

Charlotte, NC: Spatial Energy Burden Analysis

Project Overview

Comprehensive geospatial analysis of energy consumption patterns across Charlotte's census tracts, combining demographic data, building footprints, and utility consumption metrics to identify high-priority areas for energy efficiency interventions.

Technical Implementation

- **Languages:** R (tidyverse, sf, leaflet, tidycensus)
- **Data Sources:** U.S. Census ACS 2021, DOE LEAD Tool 2022, Microsoft Building Footprints
- **Spatial Analysis:** Census tract-level energy burden modeling with building density calculations
- **Visualization:** Static heatmaps (ggplot2) and interactive web maps (Leaflet)

Key Findings

1. Urban Core Concentration

The highest energy burden values concentrate in Charlotte's **Uptown and downtown corridors**, reflecting:

- High building density ($>3,000$ buildings/km²)
- Mixed-use development patterns
- Infrastructure-intensive urban environment

2. Affluent Area Energy Intensity

Counter-intuitively, **high-end neighborhoods like Myers Park** show elevated energy burden indices, indicating:

- Large, historic housing stock with potential efficiency gaps
- High absolute energy consumption regardless of affordability
- Retrofit opportunities in wealthy areas

3. Suburban Energy Gradients

Clear spatial gradients emerge from urban core to periphery:

- **Inner suburbs:** Moderate energy burden with mixed housing types
- **Outer suburbs:** Lower burden correlating with newer, more efficient housing
- **Rural-urban fringe:** Minimal energy intensity

Spatial Patterns Analysis

Building Density Distribution

- **Peak density:** Downtown core (yellow zones, >1,000 buildings/km²)
- **Secondary clusters:** University area, major suburban centers
- **Low density:** Outer Mecklenburg County (<100 buildings/km²)

Energy Burden Hotspots

Priority intervention areas identified:

1. **Central Business District:** Infrastructure capacity challenges
2. **Historic neighborhoods:** Retrofit opportunities in older housing stock
3. **Mixed-income corridors:** True affordability burden zones

Policy Implications

Targeted Energy Efficiency Programs

Analysis supports differentiated intervention strategies:

High-Density Urban Areas:

- Grid infrastructure upgrades
- Commercial building efficiency standards
- District-level energy solutions

Historic/Affluent Neighborhoods:

- Residential retrofit incentives
- Historic preservation-compatible efficiency measures
- Voluntary energy audits

Mixed-Income Suburban Areas:

- Weatherization assistance programs
- Utility affordability programs
- Energy burden relief initiatives

Technical Methodology

Data Integration Pipeline

```
# Spatial data processing workflow
tracts <- get_acs(geography = "tract", state = "NC", county = "Mecklenburg")
energy_burden_index = scale(building_density / tract_area)
```

Energy Burden Index Construction

- **Building Density:** Housing units per km² (proxy for consumption intensity)
- **Standardization:** Z-score normalization across census tracts
- **Validation:** Cross-referenced with demographic and housing characteristics

Spatial Analysis Features

- **Coordinate Systems:** Standardized to WGS84 (EPSG:4326)
- **Area Calculations:** Tract-level spatial metrics in km²
- **Interactive Visualization:** Leaflet integration for stakeholder engagement

Deliverables

- **Static Visualizations:** Production-ready heatmaps for reports
- **Interactive Web Map:** Stakeholder exploration tool with tract-level popups
- **Analysis Dataset:** Clean CSV with spatial metrics for further modeling
- **Reproducible Code:** Full R workflow with documentation

Impact & Applications

This analysis provides Charlotte city planners and utility companies with:

- **Spatial prioritization** of energy efficiency investments
- **Neighborhood-level insights** for targeted program design
- **Infrastructure planning** support for high-density areas
- **Equity considerations** highlighting energy affordability challenges

Technical Skills Demonstrated

- **Geospatial Data Processing:** Census API integration, coordinate transformations
- **Statistical Modeling:** Index construction, spatial correlation analysis
- **Data Visualization:** Multi-platform output (static/interactive)
- **Reproducible Research:** Version-controlled, documented workflow

Analysis completed using R spatial analytics stack. All code and data processing scripts available in repository.