# How District Energy Systems can be Used to Reduce Infrastructure Costs and Environmental Burdens

**Terri Chu and Sandra Yee**

**Abstract** District Energy Systems are increasing in popularity but their economic viability is usually analyzed narrowly in terms of capital costs and energy savings to the customer and revenues to the utility provider. Traditional feasibility analyses of DESs do not recognize the economic benefits to municipalities and regional governments. By having a DES, electricity demand during peak times can be reduced. A reduced demand means fewer electrical peaking stations will need to be built thereby saving regional governments substantial sums in infrastructure costs. Another noteworthy benefit is the cost of storm water retention. DES is an enabler of storm water retention technologies. By using DES rather than a traditional rooftop mechanical room, space is made for water retention technologies that could not otherwise be built. By reducing the amount of water flowing from a building site, municipalities reduce the risk of sewer overflows and can reduce the infrastructure required for storm water containment. Lastly, a DES produces thermal energy on a large scale and is technology neutral. The nature of DES allows for fuel diversity and flexibility. Should the cost of any one type of fuel increase dramatically in price, DESs have the ability to switch sources with minimal investment. DESs will allow municipalities to ensure their communities will be able to maintain reasonable fuel costs and a high standard of living. None of these economic benefits are included in current feasibility analyses yet they can be substantial. If these factors were included, the economic case for DES would be made quite easily and communities could then benefit from the reduced carbon

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footprint for their heating and cooling. This makes a compelling case for municipalities to support DES in their communities or legislate building connections to DES.

**Keywords** District energy · Municipalities · Energy reduction

## 1 Addressing Energy Security and Reducing Infrastructure Costs in Power Generation and Storm Water Management

A District Energy System (DES) has the potential to help governments, at all levels, reduce operating and infrastructure costs. These opportunities, however, are often left unexplored. In a free market environment, DES development will only take place with a strong business case for a DES Utility and its customer base. By recognizing and crediting the cost savings that a DES affords governments, the business case for DESs would be strengthened and help policy makers to take advantage of the eco-efficiencies these systems provide.

Understandably, governments are averse to providing financial or human capital to support the private sector without a reasonable expectation of socio-economic benefits for taxpayers. While these capital intensive systems do not necessarily need government support to be economically viable, returns are often marginally below acceptable levels for investors. By helping the private sector breach the risk/reward threshold, municipalities could reduce their own operating costs by millions of dollars with minimal investment and risk.

To realize the additional benefits of DESs, it is crucial to understand what district energy systems are, the current business case for district energy, and the economic and environmental opportunities that are complementary to government objectives such as: power generation, storm water management, energy security, and economic growth.

## 2 District Energy 101

District energy is a technical solution for providing the thermal energy used for conditioning indoor spaces. DESs are generally comprised of three major components:

- A common or shared energy generating facility referred to as a central energy plant or community energy centre,
- A system of interconnected pipes that link the energy centre(s) to multiple buildings referred to as a distribution piping system or thermal grid,

- A thermal interface at the customer building referred to as a customer substation or energy transfer station.

In the case of district heating, hot water (or steam) is transported through a system of pipes and delivered to the customer buildings for space heating and domestic water heating. The heat energy carried in the fluid is extracted by the building's systems and the cooled water is returned to the central energy centre, in a closed loop piping system, where it is reheated for redistribution. Similarly with district cooling, chilled water is pumped through a network of pipes and the cooling energy is extracted by the building for air conditioning or process cooling and then the warmed water is returned to the plant to be cooled again.

Figure 1 illustrates that District Energy is not technology specific; multiple or single fuel sources and/or technologies can be employed including but not limited to: absorption chillers, ambient cooling, deep lake water cooling, combined heat and power, biomass incineration, waste incineration, geothermal, and conventional boiler and chiller technologies. Figure 2 illustrates how district energy typically works. Pipes run underground bringing heating and cooling energy to buildings from a central energy plant.

Economies of scale and advancements in technology have enabled DESs to achieve greater efficiencies than individual building systems. Serving multiple buildings from a common facility allows for large scale systems to be built that can accommodate state-of-the-art technologies in heating and cooling. For example, individual buildings could not cost effectively make use of natural lake water cooling or Combined Heat and Power (CHP). Using natural sources of cooling or

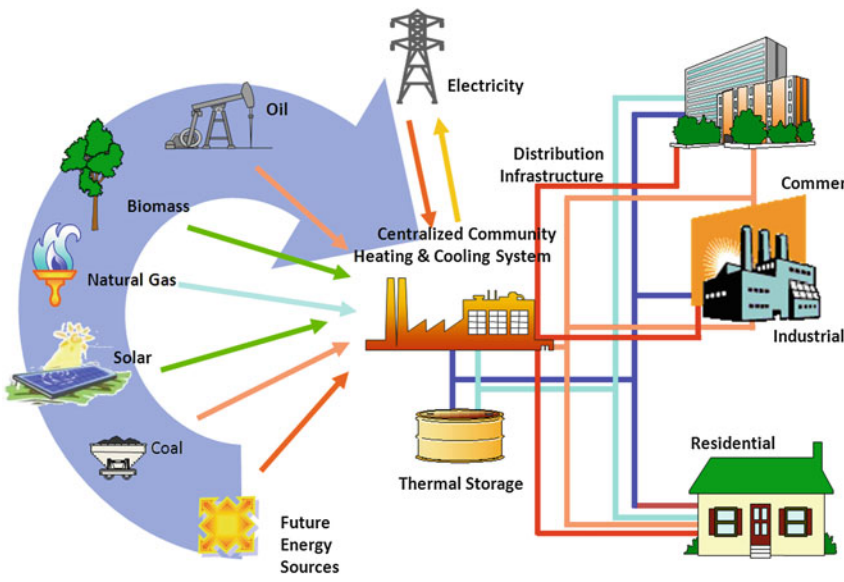


**Fig. 1** DES can accept any form of energy source (IDEA 2012)

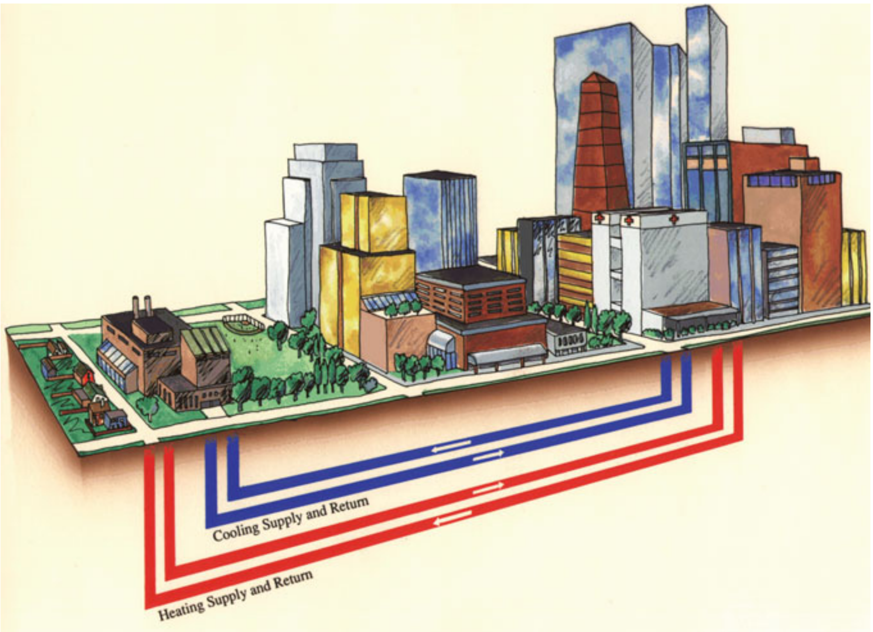


**Fig. 2** Typical district energy system (IDEA 2012)

waste heat sources from manufacturing or electricity generation can reduce energy consumption for the production of thermal energy to near zero.

In addition, economies of scale in DESs enable the efficient use of conventional equipment by:

- Having purpose built facilities that are actively maintained and operated
- Aggregating thermal loads from multiple and a variety of types of buildings so that equipment can be run optimally with less part loading.

Thermal energy generating equipment such as boilers and chillers operate most efficiently at a single load factor (Chan 2002). This concept is analogous to the fuel efficiency of a car, reaching optimal fuel economy between 50 and 80 km/h (NRCAN 2012a, b). A car traveling outside of its 'sweet spot' will use more fuel per km travelled. Likewise, a boiler or chiller will use more energy for every unit of thermal heating or cooling when forced to operate above or below its 'sweet spot'. By having an aggregated load, a DES can 'stage' its boilers and chillers by operating only the number required by while maintaining each in its efficiency 'sweet spot'.

The earliest DES is dated as far back as the 1300s (CDEA 2011). The first known system distributed warm water through a series of wooden pipes in France. In 1877, the first commercial DES was built in New York (CDEA 2011). DESs are not a new concept. Though widely embraced in Europe, DESs have not seen the same rate of adoption in North America. Abundant and low cost energy supplies have reduced the urgency for conservation and innovation in thermal energy production. However, energy constraints, limited dollars, and environmental concerns are putting DESs on the public agenda. To address these concerns, policy makers can examine the synergistic opportunities that DES can provide.

## 3 The Current Business Case for DES

The current business case for DES fails to examine or value the economic and environmental benefit to other stakeholders such as industries, communities, and governments. The industry standard for determining the feasibility of investing in DESs is based solely on the economic benefit to both the building owner(s) (customers) and the DES utility.

For the DES Utility, the profitability of developing a DES is evaluated by comparing the initial capital investment costs to the expected cash flow over the life of the system. Capital costs include the cost to build the DES infrastructure: the energy centre, the distribution piping system, and the customer connections. Expenses are dictated by fuel, operating, maintenance, and administration costs. Revenue is based on a capacity charge to the customer as well as energy delivery charges. The price is dictated by the Business-As-Usual (BAU) cost to produce thermal energy for space heating, cooling, and domestic hot water. After a financial analysis, the DES Utility decides if the business case for DES passes the risk/reward threshold that the investor is willing to accept.

A similar economic analysis is performed by the building developer or owner comparing the price of the district energy service to the current (or estimated) capital and operating costs of providing building heating and cooling. The district energy service is priced competitively, equal to or below, the BAU model. The cost savings a building would realize by connecting to a DES is comprised of some or all of the following:

- Reduction in initial and/or replacement capital cost for major mechanical equipment including cost of associated space, electrical installation, and auxiliaries
- Fuel costs (i.e. natural gas for heating, and electricity for cooling)
- Cost of water, sewer, and water treatment
- Equipment operating and maintenance cost, including yearly preventative maintenance and ongoing repair/over haul costs
- Cost of labour, administration, and insurance
- Value of "freed up" roof space, greenhouse gas reduction, risk mitigation, and liability.

# 4 A "Broader" Business Case for DES

A broader business case for DES may be developed by understanding how DESs can create eco-efficiency opportunities for governments. Three such opportunities and their respective benefits can be found in:

- Reduction in electrical generating capacity,
- Storm water management, and
- Improving energy security: risk mitigation and management.

The important benefits listed above, may not be categorized as direct benefits to either the DES Utility or the building owner, however, they are the only two parties paying for DES development. Measuring and giving credit to the private sector for the positive contributions of DESs to the public sector, would help policy makers take advantage of synergistic eco-efficiencies.

# 5 Electricity Generation

## *5.1 Eco-efficiency Opportunity*

In most of North America, the electrical grid faces the most strain during the hottest days of the year due to the electricity requirements for air conditioning. Cooling loads, however, can vary substantially throughout the day and because the highest electricity demand comes in the summer time during the hottest time (IESO 2010), the greatest benefit from conservation efforts will come from reducing energy demand at that time.

1 kWh saved during peak time is more significant than one saved at night. Exacerbating the problem, line losses are higher during peak times than low usage times. When the electricity transmission and distribution systems get hotter, the loss can be substantially higher than the average. In Ontario, the variation ranges from 5 % during low usage times to 25 % during peak hours according to an Ontario Hydro study. Taking into account the total losses from generation to delivery, saving 1 kW during peak times can reduce generating requirements by 1.47 kW (Ontario Hydro 2007).

> By reducing peak demand, the province can reduce its use of the less environmentally attractive resources that are called on when demand is high. In the long run, lower peak demand will mean less need for new generating facilities and transmission and distribution infrastructure, lowering costs for all Ontarians (Ontario Ministry of Energy).

Figure 3 shows the electricity demand of a 30 story glass office tower in Toronto for the year before the transition to district cooling and after. It is indicative of the savings that DES could provide. From the graph, it is clear when this particular building switched from running its own chillers to a DES; the

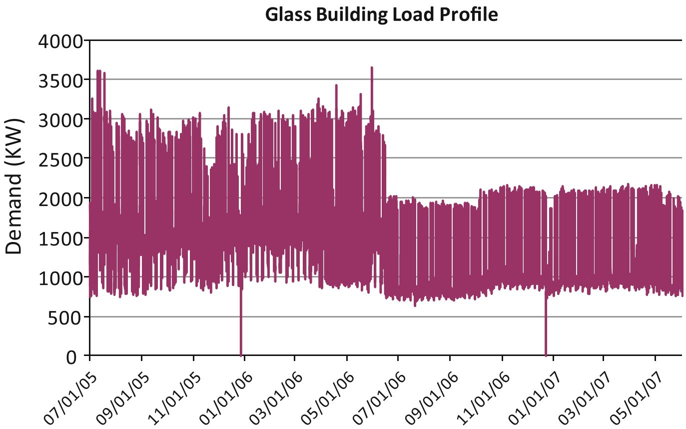


**Fig. 3** Electrical load before and after conversion to DLWC for a glass building in Toronto (Toronto Building Manager 2011)

demand in electricity drops by roughly one third at the time of switchover. Reducing electrical demand translates into fewer gas fired generating stations needing to be built in populated areas.

## *5.2 Cost Savings*

Electrically driven chillers for the most part generate more than 1 thermal unit of cooling energy for each unit of electricity. Rather than reference efficiencies in terms of percentages greater than 100, it is common practice to refer to chiller efficiencies in terms of Coefficient of Performance (COP). A fairly inefficient chiller with a COP of 3 produces 3 units of thermal energy for each unit of electrical energy. Assuming that chillers in the DES on average can produce a COP of 5 (requiring 0.1 $kW_e$ of electricity per $kW_{th}$) compared to a BAU COP of 3 (requiring 0.3 $kW_e$ of electricity per $kW_{th}$) (mostly due to scale efficiencies) at peak times, each kilowatt thermal ($kW_{th}$) of cooling demand translates to 0.2 $kW_e$ of electricity demand reduction.

If DES utilities are able to capitalize on their size and generate and store chilled water at night (instead of producing it during the day), the peak time generation demand can reduce the cooling energy to effectively zero, saving 0.5 (kilowatt electrical) $kW_e$ for each $kW_{th}$ of cooling required.

In the case of free cooling by snow, lake water, or other natural sources, the peak time savings are also on the order of 0.5 $kW_e$ for each $kW_{th}$ of cooling since in both cases of chill storage and free cooling, only pumping energy for the water is required. Table 1 summarizes the possible load reductions.

For a contracted gas fired power plant in Ontario, each MW of electricity generation cost nearly \$1 M CDN (Pristine Power 2011). However, this cost is

**Table 1** Peak reductions at generation source per $kW_{th}$ cooling due to DES when compared to BAU

| | District energy technology | | |
|---|---|---|---|
| | Centrifugal chillers | Thermal storage | Free cooling |
| Peak reduction (at source)/$kW_{th}$ | 0.1–0.3 $kW_e$ | ~0.5 $kW_e$ | ~0.5 $kW_e$ |

strictly for technical costs. These costs could escalate quickly when projects are delayed or cancelled after contracts have been signed. Every MW of generation that can be avoided translates into significant savings.

### 5.3 *Environmental Benefits*

Reducing electricity use at peak times not only reduces the need to build more generating capacity, it potentially reduces atmospheric pollution and Greenhouse Gas (GHG) emissions.

Ontario, for example, uses a combination of nuclear and hydro power to satisfy the base load of electricity. As demand increases, the source of power tends to get dirtier. Figure 4 is a representative day of electricity generation in Ontario. As demand increases, high pollution and GHG emitting sources of generation come online. By using less energy during peak times (usually from noon to early evening), DES can reduce $CO_{2e}$, $NO_x$, and $SO_x$ in the atmosphere.

Figure 4 shows a single day snap shot of the electrical output in Ontario. It is readily apparent that a base load is supplied by nuclear and hydro while natural gas

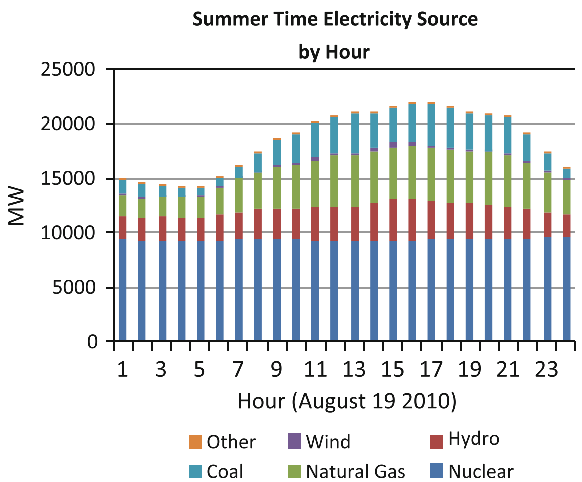


**Fig. 4** Typical summer electrical output by source in Ontario (IESO)

**Table 2** $NO_x$ and $So_x$ output for various electricity generation forms (NRCAN GHGenius 2010)

| | g/kWh | | | | |
|---|---|---|---|---|---|
| | Coal | NG Boiler | NG Turbine | Nuclear | Hydro |
| $NO_x$ | 2.64 | 0.59 | 0.56 | 0.00 | 0.00 |
| $SO_x$ | 4.96 | 0.01 | 0.01 | 0.00 | 0.00 |

is the first choice for marginal requirements. As the demand increases, coal starts to come online as a last resort given how dirty it is.

Table 2 shows the difference in $NO_x$ and $SO_x$ output between different forms of electrical generation. Ontario still requires coal to meet its demand at peak times. Coal fired power plants produce nearly 3 g of $NO_x$ for each kWh of electricity and 5 g $SO_x$ for each kWh of electricity. Conversely, nuclear and hydro do not add atmospheric pollution (during the operational phase of the life cycle). Using DESs to simply shift what time electricity is used for heating and cooling buildings could have a dramatic effect on pollutant emissions.

Although, studies have shown the correlation between $NO_x$, and $SO_x$ with asthma and other respiratory illnesses (Lebowitz 1996; Detels et al. 1991), the cost savings from reducing emissions is difficult to calculate. Countries such as Canada, with government funded health care, can consider the cost savings associated with reducing the incidences of asthma and related respiratory illnesses as a bottom line benefit. A person with asthma in Ontario will on average cost the health care system twice what a person without the disease would cost (To 2007). If regulators and medical professionals can estimate the correlation between health care costs and the amount of pollution in the air, policy makers can begin to understand the dollar value of preventative versus reactionary health care costs.

In the same way that atmospheric pollution can be reduced, DESs can play a role helping countries meet GHG reduction targets. The authors conducted a study based on the electrical output in Ontario for 2009 and 2010; Table 3 shows that DES could decrease GHG emissions by as much as 145 g of $CO_{2e}$ for each kWh of thermal cooling.

In many jurisdictions, there is no value assigned to GHG reduction. In these areas, DES utilities and building owners receive no economic benefit for the reduction in GHGs that a DES offers. Governments can encourage adoption of DES by providing an incentive equal in value to reduction initiatives. Alternatively, a fee or tax on emissions could incentivize connection to DESs.

**Table 3** GHG reduction per $KWh_{th}$ cooling (IESO, NRCAN 2010)

| | District energy technology | | |
|---|---|---|---|
| | Centrifugal chillers | Thermal storage | Free cooling |
| GHG reduction/$kWh_{th}$ | 67 g | 35–145 g | 145 g |

Putting a price tag on GHG emissions and pollution reduction may not be popular in many jurisdictions but policy makers should recognize its merits. Deciding the value of each ton of GHGs reduced and applying that value to projects could spur innovation beyond DES.

# 6 Storm Water Management

## *6.1 Eco-efficiency Opportunity*

DESs can free up rooftop space for green roofs. Traditionally, large buildings install thermal generating equipment such as boilers, chillers, and cooling towers in a penthouse mechanical room. These rooms diminish the ability to apply Low Impact Development techniques such as green roofs or rainwater harvesting for retaining storm water; water that runs into the city sewer system adding to the risk of Combined Sewer Overflows (CSO). By migrating to a DES connection building roof space is freed, enabling the application of low impact storm water containment strategies and government to capitalize on this synergistic opportunity.

## *6.2 Cost Savings*

In the United States alone, $44 billion (USD) is spent annually in CSO management (Montalto et al. 2007). Mitigating the risk of overflow can be a costly endeavor depending on local climate patters. Containment tanks and other end of the line solutions are effective but expensive solutions to CSO management. The local cost of CSO management needs to be considered, since it will vary from jurisdiction to jurisdiction, to evaluate the benefit in increasing rooftop green space that can be realized by connecting buildings to a DES. In order to determine the value of CSO mitigation, governments must weigh:

- The cost of standard CSO techniques
- The cost of land devaluation
- The public opinion on containment tanks and retention ponds.

Storm water containment is a difficult task given the variability of rain and flash flooding. As cities densify and the built urban form becomes less accommodating to storm water management, this will be more of a challenge for city planners. Standard CSO techniques may include ponds or containment tanks. These solutions are both costly and undesirable in neighbourhoods. When undesirable infrastructure is built, the land around it may depreciate in value which can adversely affect municipal tax revenue. Public opposition to CSO containment could also contribute to the cost of the infrastructure to municipalities.

Mismanagement of storm water can be costly. A single heavy storm in Toronto in August of 2005 cost the city $34 M (CDN) to repair damages. An additional $400 million (CDN) was paid out to private citizens from insurance companies due to the damage from this one storm (Riversides 2009a). The cost to mitigate the risk associated with CSO can quickly be paid back to municipalities by avoiding these types of events.

A cost metric of standard CSO containment can be established and compared with the mitigation provided per unit area of roof space by quantifying the cost and potential costs of a municipality's CSO containment strategy. An incentive could then be offered to building owners on a percentage of runoff reduction, since not all green roofs will have equivalent performance. If building owners are given an incentive that amounts to less than what a municipality would spend in containing an equivalent volume of storm water, storm water management costs to the municipality will be reduced.

### *6.3 Environmental Benefits*

In addition to the cost of managing storm water, municipalities often contend with polluted water ways as a result of the runoff. The prevalence of cars in urban environments means that brake pad dust, tire wear fragments and motor oil are a normal part of storm water (Johnson 2009). New Jersey Department of Environmental Protection recognizes that "pollutant release is a serious threat to water quality" (NJDEP).

Excessive runoff transports toxins, picked up on roadways, into aquatic environments that can weaken or destroy plants and animals that depend on these (Riversides 2009b). In places, such as Toronto, the runoff overflows into the same body of water where potable water is drawn from. The effects of storm water present a serious concern, for public health and local ecology, that can be reduced by DESs.

## 7 Energy Security: Risk Mitigation and Management

### *7.1 Eco-efficiency Opportunity*

DESs provide governments an opportunity to protect the reliability of local energy systems through conservation, diversity, flexibility, and availability. The International Energy Agency (IEA) defines energy security as "the uninterrupted physical availability at a price which is affordable, while respecting environmental concerns." With the growth of urban centers and the associated energy intensification required to provide essential services, governments are increasingly challenged to address issues of energy security. DESs can address factors, such as supply, price stability, and sustainability that contribute to greater energy security and independence.

The DES thermal grid which connects energy producers to end-users aids in conservation efforts. This connection allows waste heat from industrial or power generating processes to be used for residential and commercial heating. By utilizing waste heat sources, DESs reduce the amount of fuel burned for space heating and improve the efficient use of fossil fuels. Figure 5 illustrates that using waste heat from conventional power production, a concept known as CHP, can increase system efficiency and reduce fuel input from 147 to 100 units, a 30 % reduction. It is estimated that 61 % (OEE 2008) of building energy usage in Canada is used for space heating and cooling and water heating; a 30 % reduction fuel used in buildings is substantial. Waste and renewable fuels are available for heating and since fossil fuels are finite, there is value to reserving this precious resource for applications that have no other alternative such as pharmaceuticals and medical devices and equipment.

DESs can expand the diversity of fuel types used for heating and cooling by taking advantage of local fuel sources that would otherwise remain unused. Fuels such as biomass (wood chips, sawdust, straw), geothermal, biogas, and municipal waste are difficult to manage on a small scale—largely due to handling issues. The availability of local fuel sources and the ability to use them reduces the reliance on supplies from countries or jurisdictions that may be adversely affected by war, politics, or natural disaster. According to Sandor Boyson, research professor and co-director of the Supply Chain Management Center, “The longer the supply chain, the more that can go wrong and the more it costs with high gas prices.”

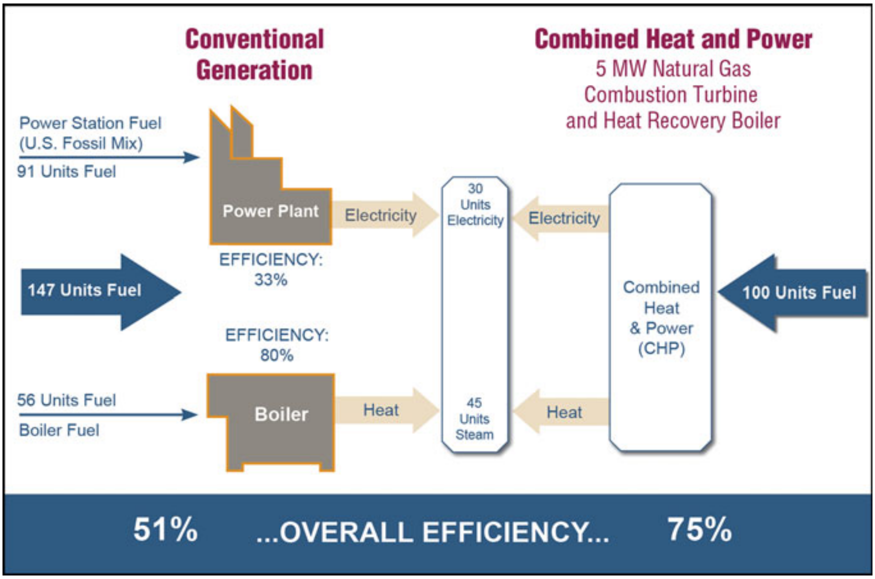


**Fig. 5** Efficiency in combined heat and power systems (EPA 2012)

(University of Maryland, date unknown). In other words, a diverse fuel mix that incorporates local sources increases energy independence and reduces risk of supply interruptions and price instability.

The thermal grid and the centralized nature of energy production facilities allow DESs to support fuel switching and the implementation of state-of-the-art technologies. These qualities are referred to as fuel flexibility and technology flexibility; both improve the ability to optimize energy production in terms of cost and efficiency. The scale and centralized nature of DESs allow multiple fuel sources and/or technologies to be integrated at one location at a lower cost, than at many, in each individual building. In some cases certain fuels and technologies cannot even be applied on an individual building scale.

## *7.2 Cost Savings*

The risk of not addressing energy security is real and can have a significant impact on the economy. Costs can be examined from at least two perspectives:

- Cost of interrupted to fuel/energy supply
- Cost of the inflexible nature energy production.

The recent power outage in India of July 2012, the North-eastern Blackout of August 2003, and the North American Ice Storm of January 1998 are only a few reminders of our reliance on energy. An estimate of the economic impact of the North-eastern Blackout of 2003 is in the range of $7.0 billion dollars (USD) from food spoilage, lost production, wages, etc. with the loss of 61,200 MW (ECLON 2004). Using the above figures, the economic impact of an energy supply interruption could be on the order of magnitude of $114,000 (USD)/MW of electrical supply loss (over the outage period). A catastrophic failure, similar in duration, of the W.A.C. Bennett Dam in B.C. at 2,730 MW or the Adam Beck I and II (Niagara River) in Ontario at 2,278 MW can have an economic impact in the order of $228 M (USD).

The value of mitigating energy (thermal and electrical) supply interruptions and pricing is difficult to estimate. As a gross estimate, municipalities could estimate the value of lost productivity as a function of the average GDP. This may help put into perspective the cost of each hour of unavailable electricity and thermal energy.

The inability of buildings to retrofit existing equipment to use alternate or renewable fuels or to implement more efficient technologies can reduce the competitiveness and robustness of an economy. Many industries, businesses (especially small ones), and households would encounter financial difficulties dealing with the consequences of a sharp increase in energy prices. Fluctuating energy prices can have a negative effect on many industries such as manufacturing, mining, transportation, forestry, and agriculture resulting in unemployment, loss of skilled labour and high paying jobs, as well as higher priced food and consumer goods resulting in a decreased standard of living and dampening of economic activity.

The value of being prepared for changes in the future, of being flexible, and of having a diversity of local fuel sources can be estimated by exploring the capital cost to modernize existing building heating and cooling systems for a group of buildings compared to a large scale DES. Additional factors to examine can include depreciated building value and the exposure to utility cost fluctuations of relying on a single fuel source for example, electric baseboard heating).

### *7.3 Environmental Benefits*

Retrofitting hundreds of small boilers to use waste wood, bio-fuels, or solar energy would be much more expensive than modifying a single energy centre. The ability to switch fuels in a cost-effective manner means a higher likelihood of space heating and cooling needs being met by renewable sources.

Oujé-Bougoumou, an early adopter of DES in Canada has found that the presence of DES has displaced conventional energy sources such as fossil fuel and raised community awareness to environmental issues (Ouje 2012).

Energy is integral to modern living and the impact of energy supply interruptions is real and tangible. Through conservation, diversity, and flexibility, DESs contribute to greater energy security and independence.

## 8 Public Benefits of District Energy

### *8.1 NIMBY Infrastructure Reduction*

Infrastructure, such as subways, roads, and clean water distribution, generally increase the value of land, however, certain forms of infrastructure, though necessary, decrease the value of land or add no value at all. NIMBY (Not-In-My-Back Yard) infrastructure is considered to be any infrastructure that is necessary yet undesirable. Examples of this are train tracks, hydro lines, and electricity generating stations. Although all are invaluable to society, opposition to building these forms of infrastructure is often fierce and the land around them rarely prized.

Building NIMBY infrastructure is costly and unpopular. It is difficult to overcome public opposition to where NIMBY infrastructure gets located. In Ontario, the difficulties in locating gas fired power plants were recently highlighted by the high-profile cancellation of a plant in the city of Mississauga. Despite having broken ground, the government was forced to cancel the project mid-election at a cost of $190 M (CDN) (Leslie 2012). Much of this could have been avoided if a DES was in place to mitigate the need for such infrastructure. Reducing the construction of NIMBY infrastructure has benefits both environmentally and politically.

### *8.2 Benefits Beyond Price*

In evaluating eco-efficiency opportunities, in some cases, there are direct costs; for example the cost of NIMBY infrastructure reduction can be calculated. Not all benefits have obvious or cost savings. For example reducing the incidence rate of asthma and other pollutant related diseases could reduce the burden on state funded health care systems but it is difficult to put a price tag on the value of a healthy person or improved quality of life. Important questions to ask when developing sustainability plans include:

- What is it worth to the city/town to avoid living next to an electricity generator?
- What is it worth of reducing air emissions? If a price cannot be put on health, can a price be put on net emissions?
- How much has it cost to the economy, historically, when the electricity grid fails? How much financial risk is the municipality willing to accept?

There are challenges to limiting evaluation metrics to only measurable cost but it does not diminish the value of considering externalities such as clean air and water, improved health, community engagement, and public opinion.

By reaching outside of the direct cost benefits and including ancillary benefits to the analysis, the authors hope to create a broader more accurate evaluation of DES and the role it plays in reducing demands on energy infrastructure and consumption.

## 9 Policy Recommendations

Municipal, regional, and federal governments should take advantage of the real dollar savings that DES affords. This can only be done by identifying, understanding, and quantifying the costs and eco-efficiencies that DESs could save municipalities. Table 4 summarizes the opportunities and benefits that have been

**Table 4** Eco-efficiency opportunities of district energy systems

| Eco-opportunity | Benefit | Metric/Key performance indicators |
|---|---|---|
| Electricity generation | Demand reduction | kW demand reduction/kW generating capacity reduction<br>Air pollution reduction |
| Storm water management | Runoff reduction | %/$ reduction in CSO needs or mitigation<br>Water pollution reduction |
| Economic risk mitigation | Electrical grid stability | % reduction of blackouts |
| | Energy price stability | Reduce volatility |
| | Fuel flexibility | Minimize time to convert primary fuel sources |

identified. The metrics and key performance indicators can be used as a guide for developing sound public policy surrounding DES. Without strong public policy to lead the way, the full environmental benefits of DES will be difficult to realize.

Beyond financial incentives or economics, the greatest hurdle to developing DESs, as in any business, is getting customers—without customer buildings, there can be no DES development. Even with a business case, signing customers is challenging because the status quo or engrained industry practices are difficult to overcome. People are generally adverse to change current business practices, especially when a proven method is achieving good results. Exacerbating the problem, many buildings are built and developed by a separate entity which owns and operates the building leaving little incentive to seek out efficiencies, reduce GHG emissions, or address energy security. All levels of government can do more to encourage DES development and bridge the gap toward affecting change.

## 9.1 Lead by Example

Public buildings should lead the way and be the first to connect to DES. In the absence of a DES in the municipality, government buildings should declare their intentions to connect at the earliest opportunity and even take steps to becoming DE Ready. DE Readiness means that buildings are able to convert to DES with minimal effort which means ensuring that buildings are designed with the following characteristics:

- Main mechanical room located in the basement or ground floor level,
- A centralized water-based (hydronic) heating and cooling system,
- Lowest hot water return temperatures and highest chilled water return temperatures as possible,
- High density or energy usage buildings, situated in close proximity to one another with a variety of usages.

There is often strong resistance to being the first to use a new or different technology or system. By leading the pack, government buildings can reduce the apprehension of other building owners by providing an example to inspire.

## 9.2 Create a Customer Base

One of biggest problems for DE Utilities is the absence of a ready customer base. Municipalities can take North Vancouver's example and mandate DE Readiness in all buildings before issuing permits. The next step would be to mandate DE connections in areas with an existing DES.

### *9.3 Minimum Performance Requirements*

The authors also recommend that municipalities or regional governments establish minimum performance requirements in their jurisdictions. These performance metrics should be based on new state of the art technologies as opposed to existing building codes. Performance metrics should clearly include maximum allowable energy use, peak energy demand, and storm water runoff.

## 10 Further Research

To help municipalities and regional governments get the most out of eco-efficiency opportunities presented by DESs, policy makers must quantify their costs in managing storm water, securing electrical capacity, and addressing energy security in order to realize the potential synergies and cost savings.

Mitigating storm water run-off is a continual and potentially increasing problem for municipalities with the changing climate. As municipalities grow, the sewer system must deal with the corresponding increase in run off. The cost of dealing with high run off coefficients will vary from location to location and budgeted for by city engineers. Knowing the cost and benefits of various storm water runoff management strategies will help sustainability managers design appropriate incentives to reduce overall costs to the municipality.

Electrical utilities are common and the cost of each additional kW of new generation (for each technology) is fairly well studied, however, societal costs are of-ten ignored and focus only on design and construction costs. The cost of overcoming public outrage to this type of infrastructure should be taken into account when determining an overall cost per kW of additional generation. This will help policy makers appreciate the cost of cancelled plants, relocations, and other risks that are often difficult to budget.

## 11 Conclusion

It is critical to recognize the ancillary benefits of energy reduction techniques and the multiple benefits of DES to identify eco-efficiency opportunities. By quantifying the cost savings of avoided NIMBY infrastructure, recognizing the benefits of emissions reduction, and valuing energy security on the local level, municipalities and regional governments can make sustainable initiatives more cost effective for all parties—and in doing so reduce infrastructure costs and environmental impact.

Recognizing how systems interact with each other and the benefits they provide is an essential part of developing sustainable systems. The recognition of cost reduction and environmental benefits will allow governments at multiple levels to optimize their municipal service and pollution reduction strategies.

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