An Evaluation of District Energy Systems in North America: Lessons Learned from Four Heating Dominated Cities in the U.S. and Canada

Lauren T. Cooper, University of Michigan
Nicholas B. Rajkovich, University of Michigan

ABSTRACT

In North America, a number of efforts are underway to achieve high levels of energy efficiency in commercial and residential buildings. Most of these programs aim to increase the performance of the building envelope, efficiency of equipment, or to effect behavioral changes to reduce greenhouse gas emissions from the building stock. One area generally overlooked by program managers is the source of energy supply to a building; district energy systems (DES) are a proven method to supply thermal energy to buildings while reducing peak demand, annual energy use, and total greenhouse gas emissions.

This paper provides a background on the concept and configuration of district energy systems. It then reviews several systems (Toronto, St. Paul, and Cornell University) currently in operation. A section of the paper then provides an analysis of the operation and implementation of one DES-reliant sustainable community (Drake Landing Solar Community). Finally, the paper provides an overview of policies used to increase the presence of DES systems in the U.S. at the local, state, and federal levels.

The paper concludes that DES can decrease waste heat, pollution, fossil fuel use, and long-term costs, and should be a technology considered alongside building-scaled improvements as part of an energy efficiency portfolio. In addition, as energy efficiency programs reduce the need for additional utility generation, the design, operation, and maintenance of DES represents a new business opportunity for electric and gas utilities. Overall, the paper finds that local communities should emphasize DES because they are the direct beneficiaries of these systems.

Introduction

Today, over 112 Canadian and 5,800 U.S. district energy systems (DES) are in operation and serving more than 6.5% of commercial buildings, downtown districts, campuses, military bases, research facilities, and even some residential locations (Gilmore & Warren 2008; Spurr 1996). While steam was the predominant type of DES in the last century, systems expanded into cooling and heating technologies in the 1960s (Thornton 2005). The energy crisis of the 1970s led to a push for energy efficiency and DES was recognized as an effective approach to reducing peak demand (Thornton 2005; Rogner 1993). However, it remains a largely underutilized energy option in North America, particularly for serving residential areas.

DES provides service to connected structures within its particular service area. Therefore, DES is inherently community based and demands a range of actors and stakeholders to implement successfully. DES and combined heat and power (CHP), or cogeneration, are terms sometimes used interchangeably though DES is a broad term for many systems and CHP specifically utilizes waste energy from industrial processes, electricity production, and heat production for energy and space heat provision (Shipley et al. 2008; Spurr 1996) DES systems are flexible in scope, fuel sources, and technology, taking multiple forms including chilled water, heated water, electricity and steam, and in energy storage systems, an example used later in this paper (Gilmore & Warren 2008). Differences in city size and climate encourage a wide range of successful DES variations.

District energy systems (DES) have been in use for over a century and are an important energy source throughout Europe because of greater urban density, government investment, and, arguably, better long-term planning and communication between the public and private sectors (Rogner 1993; Thornton 2005). North American cities have shown growing DES interest in the last three decades due to increasing energy costs, national security issues associated with foreign fuels, increasing fuel prices, new technology, local economic issues, increasing energy demand, and environmental considerations (Martinot, Wiser & Hamrin 2009). DES has wide ranging benefits that address some, if not all, of these concerns. Primarily, it allows for economy of scale in energy provision and "presents a rare opportunity to reduce costs without any adverse effects on the quantities and qualities of the energy services provided" (Rogner 1993: 120).

Buildings in DES are connected through piping and do not need to house boilers, cooling towers, or chillers. Connected buildings use energy from the piped steam or water for space heating, space cooling, or water heating. Systems are typically closed loop, meaning that heated or cooled water is returned to the central plant and again circulated after being cooled or heated by an energy source. These are highly efficient systems, eliminating waste energy that is associated with typical energy transfers (Spurr 1996).

Finally, there are significant local and global environmental benefits to increasing the use of DES. Importantly, in 2008, electrical energy production was responsible for the release of 2,359.1 million metric tons of carbon dioxide in the United Sates alone (USEIA 2009). Centralized DES plants increase efficiency, reduce overall energy consumption, allow for stricter controls, and have fewer sources of leaks and pollution (Spurr 1996). Further, it can reduce strain on the entire system during peak demand which allows the energy provider to reduce peak energy supply, further reducing emissions (Spurr 1996). DES systems may even have the option to operate entirely independently, though states must maintain regulatory policies to ensure DES reduces overall emissions (Thornton 2005).

DES is also an important energy option on a global scale because of significant decreases in greenhouse gas (GHG) production (Spurr 1996). District energy options that increase efficiency of, or eliminate, fossil fuel combustion produces emissions savings of SO_2, NO_X, and CO_2 (Gilmore & Warren 2008). Fuel transportation emissions are reduced because DES is more adaptable to utilizing local fuel sources (Thornton 2005). CHP systems provide additional benefits by operating at up to 80% efficiency, while traditional energy and heat production average approximately 45% efficiency (Shipley et al. 2008). More than two-thirds of fuel energy used to produce power in traditional production is lost as heat energy, which a DES could utilize to provide energy (Shipley et al. 2008).

Economic and Consumer Considerations

While there are significant and long-term economic benefits to implementing district energy, the upfront capital costs can be substantial. DES can save money for building owners, developers, and residential consumers because the bulk of equipment is isolated in the DES network, eliminating the need for stand-alone systems (boilers, chillers, water heaters) in individual buildings, reducing maintenance and operating costs (Gilmore & Warren 2008). DES saves space in buildings that would otherwise store combustion or cooling equipment and reduces the interruption and expense of siting, permitting, and monitoring of equipment. Changing equipment at one central location is simpler and less costly than updating individual buildings, making it easier to adapt to improved technology (Osboda et al. 2008). Centralized professional staff provides reliable energy service when compared to non-DES buildings with isolated boilers, coolers, and furnaces without onsite support (Spurr 1996).

DES also provides protection for building occupants from fuel price volatility because of fuel flexibility and the ability to use local and domestic sources (Gilmore & Warren 2008). DES can save from $800,000 to $2.4 M[1] in energy costs for a 45,000 sq. meter (500,000 sq. ft.) commercial building (Thornton 2005). Energy provision can take the form of long-term contracts, reducing uncertainty of energy costs over time. Investors in DES can view the systems as a "competitive investment opportunity" with a high return on investment (Gilmore & Warren 2008: 23). As an incentive for development, the presence of a DES can mean long-term reduced costs for developers, tenants, and investors because of both reduced capital investment and long term energy costs (Gilmore & Warren 2008).

Cities benefit from implementation because DES promotes density and mixed-use development, reducing waste and infrastructure costs and may even reduce sprawl to fringe urban areas (Gilmore & Warren 2008). However, DES relies on density in order to be effective and so both relies on and supports density. Like other large-scale infrastructure projects DES has an important role in regional economics, having been found to secure investment and even revitalize urban cores for large city-regions (Gilmore & Warren 2008). Further, funding and building DES can be a source of both short-term and long-term job creation (Gilmore & Warren 2008). DES also uses less land than traditional energy sources, further reducing sprawl, and may even use urban brownfields as prime locations for DES redevelopment (Gilmore & Warren 2008).

North American City Case Studies

Because of the factors described earlier, including high fuel costs and global climate change concerns, there has been an increase in DES exploration, implementation, and investment in both the US and Canada including launching thirty-four new downtown district cooling businesses in North America since 1990 (Thornton 2005). Four examples of DES will be discussed here followed by a discussion of barriers to implementation.

[1] All monetary values are in United States currency.

Table 1. Case Study Overview

System	*Cornell CHP; Lake Source Cooling*	*Toronto Deep Lake Water Cooling*	*Drake Landing Solar community*	*St. Paul District heating; district cooling*
Costs	CHP - $82 M	~$190 M	Over $7M from Gov't; private	District heat $55M
Age	CHP and LSC in last 20 yrs.	Less than 10 years	2006/ 2007	Started in 1983
Financing	Institutionally funded	Private, with public ownership	Private; Gov't support	Non-profits, Grants
Energy Source	Natural gas; cool water	Cold water	90% solar	Organic material of local wood and brush; gas
Emissions Reduction	Reduced GHG emissions 85,000 tons, LSC reduced energy by 86%	Estimated 40,000 tons CO_2 diverted CFC emission reduction	Cut CO_2 by 5 tons/ house (27,000 tons)	280,000 tons/yr. carbon dioxide emissions between systems
Size/Scope	Central system 150 buildings	50 buildings, and growing	52 residences	Heating: >187 buildings Cooling: 97 Buildings

Toronto, Ontario, Canada

This DES system has space heating, domestic hot water, space cooling, industrial processes, and electricity capabilities (Rogner 1993). In 1994, Toronto launched the Deep Lake Water Cooling Project, one of the first commercial efforts to draw on a natural cold water reservoir (Rogner 1993). A $190 million investment, this system is owned by Enwave District Energy Limited with tax-payer shares: 43% owned by the city of Toronto and 57 % owned by the Ontario Municipal Employees Retirement System (Wong 2004).

The system features a pipe, 5 kilometers long and 1.6 meters in diameter, 83 meters beneath the surface of Lake Erie. This pipe draws in water below the thermocline, at a constant 3.8°C. After being used for system cooling, the water then enters the city's drinking water system thus not impacting local ecology through warmed water return (Spears 2004; WTDEMP 2008). The thermal distribution consists of a system of pipes beneath public roads (WTDEMP 2008). After water is pumped, it enters an energy transfer station where metal plates transfer coolness to water running through pipes on the other side of the plate (Langin 2007).

The DLWCP has direct economic benefits for the downtown Toronto business district, building owners, and energy consumers. The system eliminates the need to replace chillers, which can cost millions of dollars, and have a life span of only about 25 years (Spurr 1996). Fewer chillers decrease the noise nuisance to building occupants and increased space for repurposing. Buildings can enter a multi-year contract to lock in low rates, which are predictable due to reliance on the lake's natural cool temperature. Capital costs for individual buildings are about a third of the costs associated with their traditional heating and cooling equipment equivalent (WTDEMP 2008).

The DLWCP provides environmental benefits for Toronto by contributing to better air quality. The chillers discussed above are responsible for large amounts of pollution and are significant contributors to global climate change, particularly through CFC emissions. This system is estimated to mitigate 40,000 tons CO_2, equivalent to 8,000 cars or of 12,000 air-conditioned homes, with energy savings of up to 35 megawatts daily, or about 75% of current air conditioning demand in the buildings it serves (Spears 2004). DLWP can relieve energy use on the grid during the summer months when demand is at its highest.

At onset, the system cooled 20 buildings but grew to 50 buildings by 2007 and is estimated to be approximately 50% of design capacity (Enwave 2007). Early on, public enthusiasm was slowed because subsidized electricity prices kept consumer energy costs artificially low. Additionally, concerns over tax fund expenditures added some level of controversy to this expensive project. Today, however, the system enjoys predominantly widespread support because initial capital costs are in the past and the system has proven successful. This system requires cool water at 4 degrees Celsius or below, and a concentrated need for cooling. Therefore, other large cities located on the Great Lakes may be feasible locations for deep lake cooling.

St. Paul, Minnesota

St. Paul has a district cooling system as well as a district heating system that features a CHP component. Started in 1983, today's system fuels 80% of downtown St. Paul with service reliability exceeding 99.997% (District 2010). As seen in recent expansions, this system is easily scalable because of urban density, community characteristics, new technologies, and high commitment level by stakeholders through continued investment in buildings tapped into the systems.

St. Paul's hot water district heating is owned and operated by District Energy St. Paul, a nonprofit organization started by the city. The largest hot water district heating system in North America, it produces energy for space heating, domestic hot water, and industrial use (District 2011). In the downtown area, 32,125.9 meters of dual supply and return piping service more than 187 buildings and 300 townhouses (District 2011). This system combines energy production mechanisms including natural gas and biofuel, but also through oil burning boilers, providing a total of 289 MW of thermal energy (District 2011). CHP provides an additional 25 MW of utility electricity and 65 MW of thermal energy (District 2011).

Flexible fuel sourcing is a highlight of this system, particularly the ability to procure local and domestic fuels including wood and other bio-sources, natural gas, and low-sulfur Eastern coal (District 2011). Exploration of incorporating solar panels for an emission-free energy source is currently underway (McAuliffe 2009). Directly eliminating over 150 smokestacks on buildings from individual boilers and furnaces provides significant environmental benefits (District 2011). Additionally, SO_2 and particulate emissions are reduced by 75% in comparison to per unit end-use energy (District 2011).

St. Paul Energy, an affiliate of District Energy St. Paul, provides district cooling. Funded through bonds and a loan through the St. Paul Housing and Redevelopment Authority, costs totaled $55 million (District 2011). Today serving 97 customers with over 1.97 million sq.

meters of service area, the system was developed incrementally (Osboda et al. 2008). Dual supply and return chilled-water pipelines up to 76.2 cm in diameter move more than 35,000 tons of chilled water, with an overall storage capacity of 24.7 million liters (District 2011; Osboda et al. 2008). Because it produces chilled water at night when consumer demands for energy are lower, this system can displace daytime peak demand (District 2011).

System-wide economic benefits for the City of St. Paul include stable energy rates and 2008 operating revenues reaching $10.3 M (Osboda et al. 2008). The St. Paul Development Authority believes that the presence of DES has encouraged stable infill and economic security for the area (District 2011). Adjusting for inflation, customers pay less for energy today than they did 27 years ago (District 2011).

Cornell University, Ithaca, New York

Cornell district energy is the result of 25 years of continuous upgrades and development (CCJ 2010). While master planning for the central heating system was initially completed in 1919, the majority of the investment has been in recent decades, particularly since hydropower installation in 1981 (Peer & Curlett 2012). As the Central Energy Plant (CEP) system operator, the Cornell Utilities Department supplies energy to 150 campus buildings totaling 1.2 million sq. meters (Peer 2011).

The system has multiple components including a hydroelectric plant, cogeneration facility, thermal storage system, Lake Source Cooling (LSC) and steam heating components (Peer, Beyers & Joyce 2008). Producing 215 million kWh of electricity, 1,200,000 thousand lbs. of steam, and 45,000,000 ton-hours of chilled water annually, the International District Energy Association (IDEA) named it District Energy System of the Year in 2001 (Brand 2001; Peer 2011). Continued planning and implementation has allowed Cornell to reduce emissions to 30% below 1990 levels despite service area increasing by 15% between 1990 and 2010 (Robb 2009).

Incorporating a Lake Source Cooling (LSC) project in 2000 allowed Cornell to further increase energy efficiency. The system uses cold water from the Cayuga Lake to cool campus buildings (Peer et al 2008). LSC replaced chillers, uses 86% less electrical energy, and eliminates the release 40,000 lbs. of refrigerant-sourced chlorofluorocarbons (CFCs) (Brand 2001). The system saves approximately 25,000,000 kWh annually, with the majority of these savings in summer months, and has lowered GHG emissions by 3 tons/year of SO_2, 16 tons/year of NO_2, and 11,000 tons/year of CO_2 (Peer et al. 2008: 13). It is important to note that using the water in the lake has not been without controversy. Private property owners and environmentalists have taken issue with Cornell's use of Lake Cayuga's water resources, but the most recent reports have not yet found significant impacts (Cayuga 2011; Sermonis 2007).

The newest addition to the CEP is an $82 million dollar investment called the Cornell Combined Heat & Power Project (CCHPP). The CHP utilizes excess heat from electricity production for heat recovering steam generators and provides more than 75% of campus electricity (Peer 2011; Peer & Curlett 2012). Specifically, Cornell installed two 14 MW combustion turbines fueled by a newly installed gas line, tapping the interstate gas transportation system (Robb 2009). Shifting to reliance on natural gas has allowed the system to use zero coal as of July 2011 (Peer 2011). By moving away from coal, the new system decreased CEP emissions of greenhouse gases by 34% a year (Peer 2011; Robb 2009). The EPA recognized the project for pollution and energy use reduction, awarding Cornell University a 2011 Energy Star CHP Award (Peer 2011).

Drake Landing Solar Community (DLSC), Calgary, Alberta, Canada

DLSC is a community of 52 moderately sized homes obtaining approximately 90% of energy needs from the sun (McClenahan 2010). At roughly 1500 square feet, both the lot and home size lend to a relatively compact community being approximately 2/3 that of the recent U.S. census average (U.S. Census 2010). Though similar systems exist in Europe, this is the first system to operate in such a cold climate (Sibbitt et al. 2011). This system takes time to develop peak functioning but increased energy load capabilities each of the first three years of service. Early estimates of annual solar fraction capability, defined as system-provided solar energy divided by the system energy requirements, were approximately 70% of maximum. Following upgrades in January 2010, it achieved 90% annual solar fraction capability (McClenahan 2010). The DLSC was the first solar site in the world to achieve this percentage of solar fraction (McClenahan 2010).

Eight hundred solar panels mounted on garage roofs collect solar energy for distribution through a network of insulated pipes from the residential community (DLSC 2010). To ensure year round energy, long-term underground storage retains solar energy from sunny summer months for winter heating (DLSC 2010). This long-term energy storage is an important component of the DLSC energy plan for energy extraction during surplus demand (McClenahan 2010). The system includes Borehole Thermal Energy Storage (BTES), featuring 144 boreholes, 3.8 meters by 35 meters, which hold a high solids grout consisting of 9% Blast Furnace Cement, 9% Portland cement, 32% fine silica sand, and 50% water (DLSC 2010). Connected through a series of U-pipes back to the Energy Centre, cooler water moves through the BTES to pick up heat energy that then flows through short-term energy storage tank before being distributed through DES (DLSC 2010). Additionally, a solar hot water heating system and "specialized air handler unit" replace need for a conventional furnace in each home (DLSC 2010).

Developers, individual homeowners, and provincial and national government invested in this project. The land was donated by the local municipality, the Province of Ottawa contributed more than $2 M, and additional donors, including the Province of Alberta, provided more than $5 M in development funding (McCormick 2009). Additional project partners include a land development company and utility company (DLSC 2010). Because of this additional investment, home purchasing costs did not include the estimated $40,000/house for the district energy infrastructure, making home purchasing more feasible (DLSC 2010).

This specific system is only possible in a new development because the technology used to develop this site is so deeply integrated that retrofitting existing buildings would be costly, if even possible (McCormick 2009). Despite this limitation, the case highlights DES meeting residential energy needs through significant per household investment from both private and public sources. DLSC consists of only 52 homes and an expanded project would need to be at a larger scale to be cost effective. A program manager for the lead developer, the Sterling Group, estimated that an additional project would need approximately 500 or 1000 homes to move forward (McCormick 2009). Further, despite being at a high latitude, this location is well suited to solar, receiving as much energy as places like Florida, Italy, and Greece (DLSC 2010). An additional or expanded project would need to meet similar requirements and additional monitoring will be needed to determine if greater density could be achieved with this technology.

Currently, energy data during the 2008-2009 year shows an average of 84.1 GJ collected weekly, for an annual collection of 4390.9 GJ (SAIC 2010: 10). Solar energy is estimated to cut emissions for each house by five tons/year (DLSC 2010). The total measured incident solar energy available for this year was 13902.1, which indicates collection efficiency of 31.6% (SAIC 2010: 10). The highest value collected during a one-week period was 168.9 GJ and the lowest was 0.0 GJ (SAIC 2010: 10). There were only a few weeks in which collection was not possible, two were for maintenance and the other two were due to complete snow cover (SAIC 2010). Overall, it appears the DLSC had a successful launch and is operating at nearly ideal levels.

Overarching Benefits

Benefits of DES include

- Easier incorporation of renewable energy sources in the future
- Shift demand to off-peak hours
- Reduce the need for new energy plant construction
- Reduce future costs
- Stabilizing urban areas and incentivize continued investment
- Remove energy cost uncertainty

Investing in communities to advance energy systems provides wide-ranging energy and environment benefits. It has been estimated that increasing U.S. CHP capacity to 20% of energy needs would be equal to taking 152 million vehicles off the road in CO_2 reductions, save 5.3 quadrillion Btu (Quads) of fuel annually, equate to 1 million new skilled jobs, reduce emissions by 800 million metric tons (MMT) each year, and create over $200 billion in new investments (Shipley et al. 2008). This range of short term and long-term benefits makes DES an important consideration. Additionally, increasing DES can upset the power balance between utilities and consumers by providing greater flexibility and localized decision making about fuels and systems.

As the case studies show, there are a wide range of DES configurations within the cold winter areas of North America indicating even greater variation in disparate climatic zones (Rogner 1993). Highly adaptive, variations between systems include types of CHP systems, size, scope, fuel, and necessary investment (Rogner 1993). Successful implementation can also be scalable and implemented in phases, further increasing flexibility. DES provides an opportunity for strategic investment with long-term results and mixed load capabilities for reliability and price stabilization (Osboda et al. 2008). The margin of net benefit in DES will continue to expand as fuel costs increase and maximizing energy per unit of input becomes increasingly important (Osboda et al. 2008).

Barriers to Implementation

In order to achieve these benefits, North America must overcome the barriers that have slowed DES implementation including a limited knowledge base, the necessity of complex partnerships, a lack of integrated planning land use and energy, and unclear cost and benefit distribution (Gilmore & Warren 2008; Spurr 1996). Overall, DES involves higher upfront costs with diminished energy and maintenance costs over time. Due to the increased need for front-end financing, debt-service costs are approximately one-third higher in developing DES than in conventional energy production (Spurr 1994).

Regulatory constraints can complicate the issue of cost for DES implementation. Because of the high upfront capital costs and a payback period "resembling those in the utility sector … utilities are best suited to own and operate DES. In addition, regulators are often concerned because there is no mechanism in place that would allocate costs ... in a truly equitable manner" (Rogner 1993: 16). The sheer scale of energy provision can be a daunting endeavor, but this is another reason for DES implementation because it shrinks energy provision to an achievable size. Further, high costs discourage investment so mechanisms to incentivize utilities, municipalities, and companies are necessary. To be economically viable, these must allow for changes in the current profit structure by incorporating life cycle economics and by integrating the sale of energy services rather than simply kWhs or BTUs, or by investing in DES similar to other types of municipal infrastructure projects through bonds and/or user fees (Rogner 1993).

Further, the necessary complexity in partnerships and communication is an additional issue limiting DES development. Unfortunately, because of the range of investors, business structures, and customer bases exhibited here, it seems there is not a clear solution. Fundamentally, each city will need to explore various DES options by taking into account municipal interests, local zoning laws, development needs, utility companies, and grant and other funding opportunities. Balancing the interests of utility companies and municipal entities may pose a challenge.

Each of the case studies developed their own mix of public and private funding to allow projects to move forward. For example, some cities had existing infrastructure (Cornell) while another embarked on major construction (Toronto). Although this can be seen as a hurdle, it can also highlight system flexibility to encourage additional cities to explore DES possibilities. Finally, leadership and planning is necessary to grow support and provide the structure for DES to succeed. These leaders can be identified and nurtured through workshops and educational outreach and encouraged with financial assistance and clear support from government and through leadership from individuals in successful cities and systems. Without knowledge of these systems and their outcomes, DES is a long term visioning approach that can too easily be set aside.

Policy Recommendations to Increase Use of DES

Regional and City

Local communities should emphasize DES because they are the direct beneficiaries of these systems. Cities can

- Provide leadership to involve stakeholders and steer the essential planning components of regulations, zoning, and community visioning (Osboda et al. 2008).
- Encourage DES through bond funding, tax incentives, and other techniques to manage investment risk (Osboda et al. 2008).
- Improve reporting and communication between cities and other DES sites on costs and benefits of existing systems.
- Improve land use planning by identifying target areas.
- Establish standards should be for density, growth, and land use based on DES potential.
- Incorporate energy policy in the master plan for city or region.

State Energy Policy

States can provide effective leadership to encourage DES at the local level. To achieve this, states can

- Provide basic incentives such as tax breaks, cost sharing, and financing assistance.
- Develop energy plans that incorporate DES language and communicate these broadly.
- Enact development requirements legislation DES consideration or maintaining the ability to incorporate in the future.
- Act as a research and information resource regarding DES feasibility, success sharing, and documenting DES within the State.
- Provide incentives for utility companies by easing of the permitting process as regulatory constraints can limit utility activities (Rogner 1993).
- Increase the power of Renewable Portfolio Standards (RPS) (Thornton 2005).
- Decouple utilities to encourage energy efficiency (Martinot, Wiser & Hamrin 2009).
- Reward partnerships between utilities, nonprofits, and governmental bodies.

Federal Policy

National policy can encourage DES, and should view it as an option to reach National goals of reduced emissions and energy security. Federal policy can encourage DES by

- Reinvigorate Federal legislation such as Public Utilities Regulatory Policy Act of 1978 (PURPA) (Lemar 2001; Martinot, Wiser & Hamrin 2009).
- Provide educational programming to address knowledge barriers.
- Provide tax incentives and credits, grant opportunities, adjusted depreciation schedules, and long-term investment strategies.
- Increase funding in research, design, and development (RD&D).
- Continue to participate in international knowledge sharing through the International Energy Agency (Spurr 1996).
- Explore project feasibility through Department of Defense and other agencies.
- Improve communication about DES between the Department of Energy, Housing and Urban Development, and others.
- Mandate energy planning in municipal and regional governments.
- Incorporate DES into acts such as Resource Conservation and Recovery Act.
- Adopt climate legislation that will make incorporating DES more appealing.

Conclusions

Because demand for energy continues to increase, DES offers North American cities an appealing option to provide energy while reducing emissions. Incorporating DES can effectively lower air pollution, encourage economic development, increase job production, and lessen fossil fuel dependency. Most importantly they show DES flexibility in a wide range of energy sources, production levels, age, and cost, both novel and traditional technologies, partnerships, and systems. The implications for climate change mitigation and adaptation are of fundamental importance. Future research can estimate the potential for increasing DES in North America by analyzing new development, large-scale infrastructure, and/or state and national level regulatory changes.

Despite the large upfront investment, DES saves money for building owners, incentivizes development, and lowers energy costs for building occupants. Further, in larger city-regions, the presence of DES may promote density, walkability, and decrease sprawl by keeping urban cores highly invested and desirable.

An encouraging financial framework in the form of grants, subsidies, and various cost-sharing options between utility companies, municipalities, and consumers can overcome implementation barriers. There are a range of policy approaches that can be implemented on the local, state, and national level to improve the awareness and enthusiasm for DES implementation. Fundamentally, dedicated local leaders relying on partnerships and communication seem to be a unifying trend in successful implementation. Local communities should emphasize DES because they are the direct beneficiaries of these systems, in both economic and environmental terms.

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