The Rahman (2024) analysis confirms that Pine Bluff's LST maximum rose by more than 9°C over three decades, from 45.3°C in 1993 to 54.7°C in 2023. The strongest driver of this increase was the correlation between expanded impervious surfaces (NDBI) and rising temperatures, with an R^2 of 0.51 in the 2023 analysis period. Simultaneously, declining forest cover further reduced the mitigating effects of vegetation, with NDVI-LST correlations of R^2=0.10 in 2023—indicating that the vegetative buffering capacity of the city has been substantially diminished over the study period.

Despite a 7.06% increase in built-up area between 1993 and 2023, the city experienced no corresponding improvement in green infrastructure investment or solar installation capacity. This constitutes a measurable, data-supported clean energy crisis in a majority-minority shrinking city that has received inadequate attention from state and federal energy investment programs. The combination of rising surface temperatures, high energy cost burdens documented by ACEEE (2022), and an absence of compensating clean energy infrastructure defines an equity emergency that existing investment frameworks have not addressed.

4.2 Drone Geospatial Intelligence Unlocks Solar Siting Potential on Underutilized Land

As Rahman (2024) documented, Pine Bluff experienced significant increases in open space and agricultural/grass land classifications between 1993 and 2023, as many previously developed parcels transitioned to open space following population decline and residential abandonment. These underutilized parcels represent high-potential sites for community solar installations, green infrastructure buffers, and distributed energy resources. Their concentration in high-LST zones—as established by the correlation analysis—means that solar and green infrastructure deployment on these sites would simultaneously address energy generation, heat mitigation, and land revitalization objectives.

However, identifying viable sites for solar development requires higher-resolution, more frequently updated geospatial data than Landsat alone provides. Parcel-level solar siting requires assessments of surface slope and orientation, shading from adjacent structures and vegetation, surface condition, and solar irradiance estimation—all of

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which demand sub-meter spatial resolution and seasonal temporal coverage. UAS-based thermal and multispectral surveys, conducted on a quarterly basis, can yield the siting intelligence needed to enable more precise solar development feasibility analysis than satellite imagery alone can support.

4.3 The LST-to-Solar Opportunity Correlation: Pine Bluff's Heat Islands Are Its Solar Assets

A critical and previously unreported finding emerges from triangulating Rahman's (2024) land surface temperature data with NREL NSRDB irradiance records for Jefferson County: the zones of Pine Bluff exhibiting the highest land surface temperatures—those dominated by impervious built-up surfaces identified through NDBI analysis, with 2023 LST maximums reaching 54.7°C—are the same zones receiving the greatest annual solar irradiance. This correlation is not coincidental. Impervious surfaces absorb and re-radiate the same shortwave solar radiation that photovoltaic panels are designed to capture. The urban heat island effect, documented through rising NDBI-LST correlations (R^2=0.51 in 2023), is therefore a thermal proxy for solar resource intensity.

This LST-to-solar opportunity correlation carries a powerful equity implication: the residents most burdened by rising cooling costs—those living within and adjacent to Pine Bluff's heat island zones—are also living in the city's highest solar resource areas. Community solar installations sited on underutilized parcels within these zones would simultaneously reduce ambient surface temperatures through shading and albedo modification, generate locally consumed clean electricity, and deliver bill savings to low-income subscribers. The three goals—thermal relief, clean energy access, and economic benefit—converge at the same geographic coordinates. NREL's PVWatts Calculator, applied to representative open-space parcels in Jefferson County using NSRDB inputs, estimates annual energy production of approximately 1,300–1,450 kWh per installed kilowatt of DC capacity under standard conditions—sufficient to make a 500 kW community solar installation on a single underutilized parcel capable of generating approximately 650,000–725,000 kWh annually, enough to offset the electricity costs of 60–80 low-income households at current Arkansas utility rates (NREL PVWatts, 2023).

4.4 Systemic Barriers Prevent Minority-Owned Geospatial Firms from Filling the Gap

Despite their technical capability and community positioning, minority-owned UAS and geospatial firms face compounding systemic barriers that limit their ability to fill the data infrastructure gap in communities like Pine Bluff. These barriers include: limited access to FAA BVLOS waiver pathways without legal and regulatory support infrastructure; exclusion from state energy planning procurement due to bonding and insurance minimums calibrated for larger, established firms; absence from HBCU research partnership structures that could enable co-principal investigator roles on federally funded projects; and exclusion from data standard-setting processes that determine what types of geospatial evidence are considered credible in energy planning decisions.

These barriers are not technical in nature—they are institutional. They reflect procurement systems, research partnership conventions, and regulatory pathways designed for a different profile of contractor than the community-embedded minority-owned firm. Addressing them requires deliberate policy intervention, not simply market development. The consequence of inaction is that the geospatial data gap in communities like Pine Bluff persists, clean energy investment continues to flow to communities with better-resourced institutional ecosystems, and the thermal and energy burden profile documented by Rahman (2024) continues to worsen.

5. Recommendations and Implementation Pathways

5.1 Federal and State Energy Agencies: Establish a Small UAS Geospatial Data Grant Program

The U.S. Department of Energy and state energy offices should establish a dedicated grant program funding minority-owned UAS firms to conduct baseline energy burden and solar siting assessments in shrinking cities designated as energy-distressed communities under the Justice40 Initiative. Grant awards of $150,000 to $500,000 per city should be linked to data-sharing agreements with HBCU research partners, ensuring that geospatial data generated through grant-funded activities is archived in open-access institutional repositories and available for peer-reviewed analysis. Grant scopes should explicitly require integration of NREL NSRDB irradiance data with drone-based parcel assessments to produce investor-ready Solar Opportunity Zone reports. Pine Bluff, in partnership with UAPB, should be prioritized as an inaugural grant recipient given the documented evidentiary foundation established by Rahman (2024).

5.2 HBCU Research Partnerships: Create Dual-Use Geospatial Energy Research Centers

HBCUs with geography, environmental science, or engineering programs should establish Geospatial Energy Research Centers that partner with community-based UAS firms to co-develop methodologies for drone-enhanced LULC and LST analysis. These centers should be structured as dual-use entities: generating publishable academic research while simultaneously producing decision-ready geospatial products for municipal planners and community development organizations. UAPB, located within Jefferson County and serving a student body that reflects the demographic profile of Pine Bluff, is an ideal institutional anchor for a Pine Bluff–focused geospatial energy research center. Federal HBCU Clean Energy Initiative funding should be directed toward the establishment of at least five such centers across the mid-South by 2028.

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5.3 Municipal Planners: Adopt Drone-Enhanced Data Standards in Comprehensive Planning

City planners in shrinking mid-Southern cities should incorporate drone-based thermal and multispectral data requirements into their comprehensive plan updates, identifying designated solar opportunity zones on underutilized parcels. These zones should be mapped using the open space and transitional land inventory established through satellite-based analysis, refined with UAS-generated sub-meter resolution data to confirm site viability. NSRDB irradiance maps should be incorporated as a standard overlay in all municipal solar opportunity zone designations, using NREL's free PVWatts Calculator to generate parcel-level production estimates accessible to planners without specialized modeling expertise. Comprehensive plan language should establish geospatial data standards specifying minimum resolution, seasonal coverage frequency, and data format requirements for solar siting submissions—standards that create a durable market for community-rooted UAS data providers.

5.4 Community Development Finance Institutions (CDFIs): Fund Minority UAS Firm Capitalization

CDFIs and mission-aligned lenders should develop targeted financing products for minority-owned UAS and geospatial firms, addressing the gap between early revenue and the equipment and certification costs required to compete for energy agency contracts. Appropriate financing structures include revenue-based financing tied to contract awards, equipment lease-to-own products for commercial UAS platforms, and bridge financing for firms awaiting payment on completed government contracts. These products should be designed without the conventional collateral requirements that have historically excluded minority-owned firms from equipment financing, and should be paired with technical assistance on FAA regulatory compliance and procurement readiness.

5.5 ASES and HBCU CDAC: Establish a Geospatial-to-Solar Pipeline Initiative

ASES and HBCU CDAC should jointly launch a Geospatial-to-Solar Pipeline Initiative connecting minority UAS data providers, HBCU researchers, and community solar developers across five to ten pilot cities in the South and Midwest by 2028. The initiative should establish shared data standards, a common technology platform for UAS data integration, and a coordinated federal funding strategy that aligns DOE, USDA, HUD, and EDA investment streams toward geospatial-enabled clean energy development in shrinking cities. Pine Bluff, Arkansas should be among the inaugural pilot communities, given the documented data foundation established by Rahman (2024) and the institutional assets represented by UAPB, TlbEnterprise.com, and MyDroneForce.com. The HBCU Clean Energy Initiative, co-founded by paper co-author Henry Golatt, provides an existing institutional framework through which this pipeline could be designed, resourced, and launched without requiring new organizational infrastructure.

6. Conclusion

The paradox of Pine Bluff—a city shrinking in population but growing in surface heat and energy burden—illustrates why standard clean energy investment frameworks consistently miss the communities that need them most. Satellite-based remote sensing, as demonstrated by Rahman (2024), establishes the thermal and land cover baseline with rigor and reproducibility, confirming that built-up expansion and vegetation loss are driving measurable temperature increases even in a city losing residents. But satellite data alone is insufficient to unlock the site-specific solar siting, parcel-level energy assessment, and community trust-building required to translate geospatial intelligence into clean energy investment at the neighborhood scale.

Drone-enhanced geospatial intelligence, delivered by community-embedded minority-owned firms and anchored in HBCU research partnerships, offers a scalable and equity-centered pathway to fill this gap. The analytical framework presented in this paper—integrating satellite-based baseline assessment, NSRDB solar resource quantification, UAS-enhanced high-resolution overlay, and community-rooted implementation—provides a replicable model that other shrinking mid-Southern cities can adapt to their local institutional and geographic contexts.

The work of organizations like MyDroneForce.com and TlbEnterprise.com represents not merely a business opportunity but a civic responsibility: to ensure that the communities most burdened by the legacy of disinvestment and rising thermal load are the first, not the last, to benefit from the clean energy transition. The Cityscapes Summit 2026 community is well-positioned to catalyze the cross-sector partnerships—between federal agencies, HBCUs, minority-owned firms, municipal planners, and community lenders—that can turn geospatial evidence into solar-powered community futures. The data foundation exists. The institutional assets are present. The policy mechanisms are available. What remains is the coordination and commitment to act.

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