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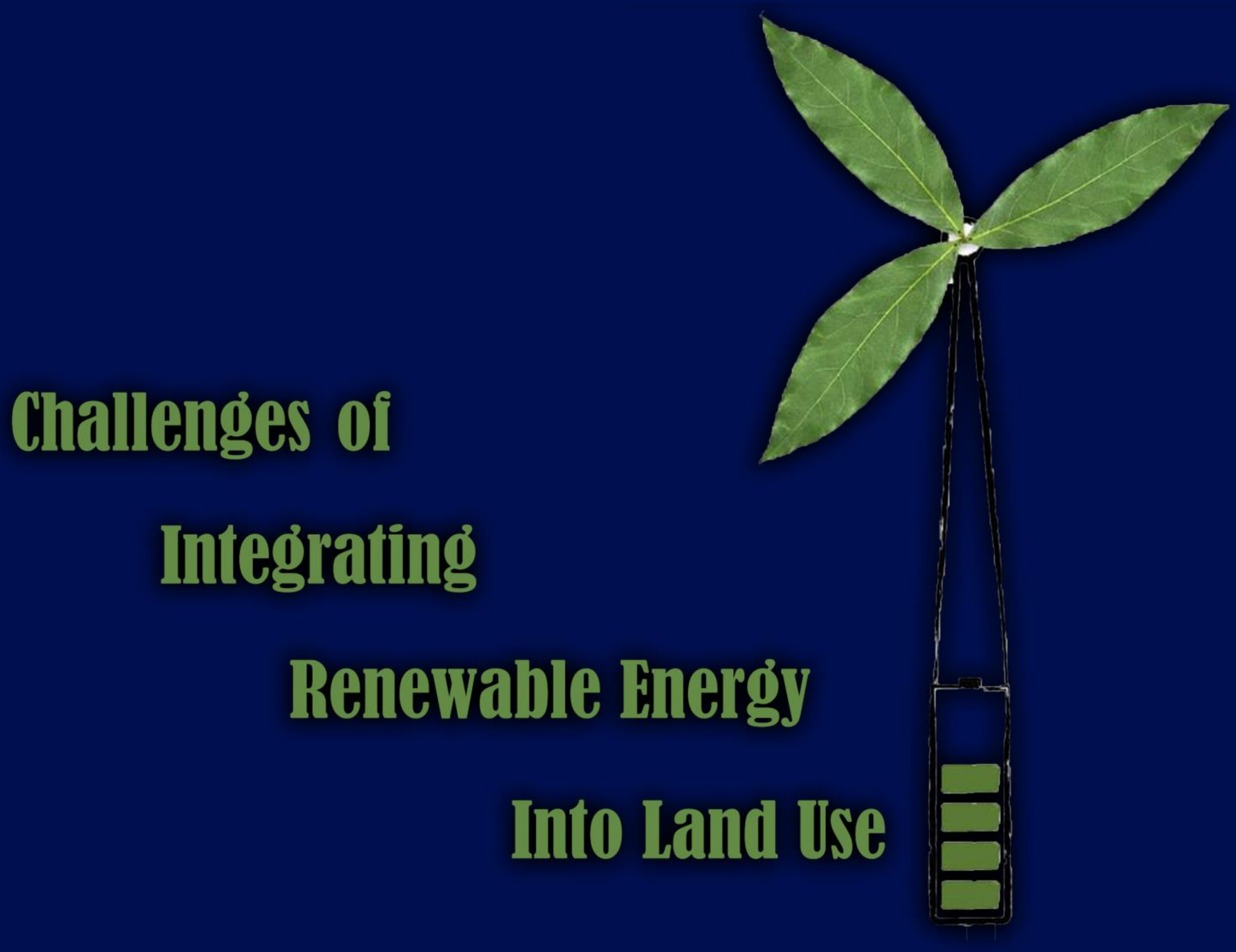

Preface

This thesis is the culmination of five years of bachelor's in architectural engineering, and two years of postgraduate studies in urban planning and renewable energy solutions at the University of Stavanger. The university's comprehensive academic journey has been instrumental in my intellectual growth and has afforded me numerous development opportunities.

Throughout the master's program, I have deeply enjoyed my studies and am profoundly grateful for the enriching experiences and knowledge I have acquired. My academic journey has expanded my understanding of our world's principal challenges and honed my educational and practical skills in addressing planning and environmental issues. The insights gained have prepared me to contribute meaningfully to future endeavors to improve our planet.

Achieving a net zero-emission society is a formidable challenge. However, the ongoing transformations in the renewable energy sector present numerous opportunities for our society to realize sustainable urban environments. The thesis topic aims to contribute to this endeavor by proposing a conceptual framework that addresses the challenges of integrating renewable energy within land use planning. I firmly believe that tackling these challenges is crucial for attaining the sustainable future we all aspire to achieve.

Acknowledgments

Willingly and foremost, I extend my deepest gratitude to my thesis supervisor, Prof. Harald Nils Røstvik. His insightful lectures on energy issues significantly influenced my choice of thesis topic. His constructive feedback, extensive scientific knowledge, and provision of relevant literature have been invaluable to me throughout this research.

I also wish to thank the group of supervisors who made significant contributions to my research. Their advice and learning have greatly influenced how this thesis has turned out in the end.

On a personal note, I am immensely grateful to my family for their unwavering patience and moral support. I especially thank my parents for their emotional support during my studies, especially during the long days and nights dedicated to working on this thesis.

Abstract

This thesis examines the challenges of integrating land-based, utility-scale renewable energy (RE) systems, specifically wind and solar, into diverse urban and rural environments. It highlights these systems' pivotal role in achieving long-term carbon emission reduction goals. The study focuses on local government responses, including adopting specific goals and policies to facilitate successful RE implementation within their jurisdictions. Through detailed case studies of Canmore, Alberta, Canada, and the Indira Paryavaran Bhawan in New Delhi, India, this research compares strategies for incorporating solar photovoltaics (PV) in Canmore and building-integrated photovoltaics (BIPV) in the Indira Paryavaran Bhawan. The thesis comprehensively explains the challenges, obstacles, and strategies associated with renewable energy integration by integrating these case studies with a broad literature review.

The findings highlight the critical importance of balancing technological advancements with environmental preservation, fostering robust community engagement, and implementing innovative design solutions tailored to specific contexts. In Canmore, the primary challenges involve maintaining the town’s natural beauty and addressing seasonal weather variations while integrating PV systems. The city emphasizes careful site selection, aesthetic integration, and strong community involvement. Conversely, in the high-density urban environment of New Delhi, the challenges include maximizing energy efficiency within limited space and mitigating the urban heat island effect. Using BIPV in Indira Paryavaran Bhawan demonstrates the potential of innovative architectural solutions to achieve net zero energy status and optimize space usage.

List of abbreviations

Renewable Energy Resources	**(RE)**
Renewable Energy Resources	**(RER)**
Greenhouse Gas Emissions	**(GHG)**
Global Energy Landscape	**(GEL)**
Low-Carbon Energy	**(LCE)**
Integrating Renewable Energy	**(IRE)**
Fossil Fuel	**(FF)**
Renewable Energy Planning	**(REP)**
Climate Change	**(CC)**
Renewable Energy Technologies	**(RET)**
Renewable Energy Integration	**(REI)**
Renewable Energy Deployment	**(RED)**
Energy Future	**(EF)**
Research Question	**(RQ)**
Renewable Energy Source	**(RES)**
Solar Photovoltaic	**(PV)**
Building Integrated Photovoltaics	**(BIPV)**
Indirect Land Use Change	**(ILUC)**
Land Use Bylaw	**(LUB)**
Net Zero Energy	**(NZE)**

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Introduction

1.1 Background & Context

Figure 1. *Plan World for Developed and Undeveloped Countries taken from (Gelb et al, 2020) & edited by Author's.*

Renewable energy (RE) has become a crucial element in the global energy landscape (GEL), experiencing rapid adoption across both developed and developing nations, as shown in Figure 1, including China, Denmark, France, Germany, Australia, Canada, India, South Africa, Sweden, Italy, the Netherlands, Portugal, Japan, the United Kingdom, and the USA. This widespread adoption highlights the essential role of renewable energy resources (RER) in shaping the future of electricity production.

Hydropower, wind, and solar energy sources are increasingly valued for their electromagnetic properties and environmentally friendly and sustainable characteristics. Unlike conventional power sources, these attributes are vital for reducing greenhouse gas emissions (GHG) and switching towards a low-carbon energy (LCE) model. However, the large-scale deployment of these renewable energy technologies presents significant environmental and land-use challenges that require thorough consideration (Outka, 2010).

Many regions worldwide have set ambitious targets to switch to renewable energy (RE) projects in land use, such as building-integrated photovoltaics (BIPV), into existing land use patterns and building cycles to mitigate climate change.

Integrating photovoltaics into buildings through Building-Integrated Photovoltaics (BIPV) replaces conventional materials with photovoltaic modules, allowing on-site electricity generation without additional land. This approach reduces land use conflicts by utilizing existing building surfaces and infrastructure, making it especially valuable in dense urban areas and regions with strict land use regulations. However, implementing BIPV systems may still need help with building codes, zoning regulations, and permitting processes, which require appropriate policies and regulations. However, integrating RE projects in building-integrated photovoltaics (BIPV) into existing land use patterns and building cycle use patterns presents several theoretical challenges.

Renewable energy (RE) facilities typically exhibit lower power densities than fossil fuel counterparts, necessitating larger land areas to generate equivalent power outputs. This increased spatial requirement can lead to conflicts over land use allocation, exacerbate habitat fragmentation, disrupt rural landscapes, and provoke resistance from nearby communities (Outka, 2010).

The convergence of the two curves is imperative in achieving synergy between renewable energy (RE) development and environmental conservation objectives. After this alignment, a comprehensive overview of requirements is essential, ensuring the harmonization of renewable energy expansion with sustainable land management practices.

This equilibrium necessitates a strategic approach from technical mapping to site selection for renewable energy (RE) installations, accounting for diverse theoretical challenges and considerations to pinpoint locations and formulate new protocols that increase integrated renewable energy in land use, as in Canmore town.

Figure 2. *Views from Alberta's Bow Valley.* (Eleanor Miclette, 2022)

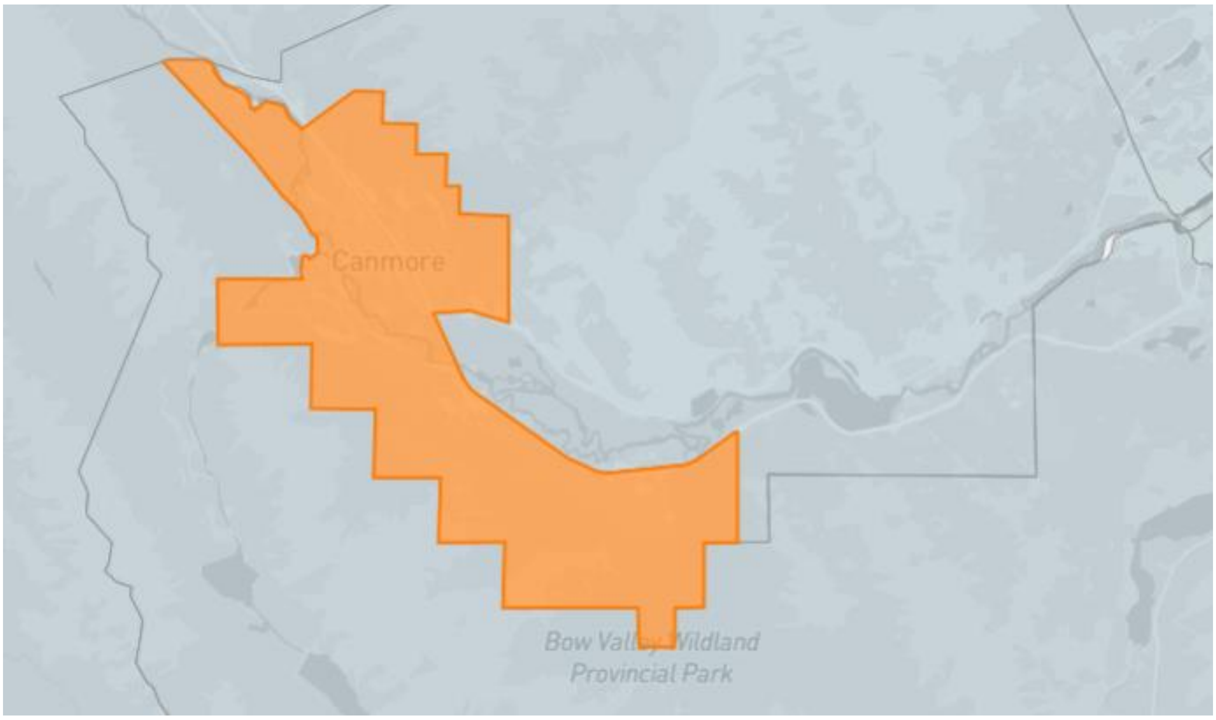

Figure 3. *Canmore border.* (Eleanor Miclette, 2022)

Canmore, a picturesque mountain town in Alberta's Bow Valley near Banff National Park which shown in figure 2&3, is a fascinating case study for investigating the challenges faced by land-constrained mountain communities surrounded by the Canadian Rockies and environmentally sensitive areas like Banff National Park (Mayor et al., 2021). Its unique geographic position provides a compelling opportunity to explore strategies that effectively balance the demands for renewable energy with the imperatives of sustainable land management and environmental conservation within a restricted spatial context.

Despite the surrounding Canadian Rockies' geographical constraints, Canmore exhibits notable potential for installing rooftop solar photovoltaic (PV) systems. These systems use solar cells made of semiconductor materials such as silicon to transform the sunlight into electricity through the photovoltaic effect. These cells are interconnected to form solar panels and assembled into arrays (Mayor et al., 2021).

Canmore is a prominent example of a commitment to renewable energy adoption. It is implementing a substantial 400.5 kW rooftop solar PV system atop the Canmore Recreation Centre, which incorporates 890 solar panels (Mayor et al., 2021). This initiative underscores the town's proactive approach to embracing sustainable energy practices.

Moreover, it highlights the importance of theoretical challenges to classifying land for urban planning use, such as steep creek hazard zones, habit patches, wildlife corridors, and buffer zones. Local governments face challenges in making rated land use decisions to draw a balance of energy needs with sustainability goals (Guo, 2022).

In brief, large-scale integration of renewable energy (RE) into present land use requires addressing challenges in land use, environmental effects, community support, and regulatory obstacles, as well as providing tools for decision-making for sustainable planning at the local and regional levels. Renewable energy (RE) projects align with conservation objectives and sustainable land management techniques while minimizing environmental effects, addressing community concerns, and getting past regulatory roadblocks. Comprehensive strategies are required to successfully engage stakeholders, evaluate potential impacts, and locate viable locations. Using these strategies, can protect the environment and advance sustainable development while fostering the peaceful integration of renewable energy.

1.2 Overview of Renewable Energy and Land Use Integration

Integrating renewable energy (IRE) into land use planning is crucial for achieving new resources for a sustainable energy future (SEF). As communities transition away from fossil fuels, there is a pressing need for strategic land use planning to accommodate renewable energy (RE) sources such as solar, wind, and hydropower. This transition demands a balance between meeting growing energy demands and promoting environmental conservation and sustainable land management practices.

Historically, land use planning frameworks have evolved alongside fossil fuels, resulting in landscape patterns and social structures that Favor these traditional energy sources. This historical co-evolution poses significant challenges to effectively integrating renewable energy (RE). Fossil fuel (FF) infrastructures, such as coal mines, oil refineries, and natural gas pipelines, have profoundly influenced the spatial organization of many regions, creating entrenched systems that resist change (Outka, 2010).

To expedite renewable energy development, modifying these existing frameworks by integrating energy planning (EP) into land use planning is essential. This integration aims to accelerate renewable energy (RE) deployment and manage renewable infrastructure development's inherent trade-offs and impacts.

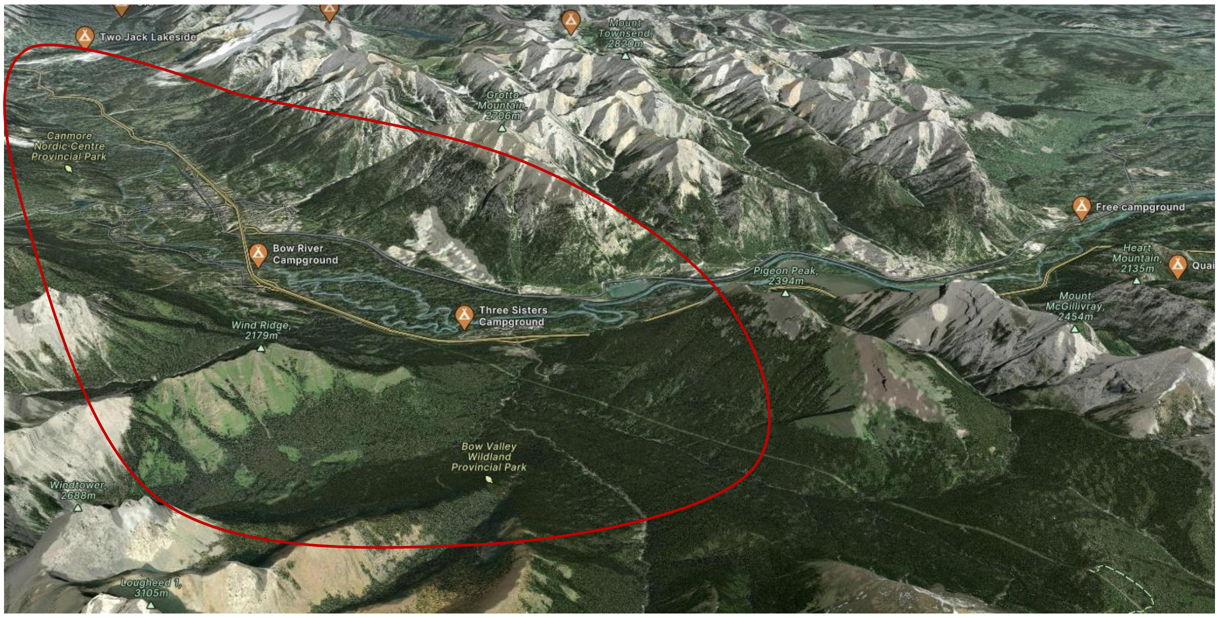

Figure 4. *Canmore's distinctive topography with Nordic Center Park and Bow Valley Park.* (Stava, 2023)

The town of Canmore, Alberta, serves as a case study that highlights the unique challenges and opportunities of integrating renewable energy (IRE) and land use. Canmore's distinctive topography as shown in Figure 4 and regulatory environment significantly hinder renewable energy development. The town's existing land use bylaws and the intersection of land with provincial parks complicate future renewable energy projects (Guo, Jiaao, 2020).

While essential for protecting natural landscapes and biodiversity, these regulations limit the areas available for renewable energy installations. Despite these challenges, Canmore's approach to meticulously integrating its land-use bylaws demonstrates a commitment to strategic planning and stakeholder engagement. This approach provides a valuable framework for identifying suitable lands for renewable energy projects based on theoretical resources, legal accessibility, and spatial capital costs.

Canmore's experience underscores the importance of local context in renewable energy planning (REP). By engaging with community stakeholders and leveraging local knowledge, Canmore has navigated regulatory complexities and identified viable sites for renewable energy (RE) projects. This participatory approach enhances community support and guarantees that renewable energy (RE) development's benefits are distributed equitably.

Globally, the urgency of integrating renewable energy (IRE) into land use is underscored by the increasing demands for land driven by urbanization, agriculture, and infrastructure development. This intensifying competition for land resources presents a significant challenge for policymakers and planners. Effective integration requires a comprehensive understanding of the interactions between renewable energy (RE) projects and land use patterns. Such experience allows stakeholders and local governments to make informed decisions encouraging sustainable development and environmental stewardship (Guo, 2022).

Despite their environmental benefits, the extensive deployment of renewable energy technologies (RET) poses significant land-use challenges. Renewable energy (RE) facilities typically require more giant land footprints than fossil fuel counterparts, leading to potential conflicts over land use allocation, habitat fragmentation, and disturbances to rural landscapes.

According to a study by Trainor, McDonald, and Fargione (2016), renewable energy projects, particularly solar and wind, necessitate more extensive land areas for energy production, potentially impacting land use patterns and ecological systems. This expansion can lead to habitat loss and fragmentation, raising concerns about biodiversity conservation and land management (Trainor, A. M., McDonald, R. I., & Fargione, J. , 2016).

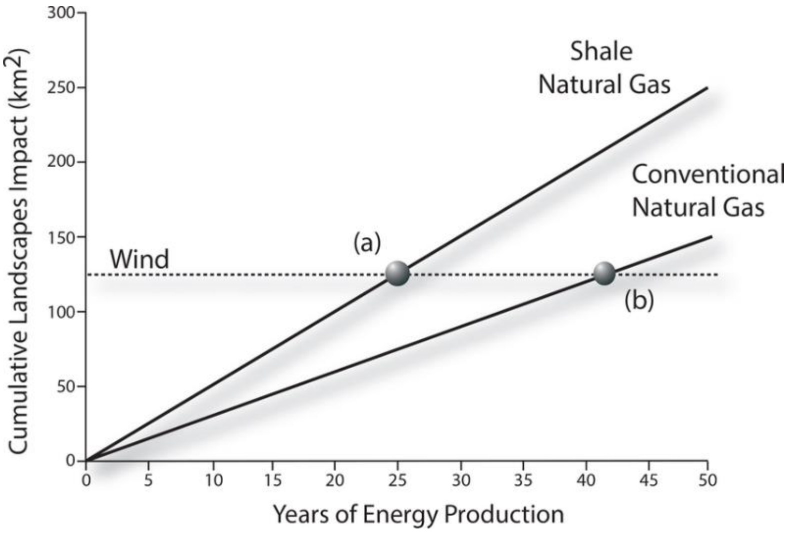

Figure 5. *The schematic depicts the timeline to land use equivalence for extractive and renewable energy sources in the United States. (Trainor , 2016).*

According to a study by Trainor this schematic illustrates in Figure 5, the time-to-land use equivalency for renewable and extractive energy sources. It depicts the cumulative land required to produce 1 TWh/year for three energy sources. RES can reuse the same land annually, not increase the cumulative land required over time. Conversely, the land needed for extractive energy sources expands each year. Point (A) indicates the time to land use equivalency between wind energy and shale natural gas, which is 25 years, while point (B) shows the equivalency between wind energy and conventional gas, calculated to be 44 years. Both comparisons are based on landscape impacts (Trainor , 2016).

Another supporter example is large-scale solar farms, which can occupy vast areas, potentially displacing agricultural activities or natural habitats. Wind farms occupying less ground can impact bird and bat populations and alter landscape aesthetics. Therefore, strategic planning must address these spatial requirements and manage the trade-offs.

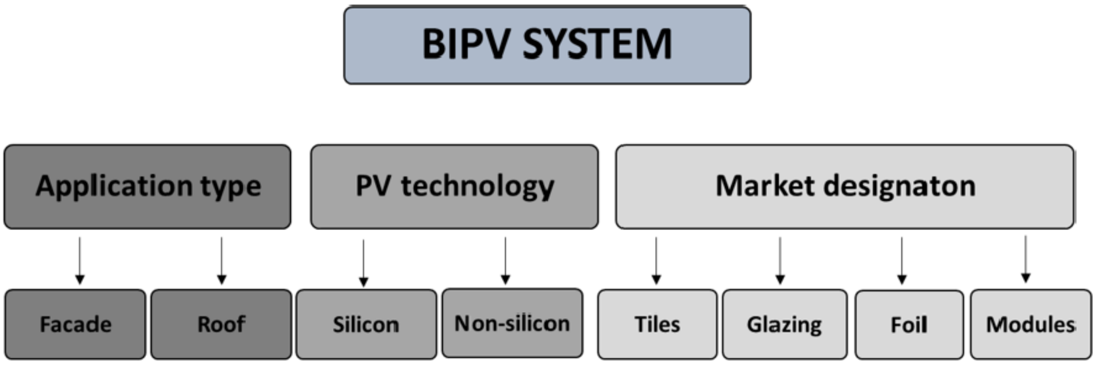

Figure 6. *Classification and types of BIPVs.* (Emrah Biyik, 2017)

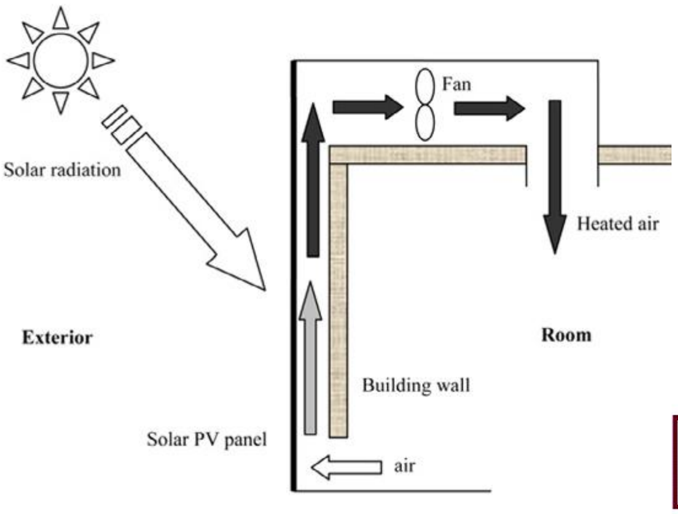

Figure 7. *Illustration sketch solar thermal system working.* (Emrah Biyik, 2017).

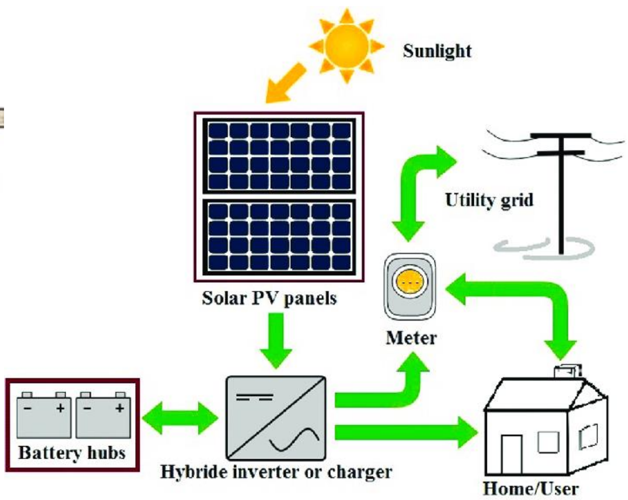

Figure 8. *Schematic diagram of a solar photovoltaics (PV) system.* (Kumar, 2021)

Innovative deployment strategies, such as integrating solar systems—both photovoltaics system (PV) as indicated in Figure 8 for electricity and solar thermal for heat—and building-integrated photovoltaics system (BIPV) into rooftops, walls, and other applications, as illustrated in Figures 6&8, or combining wind turbines with agricultural activities, can mitigate land use pressures and landscape impacts. These strategies support sustainable development goals, create jobs, reduce pollution, and promote a circular economy. For example, agrivoltaics, which combines agriculture with photovoltaic energy production, allows land to be used for both food production and energy generation, thereby maximizing land use efficiency. By leveraging these innovative approaches, it is possible to enhance land productivity and contribute to broader environmental and economic benefits.

Communities can more effectively navigate the evolving legal and regulatory landscape by leveraging participatory mapping and engaging stakeholders in identifying preferred areas for renewable energy (RE) development. Participatory mapping involves community members identifying suitable sites for renewable energy projects (REP), ensuring that local values and priorities are considered. This inclusive strategy encourages community support for renewable energy (RE) programs while strengthening the legitimacy of planning decisions.

The global crisis of land use further emphasizes the need for integrated planning. By balancing competing demands for land resources with the expansion of renewable energy, policymakers can foster a more sustainable future. This integrated approach is essential for addressing the complex challenges of climate change and resource management. As the world's population keeps increasing, the pressure on land resources will only intensify. Urbanization, agricultural expansion, and infrastructure development compete for limited land, making allocating land efficiently and sustainably crucial.

Integrating renewable energy (IRE) into land use planning requires a paradigm shift in how land is valued and utilized. Traditional land use planning often prioritizes economic development and urban expansion, sometimes at the expense of environmental conservation. To transition to a sustainable energy future, planners should embrace a holistic strategy considering land use decisions' long-term ecological, social, and economic impacts.

Integrating renewable energy (RE) into land use planning is a pivotal step towards new resources and a sustainable energy future. Communities can effectively balance energy needs with environmental conservation by understanding the interactions between renewable energy projects (REP) and land use patterns and through strategic planning, stakeholder engagement, and innovative solutions.

The Canmore, Alberta case study illustrates the challenges and opportunities in this integration, providing valuable insights for other municipalities. Canmore's approach highlights the importance of local context and community involvement in successful renewable energy planning (REP). Ultimately, this integrated approach supports the transition to renewable energy (RE), promotes sustainable land management, and addresses the international challenges of climate change (CC) and resource competition. The lessons learned from Canmore can act as a standard for other communities seeking to reach a sustainable energy future, demonstrating that with careful planning and community engagement, the transition to renewable energy (RE) can be both feasible and beneficial.

1.3 Problem Statement

A. Identification of the Research Gap

Integrating land use and renewable energy presents a multifaceted set of challenges and opportunities, and this integration must be meticulously identified and addressed to facilitate a successful transition to sustainable energy systems. This integration is critical for achieving long-term environmental sustainability, economic viability, and social acceptance of renewable energy projects. However, several research gaps and problems hinder this process, necessitating a comprehensive analysis to advance the field effectively.

Identifying and analyzing challenges about integrating renewable energy (IRE) into land use is imperative for advancing innovative research and addressing knowledge gaps. This endeavor necessitates a comprehensive understanding of the challenges and opportunities associated with renewable energy (RE) in land use, which is crucial for navigating potential conflicts. Such navigation is essential for achieving ambitious renewable energy targets without infringing on or devaluing high-value land (Wu G. C., 2018).

The alteration of land use for sitting power plants or limitation of the version of indirect land use change. Permissive land is classified as an independent entity, such as agricultural land. Alterations can pose significant obstacles to accepting renewable energy systems within local communities, thus complicating the transition to sustainable energy sources. The primary problem/challenge is that the great majority of land is already being utilized for ecological services like habitat and economic purposes like agriculture. A minimal amount of land can be used for RE recovery without affecting the current ecology and financial benefits (Wu, Land Use in Renewable Energy Planning, 2018).

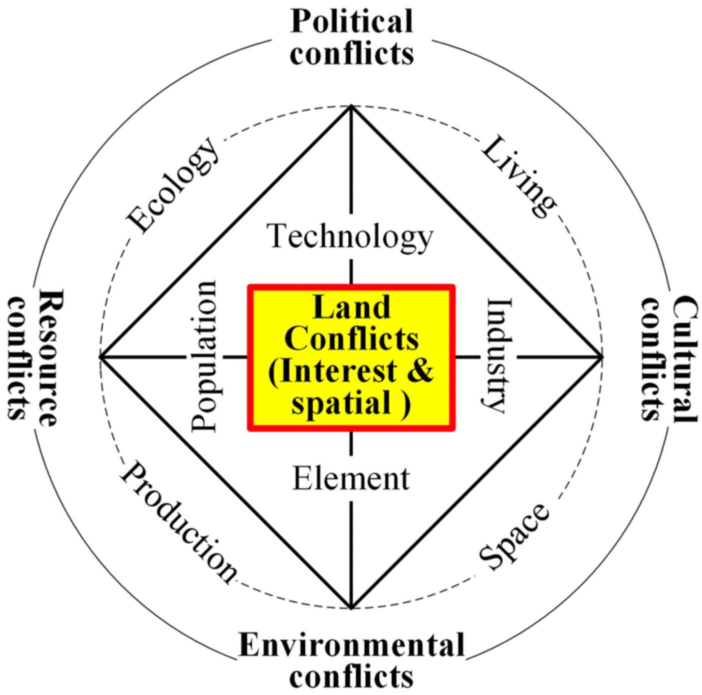

Figure 8A. *The theoretical structure pertaining to spatial conflicts and result in risk concerns in land use.* (Emrah Biyik, 2017).

One of the main obstacles to adoption at the local level is the lack of comprehensive planning tools to identify the "least-conflict lands," land that can sustain renewable energy systems with the fewest conflicts related to environmental , cultural , resources and political regulations refer to Figure 8A. Standardized frameworks for RE planning that can anticipate regulatory roadblocks, promote implementation, and involve stakeholders and local communities take time to come by.

One of the main obstacles to adoption at the local level is the lack of comprehensive planning tools to identify the "least-conflict lands," land that can sustain renewable energy (RE) systems with the fewest conflicts related to regulations, technology, economy, or society. Standardized frameworks for RE planning that can anticipate regulatory roadblocks, promote implementation, and involve stakeholders and local communities take time to come by.

Canmore, Alberta, needs more comprehensive planning tools to Assess land availability and suitability constraints to Canmore's geography and topography. The mountainous terrain and canyon site that Canmore has may pose a gap in identifying suitable land areas for large-scale renewable energy projects like solar farms (Guo, Jiaao, 2020).

Quantifying environmental impacts creates the second place because of the lack of tools. In addition to evaluating the effect of indirect land use change, integrating community perspectives, assessing regulatory and policy barriers, and exploring innovative integration approaches, all these gaps highlight the need for further investigation to find a solution and support the successful integration of renewable energy (RE) in land use in Canmore, Alberta (Guo, Jiaao, 2020).

B. Significance of Investigating Renewable Energy Integration in Land Use

Investigating renewable energy integration in land use planning is significant because it has the potential to simplify the transition to a low-carbon energy future and be sustainable. Integrating renewable energy into land use planning is crucial for mitigating carbon emissions, fostering economic growth, and bolstering energy security. Nonetheless, this integration presents many challenges and complexities, including trade-offs with sustainable development objectives, conflicts with existing land uses at the local level, and constraints on expanding the bioenergy supply.

Therefore, to identify and tackle these challenges effectively, it is imperative to delve into renewable energy integration (REI) within land use. This necessitates the development of comprehensive strategies that harmonize the expansion of renewable energy (RE) with local land use priorities and environmental sustainability goals.

This integration is crucial for optimizing resource utilization, minimizing environmental impacts, and promoting socio-economic development. Moreover, there is a pressing need for standardized mapping frameworks and multi-criteria decision analysis tools to support local government decision-making processes in renewable energy planning (REP). These tools enable policymakers to systematically and transparently assess various factors, including land suitability, environmental impacts, economic feasibility, and social acceptability.

Investigating renewable energy integration (REI) in land use planning reveals insights into potential land requirements and associated land use change emissions in solar energy. This information is essential for assessing the environmental footprint of renewable energy projects and guiding land use decisions to minimize adverse impacts on ecosystems and biodiversity. By quantifying the land use implications of renewable energy deployment (RED), policymakers can make informed decisions and prioritize locations that minimize conflicts with other land uses and maximize environmental co-benefits.

Furthermore, exploring renewable energy integration (REI) in land use planning provides an opportunity to engage stakeholders and foster collaborative decision-making processes. Engaging local communities, industry stakeholders, environmental organizations, and government agencies in planning promotes transparency, builds trust, and ensures that renewable energy projects (REP) align with local needs and priorities. Moreover, participatory approaches enable stakeholders to contribute local knowledge and perspectives, leading to more informed and inclusive decision-making outcomes.

Investigating renewable energy integration (REI) in land use is essential for navigating the complex challenges and occasions associated with transitioning to a sustainable energy future

(EF). By addressing trade-offs, leveraging synergies, and engaging stakeholders, policymakers can develop strategies that promote renewable energy (RE) deployment while safeguarding environmental and socio-economic interests. This requires a holistic approach that integrates technical expertise, policy frameworks, and stakeholder engagement processes to ensure that renewable energy projects (REP) contribute to sustainable development goals and enhance the resilience of communities in the face of climate change (R D Van Buskirk, 2020).

1.4 Research Objectives

C. Main goal of the Study

The master thesis research aims to create a conceptual framework for incorporating renewable energy systems into land use decisions and challenges while addressing environmental implications, land use conflicts, and sustainable development objectives.

Sub-goals:

- This Study evaluates the area's land availability and appropriateness restrictions for renewable energy development, considering Canmore Town's geography, current land use patterns, and regulatory limitations.
- Count the possible environmental implications of renewable energy projects, considering their influence on patterns of land use change and indirect effects such as habitat fragmentation and deforestation.
- Develop structures for transparently addressing issues, encouraging local stakeholders to embrace renewable energy projects, and effectively engaging the community.
- Create multi-criteria analysis frameworks and decision support tools incorporating environmental, social, economic, and technological aspects to inform land use and planning decisions for sustainable renewable energy for local governments and stakeholders.
- Recognize and remove legislative and policy obstacles that could prevent renewable energy projects from being successfully included in land use planning procedures.
- Investigate cutting-edge strategies for incorporating renewable energy into the infrastructure and built environments already in place, such as district energy systems, building-integrated photovoltaics, and co-locating renewables and agriculture.
- Assess methods for striking a balance between renewable energy development and environmental preservation objectives, sustainable land management techniques, and community concerns about effects on current land use patterns.
- The chief objective is to deal with the issues that arise when integrating land use and renewable energy planning, including land limitations, trade-offs with the environment, the need for decision support, policy obstacles, creative deployment techniques, community acceptance, and sustainable development objectives.

D. Specific Research Questions

To develop, design, and transform a comprehensive conceptual framework of renewable energy (RE) by integrating it into land use, the following research question must be addressed: What are the challenges to incorporating renewable energy within the context of land use planning? To answer the main Research Question (RQ), the following sub-questions will be discussed as support to any presented recommendations or conclusions derived from the literature and the case study findings:

A. How can we develop a theoretical framework to facilitate the incorporation of RE sources in land use?

B. What are the primary technical criteria and considerations for identifying lands suitable for RE projects within the context of land use?

C. How can local governments' barriers to integrating RE be effectively addressed?

1.5 Structure

First, Chapter 1 introduces the research gap within the background and context to support the relevance of this master thesis. Moreover, it presents the specific research questions this study aims to answer and provides an overview of the structure of the study. Chapter 2 overviews all renewable energy sources and compares power density with fossil fuels with environmental and economic considerations. Moreover, Chapter 3 describes the methods used to answer the research question. Chapter 4 presents the topic and context of renewable energy integration land use explored with a conceptual approach to the literature review. chapter 5 explores land requirements for renewable energy projects, the impact on land use patterns, and land availability and competition. Chapter 5 aims to identify the three main factors influencing renewable energy integration, starting with variability and uncertainty due to weather dependency, location-specific properties, and geographical availability and ending with low marginal costs and resource adequacy. Chapter 6 presents the environmental impacts of indirect land use change emissions, biodiversity loss, and water use. Chapter 7 describes the details of Canmore town as a case study. Chapter 8 compares and summarizes the study's main findings and proposes recommendations for future work.

2. Use Renewable Energy Sources and Their Characteristics

2.1 Overview of different renewable energy sources (solar, wind, hydro, etc.)

2.2 Power density comparison with fossil fuels

2.3 Environmental and Economic Considerations

2.1 Overview of Different Renewable Energy Sources (Solar, Wind, Hydro, Etc.)

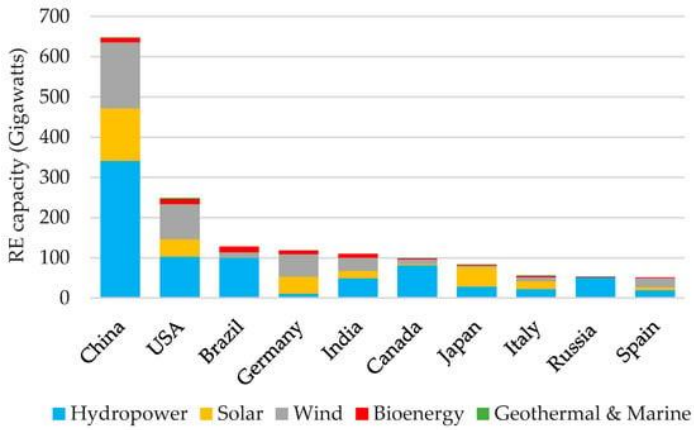

Figure 9. *The graph study is to examine how various policies have affected the installed RE capacity during an 18-year period (2000–2017) in the top three nations.* (Muhammed, 2020).

Renewable energy sources (RES) are energy derived from natural processes. The provided sources are replenished at a rate equal to or faster than the consumption rate. These sources are considered sustainable because they are not depleted when used. Examining various renewable energy sources (RES) from the provided sources reveals a spectrum of sustainable alternatives for advancing energy generation practices and RE policies. Numerous academics have attempted to investigate how RE policies affect RE development (as indicated in Figure 9). Nevertheless, most research papers have considered only a few policies, ignoring the others. Furthermore, many nations (20 to 40) have participated in the study for extended periods (Muhammed, 2020).

Firstly, solar energy emerges as a prominent contender, leveraging sunlight through photovoltaic cells or concentrated solar power systems to produce electricity. Famous for its ubiquity and sustainability. Solar energy garners widespread adoption across residential, commercial, and utility-scale settings, which can constitute a cornerstone of contemporary renewable energy industries (Moses, 2020).

Secondly, wind energy materializes as a pivotal component in the renewable energy (RE) repertoire. It employs wind turbines to convert wind power into electrical energy. The proliferation of wind farms emphasizes its substantial contribution to the energy matrix, furnishing a reliable and environmentally gentle source of power generation (Moses, 2020).

As a third facet, hydro energy uses flowing water to drive turbines within dams or barriers for electricity generation. This established renewable energy modality engenders reliability and, under certain conditions, can present commercially viable avenues for energy production (Moses, 2020).

Fourthly, tidal energy harnesses the kinetic energy of tidal currents to propel turbine generators, offering a predictable albeit intermittently available renewable energy source (RES). While its flow may not be constant, its predictability underscores its reliability within the renewable energy spectrum (Moses, 2020).

Fifthly, geothermal energy exploits subsurface heat reservoirs to either directly heat homes or generate electricity. While relatively less prevalent in certain regions such as the UK, geothermal energy is essential in locales endowed with abundant geothermal resources, exemplified by its extensive utilization in countries like Iceland (Moses, 2020).

Lastly, biomass energy converts organic materials, including agricultural residues and domestic waste, into electricity through combustion or other processes. This renewable energy variant power, thereby mitigating environmental impacts associated with traditional energy generation presents a cleaner and more energy-efficient alternative by harnessing organic matter to produce methodologies (Moses, 2020).

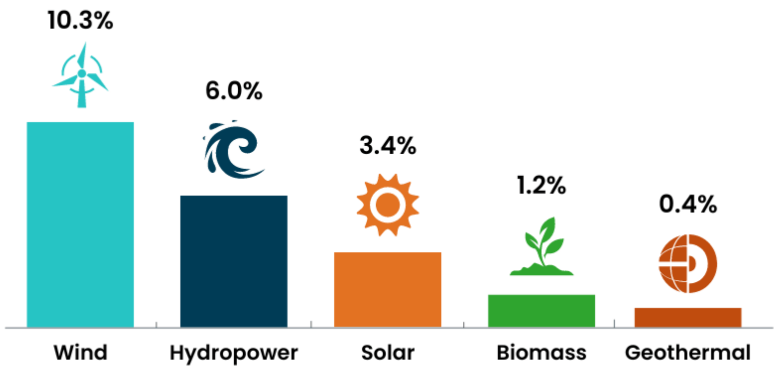

Figure 10. *The following graphic shows the percentages of total electricity generation in* United States (*2022) that each source of renewable power will contribute* (U.S department of Energy, 2023)

In concert, these diverse renewable energy sources collectively serve to diversify energy generation paradigms. For the first time, the yearly renewable energy sources collectively produced, as indicated in 10 in the United States, eclipsed coal in 2022. Domestic solar energy generation is predicted to rise by 75% and wind energy by 11% by 2025 (U.S. Department of Energy, 2023). moreover, these sources can decrease carbon emissions, fortify energy security, and encourage a more sustainable and ecologically conscientious energy landscape.

2.2 Power Density Comparison with Fossil Fuels

As defined by Smith (2024), power density refers to the amount of power (energy per unit time) generated or consumed per unit area. This metric is crucial for straightening the efficiency and impact of various energy generation systems, particularly in the context of land use. Higher power density indicates a more efficient use of space for energy production, which is essential for optimizing land use in urban and rural environments. Power density can be applied to different energy sources, measured in watts per square meter (W/m^2). It helps compare the spatial efficiency of various energy technologies and significantly impacts planning and developing sustainable energy infrastructure (Smith et al., 2020).

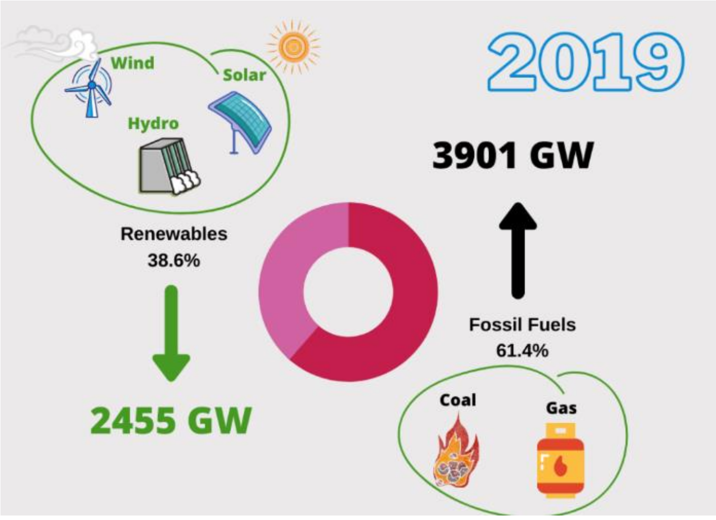

Figure 11. *comparison between the cumulative capacity of RE and FF in 2019.* (Shahab Moghadam, 2022)

There is a clear relationship between power density comparisons with fossil fuels (FF) and the challenges of integrating renewable energy (RE) into land use planning. Renewable energy sources, including biomass, solar power, and wind, exhibit significantly lower power densities than fossil fuels and nuclear energy, and this comparison can be shown in Figure 11. However, nuclear power is the priciest power generation (as indicated in Figure 12). This characteristic necessitates larger land areas to generate equivalent amounts of energy as fossil fuel or atomic power plants (Saunders, Paul, 2020).

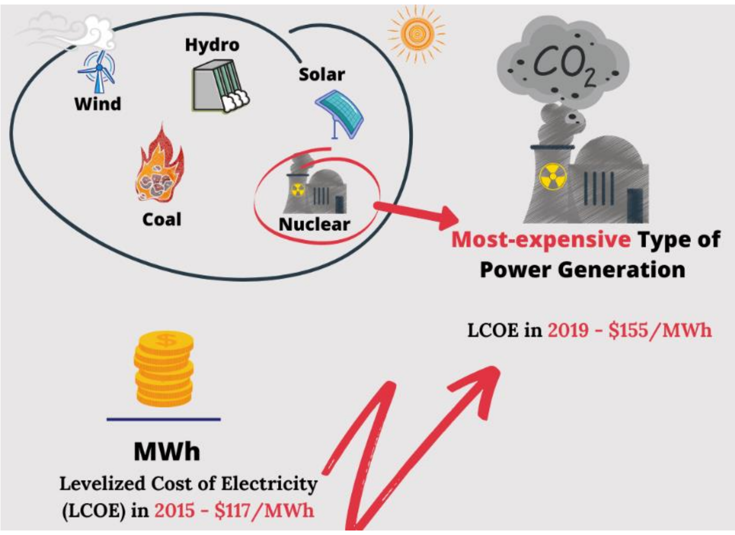

Figure 12. *The priciest kind of power generation is nuclear compared to RES.* (Shahab Moghadam, 2022)

Nuclear energy encompasses significant land use considerations related to storing nuclear waste and establishing safety zones around nuclear plants, critical for ensuring environmental protection and public safety. The long-term storage of atomic waste necessitates the development of substantial land areas dedicated to deep geological repositories. These selected locations depend on criteria such as geological stability, hydrogeological conditions, and minimal environmental impact to ensure the safe containment of radioactive materials over extended periods.

Nuclear power plants do not produce CO_2 during their regular operation because the fission process used to generate electricity does not involve burning fossil fuels. However, indirect CO_2 emissions are associated with the nuclear fuel cycle, including mining, fuel processing, plant construction, maintenance, and decommissioning.

A life cycle assessment, as illustrated in Figure 15, shows that nuclear energy has a significantly lower carbon footprint when considering these indirect emissions than fossil fuel-based power generation like coal. Thus, while atomic energy is not entirely CO_2-free, its overall contribution to greenhouse gas emissions is minimal relative to fossil fuel sources.

Furthermore, surrounding these storage facilities, safety zones or buffer areas are established to mitigate the risk of radiation exposure and other potential hazards. These zones are subject to stringent regulatory controls and are typically restricted from different land uses, rendering them unusable for residential, commercial, or agricultural purposes.

Similarly, nuclear power plants require extensive safety exclusion zones to protect the public and the environment from potential radiation exposure in the event of an accident. The size and extent of these zones depend on reactor type, plant design, and regulatory requirements. These buffer zones are mandated by national and international regulatory bodies to provide a protective barrier between the nuclear facility and populated or ecologically sensitive areas.

The land within these zones is typically restricted from development and other activities to maintain safety and security standards. These land use considerations are integral to the safety and sustainability of nuclear energy infrastructure, addressing immediate operational safety and long-term environmental stewardship.

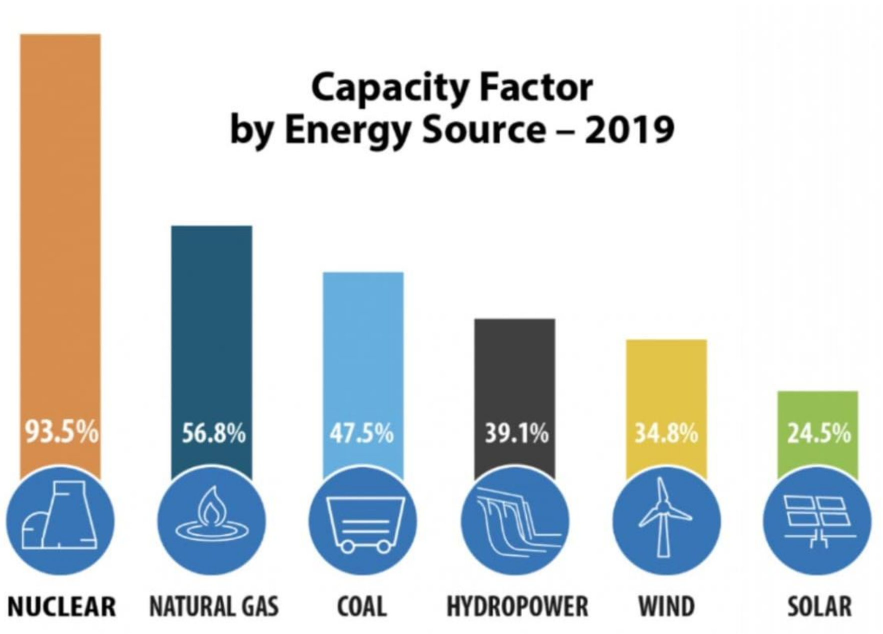

Figure 13*. Nuclear has the highest capacity factory among all sources.* (Gennaro, 2021)

In other words, Fossil fuels are not the most expensive type and have high energy density in a compact area, whereas renewable energy sources like solar and wind are more spread out and require more land. The difference is shown in Figure 13. The power density of solar photovoltaics (PV) depends on solar cell efficiency and available sunlight, typically ranging from 5-20 W/m² compared with nuclear power and fossil fuels, which have median power densities that range from about 10 to 100 W/m2. However, by producing energy from building surfaces without requiring extra land space, BIPV allows larger power densities (Saunders, Paul, 2020).

Integrating high penetrations of variable renewable energy sources with low power densities into existing power distribution systems also presents challenges. The intermittent nature of these sources can impact grid stability, necessitating additional flexibility options to maintain a reliable electricity supply.

Finding suitable land for renewable energy projects that align with existing land use plans and priorities is challenging due to the extensive land requirements of low power density sources like solar and wind. This necessitates careful coordination between land use planning and renewable energy development (Nøland, 2022).

Additionally, the larger land areas required for these renewable energy sources can lead to a larger environmental footprint, impacting ecosystems, habitats, and other land uses. Scalability concerns arise as the world transitions towards net-zero emissions targets, potentially exacerbating land use challenges due to the increased spatial extent required for low-power density renewable energy sources.

However, the extraction and use of fossil fuels also involves substantial land use. Extraction areas for activities such as drilling and mining require extensive land and often result in significant environmental disruption, including deforestation, soil erosion, and contamination of land and water bodies.

The service industry supports extraction operations comprising infrastructure like roads, pipelines, and worker housing. It also necessitates additional land use. Safety considerations around extraction sites include restricted access zones to mitigate hazards such as explosions, spills, and other accidents, rendering these areas unusable for different purposes. Furthermore, the environmental degradation associated with fossil fuel extraction impacts the land's usability for alternative activities, contributing to long-term ecological damage.

When comparing the land use impacts of nuclear energy and fossil fuels, it is crucial to consider all aspects, including the land required for the construction and operation of facilities, the establishment of buffer and exclusion zones, and the environmental degradation resulting from extraction and related activities. Both energy sources impose distinct but significant land use demands, highlighting the need for comprehensive planning and management to mitigate environmental and social impacts.

2.3 Environmental and Economic Considerations

- Environmental Considerations

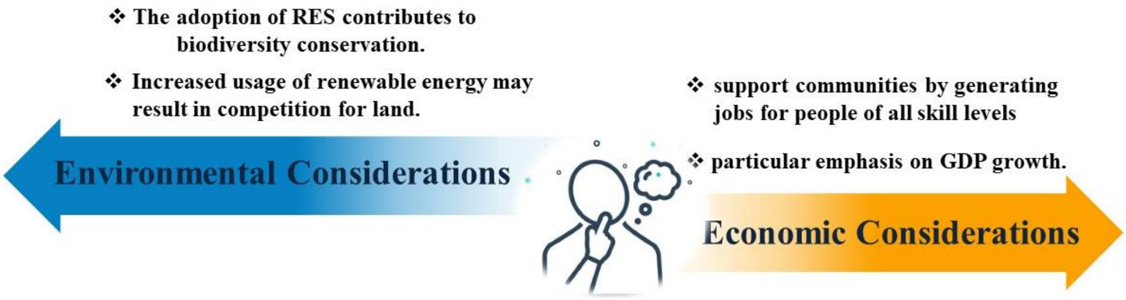

Figure 14. *Highlight the main environmental and economic considerations in integrating RE in land use. Author's elaboration*

The integration of renewable energy has significant positive effects on the environment, especially on land utilization. Switching to renewable energy sources when operating fossil fuels that release harmful pollutants can cut emissions, lessen pollution, and protect biodiversity (Electric et al., 2023). Otherwise, renewable energy sources emit little to 0% of greenhouse gases. This addresses climate change by lowering carbon dioxide emissions. (Ven, Dirk-Jan Van de, 2021).

However, switching to renewable energy will make land more competitive globally, which could influence emissions from land use change. For example, by 2050, solar energy may account for 0.5–5% of the total land area in areas where the power mix accounts for 25–80% (Ven, Dirk-Jan Van de, 2021). This could lead to changes in land cover that release carbon depending on several factors, including the effectiveness of solar technology and land management techniques in solar parks. To achieve sustainable development and successful climate change mitigation, it is crucial to consider potential land requirements and related repercussions.

Integrating renewable energy sources improves the environment by reducing carbon Emissions and Pollution. The integration of Renewable energy offers significant environmental benefits. They are particularly concerning land use. The critical benefits have increased since the Transition from FF to renewable sources such as solar, wind, hydroelectric power... etc.

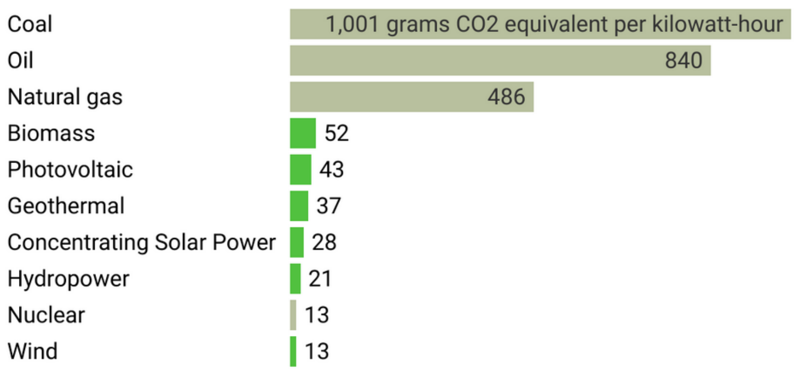

***Figure 15**. Rocket Solar analyzed data from the National Renewable Energy Laboratory analysis of the median life cycle of green gas emissions from renewable and fossil fuel sources (coal, oil, and gas).* (Rocket Solar, 2023)

Briefly, RES operates with minimal to no emissions during its lifecycle, unlike fossil fuel-based energy generation, which releases harmful greenhouse gases (as indicated in Figure 15). This reduction is pivotal in combating climate change and improving overall air quality. By adopting RES, we decrease pollution levels and enhance environmental health, which releases harmful greenhouse gases.

The second significant environmental benefit is biodiversity preservation. The adoption of RES contributes to biodiversity conservation. Traditional power plants can harm habitats and disrupt ecosystems, so renewable energy source installations have minimal adverse effects. By minimizing reliance on non-renewable resources, we directly support the conservation of various species and maintain ecological balance. The positive impact on ecosystems ensures the well-being of both flora and fauna, reinforcing the importance of RES in sustainable energy development.

- Economic Considerations

The world's Transition to renewable energy sources has accelerated noticeably in recent years, particularly in the wake of the Paris argument. Therefore, industrial players, legislators, and environmental researchers know the potential financial advantages of incorporating renewable energy into the existing energy infrastructure. Renewable energy provides significant economic benefits, with particular emphasis on GDP growth, job creation, Additional Revenue Streams, and cost savings.

Using renewable energy provides significant economic benefits, with particular emphasis on GDP growth, job creation, and Additional Revenue Streams, besides cost saving. Using renewable energy offers substantial financial benefits, with a specific focus on GDP growth, job creation, and Additional Revenue Streams, besides cost saving. Initiatives centered around renewable energy diversify local economies and support communities by generating jobs for people of all skill levels (Public Landowners, 2024). As stated by the U.S. Office of Energy Efficiency, RE, over 8 million jobs are currently in the renewable energy sector, and the industry is growing faster than the country (Public Landowners, 2024).

Secondly, producing jobs or Additional Revenue Streams renewable energy projects on public lands gives state and local governments access to new funding sources. Monetizing public land with renewable energy resources can provide state and municipal governments with a steady revenue stream through leasing and royalty payments. The extra money can be paid for critical services like healthcare, education, and infrastructure upgrades (Public Landowners, 2024).

Eventually, all waves settle at cost saving, reducing fossil fuel dependency; investing in renewable energy on public lands lowers energy prices and lessens the need for costly infrastructure upgrades. State and municipal governments save money in the long run because of this. Economic benefits not only stimulate local economies but also contribute to governments.

***Figure 16**. Ivanpah, the largest concentrating solar power installation in the world, was completed in January 2014. The amount of solar thermal energy produced in the US nearly doubled from the previous year.* (U.S department of Energy, 2023)

Ivanpah Solar Electric Generating System (California) is an excellent example of a successful renewable energy integration project with positive economic impacts. Ivanpah has the biggest Solar Electric Generating System as indicated in 16. This system is the largest solar thermal power plant globally, covering 3,500 acres and producing 392 megawatts of electricity, enough to power approximately 140,000 homes (U.S department of Energy, 2023). This project showcases the viability of large-scale solar power plants for renewable energy integration, offering consistent and reliable electricity generation (Electric et al., 2023).

Furthermore, Energy Independence can be classified as one of the most significant economic impacts of integrating land use with renewable energy by 2050. Integrating renewable energy sources within borders reduces dependence on external suppliers, enhances energy security, and reduces vulnerability to energy supply disruptions. This shift can also reduce trade deficits associated with energy imports and provide reliable access to electricity in remote areas (Electric et al., 2023).

Overall, these integration plans' economic impact and benefits extend beyond job creation to include revenue generation, cost savings, enhanced energy security, etc. It can highlight the positive impact on local economies and sustainable development.

3. Methodology

3.1 Qualitative Research Method

3.2 Application of The Methodology

Methodology

To handle the research question scientifically, the direct method for this master research thesis is qualitative research method.

3.1 Qualitative Research Method

Qualitative research is a subset of social science studies that gathers and analyses non-numerical data. As per Patton (2001), qualitative research generates findings from real-world settings through a naturalistic approach that aims to comprehend phenomena in context-specific settings. These settings include real-world settings wherein the investigator refrains from controlling the phenomenon's benefit but instead lets it unfold naturally (Patton, 2001).

This method's ability to provide this kind of phenomenon structure can be crucial in exploring and understanding the complex, multifaceted challenges of integrating renewable energy in land use. It permitted the study to gain a thorough knowledge of the concept through a literature review and insight into challenges related to the idea through the Canmore case study presented in this master's thesis.

Based on Neuman's framework 2009, There are seven phases in the Qualitative Research method.

1. "Acknowledge self and context. Qualitative researchers depend on biography, personal beliefs, or specific current issues to distinguish or identify a topic of interest or importance." (Neuman, 2009). As part of this master's Program, I am deeply interested in the challenges faced by land use, renewable energy, and environmental impact.

The main issues that Canmore City faced were well documented throughout the thesis research, and possible solutions were discussed. In this regard, one of the biggest issues faces is classifying land to make the decision. The concept of the challenges in integrating renewable land use is to format protocols that increase the use of renewable energy in land use to find a path toward sustainability.

2. "Adopt a perspective. Qualitative researchers may uphold the theoretical-philosophical paradigm or situate their investigation within the framework of continuing conversations with other researchers. This is selecting a direction that can raise numerous questions rather than focusing on a certain subject." (Neuman, 2009). Integrating renewable energy in land use is new in academic literature, and many questions still need to be answered. Developing a conceptual framework creates the opportunity to develop different approaches towards specific areas. For this master's thesis, the aim is to gain advanced knowledge of all factors and challenges regarding renewable energy while combining it into the land use concept.

3–6. “Design a study and manage, analyze, and interpret data. This is a runny process with much going back and forth among the phases numerous times. Often, the researcher uses or tests a past theory and builds a fresh one. At the interpret data stage, the qualitative researcher develops fresh concepts and theoretical interpretations.” (Neuman, 2009). Through the literature review and the submitted case studies, the information contained should be adequate to conduct a proper analysis, enabling the possibilities for additional assumptions regarding the conceptual framework for principles and strategies to integrate renewable energy in land, as well as the primary supportive data toward any conclusions and recommendations for future studies.

7. Inform others. This is similar for both strategies, but here again, the style of a message varies according to the strategy used." (Neuman, 2009). This study's communication style is the master thesis itself and the conceptual framework for renewable energy in land use, which will be unrestricted for any interested parties.

3.2 Application of the Methodology

Figure 17. *Qualitative research method conceptual framework for the challenges of integrating RE in land use. Authors elaboration.*

To answer the research questions and suggest the conceptual framework for renewable energy in land use, this chapter describes the methodology involved in identifying technical criteria and considerations for identifying lands suitable for renewable energy projects within the Canmore case or context of land use. This research is divided into different qualitative research methods to fulfill the aim.

First, a literature review was performed to answer the question (central question), as shown in figure1. Various scientific articles, books, and other literary texts on renewable energy and land use were consulted and analyzed to identify the conceptualization of renewable energy integration and the definitions and principles of land use planning. Therefore, it identifies factors, strategies, principles, successes, and challenges in developing renewable energy and land use from previous studies. The literature review aims to provide broad knowledge within the contextualization of the interrelationship between renewable energy integration and land use planning and serve as input to the conceptual framework.

Exploring previous studies on opportunities in renewable energy-land use integration complements this literature review. Analyzing this chapter investigates the main drivers and challenges of the barriers to actual tasks; moreover, it compares the consequences of the literature review with the case studies in Canmore, as shown in Figure 17. This section aims to find the current correlation between the application in the current result and the literature.

Finally, based on the results from the previous chapters, this section provides valid information for developing a holistic, multidimensional framework that evaluates all elements that can be positive for the further development of challenges in renewable energy-land use integration.

Literature review

4.1 Conceptualizing Renewable Energy Integration

4.2 Land Use Planning: Definitions & Principles

4.3 Interrelationship between Renewable Energy Integration & Land Use Planning

4.4 Earpieces Research on Including Renewable Energy in Land Use

4.5 Successfully Integrating of BIPV in a Building's Design

4.1 Conceptualizing Renewable Energy Integration

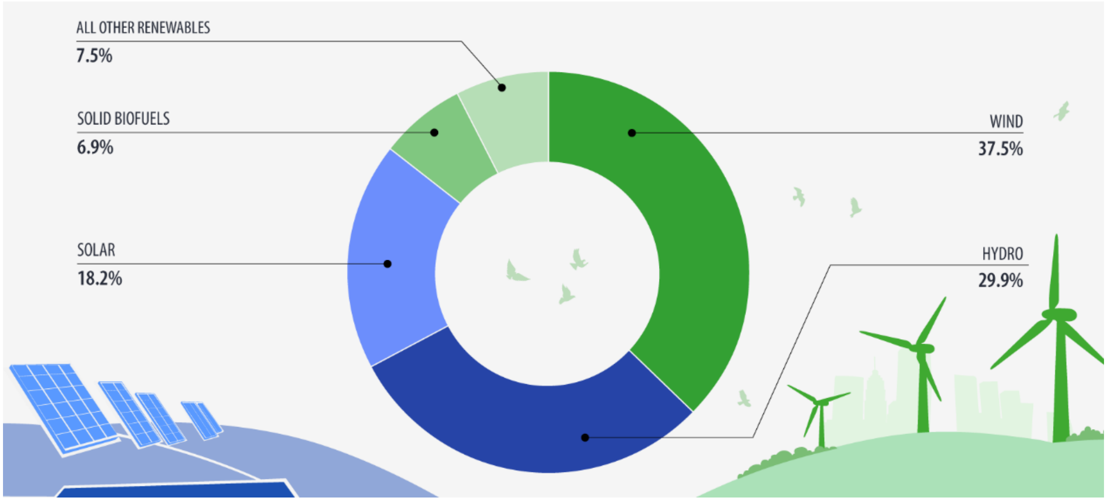

Figure 18. *More than two-thirds of the electricity from renewable sources came from wind and hydropower (37.5% and 29.9%, respectively). Solid biofuels (6.9%), other renewable sources (7.5%), and solar (18.2%) accounted for the remaining one-third of the electricity generated. The fastest-growing energy source is solar power, which comprised just 1% of the EU's total electricity consumption in 2008.* (eurostat, 2024)

The conceptualization of renewable energy revolves around harnessing naturally replenishing energy sources abundant in our environment without depleting and emitting harmful greenhouse gases. Renewable energy sources include wind, hydroelectric, geothermal, solar, and biomass (Guo, 2022). These sources offer diverse options for generating electricity, heating, and powering vehicles, homes, etc. Figure 18 presents a statistical study 2022 in the EU of electricity from renewable sources up to 41% (eurostat, 2024). The underlying principle is to tap into the Earth's natural energy flows in a way that minimizes environmental impact and contributes to mitigating climate change for a sustainable future.

From a theoretical framework, renewable energy is fundamental to transitioning towards a low-carbon and sustainable energy future in the coming thirty years. It represents a departure from the reliance on fossil fuels, which are restricted resources with significant environmental, economic, and social costs associated with extraction, combustion, and pollution. Therefore, conceptualizing renewable energy integration involves understanding the theoretical frameworks and practical approaches to incorporating renewable energy sources into existing energy systems. Thus, synthesizing extant literature about the conceptualization of renewable energy integration and the integration of renewable energy sources elucidates several salient findings (Guo, 2022).

The transition towards intelligent energy systems, concurrent with integrating diverse energy sectors and infrastructural components, is pivotal for facilitating the productive, effective, and sustainable assimilation of renewable energy sources. Therefore, Numerous scholarly sources underscore the imperative of harmonizing renewable energy sources with assorted technologies to mitigate challenges and engender technological innovations conducive to seamless integration. This encompasses but is not limited to, wind, solar, hydroelectric, and other renewable energy modalities.

Furthermore, the European Journal of Futures Research accentuates the pivotal role of renewable energy in satiating the burgeoning energy requisites and espouses the imperative of harnessing sustainable energy reservoirs (Darani, 2021). The integration of renewable energy sources engenders a multifaceted and intricate landscape, as posited by Vijay Prakash, which proffers valuable insights into the attendant challenges and prospective avenues for achieving efficacious and sustainable integration (Vijay Prakash Sharma1, 2022).

Secondly, a notable scholarly focus resides in examining the interaction between the technical dimensions inherent in renewable energy systems and the social dynamics governing resource consumption within domestic environments (Sheikh, 2016). Various scholarly inquiries elucidate the intricate relationship encompassing energy transitions, technological advancements, disaggregated energy utilization patterns, and their implications for sustained economic development.

Furthermore, scholarly discourse underscores the significance of comprehensively grasping resource consumption patterns at the household, community, and societal levels, leveraging insights from behavioral and social practice theories (Troy Malatesta, 2023). This underscores the imperative of integrating the technical facets of renewable energy systems and the socio-behavioral determinants shaping resource consumption behaviors within residential settings.

Moreover, the review accentuates the significance of community energy initiatives and energy communities, epitomizing collaborative endeavors within the energy sector (Bauwens, 2022). Energy communities represent cooperative ventures wherein members collectively develop and administrate renewable energy infrastructure, fostering localized energy frameworks characterized by sustainability and self-reliance (researchers, 2023).

Scholarly investigations indicate that the establishment of local energy communities yields notable advantages, including the facilitation of renewable energy deployment, enhancement of energy efficiency, reduction in utility expenditures, and the creation of employment opportunities at the local level, thereby serving as effective mechanisms for fostering more inclusive, equitable, and resilient energy systems (Prin, 2023). Through adopting renewable energy sources, communities stand to realize manifold benefits such as economic expansion, job generation, mitigation of energy costs, and promoting sustainable development (Utilities, 2023).

In addition, the literature review underscores the multifaceted nature of integrating renewable energy, which encompasses technical, social, and community-oriented dimensions. Extensive scholarly discourse highlights the intricate challenges associated with the grid integration of renewable energy, stressing the imperative of addressing technical, operational, and regulatory obstacles to achieve seamless integration (Bhuiyan, 2022).

Additionally, the pivotal role played by energy communities in driving the uptake of renewable energy within local electrical systems is emphasized, with a particular focus on their capacity to stimulate energy production, foster local employment opportunities, and catalyze regional economic growth (Johnson & Brown, 2018; Patel et al., 2019).

Furthermore, empirical evidence suggests that local energy communities significantly contribute to establishing inclusive, equitable, and resilient energy systems, promoting clean energy generation, and facilitating equitable surplus energy distribution among community members (García-Gómez et al., 2020).

Moreover, the literature delves into discussions on the challenges and technological remedies for integrating renewable energy sources, emphasizing discerning disparities between renewable and conventional power plants and advocating for systematic mapping of various challenges and corresponding technological interventions (Jones et al., 2021). These findings underscore the imperative of adopting a comprehensive approach to renewable energy integration encompassing technical intricacies and socio-economic dynamics.

4.2 Land Use Planning: Definitions & Principles

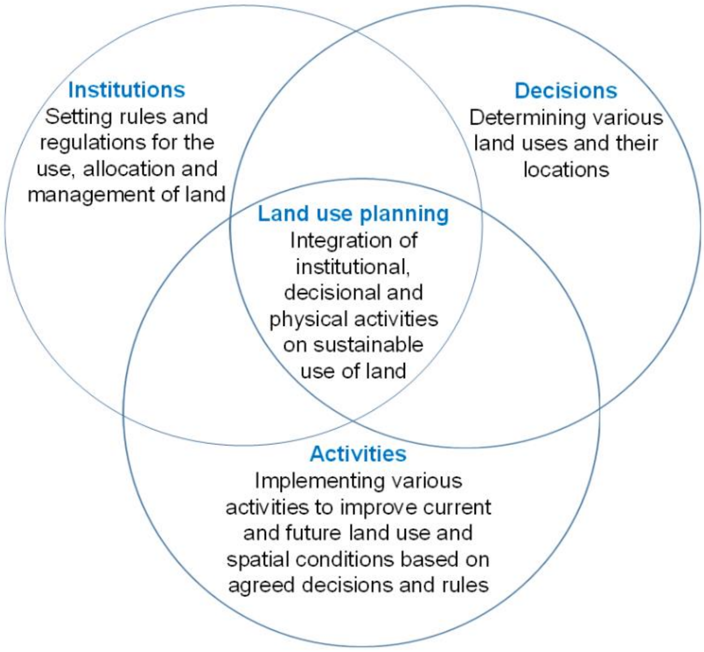

Figure 19. *An illustration of the meaning and significance of land use planning.* (Chigbu, 2016)

However, anyone can define land use planning as the result of three things: institutions, decisions, and activities concerning the distribution and utilization of land as indicated in 19. The general goal of land use planning is to position and impact land use to enhance both human and environmental well-being. It is implemented and determined by the goals it intends to accomplish.

Planning for land use is a multifaceted process characterized by its complexity and multifaced land allocation for various uses while balancing economic, social, and environmental considerations. The main objective of land use planning is to facilitate sustainable development by regulating, controlling, or directing changes in land use to maintain the quality of the environment and boost sustainable development.

Land use planning encompasses general and urban land use planning, each focusing on various scales and land use types, such as forests and pasture lands. Non-urban large-scale land use first, and natural resource management, such as forests, pasture lands, croplands, mining such as swamplands, and quarrying areas are General land use planning agreements (Jamal, 2017).

Land use planning principles include being balanced and sustainable and promoting a balance of social, economic, and environmental factors to guarantee the long-term viability of land use choices. Secondly, both responsiveness and responsibility demonstrate flexibility in responding to changing conditions and shifting societal demands when it comes to resolving equity concerns in the distribution of resources.

Cultural Sensitivity or cultural differences and similarities consider inclusivity and respect by Considering cultural heritage and traditions when developing planning procedures. Moreover, relevant and Consultative is based on grounding planning endeavors in the analysis of data collection and consultation with stakeholders to ensure informed decision-making. Besides being coordinated and collaborative, fair and equitable, accountability and transparency maintain transparency and accountability in land management decision-making and clear and consistent communication with stakeholders. Hens, Forward-looking Orientation that Anticipates future trends and prepares demographic, economic, and environmental trends accordingly to shape land use policies and plans.

Finally, Action-oriented Implementation focuses on pragmatic and actionable measures over theoretical models to facilitate the effective implementation of land use plans and Adaptive Management or adaptation: Recognizing the dynamic nature of land use systems and advocating for adaptive management approaches that allow for continual adjustments or reflect new insights and emerging situations (Jacobs, 2019).

The most important is that climate change in land use can help to minimize the negative consequences of climate occurrences such as water scarcity, flooding, drought, and heat stress, besides to lie in its capacity to cut back on emissions of greenhouse gases (GHG) by promoting nature-based solutions, and transportation, support sustainability, and reduce local greenhouse gas emissions. Strategic land use planning can also aid in reducing the frontage of valuable parts to climate risks and promoting natural solutions for the future.

By mitigating climate change in land use planning, districts can support and help their resilience, especially to severe weather conditions, and prepare for the inevitable shifts brought about by climate change. Land use planning can also boost the transition towards encouraging sustainable development and low-carbon economies (Jacobs, 2019).

4.3 Interrelationship between Renewable Energy Integration & Land Use Planning

The interrelationship between renewable energy integration and land use planning underscores a symbiotic relationship aimed at achieving sustainable development goals while mitigating the impacts of climate change to achieve the zero-emission goal. Indeed, the interrelationship between land use planning and the integration of renewable energy plays a crucial role in facilitating the achievement of carbon neutrality and balancing remaining emissions through carbon balance or removal initiatives.

Land use planning can help to identify suitable sites for renewable energy infrastructure (physical facilities and structures necessary) and minimize the negative impacts of renewable energy development on the environment and communities, such as Habitat Destruction, Land Use Conflicts, and noise and light pollution... Land use planning can guarantee that renewable energy systems are incorporated into the landscape sustainably and effectively. Renewable energy systems require land for operation, installation, and maintenance (Canada, 2022).

Land use planning can also help address the challenges associated with renewable energy development, such as the need for transmission infrastructure, which is evident in remote renewable energy resources. Often, renewable energy sources, such as wind and solar, are in remote areas far from major population centers where electricity demand is highest. Significant investments in transmission infrastructure are needed to move the electricity produced from these isolated renewable energy installations to urban areas where it is required.

Besides, it also can help the potential for conflicts with other land uses. The land use battle helps the country's economy shift to a low-carbon economy by recommending locations for renewable energy development and creating laws and policies that encourage their adoption (Guo, 2022).

Moreover, renewable energy development can also have many Beneficial impacts on land use planning, such as facilitating the repurposing of brownfield sites for renewable energy infrastructure, especially the old factories that have been vacated. This can revitalize previously underutilized and contaminated areas.

Additionally, utilizing existing land for renewable energy projects lowers demand for new land development, which helps conserve natural habitats and mitigate urban sprawl. By harnessing solar energy in densely populated areas, communities can generate renewable electricity without needing additional land development. This reduces the pressure to expand urban boundaries outward, helping to contain urban sprawl. Through this integration between renewable energy and land use, communities can enhance their resilience to climate change and advance sustainable development goals, fostering a resilient and environmentally conscious future (Ven, 2016).

The interrelationship between energy integration and land use planning is essential for achieving sustainable and decarbonized development through stakeholder collaboration. Renewable energy developers and land use planners can ensure that renewable energy infrastructure is integrated into the landscape view, which can be a beneficial way to recognize a new greenfield future for the new generation.

4.4 Earpieces Research on Including Renewable Energy in Land Use

Integrating renewable energy (RE) into land use planning has been a focal point of contemporary urban development strategies. Scholars have consistently highlighted the critical interplay between sustainable energy practices and land use policies. Smith (2024) asserts that "the successful integration of renewable energy technologies within urban and rural landscapes necessitates a harmonious combination of technological innovation and community involvement." This perspective underscores the importance of aligning renewable energy initiatives with local environmental and social contexts (Smith et al., 2020).

Integrating renewable energy (RE) into land use planning represents a multifaceted work that intersects in 3 ways: environmental, economic, and social dimensions. Previously, scholarly studies and case studies investigating challenges and opportunities in renewable energy use integration meticulously examined it. These studies confirmed the need for informed decision-making processes that account for various factors. The unpredictable nature of re-power generation is one of the most critical complexities. Moreover, these previous scholarly shed light on key factors influencing decision-making processes and outcomes.

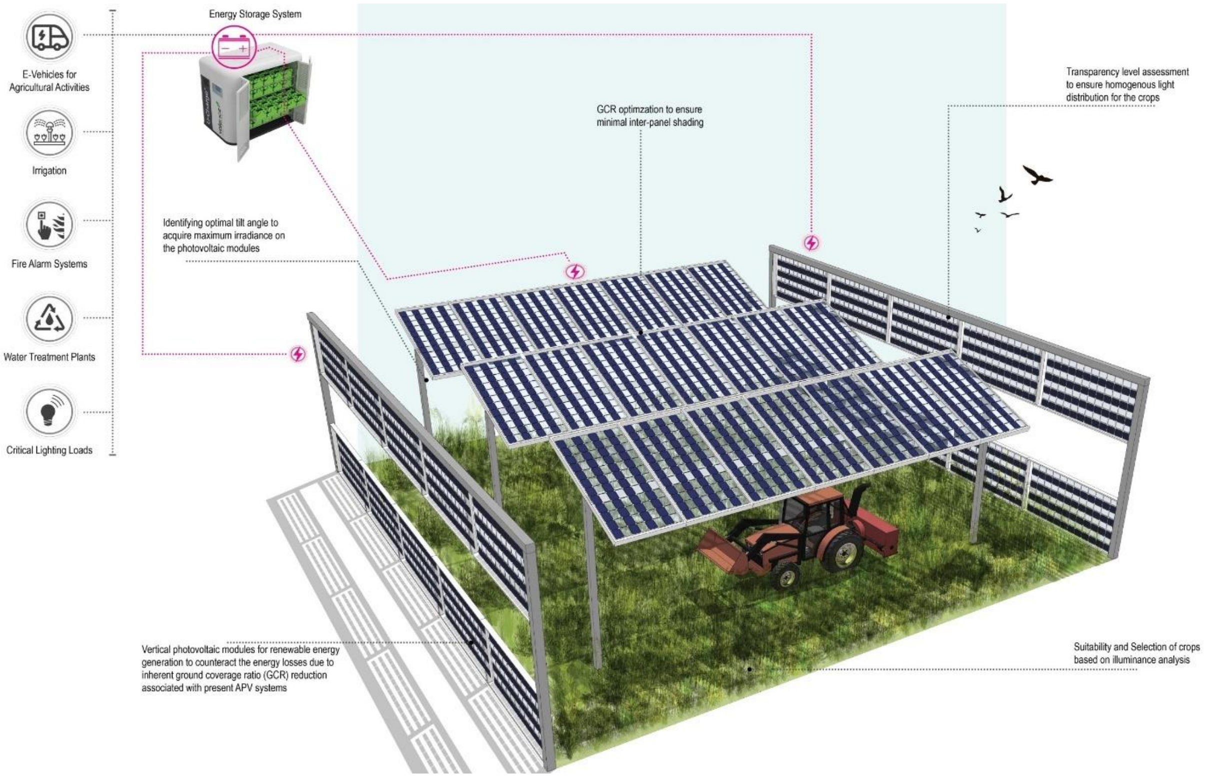

Figure 20. *3D Conceptual Illustration of Agrophotovoltaic (BIPV) Technology in Farmlands* (Clement, 2024).

The emerging global land use crisis is a critical issue that demands urgent attention. According to the Chatham House King's Report, the increasing demand for land is leading to heightened competition for productive and ecologically valuable areas. This competition is expected to intensify in the coming years due to the growing need for agriculture, climate change mitigation, and other essential purposes (King, 2021). In alignment with the Chatham House analysis, Carlos Clement suggests that integrating Building-Integrated Photovoltaics (BIPV), as shown in Figure 20, with agricultural land, known as agro photovoltaics, can significantly enhance land productivity. This combined energy and crop production approach can increase land productivity by up to 70%(Clement, 2024).

Moreover, the emerging global land use crisis influences decision-making processes and outcomes and the integration of renewable energy into mining operations. These operations present a significant opportunity for the mining sector, which can reduce its carbon footprint, enhance sustainability, and contribute to global decarbonization efforts. In addition, grid-connected mining activities use fossil fuels to some extent.

The grid offers the least expensive energy source for mining activities in the sites where the grid is available. Nevertheless, the need for backup energy sources often supplied by fossil fuels at mining sites drives increased production costs in many nations with unstable grid supplies. A study examines the challenges and opportunities of integrating renewable energy into mining operations, with the impact of these integral development goals. It delves into how renewable energy adoption in mining can contribute to environmental sustainability and resource efficiency (Pouresmaieli, 2023).

Nonetheless, market design for renewable energy helps in decision-making by evolving market designs to value the reliability, flexibility, and environmental blessings of renewable energy, which is required for its integration tableting market mechanisms that incentivize the use of renewable energy, compensating grid services equitably, and permitting the interchange of renewable energy certificates, a conducive atmosphere can be established for the deployment of renewable energy and switch to more environmentally friendly electricity(Guo, Jiaao, 2020).

Lastly, the renewable energy circular economy approach is used. The RE industry must adopt a circular economic approach to maximize resource efficiency and misjudge waste. Highlighting the recycling and reuse of RE components, such as solar panels, can minimize environmental effects and generate fresh business prospects, emphasizing the significance of sustainable methods in the growth of renewable energy (Delphin, 2021).

These conclusions underscore the significance of collaborative efforts, public engagement, supportive policies, and innovative approaches in overcoming challenges and leveraging opportunities for effective renewable energy-land use integration, ultimately contributing to a more sustainable and environmentally conscious energy landscape.

4.5 Successfully Integrating of BIPV in a Building's Design

A recurring theme in the literature is the need for renewable energy projects to complement existing land use and urban aesthetics. For instance, in low-density environments like Canmore, Alberta, the implementation of photovoltaic (PV) systems is carefully planned to preserve the town's natural beauty and low-rise character.

Smith (2024) states, "Canmore's approach to integrating PV systems illustrates the importance of selecting sites and designs that harmonize with the natural and built environment, thereby minimizing visual disruption and fostering community acceptance." This approach meets renewable energy goals and enhances the town's appeal and environmental footprint through community-driven sustainability initiatives (Smith et al., 2020).

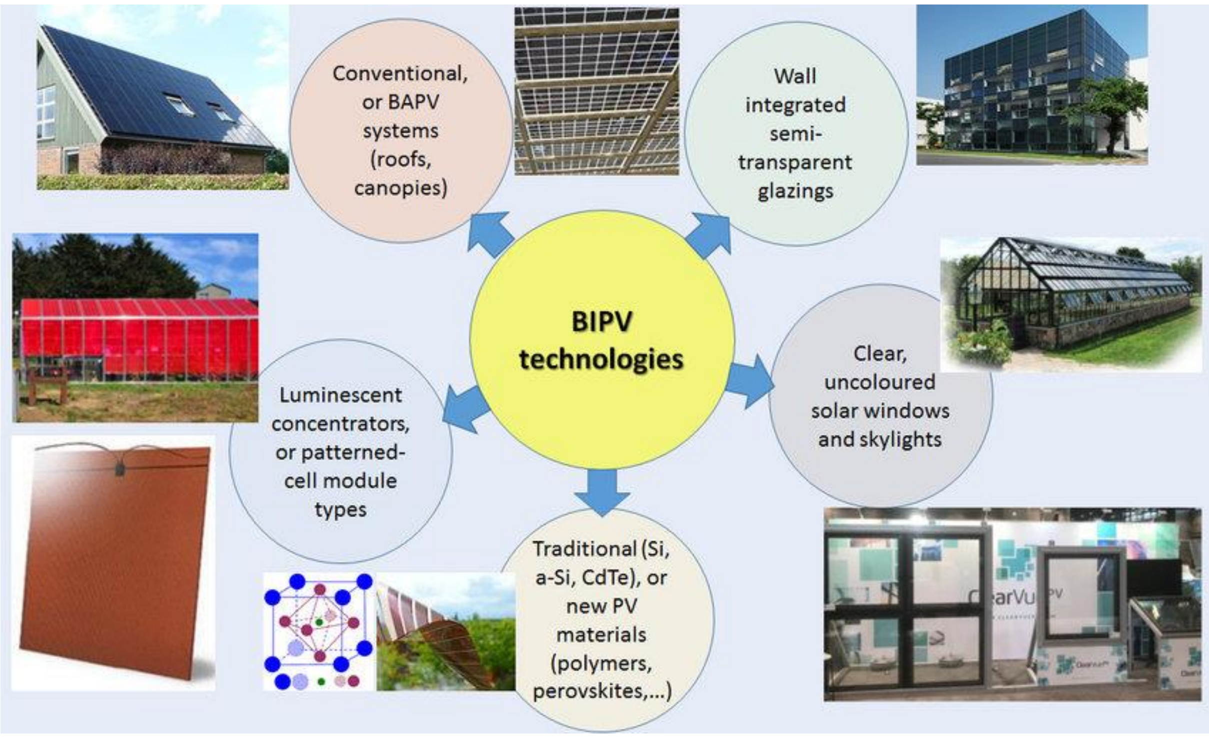

Figure 21. *Integrating Building-Integrated Photovoltaics (BIPV) into a building's design. (Klein & Rubin, 2018)*

Building-integrated photovoltaics (BIPV) and traditional Photovoltaic (PV) systems exhibit fundamental differences in their integration and application within building structures. Traditional PV systems are typically installed as separate entities, often mounted on rooftops or other external structures post-construction. These systems function independently from the architectural and structural elements of the building (El-Sayed et al., 2020). Their primary role is to generate electricity without contributing to the building's aesthetics or structural integrity.

Conversely, BIPV systems are designed to be integral to the building envelope, functioning as construction materials and energy generators. This dual functionality allows BIPV systems to replace conventional building components such as windows, skylights, and facades, seamlessly blending into the building's design and contributing to its structural performance (Klein & Rubin, 2018) as shown in Figure 21. BIPV systems thus offer a cohesive approach to incorporating renewable energy technologies within architectural design.

A notable example of BIPV implementation is the Indira Paryavaran Bhawan in New Delhi. This building exemplifies the use of BIPV by incorporating photovoltaic elements directly into its structure, enhancing its energy efficiency and aesthetic appeal. According to Sharma and Kumar (2019), the building's integration of BIPV addresses the challenges of space constraints in high-density urban environments and maximizes energy efficiency. By embedding renewable energy sources within the building fabric, BIPV technology optimizes space utilization and significantly contributes to the building's overall energy performance (Sharma, & Kumar , 2019).

Traditional PV systems are appended to existing structures, whereas BIPV systems are embedded within the building envelope, enhancing functionality and aesthetics. The Indira Paryavaran Bhawan in New Delhi is a testament to BIPV's potential to optimize space and energy efficiency in urban settings.

Indira Paryavaran Bhawan's project:

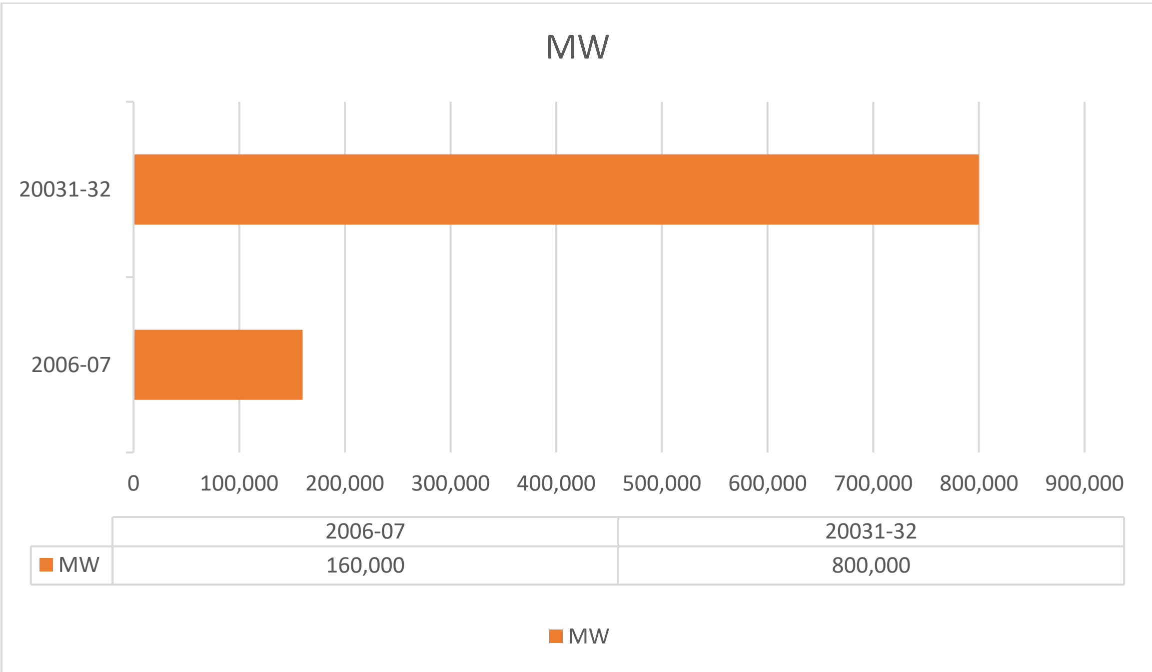

Figure 22. *Increasing the amount of power generation needs between 2006 to 2032: The Case of Indira Paryavaran Bhawan .Authors elaboration.*

India faces significant challenges in meeting its growing energy demands. With an 8% annual growth rate, the primary energy supply needs to increase by 3-4 times and electricity generation by 5-6 times from 2003-2004. By 2031-2032, this difference can be shown in Figure 22. Buildings consume substantial energy and are central to CO2 emission mitigation efforts, driving research towards net zero energy buildings (NZEBs). The Indira Paryavaran Bhawan in New Delhi exemplifies an NZEB designed with passive solar power generation and energy-efficient systems (Rati Khandelwal, Ravindra Kumar Jain, Mukesh Kumar Gupta, 2022).

Location	New Delhi
Geographical coordinates	28° N, 77° E
Occupancy Type	Office (MoEF)
Typology	New Construction
Climate Type	Composite
Project Area	9,565 m^2
Grid Connectivity	Grid connected
EPI	44 $kWh/m^2/yr$

Figure 23. *location description for Indira Paryavaran Bhawan building. (Rati Khandelwal, Ravindra Kumar Jain, Mukesh Kumar Gupta, 2022).*

The Indira Paryavaran Bhawan in New Delhi, as shown in Figure 23, is the first government building in India to achieve or realize net zero energy status. It accommodates the Ministry of Environment, Forest, and Climate Change and exemplifies a sustainable and energy-efficient building by integrating building-integrated photovoltaics (BIPV). The building demonstrates the capability of BIPV technology to generate renewable energy on-site while maintaining architectural aesthetics.

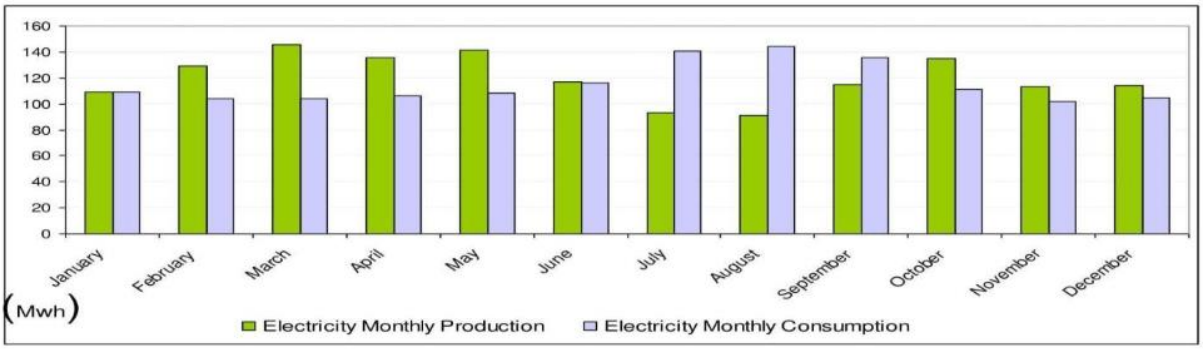

Figure 24. *Annual energy production and consumption graph from Solar BIPV. (G.Palani Selvan, 2022).*

The building generates sufficient renewable energy to satisfy its annual energy consumption needs, as shown in Figure 24. Specifically, its yearly energy consumption is 1.421 million kWh, met by an equivalent energy generation of 1.43 million kWh from its on-site solar BIPV installations, rendering it a fully autonomous, multifunctional office facility. The nation's top, green-rated structure is a role model for sustainable architecture, showing how successful government structures can influence future development toward environmentally friendly methods and help fight climate change(G.Palani Selvan, 2022).

The BIPV system is meticulously integrated into the building's facade and rooftops, fulfilling energy generation and architectural functions. Additionally, the BIPV design minimizes solar heat gain, enhancing the building's overall energy efficiency (G.Palani Selvan, 2022).

This case study emphasizes how BIPV systems can be seamlessly incorporated into building facades and rooftops, blending into architectural designs to generate renewable energy on-site while preserving aesthetic appeal. The Indira Paryavaran Bhawan illustrates the potential of BIPV systems in developing sustainable, energy-efficient buildings.

Moreover, other notable BIPV projects in India, such as the Suzlon One Earth building in Pune, the Rajiv Gandhi International Airport in Hyderabad, and the Cense building at the Indian Institute of Science in Bangalore, highlight the increasing adoption of BIPV technology in integrating renewable energy generation into building structures (G.Palani Selvan, 2022).

5. Land Use & Renewable Energy

5.1 Land requirements for renewable energy projects

5.2 Impact on existing land use patterns

5.3 Land availability & competition

Land Use and Renewable Energy

5.1 Land Requirements for Renewable Energy Projects

Land requirements for renewable energy projects vary depending on the technology employed. Across diverse technologies within the United States, solar power plants exhibit considerable variation in land requirements. There is a wide range of generation-weighted averages for total area requisites, ranging from approximately 3 acres/GWh/yr. For concentrated solar power towers and concentrated photovoltaic (CPV) installations to 5.5 acres/GWh/yr. This is for small flat panel PV plants with two axes. Different solar energy technologies require nuanced spatial requirements. Moreover, the aggregate generation-weighted average for solar energy projects across all technologies stands at 3.5 acres/GWh/yr., with a substantial proportion, i.e., 40%, of power plants occupying land areas within the range of 3 to 4 acres/GWh/yr. Technological differences significantly influence spatial requirements and characterize land allocation considerations within the solar energy domain (Ong, 2013).

In contrast, wind turbines represent another major component of renewable energy use characterized by significant land demand. The use of solar and wind turbines, as defined in the sources, has a much larger spatial footprint per unit of electricity generation compared to conventional generating equipment in terms of typical quarries; for example, wind turbines are often half a mile apart, contributing to a more terrestrial presence. Similarly, large solar farms have spread over vast areas, covering thousands of acres (Christakou, 2022). The increasing availability of land suitable for wind and solar projects highlights the need for developers to identify new sites suitable for installing renewable energy systems. This requires a proactive approach to the growing landscape of land availability and utilization, particularly to alternative energy sources, considering the increasing competition in critical areas of merit.

Moreover, regulatory constraints emerge as pivotal determinants shaping the landscape of land availability for renewable development. It is worth mentioning that the regulators are influential enough to reserve the raw land for alternative energy projects, exerting a pronounced impact on deployment prospects. For instance, in Germany, a mere 9% of the nation's potentially suitable land for wind farms remains viable for development post-consideration of regulatory, environmental, and technical constraints (Christakou,2022). Analogous regulatory impediments impede land availability for renewable energy initiatives in other jurisdictions, such as France and the United States, engendering formidable challenges for project developers. The interplay of regulatory strictures with land utilization dynamics underscores the multifaceted nature of land allocation considerations within the renewable energy domain, necessitating astute navigation of regulatory frameworks to optimize land utilization for sustainable energy deployment.

In summary, the spatial requisites inherent to renewable energy projects manifest a heterogeneous landscape characterized by technology-specific disparities in land utilization. Solar and wind energy installations necessitate substantial land allocations compared to conventional fossil fuel-based power plants, reflecting the expansive spatial footprint inherent to renewable energy infrastructure. Regulatory constraints further exacerbate land availability challenges, constraining the pool of viable sites for renewable energy development. As such, the intricacies of land allocation considerations within the renewable energy sector necessitate a holistic approach encompassing technological, regulatory, and environmental dimensions to optimize land utilization for sustainable energy deployment.

5.2 Impact On Existing Land Use Patterns

Energy and land use decisions have a meaningful impact on existing land use patterns. Local land use and energy decisions can influence a community's energy consumption, involving economic growth, municipal and individual budgets, and the environment.

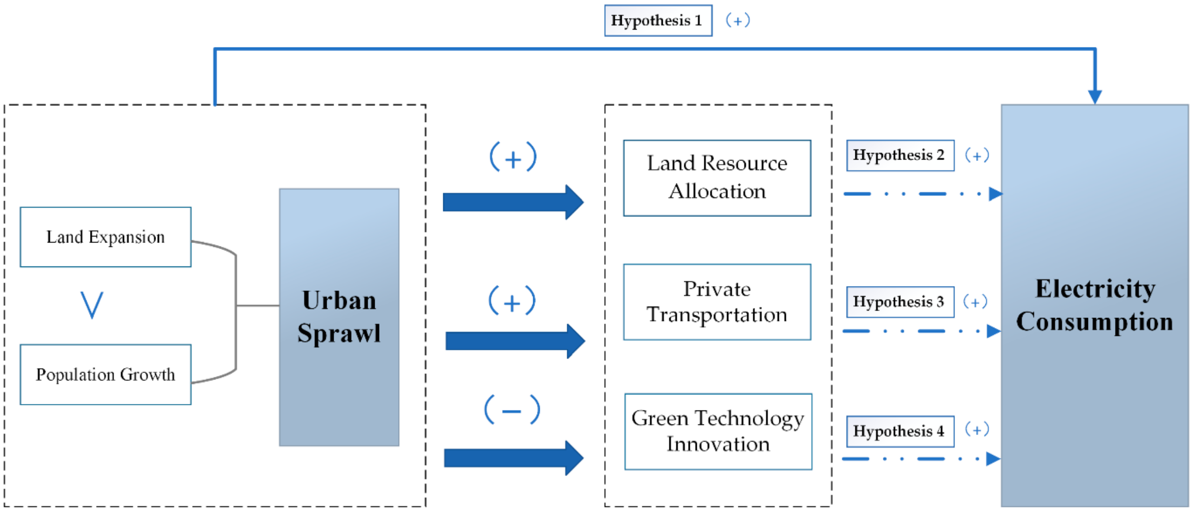

Figure 25. *Hypothesis 1. Urban sprawl can worsen electricity consumption. Hypothesis 2. Urban sprawl exacerbates electricity consumption by altering land resource allocation—hypothesis 3. Urban sprawl worsens electricity consumption by growing reliance on private transportation—hypothesis 4. Urban sprawl worsens electricity consumption by inhibiting green technology innovation* (Qiangyi Li, 2023).

Land use patterns like sprawl growth can induce greater energy consumption by prioritizing personal transportation (as shown in Figure 25 hypothesis 1), electrical supply distribution (as shown in Figure 25 hypothesis 3), and infrastructure. In contrast, mixed-use development, which incorporates different land uses like residential and commercial nearby, can reduce energy consumption by enabling people to live nearer to where they work, reducing the requirement for long commutes, and promoting alternative transportation modes like biking and public transit (Keeley, 2014).

Moreover, expanding renewable energy, particularly wind power, can deliver dynamic land use implications. Wind technology development and innovation shape landscape interactions with social and ecological systems, impacting land occupancy patterns and regional trends.

Wind power deployment can involve diverse land use and outside types. A high percentage of the typical wind plant footprint is not directly impacted by permanent physical infrastructure, permitting multiple uses in the spaces between turbines. Comprehending these impacts is essential for optimizing future wind-intensive energy systems for pure energy, social, and environmental objectives (Harrison-Atlas, 2022).

The decisions about land use and energy, as well as the expansion of renewable energy projects like wind power, can profoundly impact energy consumption, existing land use patterns, and the environment. Communities must evaluate these impacts when planning sustainable energy transitions and optimizing land use for efficient and environmentally friendly development.

5.3 Land Availability and Competition.

Land availability and competition are critical concerns with far-reaching implications for various sectors, including agriculture, food production, urban development, and environmental conservation. As competition for land intensifies, it becomes a significant driver affecting land use, food production, and farming practices (Smith et al., 2020). The rising trends in land consumption, particularly for settlement and transport infrastructure, pose substantial challenges to preserving biodiversity, achieving sustainable land use, and mitigating climate change (Johnson & Brown, 2021).

Urban sprawl and infrastructure development significantly reduce land availability, creating obstacles to meeting targets for land consumption reduction. For instance, the areas designated for settlements and transport infrastructure in Germany have doubled over the past six decades (Harrison-Atlas, 2022). This intense competition for land impacts multiple areas, including food production, nature conservation, renewable energy deployment, and climate adaptation efforts (Williams et al., 2019).

Recent literature emphasizes the need for international cooperation to address land competition issues, highlighting the importance of global collaboration in finding solutions. Practical international cooperation is essential for promoting sustainable land management practices and addressing environmental concerns (Miller & Thompson, 2022). Countries can develop strategies to balance land use demands, preserve natural resources, and ensure sustainable development by working together.

6. Key Factors Influencing Renewable Energy Integration

6.1 Variability & uncertainty due to weather dependency

6.2 Location-specific properties & geographical availability

6.3 Low marginal costs & resource adequacy

Key Factors Influencing Renewable Energy Integration

6.1 Variability & Uncertainty Due to Weather Dependency

Variability and uncertainty from weather dependency present significant challenges in integrating RES into the current energy landscape. This issue is particularly pronounced in solar and wind power generation, where energy output fluctuates based on weather conditions like cloud cover, wind speed, and sunlight intensity. The intrinsic unpredictability of these weather-dependent energy sources poses complexities for energy grid management, impacting grid stability, energy supply reliability, and overall system efficiency.

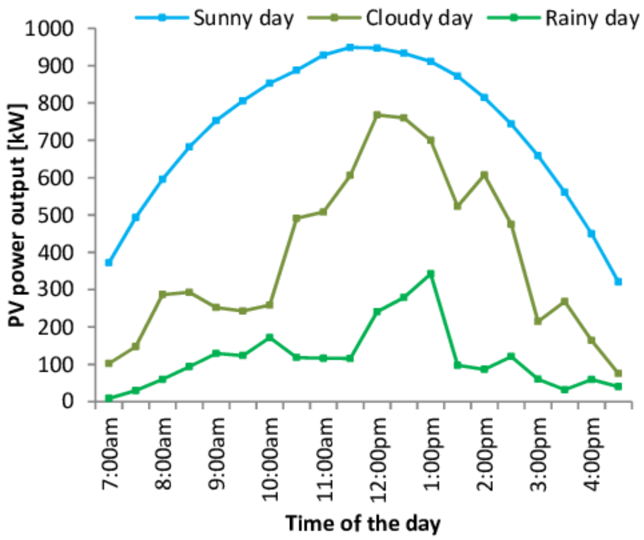

Figure 26. *Solar power output on a sunny day (20 April 2013), a cloudy day (15 April 2013), and a rainy day (13 April 2013) in the same month show three different weather conditions. (Min, 2019).*

Solar energy, harvested through photovoltaic systems, relies heavily on sunlight availability. Cloud cover and variations in sunlight intensity throughout the day cause fluctuations in solar power generation, posing challenges in matching energy supply with demand. Similarly, wind power generation is subject to variability due to changes in direction and wind speed, making it difficult to manage energy output and predict accurately. Figure 26 shows an example of solar power output for different weather conditions: a bright day (20 April 2013), a sunny day (15 April 2013), and a rainy day (13 April 2013). These fluctuations in output introduce uncertainty into the energy system, necessitating quick adaptation by grid operators to maintain stability and ensure a continuous power supply (Min, 2019).

Energy grid operators may face operational tribulations due to weather-dependent renewable energy sources, unpredictability, and uncertainty. The more renewable energy sources in the energy mix, the more difficult it is to balance supply and demand. This calls for creative ways to deal with the intermittent nature of solar and wind power.

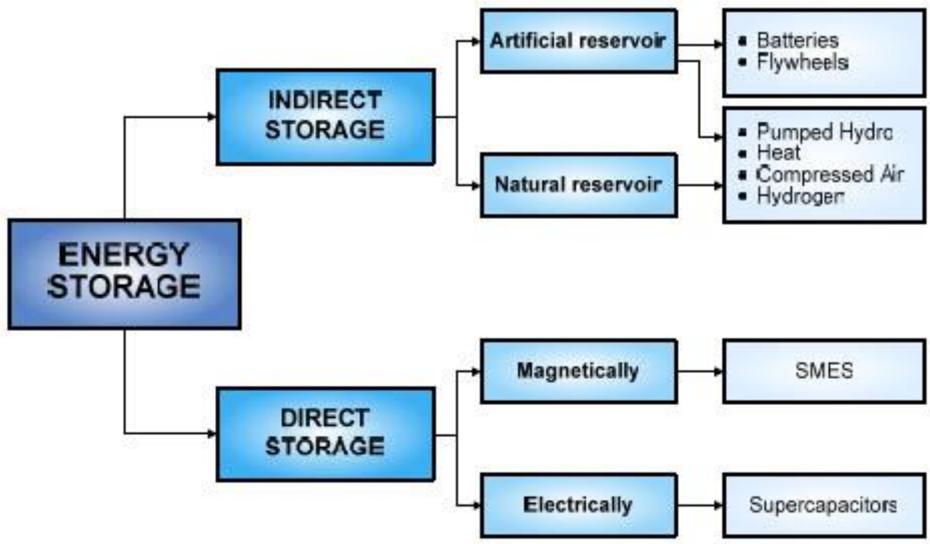

Figure 27. *an overview of various energy storage devices, highlighting their distinct characteristics and applications (Luo et al., 2015)*

Therefore, batteries and pumped hydro storage are two samples of energy storage technologies and classified as indirect storage as shown in Figure 27, essential for holding excess energy during peak generation times and removing it when the system needs stabilization. Energy storage devices reduce the effects of variability and uncertainty on grid operations by buffering variations in renewable energy generation.

Advanced forecasting models are another essential tool in addressing the challenges posed by weather-dependent energy sources. Factual weather forecasting enables grid operators to anticipate changes in renewable energy generation and adjust grid operations accordingly. Grid operators may guarantee grid stability in the face of fluctuating renewable energy generation by optimizing energy dispatch, planning maintenance activities, and making well-informed decisions using real-time data and predictive analytics.

Variability and uncertainty due to weather dependency present complex factories in integrating renewable energy into the energy system. While solar and wind power deliver sustainable and clean energy solutions, their intermittent nature demands careful planning, innovative technologies, and effective grid management strategies to provide a reliable and resilient energy supply by investing in forecasting tools, energy storage, and grid flexibility measures. Stakeholders can crush the challenges of weather-dependent renewable energy sources and accelerate the transition toward a more sustainable and decarbonized energy future (E. Ela, 2013).

6.2 Location-specific properties & geographical availability

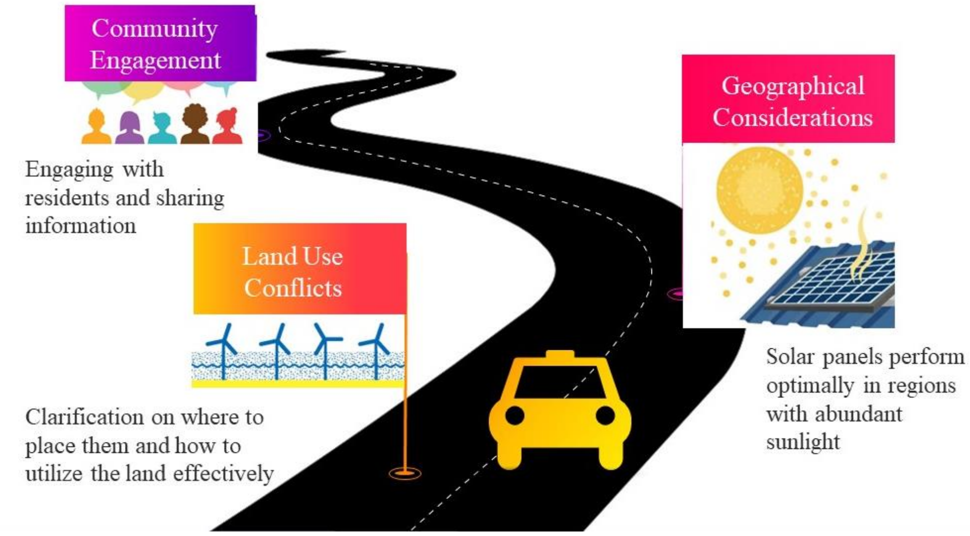

Figure 28.*The challenges of Location-specific properties and geographical availability. Author's elaboration*

Integrating renewable energy into land use presents a complex array of challenges, which are significantly influenced by geographic location and the availability of resources. Solar and wind power installations face unique obstacles due to their distinct requirements. Understanding and addressing these challenges as shown in Figure 28 is important to successfully integrating renewable energy systems.

Challenges:

Land Use Conflicts: When designing renewable energy projects such as wind and solar installations, one often needs clarification on where to place them and how to utilize the land effectively. This arises because it is essential to position power plants and transmission lines in areas that may have yet to be previously used for industrial purposes. Such placement can lead to resistance from local communities who may oppose changes to their location. Additionally, wind and solar energy require significant land for each power unit produced, further exacerbating these conflicts (Kolkowska, 2023).

Geographical Considerations: A place's geography determines where renewable energy projects can be situated. Solar panels perform optimally in regions with abundant sunlight, such as open plains, while wind turbines require consistent wind, typically found on ridgetops. However, locating sites that meet these criteria and are convenient for people and existing infrastructure can pose challenges. It is necessary to balance the availability of resources with the needs and preferences of the community and the existing infrastructure (Kolkowska, 2023).

Community Engagement: To address conflicts over land use and other challenges specific to certain locations, involving the decision-making process and local community in the planning is essential. By engaging with residents and sharing information about the benefits of renewable energy, we can help alleviate concerns and garner support for these projects. Transparent communication and collaboration between project developers, policymakers, and community members are crucial for navigating the complexities of land use in renewable energy projects (Kolkowska, 2023).

Integrating renewable energy into land-use factories requires careful consideration of location-specific factors and resources. By balancing the need for renewable energy development with concerns about land use, engaging with the community, and adhering to regulatory frameworks, we can overcome these challenges and successfully integrate renewable energy projects into our existing landscape.

6.3Low Marginal Costs & Resource Adequacy

Low marginal costs and resource adequacy are significant factors in incorporating land use into renewable energy. Low marginal costs are often associated with renewable energy sources like solar and wind in electricity markets.

These sources have a distinct advantage: once the initial infrastructure is in place, the ongoing cost of generating electricity becomes minimal. However, this advantage poses a dilemma. Low marginal costs can make it challenging to ensure a stable electricity supply while peak demand periods or when variable renewable sources are not actively generating power.

The second factor revolves around resource adequacy. Imagine when everyone turns on their air conditioners during a scorching summer afternoon—now, sufficient electricity is needed to meet this heightened demand.

However, relying solely on solar and wind power becomes precarious if the sun isn't shining or the wind isn't blowing (which can happen due to weather conditions). Resource adequacy involves striking a balance between harnessing clean energy from renewable sources and ensuring our overall power supply reliability.

Integrating land use into renewable energy requires thoughtful solutions and requirements that address these factories. It's a delicate dance between sustainability and practicality, aiming to create a resilient energy system for the future.

7. Environmental Impacts

7.1 Indirect Land Use Change (ILUC) Emissions

7.2 Biodiversity Loss & Water Use

7.1 Indirect Land Use Change (ILUC) Emissions

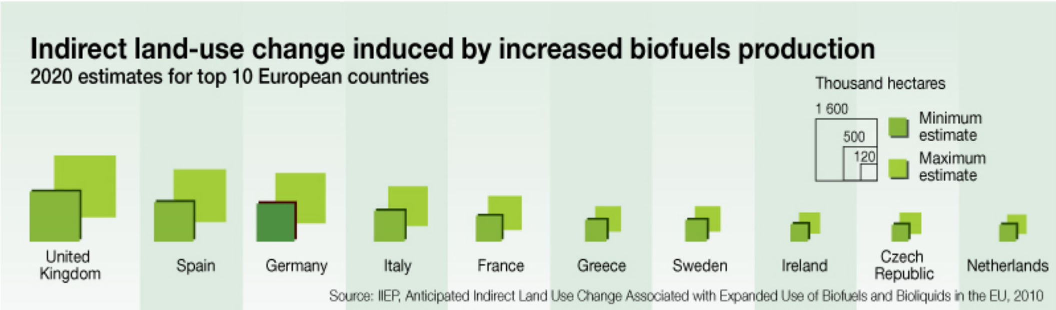

Figure 29. *Indirect land-use change induced by increased biofuel production for European countries.* (Riccardo Pravettoni, 2016)

Indirect Land Use Change (ILUC) emissions represent a pivotal consideration when evaluating the environmental impact of biofuel production and other renewable energy sources. These emissions occur due to alterations in land use patterns driven by the increased demand for biofuels. Figure 29 shows ILUC induced by increased biofuel production in some European countries during 2020 (Riccardo Pravettoni, 2016).

It often leads to converting natural ecosystems or agricultural land for biofuel crop cultivation. This conversion process can displace existing land uses, such as food production or forest cover, and release carbon stored in vegetation and soil, contributing to greenhouse gas emissions beyond those directly associated with biofuel production and utilization (Hugo Valin, 2015).

The concept of ILUC emissions is integral to understanding the broader environmental implications of biofuel production and renewable energy development. By considering the indirect effects of land use changes, policymakers and researchers can gain insights into biofuels' total carbon footprint and make informed decisions regarding their sustainability and contribution to mitigating climate change.

At its core, ILUC emissions underscore the interconnectedness between land use, carbon emissions, and climate change mitigation efforts. As biofuel demand increases to meet RE targets and lessen dependence on FF, the associated land use changes must be carefully examined to assess their environmental consequences. It necessitates a comprehensive understanding of land use decisions' complex dynamics and their implications for carbon sequestration, biodiversity conservation, and ecosystem integrity.

Addressing ILUC emissions requires a multifaceted approach integrating environmental considerations into biofuel production and renewable energy planning processes. It entails evaluating the trade-offs between energy security, economic development, and environmental sustainability and implementing policies and measures to mitigate adverse impacts on land use and carbon emissions.

Promoting sustainable land management techniques, such as agroforestry and conservation agriculture, to reduce land conversion and protect natural ecosystems is one of the main ways to mitigate ILUC emissions. Furthermore, encouraging the growth of non-food feedstocks and using marginal lands for biofuel production will help relieve strain on agricultural land and lessen competition with food production.

Furthermore, enhancing transparency and accountability in biofuel supply chains through certification schemes and traceability mechanisms can help ensure that biofuels meet sustainability criteria and do not contribute to deforestation or land degradation. It requires collaboration among governments, industry stakeholders, civil society institutions, and research institutions to develop and implement effective policies and practices (Hugo Valin, 2015).

In conclusion, addressing ILUC emissions is essential to ensure that renewable energy projects contribute to climate change mitigation efforts without exacerbating environmental degradation. By accounting for the indirect effects of land use changes, policymakers and stakeholders can make informed decisions that balance energy needs with ecological conservation goals, fostering a sustainable and resilient future (Hugo Valin, 2015).

7.2 Biodiversity Loss & Water Use

In moving towards a more environmentally friendly energy system, the difficulties in incorporating renewable energy into land use, especially biodiversity loss and water use, present essential factors to consider. Astute observations from various sources highlight these issues and provide insightful viewpoints for successfully resolving them.

Firstly, concerning biodiversity loss, a comprehensive analysis by Nature Serve underscores the gravity of the situation, revealing alarming statistics indicating that many plants, animals, and ecosystems in the United States are at risk of extinction or range-wide collapse. Of particular concern are freshwater invertebrates and pollinators, which face steep declines due to habitat degradation, and the effects of climate change. It highlights the urgent imperative to safeguard imperiled biodiversity, with specific attention directed toward vulnerable ecosystems such as grasslands and wetlands (Tim Lumley, 2023).

Secondly, the interaction between renewable energy facilities and fauna presents a complex dynamic, with each renewable energy source posing unique conservation concerns and opportunities for mitigation. While solar and wind energy facilities emit minimal air pollution, they still exert environmental impacts, notably regarding water use and quality (Tim Lumley, 2023).

Some renewable energy technologies entail significant water consumption for irrigation, reservoirs, and cooling purposes, necessitating a thorough water footprint assessment. Adopting water-efficient practices and minimizing potential impacts on water availability and quality emerge as essential strategies for renewable energy projects to mitigate their environmental footprint.

Several difficulties arise when integrating renewable energy into land usage, including biodiversity loss and water use. A thorough plan that includes several key components is needed to overcome these challenges.

Coordinated actions are necessary to safeguard threatened species and ecosystems by prioritizing the mitigation of the primary hazards identified—such as habitat loss, invasive species spread, and the adverse consequences of climate change. Renewable energy projects must prioritize adopting sustainable practices, particularly concerning water quality and utilization, to lessen their environmental impact (Tim Lumley, 2023). To reduce any negative consequences, this calls for thorough evaluations of water usage, the implementation of water-efficient practices and technology, and the responsible management of water resources.

In summary, incorporating renewable energy into land usage is a critical step toward realizing a cleaner and more sustainable energy future. However, the problems caused by biodiversity depletion and water consumption highlight the need for careful planning, proactive mitigation, and well-considered decision-making. By tackling these issues head-on and working together, stakeholders may successfully navigate a peaceful transition to renewable energy while preserving biodiversity and guaranteeing the sustainable management of water resources for the present and the future.

8. Case Study

8.1 Theoretical

8.2 The Designated Study Site

8.3 Strategies & Initiatives Driving in Town of Canmore

8.4Analysis & studying of the Challenges before commencing

8.5 Theoretical Challenges Through a Structure to Uniform RE Mapping

8.6 Map of Various Policy Situations

8.7 Scenario Maps

8.8 Calculating the Generation of RE

8.9 Discussion & Conclusion

Figure X. *Sketch show the location of case study*

Source. The photo take from Google and edit by Author's.

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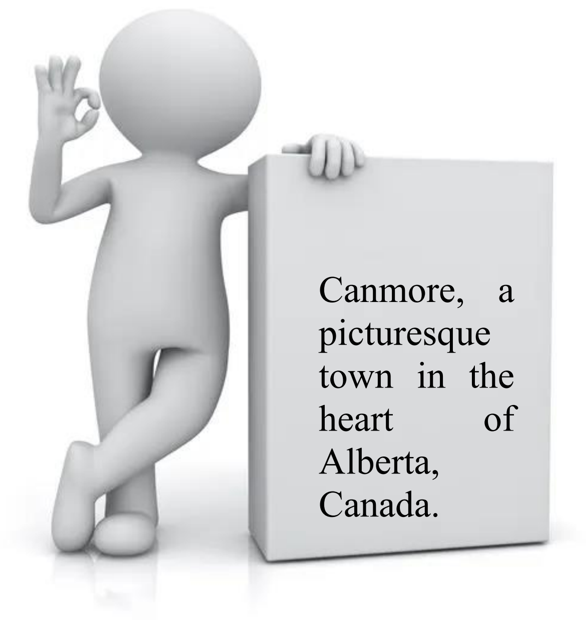

Case Study

- **Urban Renewal Projects in Canmore, Alberta Canada**

8.1 Theoretical

Canmore, a picturesque town in the heart of Alberta, Canada, is embarking on proactive urban renewal initiatives to enhance its community and accommodate growth. Situated amidst the majestic Canadian Rockies, Canmore boasts a small municipal territory governed by intricate land-use regulations encompassing ecologically delicate areas.

In this case study, they employed a comprehensive mapping approach, which considers theoretical resources, technically recoverable lands, legally accessible parcels, and the spatial capital cost associated with establishing new renewable energy (RE) facilities. The analysis encompasses various land-use planning scenarios, including extending construction limits to environmentally sensitive districts and modifying setback buffers. By identifying the main challenges, which are least-conflict lands, we assess the total RE potential within Canmore. The seamless integration of RES into land use planning is fundamental to sustainable development.

This case's approach deliberately incorporates sustainable energy technologies, like solar photovoltaic (PV) panels and wind turbines, focusing on reducing environmental impact. However, careful consideration is required during placement to mitigate noise disturbances in residential areas. Despite having ample acreage, Canmore faces implementation challenges due to restricted land suitability. Nevertheless, the town remains committed to ambitious RE targets.

To achieve its long-term emission reduction goals, Canmore must balance land-use changes, growing energy demands, and realistic RE development. Finally, to navigate this complex landscape, Canmore relies on sophisticated mapping tools that analyze the impact of land-use planning decisions on RE potential. These tools serve as essential guides, facilitating informed choices and ensuring a sustainable energy future for the town.

Figure 30. *Plan World for Alberta, Canada (Guo, Jiaao, 2020).*

8.2 The Designated Study Site.

Canmore, located near the southeastern boundary of Banff National Park and about 81 kilometers (50 miles) west of Calgary, sits nestled within the scenic Bow Valley, surrounded by Alberta's majestic Rocky Mountains., as depicted in Figure 31. Renowned for its properties subject to stringent land-use regulations and challenging terrain, Canmore experiences notable variations in solar and wind resources across the town due to its unique topography (Guo, Jiaao, 2020).

The town exhibits proactive involvement in combating climate change, which is evident through its membership in the Global Covenant of Mayors (COM) and unwavering support for local climate initiatives. In alignment with provincial and federal sustainability objectives, Canmore has set ambitious targets for reducing carbon emissions. Alongside its long-term goal of achieving an 80% reduction from 2015 levels, Canmore aims to lower its greenhouse gas (GHG) emissions by 30% below 2015 levels by 2030, corresponding to an approximate decrease of 275,000 tons of CO2 equivalent (Guo, Jiaao, 2020).

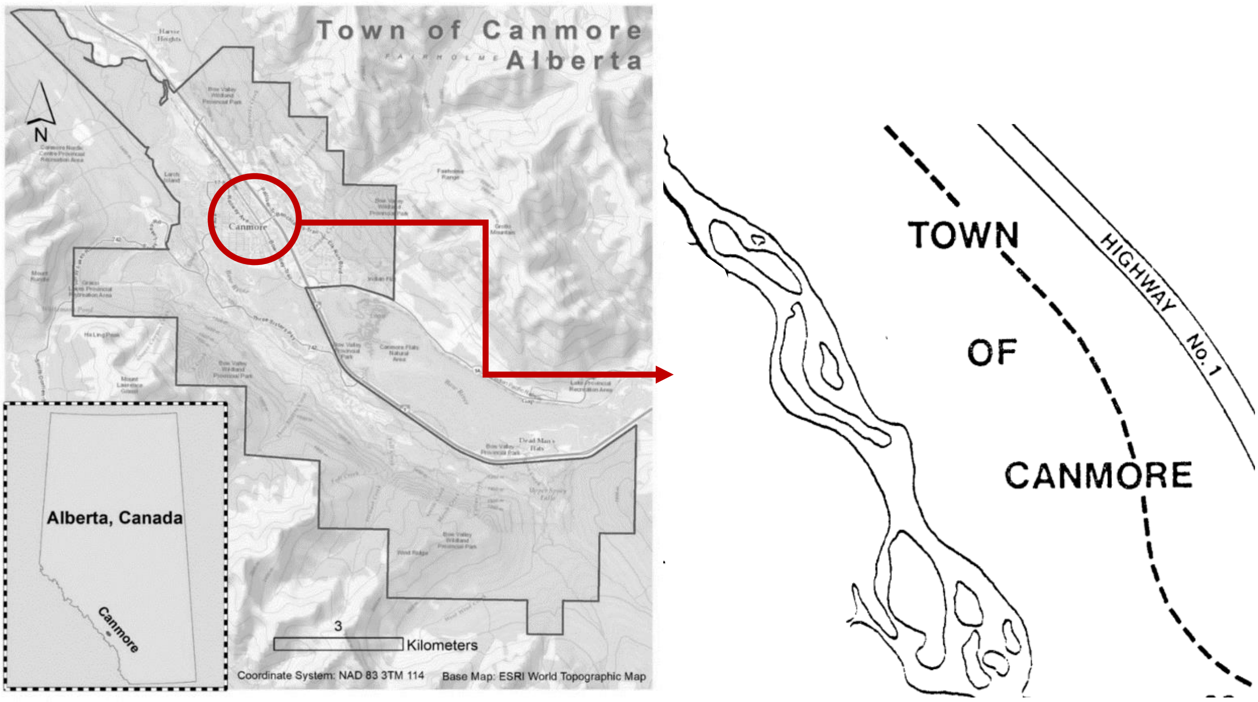

Figure 31. *show the border of Canmore Town, Alberta, from all sides. (Guo, Jiaao, 2020).*

8.3Strategies & Initiatives Driving in Town of Canmore.

In the scenic municipality of Canmore, Alberta, incorporating renewable energy into land use planning has emerged as a significant obstacle. In response to this complex challenge, Canmore embraces a holistic approach to curbing emissions and fostering sustainable development. The town has embarked on various strategic measures and programs to confront the urgent matter of climate change.

In combating the climate crisis, Canmore is prioritizing the "Accelerating the Growth of Renewable Energy Strategy," recognizing that urgent and ambitious action is imperative. By

2030, Canmore aims to derive 30% of its energy from renewable sources, underscoring its commitment to elevating Alberta's renewable energy production (Schulz & Neudorf, 2023)

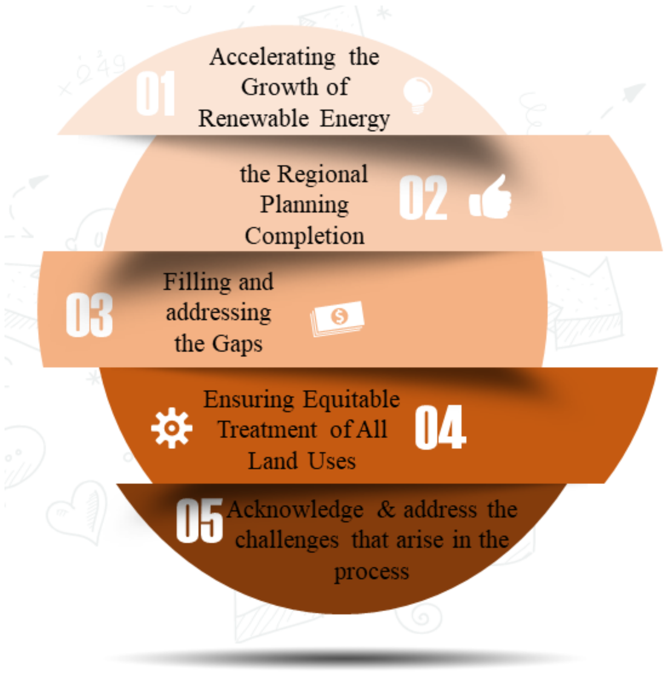

Figure 32. *show the Strategies and Initiatives of Canmore Town. Author's elaboration*

This endeavor seeks to lower consumer costs and holds promise for generating revenue for municipalities and landowners while fostering job creation opportunities, reflecting a comprehensive and human-centered approach to addressing the climate challenge (Schulz & Neudorf, 2023).

In the hierarchy of priorities, "the Regional Planning Completion Strategy," as stipulated by the Alberta Land Stewardship Act, occupies a significant position. The strategy is designed to advance long-term sustainable development, ensure the well-being of future generations, and address cumulative effects within the region. However, despite the fifteen years since its inception, land-use plans still need to be completed in five of Alberta's seven land-use planning regions. Some plans have undergone or are on the brink of undergoing their 10-year review (Schulz & Neudorf, 2023).

Canmore is actively engaged in the overdue completion of regional planning processes mandated by the Alberta Land Stewardship Act. The town endeavors to establish a robust framework that promotes R's development, prioritizes ecosystem preservation, and fosters sustainable development. By addressing the deficiencies and delays inherent in land-use planning, Canmore aims to provide a comprehensive approach to regional planning that aligns with the objectives of the Alberta Land Stewardship Act (Schulz & Neudorf, 2023).

The third strategic approach is "filling and addressing the gaps," mainly because a notable deficiency exists in the conservation of natural landscapes in Canmore. This is particularly evident in regions conducive to renewable energy development (Schulz & Neudorf, 2023).

The Parkland and Grasslands natural regions, characterized by their potential for sustainable energy ventures, are markedly underrepresented in legally protected areas, with a mere 0.93% and 1.25% coverage, respectively. This stark contrast is accentuated when compared to jurisdictions such as Yukon, Manitoba, Quebec, and British Columbia, which have committed to conserving significantly larger proportions of their landmass by 2030, underscoring a disparity in conservation efforts (Schulz & Neudorf, 2023)

Consequently, Alberta's inability to align with international conservation objectives threatens its status as a frontrunner in responsible energy development. By embracing and actively pursuing the goal of expanding nature protection, Alberta can keep up with its peers and maintain its reputation as a leader in environmental stewardship.

The final strategy, "Ensuring Equitable Treatment of All Land Uses," emphasizes the importance of treating all land uses pretty and consistently, regardless of their nature. This includes mining, forestry, agriculture, urban growth, and renewable and non-renewable energy projects. The Government of Alberta has highlighted instances where the expansion of industrial activities has led to adverse environmental impacts. However, it is crucial to recognize that these are not the sole reasons for the halt in renewable energy approvals (Schulz & Neudorf, 2023).

The Canmore approach is committed to incorporating renewable energy by prioritizing energy efficiency. The town's efforts concentrate on integrating renewable energy into land use planning and shifting away from reliance on fossil fuels. Despite the potential benefits of this integration for fostering environmental sustainability, it is crucial to recognize and tackle the challenges illustrated in Figure 32 that may emerge during implementation. Through proactive engagement with these obstacles, Canmore can chart a course toward a successful transition to renewable energy and sustainable development.

8.4Analysis & Studying of the Challenges Before Commencing

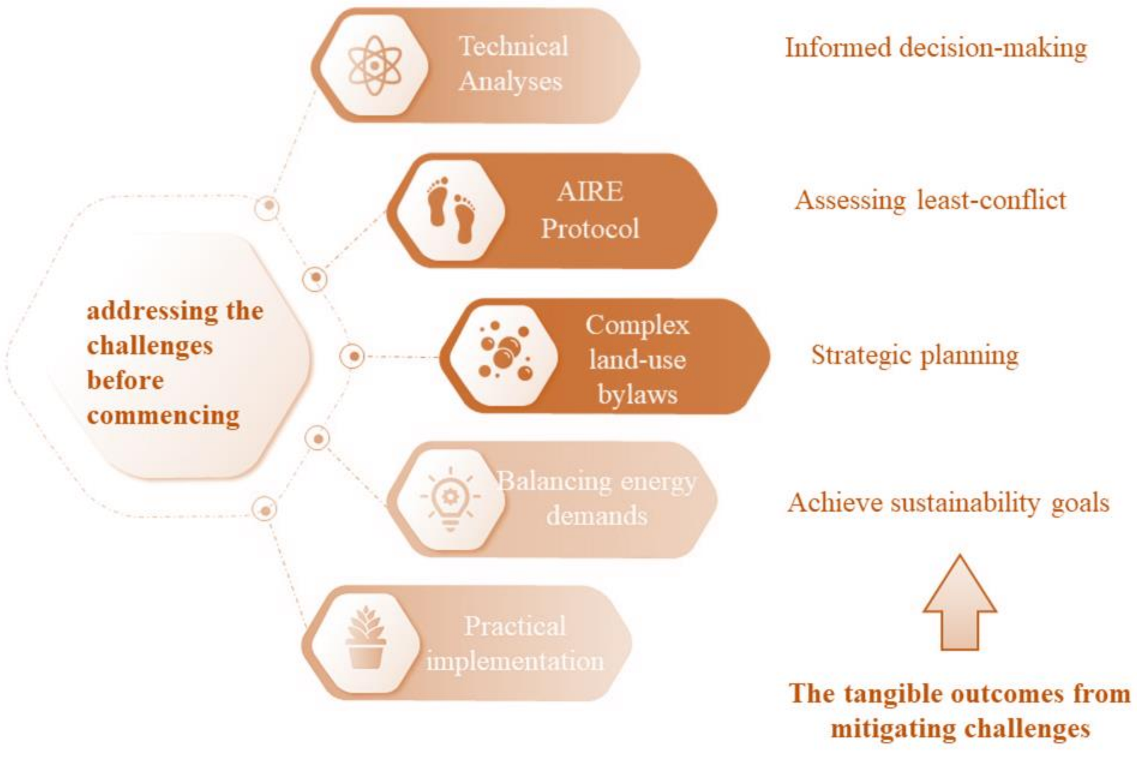

Figure 33. *The tangible outcomes from analyzing the challenges. Author's elaboration*

Urban renewal in Canmore confronts hurdles crucial for success, notably limited land due to existing economic and ecosystem uses. This constraint narrows the potential areas for renewable energy deployment, as balancing economic activities and ecological preservation is paramount. Negotiating this intricate balance underscores the complexity of urban renewal efforts in Canmore. A nuanced approach is essential to navigate these challenges effectively and foster sustainable development.

A fundamental obstacle in Canmore pertains to Technical Analyses, which are pivotal for tackling infrastructure, environmental impact, and land use planning within the urban renewal endeavor. Comprehensive technical analyses are imperative to navigate these complexities, guiding the concept development phase and ensuring alignment with the town's sustainability objectives. This challenge accentuates the criticality of conducting meticulous technical assessments to facilitate informed decision-making and the project's successful implementation (Guo, Jiaao, 2020).

Hence, obstacle the AIRE Protocol poses a significant local challenge, displayed in Figure 33, offering a standardized framework for local governments. It aims to advance renewable energy (RE) implementation within land-constrained areas by integrating academic resources, technically recoverable lands, legal accessibility, and spatial capital costs. The protocol evaluates overall RE potential by assessing least-conflict lands and various land-use planning scenarios (Guo, Jiaao, 2020).

Moreover, Canmore needs more resources. It is considered a small land constrained and encounters significant limitations regarding financial capabilities and human resources, which can impede the successful implementation of renewable Canmore energy projects. The scarcity of resources poses a considerable challenge, as local government must strategically allocate their limited funds and personnel to various competing priorities, often leaving renewable energy initiatives underfunded or understaffed. Furthermore, Canmore municipality did not accept surrendering to this challenge.

On the other hand, Complex land-use bylaws pose significant challenges for Alberta governments, particularly in the context of urban renewal energy projects in Canmore (Guo, Jiaao, 2020). These regulatory frameworks are formidable barriers to implementing renewable energy initiatives, complicating alignment with sustainability goals.

Such intricate regulations require substantial expertise, time, and resources to ensure compliance and promote clean energy development. Overcoming these challenges necessitates strategic planning, stakeholder engagement, and a profound comprehension of the regulatory landscape to advance renewable energy projects amidst complex land-use regulations effectively.

The challenge of balancing Energy Demands and Practical Implementation stands as the final hurdle before embarking on the journey to achieve sustainability goals in Canmore. Striking a delicate equilibrium between burgeoning energy needs, evolving land-use dynamics, and the pragmatic execution of renewable energy projects is paramount yet intricate. Canmore's governing bodies navigate this equilibrium to ensure renewable energy's sustainable and efficacious integration into land use planning (Guo, Jiaao, 2020).

Furthermore, Practical Implementation Challenges emerge as formidable obstacles despite the availability of ample land to realize ambitious renewable energy targets within restrictive scenarios. These challenges encompass technical constraints, financial limitations, and community acceptance issues, which must be addressed comprehensively. Overcoming these practical hurdles is essential to translate renewable energy aspirations into tangible outcomes, fostering a resilient and sustainable energy landscape in Canmore, as displayed in Figure 33.

Addressing these challenges proactively necessitates preemptive action before commencing to mitigate potential disruptions. Strategic planning and stakeholder engagement are imperative and mainly directed towards the Canmore government. Innovative solutions leveraging new technical analyses and a comprehensive understanding of the local context are essential for successfully integrating land-use and renewable energy planning decisions. This concerted effort is vital for fostering sustainable development in Canmore and underscores the collaborative commitment to responsible governance and environmental stewardship.

8.5 Theoretical Challenges Through a Structure to Uniform RE Mapping

This study employs a framework established to accelerate the implementation of the Renewable Energy Initiative. This initiative is designed to aid governments in achieving their goals for carbon reduction and fostering energy-related economic development, particularly in overcoming associated challenges.

The primary aim of this project is to formulate protocols facilitating the expeditious adoption of renewable energy sources within land use planning. A framework has been devised to enable regional and local governments to adopt uniform terminology for renewable energy (RE) planning and development.

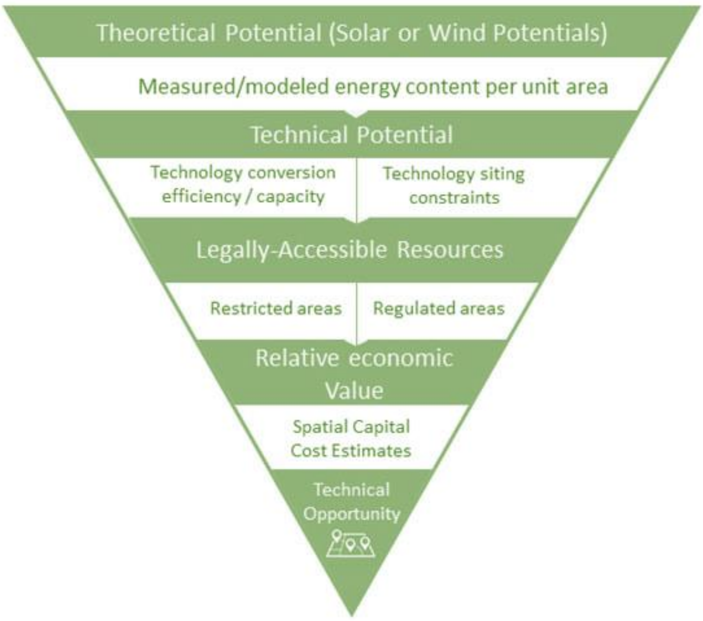

Figure 34. *The framework employed in the Canmore study to achieve detailed technical mapping for local energy planning. (Guo, Jiaao, 2020).*

Figure 34 shows that utilizing an inverted triangle framework is the most productive method for comprehending and illustrating the technical mapping framework. A comprehensive data table (Table 1) is constructed to summarize the available data pertinent to Canmore succinctly. The initial mapping endeavor prioritizes theoretical resources, examining the region's wind and solar energy potential.

Subsequently, an assessment of recoverable resources ensues, necessitating the exclusion of technical constraints such as slope and aspect requirements. The critical focus is directed toward the digital elevation model (DEM), delineating lands with slopes below 35° or less than 10°

when oriented northward as recoverable. Nevertheless, despite meeting these criteria, certain areas remain technically unrecoverable for renewable energy facility development due to the prevailing land-use regulations governing Canmore. This challenge can potentially hinder numerous endeavors (Guo, Jiaao, 2020).

Furthermore, the identification of legally accessible resources entails applying filters aligning with provincial and local land-use regulations and bylaws. This process is predicated on a meticulous classification of Canmore's lands, necessitating a nuanced understanding of the dynamic local environment. Critical to this endeavor is the consultation with Canmore's municipal officials, fostering collaborative decision-making to pinpoint suitable areas, such as municipal parking lots, while not exclusively fixating on unsuitable lands.

The mapping process involves designating roads, railways, and water bodies as legally accessible resources. However, due to the extensive presence of provincial parks and environmentally sensitive lands within Canmore's jurisdiction, a binary filter is applied: semi-permissive areas with partial restrictions and non-permissive areas prohibited from renewable energy (RE) development.

Ground-mount photovoltaic (PV) capacity requires a minimum of 4 hectares of land per megawatt (MW), while wind turbine locations are unrestricted by a minimum area filter, encompassing all (semi-) permissive lands. Theoretical installation capacity incorporates turbine spacing considerations (Guo, Jiaao, 2020).

Finally, the relative economic value of resources is evaluated by assessing the spatial capital costs associated with connecting new facilities, including roads and power lines, to these resources. These intricate steps pose theoretical challenges, beginning with a comprehensive understanding of technical mapping for local energy planning. Subsequent stages involve evaluating recoverable resources to align with lands characterized by suitable slopes and ensuring legal accessibility. Each phase necessitates thorough analysis and requires individuals with professional expertise to interpret and navigate effectively.

8.6 Map of Various Policy Situations

Creating a map delineating various policy situations is a valuable tool for comprehending the evolving landscape of land availability. Certain land-use classifications may still be subject to regulatory or environmental sensitivities, notwithstanding their absence in Canmore's land use bylaw (LUB). This classification presents a notable theoretical challenge, particularly within urban planning and environmental science.

<table>
<tr><th></th><th>Population</th><th>Population Increase Rate</th><th>Per Capita Consumption</th><th>Population Projection</th><th colspan="2">Total Electricity Demands (MWh)</th></tr>
<tr><td>2000</td><td>10,517</td><td rowspan="3">33%</td><td rowspan="3">9166 kWh (2008)</td><td></td><td colspan="2"></td></tr>
<tr><td>2016</td><td>13,992</td><td></td><td colspan="2"></td></tr>
<tr><td>2050</td><td></td><td>>25,000</td><td colspan="2">230,000</td></tr>
<tr><th rowspan="2"></th><th rowspan="2">Required Lands (ha)</th><th rowspan="2">Yearly Production (MWh)</th><th colspan="2">Semi-Permissive Lands (ha)</th><th colspan="2">Maximum</th></tr>
<tr><th>Original</th><th>Recoverable</th><th>Yearly Production (MWh)</th><th>Total Capacity (MW)</th></tr>
<tr><td>A 2.5 MW wind turbine</td><td>25–100</td><td>~6000</td><td>649</td><td>625</td><td>36,000–150,000</td><td>15–225</td></tr>
<tr><td>A 1 MW solar farm</td><td>4</td><td>1300–1600</td><td>559</td><td>537</td><td>174,000–215,000</td><td>134</td></tr>
</table>

***Table 1**. Power requirements and assessment of land-based potential.* (Guo, Jiaao, 2020).

Table 1 examines four scenarios of challenges for solar and wind energy development, incorporating considerations such as habitat patches (depicted in Figure 35A), steep creek hazard zones (Figure 35B), and animal corridors (Figure 35A) within solar energy scenarios. Figure 3D illustrates potential wind turbine installations in wind energy scenarios, encompassing habitat patches and setback buffer distances from residential zones. Consequently, scenario mapping offers an insightful evaluation of the impact of diverse land-use policies on the availability of land for wind and solar energy development (Guo, Jiaao, 2020).

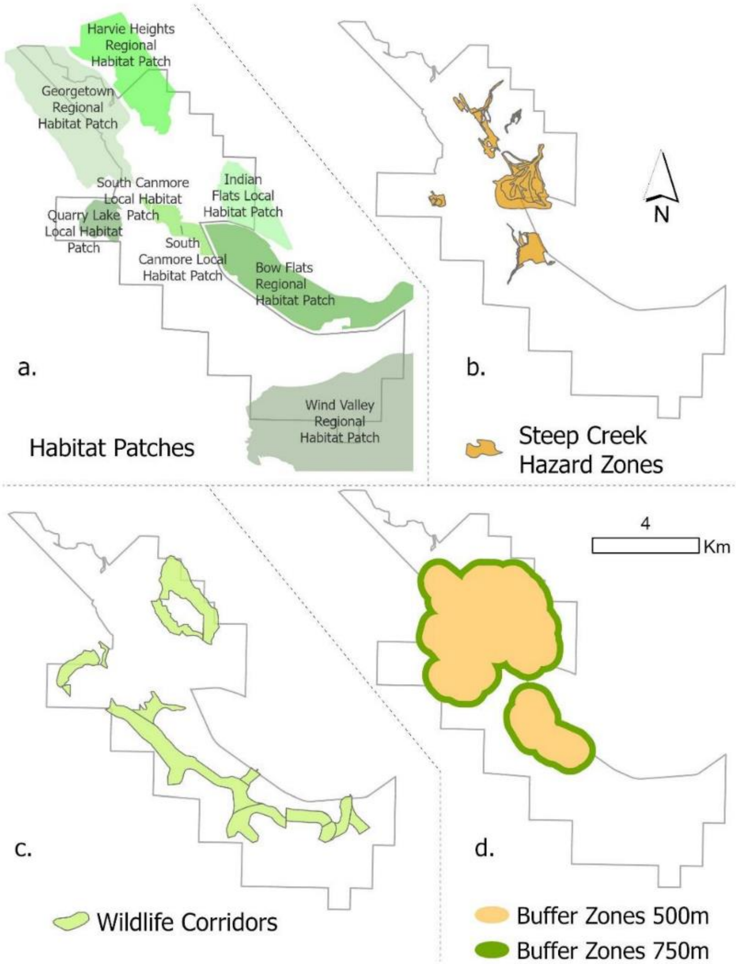

Figure 35. *To corresponding legally accessible layers, four additional criteria are added as scenarios: (a) regional habitat patches; (b) steep creek hazard zones that are susceptible to mass wasting; (c) wildlife corridors; and (d) two setback buffers zones, separated from Canmore's residential areas by 500 and 750 meters, respectively* ***(Guo, Jiaao, 2020)****.*

Scenarios		Solar Energy		Wind Energy	
				Setback Distance	
		Excluding Wildlife Corridor	Excluding Steep Creek Hazard zones	500 m	750 m
Including	Habitat patches	1. Only excludes the wildlife corridor that overlapped with legally accessible lands	2. Steep creek hazard zones are extracted from scenario 1	1. Excludes lands within 500 m of noise receptors (residential zones)	2. Excludes lands within 750 m of noise receptors (residential zones)
Excluding		3. Habitat patches within Canmore boundary would be excluded + scenario 1	4. Both habitat patches and steep creek hazard zones are excluded.	3. Excludes habitat patches + scenario 1	4. Excludes habitat patches + scenario 2

Table 2. *Scenarios for potential solar energy and wind energy development.* ***(Guo, Jiaao, 2020)***.

RE resources that are easy to Access Figure 36a, b maps theoretical resources (solar and wind potentials). The basic patterns of power potential for wind and solar energy are the opposite: Canmore's south and east have higher wind speeds, while its north and west have more potential for solar power. The annual average wind speed (max) of the IEC wind classes is the basis for the wind classification. Figure 4c shows the theoretically recoverable lands.

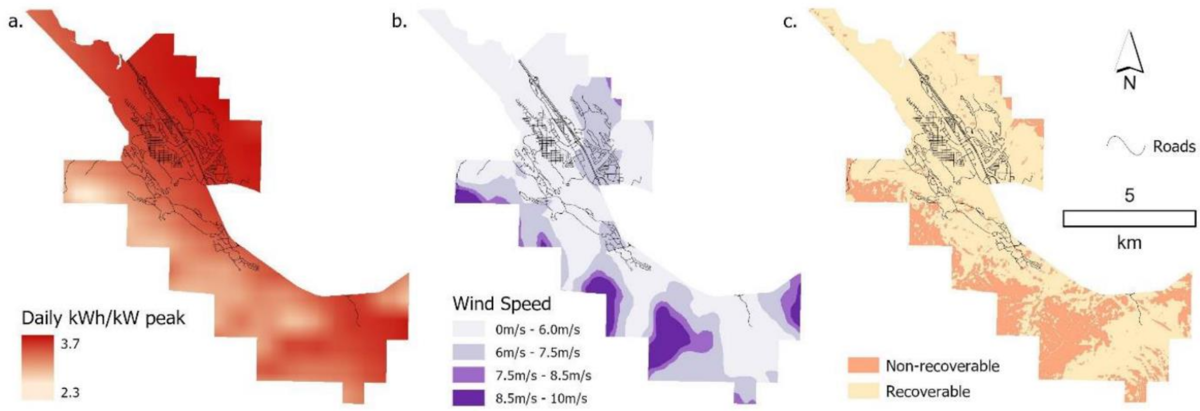

Figure 36. *shows the theoretical resources for (a) wind potentials and solar PV input, and (b) technically recoverable potentials that take slopes and aspects into account.* (Guo, Jiaao, 2020)

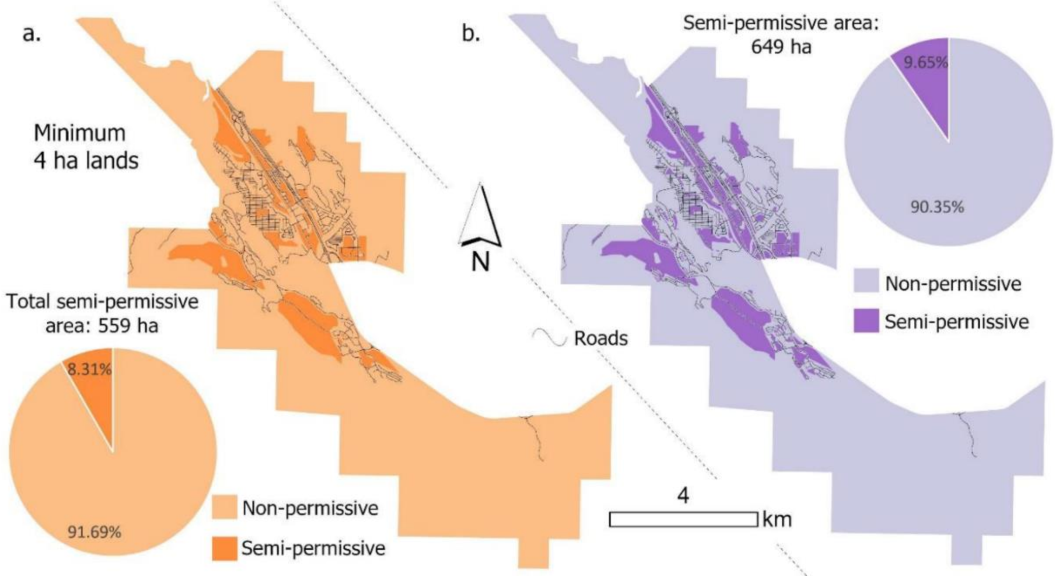

Figure 37. *Resources for solar (a) and wind (b) energy that are legally available, largely determined by land use bylaw (LUB).* (Guo, Jiaao, 2020)

Canmore's land-use bylaw (LUB) governs the arrangement of legally accessible areas (Figure 37). Here, there is a distinction between two classes: semi-permissive and non-permissive areas. The site may be developed for RE use under the semi-permissive class (darker colors in Figure 37), but only with some potential concessions made by stakeholders, decision-makers, and community members.

LUB determines the setback distances for roads, railroads, and bodies of water. Developments on properties classified as non-permissive (Figure 37, lighter colors) are not given priority for RE development. In addition to the LUB classification, other legally accessible levels are considered. Provincial parks are considered off-limits areas, and municipal parking lots are regarded as semi-permissive lands. The town has 559 ha of semi-permissive land for solar energy development, or around 8.3% of the total land area. A total of 650 acres of land are partially permitted to install wind turbines. None of the properties are entirely permissive; all are at least somewhat so due to stringent land-use laws (Guo, Jiaao, 2020).

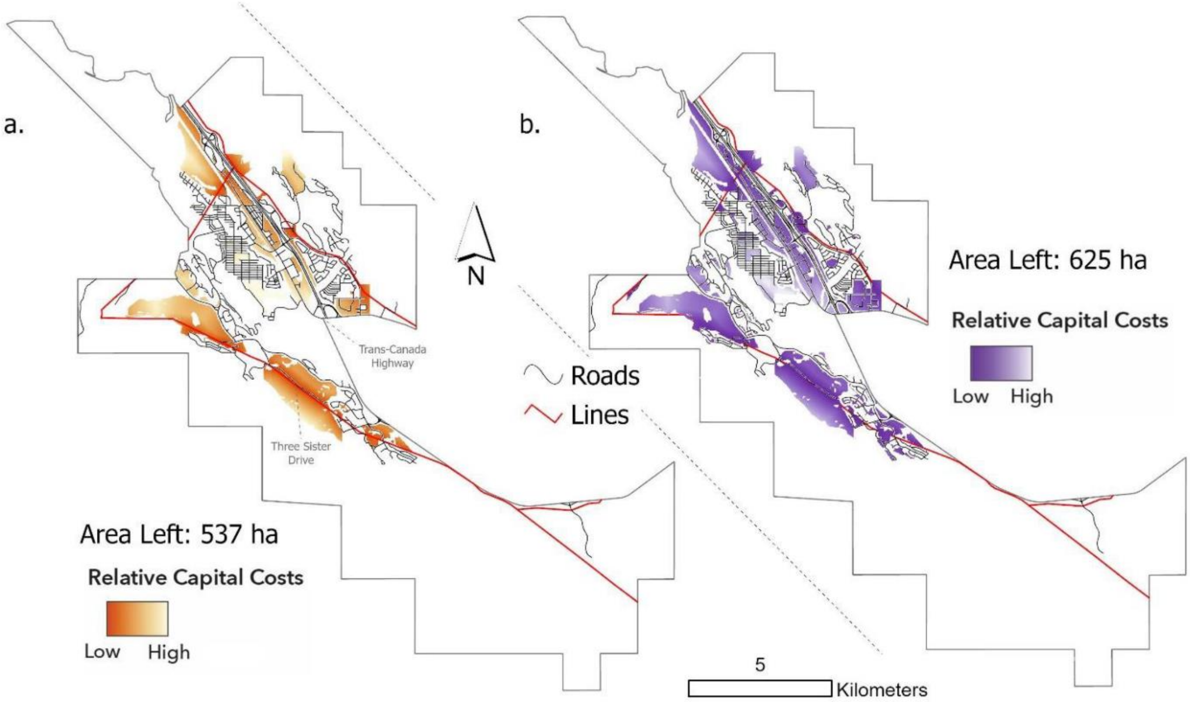

Figure 38. *shows the relative capital cost of extending those resources to the current lines and roadways following the application of constraints for (a) wind and (b) solar potential.* Technically recoverable resources and those semi-permissive lands under legally accessible resources are examples of constraints. (Guo, Jiaao, 2020).

Figure 38 shows the relative economic cost with relative economic cost gradients for solar (left) and wind (right) developments, filtered by non-recoverable lands and non-permissive legally accessible resources. A total of 625 hectares of land remains for wind energy development, and 537 hectares of semi-permissive land are appropriate for solar power development. The areas with extended power transmission and car transportation lines are the most economically viable. Many of the lands are located along Three Sister Drive and the Trans-Canada Highway in northern and central Canmore. (Guo, Jiaao, 2020).

8.7 Scenario Maps

An analysis of the four potential outcomes highlights their impact on land availability for wind (Figure 40) and solar (Figure 39) energy development. A notable observation is the considerable overlap between current legally accessible areas and habitat patches, including the South Canmore Local Habitat Patch, Georgetown Regional Habitat Patches, and Quarry Lake Local Habitat Patch. Conversely, there is minimal concurrence between existing semi-permissive areas and wildlife corridors.

Significantly, the imposition of setback buffers for wind power development renders most semi-permissive lands in northern Canmore unusable. Hence, the town's decision to adopt wind turbine buffer zones will profoundly influence future developments in wind energy initiatives. This assessment underscores the critical role of municipal policies in shaping the trajectory of renewable energy projects within Canmore's landscape.

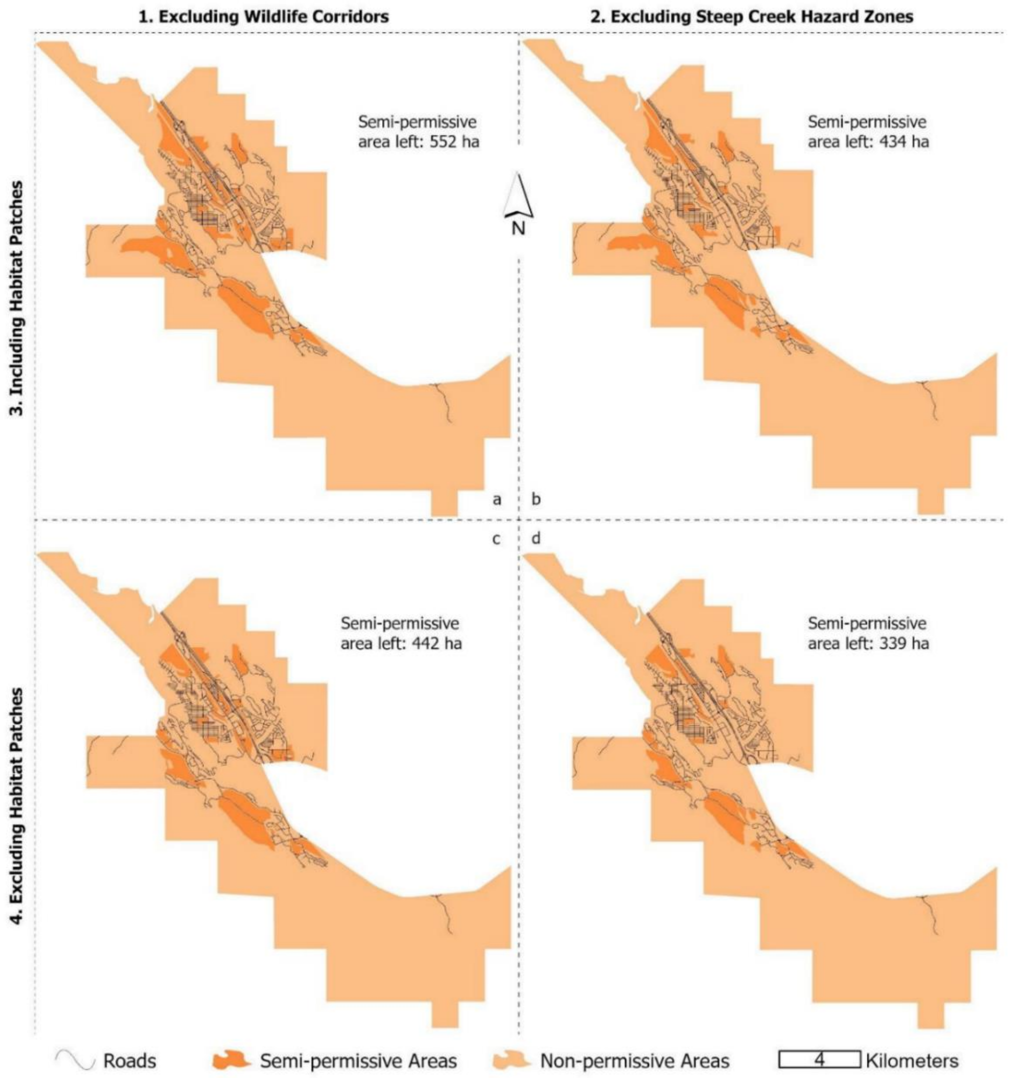

Figure 39. *A) omitting wildlife corridors; b) ignoring wildlife corridors and steep creek hazard zones; c) excluding wildlife corridors and habitat patches; and d) excluding habitat patches and steep creek hazard zones are the four solar energy development scenarios.* (Guo, Jiaao, 2020).

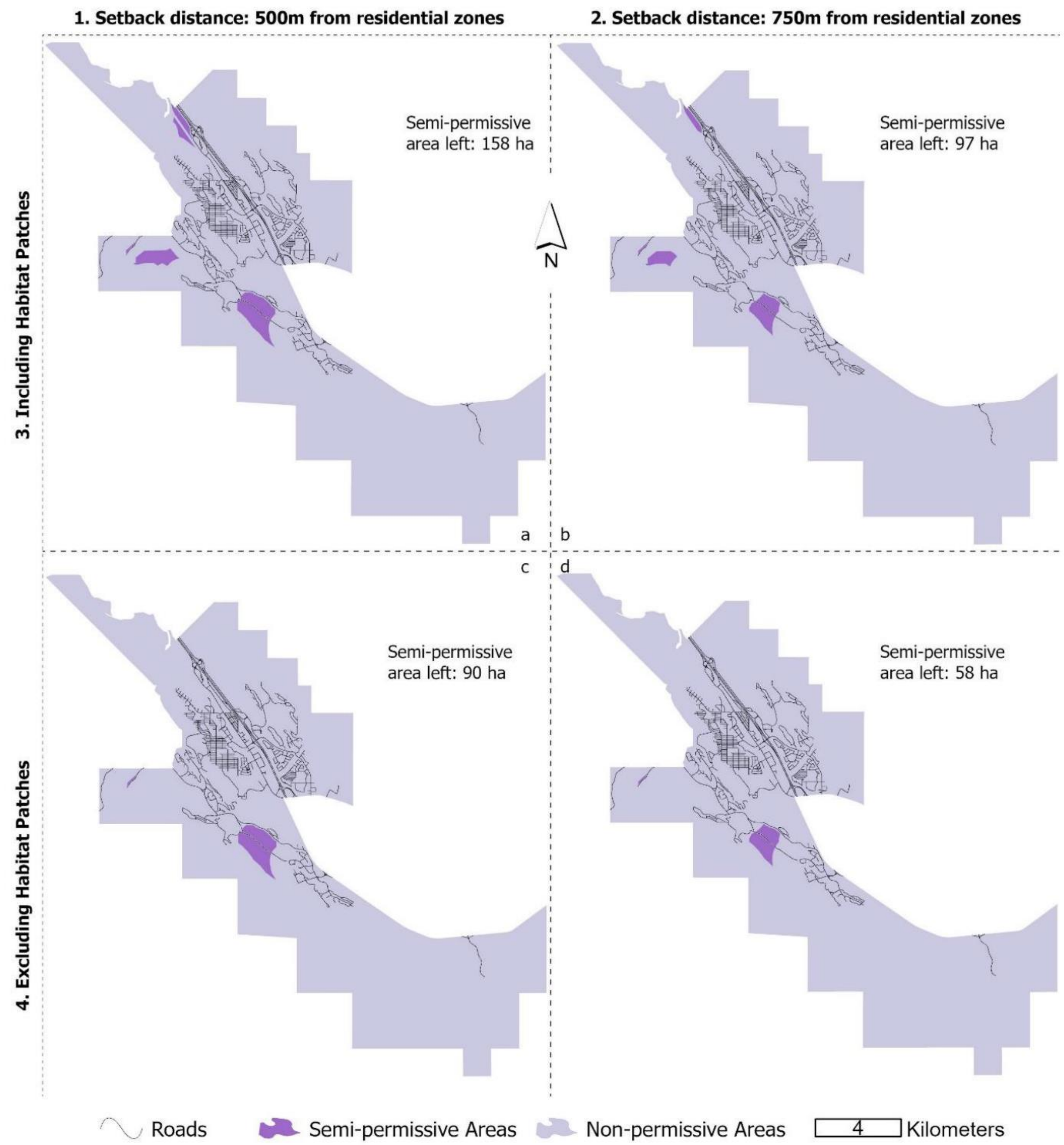

Figure 40. *A 500 m setback distance from residential zones is applied in (a) wind development scenario. A 750 m setback distance is applied in (b) wind development scenario (Figure 8). A 500 m setback distance is applied in (c) wind development scenario (and habitat patches are excluded). A 750 m setback distance is applied in (d) wind development scenario.* (Guo, Jiaao, 2020).

8.8 Calculating the Generation of RE

We could calculate the relevant energy production potential in Canmore based on the technical mapping results of the available lands, land demand, and annual output of utility-scale solar farms or wind turbines. It contrasts this with the anticipated increases in population growth and per capita consumption to determine the future electricity demands. However, estimating energy output and future demands might take work.

All the characteristics that need to be considered could drastically change in several ways, including production changes brought about by improvements in the efficiency of solar panels or wind turbines, consumption changes brought about by inhabitants' changing lifestyles, population changes, or an increase in the number of electric vehicles. To simplify the process, the number of factors used to assess the RE potential will be restricted to the town's per capita emissions and population growth.

Table 2 estimates the power demands by 2050, population increase, per capita power consumption, and the necessary and accessible acreage for solar and wind energy options based on yearly unit production. According to this approximation, if semi-permissive areas turned into solar farms, they will be sufficient to meet Canmore's emission-reduction target (eighty percent below 2015 levels by 2050). Wind turbines might be a significant factor in Canmore's energy transition, depending on the future conditions. Because solar energy does not have strict land requirements, it is often more promising in Canmore (Guo, Jiaao, 2020).

8.9 Discussion & Conclusion

It is imperative to underscore the conceptual framework's design, aiming for transferability and universality (Figure 34). However, specific parameters must adapt to local demands, as evidenced in Canmore. Here, judgments on semi-permissive areas significantly impact renewable energy potential, entailing challenges. Canmore's topography yields variations in theoretical resources and legal constraints, complicating future RE prospects. Moreover, existing regulations and land intersections with provincial parks add complexity, necessitating policy focus.

Canmore's small scale offers an opportunity to meticulously integrate the jurisdiction's land-use bylaw, challenging broader RE planning. Evolving laws governing land use and renewable energy underscore the need for continual adaptation. Engaging residents through participatory mapping leverages local insights, advancing RE planning amid changing legal frameworks. Balancing dynamic regulations with practical implementation requires effective stakeholder engagement, ensuring that local preferences are integrated and enhances project feasibility and sustainability.

Challenges revolve around balancing the dynamic nature of legal frameworks with practical implementation. Effective stakeholder engagement reconciles diverse interests, promoting successful RE project integration. This inclusive strategy enhances initiatives' legitimacy by incorporating local preferences, thus improving overall feasibility and sustainability.

Data limitations in Canmore hinder technological mapping, highlighting the need for improved data collection and resolution. Additionally, the economic layer's relative scale underestimates expenses, warranting refinement in estimating energy generation potential and comprehensive cost assessments.

During the study period, Alberta's new government halted incentive programs, casting uncertainty on Canmore's energy transition. Without provincial support, the local transition remains uncertain despite declining renewable energy costs. Addressing these issues demands policy interventions, supporting renewable energy, and revising carbon pricing.

Moreover, Canmore's potential transition to renewable energy poses uncertainty in provincial policy, necessitating collaborative efforts. Canmore acknowledges the necessity of forging alliances, demonstrating the significance of collective action in driving a sustainable energy future.

The provincial administration's suspension of incentive programs highlights the necessity for policy measures to reinstate or establish renewable energy incentives, amend carbon pricing, and delineate transparent emission reduction strategies. A stable policy framework providing unwavering support for renewable energy is indispensable for achieving a smooth transition in the energy sector.

Conclusion

The alignment of land-use and renewable energy planning offers a substantial chance to advance sustainable development and curb greenhouse gas emissions, exemplified by Canmore, Alberta. The municipality is proactively enhancing renewable energy generation, aiming to derive 30% of its energy from renewable sources by 2030 (Guo, Jiaao, 2020).

Canmore seeks to create a framework facilitating renewable energy expansion while conserving habitats and promoting sustainable growth. This initiative includes rectifying nature protection gaps and fulfilling overdue regional planning mandates under the Alberta Land Stewardship Act.

Despite completing the initial phase of studying the potential benefits of integrating renewable energy into land use planning, Canmore may encounter challenges such as limited municipal area, complex land-use bylaws, access to legally available lands, spatial capital costs, and reconciling energy demands with land use changes. These obstacles require strategic planning, stakeholder engagement, and innovative solutions to ensure successful integration and achieve emission reduction goals. The next phase of the study will involve:

- Mapping community input on potential locations for renewable energy facilities.
- Requiring a better understanding of local objectives.
- Renewable energy sources.
- The energy system.

The intricate nature of legal frameworks, environmental concerns, and the requirement for thorough regional planning might impede Canmore's integration of renewable energy into land use planning. Collaborative efforts among stakeholders, lawmakers, and local communities are crucial to prioritizing sustainability, reducing emissions, and fostering renewable energy growth. By tackling these obstacles and leveraging opportunities for renewable energy expansion, Canmore can improve its effectiveness in merging land-use and renewable energy planning choices, ultimately advancing toward a more sustainable future that harmonizes economic development with environmental preservation.

Moreover, transitioning to renewable energy entails balancing energy provision, predominant land-use functions, and related social values. We recommend that local governments and tiny municipalities evaluate how their land-use strategies affect renewable energy availability, monitor market rates of different renewable energy sources, and manage energy demands to facilitate the transition. Significantly, we illustrate how a standardized approach to renewable energy planning, aided by technical mapping, can be applied universally with varied resource recoverability criteria.

The challenges highlighted in integrating land-use and renewable energy planning decisions underscore the complexities faced by local governments, particularly in regions like Canmore, Alberta. The technical mapping guide for Canmore underscores the importance of identifying suitable lands for renewable energy development while sustaining land-based economies and ecosystem services. Despite ambitious renewable energy targets, challenges such as limited resources, complex land-use bylaws, and practical implementation issues pose significant hurdles.

In conclusion, the case study in Canmore illustrates the delicate balance required to advance renewable energy projects effectively within small, land-constrained local governments. Overcoming these challenges necessitates strategic planning, stakeholder engagement, and innovative solutions to navigate regulatory complexities and resource constraints. Achieving long-term emission reduction goals depends on finding an equilibrium between energy demands, land-use changes, and practical renewable energy development. Mapping systems analyzing the impact of land-use planning decisions on renewable energy potential are essential for achieving this balance and fostering sustainable energy initiatives in communities like Canmore.

9. Comparison Between Literature Review & Urban Renewal Projects in Canmore

9.1Comparison

E. Implementation Context

F. Solar Photovoltaics (PV) Usage & Building-Integrated Photovoltaics (BIPV)

G. Impact & Legacy

9.2 Discussion

Figure Z. *Sketch shows the comparison between two side.*

Source. The photo take from Google and edit by Author's.

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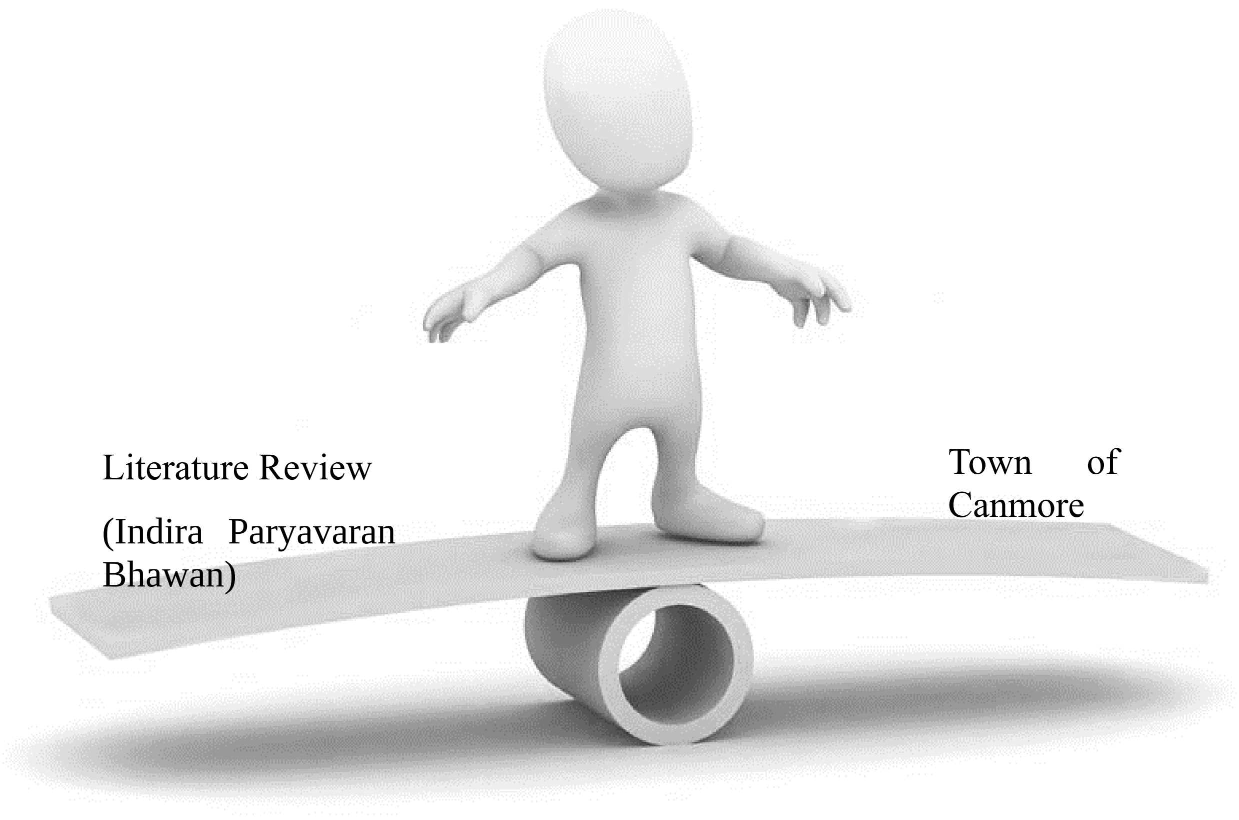

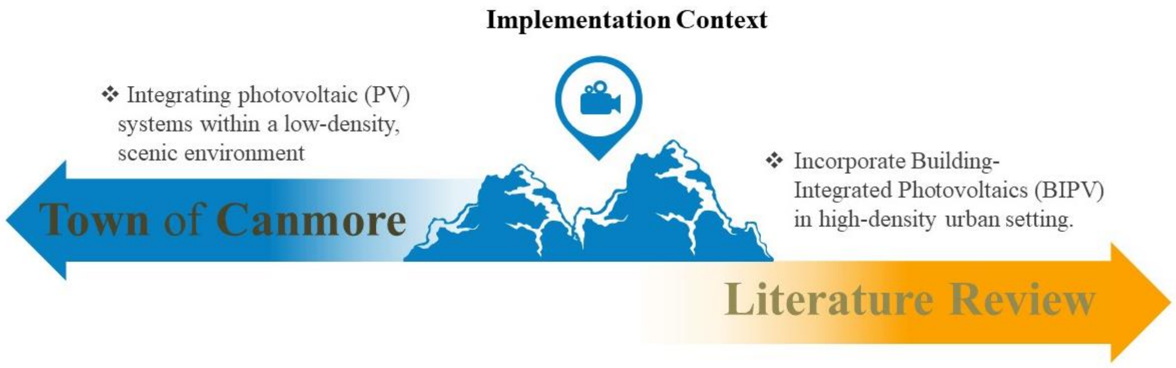

Figure 41. *application of implementation context between Town of Canmore literature review. Author's elaboration*

E. Implementation Context:

The implementation contexts of Canmore, Alberta, and Indira Paryavaran Bhawan, New Delhi, exemplify the practical application of renewable energy integration and land use planning as discussed in the literature review.

Canmore's focus on integrating photovoltaic (PV) systems within a low-density, scenic environment to preserve natural beauty and enhance sustainability aligns with principles of community involvement and minimal environmental disruption. This approach adheres to and exemplifies the theoretical concepts outlined in studies emphasizing the significance of community-driven sustainability initiatives and the careful integration of renewable technologies into existing landscapes (Smith, 2024).

Conversely, Indira Paryavaran Bhawan, in a high-density urban setting, employs innovative design to incorporate Building-Integrated Photovoltaics (BIPV) into facades, rooftops, and shading devices. This strategy maximizes space efficiency and achieves net zero energy consumption, demonstrating how advanced design techniques can be utilized in constrained urban environments to meet sustainability goals. The project's success in integrating BIPV reflects previous research findings highlighting the importance of innovative architectural solutions in dense urban areas (Smith, 2024).

F. Solar Photovoltaics (PV) Usage and Building-Integrated Photovoltaics (BIPV):

In Canmore, photovoltaic (PV) systems are strategically installed on rooftops or open spaces. Typically, these installations are part of community-driven sustainability initiatives, reflecting the broader literature on renewable energy integration (Smith, 2024). For instance, if a typical PV system in Canmore generates about 1.2 kWh per square meter per day, a 100-square-meter installation can produce approximately 120 kWh daily, amounting to 43,800 kWh annually.

This approach emphasizes incorporating technologies like PV systems to reduce carbon footprints, aligning with fundamental land use planning principles. Canmore's practices illustrate the interrelationship between renewable energy integration and land use planning by ensuring that PV installations complement the environment without causing disruption.

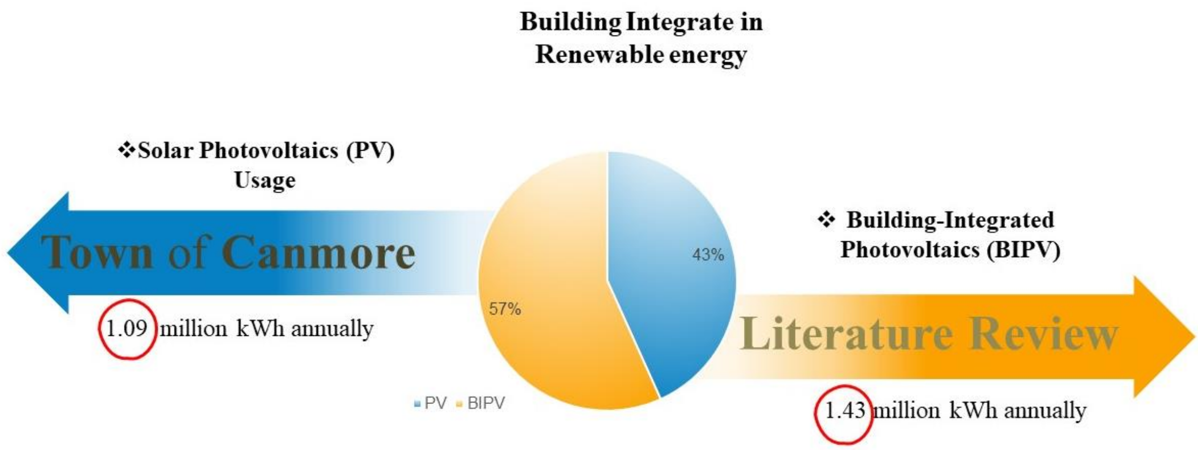

Figure 42. *comparison of KWH annually between PV in Canmore and BIPV in Indira Paryavaran Bhawan's. Author's elaboration*

The careful site selection and strong community involvement observed in Canmore's strategy are consistent with findings from previous studies on renewable energy integration, highlighting the importance of factors such as geographical location and public participation (Smith, 2024). For example, a community-driven project might involve 50 households, each installing 20 square meters of PV panels, collectively generating 1,095,000 kWh annually (assuming the same 1.2 kWh/m²/day efficiency), significantly contributing to the town's renewable energy targets.

The careful site selection and strong community involvement seen in Canmore's strategy are consistent with findings from previous studies, highlighting the importance of factors such as geographical location and public participation in successfully integrating renewable energy (Smith, 2024).

Conversely, Indira Paryavaran Bhawan employs Building-Integrated Photovoltaics (BIPV) in a high-density urban environment, incorporating PV systems into the building's facades, rooftops, and shading devices. This innovative design maximizes space efficiency and achieves net zero energy consumption. The building generates 1.43 million kWh annually, slightly exceeding its energy consumption of 1.421 million kWh, demonstrating the effectiveness of BIPV in optimizing limited urban space.

The integration of BIPV at Indira Paryavaran Bhawan showcases advanced sustainable development practices. For instance, the building's design ensures that every possible surface contributes to energy generation, optimizing available space in a densely populated urban area (Smith, 2024).

While Canmore and Indira Paryavaran Bhawan differ significantly in their environmental contexts—low-density scenic versus high-density urban—they share a commitment to sustainability through the integration of PV systems. Canmore's standalone PV systems reflect a community-driven, context-specific approach that ensures renewable technologies blend seamlessly with the natural landscape. For instance, a typical community project in Canmore can produce over 1 million kWh annually, contributing significantly to local energy needs without disrupting the environment.

In contrast, Indira Paryavaran Bhawan's use of BIPV represents a sophisticated application of renewable energy in a constrained urban setting. Generating 1.43 million kWh annually, the building not only meets but slightly exceeds its energy requirements, illustrating the potential of BIPV to achieve high-performance sustainability goals in urban areas.

Both cases underscore the importance of context in renewable energy integration. Canmore's approach demonstrates how standalone PV systems can effectively contribute to sustainability in low-density areas by leveraging open spaces and community involvement. Meanwhile, Indira Paryavaran Bhawan exemplifies how BIPV can optimize energy generation in high-density settings, setting a precedent for urban renewable energy projects.

These examples illustrate the broader applicability of PV technology across diverse settings, reinforcing the argument that tailored renewable energy solutions, aligned with local conditions and needs, are essential for achieving comprehensive sustainability goals (Smith, 2024).

G. Impact & Legacy

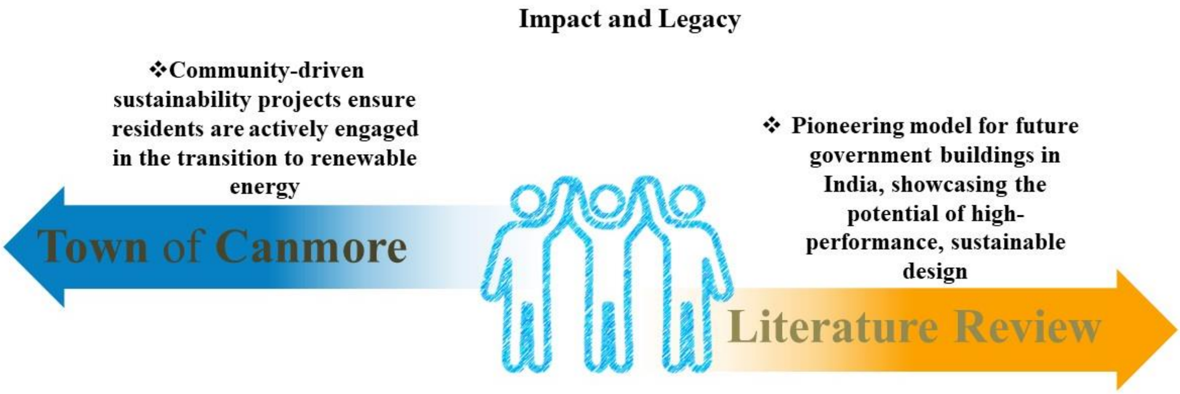

Figure 43. *comparison of* impact and legacy *between Canmore and literature review. Author's elaboration*

Integrating photovoltaic (PV) systems in Canmore significantly impacts the town's commitment to mitigating its carbon footprint and promoting sustainable tourism and living. By incorporating renewable energy technologies into urban renewal projects, Canmore exemplifies how small towns can contribute to global sustainability efforts. These initiatives aim not only to achieve environmental goals but also to foster community involvement and awareness.

Smith (2024) notes, "Community-driven sustainability projects ensure residents are actively engaged in the transition to renewable energy, increasing public understanding and support for such measures." The emphasis on harmonizing PV systems with the natural and built environment further strengthens Canmore's reputation as a leader in sustainable development.

Indira Paryavaran Bhawan is a pioneering model for future government buildings in India, showcasing the potential of high-performance, sustainable design. The project sets a precedent for adopting similar green building practices nationwide.

According to Smith (2024), "The building influences architects and builders in India and internationally by effectively demonstrating the viability and benefits of Building-Integrated Photovoltaics (BIPV) in urban settings." Integrating BIPV systems into the building's design highlights such technologies' practical and aesthetic advantages, encouraging their wider adoption.

The successful implementation of these advanced sustainability measures in a high-density urban environment underscores the feasibility of achieving net zero energy consumption, inspiring future projects to pursue ambitious environmental goals. Indira Paryavaran Bhawan thus leaves a legacy as a benchmark for sustainable urban architecture.

9.2 Discussion

Integrating renewable energy (RE) technologies into land use planning presents complex challenges that vary significantly depending on geographic and socio-economic contexts. This discussion synthesizes insights from literature and a case study of Canmore, Alberta, to explore these challenges and strategies for addressing them.

Environmental & Aesthetic Considerations

A prominent challenge identified in the literature is balancing landscapes' aesthetic and environmental integrity with deploying renewable energy systems. This is particularly relevant in regions like Canmore, which is known for its natural beauty. According to Jones, Smith, and Thompson (2023), RE projects must be designed to blend seamlessly with their surroundings to minimize visual and environmental impact. Canmore exemplifies this challenge by striving to preserve its scenic views while integrating photovoltaic (PV) systems.

In Canmore, the aesthetic integration of PV systems is crucial. Standalone PV installations are carefully sited to ensure minimal visual disruption. For example, a 100-square-meter PV installation in Canmore, producing approximately 43,800 kWh annually, is positioned in open spaces that do not detract from the natural landscape (Smith, 2024). This strategy aligns with the findings of Jones et al. (2023), which emphasize the importance of aesthetic considerations in RE project planning.

Community Engagement & Public Support

The literature highlights the critical role of community engagement in integrating renewable energy technologies successfully. Community-driven sustainability initiatives are essential for gaining public support and ensuring the long-term success of RE projects.

Canmore's approach exemplifies this principle through robust community involvement. Residents participate in planning and implementing PV projects, enhancing public acceptance and commitment to sustainability. For instance, community projects involving multiple households can generate significant energy, contributing to the town's renewable energy goals (Smith, 2024). This aligns with broader findings in the literature that emphasize the importance of public participation in renewable energy adoption (Smith, 2024).

Technological & Spatial Constraints

Technological advancements have enabled more efficient and flexible integration of RE systems, but spatial constraints, particularly in urban and peri-urban areas, remain a significant hurdle. The literature suggests that Building-Integrated Photovoltaics (BIPV) offer a promising solution for optimizing space usage in dense environments (Brown & Green, 2022). However, such technologies require innovative design and engineering solutions to maximize efficiency and minimize spatial footprint.

While Canmore primarily utilizes standalone PV systems, the principles of BIPV integration observed in urban settings such as Indira Paryavaran Bhawan can provide valuable insights. Indira Paryavaran Bhawan maximizes energy generation from available surface areas by integrating BIPV systems into facades, rooftops, and shading devices. This building achieves net zero energy status, generating 1.43 million kWh annually and slightly exceeding its consumption of 1.421 million kWh (Smith, 2024). This demonstrates the feasibility of achieving high performance in space-constrained environments through innovative architectural solutions.

The strategies employed in Canmore can be contrasted with those used in high-density urban environments. Canmore's focus on standalone PV installations in open spaces aligns with its low-density, scenic context. In contrast, Indira Paryavaran Bhawan employs BIPV systems to maximize energy efficiency in a high-density urban setting. According to Smith (2024), "The building influences architects and builders in India and internationally by effectively demonstrating the viability and benefits of Building-Integrated Photovoltaics (BIPV) in urban settings." This comparison underscores the importance of context-specific solutions in RE integration, highlighting that different environments require tailored approaches to overcome unique challenges.

Conclusion

10.1 Summary

10.2 Key Findings

10.3 Implications for Future Research

Conclusion

10.1 Summary

Integrating renewable energy (RE) technologies within land use planning frameworks presents complex challenges that vary significantly depending on geographic, socio-economic, and environmental contexts. This thesis explored these challenges through a comprehensive literature review and a detailed Canmore, Alberta case study. The findings underscore the critical importance of balancing technological advancements with environmental preservation, fostering robust community engagement, and implementing innovative design solutions tailored to specific contexts.

In Canmore, the primary challenges revolve around maintaining the town's natural beauty and addressing seasonal weather variations while integrating photovoltaic (PV) systems. The town's approach emphasizes careful site selection, aesthetic integration, and strong community involvement, which are necessary for achieving public support and ensuring the successful implementation of RE projects. These strategies align with broader principles identified in the literature, emphasizing the significance of aesthetic considerations and public participation in the effective deployment of renewable energy technologies.

Conversely, in high-density urban environments such as Indira Paryavaran Bhawan in New Delhi, the challenges include maximizing energy efficiency within limited space and mitigating the urban heat island effect. Building-integrated photovoltaics (BIPV) in Indira Paryavaran Bhawan demonstrates the potential of innovative architectural solutions to achieve net zero energy status and optimize space usage in dense urban areas. This case illustrates how advanced design techniques can overcome spatial constraints and achieve substantial environmental benefits.

10.2 Key Findings

- **Aesthetic and Environmental Integration:**

Successful renewable energy (RE) integration necessitates careful consideration of aesthetic and environmental factors to ensure that RE systems harmonize with the natural or built environment. Canmore's blending of photovoltaic (PV) installations with the scenic landscape exemplifies this principle, demonstrating that renewable energy infrastructure can coexist with and even enhance the visual appeal of its surroundings.

- **Community Engagement**

Community-driven sustainability initiatives are crucial for gaining public support and ensuring the long-term success of RE projects. The experience in Canmore illustrates that active community involvement encourages a sense of ownership and improves the overall effectiveness of renewable energy integration. Engaging the community builds support and leverages local knowledge and resources, contributing to more resilient and adaptive energy systems.

- **Technological & Spatial Constraints**

Overcoming spatial constraints, especially in urban areas, requires innovative design and engineering solutions. Integrating Building-Integrated Photovoltaic (BIPV) systems, as Indira Paryavaran Bhawan demonstrates, highlights how advanced architectural techniques can maximize space efficiency and achieve net-zero energy consumption in high-density settings. This approach underlines the importance of incorporating RE technologies into the very fabric of urban infrastructure to optimize energy generation and usage.

- **Context-Specific Strategies**

Different environments demand tailored approaches to renewable energy integration. Canmore's strategies, which focus on standalone PV installations and community involvement in a low-density setting, contrast with urban projects like Indira Paryavaran Bhawan that utilize BIPV systems to optimize energy generation within limited space. This indicates that the effectiveness of RE solutions is highly reliant on contextual factors such as population density, available space, and community engagement levels.

- **Policy And Planning Frameworks**

The effective integration of RE technologies requires supportive policy and planning frameworks that encourage innovation and facilitate the alignment of renewable energy projects with broader environmental and societal goals. Policies that incentivize adopting RE technologies, streamline regulatory processes, and promote sustainable urban planning are essential to overcoming barriers and achieving widespread RE adoption. These frameworks must adapt to different environments' specific needs and challenges, ensuring that RE integration contributes positively to local and global sustainability objectives.

These findings underscore the multifaceted nature of renewable energy integration, highlighting the importance of aesthetic considerations, community engagement, innovative technological solutions, context-specific strategies, and supportive policy frameworks. Collectively, they provide a comprehensive approach to advancing renewable energy adoption and sustainability goals across diverse settings.

10.3 Implications for Future Research

The findings of the thesis suggest several paths for future research. Further studies are needed to explore the long-term impacts of renewable energy integration on local communities and ecosystems. Comparative analyses of different geographic and socio-economic contexts can provide deeper insights into the best practices for RE integration. Additionally, research into developing new technologies and materials that enhance the aesthetic and functional integration of renewable energy systems could significantly advance the field.

In conclusion, integrating renewable energy technologies into land use planning requires a multifaceted approach that balances environmental preservation, technological innovation, and community involvement. By addressing these challenges through context-specific strategies, substantial environmental benefits can be achieved, and contributions to global sustainability efforts can be made.

References

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- *Bauwens, T. (2022, December 18). Conceptualizing community in energy systems: A systematic review of 183 definitions. p. 16. Retrieved from https://example.com/community-energy-systems-review*

- *Bhuiyan, M. A. (2022). Renewable energy consumption and economic growth nexus—A systematic literature review. Frontiers in Energy Research, 12-25. Retrieved from https://www.frontiersin.org/articles/10.3389/fenrg.2022.00012/full*

- *Chigbu, U. E. (2016, March 14). Tenure responsive land use planning: Critical steps for actions in tackling urban poverty in developing countries. Illustrating the meaning of land use planning, pp. 5-6. Retrieved from https://example.com/tenure-responsive-land-use-planning*

- *Christakou, N. (2022, October 31). Renewable-energy development in a net-zero world: Land, permits, and grids. Implications for developers, pp. 6-8. Retrieved from https://example.com/renewable-energy-net-zero-world*

- *Clement, C. (2024). Agrophotovoltaics—Sustainable way to produce food and electricity. Singapore: BIPV Seris. Retrieved from https://bipv.sg/about-seris/agrophotovoltaics-sustainable-way-to-produce-food-and-electricity/*

- *Darani, Z. T. (2021, November 8). Conceptualization of a new generation of smart energy systems and the transition toward them using anticipatory systems. Emerging energy systems, p. 17. Retrieved from https://example.com/smart-energy-systems*

- *Delphin, O. (2021, August 15). Obstacles to the development of integrated land-use planning in developing countries: The case of Paraguay. Lack of Political Will, pp. 5-8. Retrieved from https://example.com/integrated-land-use-paraguay*

- *Ela, V. D. (2013). Impacts of variability and uncertainty in solar photovoltaic generation at multiple timescales. Denver: National Renewable Energy Laboratory. Retrieved from https://example.com/solar-pv-generation-variability*

- *Miclette, E. (2022, May 14). Alberta. Retrieved from regionaldashboard: https://www.canmore.ca*

- *Electric service restoration. (2023). Renewable energy integration implications for electric service restoration. Utilities One, 3-4. Retrieved from https://example.com/renewable-energy-electric-service*

- *Biyik, E. (2017, June 3). A key review of building integrated photovoltaic (BIPV) systems. System description, p. 837. Retrieved from https://www.sciencedirect.com/science/article/pii/S2215098616309326*

- *Eurostat. (2024). Electricity from renewable sources up to 41% in 2022. Eurostat, 1. Retrieved from https://example.com/eurostat-renewable-sources-2022*

- *Selvan, G. P. (2022). Case study on zero energy building (Indira Paryavaran). IJCRT, 976-978. Retrieved from https://example.com/zero-energy-building-india*

- *Gennaro, G. (2021). A zero-emission revolution at sea. London: NCE Maritime Cleantech. Retrieved from https://example.com/zero-emission-revolution-sea*

- *Guo, J. (2022, May 9). Integrating land-use and renewable energy planning decisions: A technical mapping guide for local government. Study Site, pp. 7-9. Retrieved from https://example.com/land-use-renewable-energy-guide*

 Guo, J. (2020, May 14). Integrating land-use and renewable energy planning decisions: A technical mapping guide for local government. Multi-Criteria Decision Analysis and RE Planning, pp. 4-6. Retrieved from https://example.com/land-use-re-planning

 Harrison-Atlas, J. (2022). Dynamic land use implications of rapidly expanding and evolving. Denver: IOP. Retrieved from https://example.com/dynamic-land-use

 Valin, H. (2015, August 27). The land use change impact of biofuels consumed in the EU. ILUC modelling, pp. 3-5. Retrieved from https://example.com/biofuels-land-use-impact

 Jacobs, J. (2019). Essential land use planning principles. Manila: PlannerSpace. Retrieved from https://example.com/essential-land-use-principles

 Jamal, H. (2017, January 23). Land use planning—Techniques, classification & objectives. Objectives of Land Use Planning, pp. 1-2. Retrieved from https://example.com/land-use-planning-objectives

 Keeley, C. (2014, December 6). Land use and energy: Connecting the dots to enhance communities. (Student, Interviewer) 2014. Retrieved from https://example.com/land-use-energy-communities

 King, R. (2021). The emerging global crisis of land use. Chatham House, 2-3. Retrieved from https://example.com/global-land-use-crisis

 Kolkowska, N. (Director). (2023). Challenges in Renewable Energy [Motion Picture]. Retrieved from https://example.com/challenges-renewable-energy

 Kumar, A. (2021, May 21). Towards better performances for a novel rooftop solar PV system. Design methodology, pp. 518-529. Retrieved from https://www.researchgate.net/publication/349067990_Towards_better_performances_for_a_novel_rooftop_solar_PV_system

 Borrowman, M. J. (2021). Canmore Recreation Centre Roof Mount Solar PV System – Town of Canmore. MCCAC, 1-2. Retrieved from https://www.canmore.ca/projects/renewable-energy/canmore-recreation-centre-roof-mount-solar-pv-system

 Min, C.-G. (2019). Analyzing the impact of variability and uncertainty on power system flexibility. Goyang-si: MDPI. Retrieved from https://example.com/power-system-flexibility

 Moses, M. (2020, July 2). Types of renewable energy. The most popular renewable energy sources currently, pp. 2-5. Retrieved from https://example.com/types-of-renewable-energy

 Muhammed, G. (2020, September 7). Development of renewable energy in China, USA, and Brazil: A comparative study on renewable energy policies. Introduction, pp. 8-10. Retrieved from https://example.com/renewable-energy-policies-comparative-study

 Nøland, J. K. (2022). Spatial energy density of large-scale electricity generation from power sources worldwide. Scientific Reports, 10-11. Retrieved from https://example.com/spatial-energy-density

 Ong, S. (2013). Land-use requirements for solar power plants in the United States. Denver: National Renewable Energy. Retrieved from https://example.com/solar-land-use-requirements

 Outka, U. (2010). Siting renewable energy: Land use and regulatory context. GSTOR, 1041. Retrieved from https://example.com/siting-renewable-energy

 Pouresmaieli, M. (2023, December 20). Integration of renewable energy and sustainable development with strategic planning in the mining industry. Challenges of integrating renewable energies in the mining, pp. 4-6. Retrieved from https://example.com/renewable-energy-mining

 Prin, M. (Director). (2023). The Role of Local Energy Communities in Clean Energy Transitions [Motion Picture]. Retrieved from https://example.com/local-energy-communities

Public Landowners. (2024, January 9). Economic benefits of renewable energy on public lands. Retrieved from Landgate: https://www.landgate.com/news/economic-benefits-of-renewable-energy-on-public-lands

Li, Q., & Yang, L. (2023, August 15). The effects of urban sprawl on electricity consumption: Empirical evidence from 283 prefecture-level cities in China. The impact of urban sprawl on electricity consumption, pp. 5-6. Retrieved from https://www.mdpi.com/2073-445X/12/8/1609

QuestCanada. (2022, August 22). Quest. Retrieved from Quest Canada: https://questcanada.org/aire-protocol

Van Buskirk, R. D., & Louie, C. (2020, July 10). Low-impact land use pathways to deep renewable resource availability, pp. 2-5. Retrieved from https://example.com/low-impact-land-use-pathways

Khandelwal, R., Jain, R. K., & Gupta, M. K. (2022). Case study: India's first net-zero energy building—Indira Paryavaran Bhavan. International Journal of Scientific & Technology Research, 353. Retrieved from https://example.com/indira-paryavaran-bhavan-case-study

Researchers, U. E. (2023, November 10). The role of energy communities in driving the adoption of renewable energy in local electrical systems. Retrieved from Energy5: https://energy5.com/the-role-of-energy-communities-in-driving-the

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