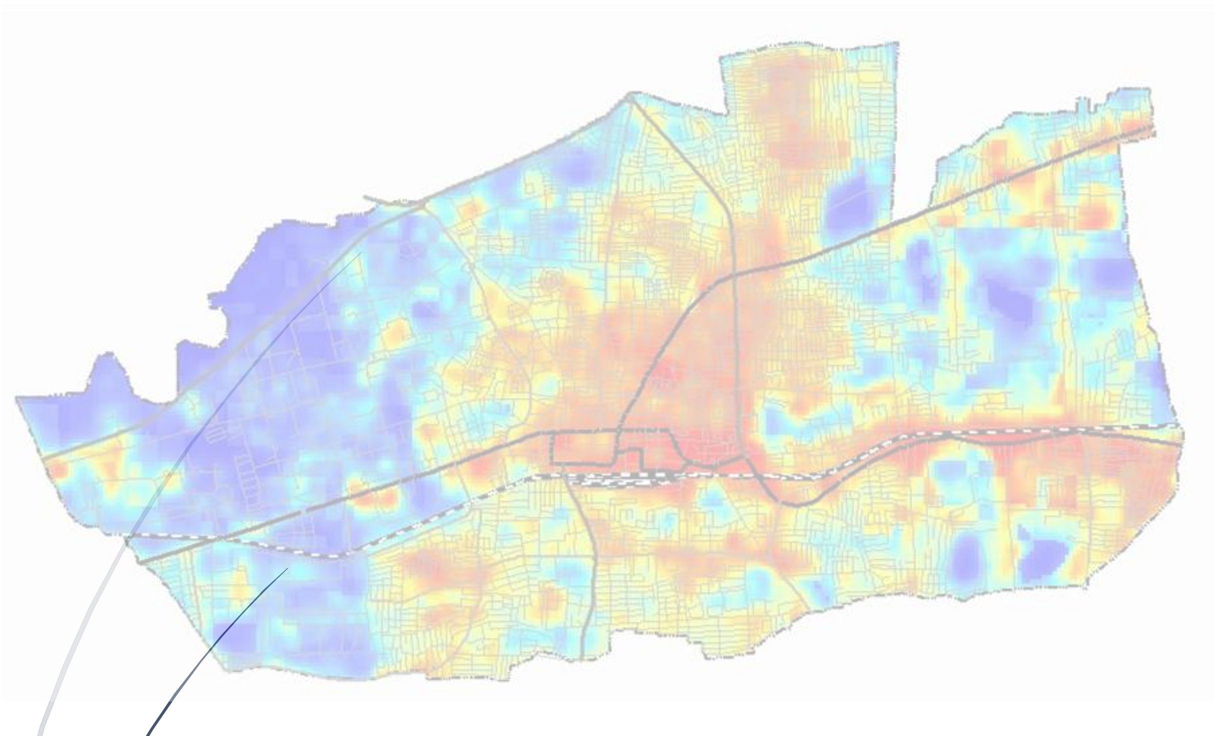
PROJECT CODE – CAR_24_02

ENERGY EFFICIENCY CONSIDERATIONS IN ZONING REGULATIONS OF A CITY, A STUDY OF TIRUPATI

INTERIM REPORT – APRIL 2025



Principal Investigator: Dr. Janmejoy Gupta

Faculty Team: Dr. Adinarayanane.R, Prof. Dr. Ayon Tarafdar, Dr. Valliappan AL, Dr. Fiaz Ahmed

Project Officer: Kativarapu Blessy Amulya Deepika

TABLE OF CONTENTS

Chapter 1: BACKGROUND STUDY:

Urban energy consumption, particularly electricity usage, is a critical area of focus in the context of sustainable development and urban planning. The **International Energy Agency (IEA)** has identified several key strategies for managing urban energy consumption, recognizing that cities are major contributors to global energy use and emissions. Urban areas account for around 70% of global energy consumption and more than 60% of CO2 emissions, with a significant portion of this demand coming from buildings, and industrial activities. As urbanization continues to rise globally, the demand for energy in cities is expected to increase, making energy efficiency a critical issue. To address this, the IEA emphasizes the importance of improving energy efficiency in urban environments through a variety of measures, particularly in sectors like residential and commercial buildings, and energy systems.

The global annual energy consumption is estimated to rise by 77% in between 2000 to 2040, to approximately 13,860 Mega Tons of Oil Equivalent (MTOE). 83 % of the global energy used comes from fossil fuels. (Energy Institutes Statistical Review of World Energy, 2023). As per International Energy Agency (2021) India's share of global energy consumption was 6.1 % in 2021. It is expected to increase to 9.8% by 2050. Cities are the largest consumers of supplied electricity. In India, urban population consumes more than 70-75% of national electricity. (Ministry of Power, GoI,)

Energy consumption patterns are influenced by various factors such as urbanization, economic development, population density, and land use configurations. In India, where rapid urbanization is reshaping cities, understanding these dynamics is essential for creating efficient and resilient urban systems. Andhra Pradesh, as a rapidly developing state, faces unique challenges and opportunities in managing energy consumption through zoning regulations, energy efficiency measures, and integrated urban planning

Energy Consumption in Terms of Electricity:

Electricity consumption in urban areas is driven by socioeconomic factors such as income levels, housing size, industrial activities, and climatic conditions. Urbanization increases residential electricity demand due to the proliferation of energy-intensive appliances like air conditioners, water heaters, and cooking equipment. In India, urban households consume significantly more electricity than rural ones due to higher appliance penetration and better access to reliable power supply.

In Andhra Pradesh, residential electricity consumption constitutes a significant portion of total energy use. Urban households experience higher per capita electricity demand compared to rural counterparts due to lifestyle changes associated with urbanization. Additionally, industrial growth in cities contributes substantially to electricity consumption, particularly in manufacturing hubs and special economic zones. The state's climatic conditions also play a role; cooling needs during hot summers lead to peak electricity loads in urban areas.

Electricity pricing mechanisms further influence consumption patterns. Higher tariffs can encourage conservation efforts but may disproportionately impact low-income households. Urban planning must consider these disparities while designing policies that balance affordability with sustainability. Efficient forecasting models are necessary to predict electricity demand accurately and ensure adequate infrastructure planning.

Energy Efficiency:

Energy efficiency is a cornerstone of sustainable urban development. In the Indian context, improving energy efficiency can significantly reduce waste and mitigate environmental impacts. Urban buildings are major contributors to energy consumption due to heating, ventilation, air conditioning (HVAC), lighting systems, and other operational needs. Retrofitting existing structures with energy-efficient technologies such as insulation materials, LED lighting, and smart sensors can reduce electricity usage by up to 30%.

In Andhra Pradesh, energy efficiency measures are being integrated into building codes and municipal regulations. The Energy Conservation Building Code (ECBC) mandates design standards that optimize building orientation and envelope insulation to minimize heating and cooling loads. Public infrastructure like street lighting is being upgraded with IoT-enabled LED fixtures that consume less power while providing better illumination.

The **Government Order (GO) 119** in Andhra Pradesh, relating to **Development Control Regulations (DCRs)**, plays a crucial role in promoting energy efficiency in the state's urban development. This order has incorporated key elements from the **Energy Conservation Building Code (ECBC)**, making them mandatory for the approval of building plans. The ECBC is a set of guidelines issued by the Bureau of Energy Efficiency (BEE) to promote energy-efficient practices in building design and construction. Under GO 119, the application of ECBC standards is **no longer optional but a required condition for obtaining building plan approval in Andhra Pradesh**. This incorporation ensures that newly constructed buildings adhere to energy-efficient designs, including the use of efficient lighting, HVAC systems, insulation, and other energy-saving technologies. The inclusion of ECBC within the DCRs under GO 119 aligns with the state's broader goals of reducing energy consumption, minimizing environmental impact, and promoting sustainable building practices. This policy helps to ensure that energy conservation becomes a fundamental part of urban planning and building construction, contributing to the reduction of the state's overall energy demand and encouraging the adoption of green building technologies. By making adherence to the ECBC mandatory, GO 119 establishes a regulatory framework that enforces energy-efficient practices in all new construction projects, thereby promoting sustainable urban development in Andhra Pradesh.

Zoning Regulations:

Zoning regulations play a pivotal role in shaping urban energy landscapes by dictating land use patterns and density levels. Mixed-use zoning reduces transportation energy demand by shortening commute distances between residential areas and workplaces.

Zoning regulations are an essential part of urban planning that establish the framework for how land can be utilized within a city or town. These regulations serve as a guide for the orderly development of urban spaces, ensuring that different activities and structures are appropriately located and designed to maintain a harmonious urban environment. Zoning regulations typically address both **broader land-use aspects** and more **detailed building-level bylaws**, ensuring that urban development meets the goals of functionality, sustainability, and livability.

At the **land-use level**, zoning regulations determine the permissible uses of land in various areas of a city. These regulations often define distinct zones based on land functions, such as **residential, commercial, industrial, recreational**, and **mixed-use** areas. The objective at this level is to segregate conflicting land uses and to guide growth in a way that enhances efficiency and quality of life. For example, **residential zones** may be designated away from noisy industrial zones to reduce exposure to pollution, while **commercial zones** may be planned near transportation hubs to ensure easy access for businesses and customers. Zoning at the land-use level also helps in managing the density of development, controlling urban sprawl, and preserving open spaces or agricultural land. Such broad regulations establish where different activities can be carried out, providing a balance between urban development and environmental protection.

At the **building level**, zoning regulations go further by specifying the **design, height, bulk, and form** of individual structures within a given zone. These **building-level bylaws** provide more granular details, such as setbacks, floor-area ratios, permissible building heights, and the materials and aesthetics of buildings. They also include standards for the **building's energy performance**, sustainability features, and environmental considerations, such as **water efficiency**, **solar orientation**, or **green roofs**. For instance, regulations at this level may dictate the distance between buildings (setbacks) to ensure proper air circulation, natural light, and privacy. They might also set requirements for parking spaces, ensuring that development supports the transportation needs of its inhabitants without leading to congestion.

Furthermore, **building codes** within zoning regulations play an essential role in ensuring safety and functionality, setting guidelines for structural integrity, fire safety, and accessibility for people with disabilities. These bylaws go beyond just spatial aspects and address the **health, safety, and well-being** of those who will inhabit or use the buildings. In the context of **energy efficiency**, building-level regulations often integrate standards for **energy-saving materials**, **insulation**, **ventilation**, and **lighting systems** that align with broader sustainability goals. Some regions also require **green building certifications** for new construction to meet energy efficiency standards, aligning with broader environmental objectives.

In short, zoning regulations create a layered and comprehensive framework that addresses both **macro-level land-use planning** and **micro-level building design**. At the land-use level, they manage the overall structure of urban spaces, ensuring appropriate placement of different functions, while at the building level, they provide specific technical standards that regulate the appearance, performance, and environmental footprint of individual buildings. This dual approach ensures that urban development remains organized, sustainable, and livable, promoting balanced growth while also addressing individual building needs for functionality, safety, and energy efficiency.

In Andhra Pradesh, zoning regulations are being leveraged to promote renewable energy integration into urban infrastructure. Industrial parks are required to allocate land for onsite solar generation and green cover, reducing their carbon footprint while meeting local energy needs. Coastal Regulation Zones (CRZ) impose restrictions on construction activities near vulnerable coastal areas to enhance climate resilience.

However, challenges persist in enforcing zoning laws effectively across diverse urban contexts. Unauthorized constructions often exceed permitted floor area ratios (FAR), leading to inefficient land use and increased cooling demands in densely populated areas. Addressing these issues requires robust regulatory frameworks supported by advanced spatial analysis tools.

Importance of Energy Efficiency consideration in Master Plan:

Integrating energy considerations into urban planning ensures sustainable growth while mitigating environmental impacts. Master plans must prioritize strategies that optimize resource allocation across sectors such as housing, transportation, industry, and public services. Scenario modelling techniques can forecast future energy demand under different development trajectories, enabling planners to design resilient infrastructure systems.

Urban planning also plays a critical role in addressing equity issues related to energy access. Policies should aim to provide affordable electricity connections for low-income households while incentivizing conservation efforts among high-consumption users. Resilience planning is essential for preparing cities to cope with climate-induced load fluctuations through diversified grids that combine centralized generation with decentralized renewable sources. There is need to identify high Energy Use Intensity Zones within a city and ensure that future master planning approaches and zoning regulations address the issues of excessive energy use intensity in urban areas. The need to analyze urban energy consumption and evaluate the influence of Zoning Regulations on Energy consumption, is more important than it ever was.

Renewable methods like integrating rooftop solar installations into residential neighbourhoods can decentralize power generation while reducing transmission losses.

Energy Land-use Interaction Model:

The interaction between energy systems and land use configurations offers valuable insights for optimizing urban development strategies. Spatial mapping techniques can identify high-consumption zones within cities based on population density, building types, industrial activities, and climatic conditions. Such analyses enable planners to target interventions where they are most needed.

Policy impact simulations can assess how zoning changes affect long-term energy demand across different sectors. For instance, shifting from suburban sprawl to compact high-rise developments may reduce transportation-related emissions but increase cooling loads due to higher population density within confined spaces.

Renewable integration remains a key focus area under this model; solar potential mapping can identify suitable locations for photovoltaic installations based on land availability and consumption patterns.

Energy consumption patterns in cities reflect complex interactions between socioeconomic factors, infrastructural developments, zoning regulations, and policy interventions. In India—and specifically Andhra Pradesh—rapid urbanization necessitates holistic approaches that balance growth aspirations with sustainability goals. By prioritizing energy efficiency measures across buildings and transport systems while leveraging zoning regulations for renewable integration into urban landscapes, planners can create resilient cities equipped to meet future challenges.

Urban energy consumption, particularly electricity use, is one of the most pressing issues in modern cities due to the increasing demand for resources driven by population growth, urbanization, and economic activities. Efficient management of energy consumption is crucial to reduce environmental impact, optimize energy use, and meet sustainability goals. One key strategy in addressing this challenge is understanding the spatial distribution of energy use across different parts of the city, which can be achieved through the identification of Energy-Use Intensity (EUI) zones**.** EUI is a measure of how much energy is consumed per unit area of a building or urban zone and provides valuable insights into where energy efficiency improvements are needed. By identifying EUI zones, urban planners can develop targeted strategies for reducing electricity consumption and enhancing energy efficiency.

This background study aims to provide the necessary foundation for analysing urban energy consumption, identifying EUI zones, and recommending zoning regulations that can support energy-efficient urban development. In particular, it focuses on the role of zoning regulations in shaping energy consumption patterns at neighbourhood and zonal level, and how these regulations can be upgraded to achieve better energy efficiency outcomes.

Chapter 2: LITERATURE STUDY:

2.1 Copenhagen's Energy Plan 2025

Copenhagen's **Energy Plan 2025** is a pioneering example of how cities can integrate energy efficiency and sustainability into urban planning and zoning regulations. By focusing on reducing energy consumption and carbon emissions, Copenhagen has developed a robust framework that aligns urban planning, zoning regulations, and energy efficiency goals.

2.1.1 Key Aspects of Copenhagen's Energy Plan 2025

Copenhagen's Energy Plan 2025 can serve as a model for cities looking to integrate energy efficiency into their zoning regulations. The Plan emphasizes sustainable urban design, where energy-efficient infrastructure is prioritized. The key objectives of this plan — reducing carbon emissions, improving energy efficiency, and promoting the use of renewable energy — can be adapted to the zoning regulations of any city aiming to create an environmentally sustainable urban environment.

Objective for Zoning: Zoning regulations should incorporate energy performance standards for buildings, encourage mixed-use development (reducing the need for energy-intensive transportation), and ensure that renewable energy infrastructure is included in the urban development plan

Lessons from Copenhagen's Approach:

Incorporating **Energy Efficiency into Zoning Regulations**: Cities can adopt Copenhagen's approach of embedding energy performance standards within zoning codes. For example, zoning regulations can mandate that new developments be energy-efficient, use renewable energy, and are part of a larger district heating or renewable energy system.

District **Heating and Renewable Energy Zones**: Zoning regulations can designate specific areas for district heating infrastructure, and these zones can be planned to maximize the efficiency of renewable energy generation, such as wind or solar power. Renewable energy zones can be prioritized in urban master plans, just as Copenhagen has done to facilitate the growth of green energy infrastructure.

Zoning for Renewable Energy Integration: One of the strongest features of Copenhagen's Energy Plan 2025 is its focus on integrating renewable energy infrastructure into the city's zoning laws. The city has designated zones for wind energy and solar panel installations, ensuring that energy production is closely aligned with urban development. Zoning regulations should prioritize areas that can accommodate renewable energy infrastructure, and municipalities can provide incentives for developers who integrate these systems into their designs.

Sustainable Building Practices and Energy Codes: Copenhagen's zoning laws require that all new buildings meet stringent energy efficiency standards. This focus on **passive energy design** — which minimizes energy needs through improved insulation, ventilation, and shading — can be integrated into zoning regulations in other cities to promote sustainable building practices.

2.2 "Energy Efficiency in Indian Cities: A Case Study of Bangalore" by V. R. S. Sundararajan et al. (2016) as Literature for "Energy Efficiency Considerations in Zoning Regulations of a City"

Objective of the Study: The study by Sundararajan et al. (2016) seeks to evaluate energy efficiency measures in Bangalore, particularly focusing on how these measures can be integrated into urban planning and building design. The authors explore energy use across residential, commercial, and industrial sectors, analysing potential strategies for reducing energy consumption and enhancing sustainability.

Key Aspects:

Energy Demand by Building Type: The study identifies the major sources of energy consumption in Bangalore, focusing on commercial, residential, and industrial sectors. It discusses the energy performance of buildings and highlights areas for improvement, such as the use of energy-efficient appliances, lighting, and air-conditioning systems. Understanding how different building types contribute to energy consumption helps inform zoning regulations to target specific areas for energy improvements.

Building Codes and Regulations: Bangalore's approach to energy-efficient building codes is a major focus of the study. It describes how energy codes can be introduced or strengthened within building regulations to improve energy efficiency. Zoning regulations can be aligned with these codes to ensure that new buildings or refurbishments meet these energy performance standards.

Green Building and Sustainable Architecture: The study emphasizes the importance of promoting green building practices, such as using energy-efficient materials, implementing passive cooling techniques, and designing buildings for optimal natural light. Zoning regulations can incentivize such practices by designating specific zones for green development or mandating energy-saving designs in particular areas.

Integration of Renewable Energy: The study also suggests that integrating renewable energy, such as solar power, into urban development can significantly reduce energy consumption. Zoning regulations can promote the installation of solar panels in residential, commercial, and public spaces, as well as encourage the creation of renewable energy zones within cities.

Urban Form and Density: Bangalore’s growth and the study’s findings on urban sprawl highlight how urban form affects energy use. Densely populated areas with mixed land uses typically use less energy than sprawling, car-dependent areas. Zoning regulations that encourage higher-density, mixed-use developments can reduce energy consumption by promoting walking, cycling, and the use of public transport.

2.3 Assessing Energy Efficiency in Indian Cities: A Case Study Approach" by Bajaj and Agrawal (2017)

Objectives of the Study:

- **Assessing Energy Use in Indian Cities:** The study aims to understand how urban energy consumption patterns vary across different Indian cities. By using case studies, the researchers explore how energy efficiency can be improved in urban areas through planning, policies, and technology.
- **Identifying Energy Efficiency Gaps:** It identifies areas where energy efficiency measures are either underdeveloped or insufficient, with a particular focus on urban areas undergoing rapid growth and development.

Application:

i. Assessing Energy Use in Tirupati:

- **Current Energy Consumption Patterns:** First, a comprehensive energy audit should be conducted in Tirupati to assess energy consumption across different sectors such as residential, commercial, and transportation. This will highlight which sectors are the most energy-intensive and where efficiency improvements are needed.
- **Comparative Analysis:** Draw comparisons with other similar cities (such as Vijayawada or Mysuru) to understand Tirupati's unique challenges and opportunities.

ii. Identifying Energy Efficiency Gaps:

- **Building Sector Improvements:** As Tirupati grows, new residential and commercial buildings must follow stringent energy efficiency codes. Given the city's hot climate, improving building insulation, encouraging the use of energy-efficient air conditioners, and promoting passive cooling designs (e.g., shaded areas, natural ventilation) could greatly reduce energy consumption.
- **Public Infrastructure and Street Lighting:** Tirupati can implement LED street lighting and smart grid technologies, which have been successfully used in other cities to reduce energy wastage.

2.4 "Local Government and Energy Efficiency: A Review of Municipal Energy Programs" by H.J. Davidson (2014)

The study emphasizes the importance of local governance in implementing energy-saving measures, particularly in urban settings.

Key Focus:

Local **Governments as Key Drivers of Energy Efficiency:** The study emphasizes that while national and state governments play crucial roles, it is the local governments that have the most direct influence on day-to-day energy consumption. Local governments control urban planning, building codes, infrastructure development, and public services, making them ideally positioned to implement energy-efficient policies.

Successful **Energy Programs at the Municipal Level:** The paper highlights a variety of municipal energy programs from different cities, including energy efficiency retrofitting of public buildings, installation of energy-efficient street lighting (LEDs), and district-wide energy-saving initiatives.
Building **Codes and Zoning Regulations:** One of the critical areas highlighted is the role of **building codes** and **zoning regulations** in promoting energy efficiency. Local governments can mandate energy-efficient standards for new buildings, offer incentives for retrofitting old buildings, and ensure that energy efficiency is a part of urban zoning regulations.
Financing **and Incentives:** The study also looks at how local governments can provide financial incentives, grants, and low-interest loans to businesses and homeowners to encourage energy-efficient building practices, the installation of renewable energy systems, and energy-efficient appliances.

Application:

- Implementing Energy-Efficient Programs:
- **Street Lighting Program:** Tirupati can adopt energy-efficient street lighting, particularly using LEDs, which is a low-cost, high-impact solution already implemented in several cities around the world. Local government can pilot this program in a few areas of the city and gradually expand it to the rest of the city.
- **Incentives for Energy-Efficient Buildings:** The local government can introduce incentives for new buildings to be constructed with energy-efficient designs or for older buildings to undergo retrofits. This could include offering tax rebates or subsidies for installing solar panels, better insulation, energy-efficient windows, and high-efficiency HVAC systems.

2.5 Energy-efficient urban planning and development" by J. Lee (2012)

Objectives of the Study: The main objectives of J. Lee's (2012) study are as follows:

Assessing the Role of Urban Planning in Energy Efficiency: The study explores how urban planning and development can contribute to energy efficiency, particularly by integrating energy-saving measures into zoning, building codes, and infrastructure planning. It emphasizes that urban design and development have a direct impact on energy consumption.

Identifying Key Strategies for Energy-Efficient Urban Design: Lee identifies and analyzes strategies for energy-efficient urban planning, focusing on the importance of sustainable infrastructure, energy-efficient buildings, renewable energy integration, and transportation systems.

Insights from the Study:

Urban Form and Energy Consumption: The study highlights that the design and structure of a city—such as its layout, building density, and land use—have a significant impact on energy consumption. Dense, mixed-use neighbourhoods typically use less energy per capita compared to sprawling, car-dependent areas. Urban planning that focuses on reducing urban sprawl, encouraging public transportation, and promoting high-density development can help reduce energy use.

Energy-Efficient Buildings and Infrastructure: Energy-efficient buildings play a major role in reducing energy consumption. The study suggests incorporating energy-efficient building materials, optimizing insulation, and using renewable energy sources (e.g., solar panels) to reduce the energy needed for heating, cooling, and lighting. Additionally, energy-efficient public infrastructure, including street lighting, water systems, and public transportation, should be prioritized.

Green Spaces and Urban Heat Island Effect: Lee discusses the importance of integrating green spaces, parks, and trees into urban planning to help mitigate the urban heat island effect. Green spaces reduce the need for air conditioning, improve air quality, and promote energy savings. They also contribute to the overall quality of life for residents.

Renewable Energy Integration: The study points out the importance of integrating renewable energy sources, such as solar, wind, and biomass, into urban planning. Cities that adopt renewable energy solutions at the district or community level can significantly reduce their dependence on grid electricity and lower their carbon footprint.

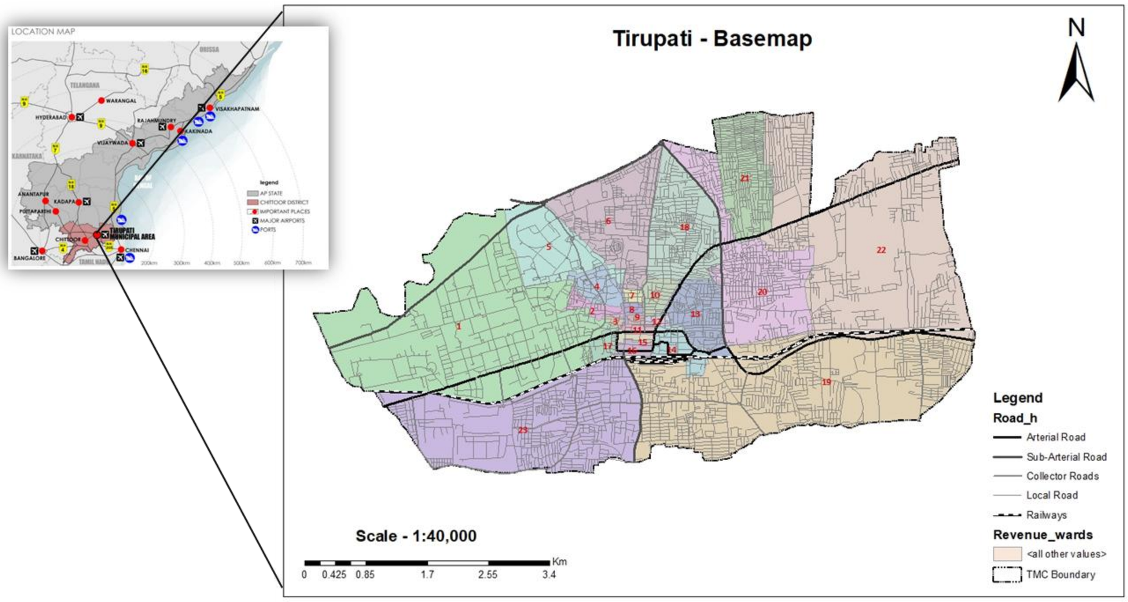
Policy and Governance: Effective governance and strong policy frameworks are necessary to ensure that energy-efficient urban planning strategies are implemented. Lee emphasizes that policies must be supportive of energy efficiency and sustainability, and local governments should engage with communities and stakeholders to ensure successful implementation.

Application:

Promoting **Mixed-Use Development:** To reduce energy consumption and encourage more sustainable living, Tirupati could implement zoning regulations that promote mixed-use development. This approach would reduce the need for long commutes, encourage walking and cycling, and improve the overall efficiency of land use.
Incorporating Green Spaces: Tirupati can integrate more green spaces into the urban landscape, such as parks, gardens, and tree-lined streets. This would help mitigate the urban heat island effect, reduce the need for air conditioning, and enhance the quality of life for residents.
Water Conservation and Green Infrastructure: Rainwater harvesting, efficient irrigation systems, and the use of green infrastructure (such as permeable pavements and green roofs) can help reduce the energy required for water management and cooling.
Solar Power for Buildings and Infrastructure: Given Tirupati's sunny climate, solar power could be a key part of the city's energy strategy. Incentives for solar panel installations on rooftops, as well as large-scale solar farms, could reduce the city's reliance on grid electricity and lower energy costs.
Energy Monitoring and Data Collection: By leveraging data from sensors and smart technologies, Tirupati could monitor energy use across different sectors and identify areas for improvement. This data could also help inform future urban planning and development strategies.

Chapter 3: TIRUPATI CITY PROFILE

Tirupati is a temple city in Tirupati District in the Indian state of Andhra Pradesh. It serves as the administrative headquarters of Tirupati district. It is located at the foot hills of Tirumala which is being home to the renowned Tirumala Venkateswara Temple, a major Hindu pilgrimage site. The temple of Lord Venkateshwara is the richest Hindu temple and the second most visited religious center in the world. It has made Tirupati city a major pilgrimage and cultural city. It is the 2nd largest city in the Rayalaseema region. Tirupati City is located 550 km south of Hyderabad, the capital of the state, 250 km east of Bangalore, 65 km from Chittoor, and 150 km north of Chennai. The city functions as a municipal corporation and serves as the headquarters for the Tirupati district, Tirumala Tirupati Devasthanams, Tirupati Urban, Tirupati Rural mandals, the Tirupati revenue division, the Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL), and the Tirupati Urban Development Authority (TUDA).



Map 1 Tirupati city

In 2012–2013, Tirupati was recognized by India's Ministry of Tourism as the "Best Heritage City". Additionally, in 2016, it was selected as one of the hundred Indian cities to be developed under the AMRUT Cities Mission, a Government of India initiative aimed at urban development and modernization. Tirupati District headquarters is Tirupati city.

3.1 <u>History and Evolution</u>

Tirupati's growth has been shaped by its religious significance. The history deeply ties with the Venkateshwara temple. There is no clear history on the origin of the temple of Lord Venkateshwara, but it was maintained and upgraded by various kingdoms. These include the Pallava Kingdom around 9th Century AD, Chola Kingdom around 10th century AD and the latest one being Vijayanagara Empire around 14th to 15th century AD. It was during the rule of Vijayanagara Empire that the temple received increased contributions. The site was an established center of

Vaishnavism around 5th century A.D. during which Tirupati was praised by Alvars (Vaishnava saints); belonging to the Bhakti movement in Dravidian Land, who were known for their poems and literary works on Lord Venkateswara. Tirupati's significance in Southern Vaishnava tradition is next only to Srirangam, and the temple rites were formalized by the Vaishnavite saint Ramanujacharya himself, in the 11th century AD. Later the temple administration was controlled by British under indirect rule, it remained a religious center with minimal economic and infrastructural expansion. The Madras legislature passed a special act in 1933 whereby the Tirumala Tirupati Devasthanam (TTD) committee was invested with powers of administration and control through a commissioner appointed by the Government of Madras. A Ryot Advisory Council was formed for the management of the estates of the TTD, and was assisted by a Religious Advisory Council with regard to religious matters The first establishment of the city was near Kotturu, today's K.T. Road area. Later it was shifted near the temple of Govindaraja Swamy with the temple as the center of the city. It is today's railway station area. After independence Tirupati expanded as a Municipality in 1965and got upgraded to Municipal Corporation in 2027.Now the city is expanded to the nearby periphery areas.

3.2 <u>Accessibility –</u>

3.2.1 Road Network

The city is well connected to major cities through national and state highways. The National highways passing through Tirupati are, National Highway 71 which connects Madanapalle and Nayudupeta, National Highway 140 connecting Tirupati with Puthalapattu. Constructed one in 1944 and the other in 1974, there are two all-weather, asphalt Ghat Roads between Tirupati and Tirumala. There is a total of 449.44 km of Roads within the Tirupati Municipal Corporation Limits.

3.2.2 Rail Network

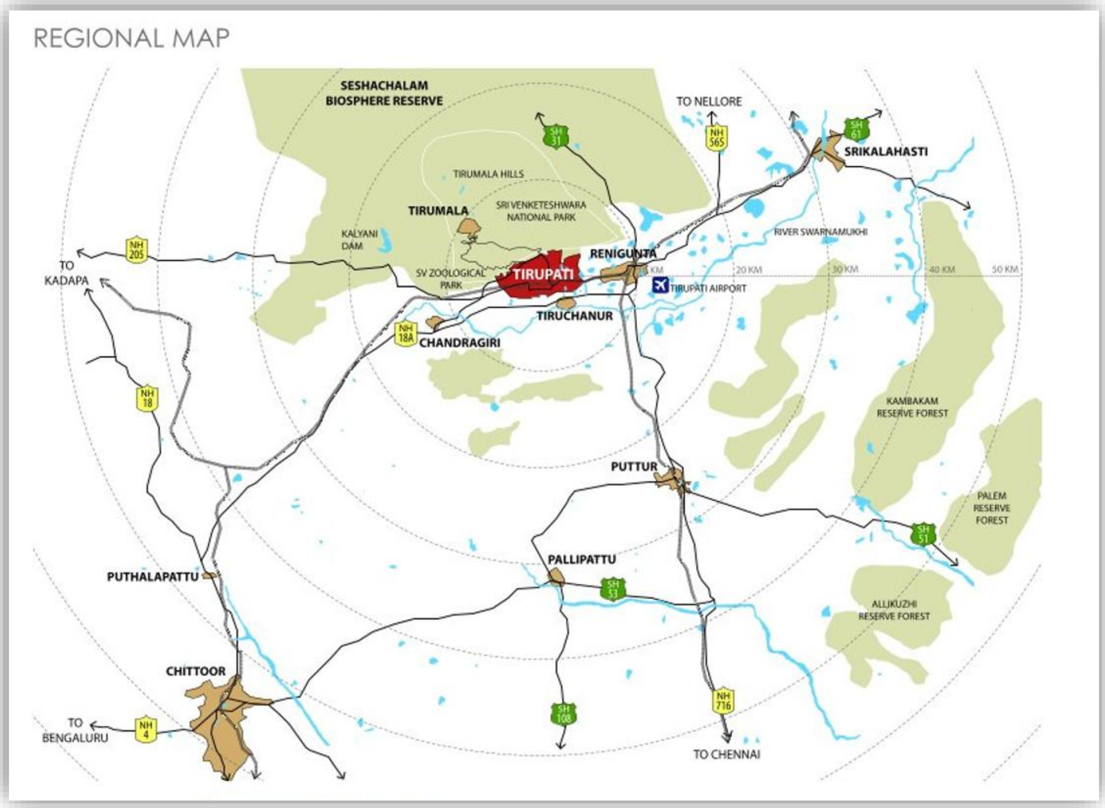
Tirupati Main is classified as an A1 station in the Guntakal railway division of South-Central Railway zone. Tirupati West Halt and Tiruchanur are the satellite stations, used for decongesting rail traffic at the main station. In addition to these, Tirupati also has Chandragiri, Yerpedu and Renigunta Junction railway stations to serve the needs of the people of the city

3.2.3 Airport –

Sri Venkateswara Airport is located 15 km from the city centre and has regular flights to Coimbatore, Hyderabad, Kolkata, Mumbai, New Delhi, Vijayawada and Visakhapatnam. The closest international airport is Chennai International Airport which is 130 km (81 mi) from Tirupati. Tirupati Airport is being upgraded to international airport.

3.2.4 Public Transport –

APSRTC is the state-owned transport service, which operates buses to various destinations from Tirupati bus station complex. The bus station comprises of three mini bus stations to various destinations, such as Srinivasa bus station for westbound destinations, Sri Hari bus station for east bound destinations and Yedukondalu bus station is utilized for bus services to Tirumala. Balaji Link bus station at Alipiri is also used for bus services to Tirumala. Tirumala Tirupati Devasthanams runs free buses from the railway station and Central bus stand to Alipiri for pilgrims. The buses to Tirumala are known as Sapthagiri Express. Tirupati is in close proximity to the states of Karnataka and Tamil Nadu. Hence, buses from KSRTC, TNSTC, and SETC also operate their services. There is also private transport which operates in the city.



Map 2 Regional Setting

3.3 <u>Population –</u>

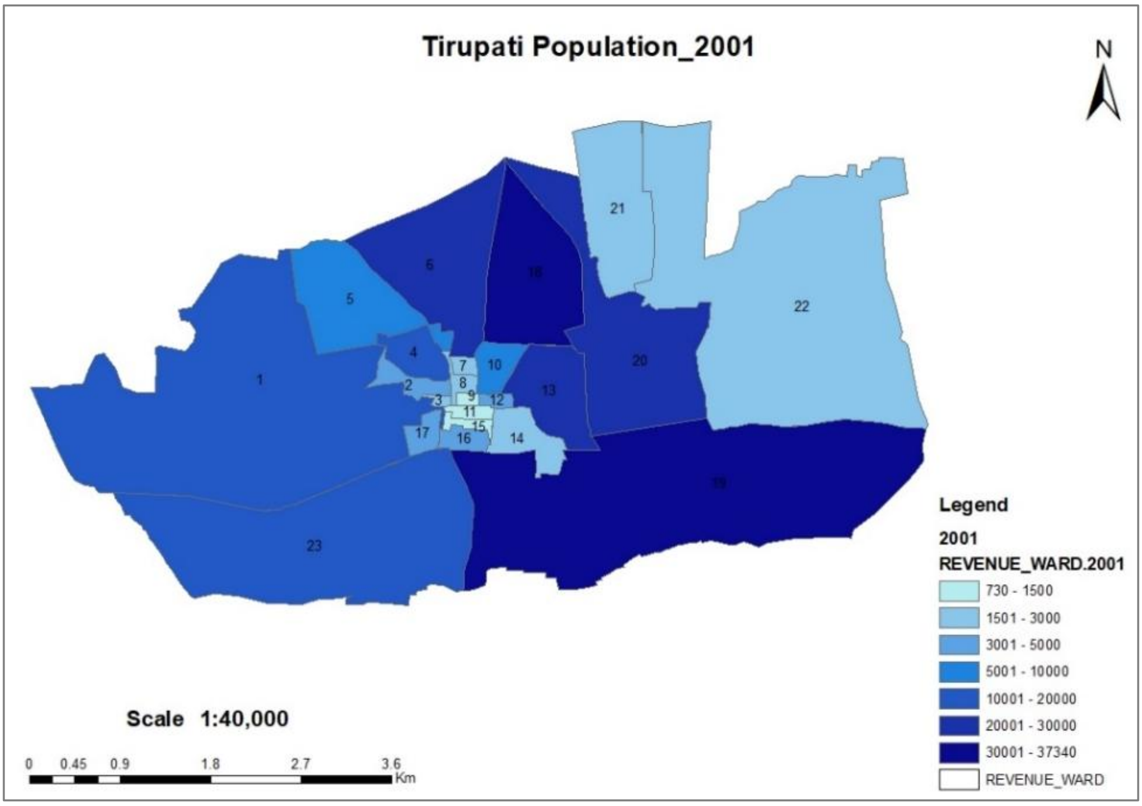
As per Census 2011, total population of Tirupati is 3.74 lakhs with total area of 27.44 sq. km. Tirupati city is divided into 23 Municipal wards.

Table 1 City - Particulars

S.no	Particulars	Info
1	Area	27.44 sq.km
2	Population (2011)	3,74,260
3	Population density (2011)	13,639 persons/sq.km
4	Average Floating population per month	21 lakh
5	Literacy rate	86%
6	Sex ratio	966 females /1000 males

7	Slum population	31.8%
8	Revenue wards	23
9	Election wards	50

3.3.1 Population 2001



Map 3 Population 2001

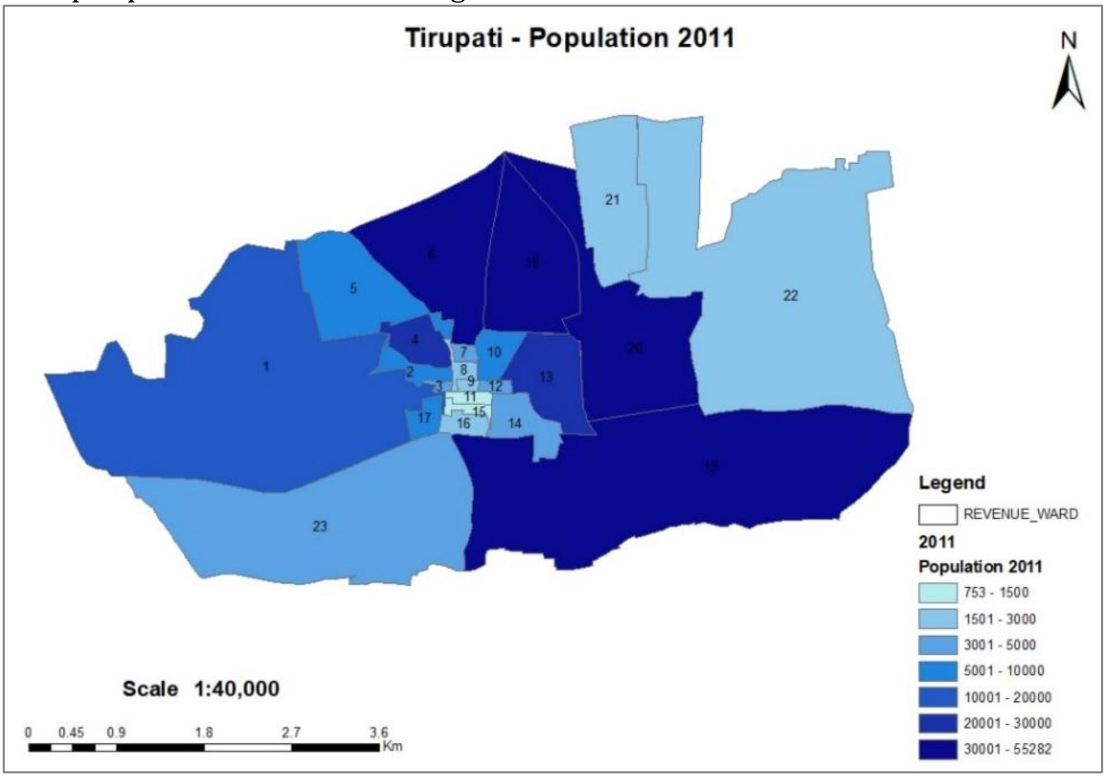
Observations:

- **Population Distribution:** The central wards (e.g., Wards 7, 8, 9, 10, 11, etc.) have higher population densities, indicated by darker blue shades (30,001–37,340 individuals. Peripheral wards (e.g., Wards 1, 5, 22, and 23) have lower population densities, shown in lighter blue shades (730–10,000 individuals).
- **Population Range:** The population ranges from as low as 730 to as high as 37,340 individuals across different wards. Central areas have populations exceeding 20,000 individuals, while outlying areas generally have populations below 10,000.

Inferences:

- **Urbanization:** The central wards likely represent the urban core of Tirupati with dense residential or commercial areas Peripheral wards may be more rural or suburban with lower population density
- **Infrastructure and Services:** Higher population density in central areas suggests these regions might have better infrastructure and services such as transportation, markets, and healthcare facilities
- **Development Trends:** The population distribution indicates a concentration of economic activity and urban development in the central wards. Peripheral areas might be less developed or primarily agricultural.
- Future urban planning should focus on managing congestion in densely

populated central wards while promoting development in sparsely populated peripheral areas to balance growth



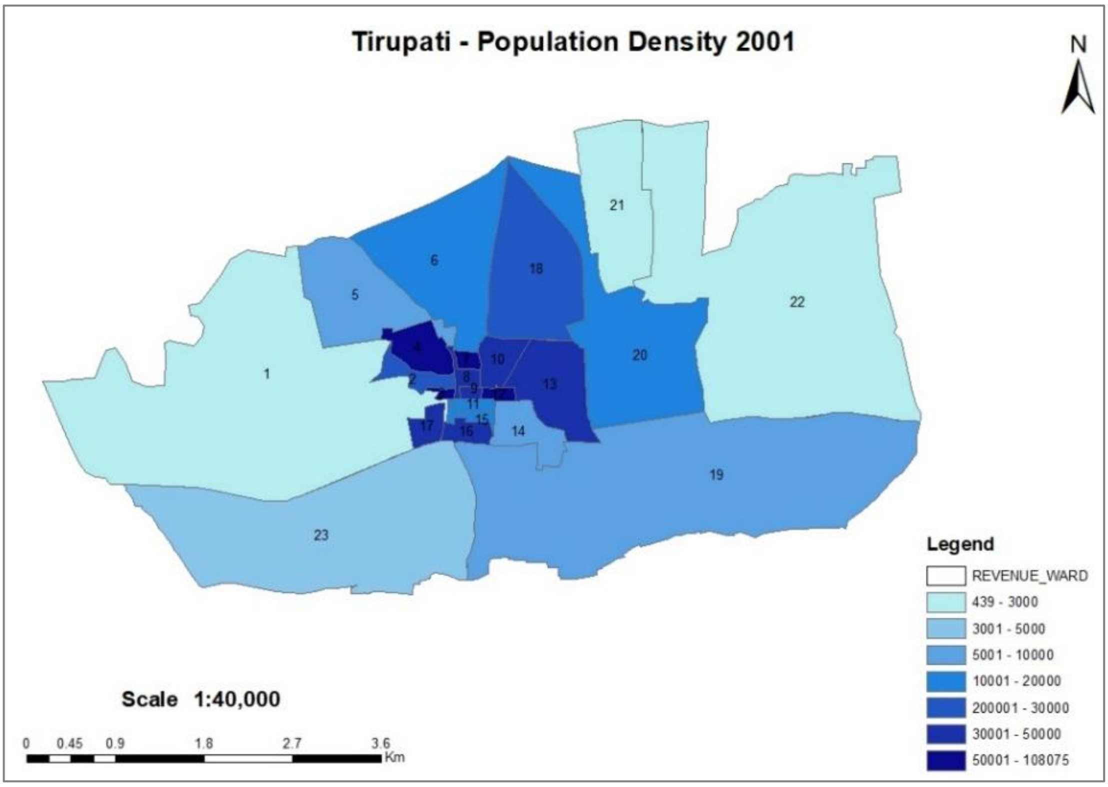
Map 4 Population 2011

3.3.2 Population Density 2001 vs 2011

Observations:

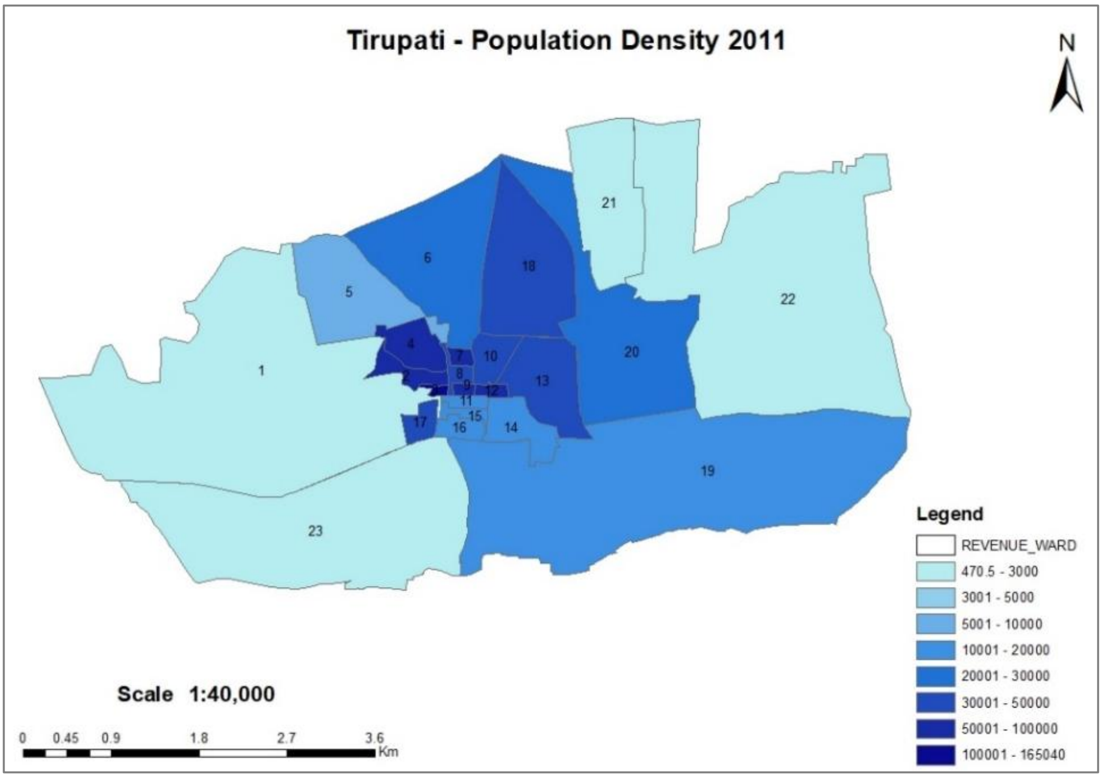
1. Population Growth (2001 vs. 2011):
   - The population has increased significantly in many wards.
   - The darker shades representing higher population categories (e.g., 30,001 - 55,822 in 2011 vs. 30,001 - 37,340 in 2001) indicate an increase in the number of high-population areas.
   - Central wards have experienced more growth compared to peripheral wards.
2. Population Density Increase:
   - The density maps show that higher-density regions (darker shades) have expanded in 2011 compared to 2001.
   - The highest density categories in 2011 have increased in both number and intensity, indicating urban expansion and densification.
3. Urban Expansion and Concentration:
   - While some outer wards (such as 22 and 23) still have lower population densities, their population has also grown over the decade.
   - The city's core remains the most densely populated, with small central wards experiencing the highest densities.
   - There is evidence of urban sprawl, as more areas are now in higher density categories compared to 2001.
4. Shift in High-Density Areas:

Map 5 Population Density 2001



   - Some wards that had moderate density in 2001 have transitioned to high-density categories by 2011.

- The expansion of high-density areas suggests increasing residential and commercial development.



Map 6 Population Density 2011

Inferences:

1. Rapid Urbanization:
   - The city has seen rapid population growth and densification, likely due to economic development, migration, and infrastructure improvements.
2. Increased Pressure on Infrastructure:
   - Higher population densities in central areas may indicate increased demand for housing, transportation, water, and sanitation facilities.
3. Urban Planning Challenges:
   - The shift in density patterns suggests the need for improved urban planning, especially in core areas experiencing congestion.
4. Possible Future Trends:
   - If current growth trends continue, the outskirts (currently lower-density areas) may become more developed, leading to urban expansion beyond existing city limits.

3.4 ***Geography:***

The city lies at the foothills of the Seshachalam Hills, which is part of the Eastern Ghats. . Tirupati is surrounded by Srikalahasti towards the East, Puttur towards the South, Poothalapattu towards the west and the Seshachalam hills towards the North. The elevation varies between 600 to 900m above sea level with the rising hills. Shallow gravelly reddish-brown soils are predominant in this area over the granites and gneisses of peninsular gneissic complex, quartzites, shales/phyllites and limestones of the Cuddapah super group.

The Swarnamukhi River flows north to south, along with the streams and rivulets contributing to the ground water recharge. The hill range dominates the landscape of the city acting as the natural barrier and influencing the micro climate. Tirupati lies in Seismic Zone II, indicating low to moderate seismic activity. However, landslides and rock falls occurs due to heavy rainfalls.

3.5 ***Climate:***

Tirupati region is semi-arid with pronounced variation in temperature. The temperature is high during March – May and low during November – January. The yearly average minimum and maximum temperatures are about 25°C and 35°C. Difference in minimum and maximum monthly temperatures remain, in general, less than about 20°C for the entire year. Variations in minimum and maximum temperatures and during different months of the year reflect typical semi – arid climate. The variations in the relative humidity throughout the year reflect tropical semi – arid climate. Between July and December, the relative humidity is about 70% to 80% in the morning and about 60 to 65% in the afternoon. During summer, the relative humidity in the afternoon is about 25 to 40%. The annual rain fall in the region varies between 860 and 1050mm. Rain fall occurs as high as 1450mm with a recurrence interval of around 4 years. The South West monsoon (June – September) receives about 45-55% and the North-East Monsoon (October-December) receives about 30-45% of annual rainfall. The annual rainfall in the region varies between 860 and 1050mm.

3.6 ***Civic administration***

Tirupati Municipal Corporation (TMC) oversees the administration of the city. Tirupati was constituted as a municipality on 1 April 1886; it was upgraded to a second-grade municipality on 1 October 1962, to a first-grade municipality on 12 December 1965, to special grade municipality on 13 February 1970, and to selection grade municipality on 7 October 1998. Tirupati Municipality was upgraded to a municipal corporation on 2 March 2007. The area of the municipal corporation at the time of formation was 16.59 square kilometres (6.41 sq mi). While, at present the area of the city is 27.44 square kilometres (10.59 sq mi). Tirupati has been ranked among the top ten cleanest cities in India as per Swachh Survekshan 2022 report.

3.7 ***Utility Services –***

Electricity to the city is distributed by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL), headquartered at Tirupati. The city mostly depends on groundwater for its needs, though it also gets water from Telugu Ganga canal and Kalyani dam. There are dams in the vicinity: Kalyani Dam, Papavinasanam Dam, Gogurbham Dam, Pasupudara Dam, Kumaradara Dam, and Akasa Ganga, all in the Tirumala Hill ranges. Of these, Papavinasanam, Gogurbham, Pasupudara, kumaradara, and Akasa Ganga completely cater to the water needs of Tirumala and

Venkateswara Temple while 49% of Kalyani Dam water is being supplied to Tirumala and remaining water is supplied to Tirupati.

The city ranked sixth in India among the 200 cities that competed during Swachh Survekshan – 2018 conducted by Ministry of Urban Development, Government of India, and the Central Pollution Control Board (CPCB) of India. According to the National Urban Sanitation Policy, the city was ranked 117th in the country in 2009–10, with a total of 39.363 points. As part of 'Swachh Tirupati', Tirupati Municipal Corporation has started household waste segregation programme. As of May 2015, 150 Tonnes of waste is being collected per day from households within the municipal limits. The city is the 11th cleanliest city with 66 points in the cleanliness scorecard, published by Union Tourism Ministry of India

3.8 *Tourism:*

Tourism sector is of great importance to the city. It is because of the presence of Tirumala Venkateswara Temple and a number of other temples in and around the city. It attracts large number of tourists which helps the tourism department of the state in generating revenue. Tirumala is said to be one of the most visited religious sites on earth, and Tirupati Temple is currently a Guinness World Record holder for most visited temple in the world**.**

3.9 *Economy*

Tirupati's economy majorly is driven by the religious tourism. The primary factor has enhanced education, healthcare, manufacturing and other agricultural activities to contribute to its economy. The Venkateshwara temple known to be one of the richest temples and most visited temple attracts around 30-40 million pilgrims yearly. It provides employment associated with the religious activities, its administration and maintenance. This tourism is also significantly contributing to hospitality related sector along with transportation and other local business. Tirupati has evolved into an education hub, attracting students from various part of the country providing opportunities in research and innovation driven institutes. Various industrial parks have started evolving in this city boosting the economy. The textile and handicraft product have been showing its impact on the economic status over the years. Along with it the demand of locally produced food has grown the processing industry.

3.10 Problem Description:

Tirupati, a rapidly growing city in Andhra Pradesh, India, faces several significant challenges regarding energy consumption and energy efficiency. The city's energy demand has surged in recent years due to population growth, urbanization, and increased industrialization, leading to inefficiencies in various sectors. Despite its importance as a religious, cultural, and educational hub, Tirupati's energy infrastructure and policies are still evolving, and various sectors in the city are struggling with high energy consumption and inadequate energy-efficient solutions. These challenges, when not addressed adequately, pose a threat to the city's sustainability and economic development.

One of the primary issues is the **high energy consumption in residential areas**. As Tirupati's population continues to grow, particularly due to the influx of pilgrims and students, the demand for electricity has escalated. This surge is mainly attributed to the increased use of household appliances like air conditioners, refrigerators, lighting systems, and heating devices. Given the hot climate in Tirupati, cooling needs are particularly high during the summer months, leading to spikes in energy consumption. Additionally, a significant portion of the city's residential buildings are not equipped with energy-efficient systems. Many homes use outdated, energy-inefficient appliances, resulting in higher energy consumption and waste. Furthermore, the adoption of energy-efficient appliances like LED lights, energy-efficient air conditioners, and smart meters remains limited, mainly due to the high initial costs and lack of awareness about the long-term savings.

In the **commercial and institutional sectors**, Tirupati faces a similar problem of inefficient energy use. Numerous commercial buildings, including shopping malls, office spaces, hotels, and educational institutions, operate with outdated electrical systems, inefficient lighting, heating, ventilation, and air conditioning (HVAC) systems. These systems, while functional, are often not optimized for energy efficiency, contributing to excess energy use. Moreover, due to the high influx of pilgrims visiting the city throughout the year, the energy demands of religious structures, notably the **Tirumala Venkateswara Temple** and other temples, are significant. These temples use a considerable amount of electricity for lighting, cooling, and other operations, and the energy systems are often not designed with sustainability or efficiency in mind. The lack of comprehensive energy management strategies in these areas further exacerbates energy inefficiency.

Another significant issue is the **inefficiency of the power distribution system**. Tirupati's power grid faces significant challenges in terms of distribution losses. Transmission and distribution (T&D) losses are prevalent due to the outdated and overloaded infrastructure. The city's distribution network is often incapable of handling the growing demand, leading to power outages and inefficiencies in energy delivery. These losses not only reduce the overall energy efficiency but also increase the pressure on the existing grid, further exacerbating the issue of power shortages. Additionally, there is a lack of **smart grid technologies**, which could otherwise help in improving energy efficiency by enabling real-time monitoring of energy usage and efficient load distribution. Furthermore, **power quality issues**—such as voltage fluctuations and power interruptions—are common in some areas, reducing the reliability of energy supply and causing unnecessary energy waste.

Renewable energy adoption in Tirupati has been slow, despite the city being situated in a sunny region with significant potential for solar energy. The city has yet to fully tap into the **solar energy potential** available from rooftops and open spaces. While there have been some initiatives, such as the installation of a few solar panels on public buildings, these efforts remain limited. The lack of substantial financial incentives, awareness programs, and technical support for individuals and businesses to install solar systems is a significant barrier to increasing solar energy usage. Moreover, the integration of solar energy into the city's grid system has been slow, and there is little evidence of large-scale solar power projects. This dependency on conventional grid electricity, primarily sourced from fossil fuels, leads to high energy consumption and an increased carbon footprint for the city. The slow pace of renewable energy adoption also means that Tirupati is missing out on opportunities to reduce its reliance on non-renewable energy sources, such as coal, which contributes to global warming and other environmental issues.

Urban sprawl is another challenge for energy efficiency in Tirupati. As the city continues to expand, particularly along the periphery, there is an increased demand for infrastructure, public services, and energy. The sprawling nature of development leads to longer commuting distances, higher transportation energy use, and greater energy demand for infrastructure development, such as street lighting, water pumping, and waste management. The inefficient land use, combined with low-density development, has led to an increase in the overall energy consumption of the city. Moreover, the lack of effective **urban planning** that integrates energy-efficient measures has exacerbated this issue. Poorly planned urban expansion can lead to isolated neighborhoods with inadequate access to public transport or energy-efficient amenities, which, in turn, increases overall energy demand.

Another significant issue is the **energy inefficiency in water and wastewater management**. Tirupati's water supply system requires substantial energy input, primarily for pumping water from distant reservoirs and treating it for distribution. The existing water supply system is not optimized for energy efficiency, leading to high energy consumption in pumping and treatment processes. Furthermore, the wastewater treatment plants in the city require considerable energy to treat sewage and other waste materials. Energy wastage in these systems is a significant problem, as much of the energy used could be reduced with the adoption of more efficient technologies, such as solar-powered water pumps or more efficient wastewater treatment systems.

There is also a **lack of public awareness** regarding energy-efficient practices. Most residents are unaware of the importance of energy-saving measures like switching to LED lighting, using energy-efficient appliances, and implementing proper insulation in buildings. The lack of knowledge about the long-term benefits of energy efficiency, coupled with the relatively high upfront costs for energy-efficient solutions, hinders their widespread adoption. In addition, there are very few **government-led programs or initiatives** aimed at educating the public about energy efficiency, renewable energy, and sustainability practices. This lack of awareness and engagement from the general public limits the potential for widespread change in the city's energy consumption patterns.

The **governance and policy framework** in Tirupati, though improving, is still in the early stages when it comes to promoting energy efficiency. While there have been some initiatives at the state and national levels, such as the Energy Conservation Building Code (ECBC) and policies to promote solar energy, the local governance framework in Tirupati has not fully embraced energy efficiency in urban planning and development. The city lacks a comprehensive, city-wide **energy efficiency strategy** that addresses energy consumption in all sectors, from residential to industrial, and includes both short- and long-term goals. The implementation of such strategies is often hampered by limited financial resources, lack of expertise, and political challenges in prioritizing energy efficiency over other development goals.

Tirupati is facing a variety of **energy consumption and energy efficiency challenges** due to rapid urban growth, inefficient infrastructure, limited adoption of renewable energy, and a lack of awareness and technical capacity. These issues are compounded by insufficient policies and governance frameworks to guide the city's development towards a more sustainable and energy-efficient future. Addressing these challenges requires a concerted effort from local authorities, businesses, and residents, along with robust planning, improved infrastructure, and greater investment in energy-efficient technologies. As the city continues to grow, it is crucial for Tirupati to adopt a holistic approach to urban planning that prioritizes energy efficiency across all sectors to ensure a sustainable future for its residents.

Chapter 4: Objectives and Detailed Methodology

4.1 Objectives:

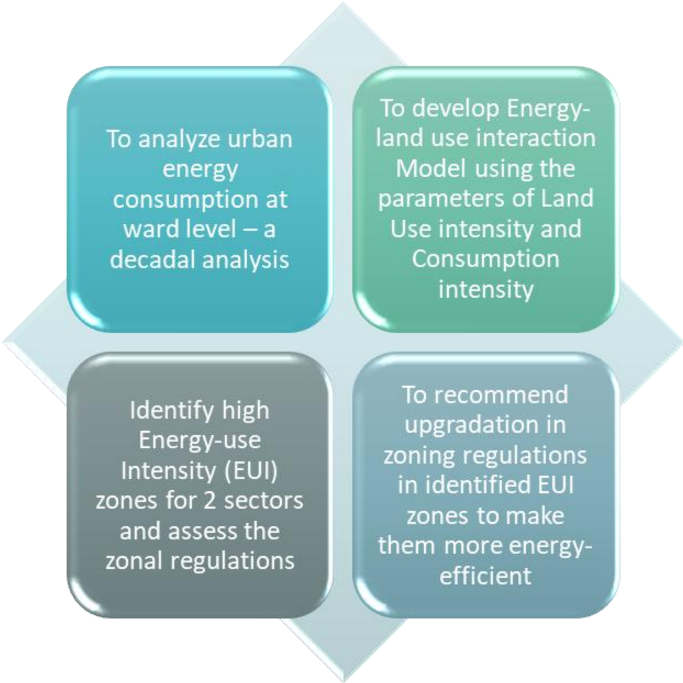
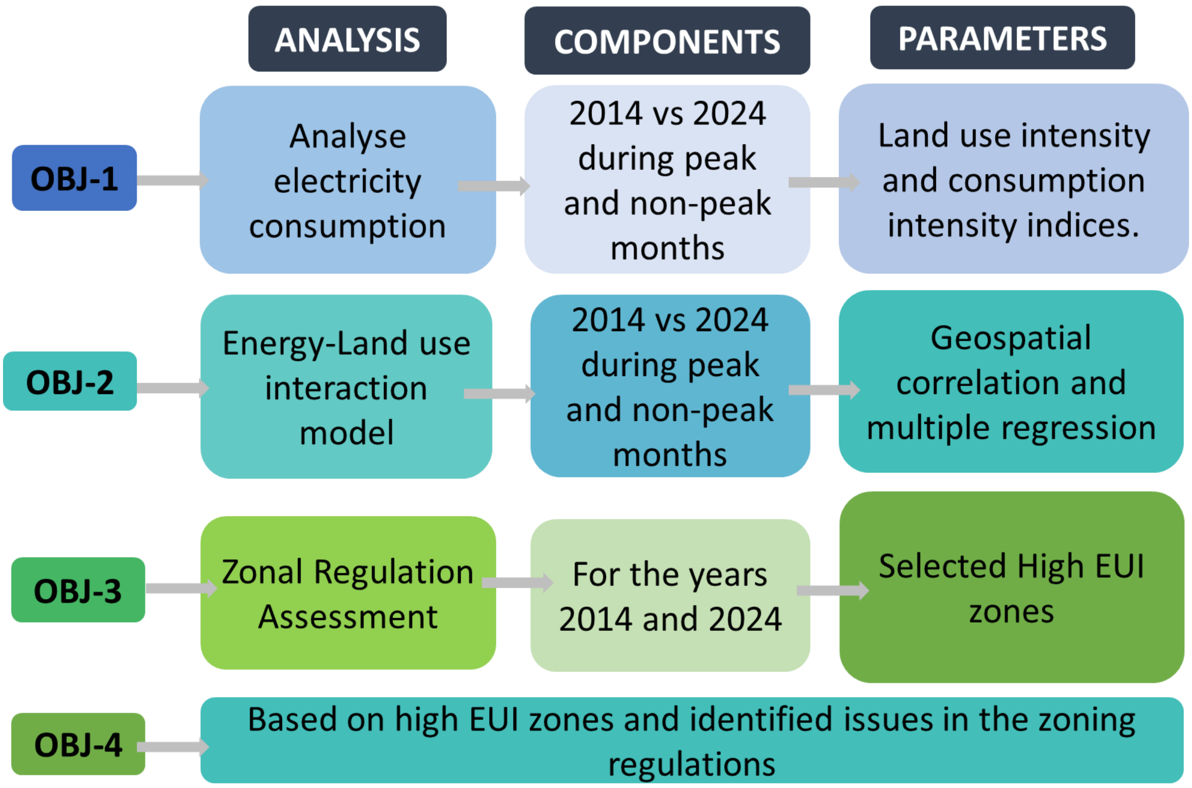


Figure 1 Objectives

4.2 Methodology



4.3 <u>Description of data used (to be used)</u>

4.3.1 Decadal Energy Consumption Trend Analysis

- **Purpose**: To analyze the changes in energy consumption across different wards over the last decade and identify trends, patterns, and outliers.
- **Approach**:
    - **Annual and Monthly Breakdown**: Analyze annual and peak and non-peak monthly energy consumption data for each ward to understand how consumption has evolved over the years. This can help identify seasonal variations, long-term trends, and shifts in consumption.
    - **Rate of Change**: Calculate the percentage increase or decrease in energy consumption over the decade for each ward. Identify which wards have seen significant growth in consumption and which have reduced their energy use.
- **Tools & Data**: Time-series analysis using consumption data from utility companies, energy meters, or census data.

4.3.2 Sectoral Energy Consumption Analysis at Ward Level

- **Purpose**: To break down energy consumption by sector (e.g., residential, commercial, mixed, industrial and institutional) at the ward level and identify trends specific to each sector.
- **Approach**:
    - **Residential vs. Commercial Consumption**: Analyze energy consumption in residential areas compared to commercial and industrial zones. Assess how energy consumption in each sector has evolved over the decade.
    - **Sector-Specific Trends**: Identify how sectoral energy consumption trends differ across wards (e.g., increasing energy demand in commercial wards, residential areas with significant energy use due to air-conditioning, etc.).
- **Tools & Data**: Energy consumption data segmented by type of usage (e.g., residential, commercial), ward-level population and land-use data.

4.3.3 Energy-Land Use Interaction Model Development

- **Purpose**: To develop a model that integrates energy consumption data with land use patterns, helping to understand how different land uses (e.g., residential, commercial, industrial) impact energy consumption and vice versa.
- **Approach**:
    - **Model Framework**: Develop a conceptual framework for the Energy-Land Use Interaction model. This could be based on integrating geographic data (land use maps) and energy consumption data (EUI, energy consumption per building, sector, etc.).
    - **Data Inputs**: Include land use data (e.g., residential, commercial, industrial), demographic data (e.g., population density, income level),

infrastructure data (e.g., building type, age), and energy consumption data (e.g., residential, commercial electricity use).
    - **Model Calibration**: Use historical data from the past decade to calibrate the model, ensuring that it accurately reflects energy consumption patterns and land use changes over time.
- **Tools & Data**: GIS, energy consumption data, land use and zoning data, spatial modelling tools, regression modelling, or machine learning techniques.

4.3.4 Identification of High Energy Use Intensity (EUI) Zones

- **Purpose**: To identify and map high EUI zones in the city based on energy consumption and land use patterns.
- **Approach**:
    - **EUI Calculation**: Calculate the Energy Use Intensity (EUI) for each zone or ward in the city. EUI is typically defined as energy consumption per unit of area (e.g., kWh/m^2/year) or per capita.
    - **Thresholds for High EUI**: Establish thresholds for high EUI based on the calculated values and the standard deviations from the average energy consumption in the city.
    - **Spatial Mapping**: Use GIS tools to map areas with high EUI and visually identify the top 3 high EUI zones. These zones could be based on both high energy consumption and low energy efficiency.
- **Tools & Data**: GIS mapping, energy consumption data, EUI calculations, spatial analysis tools

4.3.5 Impact of Zoning Regulations on EUI

- **Purpose**: To assess how zoning regulations and land use policies have influenced energy consumption and efficiency in different areas, particularly high EUI zones.
- **Approach**:
    - **Review of Zoning Regulations**: Review existing zoning regulations and land use policies to understand their impact on energy consumption. For example, are mixed-use zones leading to lower EUI by integrating residential and commercial areas?
    - **Zoning vs. EUI Comparison**: Compare high EUI zones with areas under stricter energy-efficient zoning codes or policies to understand the effect of such regulations on energy consumption.
    - **Policy Impact Analysis**: Evaluate how introducing more stringent zoning laws, such as mandatory green building codes, higher insulation standards, or renewable energy requirements, can reduce EUI in these areas.
- **Tools & Data**: Zoning regulation documents, energy consumption data, policy analysis.

4.3.6 Predictive Analysis for Future EUI Zones

- **Purpose**: To predict future trends in EUI based on historical energy consumption and land use changes.

- **Approach**:
  - **Trend Forecasting**: Use historical energy consumption and land use data to predict future trends in EUI for different zones. This could involve using time-series forecasting methods (e.g., ARIMA, exponential smoothing).
  - **Scenario Modelling**: Simulate different future scenarios, such as increased energy efficiency, population growth, or changes in land use (e.g., more high-density development), and predict how these factors will impact future EUI zones.
- **Tools & Data**: Predictive modelling tools (e.g., R, Python), historical energy consumption data, land use change data, population forecasts.

4.3.7 Carbon Emissions Estimation from Electricity Consumption

- **Purpose**: To estimate the carbon emissions resulting from electricity consumption over the decade at the city or ward level.
- **Approach**:
  - **Carbon Intensity Calculation**: Calculate the carbon emissions based on the carbon intensity of the electricity consumed. The formula typically used is:

    Carbon Emissions=Electricity Consumption (kWh) ×Carbon Intensity (kg CO_2 per kWh)\{Carbon Emissions} = \{Electricity Consumption (kWh)} \times \{Carbon Intensity (kg CO}_2\{ per kWh)}

  - **Use of Emission Factors**: Use the appropriate emission factors based on the energy mix (coal, natural gas, renewable, etc.) of the electricity grid in your region to estimate emissions for each year.
  - **Yearly Carbon Emissions**: Calculate the total carbon emissions from electricity consumption for each year within the decade.
- **Tools & Data**: Electricity consumption data, carbon intensity data, emission factor data (e.g., from the IPCC or local government reports).

4.3.8 Energy Efficiency and Emissions Reduction Potential

- **Purpose**: To assess the potential for reducing carbon emissions by improving energy efficiency in electricity consumption.
- **Approach**:
  - **Energy Efficiency Potential**: Estimate the potential reductions in carbon emissions if energy efficiency measures (e.g., better insulation, energy-efficient appliances, LED lighting) were implemented across different sectors or areas.
  - **Carbon Emissions Reduction Scenarios**: Model different scenarios of energy efficiency improvements, calculating the resulting carbon emission reductions for each scenario.
  - **Cost-Benefit Analysis of Energy Efficiency**: Evaluate the cost-effectiveness of energy efficiency interventions in reducing emissions,

considering factors like investment in technologies vs. long-term savings in emissions.

- **Tools & Data**: Energy efficiency audit data, modeling software, cost-benefit analysis frameworks, energy consumption data.

4.3.9 Sustainability and Carbon Emissions Analysis in High EUI Zones

- **Purpose**: To assess the sustainability and carbon emissions impact of high EUI zones and suggest actions for emissions reduction.
- **Approach**:
  - **Carbon Emissions Calculation**: Calculate the carbon emissions associated with energy consumption in the high EUI zones. This can be done by applying carbon intensity factors to the energy consumption data of each zone.
  - **Emissions Reduction Strategies**: Identify potential strategies for reducing carbon emissions in high EUI zones. These could include increasing energy efficiency, transitioning to renewable energy sources, and reducing energy demand in key sectors.
  - **Policy Implications**: Recommend policies that can help reduce carbon emissions in high EUI zones, such as incentives for energy-efficient buildings or the introduction of low-carbon energy systems.
- **Tools & Data**: Carbon intensity data, energy consumption data, emissions reduction models.

Chapter 5: Survey/Field-Visit Description

Data Checklist:

Tirupati Urban Development Authority

1. Land Use Maps
2. Land Use Land Cover (LULC)
3. Topographic Map/ Digital Elevation Model (DEM) file
4. Shape files and Survey Nos.

Tirupati Municipal Corporation

1. Ward Maps & Ward Data
2. Demographic Data
3. Household level Data

AP State Energy Conservation Mission, Gunadala, Vijayawada

1. Any schemes on Energy Efficiency/Cool Roofs/Green Roof
2. Policy Measures at City Levels on Heat/Energy
3. Incentives (if any) for lower energy consumption areas or developments
4. Heat Action Plan in place (if any)

AP Central Power Distribution Corporation Ltd., Tirupati

Data required at Ward level – 2014 and 2024 (for a decadal analysis)

1. Sectoral energy consumption

- Domestic
- Agricultural
- Industrial
- Commercial
- Mixed use
- Public/Semi-public
- Municipal Services
    - ✓ Water supply – pumping energy
    - ✓ Waste water treatment

✓ Street Lighting

2. LT and HT consumer data + amount of electricity consumed

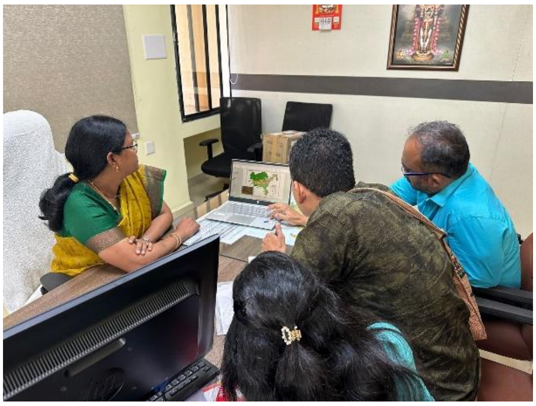
3. Peak consumption – Monthly data

4. Source of generation

- Coal
- Gas
- Solar
- Nuclear
- Hydro-electric
- How much electricity is generated vs End use consumption vs Electricity losses/theft
- Ward level electricity consumption data
- No. of industries vs types of industries vs Electricity Consumption.

TMC/TUDA officials we have contacted in person and they are fully aware of project details:

1. Mr Mahapatra, Deputy City Planner, Tirupati Municipal Corporation, & his entire team of Town Planning Section.
2. Mr. R Shivanand, Superintendent Engineer, TMC & his team.
3. Smt Devi Kumari, Chief Planning Officer, TUDA
4. Smt N.Mourya, I.A.S., Commissioner TMC, VC TUDA.
5. Mr. Sridhar, Peshi to Chaiman & MD, Southern Power Distribution Company of AP Ltd.








5.1 <u>Aspects Brought to Light in Discussions:</u>

5.1.1 WALTA, 2004 (Water, Land and Trees Act)

WALTA 2004 refers to the **Andhra Pradesh Water, Land, and Trees Act, 2002**, which was implemented in **2004**. It is a **landmark legislation** aimed at **sustainable management and conservation of water, land, and tree resources** in the state of Andhra Pradesh. Stricter enforcement of WALTA, 2004 is needed

Objectives of WALTA 2004:

1. **Regulation of Groundwater Use**
   - Prevents over-extraction of groundwater.
   - Requires **permission** for drilling borewells deeper than 60 meters.
   - Mandates registration of wells and borewells with local authorities.
2. **Protection and Conservation of Water Resources**
   - Promotes **rainwater harvesting** in urban and rural areas.

- Restricts the conversion of water bodies (like lakes, ponds) into urban land.

3. **Control on Tree Cutting and Afforestation**
    - Prohibits **indiscriminate tree felling** on private and public lands.
    - Requires permission to cut trees, ensuring afforestation and compensatory planting.
    - Encourages **social forestry and green cover expansion**.
4. **Regulation of Land Use for Sustainable Development**
    - Prevents **soil erosion** and degradation of agricultural land.
    - Promotes **eco-friendly agricultural practices**.
5. **Formation of Committees for Monitoring**
    - Establishment of **District and Mandal-level Committees** to monitor compliance.
    - Involvement of **local bodies (Gram Panchayats, Municipalities)** in enforcement.

Importance & Impact of WALTA 2004:

- Helps in groundwater conservation, especially in drought-prone regions.
- Prevents deforestation and promotes eco-restoration**.**
- Ensures equitable distribution of water resources.
- Reduces illegal borewell drilling and land degradation.
- Encourages community participation in environmental conservation

5.1.2 Other Aspects:

- Regulatory Mechanism-Mandatory Green Open Spaces On-Site
- APGBC (AP Green Building Beautification Corporation) & its role in urban greening as builders are coming to them for permissions.
- **MINIMUM PLOT SIZE-**12x10 m, i.e., 120 sq m
- RWH Provision shown only on drawing but not done afterwards. (Majority not applying for CC, so no physical verifications)
- Group Development Scheme minimum area at least equal to or more than 4040 Sq M
- Existing provisions to increase green in DCRs like 1 meter **all around green space mandatory** in Group Housing Schemes.
- Green Interventions on Sites, Green interventions in Group Housing, how developers bypass, Ways to increase green percentage in urban areas.
- **Penalties** in Group Housing schemes on Not Complying with RWH Rules and not getting it constructed: Rs 1000/year.
- **Layout Regulation Scheme of AP, 2017** states that if the plan is not approved by the authorities, **within 45 days**, it is deemed to be approved.
- One of the amendments to the scheme include reduction of road width from 40ft to 30ft.
- Compulsion for providing housing to EWS was removed under G.O 140

Chapter 6: Preliminary Analysis

6.1 Source of Electricity Generation:

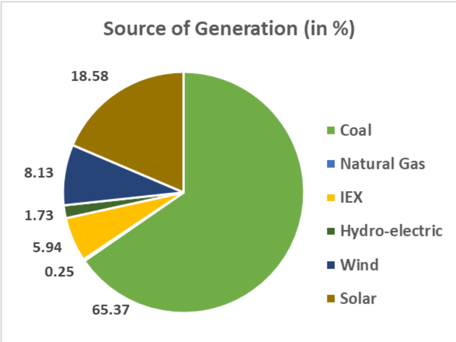


Figure 2 Renewable vs Non-renewable

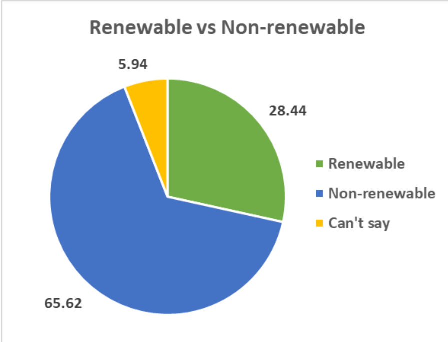


Figure 3 Source of Electricity Generation

Observations:

1. Source of Generation (Left Chart)

- **Coal dominates power generation (65.37%)**, making it the primary source of electricity.
- **IEX (18.58%)** represents electricity traded via the **Indian Energy Exchange**, possibly including a mix of sources.
- **Natural Gas contributes 8.13%**, indicating some reliance on gas-based power plants.
- **Hydro-electric (5.94%)** is the largest renewable energy contributor.
- **Wind (1.73%) and Solar (0.25%)** have minimal contributions to the overall energy mix.

2. Renewable vs. Non-Renewable (Right Chart)

- Non-renewable energy sources make up 65.62%**, highlighting heavy dependence on** coal and natural gas**.**
- Renewable energy accounts for 28.44%**, which includes** hydro, wind, and solar power**.**
- 5.94% is categorized under "Can't Say," **likely referring to electricity from** IEX or mixed sources **where the origin isn't clearly defined.**

Inferences:

1. Heavy Dependence on Fossil Fuels
   - The high share of coal (65.37%) and natural gas (8.13%) suggests a strong dependence on fossil fuels.
   - This raises concerns about carbon emissions, environmental pollution, and sustainability.
2. Limited Contribution from Renewable Energy

- Renewables contribute only 28.44%, which is relatively low considering global trends toward clean energy.
- Among renewables, hydroelectric dominates (5.94%), while wind (1.73%) and solar (0.25%) are significantly underutilized.

3. Potential for Renewable Energy Growth
    - Given the increasing focus on carbon neutrality and sustainability, there is a huge opportunity to expand solar and wind energy capacity.
    - Government policies, subsidies, and infrastructure investments could accelerate the transition toward a cleaner energy mix.
4. Need for Energy Diversification
    - Over-reliance on coal and IEX could pose risks such as fuel supply shortages, price fluctuations, and regulatory changes.
    - Boosting investments in renewable energy can ensure a more stable, diversified, and eco-friendly power sector.
5. Grid Stability and Energy Trading (IEX)
    - The 18.58% contribution from IEX indicates that a significant amount of electricity is procured from the energy exchange rather than direct generation.
    - This suggests grid dependency on external markets, which could impact energy costs and supply stability.

6.2 Sectoral Energy Consumption (2020-21)

Table 2 Energy consumption 2020-21

Consumer Category	Total Energy (MU) - Town	% of Energy Consumption - Town	Total Energy (MU) - District	% of Energy Consumption - District
Residential	382.69	41%	1212.433	**20%**
Agricultural	13.816	1%	1405.04	**24%**
Commercial/ Industrial-LT	108.992	11%	356.0231	**6%**
Commercial/ Industrial-HT	371.721	39%	2036.884	**34%**
Others	60.484	7%	913.3832	**15%**
TOTAL	**944.703**	**100%**	**5923.763**	**16%**

Observations:

1. Residential **Consumption is higher in Towns than in the district**

- In towns, **residential consumption is 41%**, whereas in the district, it is **only 20%.**
- This indicates a higher **household energy demand in urban areas**.

2. **Agricultural Consumption is higher in the District**

- Towns consume only **1%** of energy for agriculture, whereas the district **agricultural consumption is 24%**.
- This shows that **rural areas depend more on energy for farming activities**.

3. **Commercial/Industrial Energy Use in Towns vs. District**

- **Commercial/Industrial-LT (Low Tension)**: Towns have **11%**, while the district has **6%.**
- **Commercial/Industrial-HT (High Tension)**: Towns consume **39%**, while the district consumes **34%.**
- Towns have **a slightly higher proportion of energy use for industries** due to concentrated economic activities.

4. **"Others" Category Consumption is higher in the district**

- Towns: **7%**
- District: **15%**
- This suggests that **other energy uses (public infrastructure, utilities, or miscellaneous sectors) are more significant at the district level**.

5. **Total Energy Consumption Distribution**

- The last row suggests an **overall difference in energy usage patterns**, with a **16% category** which could be unaccounted energy loss or distribution inefficiencies.

Inferences:

1. Urban vs. Rural Energy Demand
   - Urban areas (towns) have a higher proportion of energy use for residential and commercial purposes.
   - Rural areas (districts) have more energy allocated to agriculture and miscellaneous sectors.
2. Economic & Industrial Activity Impact on Energy Use
   - The higher share of HT industrial energy in towns suggests that industries are more concentrated in urban areas.
   - However, the district still has significant industrial energy demand (34%), likely due to large-scale industries or manufacturing units outside the urban centres.
3. Scope for Energy Efficiency Improvements
   - Residential energy demand in towns is significantly high (41%), indicating a potential for energy-saving initiatives (LED lighting, smart grids, solar rooftops, etc.).
   - Agricultural energy consumption (24% in districts) shows the need for efficient irrigation systems, solar-powered pumps, and better power management in rural areas.
4. Potential for Renewable Energy Adoption

- With high agricultural and industrial energy demand, the districts can benefit from renewable energy (solar, wind, biomass) to reduce dependency on conventional electricity sources.

Share of Electricity Consumption:

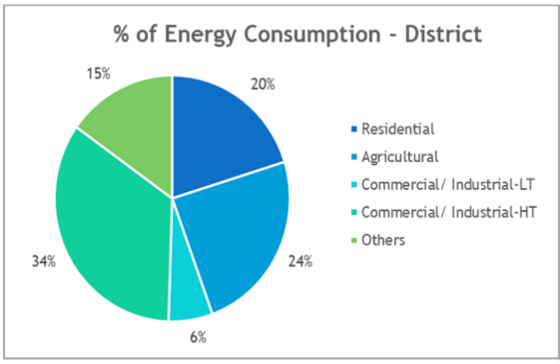


Figure 4 % of energy consumption – district

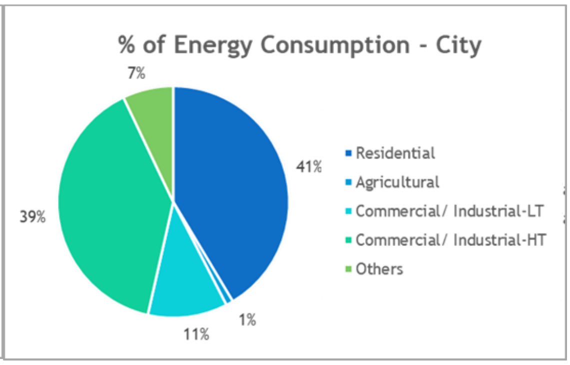


Figure 5 % of energy consumption - city

Observations:

1. Commercial/Industrial-HT (34%) has the largest share of energy consumption in the district.
2. Agriculture (24%) is the second-highest energy-consuming sector, showing the significant electricity use for irrigation and farming.
3. Residential consumption (20%) is a major part of the energy use but is lower than commercial/industrial and agricultural sectors.
4. Others (15%) represent a noticeable portion of energy consumption, possibly including public services, street lighting, and miscellaneous sectors.
5. Commercial/Industrial-LT (6%) has the smallest share, indicating that small businesses and low-tension industrial users consume the least energy.

Inferences:

1. Industrial Dominance in Energy Use:
   - The commercial/industrial-HT sector (34%) suggests that large-scale industries are a major electricity consumer in the district.
   - This indicates a well-established industrial base and economic activity requiring heavy power usage.
2. High Agricultural Dependency on Electricity:
   - The 24% agricultural consumption highlights the importance of electricity in farming, mainly for irrigation.
   - It suggests the need for energy-efficient farming methods, such as solar-powered pumps and micro-irrigation.
3. Moderate Residential Energy Demand:
   - At 20%, residential consumption is significant but lower than industrial and agricultural sectors.
   - This implies a fairly distributed population with moderate household power usage.
4. Potential for Energy Efficiency Programs:

- Industries could adopt energy-efficient machinery to optimize their power use.
- Farmers could shift to solar-powered irrigation to reduce dependency on conventional electricity.
- Smart grids and demand-side management can help balance the energy load.

6.3 Sectoral Energy Consumption (2021-22)

Table 3 Sectoral Energy Consumption (2021-22)

Consumer Category	Tirupati Town (MU)	% of consumption	Rest of District (MU)	Total District (MU)	% of city (wrto district)
Residential	362.79	35%	836.38	1199.17	30%
Agricultural	14.51	1%	1417.66	1432.17	1%
Commercial/ Industrial-LT	144.42	14%	291.24	435.66	33%
Commercial/ Industrial-HT	386.18	37%	1874.61	2260.79	17%
Others - Mixed use	130.64	13%	724.27	854.91	15%
Total	**1038.53**	**100**	**4144.16**	**5182.7**	**20%**

Observations:

1. Residential Consumption
   - 35% of total energy consumption in Tirupati Town comes from residential consumers.
   - The town contributes 30% of the district's residential energy consumption.
   - This indicates significant household energy usage in the town.
2. Commercial/Industrial Consumption
   - Low-Tension (LT) Industrial and Commercial consumers account for 33% of the total district's consumption.
   - High-Tension (HT) Industrial and Commercial consumers form the largest share (37%) of Tirupati's consumption.
   - This suggests a strong presence of industries and commercial establishments in the town.
3. Agricultural Consumption

- The agriculture sector data is missing, but it can be inferred that its consumption is lower in Tirupati, as the town is more urbanized.

4. Others – Mixed Use Category
    - This category includes miscellaneous energy consumption, likely comprising public infrastructure, street lighting, and small businesses.
5. Overall Contribution of Tirupati Town
    - Tirupati accounts for 20% of the district's total energy consumption.
    - This implies that the rest of the district consumes 80%, likely due to agricultural and industrial activities outside the town.

Inferences:

1. Tirupati is a Commercial & Industrial Hub
    - The high commercial and industrial energy consumption (both LT and HT) indicates that Tirupati houses a significant number of businesses, industries, and commercial establishments.
2. Urban Energy Demand is Residential & Commercial-Driven
    - Residential (35%) and commercial (33%-37%) sectors dominate Tirupati's energy demand, emphasizing high household and business electricity consumption.
3. Rural Areas Rely More on Agricultural Energy
    - Since Tirupati Town contributes only 20% of the total district's energy, the rest of the district (80%) is likely agriculture-dominated in terms of energy consumption.
4. Scope for Renewable Energy Adoption
    - With a high share of energy going into residential and commercial use, there is potential for solar rooftop solutions and energy efficiency measures to reduce dependency on traditional power sources.

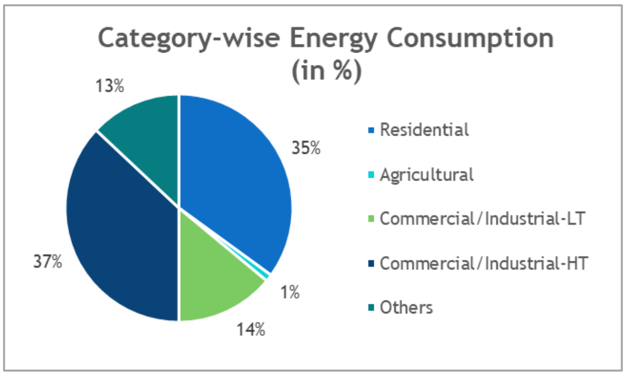


Figure 6 Energy consumption

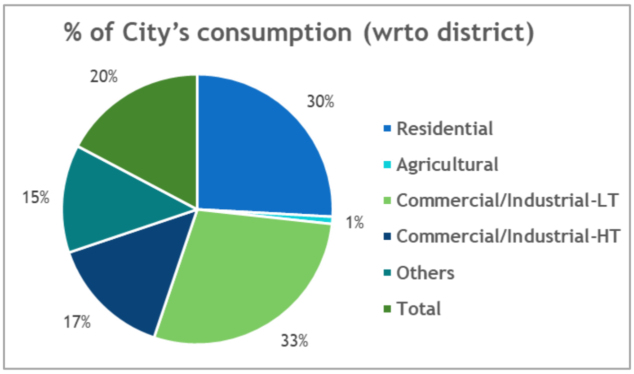


Figure 7 % of city's energy consumption wrto district

Inferences:

1. Tirupati has High Energy Demand from Industries and Businesses
    - 37% of the city's energy demand is from HT industries, and 14% from LT commercial consumers, meaning that over half of the city's energy demand (51%) is for commercial and industrial purposes.
    - This suggests Tirupati is a major commercial and industrial center.
2. Residential Consumption is Significant

   - With 35% of the city's energy consumption, residential demand is very high, which could be due to high population density and urbanization.
3. Minimal Agricultural Energy Usage in Tirupati
   - The agriculture sector's share is only 1%, showing that Tirupati is not an agricultural hub but more of a commercial and residential urban area.
4. Tirupati's Contribution to the District's Energy Usage is Limited
   - The city accounts for only 20% of the total district's energy demand, indicating that most energy is consumed outside Tirupati, likely by agriculture and rural industries.
5. Potential for Renewable Energy and Energy Efficiency
   - Given the high demand from commercial, industrial, and residential sectors, there is scope for adopting solar energy, energy-efficient appliances, and better grid management to reduce dependency on traditional power sources.

6.4 Sectoral Energy Consumption (2021-22)

Table 4 Sectoral Energy Consumption (2021-22)

Consumer Category	Tirupati Town (MU)	% of consumption	Rest of District (MU)	Total District (MU)	% of District (Town)
Residential	385.12	35%	872.35	1257.47	31%
Agricultural	15.03	1%	1489.74	1504.77	1%
Commercial /Industrial-LT	157.26	14%	318.42	475.68	33%
Commercial /Industrial-HT	410.25	38%	1990.22	2400.47	17%
Others	126.87	12%	745.62	872.49	15%
Total	**1093.85**	**100%**	**4416.35**	**5500.2**	**20%**

Observations:

1. Residential Consumption:
   - 35% of Tirupati's energy is consumed by the residential sector.
   - Residential consumption accounts for 31% of the district's total residential energy usage.
   - This indicates a significant urban population in Tirupati requiring electricity for household use.
2. Commercial/Industrial-LT (Low Tension) Consumption:

- The LT commercial and industrial category contributes 33% of Tirupati's energy usage.
- This suggests that small to medium-sized businesses and industries play a vital role in the city's electricity demand.

3. Commercial/Industrial-HT (High Tension) Consumption:
   - 38% of the city's energy is consumed by the HT industrial sector.
   - This indicates that large-scale industries and high-energy-demand businesses are concentrated in Tirupati.
   - The HT sector has the highest consumption among all categories, suggesting industrialization and commercial expansion.
4. Agricultural Consumption is Negligible:
   - There is no significant agricultural energy consumption in Tirupati, confirming that the city is not agriculturally dominant.
   - Most of the agricultural energy consumption is likely from rural areas in the district.
5. Others (Mixed-use Consumers):
   - This category has an unspecified percentage, but it contributes to the overall energy demand.
6. Total Consumption – City vs District:
   - Tirupati Town accounts for 20% of the district's total energy consumption.
   - This means that 80% of the district's energy is used outside the city, likely driven by agriculture, rural households, and industries.

Inferences:

1. Tirupati is Primarily an Urban Commercial & Industrial Energy Consumer
   - The majority of the city's energy is consumed by commercial and industrial sectors (LT + HT = 71%), confirming its business and industrial importance.
   - The HT sector (38%) dominates, implying the presence of large industries and commercial complexes.
2. Residential Consumption is High but Secondary to Industries
   - Residential consumption at 35% is substantial, indicating a high number of households and urban settlements.
   - However, the commercial & industrial sectors (71%) dominate energy use, showing that economic activities are the major contributors to demand.
3. Minimal Agricultural Energy Demand in Tirupati
   - The lack of agricultural consumption suggests that Tirupati is an urban hub with limited farming activities.

- The rest of the district likely has higher agricultural power consumption.

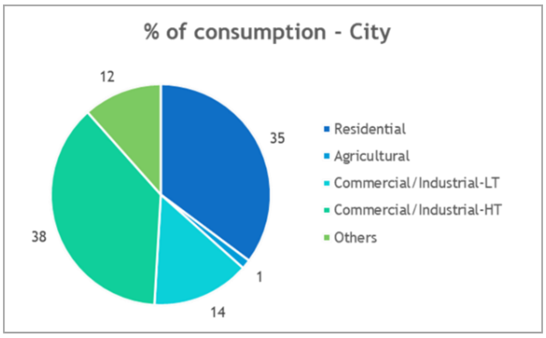


Figure 8 % of consumption (2022-23)

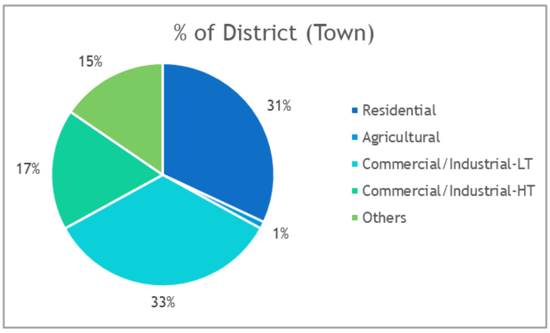


Figure 9 % of city's consumption wrto district (2022-23)

Observations:
% of Consumption – City:

- **Residential (35%)**: A significant portion of the city's energy is used by households.
- **Agricultural (1%)**: Very low agricultural electricity consumption, indicating a primarily urban setup.
- **Commercial/Industrial-LT (14%)**: Small to medium businesses and industries have a notable share.
- **Commercial/Industrial-HT (38%)**: Large-scale industries dominate the city's energy consumption.
- **Others (12%)**: Mixed-use consumers also contribute a moderate share.

% of District (Town):

- **Residential (31%)**: Similar to the city, residential power usage is substantial in the district.
- **Agricultural (1%)**: Agriculture has a very small contribution, implying that most of the agricultural load is outside the town.
- **Commercial/Industrial-LT (33%)**: More prominent than in the city, possibly due to businesses spread across the district.
- **Commercial/Industrial-HT (17%)**: A lower percentage compared to the city, indicating that large industries are more concentrated in urban areas.
- **Others (15%)**: Slightly higher than the city, reflecting a diverse energy use pattern.

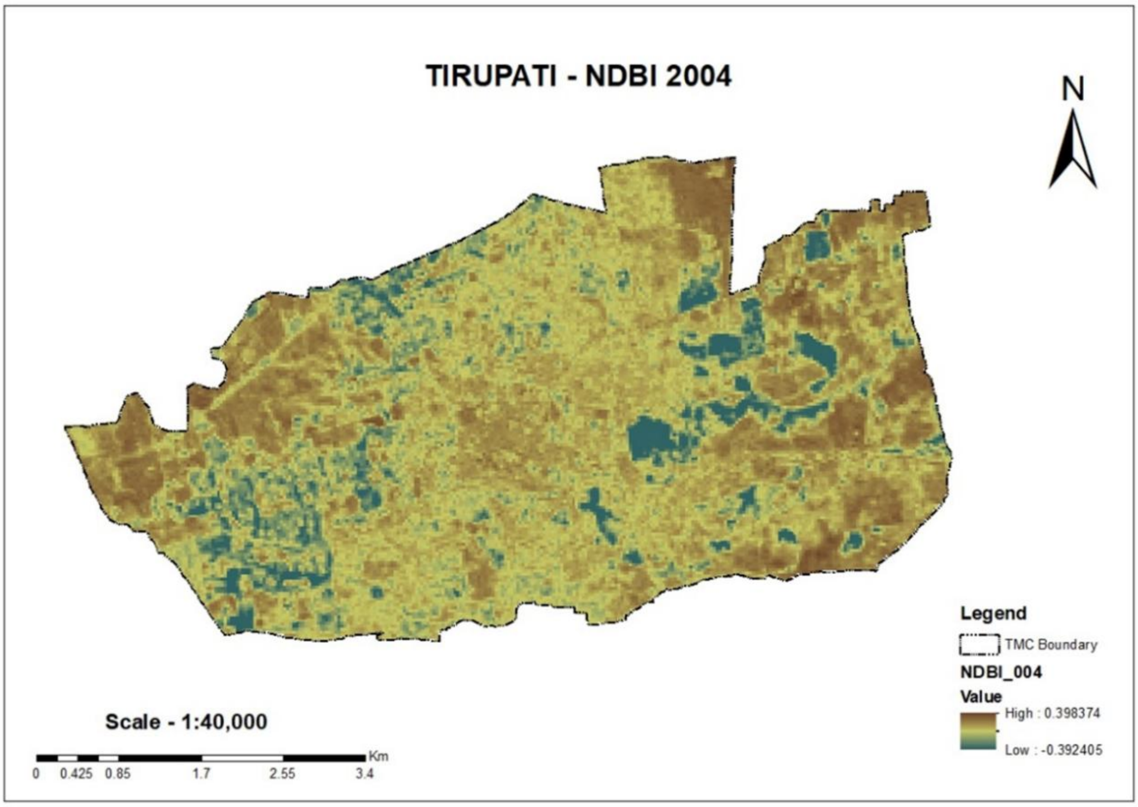
Inferences:

1. Tirupati City is Industry-Driven:
   - HT industries consume the largest share (38%), making the city an industrial hub.
   - The commercial and industrial sectors together contribute 52%, highlighting a strong business environment.
2. Residential Energy Demand is Significant (31-35%):

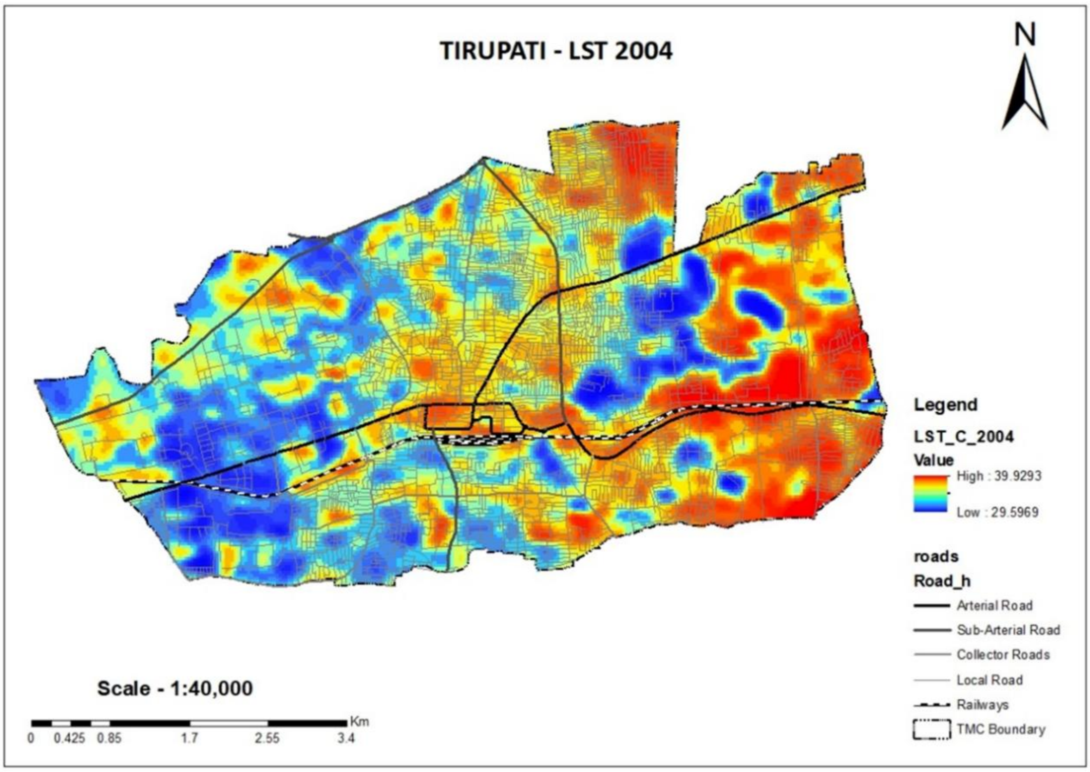
- Households in both the city and district require a major portion of electricity.
- This indicates a high urbanization rate, necessitating infrastructure for residential electricity supply.

3. Negligible Agricultural Consumption (1%):
   - Agriculture is not a major energy consumer in Tirupati city or the town district.
   - Most agricultural power usage is likely concentrated in rural areas.
4. The City Has More High-Tension (HT) Consumption Than the District:
   - HT industries (38%) dominate the city's energy usage, whereas in the district, it's only 17%.
   - This suggests large industries and manufacturing units are located within the city rather than spread across the district.
5. More LT Industrial & Commercial Usage in the District (33%):
   - This implies that small businesses and commercial establishments are more evenly distributed across the district.
6. Others Category is Consistently Around 12-15%:
   - This shows a stable demand from miscellaneous consumers in both the city and district.

6.5 <u>Energy Use Intensity Land use model</u>



Map 7 NDBI 2004



Map 8 LST 2004

Observations:

1. Normalized Difference Built-up Index (NDBI) - 2004

- The map highlights built-up areas using NDBI values.
- Higher NDBI values (brownish areas) indicate dense built-up regions, while lower values (greenish areas) correspond to non-urban or less developed land.
- The central and north-western parts of Tirupati seem to have higher NDBI values, indicating more urbanization.
- Some scattered patches of low NDBI values indicate open land, vegetation, or water bodies.

2. Land Surface Temperature (LST) - 2004

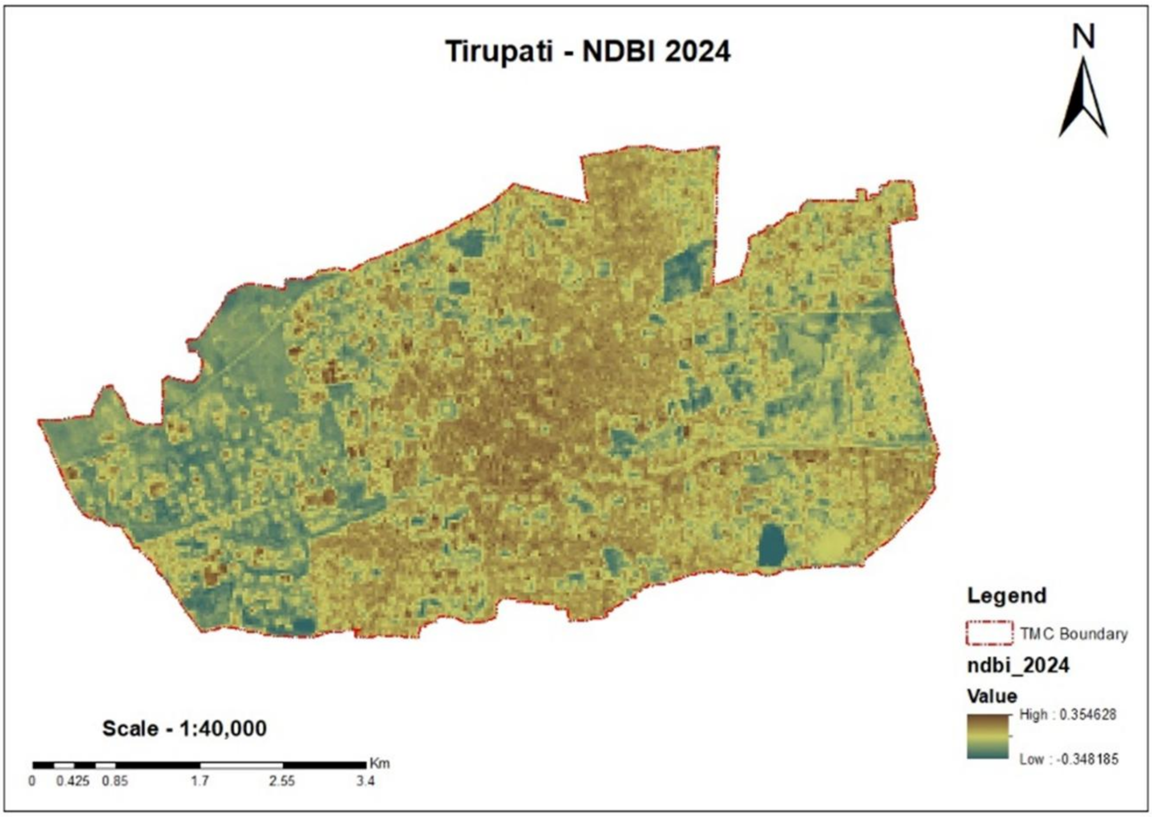
- The map represents surface temperature variations using a color gradient (blue = cooler, red = hotter).
- High LST values (red areas) are observed in the central and northeastern parts, indicating urban heat island effects due to dense built-up areas.
- Low LST values (blue areas) are visible in the western and southern regions, likely due to vegetation, water bodies, or open land.
- The major road networks (arterial and sub-arterial roads) pass through both high and low-temperature zones, influencing localized heating.

Inferences:

1. Urbanization and Energy Demand:

- The high NDBI areas align with high LST values, suggesting dense urban development leads to increased heat accumulation.
- These regions likely have higher energy consumption for cooling (air conditioning, ventilation).

2. Urban Heat Island (UHI) Effect:
   - The red zones in the LST map indicate urban heat islands, possibly caused by impervious surfaces (concrete, asphalt).
   - Measures like increasing vegetation cover or reflective roofing can help mitigate this effect.
3. Energy-Use Intensity Zones:
   - The overlap of high NDBI and high LST suggests zones with higher energy consumption.
   - These areas require focused energy-efficient policies, such as solar panels, green roofs, and better urban planning.
4. Potential for Sustainable Planning:
   - The cooler (blue) regions in the LST map could be preserved as green spaces to balance the heat impact.
   - Strategic land-use planning should focus on reducing temperature rise in high-density urban zones.



Map 9 NDBI 2024

Observations:

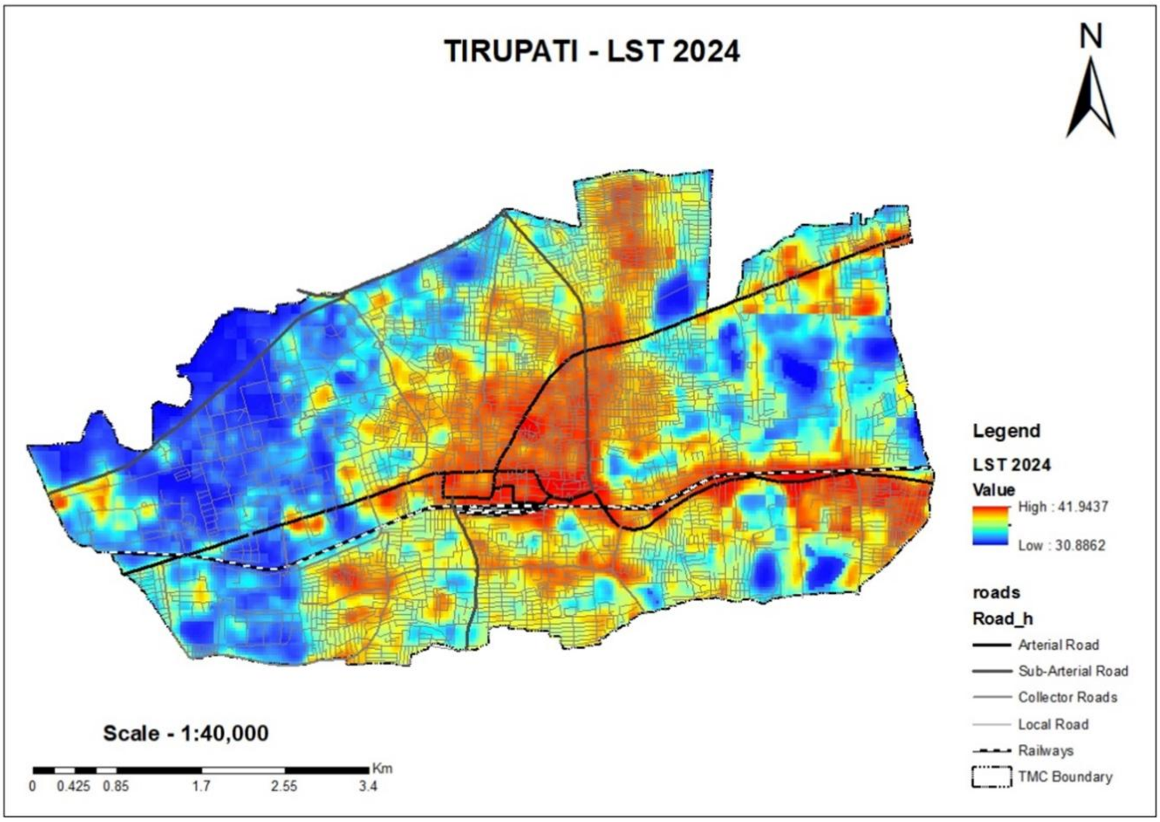
1. **Increase in Built-Up Areas:**
   - The 2024 NDBI map shows a significant increase in built-up areas compared to 2004.

- More areas are now represented in brownish shades, indicating increased urbanization.
- Urban expansion is visible in central and peripheral zones, replacing vegetation and open land.

2. **Reduction in Non-Urban Areas:**
   - The greenish patches representing non-built-up areas (vegetation, water bodies, or open land) have decreased in the 2024 map.
   - Previously less-developed zones (especially in the western and southern regions) have now transformed into built-up spaces.
3. **Urban Expansion Towards Periphery:**
   - The outskirts of Tirupati, particularly in the eastern and southwestern regions, have seen an increase in built-up areas.
   - This suggests urban sprawl and development outside the city core.
4. **Higher Density Development in Central Areas:**
   - The central parts of Tirupati, which were already urbanized in 2004, show further densification in 2024.
   - This could indicate vertical expansion (high-rise buildings) and infrastructure growth.

Inferences:

1. **Urbanization and Energy Demand:**
   - With increased built-up areas, energy demand for residential, commercial, and industrial purposes has likely surged.
   - Infrastructure like roads, commercial buildings, and housing complexes have contributed to this growth.
2. **Potential Increase in Urban Heat Island Effect:**
   - More built-up areas with impervious surfaces (concrete, asphalt) could lead to higher Land Surface Temperatures (LST).
   - This will likely increase cooling energy demand and heat stress in urban areas.
3. **Loss of Green Cover and Water Bodies:**
   - Reduction in green areas can impact ecological balance, air quality, and water retention capacity.
   - There is a need for sustainable urban planning to integrate green spaces within the city.
4. **Need for Smart Urban Planning:**
   - With rapid urbanization, energy-efficient designs, green infrastructure, and sustainable policies must be implemented.
   - Zoning regulations should promote mixed-use development, green roofs, and renewable energy adoption.



Map 10 LST 2024

Observations:

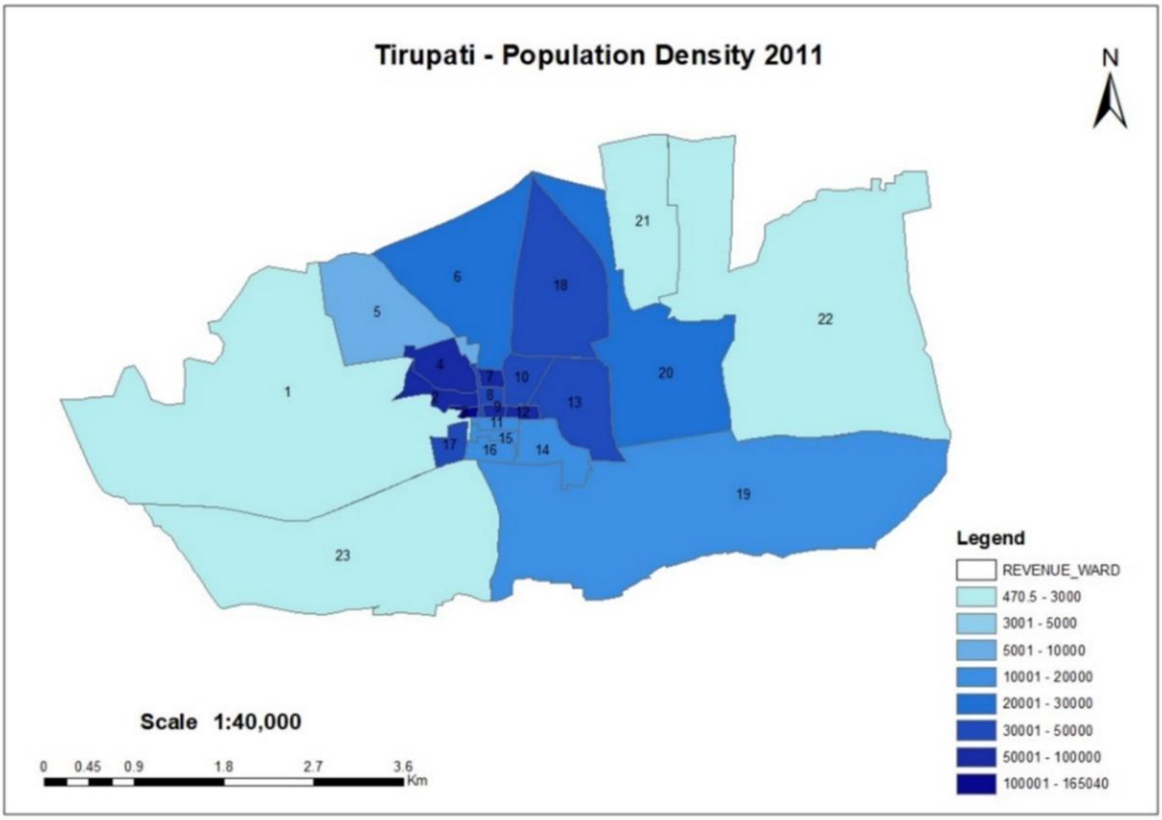
1. High NDBI and High LST zones:
   - Areas with high NDBI values (yellow regions on the NDBI map) indicate dense urbanization, such as commercial and residential hubs.
   - These zones correspond closely to high LST values (red/orange regions on the LST map), suggesting that urbanized areas experience elevated land surface temperatures
2. Low NDBI and Low LST zones:
   - Regions with low NDBI values (green areas) are characterized by vegetation, open spaces, or water bodies
   - These areas show lower LST values (blue regions), indicating cooler surface temperatures due to natural cooling mechanisms like evapotranspiration
3. Energy-use intensity
   - High-temperature zones in urbanized areas likely correlate with increased energy use intensity due to: - Greater demand for cooling systems (air conditioning) and/or Reduced efficiency of cooling appliances in hotter environments.
   - Cooler regions with vegetation or open spaces are expected to have lower energy demands for thermal comfort
4. Influence of roads and infrastructure:

- The LST map shows higher temperatures along arterial roads and densely developed infrastructure corridors, where heat absorption and retention from asphalt and concrete are significant

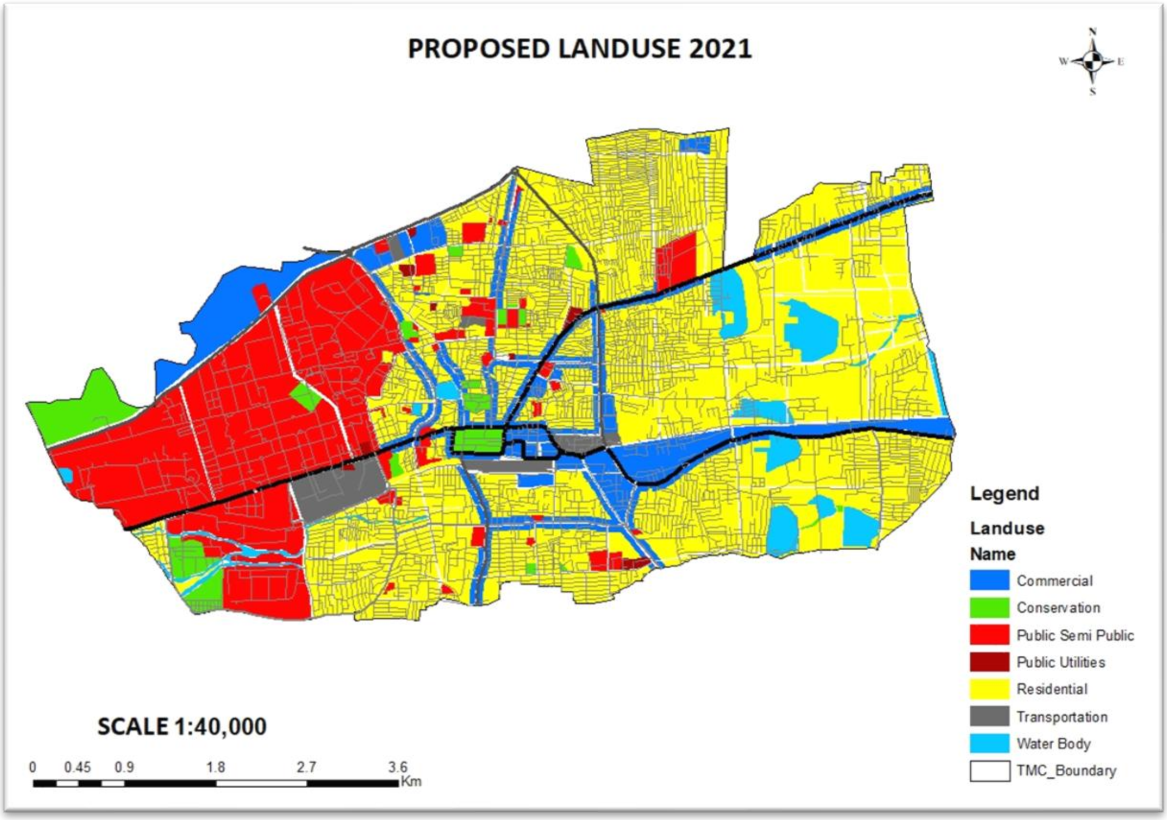
Inferences:

1. Impact on Energy Use
    - Higher temperatures in urbanized zones result in increased energy consumption for cooling purposes, especially during peak summer month
    - This can strain local energy resources and increase greenhouse gas emissions from power generation
2. Urban Heat Island (UHI) Effect:
    - The strong correlation between high NDBI and high LST values highlights the Urban Heat Island effect in Tirupati.
    - Urban materials like concrete and asphalt absorb more heat, leading to increased temperatures in built-up areas
3. Role of Green Spaces:
    - Expanding green cover within urban areas can help mitigate the UHI effect, reducing both surface temperatures and energy use intensity.

The correlation between high NDBI, high LST, and increased energy use intensity underscores the need for sustainable urban planning in Tirupati. Strategies such as increasing green spaces, using reflective materials, and implementing energy-efficient technologies can help reduce the Urban Heat Island effect and optimize energy consumption in built-up areas.



Map 11 Population Density 2011



Map 12 Landuse 2021

Observations:

1. **Population Density and Land use:**
    - **High-Density Zones:** The 2011 population density map reveals the most densely populated areas are in the central wards (around wards 7, 8, 10, 12, 13, 14, 15, 16, 17, and 18).
    - **Land Use Correlation:** The proposed land use map indicates a concentration of commercial, public/semi-public land use in these same central areas. There are also substantial areas of residential land use adjacent to the high-density areas.
    - **Inference:** High population density coupled with commercial and public land use suggests high energy consumption for lighting, cooling, heating, transportation, and business operations. Residential areas surrounding these zones will also likely have high energy demand.
2. **Land Use & Land Surface Temperature (LST):**
    - **Hotspots:** The 2024 LST map shows hotspots (red/orange zones) primarily concentrated in the central part of Tirupati where commercial and residential areas are located.
    - **Roads and Heat:** The LST map shows elevated temperatures along major road networks.
    - **Inference:** Commercial and densely populated residential areas are likely contributing to the Urban Heat Island (UHI) effect, driving up LST. Transportation infrastructure contributes significantly to the rise in local temperatures.

4. **Population Density & Land Surface Temperature:**
    - **Direct Link:** The densest populated regions in the central wards correspond to the hotspots of high land surface temperature.
    - **Inference:** The concentration of people, buildings, and activities in high-density areas leads to increased heat generation and trapping. This can increase the demand for air conditioning, leading to increased energy use and a feedback loop effect
5. **Impact on Energy Use Intensity Zones:**

    - **High Energy Use Zones:** The analysis indicates that the central wards (7, 8, 10, 12, 13, 14, 15, 16, 17, 18) are likely to be the areas with the highest energy use intensity. This is due to the convergence of high population density, commercial/public land use, and elevated LST.
    - **Medium Energy Use Zones:** Wards with primarily residential land use, like areas in 23, 19, 20, and 22, are likely to be in the medium energy use intensity.
    - **Low Energy Use Zones:** "Conservation" areas (green spaces) are expected to have lower energy use intensity. These are likely small, localized regions based on the Land Use map.

Energy Efficiency: Focusing on improving energy efficiency in buildings (especially commercial and public buildings) in the high-density zones can significantly reduce energy consumption.
Renewable Energy: Integrating renewable energy sources, such as solar power, can help reduce reliance on fossil fuels and lower the city's carbon footprint.

Land-use

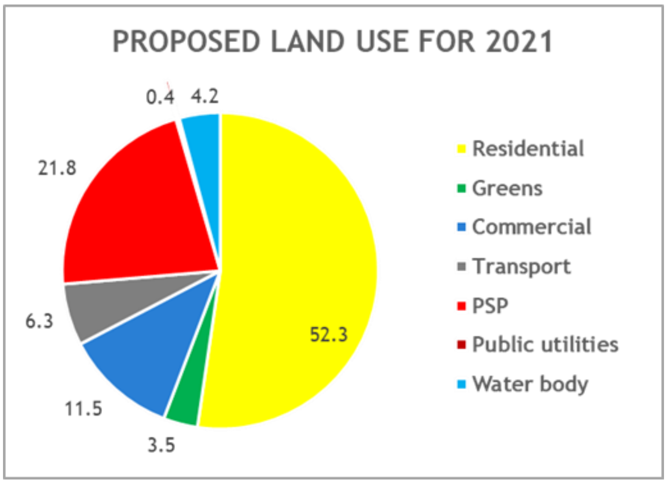


Figure 10 % of land use

Residential: The pie chart's dominance by residential land use is generally in line with standard zoning practices. Zoning regulations will specify density, building height, setbacks, and other requirements for residential zones. Depending on the location within Tirupati, there might be varying densities allowed (e.g., higher densities near the city center or along transit corridors).

Commercial: A proposed 11.5% allocation for commercial matches the need for trading and businesses. Municipal zones will have rules for trading, storage, and traffic requirements.

Public Utilities: The proposed 21.8% public sector utilization aligns.

Transport: The transport sector also needs to align.

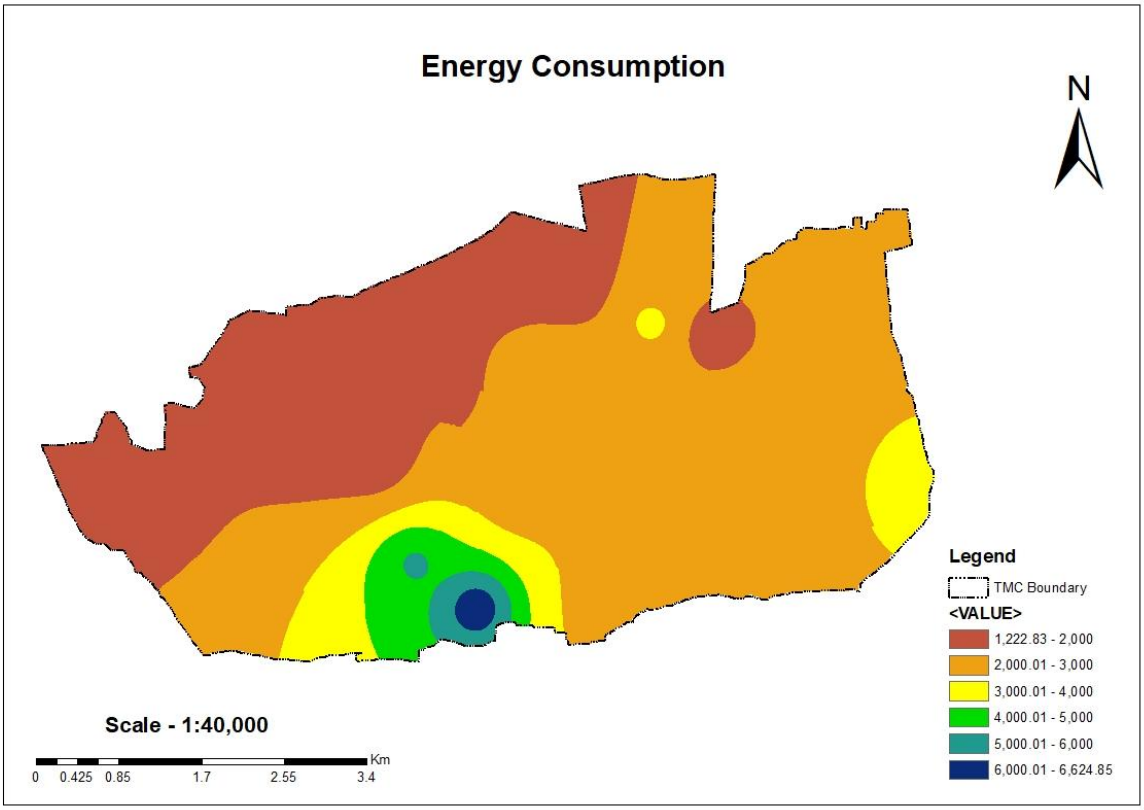
Greens: With a relatively small "greens" allocation of 3.5%, it will be important that the local zoning ordinances allow for the creation of green spaces within other zones. Regulations may encourage or require landscaping within residential and commercial developments. Also, zoning regulations may specify minimum open space requirements for new developments.

Specific Considerations for Tirupati:

> **Temple Town Context:** Tirupati's unique status as a major pilgrimage center influences its zoning regulations. There may be specific restrictions on certain types of commercial activities (e.g., those considered incompatible with the town's religious character) or requirements for preserving the visual character of the area.

Environmental Concerns: Given the surrounding hills and ecological sensitivity, environmental regulations will be important. Zoning regulations may include buffer zones around sensitive areas or restrictions on development that could harm the environment.

Infrastructure Capacity: The zoning regulations will need to be aligned with the available infrastructure capacity (water supply, sewage, roads). The amount of residential and commercial development that is allowed will be constrained by the ability of the infrastructure to support it.



Map 13 Energy consumption 2024

Observations:

- The area with the highest energy consumption (blue zone in the south-central area) corresponds strongly with the region identified as having the highest population density in 2011
- The location of highest energy consumption coincides with the proposed land use that is largely commercial, public/semi-public, and high density residential.
- The hotspot with the highest land surface temperatures largely overlaps with the location of the highest energy consumption.
- Energy consumption is generally lower in the northern and western portions of the map, gradually increasing towards the center-south

- There is a spot with high-energy consumptions to the right of the map. The location is less populated, less commercial and residential according to the LandUse map and has lower surface temperatures

Inferences:

- Denser populations require more energy for residential needs (lighting, heating, cooling, cooking), commercial activities (businesses, offices), and public services. The close alignment of these areas suggests a direct relationship between population size and energy demand.
- Commercial and public land use categories are inherently energy-intensive. These zones typically include offices, retail spaces, hospitals, schools, and other public institutions, all of which require significant energy for operations. The residential zones are likely dense apartment and housing complexes, again increasing demand.
- This strongly suggests a connection between energy usage and the UHI (urban heat island) effect. High energy consumption, particularly in commercial and high-density residential areas, leads to the release of waste heat from buildings, transportation, and industrial processes. Air conditioning use in these areas amplifies the effect, further increasing temperatures and energy demand in a vicious cycle.
- The proposed Landuse map can help us understand that the northern and western zones are primarily residential, with some patches of conservation areas. With fewer commercial activities and lower residential density than the central-south region, energy consumption is expected to be correspondingly lower.
- This suggests the presence of a facility which needs a lot of energy. Further investigation on the specific facility would be needed.

Energy-Use Intensity Zones:

Land use patterns *drive* energy consumption, and the spatial arrangement of different land uses creates areas with varying levels of energy intensity. An "energy-land use interaction model" aims to:

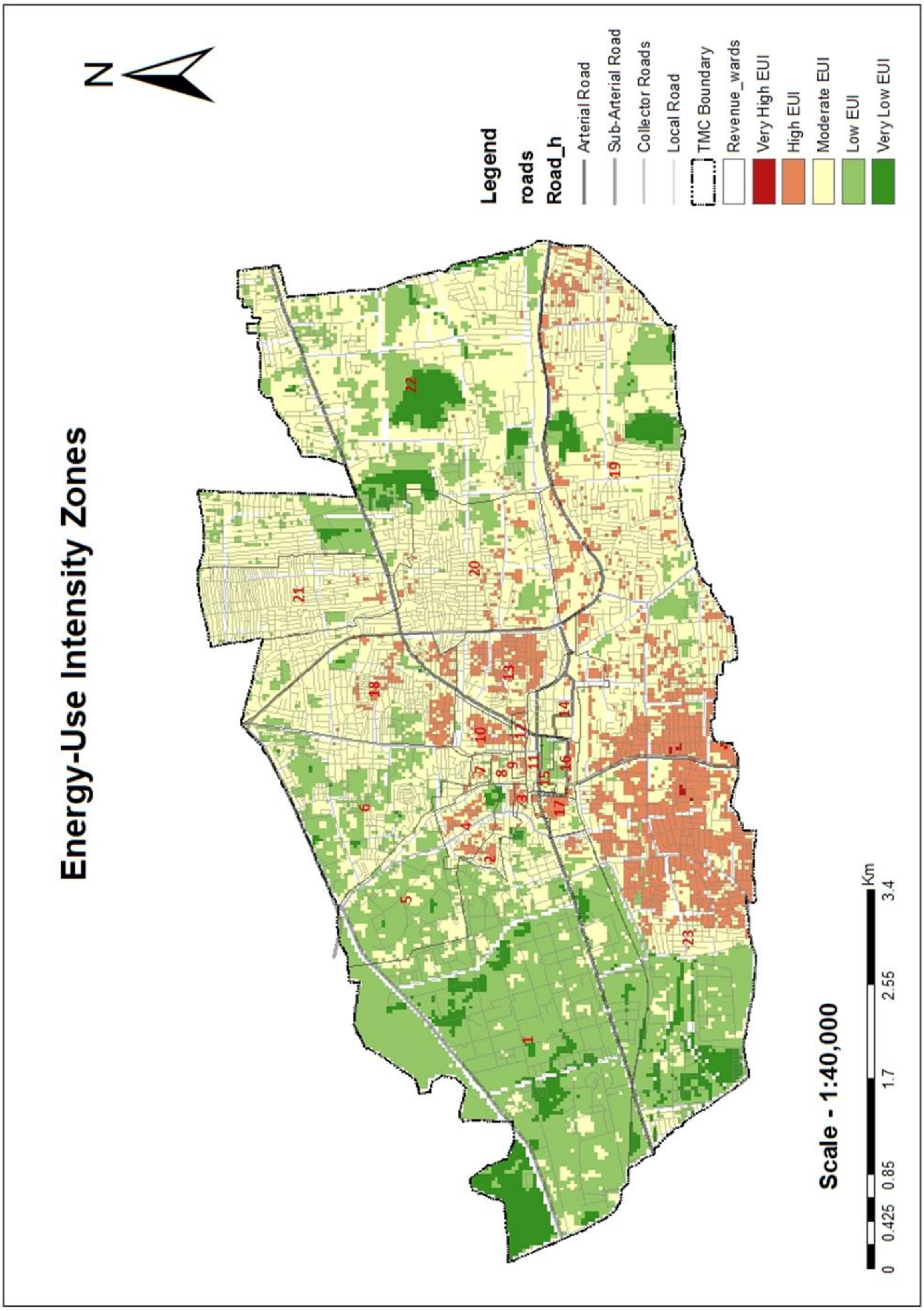
1. **Quantify the Relationship:** Determine the specific mathematical (or statistical) relationships between land use characteristics and energy consumption.
2. **Predict Energy Demand:** Based on these relationships, predict the energy demand (or intensity) of different areas within a city or region.
3. **Create EUI Zones:** Delineate areas (zones) with similar predicted energy intensities, allowing for targeted policy interventions and resource allocation.

The energy-land use interaction model is a powerful tool for understanding and managing energy consumption in urban environments. By quantitatively linking land use patterns to energy demand, it enables the identification of EUI zones and the design of targeted policies to promote energy efficiency and sustainability. While challenges exist in terms of data availability and model complexity, the potential benefits make it a valuable approach for creating more energy-conscious cities.

Observations and Inferences:

1. **High EUI Zones:**
    - **Location:** The areas identified as "Very High EUI" (dark red) and "High EUI" (red) are concentrated in the central-south regions of Tirupati and especially around wards (7, 8, 9, 11, 15, 16, 17, 14, 10)
    - **Inference:** This aligns with our previous analyses. These are the same areas where we identified high population density, significant commercial and public land use, and elevated LST. This reinforces that these regions are the most energy-intensive due to the concentration of people, activities, and buildings.
2. **Moderate EUI Zones:**

    - **Location:** "Moderate EUI" (yellow) zones tend to surround the high EUI areas. These spread out across wards (20, 21, 13, 6, 2)



Map 14 Energy-use Intensity zones

- **Inference:** These areas are likely dominated by residential land use with moderate population density. These are close enough to the commercial centers that their daily activities are influenced.

3. **Low and Very Low EUI Zones:**
   - **Location:** "Low EUI" (light green) and "Very Low EUI" (dark green) are primarily located in the outskirts of the city, specifically the North, West, and Southwest sections, and can be seen around wards (1, 5, 22, 23)
   - **Inference:** The "Very Low EUI" areas likely correspond to the areas designated for conservation. The lower EUI suggests less development, lower population densities, and potentially a greater prevalence of green spaces.
4. **Impact of NDBI:**
   - **Inference:** As NDBI accounts for the density of built-up structures, the EUI map shows how greater concentration in the central areas will significantly contribute to greater energy consumption.
5. **Impact of Roads:**
   - **Observation:** Arterial and Sub-Arterial roads have some alignment with high and moderate EUI zones.
   - **Inference:** The road density indicates the high frequency of transport needed in these areas. This contributes to high energy demand.

Overall Interpretation:

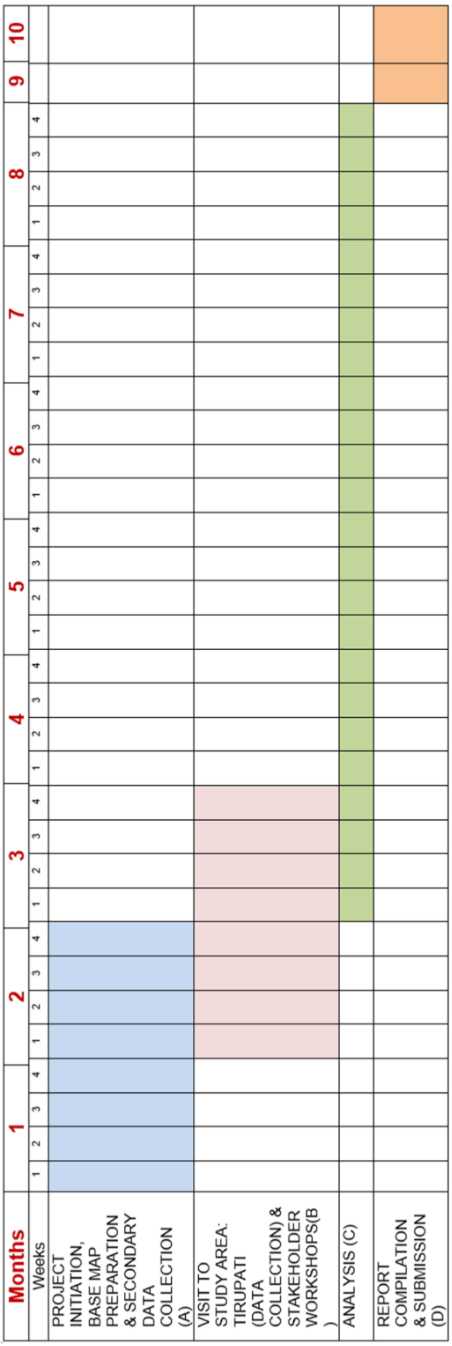
The EUI map effectively visualizes the combined impact of the different factors on energy intensity in Tirupati. The central and southern areas are the hotspots, driven by population density, commercial activities, the intensity of the build environment, and heat retention. The outskirts are relatively less energy-intensive.

Chapter 7: Self-Assessment and Way Forward

Completed tasks: Base Map Preparation, Initiation & Secondary Data Collection, Site Visit

Already Started: Preliminary Analysis – NDBI, LST, Sectoral Energy consumption, Landuse, Electricity consumption, Energy-use intensity zones

Quantification of energy consumption pattern in selected pockets through **secondary data collection** reg. Population, built-up density, electricity bill, energy consumption data, assessment vis-a-vis existing master plan provisions, LULC, URDPFI guidelines, study of existing building by laws & DCRs, other related guidelines, leading to Interim Report.



Upcoming in April:

- Developing a Land use intensity index
- Geospatial representation of Land use intensity in terms of Residential, Commercial, Institutional, industrial and mixed use
- Develop a consumption intensity index
- Correlation of Land Use intensity and Consumption intensity in the sectors mentioned above.

After identification of broad level EUI s, which is in process through Weighted Overlay Analysis, team will visit site to do on-site hot spot identification and carry out necessary surveys. Though the broad study is been done at ward level, the final selected hot spots on site would be referred.

Stakeholder Meetings.

May-June-July:

- Interpretation of primary and secondary survey data, analysis

August-September-

- Report Compilation and Submission

Chapter 8: References

- Beatley, T., & Newman, P. (2009). *Sustainable Urbanism: Urban Design with Energy Efficiency*. Island Press.
- Cervero, R. (2013). *Transportation and Land Use: An Overview*. Journal of Planning Literature, 28(3), 179-197.
- Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., & Chen, D. (2014). *Growing Cooler: The Evidence on Urban Development and Climate Change*. Urban Land Institute.
- Gartland, L. (2011). *Heat Islands: Understanding and Mitigating Heat in Urban Areas*. Earthscan.
- Glickman, T., McDaniel, D., & Reicher, G. (2018). *Energy Efficiency in Urban Buildings*. National Renewable Energy Laboratory.
- International Energy Agency (IEA). (2019). *World Energy Outlook 2019*. IEA.
- Kirkwood, A., et al. (2020). *Zoning for Energy Efficiency: Addressing Climate Change Through Local Land Use Planning*. Urban Climate Journal, 15(2), 153-168.
- Lee, S., Park, J., & Hwang, D. (2015). *Energy Efficiency and Land Use Planning: A Review*. Sustainable Cities and Society, 14, 96-107.
- Lutsey, N., et al. (2018). *Reducing Urban Energy Consumption: The Role of Building Energy Codes and Urban Planning*. Energy Policy, 118, 389-399.
- Nelson, A., et al. (2013). *Impact of Urban Density on Energy Consumption*. Journal of Urban Planning and Development, 139(3), 197-205.
- Shao, L., et al. (2020). *Smart Cities and Energy Efficiency: The Role of Zoning and Policy Integration*. Energy Research & Social Science, 61, 101379.