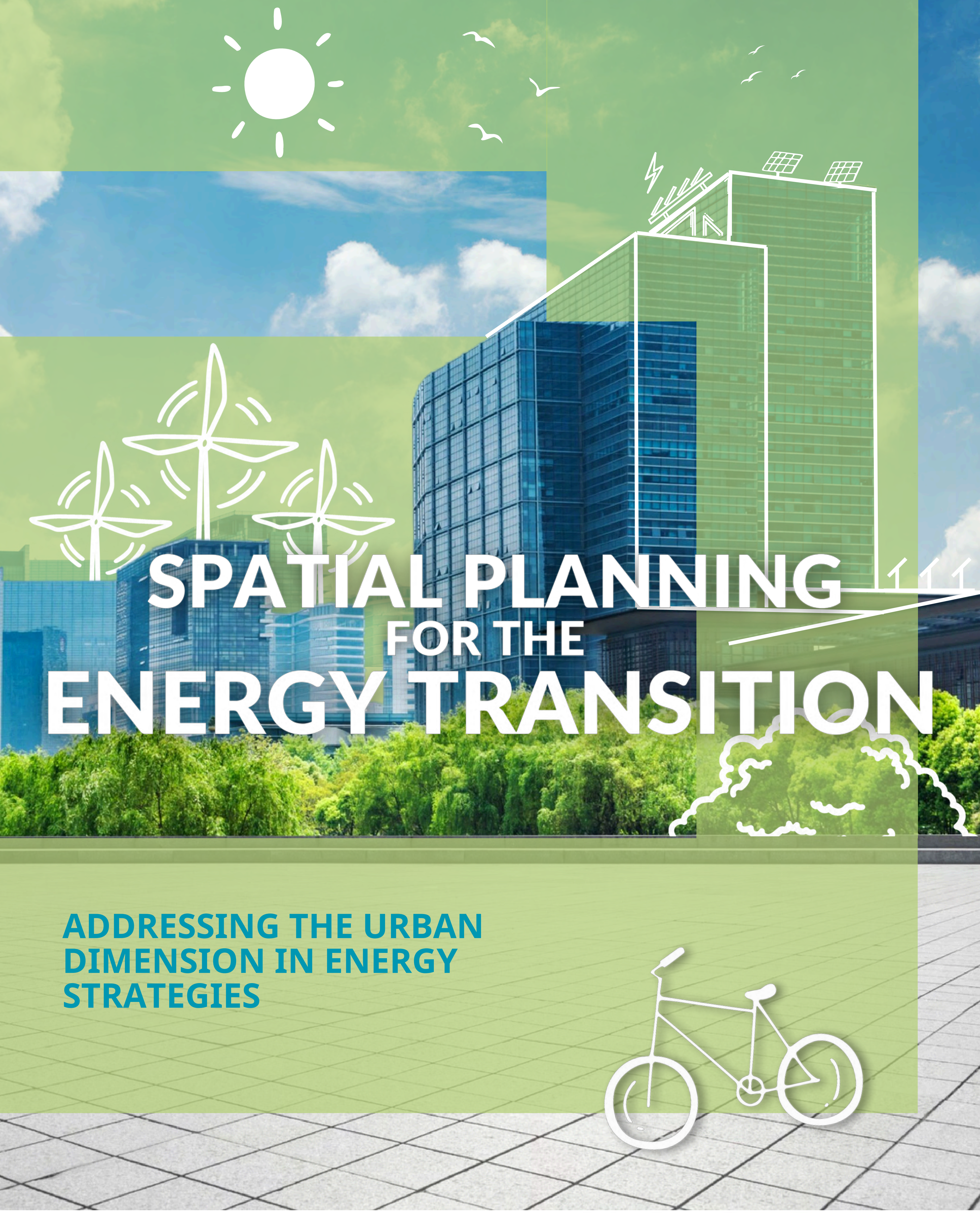

SPATIAL PLANNING FOR THE ENERGY TRANSITION

ADDRESSING THE URBAN DIMENSION IN ENERGY STRATEGIES

ICLEI Local Governments for Sustainability

1000 RENEWABLES CITIES & REGIONS ROADMAP

RENEW Southeast Asia

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

ABOUT THIS DOCUMENT
This document aims to provide guidance to local and regional governments about how to integrate energy considerations into urban planning practices. It is meant as a primer that can be used as a reference for further, context-specific research in a specific city or domain.

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ABOUT THE 100% RENEWABLES CITIES AND REGIONS ROADMAP PROJECT
The 100% Renewables Cities and Regions Roadmap project facilitates the energy transition by raising local awareness on renewable energy sources, showcasing how local and national governments can create coordinated enabling frameworks and policies, exploring access to public and private sector finance, and building local renewable energy projects to address electricity, heating and cooling. The 100% Renewables Cities and Regions Roadmap is implemented by ICLEI and funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) through the International Climate Initiative (IKI).

ABOUT THE RENEW-SOUTHEAST ASIA PROJECT
The RENEW-SEA project is implemented by the ICLEI World Secretariat and the ICLEI Southeast Asia Secretariat. It aims to develop awareness and capacities related to sustainable energy and improve multi-level coordination in Southeast Asian countries.

ABOUT ICLEI – LOCAL GOVERNMENTS FOR SUSTAINABILITY
ICLEI – Local Governments for Sustainability is a global network working with more than 2,500 local and regional governments committed to sustainable urban development. Active in 125+ countries, ICLEI influences sustainability policy and drives local action for low emission, naturebased, equitable, resilient and circular development. ICLEI's Members and team of experts work together through peer exchange, partnerships and capacity building to create systemic change for urban sustainability.

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TABLE OF CONTENTS

GLOSSARY

CHP	Combined Heat and Power
BEA	Berlin Energy Agency
EE	Energy Efficiency
EPCs	Energy Performance Contracts
ESCOs	Energy Service Companies
GHG	Greenhouse Gas
GJ/TJ/PJ	Giga/Tera/Petajoule
MSW	Municipal Solid Waste
kW/MW/GW/TW	Kilo/Mega/Giga/Terawatt
kWh/MWh/GWh/TWh	Kilo/Mega/Giga/Terawatt-hour
PV	Photovoltaics
RE	Renewable Energy
TOD	Transit-oriented Development
TDM	Transport Demand Management

INTRODUCTION

Currently, around 56% of the world's population (which amounts to around 4.4 billion people), live in cities. This trend is expected to rise significantly, potentially with nearly 70% of people living in urban areas by 2050 [1]. Urban areas are major economic centers of any country, experiencing rapid growth that drives up energy consumption and greenhouse gas emissions. Cities currently consume about 75% of the world's energy and generate 70% of its greenhouse gas emissions, and these numbers are expected to grow. [2]

Nevertheless, cities offer significant opportunities for positive change and their critical role in driving the energy transition is increasingly being acknowledged. At the COP28 conference in December 2023, governments pledged to double energy efficiency and triple renewable energy capacity by 2030. Cities, with their dense populations and economic importance, are crucial in driving this energy transition. Their unique position allows them to implement efficient energy policies and innovative infrastructure projects, accelerating the shift to renewable energy at a local level.

The spatial and urban form of cities is a key factor in achieving more efficient energy production and consumption and has become more important with rapid urbanization across much of the world. Spatial planning is therefore potentially powerful lever for the energy transition.

Whilst the aggregate demand for energy from cities is set to grow further, the amount and characteristics of that demand vary from place to place and are strongly influenced by the physical nature of the city and wider urban and regional development. Numerous studies have shown that many facets of cities and urbanization have a significant impact on energy use [3,4,5] and need to be accounted for while devising strategies and policies to improve energy efficiency [6].

Cities and energy systems have evolved on mutually dependent paths. The urban dimension—that is the pattern of spatial development and urban form and the planning that shapes it—is inseparable from the energy system. Thus, the form of urban development will strongly influence the medium and long-term future of the energy transition and vice versa. Spatial planning policies that seek to shape spatial development and urban form, therefore, have much potential to assist in reducing energy demands and increasing efficiency.

ENERGY AND THE URBAN DIMENSION

The ‘urban dimension’ refers to the characteristics **of spatial layout, urban form, and the distribution of functions** in a city. This includes the layout of streets and blocks, the design of buildings and neighborhoods, the spatial structure of urban areas, and the wider patterns of regional settlements [7].

Variations in these aspects of urban form have a direct correlation with the energy sector. Understanding the urban dimension is crucial because it influences how energy is used and distributed within a city and its surrounding areas. The way cities are designed and organized affects energy consumption patterns and the feasibility of implementing sustainable energy solutions. Overall, the urban dimension has a huge influence on energy use and emerges as both a facilitator and a barrier to the energy transition. Here are some key examples:

- **Changing space demands**: An increases in renewables deplyment alters space needs and locations.
- **Infrastructure needs**: Renewable energy sources like solar and wind require more space compared to traditional options, impacting urban development [8].
- **Decentralized power generation**: Opting for local energy production influences neighborhood planning by redefining energy distribution networks.
- **Urban form adaptation**: Some cities may require restructuring or redesigning to accommodate the transition to cleaner energy sources.

SPATIAL PLANNING AS A TOOL FOR THE LOCAL ENERGY TRANSITION

Spatial or urban planning is the main tool that local governments and planning authorities use to influence urban form and spatial development. In many countries, spatial plans are taking up the energy question, setting the policy tone, and challenging current norms in urban development that do not account for greater energy efficiency. They propose alternative ways of shaping cities and processes, requiring investors, developers, urban designers, and architects to produce innovative energy-efficient urban development models and pathways. Many cities are preparing plans that include a 'city energy strategy' or a 'climate and energy action plan' or similar.

Studies comparing spatial planning policy and energy policy conclude that most cities have only a rudimentary consideration of the potential of shaping spatial and urban forms in the interests of energy efficiency. The weak connection between energy policy and urban form and development in many countries is concerning, especially because the policy goals for energy efficiency, environmental sustainability, and climate change rely critically on combined and integrated actions, particularly in urban areas [9]. The energy sector and the urban and regional planning sector are interdependent, but in many places, they are not working in concert, reducing the efficiency and effectiveness of interventions.

Local governments can play a crucial role in bridging this gap and contributing to the achievement of national climate and energy goals by addressing specific challenges, implementing tailored solutions, and fostering community engagement [10]. Here's how they can contribute:

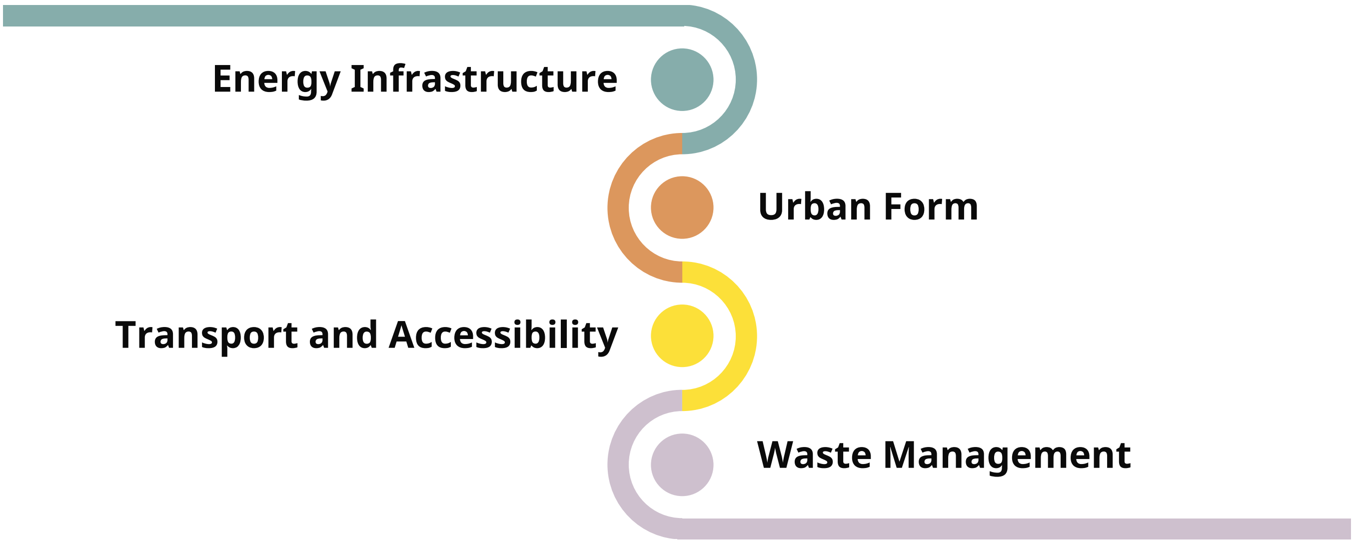
- **Planning the transition**: Develop local plans that align with national energy goals. Engage citizens in planning to support decentralized energy models.
- **Supporting local innovation**: Encourage innovative energy-efficient projects. Promote microgrids and neighborhood renewable energy systems.
- **Implementing national strategies**: Streamline permitting and inspection processes. Conduct public awareness campaigns and maintain certified installer registries.
- **Financing and collaboration**: Secure and manage funding for energy projects. Collaborate with national governments, businesses, and community organizations. Enhance coordination between municipal agencies and national authorities.
- **Communication and stakeholder engagement**: Maintain open communication with all stakeholders. Run public awareness campaigns to engage the community.
- **Monitoring and networks**: Establish systems to monitor progress and share data. Participate in networks that exchange best practices and support energy transition efforts.

HOW TO USE THIS GUIDANCE DOCUMENT

When city energy strategies address spatial planning and urban form, they must be well-informed about the appropriate measures or actions that enhance the efficiency of energy systems and support the energy transition. This document serves as a comprehensive guide to spatial planning measures that facilitate this transition and improve energy efficiency in urban areas.

Spatial planning strategies are **highly localized**. Their interpretation and application will vary based on factors such as local climate, culture, and governance structure. This document provides a starting point to evaluate how well planning strategies address energy concerns within specific contexts.

The measures outlined in this document are a starting point to assess the scope and thoroughness of how well planning strategies respond to the energy question. Moreover, they are derived from an extensive literature review and are organized into four main categories:



The categories mentioned above are interconnected and often overlap, reflecting the reality of urban development where multiple factors are interdependent. By following this guidance, city planners and policymakers can ensure that their energy strategies are well-aligned with spatial planning objectives, ultimately contributing to more efficient and sustainable urban development.

For each measure, the document:

- Highlights its relationship to energy use.
- Provides guidance on how it should be considered in spatial plans.
- Includes examples of cities that have successfully implemented the measure

ENERGY INFRASTRUCTURE

Involves the systems and technologies used for energy production, distribution, and consumption within urban areas. It includes renewable energy integration, energy-efficient buildings, and smart grid technologies.

Infrastructure and energy:

- **Renewable energy integration:** Shifting to renewable energy sources like solar, wind, and geothermal reduces dependence on fossil fuels and decreases greenhouse gas emissions.
- **Energy-efficient buildings:** Implementing energy-efficient building codes and retrofitting existing structures can significantly lower energy consumption for heating, cooling, and lighting.
- **Smart grids:** Utilizing smart grid technology enhances the efficiency and reliability of electricity distribution, facilitating better management of energy supply and demand.

INCREASING RENEWABLE ENERGY SUPPLY

Impact on energy use:
Diversifies fuel sources and moves away from hydrocarbon-based fuels which emit high levels of GHGs and pollutants.

Recommendation for energy strategy/urban development plan:
Audit sites that have the potential to support renewable energy production, and subject to other constraints, designate in plans. Plan for district heating and cooling networks that utilize renewable energy sources (such as geothermal, solar, or waste heat recovery) to provide efficient and sustainable thermal energy to buildings and neighborhoods.

Require developments to include renewable sources of energy.

CASES STUDY

Freiburg, Germany

The city district of Vauban in Freiburg, Germany, has implemented innovative policies toward the energy transition through the incorporation of civic participation in the urban planning process. This district uses different renewable energy sources such as bioenergy and solar photovoltaics. For heating systems that supply households, biomass combined heat and power (CHP) is used, as is solar energy generated on-site. A highly efficient woodchip-powered combined heat and power generator is connected to a district heating grid, producing both heat and electricity.

Other measures include the construction of low-energy buildings on municipal land, which required only 65 kWh/m²/year of heating demand, as well as the construction of “positive energy houses” that feature by rooftop solar PV [29]. These houses generate more energy than they use and can sell excess electricity back into the municipal grid, with profits being split across each household [30].

Biomass plants in Vauban use wood derivatives in addition to organic waste. This district is a good example of energy sufficiency and energy efficiency, in addition to participatory planning, showing that efforts to alter energy consumption can also contribute to a sustainable urban transition [29].

IMPLEMENT DISTRICT ENERGY SYSTEMS

Involve multi-building heating and cooling, usually by circulating hot water or low-pressure steam through underground piping from one or more central sources to industrial, commercial, or residential uses.

Impact on energy use: Reduces GHG emissions by (1) facilitating the use of non-hydrocarbon fuels for heating and cooling, and (2) replacing less efficient equipment in individual buildings with more efficient large-scale systems.

Recommendation for energy strategy/urban development plan: New neighborhoods should be planned to incorporate district energy systems.

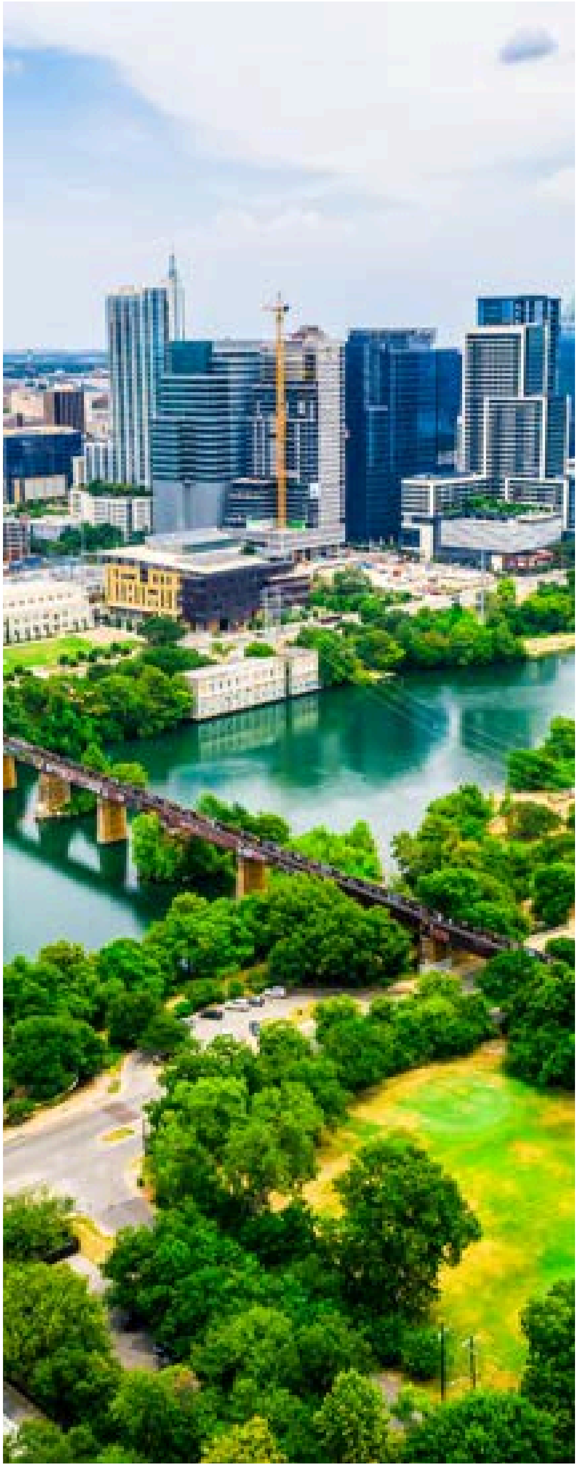
CASE STUDY

Ludwigsburg, Germany

In Ludwigsburg, the Sonnenberg district features a low-temperature district heating network. This system integrates geothermal energy and a gas-fired co-generation unit [39]. Its supply temperature is around 70°C, with a return temperature of 40-45°C. Heat storage units inside buildings are connected to the network's central control unit, allowing for adjustments that can improve overall efficiency and reduce peak loads.

For an extension of the network, an innovative low-temperature technology called LowEx was deployed. This network was linked to the return line of the existing network (i.e. temperatures of around 40°C) for greater efficiencies and reduced losses. This was bolstered by additional electric heating for multi-family units, as well solar thermal systems [39].

IMPLEMENT A SMART GRID SYSTEM



Facilitate two-way communication between the utility company and the consumer.

Impact on energy use: Improves network efficiency by balancing demand and supply, reduces energy consumption by increasing awareness amongst consumers, and can integrate different energy sources within the same network.

Recommendation for energy strategy/urban development plan: Promote policies to install smart grids.

CASE STUDY

Austin, Texas, USA

In Austin, Texas, different groups such as residents, commercial building owners, and building owners can invest in community solar projects. This city aims to achieve a total of 375 MW of local solar capacity by the end of 2030, of which 200 MW will be customer-sited. Austin will continue to expand a shared solar pilot program for multi-family housing and the development of an automated billing system [33].

Smart grid technology is one way to manage supply and demand more efficiently by better monitoring outages and losses, and increasing operational efficiencies and capabilities. Smart technologies can also empower customers through more oversight control over their electricity use.

Austin Energy has been building its smart grid for more than a decade, which includes a 437 sq. mile service area, covering over 500,000 residential and commercial meters, 11,651 miles of transmission and distribution line, and 74 substations [33].

RETROFIT EXISTING BUILDING STOCK

To improve insulation and heating and/or cooling systems to reduce energy loss and increase efficiency.

Impact on energy use: Retrofitting will modernize the built environment, improving on buildings that were built when efficiency and sustainability were not a priority, with potentially huge savings in energy demand and costs.

Recommendation for energy strategy/urban development plan: Evaluate buildings that can be retrofitted and that will benefit, reducing energy losses. Provide incentives to install the retrofits.

CASE STUDY

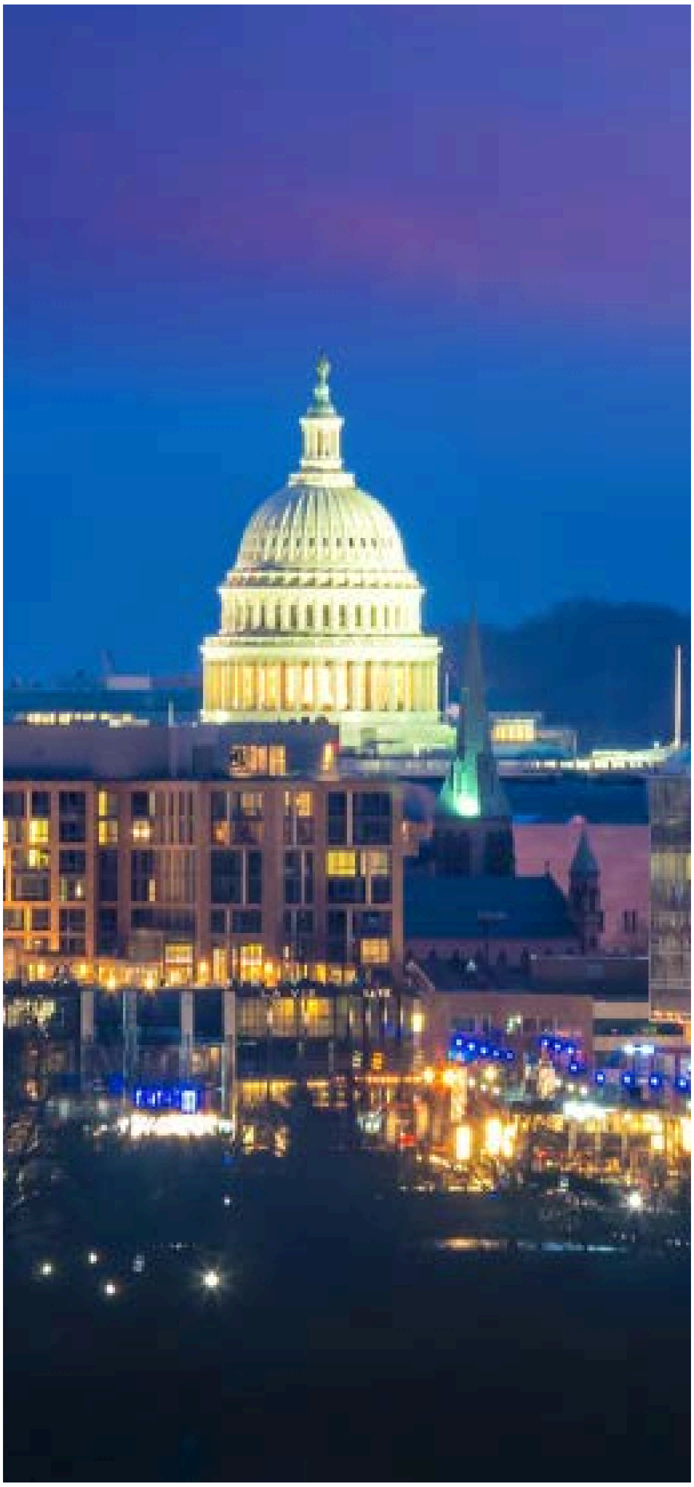
Berlin, Germany

In a bid to reduce energy costs and related emissions, Berlin chose to begin retrofitting its public buildings in the 1990s. It launched the "Energy Saving Partnership" in 1996. The program is overseen by the Berlin Energy Agency (BEA).

This program is implemented through energy performance contracts (EPCs) between public facilities and even large commercial buildings. Energy service companies (ESCOs) guarantee a certain minimum level of energy savings. Buildings can also be pooled together under one service contract. The contractor is responsible for the initial investments, which are repaid through the costs saved.

Since 1996, over 1,400 buildings have been covered under such contracts, helping Berlin realize significant cost savings, while developing a robust value chain for energy services [34].

IMPROVE ENERGY PERFORMANCE IN BUILDINGS THROUGH RATING SYSTEMS OR BENCHMARKS



Applying standardized tools to evaluate and enhance a building's energy efficiency

Impact on energy use: Encourages energy efficiency in new and existing buildings.

Recommendation for energy strategy/urban development plan: Employ ratings in planning permit procedures, and ensure design principles and technological standards are adopted.

CASE STUDY

Washington, D.C, USA

Washington, D.C.'s benchmarking policy exemplifies a comprehensive strategy to enhance building energy performance.

Applicable to both public and private buildings over 50,000 sq. ft., the policy mandates the reporting of energy and water usage. This data is meant to be publicly accessible. In collaboration with utilities, the city streamlines the process through data integration.

Initially focusing on transparency, the policy now encourages efficiency improvements for poorly performing buildings and implements standards. This approach has led to city-wide energy performance enhancements by catalyzing investments and simplifying compliance, offering a model for other cities seeking similar progress [35].

URBAN FORM

Involves the spatial layout and physical structure of urban areas, including the density and arrangement of buildings, streets, and public spaces. It aims to create compact, connected, and efficient urban environments.

Energy and Urban Form:

- **Density and compactness**: Higher-density development reduces energy use by minimizing the distances people need to travel for work, shopping, and recreation.
- **Mixed-use development:** Integrating residential, commercial, and recreational spaces reduces the need for long commutes, decreasing transportation energy demand.
- **Green infrastructure:** Incorporating green spaces and urban greenery helps mitigate urban heat islands, reducing the need for energy-intensive cooling.

PROMOTE COMPACT DEVELOPMENT

Seeking a denser urban form, reducing fragmentation of the urban fabric through intensification. Implement zoning regulations that encourage high-density, mixed-use development to reduce travel distances and enhance energy efficiency.

Impact on energy use: Reduces the need to travel and associated energy use and emissions, and increases land use efficiency in urban areas.

Recommendation for energy strategy/urban development plan: Promote policies that intensify land use and measures to improve public transport accessibility.

CASE STUDY

Porto, Portugal
A study in the city of Porto used a neural network model using variables of urban form to predict the energy demand for three relevant energy end uses in cities (heating, cooling, and travel). It suggested that urban planning that takes place in specific areas of the city leads to better energy performance than random development patterns throughout the urban territory.

The areas that yield the most energy savings are transit-oriented development and consolidated development, with 15% and 9% reductions in energy needs for travel respectively. Regarding buildings, infill development leads to significant reductions in the energy use for ambient heating, involving an overall reduction of 0.6% when 0.3% of the floor area increases [23].

DESIGNING WITH THE URBAN MICROCLIMATE

Design principles that respond to the urban microclimate are necessary to avoid heat gain/loss within the building, its immediate surroundings, and the city as a whole. Incorporate green spaces, parks, and green roofs to improve air quality and reduce urban heat and energy use.

Impact on energy use:
Adjustments to built form, street canyons, building design, materials, traffic, vegetation, and water, can ultimately decide the amount of energy needed to maintain a comfortable indoor environment.

Recommendation for energy strategy/urban development plan: Mandate considerations for urban and building design codes through regulations.

CASE STUDY

Urban design and thermal regulation

Shishegar (2013) found that street orientation influences air movement within urban areas, thereby impacting thermal gain and loss [24].

Lehmann (2008) shows that energy cost savings of 20–50% are possible through integrated planning that carefully considers site orientation and passive design strategies [25].

These savings can be further increased with on-site renewable energy production. Kleerekoper (2012) found that the use of vegetation and water in the spaces between buildings can help to mitigate heat in urban areas by about 1°C to 4.7°C and 1°C to 3°C degrees Celsius respectively [26].

DESIGNING WITH THE URBAN MICROCLIMATE

CASE STUDY

Stockholm, Sweden

A study was conducted about the impacts of the urban microclimate on the energy performance of buildings, taking into account hourly microclimate data. It showed important differences in extreme conditions compared to regular weather files. The simulations in Stockholm showed that the urban morphology can reduce wind speeds by 27% and amplify air temperature by more than 14%. Moreover, air pressure, relative humidity, and heat flux in the models are notably affected by microclimate conditions. The central buildings in the low-density area showed lower energy demand compared to the high density area [27].

CASE OF STUDY

Shenzhen, China

In Shenzhen, China, a study examined the impacts of urban growth on the local microclimate and thermal comfort by implementing on-site measurements. It used simulations to evaluate the thermal benefits and energy-savings potentials of the current trees and three types of urban green infrastructures. The results revealed that urban parks are capable of regulating the hot and cold environment in adjacent urban zones, resulting in improvements in thermal comfort and energy savings of 24.7 kW and 40 kW per day respectively in the warm and cool periods. Of the designed urban green infrastructures, greenways led to the best performance on microclimate regulation and energy savings [28].

TRANSPORT AND ACCESSIBILITY

This category focuses on enhancing mobility infrastructure to reduce energy consumption and promote sustainable transport options. It includes measures to improve public transportation, encourage non-motorized travel, and optimize traffic management.

Transport/accessibility and energy:

- **Energy efficiency:** Enhancing public transport and active travel options (walking, cycling) reduces reliance on private vehicles, thereby lowering fuel consumption and emissions.
- **Reduced traffic congestion:** Efficient public transport and traffic management decrease idle times the period when vehicles run their engines while not in motion. This minimizes fuel consumption and improves the overall efficiency of vehicles.
- **Integrated planning:** Promoting transit-oriented development (TOD) and mixed-use areas to minimize travel distances.

PROMOTE ACTIVE TRAVEL

Reduce the number of trips made by mechanical modes of transport by encouraging residents to change their travel choices.

Impact on energy use: Increasing walkability at the neighborhood scale can result in lower energy use and related greenhouse gas emissions.

Recommendation for energy strategy/urban development plan: Invest in infrastructure to support active travel with pedestrianization, pavements and biking paths.

CASE STUDY

Residents in 'walkable' neighborhoods can drive up to almost 40% fewer kilometers than their counterparts in less walkable neighborhoods [11]. A study in Graz, Austria found that if a third of trips were made by bicycles instead of cars, there would be 25% lower petroleum consumption for cars, a 37% reduction in hydrocarbon air pollutants, and a 30% reduction in traffic congestion [12].

A study in Cardiff found that walking and cycling in place of short car journeys can lower carbon emissions [13]. In Cardiff, 41% of short car trips can realistically be shifted to walking and bicycling. Currently, existing walking and cycling activity helps avoid about 4.9% of CO_2e emissions. A further 4.5% reduction of CO_2e emissions can be achieved by upgrading cycling and walking infrastructure. Walking trips under 1 mile provided 25% of the savings.

ENCOURAGE INFILL DEVELOPMENT

Impact on energy use: Promoting infill development will result in the need for fewer resources to provide infrastructure such as transport or utilities.

Recommendation for energy strategy/urban development plan: Identify underused sites and prioritize development that increases the efficiency of land use consumption.

Giving priority to the development of vacant sites within existing urban areas before urbanizing open land.

CASE STUDY

One of the largest and most successful infill projects was the Stapleton Airport, which was abandoned in 1995 and later turned into a residential development project in Denver's Central Park Denver neighborhood (formerly Stapleton neighborhood).

The project is estimated to be completed in 2024 after 24 years of development. To date, 7.5 sq. miles have been transformed into a community of 30,000 residents of varying income levels, creating 13,000 jobs and approximately 1,100 acres of new parks and open space [14]. The project was created by the Stapleton Foundation in 1990, then the Stapleton development plan was approved by Denver City Council in 1995. Working together in a public-private partnership, Forest City, the Districts, the City of Denver, Denver Public Schools, Denver Water and DURA collaborated to finance and construct the roads, sewers, parks, schools and community facilities. Another example of infill development is the Lowry neighborhood developed on the site of the former Lowry Air Force Base in the center of metropolitan Denver, where 755 hectares were transformed into one of Denver's premier neighborhoods and a national model of sustainable development, with more than 25,000 people living there [14].

Such examples of infill development near existing transit infrastructure can help reduce the amount that people drive, improving air quality and reducing greenhouse gas emissions.

PROMOTE TRANSIT-ORIENTED DEVELOPMENT

Impact on energy use: More efficient use of land and potentially reduced car-based travel as job opportunities and homes are in closer proximity.

Recommendation for energy strategy/urban development plan: Plan future developments within proximity to existing transit stops and increase mixed-use functions around public transit nodes.

Integration of land use and transport planning to concentrate development around transit stops. A TOD area is a mixed-use community that is within walking distance of a transit stop and commercial activities.

CASE STUDY

Dhaka, Bangladesh

A study in Dhaka examined transport-related CO_2 emissions of TODs in Dhaka, Bangladesh. It found that TODs have differing effects on CO_2 emissions for different types of trips. TODs have the potential to reduce CO_2 emissions for work and school trips, and residents living in TODs are less likely to use the car as a commuting mode and less likely to commute a longer distance [15]. These findings imply that a lower level of CO_2 emissions from working trips in TODs is due to the lower likelihood of car use and a shorter travel distance. The study shows that bicycles can potentially reduce CO_2 emissions from school trips. Planners need to provide sufficient infrastructure such as public bicycles, additional bicycle lanes, signs, and road markings but also promote better connectivity and integration between transit and bicycles.

Arlington, Virginia, USA

Another example is the Rosslyn Ballston Corridor in Arlington, VA, in which TOD increased development in a liveable community. This was a declining low-density commercial corridor 30 years ago when the local government decided to focus development around five closely spaced rail stations, working with residents and the private sector [16]. These efforts resulted in the increase of the value of the land around the station by 81% over 10 years, and the growth of liveable communities near transit. Around 50% of residents take public transit to work and 73% walk to stations, reducing dependency on fossil fuels [16].

TRANSPORT DEMAND MANAGEMENT

Impact on energy use: Increases the use of public transit, reduces the number of trips made by cars, encourages the use of fuel-efficient vehicles, and increases fuel efficiency.

Recommendation for energy strategy/urban development plan: Transport demand strategies are a policy tool that should be supported with incentives that are reviewed periodically.

A policy tool used to manage an existing transport system to reduce traffic congestion, pollution, and energy use.

CASE STUDY

London, United Kingdom

London provides an example of TDM, where a congestion charging zone scheme was introduced in central London in 2003, reducing vehicle travel. The initial charge of £5 per day, with an estimated annual CO_2 emissions saving of 110,000 tons, was raised to £8 in 2005 leading to 120,000 tons of CO_2 emissions saved per year [17].

Those initial charges were later increased to £10 in 2011, and in 2014 to the current charge of £11.50 per day for driving a vehicle within the designated zone during workdays, leading to a road traffic reduction of 33%. This scheme led to an initial decrease in traffic and delays. However, congestion returned to previous levels over subsequent years [18].

Some of the most effective measures in reducing car use were the Workplace Travel Plans deployed in 20 different British cities, where car use was reduced by 18% on average through a combination of parking management, company shuttle buses, public transport discounts, and improved bike infrastructure [19].

According to a review article about interventions to reduce car use in European cities, the most effective measures were congestion charges, parking & traffic control, and limited traffic zones, where local governments were the most important type of leading stakeholder [19].

All these measures can lead to improved air quality and pollution levels, lower fuel use, and improved transit times.

TRANSPORT DEMAND MANAGEMENT

CASE STUDY

Vienna, Austria

The city of Vienna also exemplifies the relevance of TDM. A recent study from 2021 showed that electric mobility in different forms (for public and private transportation) may be a solution for reducing pollution in urban areas. The subsidies, policies, and emission-free zones will have the largest impact on the future of e-mobility in Vienna, ensuring that most of the energy used comes from renewable energy sources. In an ambitious scenario for the deployment of battery-electric vehicles, the total energy demand in road transport could be reduced by about 60% in 2030 compared to 2018 [20].

Under Vienna's Smart City Strategy, all municipal vehicles will be electric from 2025 as part of the city's efforts to achieve climate neutrality. Electric and hydrogen buses are progressively decarbonizing Vienna's public transport network, with heating and air-conditioning systems in the new buses also being low on emissions or completely emissions-free [21].

CASE STUDY

Arlington, Virginia, USA

In Arlington, VA, the TDM program avoids 50,000 solo car trips each workday. According to the 2018 Arlington County Residential Building Study (which covered 36 properties throughout the county), the number of car trips was down 40% in residential buildings compared to a business-as-usual case [22].

Arlington also implemented measures to reduce parking convenience (contrary to policies elsewhere in the U. S. that tend to lower barriers to parking). For example, the requirement for parking spaces was reduced from one space for two employees in commercial offices to one space for four to five. In many residential properties, parking charges were unbundled, meaning residents paid extra for parking. This led to reduced car ownership. Similarly, parking charges at workplaces led to a drop in driving rates from 71% to 28%. These measures led to reduced congestion, and the possibilty of using the space freed up by fewer parking lots for greenery or residents instead [22].

WASTE

Involves strategies for reducing, recycling, and reusing waste materials, as well as generating energy from waste. It focuses on minimizing waste production and improving resource efficiency.

Waste and Energy:

- **Waste reduction**: Reducing waste at the source lessens the energy needed for waste collection, transportation, and processing.
- **Recycling and reuse**: Recycling materials requires less energy compared to producing new materials from raw resources, resulting in energy savings.
- **Waste-to-energy:** Converting waste into energy through processes like anaerobic digestion or incineration provides a renewable energy source and reduces landfill emissions.

WASTE-TO-ENERGY AND MANAGEMENT

Impact on energy use: The waste sector is a significant contributor to GHG emissions in cities after the transport and buildings sectors. Interventions in waste management can have a meaningul impact on emissions reduction as well as improved environmental outcomes. Waste streams can also act as a source of energy, which can help generate value and improve resource-use efficiency and circularity.

Recommendation for energy strategy/urban development plan: Waste-to-energy plants to reduce landfill load. Supportive policies to encourage waste reduction and transition to a circular economy can help inform plans and designs for urban development.

To reduce the contribution of waste to GHG emissions through more circular self-sufficient cities and neighborhoods.

CASE STUDY

MSW potential in African countries

Waste management holds significant potential for local energy supply, environmental impact reduction, and addressing energy poverty. A study assessing energy production from municipal solid waste (MSW) in countries in Africa revealed substantial energy potential from waste incineration and landfill gas recovery.

According to estimates, by 2012, Africa's waste had a total energy potential of 1125 PJ, projected to rise to 2199 PJ by 2025. Managed landfill practices could yield 283 PJ in 2012 and 530 PJ in 2025 from landfill gas alone.

With full waste collection, electricity generation could reach 62.5 TWh in 2012 and 122.2 TWh in 2025, compared to Africa's total electricity consumption of 661.5 TWh in 2010. However, actual collected waste would result in lower estimates of 34.1 TWh in 2012 and 83.8 TWh in 2025.

Implementing key waste management practices, such as segregation at the source and organic fraction treatment would enable the more efficient harnessing of this energy generation potential [36].

WASTE-TO-ENERGY AND MANAGEMENT

CASE STUDY

Makkah, Saudi Arabia

In Makkah, Saudi Arabia, daily municipal solid waste totals 2.4 thousand tons, posing a pressing challenge with no current waste-to-energy solutions in place. A waste-based biorefinery and recycling initiative was proposed, targeting key waste streams like food, plastic, paper, cardboard, and textiles. This integrated facility could process 87.8% of total waste, with the remainder earmarked for recycling. Anticipated benefits include cost savings, conservation of resources, and a lower impact on climate change. This model offers a replicable solution for other cities facing similar issues, simultaneously improving waste management and enabling the energy transition [37].

CASE STUDY

Bangalore, India

In developing countries, municipal solid waste, consisting mostly of degradable materials (>70%), is a major contributor to urban greenhouse gas (GHG) emissions [38].

A study in Bangalore, India, found that daily solid waste generation averaged 772.2 kg, with a per capita rate of 91.01 ± 45.52 g/day, which correlated with income and education levels but was inversely related to household size. The study highlighted the organic fraction (82%) as a significant component of household waste, suggesting the need for integrated waste management strategies to convert organic waste into energy or compost, thereby mitigating GHG emissions and potentially offering economic benefits [38].

KEY TAKEAWAYS

Urban areas play a critical role in global energy dynamics, consuming about 75% of the world's energy and producing 70% of greenhouse gas emissions. This highlights the necessity of effective spatial planning and urban development to achieve energy efficiency and sustainability. Here are the final key takeaways:

Urban significance
As urban populations grow, cities become central to energy consumption and emissions. Effective spatial planning can transform cities into hubs for energy efficiency and renewable energy initiatives, positioning them as critical players in the fight against climate change.

Spatial planning as a lever
The form and structure of urban development significantly influence energy production and consumption. Thoughtful spatial planning is a powerful tool for enhancing energy efficiency and facilitating the transition to renewable energy sources. This includes optimizing land use, improving infrastructure, and promoting sustainable building practices.

The urban dimension
The urban dimension, encompassing spatial layout and urban form, directly impacts energy use. Elements like street layout, building design, and regional settlement patterns play crucial roles in energy distribution and consumption. Effective urban design can reduce energy demand and support sustainable living environments.

The role of local governments
Local governments are pivotal in integrating energy policies with urban planning. They have the authority and responsibility to develop local plans that align with national energy goals and support innovative projects that promote sustainability. They can also streamline regulatory processes to facilitate the adoption of energy-efficient practices, including by setting an example through their own assets. Finally, they are at the frontlines, and so can engage communities in the energy transition to ensure broad-based support and participation.

RECOMMENDATIONS

Develop a monitoring and evaluation framework

To optimize spatial planning for energy efficiency, create a framework using technology and real-time data. Leveraging data analytics, smart city technologies, and real-time monitoring can inform decision-making and enhance the effectiveness of measures.

Emphasize the role of data and technology

Data and technology are critical for optimizing spatial planning. Using data analytics, smart city technologies, and real-time monitoring allows for informed decision-making and improves the effectiveness of measures. These tools help cities understand energy patterns and identify improvement areas.

Promote social participation

Social participation is crucial for successful city transitions. Engaging the community makes it easier to accept, help, and adopt new initiatives. Community-driven initiatives, collaborative projects, and innovative approaches to engaging residents in energy transition efforts are essential. Involving diverse stakeholders and understanding community perspectives ensure more effective and widely supported measures.

CONCLUSIONS

Cities have an important role to play in the global energy transition. The case studies and best practices outlined in the document provide valuable insights and practical examples for city planners and policymakers. These examples demonstrate the potential of spatial planning to drive meaningful progress towards a sustainable and energy-efficient future. By adopting these strategies, cities can become leaders in the energy transition, setting the standard for sustainable urban development globally.

Effective spatial planning and urban development are essential to enhancing energy efficiency and sustainability. By leveraging the unique position of urban areas, local governments can integrate energy policies with urban planning to reduce greenhouse gas emissions, pollution, and promote renewable energy and efficient consumption. A comprehensive approach is required, which includes:

- Encouraging compact and mixed-use development to optimize land use and reduce energy consumption.
- Improving transportation infrastructure to reduce emissions.
- Integrating renewable energy systems into urban design.
- Enhancing waste management practices to reduce environmental impact and promote recycling and reuse.

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