Land Use Regulation Impacts on Urban Energy Solutions:
A Review of the Port of Bellingham's Low-Carbon District Energy System

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ABSTRACT

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Jurisdictions in Washington state are faced with concerns of aging infrastructure, increasing energy demand, and complying with state and local energy performance targets. Low-carbon district energy systems are local, neighborhood utilities that integrate renewable energy and waste heat to deliver heating and cooling services to multiple buildings in a defined service area. This system can provide higher levels of energy efficiency and lower long-term operating costs compared to standalone building approaches. Through reviewing the Port of Bellingham's low-carbon district energy system, this paper highlights the motivations for developing district energy systems and examines the role of urban planning tools and regulations in shaping their feasibility. This thesis utilizes semi-structured interviews and documentation analysis, evaluated through thematic analysis. Results indicated strong alignment of motivations between energy infrastructure operators and the Port and City of Bellingham, resulting in reduced regulatory or siting constraints for district energy. However, results also highlighted zoning, siting constraints, and coordination with various public agencies as key constraints in other district energy projects. This paper highlights how shared sustainable infrastructure can support energy performance and broader community goals. As well as how district energy systems can become catalysts for innovation and experimentation, as cities explore new ways to reduce greenhouse gas emissions and invest in resilient infrastructure.

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1. Introduction

Washington State's clean energy transition has been driven by bold legislation to decarbonize energy generation, expand renewable energy investments, and increase efficiency. As jurisdictions work to meet ambitious energy performance targets and growing energy demands, local urban energy solutions, such as district energy systems, are gaining momentum as a key strategy to support the state's clean energy goals. This thesis will analyze the motivations for district energy systems and the urban planning implications of localized energy solutions.

A major turning point in Washington's clean energy transition was the Clean Energy Transformation Act (CETA) (Senate Bill 5116, 2019), which was passed into law in May 2019. It requires all electric utilities in Washington to eliminate carbon emissions from their energy resources and generate 100% of their power from renewable or zero-carbon resources by 2045 (Washington Utilities and Transportation Commission (UTC)). To further support the CETA, the State Energy Strategy was updated in 2021 to ensure alignment with the Act and the state's greenhouse gas emission reduction limits (Washington State Department of Commerce, 2020). The 2021 State Energy Strategy includes accelerating investments in renewable energy and improving building energy efficiency, primarily through electrification. Additional legislation, such as House Bill 1181, Climate Change - Planning, added to the Growth Management Act (GMA) further prioritizes the state's response to climate change. It requires cities and counties to add a climate change and resiliency element in their comprehensive plans to lower emissions and mitigate the adverse impacts of climate change. Alternative localized energy infrastructure systems like district energy systems align with these climate change policy efforts to reduce greenhouse gas emissions and provide additional resilience to the energy supply.

Buildings represent approximately one-fifth of Washington's greenhouse gas emissions (Department of Commerce, 2020, p. 67). A majority of those emissions can be attributed to the direct combustion of natural gas and other fossil fuels for space heating, water heating, and cooking (Department of Commerce, 2020). The 2021 State Energy establishes a building decarbonization policy framework set on optimizing energy use while acknowledging the "co-benefits of improved resiliency, public health, and climate adaptability" of decarbonizing the energy supply (Department of Commerce, 2020, p. 71). It highlights the need to decarbonize the building sector through maximizing electrification and energy efficiency, minimizing embodied carbon, and supporting the deployment of distributed energy resources, including renewables and load control services, such as solar and battery energy storage systems[1] (Department of Commerce, 2020, p. 67). The strategy also calls for methods to incorporate campus or district thermal distribution systems to efficiently provide thermal energy to multiple buildings and lower greenhouse gas emissions associated with the heating and cooling of buildings.

District energy systems are an underground network of pipes that provide heating and cooling to multiple buildings (such as a block, campus, or neighborhood) from a central plant. The power grid is a highly centralized network of infrastructure that relies on large-scale generation facilities located far from end users and the built environment. In this more centralized hierarchical model of energy supply, electricity generation in the built environment is sparse or limited, while energy consumption continues to rise (Watson et al., 2011). The power grid has traditionally been favored to support large-scale energy demand; however, there is a growing recognition of district energy systems' ability to offer greater efficiencies, utilize local energy sources like waste heat, and reduce pollution (Watson et al., 2011). Growing concerns of aging infrastructure, energy security, and climate change have also increased risks in large-scale energy plant investments and have opened a market for sustainable local energy solutions (Bouffard et al., 2008). Modular, small-scale energy systems that bring production closer to consumption are gaining traction as a viable and strategic alternative to investors (Bouffard et al., 2008, p. 4504). More states are realizing the benefits that sustainable urban energy systems provide in enhancing energy resilience and efficiency by working relatively independently from the main grid and leveraging local resources such as renewable energy or waste heat.

The localized nature of district energy systems makes local jurisdictions' role in shaping policies, standards, and frameworks that support sustainable urban energy system development essential. These systems require long-term planning in regulation, financing, and construction. However, their implementation in dense urban environments can bring unique land use challenges. Land use planning, at its core, envisions the future of development, guided by zoning

[1] Battery energy storage systems are "an electrochemical device that charges (or collects energy) from the grid or a power plant and then discharges that energy at a later time to provide electricity or other grid services when needed" (Bowen et al., 2019)

codes and other regulatory tools to determine what can be built and where. This plays a significant role in determining the feasibility of district energy systems in cities. Factors such as site selection, safety considerations, and varying levels of stakeholder involvement often challenge traditional planning and management models (de Boer et al., 2015). The shift to district energy is not just a technological and financial endeavor - it is shaped by a network of social actors. Municipalities are key implementers of the energy transition due to their connection with local citizens and their coordinative role with key stakeholders and sectors (Amer et al., 2020). Despite this, there is a significant research gap in the experience of infrastructure operators, designers, and managers in Washington state as they navigate land use policies and planning regulations to implement localized energy systems. Understanding the perspectives of these key actors could reveal pathways for the broader adoption of sustainable urban energy systems.

Research Objectives

Given these knowledge gaps, this thesis asks: **What are the motivations of energy infrastructure operators and designers in developing district energy systems, and how do urban planning tools and regulations hinder or support their development?** With a focus on the Port of Bellingham's low-carbon district energy system, this study aims to identify the opportunities and barriers presented by urban planning frameworks to be able to offer insights into how planners and policymakers can better support the transition to resilient, low-carbon energy systems. This study presents practical implications for integrating these systems in the built environment and provides insights for policymakers, urban planners, and energy developers to design supportive frameworks that align with Washington's climate change laws, energy efficiency goals, and support for clean energy technology.

Chapter 2 is a literature review that describes the foundations of district energy systems, the theoretical framework that informs socio-technical system transitions, such as clean energy transitions. It also provides an overview of land use and infrastructure planning for local energy systems. **Chapter 3** then outlines the use of qualitative research methods to examine the research question and understand the intersection of district energy systems and planning regulations through the perspective of infrastructure operators, designers, and managers in Washington state. **Chapter 4** provides background on the Port of Bellingham's Waterfront redevelopment plan and how a low-carbon district energy system was integrated as part of the redevelopment. Finally, **Chapter 5** synthesizes key findings from the Ports district energy system, organizing key motivations into themes and outlines planning regulations that restrict or support the development of district energy systems.

2. Literature review

This literature review provides an overview of district energy systems, outlining key components, factors that influence their performance, and key financial considerations. It then frames the transition to low-carbon energy systems as socio-technical systems whose success is informed by social, technological, and political factors. Finally, it examines the role of land use decisions in shaping energy futures to accommodate sustainable urban energy systems.

2.1 Overview of District Energy Systems

A district energy system (DES) is generally characterized as an underground infrastructure system whereby thermal energy is provided to multiple buildings from a central plant (International District Energy Association, n.d.). Buildings are connected to a central plant through underground piping, where energy transfers occur in a closed-loop system of hot and cold water constantly circulated between the central plant and the buildings it serves (Figure 2.1). A key attraction of district energy systems is the reduced need for individual building heating and cooling systems. Instead, buildings can benefit from the efficiencies of a central plant that can be regularly updated and decarbonized to meet growing building performance standards. This has been a particular attraction for university campuses that have analyzed the financial and efficiency benefits of upgrading existing legacy district systems to be low carbon as an alternative to individually updating multiple HVAC systems.

District energy systems sit at the middle of a highly centralized electric grid and an individual building energy system (Table 2.1). Individual building systems provide a highly decentralized, standalone approach whereby each building operates its energy system independently. This can include a single-family home with rooftop solar or a commercial building with its own gas boiler. On the other hand, the electric grid is a highly centralized, large-scale electrical infrastructure that procures energy from large power plants to deliver it at the city or regional scale. While operating from a central plant, district energy systems are smaller localized networks that primarily provide heating and cooling to a group of buildings. While individual building systems have a simpler governance structure with one primary owner operating the system, it’s limited in recovering or sharing waste heat. On the other hand, the electric grid has extensive transmission lines that experience energy losses during transmission and face increasing threats from climate-induced disasters such as heat waves, wildfires, and heavy rainfall (Einberger, 2023). District energy responds to some of the weaknesses of a highly decentralized and highly centralized grid as it offers enough economies of scale to be more energy efficient, allows recovery of waste heat, and can respond to local energy demands. However, the upfront costs and required coordination amongst the various parties involved to design and site a central plant and its distribution network can be a significant barrier to several communities and jurisdictions.

Table 2.1 Energy System Comparison

Scale	Service Area	Typical Ownership Models	Examples
Individual Building	1 building	Typically private	Single-family home, commercial
District Energy	Campus/ Neighborhood	Public/ Private	University campus, eco-districts
Utility-scale	City/ Regional	Large utility company or state agency	Regional electric grid

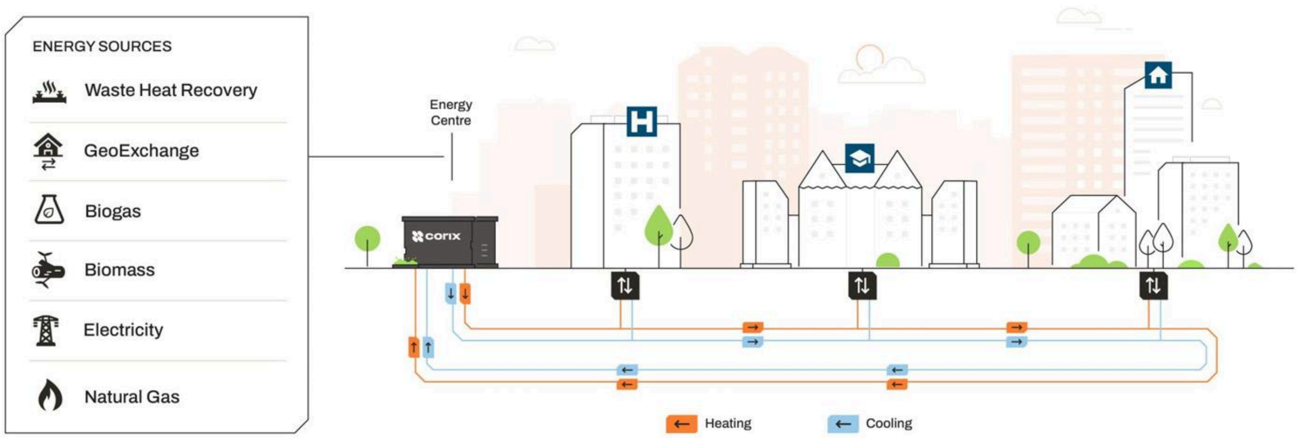

Figure 2.1 District Energy System Layout (Corix, 2025)

According to House Bill (HB) 1390, the Washington State Department of Commerce defines a campus district energy system (or non-state-owned campus district energy system) as a system that provides heating and/or cooling "through a distributed system providing steam, hot water, or cool water to three (3) or more buildings with more than 100,000 square feet of combined conditioned space, where the system and all buildings connected to the system are owned by a single entity, public-private partnership or two private entities" (Department of Commerce, 2025). District heating can contribute to a sustainable thermal energy supply at the district level instead of individual building energy systems, providing for efficient economies of scale (Lichtenwoehrer, 2019). District systems can source energy from multiple sources, such as waste heat and renewable energy sources. Waste energy is also minimized, allowing the system to perform at much greater efficiencies as "more than two-thirds of fuel energy used to produce power in traditional production is lost as heat energy, which a district energy system could utilize to provide energy" (Cooper et al., 2012). Due to its ability to use local and domestic sources, customers can also experience less volatile energy pricing compared to importing fuel (District Energy St. Paul, 2011).

The performance of district energy systems is influenced by several factors, including environmental conditions and ground temperatures, as well as equipment (Wang et. al., 2021). Variables such as the temperature distribution of water, the thermal inertia of the pipe, the level of complexity of pumping power, pipe thickness and diameters, the temperature difference between supplying and return pipelines, and the heat source are all significant factors that influence optimal performance (Wang et. al., 2021). This highlights the importance of upgrading aging piping systems to maintain desired temperatures and ensure a reliable supply of hot and cold water. Urban form is also an important factor in ensuring optimal performance. District systems rely on a dependable and sufficient building and population density to be cost-effective and efficient (Cooper et al., 2012). Having a strong customer base for the district energy can ensure efficient circulation of hot and cold water that is constantly circulated and reduce waste of unused energy (Cooper et al., 2012). Waste heat (such as from power plants or industrial areas) that can be captured and used as a heat source may also be more available in or near urban areas. Furthermore, the proximity of multiple buildings in dense environments can reduce distances for the distribution infrastructure of hot or chilled water, minimizing energy loss in the pipes and the need for extended pipelines (Cooper et al., 2012). At the same time, district energy can promote compact urban development in areas that incentivize buildings to connect to an existing district system. District energy presents an attractive opportunity for additional grid support and supplying homes with heating and cooling. To ensure their efficiencies are maximized and reduce their negative environmental impact, upgrading infrastructure, increasing investments in renewable energy, adequately assessing the system's performance, and encouraging connection to the system can optimize district energy operations and performance.

From a policy perspective, HB 1390 was an influential piece of legislation that approved district energy as a viable approach to meeting Washington's building performance standards to reduce commercial and large state-owned building emissions. The legislation provides alternative compliance pathways for state campus district energy systems (owned by either the State of Washington or by a public-private partnership) and non-state-owned campus district energy systems (approved by the Department of Commerce) to meet Washington’s building performance standards. Here, owners of an eligible district energy system are not required to meet energy use intensity targets for the system or for individual buildings connected to the system to comply with the state energy performance standard (House Bill Report 1390, 2023, p. 3). Instead, owners of the approved district energy system must implement an approved decarbonization plan to replace fossil fuel and assess opportunities for waste heat for the district energy system's service area (House Bill Report 1390, 2023). Owners of the district energy system will also have to “meet the state energy performance standard requirements for benchmarking, energy management, and operations and maintenance planning, and submit requests to Commerce once every five years” (House Bill Report 1390, 2023, p. 3). The bill was sponsored by Representative Alex Rammel, a key advocate for district energy, who expressed the system's ability to increase building efficiency, generate jobs, help save campus resources, and promote public-private partnerships as it allows privately owned district energy systems to opt in (Washington State House Democrats, 2023).

While district energy systems are assessed to have greater economic and environmental benefits, both have high upfront costs. Typical cost drivers for district energy include equipment such as boilers, chillers, pipes, pumps, and tanks (District Energy St. Paul, 2011). Tunneling and trenching can also be expensive, particularly in dense urban areas. Other cost factors include fuel costs, operations, maintenance, and labor (District Energy St. Paul, 2011). In addition to equipment costs, design considerations such as site selection and heat source are important factors in minimizing capital costs. Enforcing subsidies and policies that make district energy systems competitive in the energy market is critical. Regional energy planning standards can provide investors and government officials with confidence in long-term investments in renewable energy (Lake et al., 2017). Additionally, the optimization of demand-side management strategies and integrated heating and power systems can reduce primary energy use and CO2 emissions and make district systems more financially competitive (J. van der Leer et al., 2023).

2.2 The clean energy transition as a socio-technological transition

Culture, social actors, and stakeholder relationships present key drivers of the energy transition that are often overshadowed by the economic feasibility of decarbonization efforts. This study draws from concepts of socio-technological transitions theory to highlight and analyze the role of social actors in advancing the feasibility of low-carbon energy innovations in the clean energy transition. Geels (2017) defines sociotechnical systems as "the interlinked mix of technologies, infrastructure, organizations, markets, regulations, and user practices that deliver societal functions" (p. 2). Decarbonizing district energy systems not only requires the expansion of renewable energy technology but also the development of business models, financing mechanisms, governance structures, and social acceptance to accelerate its adoption (Reda, 2021). Energy decisions are not only informed by economic feasibility and technological aspects but also by social and cultural contexts for them to be successful (Bush et al., 2019; Tong et al., 2020). Socio-technical system transitions are informed by the various social actors during the transition, the choices made by the various actors, and their capacities. These actors can be categorized into three general groups, which consist of government (through policymakers advancing the transition), markets (through business approaches that support the transition), and society (where civil-society advocates for the transition) (Tong et al., 2020).

Other frameworks formed in the field of sustainability transitions and socio-technical system literature include the multi-level perspective (MLP) theory and strategic niche management (SNM). Multi-level perspective theory states that socio-technical transitions can be understood through the interaction of three distinct processes: the socio-technical regime, niches, and landscape (Reda, 2021). The socio-technical regime is the conventional model of supplying societal needs such as energy services (Reda, 2021). Regimes highlight the favored institutional arrangements and regulations for the delivery of that societal need (Reda, 2021). In Washington state, the dominant form of energy service delivery is through a large infrastructure network of power plants, transmission lines, and distribution centers. This is managed and governed by regional transmission organizations (EIA, 2024). A niche, on the other hand, offers a non-conventional way to fulfill those same societal needs (Reda, 2021). It is a "protected environment for early applications of a technology" (Bush et al. 2019, p. 2187). Examples of niche activities include thermal storage, demand response automation, and geothermal heating (Reda, 2021). Landscape refers to exogenous factors such as climate change and the policies in response to climate change, that pressure current regimes to "generate opportunities for niche innovations" (Reda, 2021, p. 2). Fifth-generation district energy is the latest version of district energy systems; however, it's still not advanced enough to make it fully competitive, and therefore can be viewed as a technological niche (Reda, 2021).

Strategic niche management is defined as creating and managing these protected niche spaces for experimenting with promising technologies, with the goals of assessing their desirability and accelerating their adoption (Raven et. al, 2024). It is an approach for how actors can facilitate and shape transitions whereby a network of actors can support the technology and communicate the technologies values and future visions of the technology to the wider public (Bush et al, 2019). Bush et al. (2019) also speak of niche empowering processes – which is where future visions for innovative technology are articulated to actors working beyond the niche and or include "influencing wider regime changes to enable the technology to diffuse more easily" (p. 2187). The transition process includes niche-level innovation (the advancement of new technology and business practices), stable environments for existing practices, and shared public knowledge and value systems (Tong et al. 2020, p. 2). The Clean Energy Transformation Act (CETA), HB 1390, and other legislation focused on the expansion of low-carbon and renewable energy technology initiated a long-term transition plan that created a protected niche to stimulate technological growth, and financial and political support to grow these industries.

Building on sustainability transitions literature, this paper highlights the various actors and motives in a clean energy transition to reveal relationships and transition barriers to implementing low-carbon district energy systems. Challenges to decarbonization and the clean energy transition are multidimensional, as co-evolutionary changes are required across various sectors (e.g., business models, policy frameworks, consumer preferences). Co-evolutionary framework and MLP theory have been adopted to explore district heating system transitions in

Europe; however, this is lacking in North America (Tong et al., 2020). Instead, studies in North America for district heating implementation have focused on the technical feasibility of adopting district heating. While this study does not analyze each of the institutions and actors involved in district energy decarbonization efforts, by focusing on infrastructure operators, designers, and managers of the system, it highlights actors central to the implementation of low-carbon goals into actual systems. Operators and designers can be viewed as regime intermediaries who help translate niche strategies into mainstream practice. Infrastructure operators and designers are central in understanding technical feasibility, land use, and regulatory constraints, and the required coordination with municipalities, planners, and other key stakeholders. These factors can all inform the ongoing and near future conditions of the transition and the barriers and opportunities for the transition (Bush et. al, 2019; Tong et al, 2020).

As cities are attractive grounds for innovative technology and sustainable infrastructure, policymakers and urban planners can facilitate technological innovation and strategic planning for sustainable urban infrastructure. However, innovation and the adoption of new technology can face barriers due to misalignment with broader social and regulatory frameworks (Tong et al., 2020). Therefore, alignment with stakeholders, including planners, infrastructure operators, and residents, is a necessary component in promoting and accelerating socio-technical transition in low-carbon energy planning.

2.3 Land use and local energy planning

The design and management of land use patterns is a critical factor in enabling local energy solutions. District energy systems rely heavily on the spatial configurations of neighborhoods and building densities. Therefore, they thrive in areas where land use planning supports mixed-use development, compact urban form, and buildings with complementary energy demands. In establishing low-carbon energy systems in urban areas, land use can be a prime issue due to the spatial demand and geographical dispersion of these new infrastructure systems (Wolsink, 2024). For example, district energy systems rely on underground infrastructure to distribute heat or cooling, which requires compact development, street use permits, and right-of-way regulations. Through shaping the physical layout of cities, land use decisions can either open or constrain the technical and financial feasibility of district energy.

2.3.1 The significance of mixed-use development in energy conservation

'Energy-conscious planning' whereby spatial structures are designed to yield energy savings through strategies like transit-oriented development to reduce motorized travel demand demonstrates how useful planning is in reducing a neighborhood or city's energy demand (Byerly, 2011; Kim, 1987). Land use planning in North America has historically proceeded with little attention to energy efficiency or energy costs as land use patterns continue to reflect low-density sprawl and segregated land uses (Kim, 1987). However, exogenous factors such as oil crises, threats of climate change to urban infrastructure, and rising energy demands have exposed the evident inefficiencies of urban sprawl. There are multiple benefits of compact, mixed-use development as a significant energy conservation strategy and opportunity for alternative local energy solutions, such as district heating systems (Nolan, 2012).

Energy-intensive land use patterns continue to persist; however, legislation such as the Growth Management Act (GMA) has helped concentrate future urban growth in urban areas, reduced sprawl, and spotlighted the integration of climate resilience strategies in development regulations and plans (MRSC, 2025). While not directly focused on energy, the GMA's emphasis on targeted urban development, efficient transportation networks, and climate planning has important implications for energy consumption patterns and supports the economic and spatial requirements for localized energy systems. Since the early 20th century, authors like Owens (1986) have expressed that "energy is a fundamental resource, the use of which both influences and is influenced by the spatial structure of society. If planning is concerned with the use of land, then planners should at least be aware of the possible energy implications of their policies and decisions, while recognizing the many uncertainties involved" (p. 69). More contemporary authors like Kaza et al. (2014) and Nolan (2012) continue to argue for planners to focus on the relationship between urban form, energy consumption, and sustainable energy generation. Planners have an increasingly important role in energy production and integrating opportunities for energy production in high-density, mixed-use development in neighborhood planning processes – "energy efficiency neighborhoods should be planned to encourage green building development, on-site generation, the use of renewable sources of power, efficient distribution systems and combined heat and power systems shared by multiple buildings" (Nolan, 2012, p. 331). Planners must better assess appropriate buildings and energy uses compatible with district energy and adapt land use regulations to facilitate district energy systems and other sustainability techniques (Nolan, 2012).

However, there has been limited engagement between planning professionals and energy experts, despite energy being central to sustainability (Kaza et al., 2014). While planning has mostly focused on energy conservation through the lens of building efficiency and mixed-use urban design, Kaza et al. (2014) call for a more proactive planning approach that considers both how energy systems shape land use and how land use decisions shape energy futures. Furthermore, there is more opportunity to recognize land use planning and zoning control as an energy conservation measure that can contribute to the clean energy transition (Nolan 2012; Kim, 1987)

The transformation of energy systems into low-carbon or carbon-neutral systems, the energy transition, requires using space differently. Particularly in the context of local energy solutions, where energy generation occurs closer to consumption. There is a required shift in how land and energy systems are to be designed, governed, and developed to transition from centralized top-down models or building-to-building models to a more distributed approach where land use and energy system design are more aligned.

2.3.2 The power grid and its implications for district energy systems

Understanding the dominance of highly centralized, utility-owned energy systems can highlight the limited adoption of district energy systems. In the early 20th century, monopolies formed to develop large infrastructure investments, creating a centralized power grid. Here, “electricity provision was considered a 'public good’ provided by utilities” (Wolsink, 2024, p. 10). In the wave of neo-liberal privatization, private generation was separated into private enterprise but was heavily regulated within public legislation. Utilities were authorized to cover exclusive service territories in exchange for being regulated by state public utility commissions (Roosa, 2021). While generation remains publicly managed, the actual generation and retail in many cases are privatized. Wolsink (2024) argues that this sets electricity as a market commodity, as opposed to a shared good.

> “Electricity is provided by privatized actors (generators), and the service of distribution is often provided by trading companies, which engage in wholesale purchasing and retail sales. They are using the grid that mostly is still publicly managed, a monopolistic

infrastructure, and the connection to it is a 'public good' provided by the DSO (distribution system operator), a state-controlled grid operator." (Wolsink, 2024, p. 10).

While highly regulated entities, according to Roosa (2021), utility companies are consistently working to influence political processes to ensure a monopoly in their regulated territories of operation. This allows them to recover costs and guarantee profit. This political influence and their provision of a critical public service, energy, also ensures "they are protected from default even when gross mismanagement occurs" (Roosa, 2021, p. 66). Much of the legal and institutional arrangements and infrastructure network has been created to support a centralized electric grid system, which has historically restricted the integration of localized energy sharing networks (Wolsink, 2024). This highlights systemic and regulatory barriers for integrating alternative energy systems, such as DES, as not just a technical issue but as something influenced by current planning and energy governance practices.

However, most electric grids are aging, resulting in inefficiencies and high maintenance costs. With increasing domestic consumption, many jurisdictions, including some utilities, are assessing opportunities to replace existing segments or add more modern modular technologies as a less expensive alternative to prevent future outages instead of maintaining existing equipment and infrastructure (Roosa, 2021). The increasing costs to maintain central grids have helped open a market for alternative energy, such as district energy systems and distributed energy resources.

2.3.2 Land use conflicts in energy planning

In densely populated built environments, land is a crucial resource for development. Energy and land are deeply connected, and as changes in energy production change to support production in the built environment through distributed energy systems, land use planning must be proactive in how to appropriately respond to this change -"Energy is a fundamental resource that influences and is influenced by societal spatial structures" (Owens, 1986). Even more, land is also considered a fundamental and scarce resource in the built environment (Wolsink, 2024). Planning regulations create rules and governance structures on who, when, and how shared resources can be used, harvested, and managed. While DES offers several benefits, planners must consider the potential land use conflicts of siting energy facilities and distribution networks in dense urban environments.

Key land use conflicts to consider in the implementation of energy infrastructure include the competition for scarce land, property rights, ecological impacts, and perceived landscape change (Wolsink, 2024). “Urban energy transitions and densification intensify competition for urban land, leading to increased land-use conflicts” (Koelman, 2024, p. 40). Energy infrastructure, particularly in areas with restricted availability of land, have to compete with other uses such as agriculture, residences, parks, and other infrastructure (e.g., transportation). District energy systems not only require land for the key energy facilities (e.g, the central plant), but also require land for their distribution infrastructure that has to compete with existing tunnels such as sewer lines and other utility lines. Regarding property rights, land needed for energy infrastructure involves leasing or acquiring land (Wolsink, 2024). Having fair and transparent processes for acquisition is important in addressing issues of land ownership and community acceptance (Wolsink, 2024). As with most new developments, ecological implications must be considered in site selection and design to mitigate negative environmental impacts associated with the construction and operation of the energy infrastructure system (Wolsink, 2024). Finally, the physical presence of energy infrastructure may have varying visual impacts based on varied perceptions of the energy infrastructure installed. To minimize negative visual impact (e.g, changing the character of the neighborhood), Wolsink (2024) suggests ensuring the energy infrastructure location and design “match with the character of the landscape and fit with the values of the community” (p.4).

Since land is a scarce resource that is subject to competition, it becomes highly beneficial to cooperate to acquire the space needed for energy facilities. Rights to access and generate energy raise issues of land use rights and spatial control as zoning, ownership, and easements inform who can participate in generating power either individually (e.g, through rooftop solar) or through a shared energy system (e.g, microgrid and district energy system).

While this assessment is not focused on offering insights into how the energy sector can shift from market terms to community co-productions, it recognizes the potential for a commons-oriented energy production model, where communities co-produce and manage energy through a localized energy framework. However, for this study and the current neo-liberal regime where electricity is privatized, understanding the framing of electricity as a private good may help analyze how it influences land use regulations, such as zoning incentives, and who is authorized to use public or private land for shared energy infrastructure.

Land and the scarcity of land make spatial investments an essential component. Regulations that prohibit shared access to space (either through building codes, land ownership restrictions, etc) can undermine the implementation of urban energy systems. To successfully implement district energy systems, institutional arrangements and regulatory frameworks need to allow for spatial flexibility. This may include reforming zoning, infrastructure planning, and permitting to best accommodate sustainable, more cooperative energy system projects.

3. Methods

The study analyzes the Port of Bellingham's district energy system to explore: what are the motivations of energy infrastructure operators and designers in developing district energy systems, and how do urban planning tools and regulations hinder or support the development of these systems? As argued by researchers such as Tong et al. (2020), a qualitative methods approach that utilizes document review and interviews can help us investigate socio-technical system transitions, such as the clean energy transition, and explore how policy shapes actual practice. These methods can help researchers identify key social actors in a socio-technical transition to capture how policies influence behaviors and policy adoption (Schelley, 2016). This analysis aims to highlight common narratives on the motivations for developing the Port of Bellingham's low-carbon district energy system and sentiments regarding the extent to which land use regulations impact the feasibility of developing the system.

In my initial explorations of district energy systems in Washington state, I found several examples of existing legacy steam-based district systems on university campuses, such as the University of Washington's district system. However, the Port of Bellingham's low-carbon district is set apart from the other examples as it is a new district energy system set on a brownfield site not owned by a state university. Furthermore, the low-carbon district energy was part of a long-term planning effort to develop the Port's waterfront (which calls for dense mixed-use development). Using a case outside a university context, I was able to evaluate how a local jurisdiction has incorporated and planned for district energy systems. New projects can reflect up-to-date policies, climate goals, and technologies, making the findings more applicable to today's planning and regulatory environment.

From a research perspective, the records and stakeholders involved in planning, permitting, and approval are often more accessible and active for newer projects. This allows me to capture intentions and rationales behind certain decisions, which may be harder to do retrospectively with older projects. While the system is only partially operating, the newness of the system can help study anticipated barriers and stakeholder expectations. Additionally, from a policy perspective, the study aims to explore the impacts of House Bill 1390 on non-state-owned university projects and whether the bill further encouraged DES development for redevelopment plans outside a university campus. Examining the Port's low-carbon district energy system allows analysis of how regulatory frameworks can affect district energy adoption and ease of implementation.

I performed document analysis and semi-structured interviews to gain a deeper understanding of the key social actors involved and land use regulations impacting feasibility. The documents analyzed included government policies at the state, county, and city levels, such as state energy policies, city climate action plans, and climate adaptation strategies (Table 3.1). Publicly available reports, such as feasibility studies, sub-area plans of the case studies, and planning documents such as planning comments, were also reviewed to identify regulatory constraints and capture local assessments and perspectives. Finally, media coverage, such as news articles, website content, was reviewed to explore public discourses and emerging narratives of the energy systems. Documents were reviewed to reveal institutional drivers and regulatory constraints, highlight industry perspectives, and general attitudes regarding the systems. Documents revealed the current and long-term goals of these systems, the key actors involved, challenges and opportunities, and the extent to which they can be attributed to land use regulations and/or other planning factors.

Table 3.1 Documents Reviewed

Planning and Policy Documents
Port of Bellingham Climate Action Strategy, 2023
House Bill 1390 District Energy System
House Bill 1514 Thermal Energy Networks
Waterfront District Subarea Plan 2019
Port of Bellingham Utility Master Plan 2013
Regulatory and Permitting Documents
Washington State Energy Code 2021
Bellingham Municipal Code (BMC) 20.37. (400-480) - Waterfront District Development Regulations

Waterfront District Permitting Handbook 2014
Port of Bellingham Infrastructure Agreement with Corix (2018) (2020)
Requests for Qualifications/ Proposals (RFQs/ RFPs)
RFPS Thermal Energy Network Bid Posting
RFQ
Media
Whatcom TALK, an online community article
UMC, Waterfront Revival: A New Energy Era
Other
Pacific Northwest National Laboratory, Energy Storage in Local Zoning Ordinances (2023)
Urban Land Institute, Zoning for a More Equitable, Resilient, and Sustainable Future (2023)

Empirical data draws on qualitative interviews with infrastructure designers, operators, managers, utility managers, policymakers, and advocates. Given the multiple actors involved in energy transitions, interviews can disclose these diverse viewpoints, while documents highlight formalized institutional perspectives. The goal is to have participants provide information on regulatory barriers, opportunities, motivations, conflicts, and negotiations in energy making that impact system feasibility. Interviews provide insight into collaboration across planning levels and energy departments and identify challenges and opportunities to improve collaboration. Stakeholder interviews also help gain insight into how to improve connections between policy and practical implementation through first-hand experience.

To recruit interview participants, I used two approaches. First, connections were established through mutual connections with professionals in various but connected fields. Second, connections were made through cold contacts through emails and LinkedIn connections. I used the snowball sampling method to recruit more interviewees (Tong et al., 2020). In total, nine semi-structured interviews were conducted virtually, each lasting 45 minutes to one hour. I prioritized participants directly involved with the Port of Bellingham district energy system; however also sought practitioners who have expertise in low-carbon district energy planning and operations. Interview participants included government officials, utility managers, and energy infrastructure professionals (such as consulting groups, engineering firms, and public works departments). Two government officials (with the Department of Commerce) were interviewed, and two interviews were conducted with people working at university energy and facilities departments[2]. Three interviews with professionals in energy consulting or contracting companies were conducted. One interview with a city official was conducted, and one interview with an urban designer. Semi-structured interviews were conducted with open-ended questions to allow flexibility with questions focused on;

- Their division or organization's goals in developing district energy systems and how they see these systems evolving in the context of urban sustainability and resilience planning.
- The extent to which planning regulations (e.g., zoning laws, permitting, etc.) either supported or hindered the development of district energy systems.
- The stakeholders typically involved in the system design, planning, and development of district energy systems, and the challenges in coordination.

(See Appendix A for interview participants and interview guide)

A process of thematic coding was used to evaluate documents and interview transcripts to identify and interpret themes. Dedoose, a web-based qualitative data analysis platform, and Braunes and Clark's (2021) systematic thematic analysis approach were used to organize and analyze information and ensure consistency in interpretations. Braun and Clarke list a six-step structured process for interpreting data and reporting thematic data. It begins with transcribing and familiarizing oneself with the data and importing it into Dedoose. I then created codes, where labels are assigned to key phrases that capture the core message of the data. I used a mix of deductive and inductive coding, with the first code book highlighting the ‘motivations’ as one code and the ‘urban planning factors’ as the second code. I also used code hierarchies, creating subcodes that can automatically be nested into another code (Table 3.2).

[2] Energy departments and facilities departments are responsible for the planning, operation, and maintenance of campus infrastructure and utilities. They generally play a key role in sustainability initiatives, energy conservation, and long-term capital planning.

Table 3.2 Code definitions

Main Code	Subcode	Description
Motivations		
	Ability to integrate new technologies	Refers to how easily the system can upgrade, or transition to new, cleaner energy sources and technologies without requiring extensive redesign.
	Climate and Infrastructure Resilience	Refers to the ability of an energy system to withstand and recover from disturbances such as heat waves, grid outages, or natural disasters.
	Decarbonization	Refers to the reduction of greenhouse gas emissions from heating and cooling systems by replacing fossil fuels with renewable energy or waste heat.
	Economic Motivations	The potential for financial gain and reduced long-term operating costs.
	Energy efficiency	The optimization of energy sources to reduce waste heat.
	Policy compliance	References to local or state performance standards that jurisdictions must comply with.
Urban Planning Factors		
	Land use considerations	Planning and design factors that need to be considered when designing and developing a DES
	Land use restrictions and codes	Legal or regulatory constraints that limit where and how DE can be developed, such as zoning codes, easement limitations, or restrictions on underground piping.
	Supportive land use/development policies	Policies that facilitate the integration of DES.

Next, I selected excerpts and applied existing codes or created new codes iteratively. The codes are then organized into themes to identify patterns. Dedoose visualization tools, such as the co-occurrence feature, were used to develop themes that best respond to the research question and highlight code occurrences between interview participants and documents. These tools were not used for quantitative measures but to refine themes. Identified themes were evaluated and revised to write a final narrative.

This analysis aims to understand urban planning implications for district energy development in Washington State. As well as to highlight key considerations and opportunities when developing these systems in the built environment. Based on existing policies and experiences in implementing district energy systems, the analysis aims to understand the perceived trajectory of district energy systems in Washington state and how planners should consider these systems in their long-term land use and climate change plans.

Limitations

District energy is not widely adopted in Washington state, let alone the United States; therefore, there is limited existing academic literature about DES that's contextually relevant to Washington. Secondly, while I reached out directly to the Port of Bellingham staff, I was unable to get a formal interview with a representative from the Port of Bellingham to gain their perspective on the district energy system. This resulted in a relatively significant gap in understanding the motivations for developing the system, as it is on the Port of Bellingham's property.

Furthermore, while the focus on infrastructure operators and designers was due to their central role as implementers of the system and their clear support for the system, this focus may underplay other political, social, or equity concerns around district energy system acceptance and scaling. Due to time constraints, the documents analyzed focused on official formalized planning and technical documents with a limited perspective on public engagement reports and user needs. This focus on the technical land use aspects may risk reinforcing energy transitions as primarily a technical problem and underplay some of the political and social issues associated with urban energy systems. Further research will need to expand to capture the full spectrum of actors shaping sustainable urban energy systems, such as early advocates and end-users.

Next, while the system's site offers an example of inter-agency collaboration between the Port of Bellingham and the City of Bellingham, its unique governance structure and position as a Port may limit replicability. In Washington State, Ports are publicly owned entities with unique governance structures and authorities that are distinct from cities or counties. The Port of Bellingham was able to acquire a large amount of property, making it easier to allow centralized infrastructure planning, whereas other cities with mixed land ownership will need to navigate potentially fragmented land parcels and multiple property owners. The Port of Bellingham was also able to utilize a brownfield site that was already undergoing development, easing the implementation of distribution pipes and other infrastructure needs. In all, the Port's unique governance structure and land ownership advantages may limit another city's ability to replicate its district energy system infrastructure planning and design.

4. The Port of Bellingham District Energy System

In early 2005, the Port of Bellingham acquired 137 acres of waterfront property, which was previously owned by Georgia-Pacific Corporation (Port of Bellingham, n.d.). Georgia-Pacific Corporation, an Atlanta-based company, ran a pulp and tissue mill operation and was a major employer in the area. However, with rising electricity prices (up to $3,500 a megawatt/hour), Georgia-Pacific eventually decided to shut down its Bellingham mills (The Columbus Dispatch, 2008). With its departure also came discussions on the massive environmental cleanup to make the contaminated land reusable (Department of Ecology, 2021). While the economic impact of Georgia-Pacific's departure was devastating, it marked a new era for the Port and City of Bellingham to reimagine the waterfront as an accessible, ecologically restorative, and financially vital neighborhood (The Columbus Dispatch, 2008).

After acquiring the property, the Port and the City of Bellingham launched a public planning process and developed the Sub-Area Plan for the Waterfront District. The first Waterfront District Sub-Area Plan was adopted in 2013 and rezoned the district to a new mixed-use zoning category called Waterfront Mixed Use. Before that, extensive planning efforts led by Waterfront Futures Group in 2003 and 2004 were conducted to inform the Waterfront redevelopment project. This was a citizen-led task force to "take a fresh and independent look at the future of the entire waterfront" in response to Georgia-Pacific's departure (2019, p.3). The group held 41 public meetings and 26 guest forums and special events and published the Waterfront Vision and Framework Plan, which called for a redevelopment plan that was a "mixed-use neighborhood that combines commercial, institutional, industrial, retail, and residential uses, and that over time will provide many new job opportunities and a substantial amount of urban housing." (p. 3). This vision was approved by the City Council, and the guiding principles and recommendations informed Bellingham's Comprehensive Plan update and the Central Business District (CBD) Neighborhood Plan in 2006 and 2008. Recommendations from the Waterfront Vision and Framework Plan were also included in the Waterfront District Sub-Area Plan in 2013. The 2018 Waterfront District Sub-Area Plan was then further amended to ensure consistency with the City of Bellingham Comprehensive Plan, City Center neighborhood Plan, and Waterfront Futures Group Vision and Framework Plan." (Sub area plan, 2019, p. 3).

Figure 4.1 Waterfront District (Port of Bellingham, retrieved May 25, 2025)

Key priorities in the waterfront redevelopment centered on environmental restoration, increasing job opportunities, and increasing public access and recreational opportunities. At full build-out, the district is projected to have 5.3 million square feet of building capacity, with a mix of commercial, residential, office, institutional, and industrial areas (Figure 4.1) (Puttman Infrastructure, 2014). In 2014, Puttman Infrastructure supported the City of Bellingham and the Port of Bellingham in conducting a Waterfront Utility Master Plan (WUMP) to evaluate the most appropriate utilities to support the anticipated building density and population growth. The Utility Master Plan also evaluated the most appropriate development model to finance, build, and operate the district systems. After evaluating three models ‘public, private, and public-private partnerships, the study suggested a public-private partnership development model given the projected investment returns. This model also allows parties to share financing and development as well as operating risks and functions (Puttman Infrastructure, 2014). However, the Port followed a private development model, a common model for district energy and electricity provision, as “electricity or natural gas utilities have traditionally been developed under a private development model…..Several private companies develop, own and/or operate large district infrastructure systems” (Puttman Infrastructure, 2014). Shortly after the Port’s Master Plan was published, the Port installed an energy piping system in 2018 and sent out an RFQ in April 2018 to identify an organization with the appropriate technical expertise to design, develop, and operate the district energy system.

The Port selected Corix Utility Systems Inc. (Corix) to design, construct, finance, own, operate, and maintain the District's energy utility (Infrastructure Agreement, 2020). Corix was also tasked to evaluate the feasibility of different technologies for the system, which included "biomass, heat recovery, air source heat pumps, and electric boilers" (Corix, 2023). A key energy source evaluated was the waste heat from the Puget Sound Energy (PSE) Encogen plant. The Encogen plant station previously "the Encogen station previously exported up to 7.2 MGD of steam and hot water to the former GP facility" (Port of Bellingham, 2025). Corix partnered with PSE to utilize the waste heat from their Encogen plant to heat and cool approximately 1.6 million square feet of mixed-use commercial-residential development (Corix, 2023). Corix then hired UMC (a design-build mechanical contractor) to help design the modular system that was fabricated in UMC Everett's plant and transported to the Port's site (figure 4.2) (Locke, 2025).

Figure 4.2 Waterfront district energy central plant (Corix, 2023*)*

An Infrastructure Agreement between the Port of Bellingham and Corix was established as a regulatory framework to provide independent oversight on proposed energy rate adjustments for residential and commercial customers (Port of Bellingham, 2020).

5. Findings

This research investigates the motives and land use factors that influence the development of the Port of Bellingham's low-carbon district energy system and asks: **What are the motivations of energy infrastructure operators and designers in developing district energy systems, and how do urban planning tools and regulations hinder or support their development?** Using the Port of Bellingham's low-carbon district energy system as a case study, this research aims to identify the opportunities and barriers presented by urban planning frameworks to offer insights into how planners and policymakers can better support the transition to resilient, low-carbon energy systems. Through thematic analysis of interview transcripts and documents, I synthesized motivations, land use restrictions, and supportive planning measures into key themes.

5.1 Motivations

In evaluating the motivations for implementing a district energy system, five main themes were highlighted: 1) energy efficiency and system optimization, 2) meeting climate and environmental goals, 3) economic efficiency, and 4) infrastructure resilience and reliability.

5.1.1 Energy efficiency and System optimization

Here, I defined two main codes of energy efficiency and the ability to integrate new technologies (code definition in Table 3.2). All interview participants described low-carbon district energy as the most efficient path to decarbonize the building sector instead of a standalone building approach. Even when designing high-performing buildings, Giffin expressed;

> *"These high efficiency buildings are really difficult to do correctly, are a lot to manage, and require a lot of handholding to make it work and to commission it properly. With a district energy system, you can take all that complexity out of the building and aggregate it into one central plant where instead of having 30 buildings (each with their own operating engineers trying to figure this thing out all the time), you can have a central plant to reduce time and costs"* (Giffin, Corix, 2025).

Furthermore, the site's mixed-use development helped justify the district system as linking diverse uses through a shared energy network allows the system to capture "waste" heat from one building and transfer it to be reused by another building.

> *"These widgets are very smart in moving heat around where it's needed and not needed. So what makes the systems really great is if you have opposing heat uses. For example, if you have offices and residents (next to each other) with different heating needs during the day versus at night, you can trade these heating and cooling needs as needed. So those complementary uses, those are the things that really make your systems awesome. Looking at it through those lenses has been a lot more helpful as I've gone through this. Versus just a centralized system is awesome. End of story."* (Freeman, 2025).

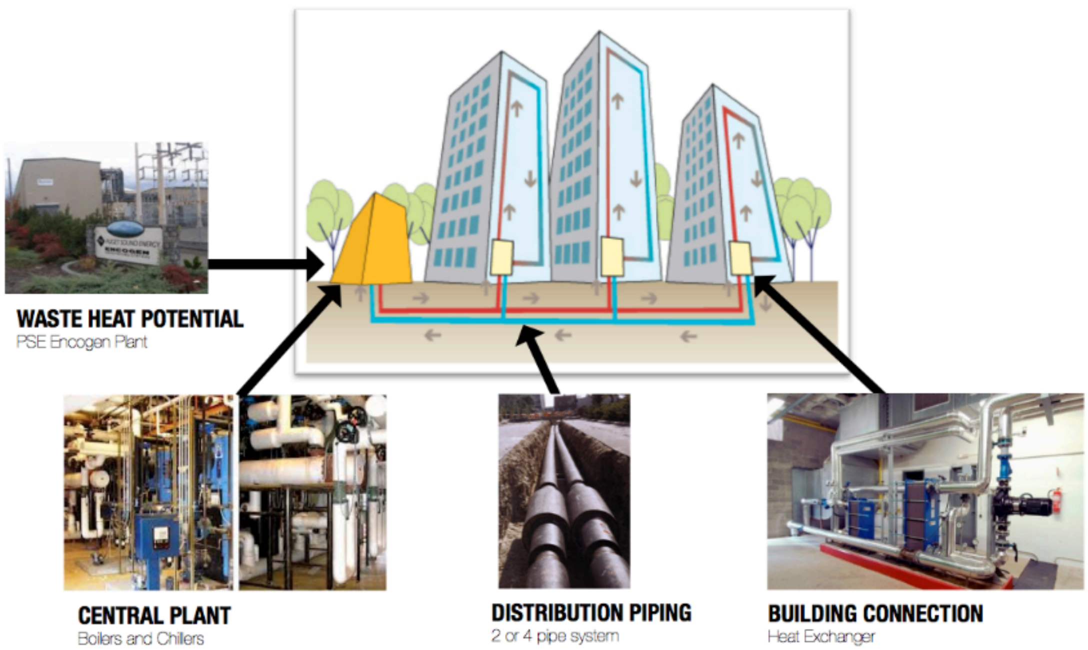

Figure 5.1.1 Port of Bellingham DES components (Puttman Infrastructure, 2013, p. 13)

Another key compelling factor that made district energy a real option was the site's proximity to the Puget Sound Energy (PSE) Encogen plant, which further maximized its energy efficiency potential;

> *"What made it pencil out is the waste heat, not the fact that you were doing a centralized heating system per se versus the distributed ecosystem. What the Corix*

central plant showed me was about balancing loads, taking heat where it isn't needed, and moving it over here is what makes these systems get the efficiencies that make them cheaper and reduce emissions….The waste heat is what really helps your bottom line.” (Freeman, 2025).

The Encogen Generating Station is a 163-net megawatt, combined cycle, natural gas-fired power generating plant (Puget Sound Energy, n.d.). It provides electricity to the PSE electrical grid, and by-product waste heat from Encogen's cooling tower is captured and run through a series of heat exchangers and heat pumps to generate heat (Figure 5.1.1)(Benoit, 2023). The partnership between Corix and PSE also helps PSE meet its larger environmental goals, such as PSE's 2030 goal of net-zero emissions from electric and gas operations and electric supply (Benoit, 2023). As well as PSE's 2045 target of a 100% carbon-free electric supply (Benoit, 2023). While PSE is not obliged to provide waste heat, this mutually beneficial partnership creates an optimal solution to secure the district energy's future.

Relatedly, the ability to integrate new technologies into a central plant was another attractive element of low-carbon district energy systems. It allows the buildings in the DES service area to comply with state building performance standards as they continue to evolve, creating a more cost-effective and easier policy-compliant pathway.

“The neat thing about district energy is that it can change over time. And you can plug and play with different technologies. So in the future, someone comes up with a little nuclear energy generator that's like the size of a briefcase. You can toss that thing in one of your boilers, and immediately, every customer that's connected to that hot water loop can benefit from all of that free heat. Whereas you wouldn't be able to do it on a building-by-building basis” (Jeff Giffin, Corix).

District energy systems continue to evolve, moving from steam-based systems to efficient, low-temperature networks that utilize various energy sources. Low-temperature networks running on water heated to 50-70 degrees Celsius provide greater flexibility as they are designed to integrate elements such as thermal storage, geothermal heat pumps, deep lake cooling, and local microgrids (U.S. Department of Energy, 2020). Additionally, low temperature networks reduce heat loss in distribution pipelines and are compatible with smart controls and thermal storage (which can store excess renewable energy, enable time-shifting of energy use, and improve grid balancing and reliability), further enhancing system flexibility and overall efficiency (Schmidt, 2017). As the Ports district energy is designed for scalability to accommodate additional buildings, the ability to integrate new technologies over time is a critical advantage in securing efficiency and diversifying the sources of energy to make the network more resilient to any energy supply disruptions (Colloide, n.d.).

District energy systems were continuously expressed as a way to simplify building operations and provide valuable flexibility that adapts to occupant changes and energy efficiency improvements. It aggregates diverse heating and cooling profiles to achieve economies of scale that enable deployment of local energy resources, such as the waste heat from the PSE Encogen plant, supporting decarbonization efforts while optimizing waste heat.

5.1.2 Climate and Environmental Goals

Seventy-five percent of interviews noted decarbonization as a key motivation for implementing a district energy system. Decarbonization is the reduction of greenhouse gas emissions from heating and cooling systems by replacing fossil fuels with renewable energy or waste heat (Michaelides, 2023). During the early stages of the Waterfront Redevelopment Plan, community-led planning efforts introduced the concepts of ecodistricts and the Leadership in Energy and Environmental Design Neighborhood Development (LEED ND) program. This helped introduce the topic of district-scale utilities (Freeman, 2025). Martin Selch, with Sustainable Connections, a local non-profit, was a key advocate for a low-carbon district energy (DE) system (Port of Bellingham, 2025).

> *"Ensuring sustainability is fully integrated into the waterfront development, Bellingham has looked to the EcoDistrict framework to help define green building, sustainable infrastructure, and community engagement. In 2012, a Bellingham waterfront team composed of the City, Port, and Sustainable Connections, participated in the EcoDistricts Incubator – a three-day intensive workshop focused on building a conceptual EcoDistrict framework to help guide future waterfront development – as they prepared to launch waterfront development efforts." (Puttman Infrastructure, 2014, p. 1)*

Informed by the principles of ecosystems, ecodistricts are a neighborhood planning effort that considers how an entire district can operate cooperatively to reduce carbon emissions, conserve resources, and support equitable outcomes for residents (New Sun Rising, n.d.). Additionally, the Waterfront District Downtown Area achieved Stage 1 Certification under the

LEED ND pilot program. LEED ND is a certification available for neighborhood-scale projects aimed to “inspire and help create better, more sustainable, well-connected neighborhoods” to look beyond the individual building scale to plan for entire communities in the goals of reducing sprawl (LEED, 2025).

This concept of ecodistricts and LEED ND helped guide discussions on district-specific utilities that aimed for net-zero or low-carbon energy goals. Another element of ecodistricts and the LEED ND program is their emphasis on compact mixed-use development, making district energy an attractive option as it relies on high density and mixed-use development for optimal performance. LEED ND and ecodistrict concepts were integrated into the development regulations and Sub-Area Plan (Waterfront District Sub-Area Plan, 2019, p. 33).

Furthermore, results from the Utility Master Plan (2014) demonstrated the potential for district energy to help meet Bellingham's already established sustainability and climate action plans. The business-as-usual model, which assumes conventional building-scale heating and cooling systems, estimated a total annual energy input of 56,747 MMBtus and an estimated 15,054 tCO2 of carbon emissions annually (Puttman Infrastructure, 2014). A district heating system that uses heat recovery would reduce annual energy input by 25% from the BAU and reduce carbon emissions by 54% from the BAU - “These potential energy and carbon savings align well with City of Bellingham sustainability and climate action plan goals” (Puttman Infrastructure, 2014, p. 35).

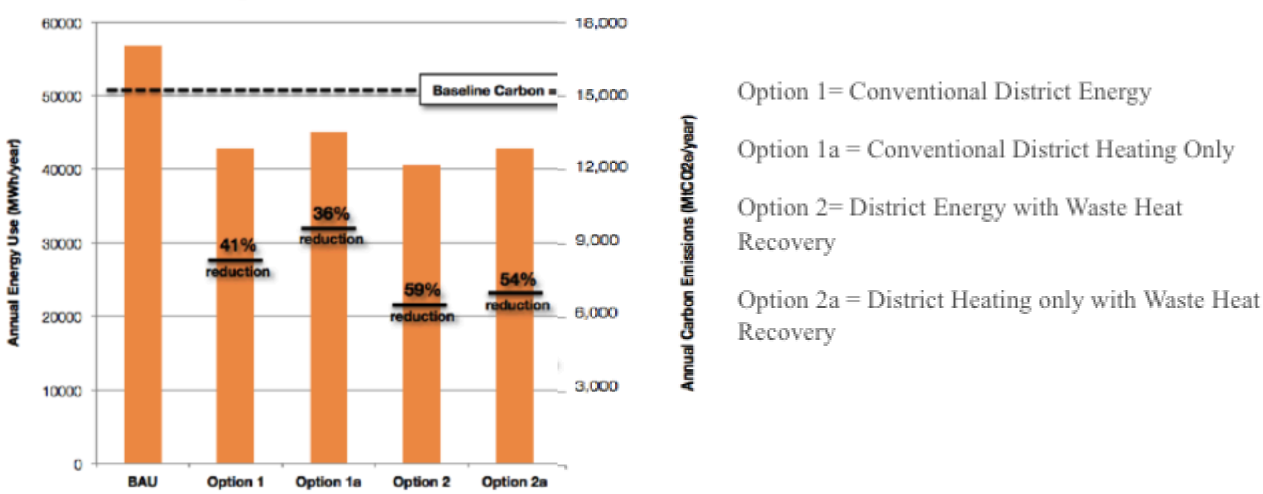

Figure 5.1.2 Energy Use and Carbon Emissions Comparison (Puttman Infrastructure, 2014)

Legislation such as HB1390 also made district energy a viable path to meet statewide building performance standards and meet state climate goals – "1390 really helped increase awareness of the system. That definitely helped and came a little later in the process and started to drive it more into the realm of consciousness" (Locke, 2025). Similarly, David Woodson (2025) states that;

> *"I like the fact that the state modified the Clean Building Performance Standard (CBPS) to have a decarbonization pathway because when the University of British Columbia (UBC) decarbonized its district system and went from steam to hot water and put in a bioenergy plant, its energy use intensity was much lower. And so, if the intent of the Clean Building Performance Standard is to reduce energy use, why not have a pathway that both reduces EUI and also addresses carbon? So I think it's brilliant that they did that."*

All interviewees agreed on the need for climate policies and the move to electrification; however, some expressed concerns for the increasing push to electrification[3] and its impact on building owners with less capital to fund the transition to electricity. In reference to the Clean Building Performance Standard, Lincoln Ferris (2025) expressed that;

> *"Strategies to find an all-electric solution can present some challenges. It's going to be increasingly important for utilities like Seattle City Light to acknowledge their generating capacity to meet the projected demand. As more building owners say, I want to electrify because that's the only way I'll meet the city's code that will continue to increase demand on the main grid. Not trying to come into compliance results in a fee of about a $10 per square foot fine starting in 2030. That's a pretty hefty hammer, and I think it's going to accelerate the number of people looking for creative solutions to figure out how to comply with state code in a financially feasible way."*

This is a concern, particularly expressed for older buildings facing high retrofit costs to comply with 100% electrification codes. Here, DES can present a more viable path as, rather than individually investing in, for example, an electric heat pump, a DES can electrify a central plant and distribute heating and/or cooling to connected buildings. This avoids costly upgrades to each building's electrical service. As pointed out by David Woodson, DES can offer a more

[3] This is the replacement of "technologies and processes that use fossil fuels, like internal combustion engines and gas boilers, with electrically-powered equivalents, such as electric vehicles or heat pumps." (International Energy Agency, n.d.)

phased approach whereby buildings can connect to a DES system that can reduce energy use and produce carbon emission savings while taking a phased approach to retrofit their buildings to reduce individual building EUI, as well as spreading costs over time.

5.1.3 Economic Motivations

In working to meet climate action goals expressed by the community and state building performance standards, DES was highlighted as a cost-effective approach for jurisdictions working to decarbonize existing DES or develop new low-carbon DESs, such as the Port of Bellingham. Low-carbon DES was expressed to have lower life cycle costs and the potential to provide stable customer rates. While upfront capital costs for the Bellingham district heating system were high at $29.2 million, a 31% increase from the business-as-usual model of $22.2 million, interviewees expressed the long-term operational savings the system could offer (Puttman Infrastructure, 2014). A district heating system with waste recovery was estimated to reduce life cycle costs to $122.4 million, a 16% decrease from the BAU of $145.7 million (Puttman Infrastructure, 2014). Seventy-five percent of interviewees stated the economic benefits of the DES approach as a key motivation for developing the system. This was particularly highlighted in the context of Washington's continuously upgraded building performance standards and evolving decarbonization technology as expressed by Giffin: “Instead of spending $100 million converting my buildings, to save maybe 10% of my campus energy, I can instead spend $100 million converting my campus from steam to hot water, to save 25% of the campus energy and a lot more carbon ...But the legislation didn't allow it at the time. There is new legislation (HB1390) that allows campuses to do that, but it had to be retroactively added to the legislation to allow it to work” (Jeff Giffin, 2025). Similarly, David Woodson expressed;

> *“In terms of trying to accelerate decarbonization at an urban scale, district energy is the most cost-effective way to do that. Now, if I had a small campus where I had like four buildings, I might have a different approach to it. But on an urban scale where I have multiple buildings, such as a downtown city, university campus, or hospital, I am hopefully having a district energy system where I can put high-intensity equipment that needs time and attention and people's eyes on it in a central location”* (Jeff Giffin, 2025)

Infrastructure operators like Corix and campus utility managers such as Lincoln Ferris also viewed district energy and other localized energy systems, such as microgrids, through a lens of energy and economic independence. District energy was assessed to offer more stable rates and less cost volatility. As the grid becomes more strained, increasing energy demand and reduced capacity for energy generation, may result in more than average rises in utility rates; "if we can ensure for ourselves that we can generate 75% to 80% of our own demand then we buffer against the utility rate increases that are coming through from Seattle City Light" (Ferris, 2025). Specifically for the waterfront district energy system, utilizing waste heat from the Encogen plant allows more energy independence as energy resources are localized and cost-effective.

5.1.4 Infrastructure Resilience and Reliability

Infrastructure resilience and reliability are the ability for an energy system to withstand and recover from disturbances such as heat waves, grid outages, or natural disasters (Weichselgartner, 2015). Infrastructure operators and campus facility managers expressed district energys ability to provide a more reliable and resilient energy supply as it centralizes energy generation and distribution at the local scale. It also integrates multiple energy sources and can include backup boilers, chillers, and thermal energy storage, providing system-wide redundancy and reducing reliance on one energy source or reliance on the main grid.

"You can just have one or two operators in a central plant with more robust equipment, with more resiliency, more redundancy and more oversight and you can do the same thing, but you're doing it for 30 buildings at the same time instead of each building having to do it by itself" (Giffin, 2025).

Modern district energy systems are able to have "continuous operational monitoring, advanced load forecasting, and advanced controls to optimize operations" (U.S. Department of Energy, 2020, p. 3). They allow local operational control and industrial-grade equipment and controls, with redundancy, support reduced peak demand by aggregating loads and shifting peak demand with thermal energy storage (U.S. Department of Energy, 2020).

In the wake of growing climate change concerns and considerations such as hotter summers and colder winters, discussion on the need to design energy systems that are reliable in the face of power outages, extreme heat, or cold is gaining more importance.

"As things get warmer, cooling is a big issue. It's in a city's interest to manage its own utility to try to mitigate that. It doesn't have to do it alone and it can go out to the marketplace and have a third party build a district cooling loop….Washington is getting close to having 100% of their electricity from renewable sources by 2045 but that energy tends to get focused on heating systems, but cooling is becoming a much bigger issue" (David Woodson, 2025).

District energy systems' ability to work at a centralized yet local scale presents an opportunity for cities and communities to respond to climate change risks. It can reduce carbon emissions and waste heat through the efficient use of resources and the removal of combustion and cooling processes from individual buildings.

> *"Having better reliability and redundancy as it relates to having our communities and our cities served by a centralized system rather than decentralized is much more efficient to maintain and take care of. I believe that for us to respond to climate change issues, we need to find that balance of efficiency and resiliency, and redundancy as well as reduce our carbon emission output, which pulls in alternative energy and electrification. There's also an opportunity to consider carbon capture, particularly when it's still difficult to completely stop using natural gas. There are district systems today that can do that. And I'm sure technologies will get better over time. We need to think big picture around, how do we solve it from a community standpoint? Or a city standpoint? And what are the different levers we can pull (i.e., waste heat, carbon capture, etc.)? It feels that centralized systems are really where we need to go"* (Lee, 2020)

Additionally, the growing energy demand from population increase, data centers, and more has brought concern about the main grid's capacity to adequately support this growing demand.

> *"Another large potential future issues we see out there is, how do we find and deliver into cities the new expanded electrical loads, which is becoming a massive problem if you talk to the utilities. There is significant concern, because the load is growing so quickly between data centers, EVs, converting from gas to electricity, and all these things going that they are not sure how they are going to generate all that electricity but bigger question in cities too is how are they going upgrade the distribution lines to be able to get into the cities with all these new expanded loads because of the significant costs to do that. That is another aspect of DE which helps to alleviate that*

expanded electricity requirement of cities, because you can significantly reduce the usage by sharing heating and cooling within the cities." (Locke, 2025)

However, in talking about resilience, Kelley (2025) also expressed the need to shape and design district energy, not only to reduce carbon emissions, but to uplift communities, support economic regeneration, and provide reliable power during climate-related disruptions. Resilience involves economic viability, social cohesion, and a neighborhood's ability to adapt to climate change and energy disruptions. Based on the Waterfronts Sub-Area Plan (2013, 209) and Waterfront Vision Framework (2003), the Port and the City of Bellingham started with social and economic objectives, like increased housing, job growth, and social well-being. Then the energy systems were later assessed and designed to support these broader goals. Aligning the energy system to align with the community's broader values and goals helped carry the district energy from design to implementation.

"You start thinking about resilience as economic viability and sustainable social cohesion. Those are the things that you need to maintain a neighborhood's health and vitality and to adapt to climate change. You wouldn't necessarily focus on energy first. But the more you make resiliency a goal, you want to have durable power, and you want to make that a part of your development strategy. You want that durable power to be low-carbon or a sustainable power so that when the power grid goes off you can still secure power." (Kelley, 2025)

Kelley speaks on the importance of social cohesion in supporting resilience goals. When working at the district scale, it's critical to have all key players collaborate and share community values. As noted by social-technical transitions theory, all actors from the government, business, and community need to acknowledge and support the transition, for climate resilience and low-carbon energy solutions, in order for it to be successful. The technology alone does not determine resilience or a successful energy transition, but the actors involved in governing, building, and advocating for the transition are critical in sustaining the transition long-term.

5.2 Land Use Restrictions

To understand land use regulation factors that support or hinder development, interviews and documents were reviewed to identify a) land use restrictions (which are regulatory constraints that limit where and how DE can be developed), b) land use policies that support DES integration and c) land use considerations (such as planning and design factors that need to be evaluated when designing a DES).

The main land use restrictions identified were zoning regulations, siting restrictions, stakeholder engagement with public agencies, rights of way for underground piping, and infrastructure financing.

5.2.1 Restrictive Zoning Regulations

Zoning codes that restrict urban energy systems and renewable energy generation were identified as a key land use restriction. In some counties, including Whatcom County, small distributed solar systems are generally permitted but larger solar array systems (greater than 100 kilowatts) are generally prohibited outside an industrial zone —"urban planning can play a role in better defining where we can put renewable energy technology such as batteries, solar panels and EV chargers" (Hawkins, 2025). For example, while King County set a battery energy storage system (BESS) ordinance to clarify where batteries are permitted in King County, there are still concerns about large BESS's and defining "what is more community resilience-based versus what is more utility scale" (Hawkins, 2025). While Hawkins primarily refers to solar panels and battery storage (which can be integrated into a district energy system), it presents a clear interface between urban development and energy planning whereby planners must define the type of energy system zoning codes should permit and the permitted scale or size of energy generation for those zones. They also must consider appropriate locations for energy generation outside industrial zones, as many of these localized energy systems need to secure a strong customer base, preferably in a mixed-use environment, to perform optimally. Land use zones will have to define what energy systems are permitted and consider appropriate locations (including outside industrial zones) that would highly benefit from district energy solutions.

Furthermore, urban planners will also have to help assess appropriate ownership models (public model, private model, public-private partnership, cooperative model[4]) based on technical, economic, and community needs. Through the Utility Master Plan, all ownership models were considered and evaluated based on investment return values, provider capacity and expertise, regulation, risk-tolerance, and community acceptance (Puttman Infrastructure, 2014). Based on this criteria a public-private development model was highlighted to offer the "most commercially viable development model" due to estimated capital requirements of the district energy, at around $30 to 35 million (compared to $25 million of the business as usual model) and positive projected investment returns, of four to eight percent (Puttman Infrastructure, 2014). Investment returns suitable for private development models are higher, with values of 10-12% and higher, whereas investment returns for public development generally align with public bond interest rates of 3-5%. Given the high upfront capital costs of DES, securing positive investment returns was important, and a public-private partnership model sat in the middle of the private and public investment return values. However, in considering the other factors, such as capacity and expertise, and risk tolerance, a private model was finally decided. Defining ownership and development models is critical for cities to assess their internal financial and technical capacity, assess opportunities for cooperative models, and assess qualifications for private third-party utility ownership.

Giffin, with Corix, also spoke to the value of planning jurisdictions being proactive in facilitating DES development through their zoning regulations. In a project based in Utah, Corix was working to build a central district energy utility plant; however, the jurisdiction's zoning code did not address DES (Giffin, 2025). This can create a blurry line of what is permissible and potentially slow progress. However, "as soon as it becomes an option in a zoning or planning document, then it's valuable. Bellingham was unique in that they included language when they did the rezoning; they knew they wanted to include district energy" (Giffin, 2025). Bellingham's Sub-Area Plan, acknowledging and allowing DES, as well as including requirements for buildings to connect, eased the process of implementing the system.

> *"Innovative district-scale systems that leverage existing waterfront assets – such as district energy, district water, and district stormwater –have tremendous potential to*

[4] Also known as stakeholder owned, as ownership is shared among co-op customers. "Stakeholders are typically customers receiving the district infrastructure service, like commercial buildings and/or residents within a defined location.

reduce resource consumption and carbon emissions while generating economic benefit to waterfront development partners…The Port is installing district heating and cooling pipes under the roads to allow for the heating and cooling of buildings from a centralized source. District energy is more efficient with less carbon emissions than localized boilers, and supports a wide range of sustainable strategies such as the recapture and reuse of waste heat from Puget Sound Energy's Encogen Station." (Waterfront District Sub Area Plan, 2019, p. 72)

Many zoning laws have outdated provisions that did not consider the installation of renewable energy and other low-carbon energy solutions in communities (Brasuell, 2022). This results in no mention of urban energy system development and unclear provisions on what is permissible. Permitting, zoning approvals, and construction also present soft costs that prevent or slow down renewable energy development (Brasuell, 2022). By updating zoning policies to support a jurisdiction's climate action and resilience goals while aligning zoning with community priorities and public-private-sector development objectives, planning departments can help simplify and streamline low-carbon urban energy systems (Forman, 2023). Jurisdictions can consider several zoning approaches, such as by-right zoning, which "allows projects that comply with certain zoning standards certain approvals and building permits through a relatively simple administration process" (Forman, p. 29). Overlays that place special districts over existing zones to encourage development, such as mixed-use, affordable, or mixed-income housing, and align this with DES development (Forman, 2023). Zoning incentives can also make it financially attractive for developers to provide certain public benefits, such as energy services from a district energy system.

5.2.2 Siting issues and community concerns

Siting and permitting leads need to consider the impact and community concerns regarding district utility-scale projects. In reference to battery energy storage systems, Hawkins highlighted;

"There's been a lot of pushback in Skagit County, in the city of Renton, Black Diamond and others, where the community is saying, we're really worried about these big

> *lithium-ion batteries being put into our communities, and we're concerned about safety, first and foremost. They're often concerned about fire risk and explosive risk, which is a real risk, but we have codes and standards to address that. And certainly need more training around how to help communities, emergency managers be prepared for lithium-ion batteries. But it brings up this whole sitting issue of where in your county are you going to allow battery energy storage systems to go?"* (Hawkins, 2025).

While the Ports DES does not include battery energy storage, several DES systems are exploring and/or implementing battery integration to complement low-carbon thermal systems. With or without battery storage, siting district energy systems requires considerations of land use and infrastructure compatibility. Because DES are optimally located closer to energy consumption, siting closer to commercial and residential areas is most attractive; therefore, preparing for and addressing community concerns is critical. Safety is a common concern in local zoning proceedings for energy storage projects (Twitchell, 2023). Coordination with local fire officials and training protocols of emergency responders should include training of equipment (such as battery safety), operations, and response guidance (Twitchell, 2023). Training and knowledge of the systems by planners is also critical in evaluating proposed urban energy projects and ensuring adequate regulatory oversight. Local planners also have to consider other community impacts, such as visual, sound, and emissions. To address the visual impacts of energy storage facilities, some energy operators and developers chose a containerized solution where the systems are built on a modular basis in a shipping container or other container (Twitchell, 2023). Corix took a similar approach in building a modular system (Figure 4.2). Some energy storage systems are fenced off as a requirement of NFPA - "Section 70 of the NFPA requires all large electrical installations, like energy storage systems, to have a perimeter fence of at least 7 feet to prevent unauthorized access to the facility" (Twitchell, 2023, p. 11). The large perimeter walls may be unattractive, resulting in some jurisdictions adding more layers of screening, such as siting trees in certain areas around the perimeters or creating vegetated buffer zones. However, "in more heavily urbanized areas where options for setbacks and screening may be more limited, some utilities and local jurisdictions have opted for more creative approaches like commissioning murals to be painted on the exterior of energy storage projects to help them blend in with the community" (Twitchell, 2023, p. 11). PSE, for example, in 2020, partnered with artists to create a mural on 21,600 sq ft of corrugated metal on one of the walls of the Encogen power station in Bellingham as part of PSE's ARTility Initiative (Zoe, 2020). This initiative was aimed at bringing more vibrancy and color to industrial spaces in Washington. In regard to noise, if a project has the potential to cause noise pollution, local planning and zoning officials can consider requiring a noise study (Twitchell, 2023). If noise impacts are then identified, officials can require setbacks and/or screening to mitigate thes impacts.

The Port's waterfront development plan created an opportunity for community discussion as several public meetings and community engagement efforts were conducted. Through planning documents like the Waterfront Vision Framework (2003), residents expressed values for a mixed-use, sustainable, affordable, and economically vibrant neighborhood that aligned with the benefits of a district energy system. Having a transparent siting process, clear benefit-sharing structures, and community ownership or governance opportunities can increase community acceptance and ensure sustained support for a district energy system.

5.2.3 Limited Awareness and Coordination with Public Agencies

In addition to siting the district energy central plant, operators also have to consider the required thermal piping networks that require access to public rights-of-way. Operators specifically highlighted getting approval for distribution piping as a major regulatory constraint –

> "*In a city like Seattle, it is very difficult because every time you cross a street, you have to go to the City Department of Transportation requirements to get the okay to go underneath the street. So every time you connect to a new block, it becomes a process. The first time we did that in Seattle, it was the same developer that owned two blocks, and they wanted to go under the street and to have one system to serve both blocks that they owned. It took a little over a year to get that approval through the Department of Transportation. We had to go to the city council, explain why it was important,and the benefits of the system. It very much hindered the process because the developers want to go and they want to build and can't get delayed because they have to make money"* (Scott Locke, UMC, 2025).

This research is not arguing for operators to skip regulatory and safety protocols, but it highlights a potential gap in knowledge between energy utilities and other public agencies. As energy operators and designers explore new and economically efficient ways to meet energy efficiency requirements, public agencies may lack the resources and technical skills to adequately assess these new technologies and strategies.

Given the shared aspect of a district energy system (through distribution lines connecting multiple buildings), several stakeholders are involved and required to achieve regulatory compliance. However, the newness of the system and the limited knowledge of district energy systems can slow down regulatory approvals. For a district energy system project using sewer heat recovery in South Lake Union, Seattle, Todd Lee recounts the several stakeholders involved including the Seattle Department of Construction & Inspections (who look at the building itself), Seattle Public Utilities (who oversee the utilities in the streets), King County Metro (who own the sewer lines), and the Seattle Department of Transportation (that oversees the streets).

> *"All agencies and stakeholders must be engaged to just put in a vault in the middle of a street to offtake sewage…It was probably a four or five-year process, and a lot of that had to do with getting through the regulatory requirements and getting stakeholder approvals. When you have something new and different like sewer heat recovery which is a newer technology, that's where you run into a lot of roadblocks because people don't quite understand it. And that's where it can slow down the process. But as more of this happens and there's more use cases to point to it will speed up just like implementing any new technology. But that's the biggest challenge I've seen is getting all of the stakeholders aligned with the process, with what it is. And getting that actual work in place has been the biggest challenge"* (Todd Lee, McKinstry, 2025).

The push to a clean energy transition has challenged traditional urban planning models, which may be outdated and need to consider the integration of new technologies and strategies in long-term planning. How can planning integrate and encourage creative new strategies, while addressing public concerns and needs? For the Port of Bellingham's district energy system, while ecodistricts and district-specific utilities were communicated as priorities from the community, city staff were originally hesitant to allow a district system because they lacked the technical expertise to manage and operate the system and had limited capacity to manage another utility (Freeman, 2025) –

"Elected officials were very supportive and were ready to allocate funding for us to do it and take on yet another utility but staff really pushed back on that. We were able to do it, though, because we did the feasibility of three different systems (stormwater, water, and energy), which really helped say we did something. We did water, we know water, so lets put this non-portable purple pipe system in the ground for irrigation and potentially other uses."

That allowed the Port and the city to navigate pressure from elected officials and from non-profits that wanted a clear response to climate change with district energy -

"We threaded the needle properly as far as being on board with the system and applying money in resources where it made sense, but also telling elected officials that this is is not our thing. You got to find a different way to do it. And for district energy systems, there's a very compelling case for them to be privatized because of the really technical nature of the plant that you use to do it and the fact that it has to talk to HVAC systems in vertical construction, right? We can get your water, we can take your sewer, and we can make the roads drain. We're good at that. But when you get into these more technical things like heating and cooling, it's less attractive to the public sector" (Freeman, 2025).

The Port and City of Bellingham found a solution that best fit for all parties through a third-party utility system, but the Port and City hope to use the waterfront district energy as a case study to promote potential new projects that could consider other ownership models.

"Some cities have decided they didn't want to actually manage and hire the staff to do that so they outsourced it to companies like Corix to run that for them. But effectively, their lens was it's just another municipal utility. That just becomes another thing that their planners plan for and their engineering department plans for." (David Woodson, 2025)

Woodson (2025) also notes that "when working in the public sector, you're working with public dollars, so there's very little room for experimentation because it has to work". Two recommendations to create space for innovation are, one, understanding that things are not always going to work, so you need to have worked in a backup plan for when it doesn't. Secondly, someone has to own it.

> *"UBC, which is one of the leading universities for sustainability and being innovative, has so many failed projects on its campus. I would suggest that all of them are because whoever was the initial champion of it had left and nobody took ownership of it after they left. If no one is there to champion it, ensuring that it's working properly, it will get lost in the shuffle and it will not function. All of these projects need a champion. …not just a company but individuals that are enthusiastic and excited"* (Woodson, 2025).

Here, Woodson speaks to one of the strengths of the Ports district system. While the Port outsourced a third-party utility, Corix, to manage and own the system, having a regional manager, Jeff Giffin, ensured on-the-ground management and someone who championed moving the project from design to actual implementation.

5.3 Supportive land use policies

5.3.1 Incentives and requirements to connect to a DES system

A key finding in the analysis of land use policies that support DES development is the critical role of planning incentives and regulatory requirements that facilitate connections to a DES plant. While legislative support, such as HB1390, helped garner more awareness of DES, the Port of Bellingham's implementation of land use tools that designate mandatory connection zones, requiring upcoming development within the DES service area to connect to the system, helped facilitate DES adoption. The Port's policies are further reinforced through development regulations, infrastructure agreements, and zoning overlays (rezoning the Waterfront District as a mixed-use development zone); "all new development within the Downtown Waterfront area shall connect to and utilize District Specific Utilities, such as district energy, district heating. and non-potable water systems. Uses in other areas may connect to District Specific Utilities as approved by the Public Works Department" (Development Regulations, 2013, p. 16).

In its infrastructure agreement with Corix, the Port stated that "the Port will support the Project and Corix's efforts to acquire new DES customers", signalling a strong public commitment to the success of the DES (Infrastructure Agreement, 2018, p.6). This helps reduce market uncertainty or risk to Corix, ensuring a stable customer base and a supportive policy environment, critical for an infrastructure system with such high upfront costs. Freeman further notes that in the Sub-Area plan, it states, "you have to hook up because we (the City of Bellingham) understand that as soon as you lose people, you lose the momentum because district energy only pencils out with some sort of volume of users. And so we built the policy into the sub-area plan that said you have to hook up if it's there" (Freeman, 2025). Because DES needs scale and density to perform optimally, planning departments can play a role, such as the Port and City of Bellingham, in supporting DES in acquiring customers through connection mandates and/or incentives. In reference to a DES system in Calgary, David Woodson describes how "The city of Calgary said if you build in this area, you have to connect to the district system. The city also put in other incentives that said if you connect to the district system, we will allow you to, in essence, add two floors to the top of your building" (David Woodson, 2025). Here, building owners were provided with financial incentivizes to connect to the district energy system. Clear communication and expectations with developers to require a connection to a DES are crucial.

> *"The city needs to be clear with developers that they will and shall get their heating and cooling from this (DES) plant. They don't have the option of just having their building isolated from that district energy source. And so as you're planning a neighborhood or development around having a district energy system, there must be clear legal ramifications and something in place that requires them to utilize the utility that's there."* (Lee, 2025).

Securing a strong customer base is also important in distributing costs. As noted by Locke (2025), "one of the challenges with district energy is the initial significant cost to build it. While the systems offer greater efficiency and lower long-term operating costs than individual building systems, they need enough scale to reach a financial tipping point." However, if a developer doesn't control enough surrounding land and there are no policies requiring nearby buildings to connect, it raises the chance of underutilization and stranded infrastructure.

DES relies on adequate building and population density to perform optimally. Embedding connection requirements into land use codes can help reduce market uncertainty, enable faster scaling of the system, and distribute costs. From an economic and energy efficiency perspective, jurisdictions need to work with DES operators to support mixed-use development and connection to the DES service area.

5.3.2 Forward Thinking Planning for Utilities

The Port and City's ability to be forward-thinking and install pipes, add connection requirements, and partner with Corix eased the process of implementing a DES. Even before securing a third-party utility to manage and own the DES system, the City of Bellingham and the Port created the right conditions early on to make the waterfront an attractive site for district-specific utilities. The Port and City of Bellingham were able to adopt district energy by embedding long-term, systems-based strategies into their land use and infrastructure planning. First, the Port was able to align land use policies, such as zoning for mixed-use, with DES planning to concentrate energy demand in targeted areas. Here, the Port and City were able to identify priority service areas where building demand and energy demand could support a DES. Furthermore, the City and Port engaged with utilities early on and partnered with Puttnam Infrastructure, a company focused on district-scale utilities, to incorporate ecodistrict concepts identified in early citizen-led and planning efforts. Utility corridors were then planned to include DE piping alongside other utilities such as water during the utility master plan, reducing future costs to install new pipes (Puttman Infrastructure, 2013).

In summary, the Port presents an example of aligning land use regulation and density optimization to create an attractive and supportive environment for district-specific utilities such as district energy. Creating a mixed-use zone with DES planning can help cities concentrate energy demand in targeted areas. In addition, defining service areas and adopting connection requirements or incentives for new development creates a stable, predictable customer base to support DES investment. Forward-thinking urban planning ensures district-scale solutions are both technically and economically viable but also well-integrated into the urban fabric to support long-term sustainability and resilience goals.

6. Conclusion

Washington state has made substantial progress on the clean energy transition. This includes legislation like the Clean Energy Transformation Act (CETA) aimed at phasing out coal-fired electricity from Washington's energy mix by 2050 and requiring electric utilities to have 100% of their electricity come from renewable or non-emitting sources. Decarbonization efforts at the building scale, with the Clean Building Performance Standard, have also been set to reduce greenhouse gas emissions from the building sector and enhance building energy performance. However, with concerns of growing energy demand adding more strain on the main grid and the limited waste recovery opportunities at the building scale, some jurisdictions, such as the Port of Bellingham, are considering and/or developing district energy systems to respond to those concerns. District energy is a cost-effective means of meeting state climate goals for low-carbon and renewable energy generation, while operating at a localized scale to enhance energy efficiency and utilize waste heat and other local energy sources. This is all to create a reliable local energy network. However, the development of district energy in urban environments can present unique land use challenges. Local governments play a critical role in zoning, policy, and investment decisions to evaluate and approve urban energy system installation. State and local policy, such as House Bill 1390, has helped create a protected niche for emerging technologies such as modern district energy systems. With the increased adoption of local sustainable solutions, planners play a key role in evaluating how urban energy systems can meet community goals and the required land use planning decisions and regulations to optimize their performance.

Using the Port of Bellingham as a case study, the experience and motivations of infrastructure operators and designers, regime intermediaries of emerging technologies like low-carbon district energy systems, were analyzed to understand current conditions and future projections of system adoption. Key motivations for developing the Port of Bellingham's low-carbon district energy systems centered on the system's ability to provide greater rates of energy efficiency compared to standalone building approaches. Higher efficiencies were calculated based on the system's ability to integrate multiple energy sources, most notably the waste heat from the Puget Sound Energy (PSE) Encogen plant. As well as the opportunity to balance and share energy loads between buildings. Meeting climate and environmental goals was a second key motivation. The Port and City of Bellingham saw district energy as an opportunity to meet the state's clean building performance standards, through House Bill 1390, as well as an opportunity to meet the Port and City’s climate action goals. At a community scale, sustainability was a key value communicated in public meetings regarding the waterfront redevelopment. District-scale utilities provided an opportunity to reduce carbon emissions, localize operations, and utilize local energy sources. From an economic perspective, district energy presents lower life cycle costs, energy independence, and a cost-effective path to meet energy performance standards compared to a standalone building approach. Finally, district energy aligned with the Port and City’s climate resilience goals in creating a reliable local energy network that could withstand disruptions such as natural disasters or outages experienced on the main grid.

Strong alignment in motivations between infrastructure operators and the Port and City of Bellingham proved to reduce land use restrictions and created a supportive environment for district energy systems. A key supportive land use policy was the requirement for buildings in the service area of the district energy system to connect to the system. District energy depends on a strong, reliable customer base to optimize operations as well as distribute costs to cover the high upfront capital costs. Embedding connection requirements signalled the Port of Bellingham's strong commitment to the district energy system, reducing market uncertainty for Corix, and enabling faster scaling of the system. Secondly, the Port of Bellingham's early planning efforts with the 2014 Utility Master Plan to explore the potential of district energy allowed them to act early and install pipes at the same time as the water system, reducing future infrastructure costs.

On the other hand, the newness of the system and required coordination with various public agencies presented some challenges. Infrastructure operators and designers noted the challenges of siting facility equipment and obtaining permits for rights of way, which slowed project development for many district energy projects. However, because distribution pipes were already installed and proximity to the PSE Encogen plant narrowed down a site for the central plant, the City and Port were able to avoid some of the siting constraints experienced in other district energy projects. Instead, the Port and City had to resolve who would manage and operate the system. The City and Port had to balance meeting the needs of advocates and elected officials who were strong champions of district energy while assessing their own internal capacity and expertise to adequately execute a district energy project. After much assessment, they were able to resolve this through hiring a third-party utility operator, Corix.

Socio-technical systems and urban planning are similar in many ways. They both evaluate complex interdependent interactions between infrastructure systems, technology, markets, regulations, and user practices. They both acknowledge the need to think holistically and long-term beyond immediate technical and financial aspects and to consider the social actors and governance structures needed to sustain and accelerate sustainable urban transitions. However, socio-technical systems theory can provide additional tools for planners to navigate the complexity of urban transitions and the interaction of emerging technology, institutions, and user practices. Socio-technical systems theory encourages planners to view innovation as non-linear and multi-dimensional, as co-evolutionary changes are required across various sectors (e.g., business models, policy frameworks, consumer preferences), requiring planners to work across various scales of policy, long-range plannin,g and direct public engagement. Socio-technical systems theory places innovations such as modern low-carbon district energy systems as a protected niche. Through strategic niche management, cities can experiment and assess the desirability and adoption of niches or emerging sustainable technologies like district energy through pilot projects. However, planners must continue to intentionally support, monitor, and assess opportunities to embed niche innovations into broader strategies to avoid isolated pilot projects. Furthermore, because shared public knowledge and value systems are critical in supporting niche innovations, planners can support niche empowering processes by communicating the future visions for innovative technology to various actors and influence wider regime changes (through regulatory changes) to allow the technology to diffuse more easily. Even more, socio-technical systems theory argues for adaptive strategies with learning mechanisms to navigate the uncertainty of transitions, as rigid plans often fail to respond to various processes in the transition (e.g, exogenous factors like climate change, oil crises, etc.) Within sustainability literature is also the question of equitable design and governance structures to evaluate who participates and benefits in sustainability transitions. Planners are responsible in engaging various actors in decision-making and implementing equitable distribution strategies of emerging technologies.

Through a socio-technical systems theory perspective, we can see planners also play a role as regime intermediaries of emerging sustainable technologies. For example, planners have a role in mediating and engaging various actors and managing cross-sector collaboration to build social capacity for sustainable urban transitions. Secondly, planners have a role in translating niche innovations, like low-carbon district energy systems and other sustainable urban systems, to the wider public and communicating their value and future potential. Additionally, planners bring an interdisciplinary perspective to evaluate how new urban energy systems can be compatible with land use development patterns, long-term infrastructure plans, equitable distribution goals, and broader community goals.

However, planners also need stronger capacity, technical fluency, and institutional support to fully evaluate and integrate emerging sustainable technology. Planning curricula should expand to improve planners' technical fluency of sustainable solutions for planners to effectively consider constraints, opportunities, and ways to integrate these solutions into inclusive planning strategies. Building technical fluency can also help develop the capacity to work with other departments, such as engineers and climate scientists. Planners should continue to facilitate cross-sector coordination between government departments, private partners, and communities regarding emerging technologies and strategies. As well as create opportunities through policies and incentives to move niche innovations and pilot projects to more mainstream practice where appropriate. Sustainability theory and practice show how investment in social capital through knowledge sharing and building capacity networks can increasethe success of sustainable innovations (Downs, 2018). Enhancing capacity, through education and increased collaboration, can ensure planners are proactive rather than reactive to changes in the energy transition.

All interview participants expressed confidence in the increased adoption of district energy systems as rising energy performance goals are likely to continue the drive for low-carbon district energy and other emerging sustainable energy technologies (e.g., demand response automation and geothermal heating). Energy and land are deeply connected, and as changes in energy production change to support production in the built environment through distributed energy systems, land use planning must be proactive in how to appropriately respond to this change.

APPENDIX

Appendix A: Semi-structured interview guide

Interviewees

Name	Title, Organization
Infrastructure operators, designers, or owners	
Lincoln Ferris	Special Assistant to the Chancellor, Seattle Colleges District
Jeff Giffin	Pacific Northwest Regional Manager, Corix
Todd Lee	Sr. Director of National Design-Build Operations, McKinstry
Scott Locke	Energy & Environment Business Development Director/ Associate, UMC
David Woodson	Executive Director, University of Washington Campus Energy, Utilities & Operations
City of Bellingham	
Freeman Anthony	Public Works Department
Tara Sundin	Community and Economic Development Manager
Department of Commerce, Energy Division	
Jeremy Berke	Management Analyst
Nora Hawkins	Renewable energy policy
Urban Designers	
Charles Kelley	Principal, Green Urban Design

Interview Guide	
1. Interview name	
2. Interview Date	(dd/mm/yy)
3. The participant agrees to the interview being recorded	Yes…… No……..

SECTION A: Experience and role

1. Would you walk me through your journey in how you got involved in this field and your interest in district energy systems?
2. From the perspective of your division, what were some of the key goals for developing district energy systems?
3. Can you describe the projects you have worked on? How do they differ in terms of scale, ownership models, or financing structures?
4. How do financing or ownership models for solar microgrids and district energy systems (e/g, public-private partnerships, power purchase agreements, community solar) influence project success?
5. From your experience, what strategies have been most effective in making these projects financially viable?

SECTION B: Policy and Regulatory Landscape

1. What significant policy or regulatory factors (e.g., zoning laws, siting restrictions, permitting processes) either support or hinder the development of district energy systems in urban areas?
2. Based on your experience, what is the role of urban planning in determining the feasibility of solar microgrids? Are there ways planners can better support the deployment of these systems?
3. Ask developers: What are some technical or spatial challenges when implementing DES or solar microgrids in urban areas?

SECTION C: Stakeholder Engagement

1. What stakeholders (e.g., utilities, government departments, developers, community organizations) are typically involved in the system design, planning, and development?
2. What are the challenges in coordinating among them?
3. What were the key pieces of information when telling the story of this project or this type of system that you think helped it gain support?
4. What were some of the expressed concerns of the project/ system, and how did you or your department address them?

SECTION D: Lessons learned and looking ahead

1. How do you see the role of district energy systems evolving in the context of urban sustainability and resilience planning?
2. What are some successful examples of DER systems (particularly in urban areas)? What made them successful?
3. What advice would you give to city planners or policymakers who want to encourage more DER adoption?

Appendix B: Figure 4.1 Waterfront District Boundaries

(Port of Bellingham/ City of Bellingham, 2019, p. 4)

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