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Community Energy Management – Foundation Paper

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INTRODUCTION AND BACKGROUND

Municipalities are not just locations where a great deal of energy is used and other activities take place that affect the level of greenhouse gas emissions and sinks. Municipalities are integrated systems that can be designed and planned to reduce energy requirements and enhance greenhouse gas sinks. A key component of this broader strategic approach is community energy management (CEM)—the integration of energy considerations into municipal planning and management processes in a way that can yield multiple benefits that exceed the impacts of individual and disjointed initiatives.

Recognizing the central importance of community energy management to effective and sustainable greenhouse gas mitigation at the local level, the Municipalities Table formed the Subcommittee on Community Energy Planning. With support from Canada Mortgage and Housing Corporation (CMHC), the Subcommittee developed this paper to elaborate on the importance of CEM to greenhouse gas mitigation and to suggest possible directions for the future work of the Municipalities Table in this area.

Community energy management includes two broad initiatives that have taken root in the Canadian planning profession.

The first is a move to change the way neighbourhoods, towns, cities and regions are designed. The overarching objective is to create more "livable" communities with affordable housing in attractive environments that improve accessibility to services and employment, preserve green space, reduce pollution and noise and, generally, create a safer urban landscape with a greater sense of place and community. The livable communities concept has spawned several urban planning initiatives such as neo-traditional urban design, pedestrian-oriented development, co-housing and eco-villages. In these and other initiatives, the more efficient use of energy and the reduction of waste are key features, including strategies for reducing automobile dependence. The resulting cost savings accrue to developers, the local government and consumers as a lower investment per household in the construction and maintenance of urban infrastructure (roads, sewers, water mains, utilities) and as lower fuel and electricity costs—savings that can be recycled in the community for additional economic development and environmental improvements.

The second broad set of initiatives that falls under the rubric of community energy planning is the extension of energy-focussed management and planning exercises, including demand-side management (DSM) and integrated resource planning (IRP). These exercises focus on meeting society's energy service needs in ways that minimize energy throughput, with potential economic and environmental benefits. Integrated resource planning has been used extensively by electric and natural gas utilities to assess choices between new supply and demand-side management alternatives. DSM and IRP within the community energy management context are directed at choices about energy delivery systems (district heating and cooling, combined heat and power, renewable energy), and building energy and resource efficiency (passive solar design, reduced building heat loss, reduced water consumption and wastewater production).

This paper explores the potential for community energy planning to contribute to the reduction of greenhouse gas emissions in Canada. The discussion begins by defining CEM and its role in achieving larger community goals such as reducing public sector expenditures, job creation and improving the quality of life. This discussion is in the context of the level and pattern of energy use in Canadian communities, particularly the portion that is subject to the influence of CEM initiatives. Two aspects of CEM are examined in some detail: the relationship between land use and energy use, and the potential for district energy systems in Canadian communities.

There is a powerful relationship between urban spatial structure and energy efficiency. The density, mix and arrangement of land uses in a community heavily influence the amount and mode of travel and, therefore, transportation energy use and its associated environmental impacts. These same urban characteristics also affect the amount of energy needed to heat and cool buildings, and to build and operate community infrastructure. Communities affect the efficiency of energy production, distribution and use by the planning and design choices they make. Communities can improve their environments, economies and quality of life by being aware of the energy consequences of their choices. These widespread benefits are due to the integral nature of energy in communities, where efficiency gains in one sector lead to related improvements in other sectors.

Because of energy's pervasive influence in a community, creating a comprehensive plan for the efficient use of both non-renewable and renewable resources is a good strategy for simultaneously accomplishing other community goals.

- *Improve air quality and reduce greenhouse gas emissions.* Fewer automobile trips and more efficient houses and businesses result in significantly lower local air pollution and greenhouse gas emissions, especially carbon dioxide (CO_2).

- *Affordable housing.* Compact developments can help create more affordable housing, and lower home energy and gasoline bills can improve eligibility for home financing and reduce rental costs.

- *Less traffic congestion and better mobility.* Easy and safe access to transit and mixing land uses reduces auto use, traffic congestion and gasoline consumption.

- *Reduce cost of providing public services.* Compact development reduces the length of water, sewer, natural gas and electric lines, thereby saving construction, operating and maintenance dollars for both the public and private sectors.

- *Open space and agricultural land preservation.* Efficient development of compact regions and cities reduces sprawl and preserves carbon emission sinks.

- *Increase personal and business income.* Energy savings become disposable income for individuals and working capital for businesses, keeping more dollars in the local economy and increasing spending on community infrastructure.

- *Job retention and creation.* Reduced commercial and industrial energy costs and local reinvestment of savings help to protect existing jobs and may create new jobs.

It is the connection between these community development goals and the underlying energy system in the community that has led to the identification of CEM as an approach to sustainable community development.

CEM typically encompasses the following measures:

- *land use planning* (zoning for specific land uses, land use densities and land use patterns);
- *transportation management* (traffic management, developing high occupancy vehicles, transit, walking and cycling infrastructure and services);
- *influencing site design* (encouraging designs that improve the economics of energy efficiency measures, alternative energy supply technologies and the use of passive solar energy and microclimatic considerations); and
- fostering efficient and environmentally *benign energy supply and delivery systems* (district energy systems using, in some cases, renewable or waste energy).

Jaccard et al. (1997) depict the relevance of urban land use patterns and urban infrastructure to energy policy by representing the determinants of energy demand in a hierarchy of energy-related choices (see Table 1). At the top of the hierarchy are very slow moving features that are largely determined by decisions made in the public sector and investment provided by public funds—the basic land use pattern (urban form) and associated infrastructure. We know that both land use decisions and infrastructure investments have a profound and long-lasting influence on the level of energy use in the community—community energy planning focusses on these connections and brings energy considerations explicitly into the community planning process.

Table 1
Hierarchy of energy-related choices

Choices		Local influence
Level 1. Infrastructure and Land Use Patterns		
• Density • Mix of land uses • Energy supply infrastructure • Transportation networks	⇦	Local plans, master plans, property tax structure, lot levies, rights-of-way allocation
Level 2. Major Production Processes, Transportation Modes and Buildings		
• Choice of industrial process • Choice of transportation mode • Building and site design	⇦	Local codes and standards, user fees, parking policies and pricing, local demand management programs, industrial and economic development policies
Level 3. Energy-Using Equipment		
• Transit vehicles • Heating, ventilation and air conditioning (HVAC) systems • Appliances • Motors	⇦	Local procurement practices, influence of local codes and regulations, education programs

Density and land use patterns affect the level of energy service requirements (e.g., commuter distances), the design of intra-urban transportation systems, the character of energy transmission systems, the potential for waste utilization and the possibilities for alternative energy supply systems. Changes in land use and urban form occur over a long period (from 10 years to a century) and, collectively, they have a profound impact on energy consumption and greenhouse gas emissions. Change in land use not only occurs slowly, it also occurs incrementally. As such, land use decisions made today may not have a large immediate impact on energy use, but will affect that usage for a long time to come. Small incremental change may eventually lead to large changes in energy consumption and greenhouse gas emissions. Conversely, land use decisions that support resource consumptive activities represent a lost opportunity that will last for an equally long period.

Further down the hierarchy represented by Figure 1 are the production processes, transportation modes, building site designs and individual energy-using technologies. Decisions about technologies and processes tend to be made on a more frequent and short-term basis toward the bottom of the hierarchy, more often by individual firms and households than by government. But the influence of the community extends, or can extend, to these decisions as well, through the myriad of ways local governments influence choices in the community. Community energy planning operates from a comprehensive and long-term view of energy use in the community, seeking to create the conditions and influence choices for sustainable community development.

ENERGY USE IN CANADA AND THE SCOPE FOR COMMUNITY ENERGY MANAGEMENT

The scope for CEM includes all the energy use over which the decisions and mandate of the local government have at least some control or influence: residential and commercial buildings, intra-city road transportation and transit, and general manufacturing establishments. In assigning greenhouse gas emissions to this energy use, we have used the technique of end use allocation of emissions: the emissions of power plants have been prorated over end use kilowatt-hours of electricity, and the emissions of the fossil fuel industry have been prorated over the end use consumption of fuels. This method corresponds to the principle of "polluter pays" allocation of responsibility, to an end use demand orientation to mitigation strategy and to an equitable distribution across Canada (and to U.S. importers) of the emissions that occur in the fuel producing regions of the country.

The results are shown in Table 2, indicating that fully 50 per cent of the greenhouse gas emissions in the country are under the direct or indirect control and influence of local governments. The total makes it clear why municipal government engagement is a necessary condition for any successful national climate strategy, and why the potential of community energy management is so important.

With full cycle end use allocation, the energy-related emissions in Table 2 total 296 megatonnes, of which oil fuels (mainly gasoline and diesel fuels for transportation) contribute 50 per cent and natural gas and electricity contribute about 25 per cent each. The size and oil dependence of the transportation sector is immediately obvious, accounting for fully 40 per cent of total energy-related emissions and over 80 per cent of oil fuel emissions. The contribution from electricity averages about 25 per cent on a national basis, but this varies widely due to the range of CO_2 intensity between the hydro-dependent and the coal-dependent provinces/territories.

With regard to the end use breakdown, the largest categories are heat and transportation fuels, even

Table 2
Community greenhouse gas emissions in Canada, 1990

(Full cycle end use allocation of emissions for both electricity and fossil fuels[1])

End Use Sector	Megatonnes of CO_2 in 1990
Residential Buildings Energy Use	**84**
Space heating	47.6
Water heating	19.2
Appliances and other electric load	17.3
Commercial and Institutional Buildings Energy Use	**53**
Space heating	26.6
Water heating	3.4
Lighting	8.0
Heating, ventilating and air conditioning systems	6.4
Other electric loads	8.6
Industry Energy Use[2]	**31**
Space and process heat	23.2
Motors	4.9
Lighting and other electric loads	3.0
Energy for Personal and Freight Transportation in Communities[3]	**110**
Personal transportation	77
Freight transportation	33
Landfill Methane	**18**
Total	**296**

Notes:

1. The end use allocation technique used to develop this inventory assigns greenhouse gas emissions from electricity generation and from oil and gas production and refining to the end users of electricity and fossil fuels. Assigning the emissions of the oil and gas industry and the electric utilities to the end users of energy gives a clearer picture of the greenhouse gas emissions associated with energy-using behaviour. This approach focusses attention where the largest long-term opportunities for emission reductions exist—where the fuels and electricity are being used. Such a focus does not remove the incentive for oil and gas producers and electric utilities to produce efficient, low-carbon products because in any future that includes greenhouse gas mitigation, there will be a premium value associated with no-carbon and lower-carbon products. The end use allocation method has the additional advantage of levelling the great (and divisive) regional disparities that result from source allocation schemes in which the oil and gas producing regions are assigned a disproportionately large share of the national greenhouse gas emission inventory.
2. Excludes petroleum refining, pulp and paper, iron and steel, industrial chemicals, mining, primary smelting and refining, cement, non-metallic minerals.
3. Excludes air, rail and marine travel, inter-city movement of people and freight.

Source:
Torrie Smith Associates Greenhouse Gas Emissions Model.

Figure 1:
Greenhouse gas emissions from community energy use, by sector and fuel, 1990

(Full cycle end use allocation of emissions for both electricity and fossil fuels[1])

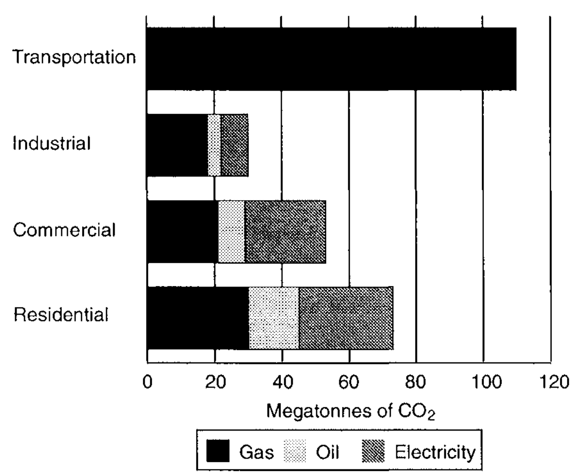
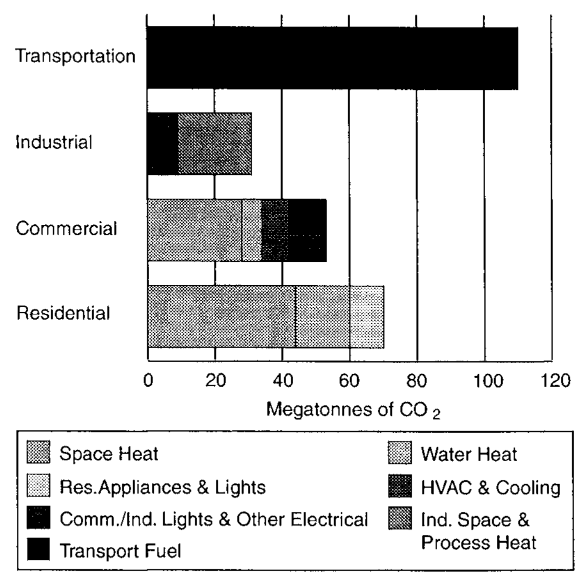


Figure 2:
Greenhouse gas emissions from community energy use, by sector and end use, 1990

(Full cycle end use allocation of emissions for both electricity and fossil fuels[1])



though these data do not include the most heat intensive industries or air, rail, marine and inter-city road transportation (all of which have been excluded from our definition of community energy). Heat and transportation fuels contribute about 42 per cent each to the total, with various electrical loads (motors, lights, appliances, HVAC systems, plug load, etc.) making up the remaining 16 per cent. These percentages are about the national averages and will vary from community to community, but are sufficient for illustrating the necessary elements of community energy planning for greenhouse gas emission reduction.

Transportation, Energy and Land-Use Patterns in Different Cities

In their empirical study of cities around the world, Newman and Kenworthy (1989) compiled compelling evidence of the inverse relation between density and transportation energy use in urban communities. Table 3 presents some of the indicator data they collected from a group of cities around the world. They concluded that at densities below 20 persons/ha, and at household sizes and land uses common to San Francisco area cities, there is a marked increase in driving, and below 30 persons/ha, bus service becomes poor. They recommend densities above 30 to 40 persons/ha for public transit-oriented urban lifestyles. Typical densities for different housing types are provided in Table 4, and population densities by city size in Canada are provided in Table 5.

There are several important conclusions that can be drawn from studying Table 3. First, density and car use are inversely correlated, while there is a direct correlation between density and percentage of passenger travel on transit. On a broad scale, these conclusions hold true, regardless of the cultural context of the city. Nonetheless, a closer examination of cities between and within different cultural milieus shows that other factors also influence car and public transit use. These include access to highways, congestion, distribution of wealth and demographic factors.

Dunphy and Fisher (1993), in a study of factors influencing transportation energy use in American cities, noted that U.S. cities with a larger poor inner-city population tended to have higher transit use and less car use than other U.S. cities. This factor is referred to as a transit system's "captive market," because these residents have few transportation choices other than public transit. Dunphy and Fisher (1993:10) also noted that in cities, such as New York, which have very high degrees of traffic congestion, many city dwellers have simply given up on car use as a viable means of transportation. The decision not to use the car in New York is also due to a good public transit system and a rich network of established services available at the neighbourhood level. The same study also noted that suburban residents tended to be in a different phase of the life cycle than inner-city dwellers. More couples with young children tended to live in the suburbs, while singles and couples with no children tended to live in the inner city.

On average, young families require greater access to services than do single individuals and couples with no children. This factor is significant, as it would tend to act as a "multiplier" to low-density, dispersed development patterns in terms of increasing auto travel.

Culture plays a crucial role in the manner in which cities with a history of low-density development achieve higher densities and more mixed uses. While there seems to be a greater acceptance of moves to limit car use in European cities, North Americans may not take to such policies so readily. However, some evidence suggests that when presented with some realistic alternatives to traditional suburban development, North Americans may move to higher-density and mixed-use alternatives. Opportunities for residential intensification in existing neighbourhoods exist in most Canadian cities. In the city of Ottawa for example, a June 1994 evaluation of lots for very low-density uses showed that 17,200 lots have the potential to be subdivided, and there are thousands of hectares of open space, some parts of which could be used for residential purposes. In the city of Toronto, an estimated 800 hectares of under-used land could be devoted to residential intensification, and about 2,200 hectares in the suburbs of Scarborough, North York and Etobicoke could be redeveloped in this way (D'Amour, 1993: 26). However, to achieve this, regulatory reform and public education to overcome public opposition would be required.

Table 3
Key transport, land use and economic data for 37 cities, 1990

City	Car use per capita (km)	% of total passenger km on transit	Roads per capita (metres)	Urban density (persons/ha)	GRP per capita (US$ 1990)
Australian					
Perth	7,203	4.3	10.7	10.6	17,697
Adelaide	6,690	4.9	8.0	11.8	19,671
Brisbane	6,467	7.4	8.2	9.8	18,737
Melbourne	6,436	7.9	7.7	14.9	21,088
Sydney	5,885	15.8	6.2	16.8	21,520
Average	**6,536**	**8.1**	**8.2**	**12.8**	**19,761**
American					
Phoenix	11,608	0.8	9.6	10.5	20,555
Denver	10,011	1.5	7.6	12.8	24,533
Boston	10,280	3.5	6.7	12.0	27,783
Houston	13,016	1.1	11.7	9.5	26,155
Washington	11,182	4.6	5.2	13.7	35,882
San Francisco	11,933	5.2	4.6	16.0	31,143
Detroit	11,239	1.1	6.0	12.8	22,538
Chicago	9,525	5.4	5.2	16.6	26,038
Los Angeles	11,587	2.1	3.8	23.9	24,894
New York	8,317	10.8	4.6	19.2	28,703
Average	**10,870**	**3.6**	**6.5**	**14.7**	**26,822**
Canadian					
Toronto	5,019	23.6	2.6	41.5	22,572
European					
Frankfurt	5,893	12.1	2.0	46.6	35,126
Amsterdam	3,977	14.0	2.6	48.8	25,211
Zurich	5,197	24.2	4.0	47.1	44,845
Brussels	4,864	17.3	2.1	74.9	30,087
Munich	4,202	29.4	1.8	53.6	36,255
Stockholm	4,638	27.3	2.2	53.1	33,235
Vienna	3,964	31.6	1.8	68.3	28,021
Hamburg	5,061	15.3	2.6	39.8	30,421
Copenhagen	4,558	17.2	4.6	28.6	29,900
London	3,892	29.9	2.0	42.3	22,215
Paris	3,459	30.5	0.9	46.1	33,609
Average	**4,519**	**22.6**	**2.4**	**49.9**	**31,721**
Wealthy Asian					
Singapore	1,864	46.7	1.1	86.8	12,939
Tokyo	2,103	63.4	1.9	104.4	36,953
Hong Kong	493	82.3	0.3	300.5	14,101
Average	**1,487**	**64.1**	**1.1**	**163.9**	**21,331**
Developing Asian					
Kuala Lumpur	4,032	24.1	1.5	58.7	4,066
Surabaya	1,064	26.1	0.3	176.9	726
Jakarta	1,112	48.7	0.5	170.8	1,508
Bangkok	2,664	33.3	0.6	149.3	3,826
Seoul	1,483	52.8	0.8	244.8	5,942
Beijing	351	70.0	0.4	141.0	1,323
Manila	573	49.1	0.6	198.0	1,099
Average	**1,611**	**43.4**	**0.7**	**162.8**	**2,642**

Notes:

GRP = Gross regional product, or Gross Domestic Product for the city in question.

Stockholm is the only city in the sample to have a per capita decline in car use (229 km) between 1980 and 1990. It grew in per capita transit use by 15 per cent in this period while increasing its density in the city centre, the inner area and the outer suburbs. Stockholm is now seen as a model for how a polycentric city, based on good rail services can provide for the needs of a sustainable global city (Newton 1997: 86).

Zurich, the wealthiest city in the sample, succeeded in increasing its transit ridership by 137 trips per capita in the 1980s to reach a level of 500 trips per person per year. The average transit trips per capita growth in European cities is more than the total per capita transit use in U.S. cities.

While transit ridership in Canada increased between 1980 and 1990, the trend has been reversed since then. At the same time, auto use in Canadian cities has been on the rise. Reasons cited for this shift to auto use include substantial increases in the real price of transit since 1986, particularly when compared to real auto purchase prices and operating costs, which have declined over the same period. The net result is that the automobile has become a more attractive transportation alternative (Perl and Pucher, 1995: 269).

Source: Newton, 1997: 166.

Table 4
Typical densities of different house forms

Density	Housing Type	Storeys	Units/ Net ha	Persons/ Net ha
Low	Single-family detached	1-2	12-17	43-48
	Two-family	1-2	19-29	48-84
Medium	Rowhouse	2-3	24-48	72-144
	Garden/ walk-up apt.	3-4	48-96	120-192
High	Multi-family (low)	5-10	96-192	192-360
	Multi-family (medium)	10-16	192-240	360-480
	Multi-family (high)	16+	240-960	480-1,680

Source: D'Amour, 1993: 12.

Table 5
Growth and change within Canadian urban-centred regions (UCRs), 1981-86

Population Class (No. of UCRs)	Area Increase (%)	Population Density pop/ha	Population Increase (%)	Rate of land conversion (rural to urban) ha/1000 pop.
25,000 – 50,000 (26)	3.3	9.0	1.5	242
50,001 – 100,000 (18)	4.0	9.8	2.9	141
100,001 – 250,000 (13)	4.9	12.8	3.6	104
250,001 – 500,000 (4)	3.2	12.4	5.2	50
> 500,000 (9)	6.6	19.5	6.3	53
Average for 70 UCRs	5.4	16.5	5.4	64

Source: D'Amour, 1993.

Making the Connections

The Newman and Kenworthy (1989) data sparked a lively debate on the importance of density vs. other demographic, social and cultural factors in determining the level of automobile dependence and transportation energy intensity of the community. Susan Owens (1991), in a report prepared for the Oganization for Economic Cooperation and Development (OECD), noted that "land use planning, siting and building regulations will be of considerable importance in urban energy management because energy systems are related in fundamental ways to patterns of land use and structure of the urban environment." Numerous empirical studies have confirmed the important relation between density, urban form and community energy use (Newman and Kenworthy, 1989; Holtzclaw, 1993; Perl and Pucher, 1995; Dunphy and Fisher, 1993; Energy Victoria, 1996; Torrie,1993).

When analyzing the manner in which energy planning can affect the level and pattern of energy use in the community, it is useful to distinguish between urban form and urban spatial structure.

Urban form is the actual physical form of the community: the natural and the built environment including the road and rail networks, river systems, ports and airports, telecommunications infrastructure, buildings, housing and so on. These elements of urban infrastructure are relatively stable, retaining their form for long periods.

Urban spatial structure refers to the relationships, especially the spatial relationships, in the way citizens, households and businesses in the community use the land and the infrastructure available to them. In contrast to urban form, urban spatial structure is dynamic, as both households and businesses tend to exhibit high levels of mobility and change (Newton, 1997: 8).

Urban form and spatial structure are interdependent, but significant changes in land use and urban structure generally occur on a shorter time frame than changes in urban form. To a certain extent, urban form lags the spatial structure of the community; hence the constant need to adapt urban form to meet changing land use patterns. Changes in master plans, official plans and land use development standards can provide the foundation for fundamental change in energy use patterns over the long term.

Both urban form and spatial structure affect the efficiency with which energy is used in urban areas and the amount of CO_2 released into the atmosphere in the following ways:

- The dispersal and separation of centres of employment, retail activity, social services, sports, recreation and cultural activity from residential areas forces citizens to travel varying distances to access those services. Dispersal also makes alternatives to the use of the automobile, such as public transit, cycling and walking, less economical and practical. The result is greater reliance on the automobile, which increases per capita energy consumption and greenhouse gas emissions.

- Developments of low-density, single-family homes also reduce the cost effectiveness of public transit and increase infrastructure costs.

- Low-density, single-use development makes it less economical to integrate buildings into district energy systems to reduce the amount of energy needed to provide space heating, space cooling and domestic hot water to residences, businesses and institutions. District energy systems work better when they are able to service a mix of building types in a relatively small geographic area. In addition, if they use waste heat, landfill methane, municipal waste or renewable energy as their source, they can make even greater contributions to greenhouse gas emission reduction targets.

- Medium- to high-density residential buildings (townhouses, apartment and condominium complexes) require less energy to heat and produce fewer emissions per square metre of floor space and per occupant than single-family detached homes, due to improved volume/surface ratios and more compact designs. It is important to note in context, however, that annual housing starts in Canada are now less than 1.5 per cent of the existing stock (averaging 140,000 to 150,000 per year over the 1991-96 period. In 1997, the $17 billion spent on new residential construction compared with $22 billion spent on renovations.

- The amount and cost of infrastructure escalates as densities decrease. The length of water and sewer mains, utilities and roads increase on a per dwelling basis. The result is an increase in both the energy required to deliver these services and the embodied energy in the infrastructure itself. The cost to build and maintain this infrastructure can seriously drain municipal coffers. Greenhouse gas emissions also rise as a consequence.

- Low-density development increases the amount of agricultural land and forests that are destroyed to build new subdivisions. The result is fewer trees and plants, which remove carbon dioxide from the atmosphere.

- The way in which roads are laid out affects the orientation of buildings. If buildings are oriented along an east-west axis, they can take advantage of passive solar heating. Building orientation also allows developments to take advantage of microclimatic effects. These factors reduce overall energy consumption and subsequent greenhouse gas emissions.

A high level of personal mobility has become an icon of modern urban design. But, it is important to realize that mobility is not generally demanded for its own sake, but for the access it provides—access to goods and services, to employment, education, cultural and educational enrichment, and recreational and cultural experiences. The market is, in fact, for access, not for mobility itself, and this distinction becomes increasingly important in the quest for sustainable urban development.

In what we might call the "mobility paradigm," the demand for vehicle kilometres of travel (VKT in the parlance of transportation planners) has been taken as a given, in much the same way as demand for fuels and electricity was a given in the first policy responses to the oil price shocks of the 1970s. To the extent that reducing VKT is considered an option in the mobility paradigm, it is a somewhat negative option, in much the same way as energy conservation was regarded before we learned to appreciate fully the derived nature of the demand for fuels and electricity, and the tremendous economic and environmental benefits of improved energy productivity.

In contrast, in what we might call the "access paradigm," society seeks ways to provide access to the various goods and services and experiences that people desire, while at the same time minimizing VKT. In this paradigm, success is not measured in traffic counts and average speeds, or even in transit modal shares, but by indicators such as the level of pedestrian activity, the total number and average length of vehicle trips, and the ratio of access to VKT. Once the derived nature of the demand for personal mobility is fully appreciated, the extent to which a community can function and thrive while reducing VKT becomes a measure of strength and success, in much the same way as energy conservation (reducing energy use per dollar of economic output) is now seen as an indicator of economic strength.

Congestion, photochemical smog and the bleak environment in which so much of the urban driving experience takes place are leading individuals and local governments to seek ways to reduce the amount of vehicle traffic in their communities. This is something new, and is where the issue of access vs. mobility becomes critically important.

In the context of this redefinition of the market from mobility to access, the key role of local governments becomes apparent. Under the mobility paradigm, the transportation market is defined in terms of vehicles and infrastructure capacity, and solutions to the environmental problem tend to focus on alternative fuels and vehicles, transit mode share and traffic management. Under the access paradigm, the focus widens to include all sorts of innovations related to urban form and spatial structure—neighbourhood and community design. How do we get access to the things we need and want without unnecessary or inefficient, or even unpleasant, personal mobility?

While much has been achieved and can still be achieved with more fuel-efficient and cleaner-fuelled vehicles, the deeper and more permanent changes needed to create sustainable transportation systems are in the area of:

- neighbourhood and community designs with inherently lower levels of VKT;
- substitution of information technologies for personal mobility; and
- radical rethinking of public transportation.

In all these areas, the importance of the local government sector looms large. Local governments are the key players when it comes to such issues as land use planning and zoning; investments in, and operation of, the road system, the transit system and the pedestrian and cycling infrastructures; parking policies and pricing; and even the development of the information technology network that serves the community.

Canada's strong urban planning tradition has moderated the North American tendency to segregated use, but automobile-dependent, low-density developments of single, detached housing are, nevertheless, the dominant form of postwar development, particularly in the 1960s and 1970s. The design of the road system, the low density and the wide spacing of retail and other services make Canadian cities energy and greenhouse gas emissions intensive. While more energy efficient than their U.S. counterparts, Canadian urban designs still lead to transportation and household energy use up to four times higher than comparable European cities. This is not to suggest that the European city is either a practical or desirable development model for Canada, only that there is a very large scope for energy savings through community energy management. Of course, the appropriate strategy will vary from community to community, but the way to lower greenhouse gas emissions will include a combination of higher density, mixed use, pedestrian and transit-friendly design, and attention to detail at the site level.

Higher density

The relationship between density and transportation energy use is well established (Owens, 1991: 4; Newman and Kenworthy, 1989). As density increases, transportation energy use declines, largely due to a modal shift away from the automobile toward public transit and walking. Minimum-density thresholds of 30 to 40 persons per hectare are suggested by Newman and Kenworthy and others. In very high-density neighbourhoods, walking and cycling also become important means of transportation. Therefore, higher-density development is often cited as a means of reducing transportation energy use. Higher-density development also reduces building energy consumption on a per unit basis.

Mixed use

Mixed-use development, in which residences, retail and other services and employment centres are built in close proximity to one another, is also a key element of community energy plans for lower environmental stress. Mixed-use development allows for higher levels of neighbourhood self-containment, providing residents with services close at hand so they can either walk or cycle to provide for their daily needs or, if they still need to use an automobile, they need not travel as far. A combination of mixed uses and higher density also paves the way for district energy systems.

Improved use of public transit

In all cases, better public transit figures prominently in energy-efficient cities. Sufficient densities are required to make public transit more economically viable. As such, clustering higher-density residential development and commercial services around major stops along bus or rail lines is considered essential. Land use strategies to promote better public transit would be only one of a number of measures designed to effect a shift in modal split.

Better siting and design parameters

Siting and design guidelines can improve the use of passive solar energy for heating and reduced energy consumption through taking advantage of microclimatic conditions.

These elements can be combined in many ways, with varying levels of emphasis, that respond with different compromises between competing community objectives (Newton, 1997).

Compact city development, in which new residential and service activity is located in the inner city, leads to lower greenhouse gas emissions, travel distance and travel time. However, it places all new residential development in the area of highest urban air pollution.

Multi-nodal city development is the most self-contained of all scenarios, with nodal city centres connected by a ring freeway and a radial rail and freeway system. It is second only to the compact city in its energy efficiency; while travel distances can be high, travel times are short, and air pollution is lower than most other forms.

Corridor city development locates growth on greenfield sites connected to the existing city by radial rail and arterial/freeway links. This type of development is less self-contained and results in high greenhouse gas emissions and long travel times, but relatively low air pollution.

Finally, in the *ultra city,* a metropolis-based region of dispersed development interconnected by high-speed communications and transportation networks, travel distances and greenhouse gas emissions are moderate to high.

Reduced Mobility: The Potential for Emissions Reductions

Research and innovation on less automobile-dependent and more environmentally sustainable community economies is taking many forms. While a reduction in energy use and greenhouse gas emissions is not usually a central objective of such innovation, it is a necessary part of any concept of sustainable urban development. A focus on the energy dimension of alternative development concepts can provide a framework for assessing other aspects of environmental sustainability.

There are numerous examples throughout North America of what has come to be known as the "new urbanism"—urban forms that place a renewed emphasis on "pedestrian friendly" and "transit friendly" neighbourhoods. American urban architect Peter Calthorpe coined the term "pedestrian pocket" for neighbourhood developments that place high-density pockets around transit stations (an idea that is not new in Canada and which, to a large degree, formed the basis for Metropolitan Toronto's development). In a similar vein, architects Andres Duany and Elizabeth Plater-Zyberk (designers of McKenzie Towne in Calgary) have led a move toward "neo-traditional" neighbourhood development, with a return to sidewalks and pedestrian-oriented streetscapes.

Neighbourhoods designed along new urbanism principles are meant to be as self-contained as possible. There is a mix of land uses, including a range of housing types, from apartments to social housing to single-family detached homes along with shops, offices and cultural buildings. At the centre of these neighbourhoods is the town centre, which is designed to accommodate pedestrians and is the focus of community activity. Streets are also designed to accommodate pedestrians, and services are located within easy walking distance of all residents.

Three Canadian examples of new urbanism developments are Cornell in Markham, Ontario, McKenzie Towne in Calgary, Alberta and Montgomery Village in Orangeville, Ontario. Cornell covers 625 hectares, and is designed to accommodate 27,000 residents. It is awaiting approvals before construction begins. McKenzie Towne is under construction, covers 970 hectares and is designed to accommodate 28,000 residents. Montgomery Village is under construction, covers 100 hectares and contains 750 units. Although innovations, such as neo-traditional neighbourhoods and other forms of the new urbanism, are likely to have an impact on household and community energy use, they are not generally the result of community energy planning. In fact, energy use is not typically a consideration in their development. As a result, there is very little data about the net environmental impact of these developments. They tend to maintain high levels of automobile dependence, however, and indications are that overall per household energy use for transportation is only marginally less than for traditional suburban development. Some argue that the residents of North America's suburbs, who are generally fairly affluent, have easy access to the automobile and demand a wide range of choice in their retail, service and cultural amenities. As such, they would tend to travel to whatever locale provided the specific services they were looking for, regardless of whether similar services were available in their own neighbourhoods. This may reduce the effectiveness of the self-containment model in reducing automobile travel. True or not, this criticism underlines the significant effect that attitudes, values, preferences and degree of mobility have on greenhouse gas emission reductions.

In the final analysis, greenhouse gas emissions and the energy intensity of personal transportation in the community come down to five factors:

- the number of trips;
- the length of the trips;
- the number of people per vehicle (occupancy);
- the fuel efficiency of the vehicle; and
- the emissions per unit of fuel.

For each mode of transportation (car, van, bus, subway, trolley, bike, walk, etc.):

$$\mathbf{CO_2\ Emissions = (A/B) \times C \times D \times E}$$

where

A = the number of person trips made using the mode
B = the number of people per vehicle (capacity factor)
C = the trip length
D = the fuel consumption per vehicle mile
E = the CO_2 emissions per unit of fuel.

A great deal of progress is being made and has already been made in the "vehicle factors"—D and E—but we are only beginning to understand how to quantify land use and urban structure impacts on the "trip making factors"—A, B and C. It is clear, however, both from the mathematics and from the empirical evidence, that reductions in the number of trips and the length of trips can have a large and essentially permanent impact on reducing air pollution and greenhouse gas emissions in the community. And, while the vehicle factors have been the focus of senior government policies (corporate average fuel economy or CAFE standards, support for alternative fuels), it is local government that controls the levers that set the trip making factors in the community.

The greatest challenge in all these alternative development patterns is achieving the high levels of self-containment (i.e., portion of trips that begin and end in the neighbourhood) necessary for automobile dependence and mobility demand to come down significantly. And while this objective was once a matter of achieving a matched balance between the resident labour force and employment opportunities, the return trip to work now represents less than half the travel of a typical Canadian household. Indeed, the work commute has the virtue of being long enough to bring down emissions per vehicle kilometre of travel and regular enough to be subject to alternative, low-emission modes (car and van pooling, transit). In contrast, all the other household travel—for shopping and a myriad of other personal business and family needs—tends to comprise relatively short trips (although mostly too long for walking or cycling) that have very diverse and complex patterns in space and time and are difficult for transit to serve. A key challenge in achieving long-term, permanent reductions in greenhouse gas emissions in Canada will be to develop less automobile-dependent, post-suburban, ecologically friendly urban forms that support true mixed-use land developments that allow greater "mobility efficiency" and corresponding increases in walking and cycling mode shares.

Table 6
Influence of urban form on energy demand

Land Use Variables	Energy Factor Influenced	Magnitude of Potential Impact
Combination of land use factors (shape, size, interspersion, etc.)	Travel requirements (esp. trip length and frequency)	Variation of up to 150 per cent
Interspersion of activities	Travel requirements (esp. trip length)	Variation of up to 130 per cent
Shape of urban area	Travel requirements	Variation of up to 20 per cent
Density/clustering of trip ends	Facilitates economic public transport	Energy savings of up to 20 per cent
Density/mixing of land uses/built form	Facilitates Combined Heat and Power (CHP)	Savings of up to 15 per cent Efficiency of primary energy use improved up to 30 per cent with district energy
Layout/orientation/design	Passive solar gain	Energy savings of up to 20 per cent
Siting/layout/landscaping/materials	Optimize microclimate	Energy savings of at least 5 per cent; more in exposed areas

Source: Adapted from Owens, 1991; Oregon Dept of Energy et. al., 1996; Blais, 1996.

The Technology and Its Strategic Importance

In societies where district heating plays a major role in the energy system, and where the planning and construction of such systems are integrated into the planning and building of the urban infrastructure, the district heating makes a big difference in the overall energy intensity of urban settlements. Next to the great differences in per capita transportation energy use, the second most important reason for the lower energy intensities of European cities compared to North American cities is the presence of district energy systems, often with combined production of heat and power (Torrie, 1993).

District energy has long been an accepted technology in Europe. Its use is widespread throughout most European countries, particularly in Sweden, Denmark and Finland, where district energy's share of the heat market is 34, 44 and 43 per cent respectively (MacRae, 1992: II-3). Other countries where district energy enjoys a significant share of the heat market include Germany, Austria and Switzerland. In Denmark and Finland, combined heat and power systems provide 58 and 68 per cent of the total heat production from district energy (MacRae, 1992: II-3).

District energy systems replace individual buildings' boilers, furnaces or chillers with a system that brings heat to buildings in the form of hot water and cooling as chilled water. Heated or chilled water is supplied from one or more central heating and cooling plants, and is distributed to consumers through buried pipes. Most district energy systems around the world provide heating only. However, a few systems in North America also provide cooling. In a combined district heating and cooling system, one set of pipes circulates hot water or steam to and from each individual building connected to the system. Separate pipes circulate chilled water. In a heating system, heat is extracted by heat exchangers in a substation located in each connected building. This extracted heat is then circulated throughout the building by a forced air system or hot water radiators. Heating systems also provide for each building's domestic hot water needs, once again through the use of a heat exchanger. The cooling system works in an identical fashion, except that the heat exchangers extract heat from the building's circulating air. The circulating chilled water is warmed, then returned to the central cooling plant to be chilled once more.

The advantage of district energy systems is the wide variety of fuels and energy sources that can be used to fire the boilers, and the overall level of efficiency that can be achieved. District energy systems are designed to provide for the space and domestic hot water heating needs of businesses and residences. Typically, temperatures of 60°C or less are required. As such, waste heat from industrial activities or power production is sufficient. District energy systems can use waste heat produced by the generation of electricity from thermal and combustion turbine power plants. This type of system is commonly referred to as combined heat and power (CHP). Such systems can achieve very high efficiencies of energy use. Typical thermal electrical generating stations are able to convert only 35 per cent of usable energy to electricity. However, CHP systems can convert 85 per cent of a fuel's usable energy into electricity or for use in district heating.

District energy systems can burn municipal solid waste, methane from landfill sites and sewage gas. Burning these materials provides the added benefit of reducing the amount of methane released into the atmosphere from the anaerobic decay of organic waste. Renewable fuels, such as wood and wood waste from sawmills or peat, can also be used. Provided they are harvested in a renewable manner, the net CO_2 released into the atmosphere is zero. More traditional fuels, such as natural gas and fuel oil, can also be used. District energy systems can be converted to use different fuels, as they become available and economical to use.

Buildings are generally cooled by using chlorofluorocarbon (CFC) or hydrochlorofluorocarbon (HCFC)-based chillers. Annual average efficiencies of these rooftop units are generally very low, and up to 25 per cent of the refrigerants are replaced each year due to leaks, improper purging and system contamination. These facts pose various problems. The low efficiencies of these units mean that far more electricity is being generated to run them than would otherwise be the case if more efficient units were available, or if alternative cooling methods were used. In addition, the release of CFCs into the environment damages the ozone layer and contributes to global warming. District energy systems can use more energy-efficient chillers, alternative sources of cold water (for example, lake water) and alternative refrigerants, and can be maintained more regularly, which will maintain higher levels of efficiency and reduce the accidental release of refrigerants into the environment.

The design of district energy systems can also be very flexible. New suppliers of hot and cold water can be connected to the system as the network grows. By the same token, the distribution system can be expanded into new areas over time. District energy systems are most economical in high-density areas, but low-density areas can also be serviced economically, particularly if mixed high-, medium- and low-density neighbourhoods are tied together as part of a single project.

Innovations that reduce the cost of district energy systems have been recently implemented. Oujé-Bougoumou developed the first district heating system using flexible plastic piping for its distribution network. Plastic piping is cheaper to install than the more traditional steel pipes used in other systems. The reduced costs of building district energy systems using plastic piping may allow less profitable projects in low-density neighbourhoods to be serviced economically.

District energy systems reduce emissions through higher levels of energy efficiency, combining heat and power production, and better emissions control. District energy customer substations use less space and need less maintenance than conventional heating and cooling equipment.

District Heating in Canada

There are over 160 district energy systems in operation in Canada, often employed on large institutional campuses (e.g., universities, military bases). However, district energy makes a relatively small contribution to total energy use. Also, the electric power system in Canada has developed according to a centralized model in which most electricity is generated in large stations optimized for electricity production, and there has not yet been any significant development of CHP facilities. There are steam-based district heating plants providing space heating to buildings in the city cores in Toronto, Winnipeg, Vancouver and Montréal; hot water-based systems are located in Ottawa and Charlottetown.

Communities served by district energy include Toronto, Montréal, Vancouver, Ottawa, Winnipeg, London, St. John's, Cornwall, London, Charlottetown, Oujé-Bougoumou (Québec) and Inuvik. Most of the systems in place are older steam systems. Both Ottawa and Charlottetown have steam systems and more modern hot water district energy systems. Cornwall has a combined heat and power system in place, and Oujé-Bougoumou has a medium-temperature hot water system fired by wood chips. Table 7 provides a brief description of each of these systems.

The Toronto District Heating Corporation (TDHC) is planning a major expansion and upgrade of the existing district heating system. It is expected to grow in size (number of customers served), extent and capacity. The system will probably use waste heat from a nearby electric generating station to provide additional steam capacity and is also expanding into district cooling, by using cold water from Lake Ontario rather than generated electricity. An expansion of the London system to include a CHP system is also being considered.

Table 7
Some district energy systems in Canada, 1990

Name of Organization	City	Built	Size (MW)	Fuel	Medium
Band Council of the Crees of Oujé-Bougoumou	Oujé-Bougoumou, Québec	1991	3.7	Wood chips	Hot water
Health Sciences Centre	Ottawa, Ontario	1992	68	Natural gas	Hot water
CDH Cornwall District Heating	Cornwall, Ontario	1994	13	Natural gas	Hot water
Trigen PEI	Charlottetown, Prince Edward Island	1985	30	Wood, MSW	Hot water, steam
Memorial University	St. John's, Newfoundland	1976	47	#2 fuel oil	Hot water, steam
N.W.T. Power Corp.	Inuvik, Northwest Territories	1955	19	Bunker C oil	Hot water
Corporation de chauffage urbain de Montréal	Montréal, Québec	1949	22	Natural gas, fuel oil	Steam
Trigen London	London, Ontario	1879	43	Natural gas	Steam, chilled water
Toronto District Heating Corp.	Toronto, Ontario	1960	276	Natural gas	Steam
Health Science Center	Winnipeg, Manitoba	–	37	Natural gas	Steam
University of B.C.	Vancouver, British Columbia	–	75.5	Natural gas	Steam
Govt of Canada	Ottawa, Ontario	1981			Hot water

Source: Arkay and Blais, 1996; Metro District Energy Systems Working Group, 1995.

Other Canadian municipalities with district energy systems in the planning stages include Sudbury, Hamilton and Windsor. An additional 18 municipalities, which are part of the Federation of Canadian Municipality's (FCM) Partners for Climate Change campaign, are considering district energy systems as part of their community energy plans.

There has been a resurgence in interest in district heating and CHP facilities in Canada, spurred partly by concern over energy-related environmental impacts of fuel combustion in cities. As the European experience has shown, the widespread application of district heating requires that its planning and development be integrated with the planning and development of both the urban infrastructure and the power supply system.

Key Considerations for the Implementation of District Energy Systems

District energy systems have grown to become a widely accepted technology, particularly in Europe but also in North America. Canadian success stories demonstrate several key, motivating factors that spurred the development of district energy systems in Canada. In Charlottetown's case, the desire to reduce dependency on imported oil and to keep more community dollars spent on energy within the province were key motivators. In Cornwall, and Oujé-Bougoumou, a community conservation ethic predated the development of a district energy system. These two communities also saw the benefits of spending less on imported energy resources and more on community development.

In the case of Cornwall, the fact that the city is not connected to the Ontario Hydro grid left the utility free to develop a combined heat and power system. The *Power Corporation Act* has given Ontario Hydro the authority to prohibit local municipal utilities from purchasing power from other suppliers. This monopoly power has served as a barrier to the development of CHP systems in Ontario. The deregulation of the electricity industry in Ontario could prove to be an impetus to municipal utilities and private industry to develop CHP systems in Ontario.

There are a number of opportunities for, and barriers to, the greater uptake of district energy that would be necessary to make a significant contribution to greenhouse gas emission reductions in Canada.

Technological considerations
In Canada, there are no significant technological barriers to the implementation of district energy systems which have been widely used throughout the world in both large and small communities. The development of flexible plastic piping will likely improve the economics of district energy systems, particularly if they are extended to include medium- to low-density residential neighbourhoods. Other technological improvements may further enhance their economics and the environmental benefits.

Economic/financial considerations
A concern over financial viability of district energy systems appears to remain a key barrier. Because district energy is still perceived to be an unproven technology in Canada, private investors still demand a risk premium and a corresponding return on their investment in the range of 25 per cent—equivalent to a payback of four years. The participation of public and institutional investors, such as public utilities and district energy corporations (e.g., Toronto District Heating Corporation), tend to lower the economic threshold to an overall return on investment in the range of 10 to 15 per cent and 18 per cent, respectively. This lengthens the payback to seven years or longer. Public utilities and district heating corporations have more knowledge and experience with district energy systems and the provision of utilities in general and, therefore, perceive the risk involved in developing a system to be much lower. As an increasing number of modern district energy systems are put in place in Canada and their economic viability is proven, it is likely that more private investment will become available at lower return-on-investment requirements.

Political/jurisdictional/institutional considerations
Natural Resources Canada (NRCan, 1996) outlines the key ingredients required for successful implementation of district energy systems.

- *An informed and committed champion.* This is the most fundamental requirement. The champion is an individual or a group that is totally satisfied that CESs represent a real community opportunity.

- *Municipal governments must understand that a CES is in their mandate.* Because a CES can have a strong impact on the local economy and environment, a municipality has a role to play in its development. Even if it is the private sector which implements the CES, the posture or attitude of the municipal government is crucial to the success of the implementation. A proactive community minimizes the risk by advocating CES as a community good.

- *Knowledgeable customers.* Customers must understand the potential benefits and the real costs and implications of meeting their energy needs. It is critical to know who the stakeholders are and to ensure that their needs and concerns have been addressed, including their need for information.

Of course, before district energy systems even begin to be considered at the municipal level, information has to be more widely disseminated so those champions within communities emerge. In partnership with the International Council for Local Environmental Initiatives, the Federation of Canadian Municipalities is helping communities involved in its Partners for Climate Protection program develop strategic plans, part of which usually involves considering district energy systems. This type of advocacy and promotion, along with providing success stories from other municipalities, is critical to increasing the uptake of district energy systems.

Jurisdictions with a monopolistic institution generating and distributing power (e.g., in a province) may have a difficult time developing combined heat and power systems. There are significant changes occurring in the electricity industry all over North America, but the precise implications of these changes to the development of CHP systems are not really known.

Municipalities do not have all the levers that could be brought to bear in encouraging district energy at their disposal. Tax incentives are the responsibility of the provincial and federal governments. In some areas, overlapping jurisdictions between different municipal governments, or between municipal and regional governments, can act as barriers to developing district energy systems that may need the encouragement and approval of every local government. The responsibility for removing these barriers rests with the provincial governments. These types of issues are difficult to address and, once again, a champion may be required to bring all the players on board.

Quantifying the District Energy Potential

The potential contribution of district energy systems to space and water heating in Canadian municipalities, and the corresponding emission reductions potential, was estimated in a study for CANMET in 1997, entitled *The Potential for CO_2 Emission Reductions in Canada by Implementing District Heating Systems* (CETC, 1997). This study relied on analysis done by Monenco Consultants in 1985, in which 75 Canadian municipalities were analyzed as potential locations for district heating systems based on their sizes and population densities.

Using a simple population-based method, and 1981 data, the Monenco study estimated the total heat consumption requirements for the 75 selected Canadian municipalities to be 600 PJ/year (167,000 GWh/year). CO_2 emissions from this level of consumption would be 46 megatonnes. Adjusting for population growth from 1981 to 1990 results in an estimate of 1990 space heat and domestic hot water of 875 PJ/year (238,000 GWh /year) and CO_2 emissions 66 megatonnes/year.

This figure is likely conservative. Using Natural Resources Canada and Torrie Smith Associates' (TSA) greenhouse gas model (calibrated to NRCan estimates), total 1990 tertiary space heat and domestic hot water energy consumption would be approximately 1,170 PJ/year and total CO_2 emissions would be approximately 110 megatonnes.

The CANMET study estimated the potential contribution of district energy systems by using cities for which more detailed feasibility studies of total connectable load were available. A potential contribution of 23 per cent (to space and water heating demand) was the average for those cities that had been studied, and the CANMET analysis assumed this average could be achieved in all 75 cities covered by the analysis. The CANMET analysis also assumed that all district energy is provided by co-generation, leading to a conservative estimate that the potential of district energy to reduce greenhouse gas emissions from space and water heating was 10 per cent, or three per cent of total municipal emissions (CETC, 1997:12).

This estimate does not include the additional emission reductions that would occur if the electricity produced by the CHP systems displaced electricity generated at coal and other fossil fuel-fired power stations. Given that coal is the marginal source of generation in most of Canada, including the displaced emissions in the estimate of the potential contribution of district energy results in much higher emission reduction potential. For example, the CANMET study shows an increase in emissions reduction potential from seven megatonnes to 40 megatonnes (CETC, 1997: 14). MacRae (1992: 53) estimates that CHP systems can reduce CO_2 emissions by 59 to 69 per cent when displacement of coal-fired generation is taken into account (MacRae 1992: 53). For these reasons, and because at least some district energy systems would use biomass or waste heat as their energy source, the likely emissions reduction potential from district energy is considerably higher than 10 per cent of total space heating and domestic hot water emissions.

COMMUNITY ENERGY PLANNING AND THE POTENTIAL FOR GREENHOUSE GAS EMISSION REDUCTION

Energy for Sustainable Communities

While district energy and land use planning for energy efficiency are important elements of energy-efficient communities, CEP is much more than the sum of individual technological and planning measures: it is the integration of energy considerations into all aspects of local government strategies for sustainable development. CEP involves the deliberate and strategic use of what might be called the municipal "spheres of influence" on energy use in the community to achieve environmental and community development objectives.

The municipal spheres of influence

Recognition of the many ways that local governments influence the level and pattern of energy use in the community reveals the potential role of community energy planning.

- Municipalities operate all kinds of buildings, vehicles, water and sewage facilities, street and traffic lights, and other energy-using equipment. Large cities can and do pay millions of dollars a year for fuel and electricity, and municipalities represent a significant contribution to the end use of energy in the community.

- Municipalities have direct responsibility for waste collection and landfill management. Landfill gas recovery and utilization have the potential to reduce significantly the contribution of methane to Canada's greenhouse gas emissions in the near to medium term. Municipalities will be key players in this effort. The Sub-Committee of the Municipalities Table was formed to further explore this potential, which represents one of the largest and most cost-effective, near-term options for municipalities to contribute to the Kyoto objectives.

- Municipalities also have responsibility for solid waste reduction, recycling and composting programs. These programs deliver multiple benefits from a greenhouse gas perspective. To the extent that organic waste is diverted from landfills (whether from reduction, recycling or composting), methane generation is avoided. Solid waste reduction and backyard composting also eliminate energy that would otherwise be required for collecting and disposing of the waste. Even more important, the "full life cycle" greenhouse gas emission reductions from solid waste reduction and recycling can be quite significant. In the case of particularly energy-intensive materials, such as steel and aluminium, plastic and paper products, the impact of recycling a tonne of material can result in more than a tonne of CO_2 emission reductions, sometimes many times more. In the case of paper products, there can be yet an additional greenhouse gas benefit due to the impact of recycling on the need for wood pulp.

- Through their control over land use, parks and community greening programs, municipalities have a central influence on the growth (or decline) of carbon sequestration within their boundaries. Urban greening and forestry programs not only increase the carbon sink in the community but also moderate the "urban heat island" effect and reduce the demand for both heating and air conditioning energy by providing windbreaks and shade to buildings.

- Many municipalities own or control gas, electricity and district energy utilities, providing an opportunity for business strategies in these organizations that will lead to greenhouse gas reductions throughout the community. Municipalities can also play a key role in stimulating the market for "green power" by purchasing it for their own needs and promoting its use in the community.

- Municipalities operate, or directly control, the design and operation of urban transit systems, key players in any strategy to reduce community greenhouse gas emissions.

- Municipalities often have regulatory authority or influence in areas that affect energy use, such as building codes, parking and traffic flow.

- Minimizing the impacts associated with climate change will require millions of relatively small individual, community and corporate actions to improve energy efficiency and apply renewable energy technologies. Local governments' proximity to the electorate and to the community will make them essential partners in delivering the integrated policies and programs that will be most effective in reducing greenhouse gas emissions.

- Local governments are one of the most important influences on the pattern of investment in infrastructure and the built environment. In the long term, achieving low carbon futures will require rethinking, redesigning and remaking the urban infrastructure. Local governments will be key players in this process through their direct investment in everything from roads and sewers to parks and bicycle paths, and their indirect influence (via regulations, by-laws, permits, etc.) on other investment in the community.

- Perhaps the most profound, long-term impact of municipal governments on the level of greenhouse gas sources and sinks in the community derives from their control of land use. As we begin to understand the factors that make one society or community more "greenhouse gas intensive" than another, the key role of urban form and structure is emerging as one of the most important. Decisions over land use changes (from agriculture to other purposes, from forestry to agriculture, from agriculture to urban development, etc.) have important impacts on carbon sinks. In urban municipalities, zoning regulations, permit conditions, municipal ordinances and by-laws all affect energy use by affecting such key factors as residential density, accessibility and proximity of commercial and retail services, the mix of uses, transit accessibility, the level of pedestrian and bicycle "friendliness" in the community, etc. These, in turn, affect the scope for energy efficiency in the community, the feasibility of district energy systems and the "mobility efficiency" of the community (i.e., how much travel is needed to get access to employment, recreation, shopping and other amenities). In the past, energy considerations have not played a significant part in these matters, but as the multiple benefits of CEM become apparent, municipalities are taking explicit account of these factors in their policies and programs.

Urban strategies for sustainable energy

Community energy planning is most effective when guided by a strategic approach of both political and bureaucratic leadership involving the community in setting and pursuing performance targets for environmental and economic improvements that are integrated with other community objectives. An innovative and integrated approach is necessary to engage the range of community and government partners necessary to make the permanent changes needed to move to a low-emission future (Torrie, 1995). Key elements of community energy planning include:

- *A strategic approach.* Local energy action plans require innovation and initiative. They will not happen spontaneously because they require a combination of elements that is often not part of the traditional mandate or conventional operations of municipal government. The impetus must be strong enough to overcome the inertia of "business as usual." This requires a long-range, strategic approach.

- *Targets.* Clearly specified targets (e.g., 20 per cent reduction in CO_2 emissions, elimination of ozone-depleting chemicals, development of all the economic savings potential in the city, etc.) are central to a strategic approach. Without a target, whether environmental or economic, the strategy has no clear objective, and a strategy without a clear objective is unlikely to be effective.

- *Recognition of multiple benefits.* Even when environmental improvement has been the original motivation for developing a comprehensive local energy action plan, (e.g., to reduce greenhouse gas emissions by 20 per cent by 2005), the policy and related programs will be most enthusiastically received by both elected officials and the community when the multiple benefits are identified and quantified. The rationale for local government action on energy includes job creation, economic development, cost savings, air quality improvement, greenhouse gas emission reduction and improvements in the overall quality of life in the community.

- *Political leadership.* Implementing effective local energy action plans requires leadership and vision from elected officials, and the active involvement, encouragement and support of city council.

- *Community involvement.* Related to the need for political leadership is the need for community involvement in the design and delivery of the action plan. Reducing energy use is not purely or even primarily a technological challenge; it also requires that the end users of energy be involved at every step. Whether planning the retrofit of the ventilating system of a single building or designing a community-wide program for retrofitting houses, success requires that all affected people be consulted and involved from the outset.

- *Bureaucratic support.* If active political support is necessary for successful local energy action, so too is enthusiastic support from municipal staff. Successful community energy strategies exist where individuals or groups inside municipal governments have embraced the concept, are excited by the challenge it presents, recognize the benefits it can bring to their municipality and realize its potential for professional development and career advancement.

- *Partnership.* Municipalities can accomplish much more through partnerships with senior levels of governments, utilities and others with an interest in energy conservation and renewables than they can by doing it alone. Not even the largest cities have all the necessary information, analytical, financial, marketing, and technical skills and resources for mounting integrated, comprehensive and effective energy plans. Municipalities can leverage their technical, managerial, financial and program delivery capacity through partnerships. The development of these partnerships is an explicit component of successful strategies.

- *Innovative financing.* Even for in-house conservation and renewable programs, and especially for municipality-wide efforts, the up-front investment costs are a major obstacle. Innovative methods for attracting investment capital are essential for success. Governments with environmental policy objectives that require "deeper savings" with longer paybacks can stimulate the necessary investment by acting as guarantors and by providing quality assurance and industry standards which increase investor confidence. The International Council for Local Environmental Initiatives (ICLEI) is pioneering new financing methods for local government energy action plans.

- *Market mechanisms.* The market can play a key role in sustainable energy strategies and in stimulating the innovation and new business activities that are needed. Environmental pollution and ecosystem deterioration do translate, at least partially, into economic costs, but these costs have remained largely uncounted and unvalued in market transactions. While not a panacea for addressing environmental problems, the economic valuation of environmental "externalities" can be an important element of strategies for sustainable energy.

- *Collaboration with other local governments.* The strength and mutual support gained through collaboration with other municipalities with similar objectives and policies are invaluable. Such collaboration can include:

  - information sharing on technical and operational measures;
  - exchanges of technical assistance and personnel;
  - pooling of research resources to develop monitoring and analytical tools, by-laws, regulations, etc.;
  - development of standardized energy-efficiency specifications;
  - joint procurement of energy-efficient equipment;
  - pooling of capital investment opportunities;
  - development of common positions on legal and regulatory issues; and
  - joint lobbying of senior government, international bodies, etc.

- *Monitoring and evaluation.* Ongoing monitoring of energy use and evaluation of energy-reducing measures are important for a number of reasons. First, monitoring allows continuous adjustment to priorities in accordance with the measures proving to be most effective. Monitoring is also necessary to know whether the strategic objective is being met. Monitoring and evaluation will be required by elected officials and financial partners to ensure they are achieving desired objectives. Finally, to the extent that a large part of becoming more energy efficient consists of becoming more aware of how we use energy and how behaviour affects the level of energy use, monitoring and evaluation are critical. Indeed, just telling people how much energy is being used in the building or facility where they work can, by itself, lead to immediate measures users can take (usually at no cost) to reduce energy waste.

- *Integrated program delivery.* Local energy action plans will be more effectively implemented if a consideration of energy can be integrated into the day-to-day activities, policies and planning of the organization and community. For example, integration of energy efficiency standards in a municipality's procurement and architectural policies will ensure that energy-reducing designs and renewable technologies are favoured when new equipment is purchased, new buildings are built or existing ones renovated. Similarly, integrating a consideration of energy use into the analysis of alternative land use and zoning plans will help the municipality develop in ways that gradually bring down energy intensity. Local energy strategies are most effectively delivered as part of an integrated environmental improvement strategy. Water conservation, waste reduction and recycling, land use and other elements of a municipality's environmental strategy should be integrated, especially with respect to program delivery and public education and outreach.

The local action plan

The foundation for effective municipal actions on energy and climate change is the local action plan. All the reviewed information and all the surveyed municipal experience with greenhouse gas mitigation strategies indicate the need for strategies specific to each individual municipality, developed with local knowledge, tailored to local energy supply and demand patterns, and integrated with other community development strategies. The local action plan (LAP) is a strategic approach to achieving a specified mitigation target both with respect to the municipality's own operations and the community at large. Both the community and in-house or "corporate" parts of the plan have three basic elements:

- A *greenhouse gas emissions analysis* contains an inventory of present emissions and projections of future emissions under business-as-usual conditions. The core of this analysis is an energy balance for the community.

- A *strategic analysis* includes selection of a specific target or set of targets and a corresponding set *of actions, measures and programs* to reach the targets. This includes analysis of the way the municipality's current activities and policies are affecting greenhouse gas emission sources and sinks, as well as new opportunities for mitigation.

- An *implementation plan* indicates the manner in which the identified measures will be carried out, including schedules, budgets, financing, assignment of responsibilities and staff, resource allocations, partnership arrangements, monitoring and evaluation strategies, and how any identified barriers will be overcome.

Nearly 60 Canadian municipalities have made commitments to develop local action plans for greenhouse mitigation, through their involvement with the ICLEI/FCM Partners for Climate Protection program. Greenhouse gas emissions in communities are predominantly from fossil fuel combustion, and a community action plan for greenhouse gas mitigation is necessarily, to a large extent, a community energy plan. Although the individual local action plans will, by definition, be unique, there is lots of room for cooperation and collaboration in the building up of the capacity to develop and implement LAPs. Standardized approaches with supporting toolkits and software exist for local action plan development, common training programs can be offered, and the sharing of experience and knowledge can be facilitated through networked projects such as the ICLEI/FCM Partners for Climate Protection program.

Although interest in tackling the climate change issue at the municipal level is quite recent and still developing, a history of research and innovation in community energy planning goes back over 20 years to the period following the OPEC oil embargo. The challenge facing the next generation of community energy planning will be to build on this experience to develop a modern and integrated approach to energy systems for sustainable community development.

The bibliography includes key references to community energy planning literature (e.g., B.C. Energy Aware Committee, 1997; Allen, 1995; Torrie and Jessup, 1995; California Energy Commission, 1993; Oregon Dept of Energy et al., 1996; Weissman and Corbett, 1992; Ontario, 1992; CMHC, 1982; Urban Consortium Task Force, 1992).

Community Energy Management: The Economic Benefits

Community energy management, when carried out in a way that integrates energy objectives with other community goals, can lead to substantial economic and employment benefits. Strategies for improving the efficiency and increasing local self-reliance in energy use almost always yield net benefits for the community from:

- the respending of fuel and electricity savings;
- reduced traffic congestion and related productivity increase;
- improved local air quality, public health and related economic benefits;
- lower infrastructure costs; and
- enhanced competitiveness in attracting business investment to the community.

There has been a limited amount of research in quantifying these various benefits, but the results are clear enough that an increasing number of municipalities are identifying the greening of their communities as not only an environmental objective, but also as a long-term economic development strategy.

A study done by the IBI group, entitled *Greater Toronto Area Urban Structure Concepts Study,* originally produced in 1990 and updated in 1995, provides some significant findings in terms of the costs of different urban development models.

- If the low density, greenfields development pattern that characterizes urban development in the Greater Toronto Area (GTA) today is maintained, future growth is estimated to require some $90 billion of supporting capital investment in new infrastructure over a 25-year period. In addition to this figure, ongoing expenditures on, and replacement of, infrastructure that already exists will be required, as well as operating and maintenance expenditures.

- The current urban development pattern is a high cost one, in comparison to more efficient alternatives. An urban form that relies to a greater degree on reurbanization, more compact development and mixed land use would decrease the capital investment required for roads, transit, water and sewer services by an estimated $10 billion to $16 billion, and decrease operating and maintenance costs by $2.5 billion to $4 billion.

- When external costs, such as those associated with emissions, publicly borne health care and accident policing are added to the capital, operating and maintenance cost savings, a conservative estimate would suggest that a total of about $700 million to $1 billion per year ($17.5 billion to $25 billion over 25 years) could be saved in the GTA by accommodating future growth in more efficient urban patterns.

- Further substantial savings could be achieved by altering the standards to which infrastructure of all kinds are built, to allow more efficient, flexible, sustainable and cost-effective alternatives.

- The mechanisms currently in place to raise revenue to pay for new infrastructure (property tax, development charges, user fees and provincial income tax) generate a subsidy to residents of low-density suburban areas by residents of higher-density, mixed-use areas. These subsidies artificially lower the cost of inefficient urban development, and distort the urban housing and property markets.

- Savings from more efficient urban development patterns would accrue to homebuyers, renters, businesses, the provincial government, local and regional municipalities and, ultimately, taxpayers (Blais, 1996: i-ii).

Another study done by CMHC (1997) attempted to quantify the infrastructure costs associated with conventional and alternative development patterns based on the theories of new urbanism. An Ottawa suburb (Barrhaven) was used as a case study. The study concluded that if Barrhaven had been designed along new urbanism principles, the total life-cycle cost (over 75 years) of infrastructure would be $11,000 per residential unit cheaper, or 8.8 per cent less than in the conventional plan. These savings would be roughly split between the public and private sectors. (The developer is responsible for building much of the infrastructure.) The per unit cost savings are attributable to the increase in residential density, and the increase in land use mix, which reduces the residential share of capital, operating and maintenance costs (Essiambre-Phillips-Desjardins Associates Ltd et al., 1995).

The linear infrastructure requirements for different housing types are presented in Table 8.

In addition to the results of these studies, Jaccard et al., (1997: 5) note in their study that the CEM

Table 8
Linear infrastructure requirements of different housing types

Housing Type	Density (units/ha)	Relative Length of Streets and Other Linear Infrastructure (per unit)
Apt. blocks, 8 floors, 6 units per floor	87	1.0
Apt. blocks, 4 floors,	73	1.7
Triplexes (groups of 4)	55	2.8
Duplexes (groups of 4)	37	4.2
Detached single-family bungalows	10	17.5

Source: D'Amour, 1993-12.

initiatives for each of the communities studied had combined life-cycle costs 15 to 30 per cent lower than the business-as-usual scenarios. They conclude, "in other words, the reduction in CO_2 emissions from CEM measures fit what has generally been defined as no regrets in that these measures are desirable from an economic perspective alone."

The Eco-Village: Shape of the Future?

Perhaps the most advanced examples of community energy planning are represented by the eco-village concept. Much more explicitly environmental in its orientation than other types of "new urbanism," the primary aim is to reduce the environmental impact and resource consumption of urban development. This approach addresses the demands urban development places on the environment, both as a source of materials and resources, and as a sink for pollution and waste. To reduce the ecological footprint of the community, eco-villages set rigorous standards for energy consumption in buildings and transportation, waste management and water consumption. Some eco-villages will also limit the size of the development according to a defined aspect of the carrying capacity of the immediate environment. Eco-villages maximize the use of renewable energy resources and reduce the impact of sewage treatment to zero on the receiving water bodies. They emphasize on-site systems for energy supply, stormwater management, water supply, sewage treatment and waste management (Hygeia Consulting and REIC Ltd, 1997: 11).

Eco-village developments share features, such as compact form and pedestrian orientation, with communities designed along the principles of new urbanism, but place a greater emphasis on the environmental impact of human habitation. In addition to the savings on linear infrastructure resulting from a more compact urban form, eco-villages reduce the capital and operating costs related to the supply of services through built-in demand management features, and lower per capita requirements for energy, water and waste disposal. In addition, some eco-villages in Europe are developing small-scale co-generation and renewable energy technologies, systems for collecting potable water and treating wastewater on site, and for returning compostable solid waste to the nutrient cycle. All these systems have the potential for reducing or eliminating the need for expensive, centralized public infrastructure.

Although still very much outside the mainstream of urban planning, the eco-village or "eco-development" approach to urban planning offers the greatest long-term potential for community energy planning for environmental improvement. There is a growing network of such experimental urban developments around the world <www.ecovillage.org>, usually located in suburban or rural settings, but including some inner-city redevelopment projects (e.g., Los Angeles Eco-village project).

Examples of eco-village developments

- The Tucson Solar Village in Arizona, also known as the Cinvano Project, is one of the best known eco-village developments in the United States. Situated on a 458 hectare (1,132 acre) site in suburban Tucson, Cinvano is now under construction. Consisting of a 40.5 hectare (100 acre) commercial centre surrounded by 2,600 homes in four neighbourhoods, 30 per cent of the site is preserved natural land, an additional 10 per cent is planned open space. The residential performance target for energy is to bring consumption to less than 50 per cent of the Arizona 1995 model building code and to reduce community traffic by 40 per cent compared to typical suburban levels <www.cinvano.com>.

- There are several dozen eco-village projects in Europe, including the Ecolonia Project in the Netherlands. Here again, the emphasis is on dramatically lower environmental impacts compared with typical development. Energy consumption per dwelling is 25 per cent below the already stringent Dutch building standards, and neighbourhood form, site layout and building orientation are all designed with solar gain and efficiency in mind (Novem, nd).

- In New York, EcoVillage at Ithaca (EVI) is a 71 hectare (176 acre) site bordering a nature preserve and overlooking the City of Ithaca. Less than three kilometres (two miles) from Ithaca's downtown, EVI includes co-housing, organic agriculture, cottage industries, an education centre and natural areas, preserving and restoring over 80 per cent of the land as green space. The residential component comprises three to five tightly clustered co-housing communities surrounding a village green <www.cfe.cornell.edu/ecovillage/>.

- In Canada, the most ambitious eco-village type of development proposed to date has been the Bamberton Development Project, north of Victoria, British Columbia. The proposal, which was successfully opposed by a number of public interest and First Nation groups, included plans for an eventual community of 12,000 to 15,000 residents in 4,900 dwellings on a 600 hectare (1,483 acre) site on the western shore of Saanich Inlet. All residential and commercial buildings were to have high levels of energy and water efficiency, cutting energy consumption to less than half that of conventional developments. The plan called for a job to household ratio of at least one, but given the proposed location of the community, criticisms that it would essentially be a bedroom community for Victoria are well founded.

How Important Could Community Energy Planning Be to Greenhouse Gas Reduction?

There is no single answer to the question of how great the emission reductions from effective community energy planning can be. The answer is as varied as local circumstances and opportunities. There are some analyses that put a number on the total, but different studies define the scope of community energy management differently and use varying methods to quantify potential impacts.

One recent Canadian study does provide an estimate of the emissions reduction potential of applying CEM in British Columbia. Jaccard et al. (1997: 1063) applied the principles of CEM to four communities representative of the province. These communities varied in size, from a small settlement not integrated into either the provincial gas or electricity grids (Anaheim Lake), to a large, high-growth suburb of Vancouver (Surrey). Each community was assumed to have made a concerted effort to apply CEM. Included in their efforts were land use planning, transportation management, site design, and local energy supply and delivery planning. The results of the modelling exercise suggested that CEM could lead to energy savings of 15 to 30 per cent and air emissions (CO_2 and NOx) reductions of 30 to 45 per cent for these communities relative to a "business-as-usual" scenario. These savings would occur over the period 1995-2010. Furthermore, the study extended the analysis to cover implementation of one aspect of CEM—land use planning—to the provincial level. The study estimated that CO_2 emissions could be reduced by 7.9 million tonnes (17 per cent) from a business-as-usual scenario by the year 2010, for a population projected to be 5.4 million.

Studies and other empirical evidence lend support to the Jaccard et al. conclusions. Owens (1991), Oregon Dept. of Energy et. al. (1996) and CMHC (1998) indicate that up to a 20 per cent improvement in space heating energy efficiency for new residential development due to better siting and house design strategies is possible. Better siting and house design strategies (for example, increasing south-facing window area) would allow communities to take advantage of passive solar gain in winter and microclimatic conditions (Oregon Dept. of Energy et al., 1996; CMHC, 1998: 46-47). Higher density and improved efficiency standards could provide up to a 26 per cent space heating efficiency improvement for new housing. A combination of these strategies could reduce the energy consumption of new housing by up to 50 per cent. It is worth noting that this is what is considered achievable just by moving to an R-2000 standard for all new housing. As indicated in Table 6, the effects of a variety of CEM measures on energy demand range from reductions of five per cent to 150 per cent.

As part of Victoria, Australia's Greenhouse Neighbourhood Project, a group of consultants attempted to quantify the impacts of developing traditional neighbourhood design (TND) neighbourhoods on greenhouse gas emissions. In terms of household heating requirements, they found a 26 per cent reduction in CO_2 emissions. This was due largely to an increase in the degree of "attachment" of dwellings (a greater use of semi-detached, rowhouses and apartments than in traditional suburban areas) and a greater degree of solar orientation of households (Loder and Bayly Consulting Group, 1993:14). Car-related emissions also fell dramatically compared with conventional suburban development, partly due to reductions in the number and length of trips, and partly due to the provision of a pedestrian and bicycle friendly infrastructure that provided quick access to local services.

However, reducing emissions in an entire city-region will occur more gradually. Stockholm represents an example of what has actually been achieved by municipal government in the transportation sector. Over a decade, Stockholm achieved a 15 per cent increase in transit ridership and a 4.7 per cent decline in per capita auto kilometres travelled.

What becomes clear from the studies cited above is that the energy and emissions reduction potential from community energy management is quite significant. Although there is a lack of empirical evidence, the Jaccard et al. (1997) assertion that British Columbia's CO_2 emissions could decline by 17 per cent over a 15-year period through the broad application of land use planning seems reasonable. As their study indicates, additional reductions would seem likely from the application of other elements of community energy management and, once again, other studies seem to support this conclusion. Evaluating all the information provided above, emission reductions from the application of other elements of energy management could include a three per cent reduction in total municipal sector emissions from a broad application of district energy, a five per cent reduction from transportation management initiatives and a further five per cent reduction from better site design, for an estimated total reduction potential of about 30 per cent. It does not seem unreasonable to think that the Jaccard et al. results could be extended to most parts of Canada. In fact, the numbers would likely be higher in every other province except Manitoba and Québec. British Columbia, Manitoba and Québec all use large amounts of hydraulic generation in their production of electricity, which reduces the emissions reduction potential of some CEM initiatives.

CONCLUDING COMMENTS

Community energy management includes a wide variety of initiatives that can result in very significant energy efficiency gains and greenhouse gas emission reductions for cities and towns. There are several important elements to CEM that should be kept in mind. The financial benefits from implementing CEM would appear to be as significant as the emissions reduction potential, probably even more significant when it comes to garnering public and political support for CEM initiatives. In addition, there are many intangible quality-of-life benefits to CEM, as managing energy and other aspects of community living are inextricably linked.

There are many barriers to implementing CEM. Lack of clear jurisdiction, lack of cooperation, lack of information, lack of political will, lack of capital, competing priorities and lack of a sense of urgency all likely play a role. All these barriers can be overcome, provided a lead agency or "champion" begins the process of removing them. Convincing decision makers that CEM is in the nation's economic and environmental interests should be the priority action item. In order to begin explaining the benefits, more information is required. More empirical studies are required to provide the evidence needed. Studying and disseminating information on the impact of existing CEM initiatives should be a priority. Tools that can monitor the impact of CEM and demonstrate how such initiatives could be applied in other communities are few and far between. Developing these tools and carrying out studies on communities across the country would be an important way of refining our understanding of the benefits of CEM.

Urban form is constantly changing. The automobile-dependent suburb of the 1970s and 1980s is quite different from the more compact suburban development of the 1950s and 1960s, and the community forms of the decades ahead will be shaped by demographic, economic and environmental constraints in ways that are difficult if not impossible to predict. We do know that local government planning and policies have a profound impact on urban form and on the associated level and pattern of energy use in the community. The sprawling suburbs around Toronto, Vancouver and other Canadian cities are much more energy intensive and automobile dependent than their earlier counterparts, and provincial and local government policies and infrastructure investment are largely responsible for this difference. Community energy management offers the possibility of very deep and long-term reduction in the environmental stress, including greenhouse gas emissions, in Canadian towns and cities. While the fairly modest emission reduction targets in the Kyoto Protocol may be achievable with incremental technological innovation to the existing infrastructure and urban form, the possibility of achieving long-term, deep and permanent reductions in Canada's greenhouse gas emissions will certainly require the development and application of CEM capacity throughout the country.

BIBLIOGRAPHY

Allen, Eliot. (1995). *Community Energy Planning and Design Bibliography.* Criterion Planners and Engineers, Portland, Oregon.

Arkay, Katherine and Caroline Blais. (1996). *The District Energy Option in Canada.* Natural Resources Canada.

Bartholomew, Keith A. (1992). *City Planning, Energy and the Environment OECD Workshop.* May 21-22, 1992, Newcastle upon Tyne, Portland Oregon Case Study.

B.C. Energy Aware Committee. (1997). *A Tool Kit for Community Energy Planning in B.C.* Prepared by Compass Resource Management Ltd and The ARA Consulting Group, Vancouver.

Bernsen, Else. (1991). *District Heating, Combined Heat and Power, and Urban Infrastructure: Co-ordination of City Planning and Energy Supply, Draft State of the Art Paper.* OECD Environment Directorate Group on Urban Affairs, April.

Blais, Pamela. (1996). *The Economics of Urban Form.* Prepared for the GTA Task Force, Berridge Lewinberg Greenberg Dark Gabor Ltd., January.

California Energy Commission. (1993). *Energy Aware Planning Guide.* Sacramento, January.

Calthorpe, Peter. (1991). *The Post-Suburban Metropolis, Whole Earth Review.* Winter.

CETC (Community Energy Technologies Group). (1997). *The Potential for CO_2 Emission Reductions in Canada* by Implementing District Heating Systems. CANMET, September.

City of Newcastle Upon Tyne. (1992). *Energy and The Urban Environment: Strategy for a Major Urban Centre—Newcastle Upon Tyne,* U.K. Newcastle Upon Tyne City Council, May.

CMHC (Canada Mortgage and Housing Corporation). (1982). *Tumble Ridge Planning Framework for Energy Conservation Planners.* Technical Research Division, Policy Development and Research Sector, CMHC, Ottawa.

———. (1995). *Resettling Cities: Canadian Residential Intensification Initiatives, Research & Development Highlights.* Issue 20, January.

———. (1997). *Conventional and Alternative Development Patterns Phase I: Infrastructure Costs.*

———. (1998). *Tap the Sun: Passive Solar Techniques for Canadian Housing.*

D'Amour, David, (1993). *Towards an Investigation of Sustainable Housing.* Canada Mortgage and Housing Corporation, July.

Duany, Andres. (1991). *Land Use, Urban Form and Environment.* Metro 1991 Growth Conference Proceedings.

Dunphy, Robert T. and Kimberly Fisher. (1993). *Transportation, Congestion, and Density: New Insights.* Urban Land Institute, August.

Energy Victoria, Environment Protection Authority, Department of Infrastructure. (1998). *Urban Village Tool Kit.* February.

Energy Victoria, Environment Protection Authority, Department of Infrastructure and Energy Research and Development Corporation. (1996). *Urban Villages Project – Encouraging Sustainable Urban Form - Summary Report.* August.

Essiambre-Phillips-Desjardins Associates Ltd., J.L. Richards & Associates Limited and C.N. Watson Associates Ltd. (1995). *Infrastructure Costs Associated with Conventional and Alternative Development Patterns: Summary Report.* CMHC and Regional Municipality of Ottawa-Carleton, June.

Global Cities Project. (1993). *Building Sustainable Communities, An Environmental Guide for Local Government; Land Use: Stewardship and the Planning Process.* Centre for the Study of Law and Politics, May.

Grant, Jill et al. (1993). *Sustainable Development in Residential Land Use Planning*. Canada Mortgage and Housing Corporation, Ottawa.

Holtzclaw, John. (1993). *Sustainability: Where Cities and Cars Collide.* Community Sustainability Conference, George Mason University, Sierra Club, November 19.

Hygeia Consulting and REIC Ltd. (1997). *Changing Values, Chancing Communities – A Guide to the Development of Healthy Sustainable Communities.* Canada Mortgage and Housing Corporation.

IBI Group. (1990). *Greater Toronto Area Urban Structure Concepts Study: Background Report.* Prepared for Greater Toronto Coordinating Committee.

International Council for Local Environmental Initiatives. (1997). *Reducing Greenhouse Gas Emissions from the Transportation Sector – Workshop #3.* The Cities for Climate Protection Campaign-US Workshop, Santa Monica, California, February 5-8.

IRT Environment, Inc. (1992). *Sacramento Municipal Utility District – Commercial Lighting & Industrial Program.*

Jaccard M., L. Failing and T. Berry. (1997). "From Equipment to Infrastructure: Community Energy Management and Greenhouse Gas Emission Reduction." *Energy Policy.* Vol. 25, no. 13, pp.1065-1074.

Jessup, Phillip and Ralph D. Torrie. (1996). *Saving the Climate – Saving the Cities.* 3rd edition, International Council for Local Environmental Initiatives, Toronto.

JHK & Associates, Inc. and Brady and Associates. (1995). *Transportation-Related Land Use Strategies to Minimize Motor Vehicle Emissions: An Indirect Source Research Study, Final Report.* California Air Resources Board and the California Environmental Protection Agency, June.

Kates, R.W. and R. Torrie. (1998). "Global Change in Local Places." *Environment.* Vol. 40, no. 2: 5, pp. 39-41.

Loder and Bayly Consulting Group, RJ Nairn & Partners Pty Ltd., Sustainable Solutions Pty Ltd., PPK Consultants Pty Ltd. (1993). *Greenhouse Neighbourhood Project; The Low Energy Suburb, Summary Report.* Environment Protection Authority and Energy Victoria, July.

MacRae, Morgan. (1992). *Realizing the Benefits of Community Integrated Energy Systems.* Canadian Energy Research Institute, Study no.45, ISBN 0-920522-76-9, June.

Metro DES Working Group. (1995). *The Potential for District Energy in Metro Toronto.* Metro Toronto Works Department, CANMET and Ontario Hydro, March.

Miller, Eric J. et al. (1993). *Quantitative Analysis of Urban Transportation Energy Use and Emissions: Phase I Final Report.* University of Toronto, May.

Newman, Peter and G. Kenworthy. (1989). *Cities and Automobile Dependence - An International Sourcebook.* Gower Publishing Company Limited.

Newton P.W. (Ed). (1997). *Re-Shaping Cities for a More Sustainable Future – Exploring the Link Between Urban Form, Air Quality, Energy and Greenhouse Gas Emissions.* Australian Housing and Urban Research Institute, November.

NOVEM (Netherlands Agency for Energy and the Environment). (nd). *Ecolonia – Demonstration Project for Energy and Environmentally Aware Building and Living.*

NRCan (Natural Resources Canada). (1996). *District Energy. Michael Wiggin, Energy Systems Technology Implementation Group,* CANMET Energy Technology Centre, Ottawa.

OECD (Organization for Economic Cooperation and Development). (1990). *Urban Travel and Sustainable Development – Outline of a Discussion Paper.* Paris, November.

———. (1994). *How to Combat Global Warming at the Local Level.* Heidelberg Conference, Germany, September 7-9.

Ontario Hydro. (1992). *Espanola Power Savers Project Video,* May.

Ontario Ministry of Transportation and Ontario Ministry of Municipal Affairs and Housing. (1992). *Transit Supportive Land Use Guidelines.* Toronto.

Oregon Department of Energy, Washington State Energy Office, California Energy Commission. (1996). *The Energy Yardstick: Using PLACE3S to Create More Sustainable Communities.* Center of Excellence for Sustainable Development, U.S. Department of Energy, August.

Owens, Susan. (1991). *Land Use Planning, Siting and Building Regulations: Setting the Right Directions for Efficient Urban Structures in the Long Term, Draft State of the Art Paper,* OECD Environment Directorate Group on Urban Affairs, April.

Perl, Anthony and John Pucher. (1995). "Transit in Trouble?" *Canadian Public Policy Journal.* Queen's University, Kingston.

Public Technology, Inc. (1989). *The Hidden Link: Energy and Economic Development – Phase II Marketing and Financing Strategies for Community Energy Projects.* U.S. Department of Housing and Urban Development, Washington, January.

Rocky Mountain Institute. (1995). *Community Energy Workbook – A Guide to Building a Sustainable Economy,* Alice Hubbard and Clay.

Soberman, Richard M. and Eric J. Miller. (1997). *Full Cost Pricing and Sustainable Urban Transportation: A Case Study of the Greater Toronto Area.* Ontario Ministry of Transportation, November.

Torrie, Ralph. (1996a). "Personal Mobility is Not What It Used To Be." *Ecodecision. Vol. 21,* Montréal, Summer.

———. (1996b). *Urban Greenhouse Gas Inventories and Emission Reduction Assessment in Canada—Methodological and Analytical Issues.* International Council for Local Environmental Initiatives.

Torrie, Ralph and Phil Jessup. (1995). *Saving the Climate, Saving the Cities, A Handbook on Climate Change for Local Government.* International Council for Local Environmental Initiatives, Toronto.

Torrie, Ralph D. (1993). *"Cities and CO_2: Research Results and Policy Implications from the Urban CO_2 Reduction Project."* Prepared for International Council for Local Environmental Initiatives Municipal Leader's Summit on Climate Change and the Urban Environment, United Nations, New York, January.

———. (1996). *Urban Greenhouse Gas Inventories and Emission Reduction Assessment— Toward a Standardized Quantification Framework.* Torrie Smith Associates and ICLEI, December 1995, revised 1996.

Torrie, Ralph D. and Robin Skinner. (1996). *"Urban Greenhouse Inventories and Emission Reduction Assessment in Canada—Methodological and Analytical Issues."* Torrie Smith Associates, report for the City of Ottawa and Environment Canada.

———. (1997). *"ICLEI—Cities for Climate Protection Campaign Protocol and Guidelines for Reporting." Draft 2.2.*

Torrie, Ralph, Torrie Smith Associates. (1995). *Energy for Sustainable Cities—Thinking Globally and Acting Locally. A Strategic Discussion Paper of the International Council for Local Environmental Initiatives,* Toronto, June.

———. (1996). *Business Strategies for Sustainable Development in the Canadian Energy Sector. A Discussion Paper for the National Round Table on the Environment and the Economy Workshop on Business and the Environment,* Montréal, October.

Torrie Smith Associates. (1994). *Environmental Improvement through Urban Energy Management—Canadian Overview.* Canada Mortgage and Housing Corporation, Ottawa, August.

———. (1997a). *Greenhouse Gas Emission Reductions—Quantification Guidelines for TAF Applicants.* Prepared for Toronto Atmospheric Fund, ICLEI.

———. (1997b). *Cities for Climate Protection Greenhouse Gas Emissions Software—User's Guide.* Version 2.0. International Council for Local Environmental Initiatives.

Transport Canada, Environment Canada, Natural Resources Canada, Department of Finance Canada, Industry Canada and Marbek Resource Consultants. (1998). *Foundation Paper on Climate Change—Transportation Sector (Initial Draft).* June.

Urban Consortium Task Force. (1992). *Sustainable Energy—A Local Planning Guide for a Sustainable Future.* December.

Weissmann, Steve and Judy Corbett. (1992). *Land Use Strategies for More Livable Places.* California Local Government Commission, Sacramento.

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