Options for Reducing GHG Emissions in Calgary

– Research Report Appendices

February 2011

The research presented in these appendice supports the report *Options for Reducing GHG Emissions in Calgary*, **compiled by the Pembina Institute.**

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Appendix A.1

Consumer energy conservation (electricity and heating)

Energy efficiency — technology that produces the same service or products while using less energy — is often differentiated from energy conservation —reducing the overall amount of service or products and thus the amount of energy used. For example, turning off lights is energy conservation while installing high-efficiency light bulbs is energy efficiency.

This section addresses energy (electricity and heating) conservation behaviours by consumers. While there are potentially many ways to change consumer behaviour, there is evidence to show that consumer feedback systems and increased residential densities can successfully reduce energy use. Other methods of influencing consumer behavior, such as advertising campaigns, were investigated but there was little evidence regarding their effectiveness in isolation from other strategies.[1]

Education

California utilities spent $200 million on media advertising to encourage energy conservation. The advertisements encouraged householders to install energy conserving devices and adopt habits that will decrease energy use (for example, closing the blinds during the day). Despite their high costs, these campaigns have shown little direct influence on energy use.[5]

Feedback systems

Feedback systems provide consumers with detailed feedback about energy consumption and end use patterns. To date, utility providers and residential consumers have tested feedback systems with respect to electricity consumption. Feedback delivery mechanisms can be characterized according to the type of feedback provided: direct feedback is provided in real time at the point of use while indirect feedback is provided after consumption occurs.[2]

Direct feedback systems (or energy feedback systems) provide energy information to consumers directly from a meter or through a separate display monitor or computer program. Direct display systems typically show instantaneous electricity consumption along with the cost per hour at a pre-programmed rate. The detail provided by the systems varies widely – for example, some systems show CO_2 emissions, and some sound a preprogrammed alarm when energy use rises above a certain amount.

Indirect feedback refers to information that has been processed by a utility company before reaching the energy user. Standard bills are a traditional source of feedback to households — in North American jurisdictions consumption values used for billing are often a combination of actual meter readings and estimates, and are provided on a quarterly, bi-monthly or monthly basis. Methods of enhancing the feedback to consumers to help with energy conservation range widely from creating more frequent billing cycles to providing more detailed energy use comparisons, historical data and end use, or per appliance energy use data.[3,4]

Indirect feedback is most likely to give a picture about the overall heating and electricity load, whereas instantaneous direct feedback illustrates the impact of smaller end uses.

Energy Consumption Information System – Japan

A study conducted in Japan tested the effectiveness of an online Energy Consumption Information System (ECOIS II) in reducing consumption of electricity and natural gas. The system was installed in 10 houses and provided residents with in-depth information about electric power consumption, room temperatures and city gas consumption. Participants also received energy saving tips via email.

On average, per home energy consumption was reduced by 12%. Average consumption of electricity was reduced by 18% and and city gas by 9% in the 10 test houses. In nine houses where energy use was monitored but the ECOIS II system was not used, electricity consumption decreased by an average of 5% per home, and total gas consumption increased by an average of 0.4% per home.[6]

The cost of the ECOIS II system was approximately $5000 US per home.[7]

Florida

A small scale pilot of 17 residential homes in Florida that used a low-cost direct feedback system (retail price approximately $140 U.S.) showed an average 7% reduction in the second year of monitoring after controlling for weather-related influences. However, results varied widely from home to home, ranging from an energy increase of 9.5% to an energy decrease of 27.9%. Eleven homes showed savings and six homes showed energy use increases.[14]

Real time monitoring pilot

Ontario's Hydro One utility company tested the influence of a real time feedback device on energy consumption in a pilot program that tracked consumer energy use over two and a half years. More than 400 residential households participated in five regions. The portable feedback device displayed energy consumption in dollars per hour, total dollars and predicted dollars. The same measurements were available for kWh and CO_2 emissions.

The aggregate reduction in electricity consumption (kWh) across the study sample was 6.5%. A greater range of energy reduction was reported depending on the source of residential heating. For example, houses with non-electric space heating achieved an aggregate reduction of 8.2%, compared to a 1.2% aggregate reduction for households using electric space heating. These results highlighted the need to separate feedback from electric heating load and the rest of the electricity consumption to encourage conservation in this sector. In follow-up reporting, 65.1% of users said they planned to continue using the monitor.[15]

The program controlled for external factors such as weather, appliance stock and demographic characteristics, and the results were achieved in absence of any associated incentives or price schemes.[16] However, the study revealed that the feedback device has the potential to exert greater impact on residential energy consumption when it is used in conjunction with other price and/or conservation measures.

Potential reduction

Studies suggest electricity consumption can be reduced by 5 to 18% per unit (or household) through the use of direct feedback systems that provide instantaneous information to energy consumers.[8,9,10] In general, display units that offer simple feedback to consumers account for lower energy savings (5 to 10% reduction) than more complex systems that provide detailed current and historical consumption analysis (18% reduction). To date, pilot programs have focused on evaluating direct feedback systems in the residential sector.

Savings from indirect feedback have ranged from 0 to 10% and vary according to the context and quality of information given. In general, feedback that includes historic information (e.g., comparing current use with previous recorded consumption) has been demonstrated to be more effective than feedback that compares household use to other households or a target figure.[11]

Cost implications

Installing simple electricity display feedback systems can have a positive return on investment for consumers. A reduction of 5 to 10% in electricity consumption per month translates into a savings of between $10 and $20 per month, while Table i presents the system costs.

Table i: Cost of direct feedback system

Type of Energy Feedback Device	Upfront Cost
The PowerCost Monitor	$119 Cdn + tax[12]
The Energy Detective (TED)	$200 to $500 US[13]
Interactive Online Display (pilot in Japan)	Approx $5000 US per unit

Costs for an indirect feedback program, where additional information is supplied to the consumer at the time of billing, consists mainly of administrative costs.

Approaches to implementation

Legislation or mandate

Legislation that requires all new homes to be supplied with direct feedback systems could have an immediate impact on electricity use in Calgary. A program to supply all existing homes with direct feedback systems could be implemented over a number of years by the City of Calgary.

Mandated changes to the information provided on utility bills in Calgary could reduce electricity or natural gas usage in the first year of the program.

Potential roles: Government is responsible for setting new legislation or requirements. In this case, the provincial government would likely need to be involved.

Billing for utility services is completed by a number of different utility retailers in Calgary. As the sole shareholder of ENMAX, one of the main energy retailers in the City, the municipal government could encourage the inclusion of additional, informative information on the utility bills supplied to ENMAX customers.

Key benefits: Potential for city-wide impacts.

Key challenges: Results have some uncertainty compared to other measures; results vary widely; products not always used as intended or maintained. Only demonstrated at a pilot level.

Incentives

Direct feedback systems: Financial incentives that offset or completely cover the capital cost of feedback systems could generate a significant uptake in residential homes.

Potential roles: Government (municipal, provincial or federal) or utility providers are typically the main providers of incentives for direct feedback systems. Private industry or technology companies could also provide rebates.

Key benefits: Consumer choice; lower capital costs for consumers.

Key challenges: Limited uptake; cost to government/utilities.

Supporting activities

Education and awareness to increase residential knowledge of feedback systems, although an important supporting activity, is not expected to significant increase their uptake.

Potential roles: Municipal, provincial or federal governments, utility providers or industry could launch public information, marketing and education campaigns.

Key benefits: Personal choice.

Key challenges: Limited uptake.

Increased residential densities

Another method of reducing residential energy use is to increase the number of multi-family dwellings compared with single detached houses.

Potential reduction

Multi-family units (e.g., apartments and condominiums) are typically smaller than single detached houses and use approximately 22% less energy per square metre than detached houses.[17] Even attached housing such as duplexes and townhouses use 18% less energy per square metre than detached housing.[18]

Increased residential densities can also save energy by increasing the ability to use district heating and cooling, waste heat recovery, cogeneration of heat and electricity, and shorter energy distribution networks. Research quantifying the energy saving potential of these

Ontario Hydro

A pilot program conducted by Ontario Hydro in 1992 found that 25 homes supplied with energy feedback displays produced overall electricity savings of 13%. These savings largely persisted after the devices were removed.[19]

Sacramento Municipal Utility District

The Sacramento Municipal Utility District is conducting a pilot program to determine the effect of providing a more detailed electricity consumption report during its billing cycles. Monthly billing reports are provided to 25,000 customers, while 10,000 customers are provided with quarterly billing reports. Data compiled to date indicate a 2% electricity savings for these customers, compared to the control group of 50,000 customers who received less-detailed information.[20]

Oslo Energi

In Norway, customers of Oslo Energi who received bills based on electricity meter readings at 60-day intervals achieved average savings of 10%. Prior to the changes, billing was completed on a quarterly basis, with one only bill providing a meter reading, and the remaining bills providing estimates. When the more frequent bills were supplemented by hisotric feedback comparing the consumption with the same period of the previous year and all periods in between, the electricity reduction rose to an average of 12%. Eventually, the Norway government made quarterly informative billing mandatory.[21]

Densities in Calgary

Calgary suburbs in the 1960s to 1980s had densities of 4 to 6 units per acre or about 25 to 37 people per hectare when assuming 2.5 people per unit. By the 1990s and 2000s, the densities rose to 6 to 8 units per acre or about 37 to 50 people per hectare when assuming 2.5 people per unit. This was mostly achieved by increasing the percentage of multi-family dwelling from 15% to 25%. Current plans include densities between 8 and 12 units per acre, or about 40 to 60 people per hectare when assuming 2 people per unit, with multi-family units making up 25 to 60% of the dwellings.[22]

Calgary's new Municipal Development Plan calls for 100 people or jobs per hectare within 400 metres of the primary transit network, and 200 people or jobs per hectare within Major Activity Centres or Urban Corridors. There are no specific targets for other portions of the city, but a minimum 6 units per acre is currently required within all new residential developments. The city-wide target for 2070 is 45 people or jobs per hectare.

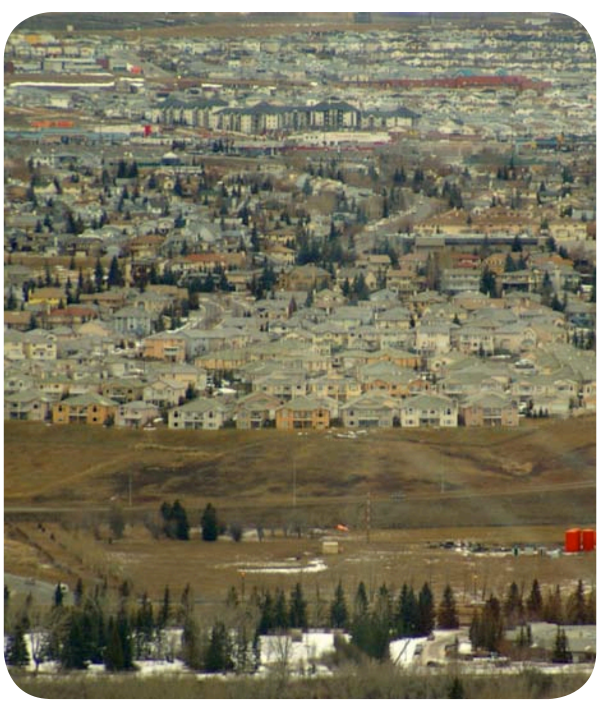

Photo: The Pembina Institute

opportunities was not found during the research phase of this report (mid-2010).

Cost implications

The cost to construct multi-family and attached units is lower per unit than detached housing, due in part to the smaller size per unit. The energy costs for heat and power are also less per unit.

Approaches to implementation

Land use planning, zoning and approvals

Land use planning policy in Calgary requires a minimum density in new areas of the city, while it also encourages increased infill density within existing areas. Density targets or requirements could be increased to reduce residential energy use even further.

Zoning and development approvals processes could also be designed to make it easier to construct multi-family dwellings within the city. This would remove some of the barriers and encourage a shift towards the construction of this type of development.

Potential roles: Municipalities often set land use planning policy, zoning and development approval processes. Land use planning policies have also been set at provincial levels. Landowners and developers are involved in deciding the type of building to be constructed on a site within the site zoning limitations.

Key benefits: City policies can have a high impact on built form; already part of the new Municipal Development Plan (MDP).

Key challenges: May restrict certain types of development; zoning and approvals processes supportive of multi-family dwellings will create changes within existing neighbourhoods; requires a market shift (there are currently more multi-family units available than single-family units); would need to be aligned with the MDP; would have to ensure diverse housing options were available to establish a complete community.

Incentives and education

Incentives and education could also be used to encourage the development of more multi-family units. Incentives could be financial or regulatory (e.g., faster approval processes or density bonusing).

Potential roles: Government is often involved in providing incentives and education programs.

Key benefits: Choice of the type of development remains with developers and consumers

Key challenges: Financial incentives could be costly to provide to all existing multi-family developments; uncertain level of impact; uncertain consumer desire for multi-family units.

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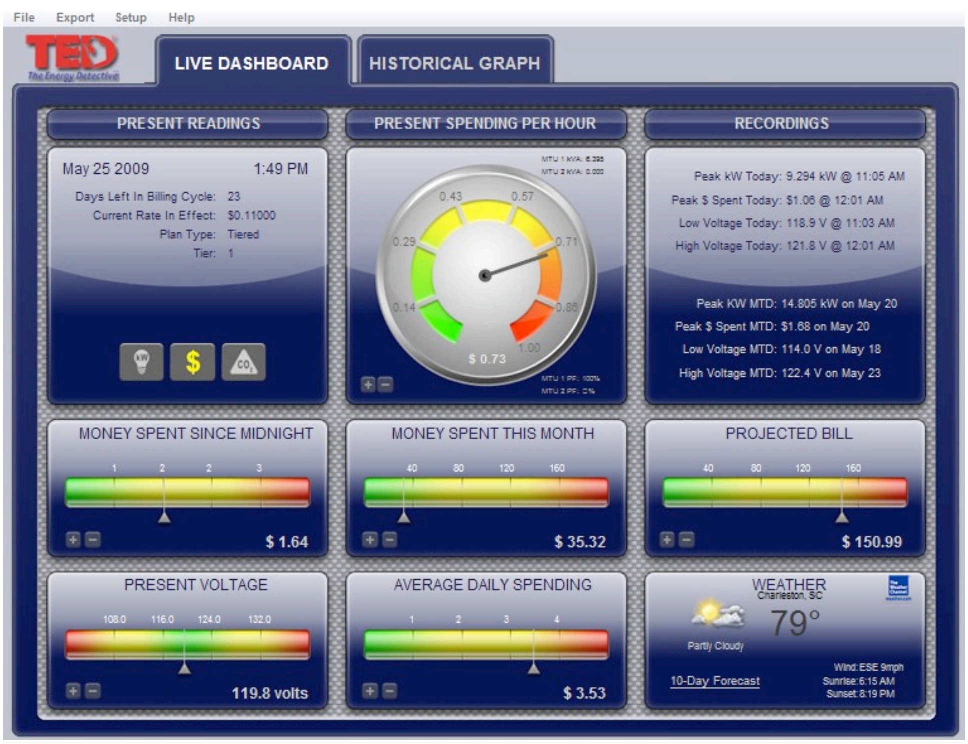

Photo: City of Calgary

Appendix A.2

Efficient building heating and cooling

In Calgary, 13% of GHG emissions come from space heating, while 1% comes from space cooling. Two-thirds of these emissions are estimated to come from residential buildings.

The demand for heating fuels, primarily natural gas, and building cooling, primarily using electricity, can be reduced through the construction of efficient building envelopes (i.e., walls, roofs, windows and foundations) and the installation of efficient heating and cooling systems. Common features of efficient buildings include high levels of insulation, air sealing (to prevent the escape of air that has already been heated or cooled), windows that reduce heat loss in winter and heat gain in summer, and high-efficiency heating and cooling systems.

Buildings are often divided into several different categories when considering their energy efficiency. First, small buildings (mostly houses) are differentiated from large buildings as the type of construction, building design, and heating and cooling systems are quite different. Second, new buildings and existing buildings are often differentiated because one involves the original construction while the other often requires retrofitting.

New houses

Over the past 17 years, heating efficiency in new houses in Alberta has increased by approximately 12% on a square metre basis. However, since dwellings in Alberta have also been getting bigger over this time, the energy use per dwelling has not changed significantly once weather variations are accounted for.

Potential reduction

A 25 to 35% improvement in energy efficiency is often cited for new houses,[++,24,25,26] compared with typical houses currently built to minimum code, although several examples of net-zero energy houses have been constructed.[27,28]

Cost implications

Increasing energy efficiency levels to EnerGuide 76 or 80 provides a positive return on investment for consumers. For example, a $6,000 investment to make a 2000-square-foot house EnerGuide 80 is estimated to save an average of about $70 each month in utilities. When the added cost of the house is mortgaged over 25 years (at an assumed rate of 5%), the increased mortgage payments are only $35 per month, showing a net positive cash flow from the first year of ownership (see Figure i), and a 13% annual return on investment.[29]

EnerGuide rating system

The EnerGuide rating system is available to homeowners as a way to measure home energy performance. A number of companies in Calgary offer EnerGuide audits, which will provide an EnerGuide rating for the house and recommendations on how to improve the house's energy performance.

The federal government has recently ended their incentive program for home renovations, while the provincial government has recently begun one. The City of Medicine Hat also offers incentives for its citizens, while The City of Calgary previously provided incentives for energy-efficient new homes.

Provincial building codes

The provinces of Ontario, British Columbia, Nova Scotia and Manitoba have all added energy efficiency to their building code while there is a process at the federal level to add energy efficiency to the National Building Code — a code that is adopted by all provinces and territories. Quebec and New Brunswick have also indicated that they intend to add energy efficiency to their codes.[30] Many of the code changes affect both small and large buildings.

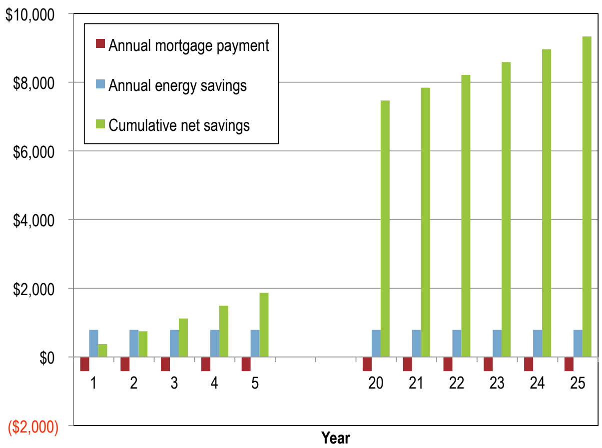

Figure i: Cash flow associated with an EnerGuide 80 house compared to a house built to minimum code

Note: Houses are 2000 sq. ft.

Berkeley

Berkeley, California requires any building sold, exchanged or substantially renovated to meet minimum energy and water efficiency standards. The extent of upgrades required is limited to a defined maximum expenditure amount.[41]

Existing houses

Potential reduction

An average of 10% improvement in energy efficiency has been achieved for home renovation programs in the past,[31] although some studies estimate that improvements of up to 25% are possible.[32,33]

Cost implications

A broad home energy retrofit program is estimated to add between 3 and 9% to the cost of an existing home renovation, while the energy savings range between $200 and $3,000 per year. The costs of the renovation are expected to be recovered within 6 years, while some individual measures pay back in 1 to 3 years.[34]

New large buildings

Potential reduction

Compared with conventional practice, new large buildings can be built with a 25% improvement in energy efficiency,[35,36] although some buildings are constructed to be 60% better.[37,38]

Cost implications

The net financial benefits of energy efficient buildings are estimated to be positive not just for energy savings but for operation and maintenance cost savings, as well as productivity and health benefits, as shown in Table ii.

Table ii: Financial benefits of LEED[39] Certified Buildings[40]

Category	20-year Net Present Value (NPV) (per sq.ft.)	
	Certified and Silver	**Gold and Platinum**
Energy value	$5.79	$5.79
Emissions value	$1.18	$1.18
Water value	$0.51	$0.51
Waste value (construction only) – 1 year	$0.03	$0.03
Commissioning O&M value*	$8.47	$8.47
Productivity and health value	$36.89	$55.33
Less green cost premium	($4.00)	($4.00)
Total 20-year NPV	$48.87	$67.31

** Commissioning process leads to lower operations and maintenance costs.*

Additionally, several other studies[42] have shown similar findings for 'green' buildings:

- Good daylighting increases productivity by 13%, can increase retail sales by 40%, and can increase school test scores by 5%, while high glare reduces performance by 15 to 21%.
- Increased ventilation increases productivity by 4 to 17%.
- Better quality ventilation reduces sickness by 9 to 50%.
- Increased ventilation control increases productivity by 0.5 to 11%.

Existing large buildings

Potential reduction

Some studies estimate that up to 25% reduction in energy use in existing large buildings is possible through renovations,[43,44] although based on the performance of residential retrofit programs an average reduction of 10% may be a more reasonable expectation.

Cost implications

A study of the potential for energy efficiency of existing private commercial buildings in the United States estimated that over a 10-year time frame, investments in energy efficiency for this sector would return savings that are 42% higher than the initial investment.[45]

Common approaches to implementation

Regulations

There are several possible ways to regulate the efficiency of buildings. These include through the building code, through efficiency standards for heating and cooling equipment, and through zoning and development guidelines.

Adoption of a new building code would have an immediate impact on all new buildings constructed, while efficiency standards for heating and cooling equipment would impact furnaces, hot water heaters, air conditioners, and the pumps, motors and fans typically used in commercial buildings for space heating and cooling.

Potential roles: The provincial government sets the building code within Alberta, although the core element of the code is the National Building code, which is set in consultation with all provincial governments and the federal government. The City of Calgary enforces the building code in Calgary and controls development permits. Builders are responsible for following the building code.

The federal government can regulate the efficiency of products travelling into and out of provinces, while the provincial government has the authority to regulate all products sold in the province whether they were built here or not.

Key benefits: Rapid adoption; net savings for consumers.

Key challenges: Readiness of builders; political will.

BOMA BESt

The Building Owners and Managers Association (BOMA) of Canada has developed BOMA BESt[46] — an environmental certification program for commercial buildings of all asset classes. There are four levels of performance for BOMA BESt. The top three levels of certification range between a 6% reduction in energy use from average commercial buildings to a 46% reduction. On average, buildings certified under BOMA BESt (450 buildings between 2005 and 2009) consume 11% less energy than the average commercial building in Canada.

A BOMA BESt Energy and Environment report is expected to be released shortly. This report is expected to provide even more information regarding the energy reduction achievements of buildings certified under BOMA BESt.

Calgary Real Estate Board

"The Calgary Real Estate Board (CREB®)'s Go Green Challenge is a 12-month pilot program, running through June 2011, designed to get REALTORS®, consumers and corporate partners working together to reduce the ecological impacts of Calgary homes.

The program introduces new energy rating and rating date fields to the Multiple Listing Service (MLS®) System that identify a home's energy efficiency based on the EnerGuide rating system.

It is the goal of the program to have at least 2,500 homes rated using the EnerGuide rating system within 12 months."[47]

Local initiatives

The Town of Hinton has established an eco-industrial park where developments are required to be energy efficient (25% better than the Model National Energy Code for Buildings) and they must orient and mass buildings to maximize opportunities for passive solar heating and cooling, natural lighting and ventilation.[51]

The town of East Gwillimbury, Ontario, mandates all new residential developments that require either Site Plan or Subdivision approval to construct to Energy Star standards. Energy Star qualified homes are approximately 30 to 40% more energy efficient than those built to minimum Ontario Building Code standards.[52]

The City of Vancouver, using powers outlined in the Vancouver Charter, has a set of energy efficiency standards for both houses and larger buildings.[53]

Energy efficiency incentives in Alberta

The Government of Alberta is spending $36 million over three years on consumer incentives for new and existing homes, and hybrid taxis.[54]

Built Green

Built Green Canada is an industry-driven voluntary program that promotes 'green' building practices. Built Green requires builders to be trained and provides a system for rating new homes (single family, row houses, and multi-story and residential towers). In Alberta, Built Green certified homes have made up between 5 and 10% of the market over the past few years, with a significant majority of the homes built to a Built Green Gold (EnerGuide 77) or Silver (EnerGuide 75) level. Built Green Canada has also recently released a renovation guide and checklist.[55]

Incentives

Incentive programs are able to motivate a portion of consumers to purchase more energy-efficient buildings or to upgrade the energy efficiency of existing buildings, but they are not able to capture the majority of consumers.

Another type of incentive is to develop an innovative financing program that pays for efficiency upgrades and allows the repayment of the loan to stay with the building even if it is sold. This could overcome a number of traditional barriers to energy efficiency upgrades.

Potential roles: Governments are typically involved in providing incentives, although innovative financing programs could be developed privately as well. Building owners would need to participate in the incentive programs.

Key benefits: Building owners able to decide level of participation; lower capital costs for consumers.

Key challenges: Limited uptake; cost to government.

Labelling

Studies have shown that consumers are willing to pay more for energy efficient buildings.[48,49,50] Having a third-party certified label that is easy for consumers to understand has been demonstrated to increase the likelihood that energy considerations will be taken into account in purchasing decisions. Increasing the market value of an energy-efficient building increases the incentive for existing owners to perform energy upgrades.

Potential roles: Governments at all levels have been involved in establishing energy labelling programs, both voluntary and mandatory. Other organizations such as the Calgary Real Estate Board have also been involved in establishing voluntary programs.

Key benefits: Consumers are better informed.

Key challenges: Indirect influence on energy upgrades; voluntary programs have limited impact.

Supporting activities

While they are not expected to result in significant emission reductions themselves, supporting activities such as education and awareness for consumers, builders and/or trades can increase the speed and ease of implementation of other approaches.

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Photo: The Pembina Institute

Photo: City of Calgary

Appendix A.3

Appliances, lighting and other equipment

Aside from space heating and water heating, electricity used in appliances, lighting and other electrical equipment is the biggest energy user in both residential and commercial buildings in Calgary. This section also includes energy used in industrial processes.

Residential sector

In the residential sector, electricity consumed by appliances and lighting accounts for approximately 31% and 11% respectively of total residential GHG emissions in Alberta, as illustrated in Figure ii.

During the last 20 to 30 years, the average energy efficiency of residential appliances has improved significantly. Figure iii illustrates the average energy consumption of common household products manufactured in each of the years 1984, 1990, 1997 and 2008.

For example, refrigerators manufactured in 2008 use on average 70% less energy than models produced in 1984. These reductions in energy use in Canada have been attributed to energy efficiency regulations, product labelling initiatives such as EnerGuide and Energy Star and consumer choice, which has helped to drive industry innovation.[56]

Figure iv shows the market penetration of Energy Star-qualified products shipped in the Prairie region between 2004 and 2007. Energy Star products made up almost 80% of the dishwashers shipped, almost 60% of the clothes washers, and almost half of the refrigerators.[57]

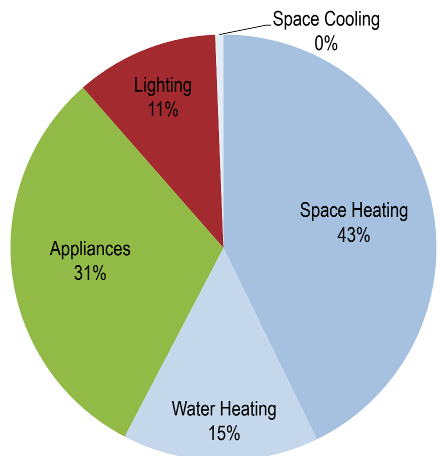

Figure ii: GHG emissions by end use in residential buildings in Alberta (2007)

Potential reduction

The energy saving potential per appliance ranges widely, as shown in Figure iii. For example, Energy Star clothes washers in 2008 used less than one-quarter as much energy as 1984 model washers. To qualify as Energy Star, products must be 10 to 50% more efficient than the minimum energy efficiency standards in Canada.

Research suggests that a combined energy savings of 10 to 50% is achievable by switching standard appliances and lighting to Energy Star labeled products.[58] Similarly, NRCan estimates Energy Star labeled products can produce a 30% reduction in energy used by appliances compared to average household appliance energy consumption in 2006.[59]

Modelling completed by federal and provincial governments and industry associations estimates that electricity consumption from appliances can economically be reduced by 26% over 20 years if all opportunities are captured. However, more realistic estimates are a 3% reduction in electricity use if incentive and education programs are used, and a 19% reduction in electricity use if regulations and price signals are used on

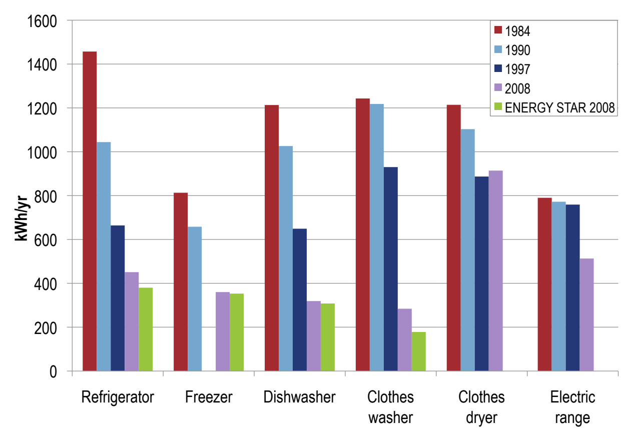

Figure iii: Average annual energy consumption of common household appliances by year of manufacture

Notes: Data not available for freezers in 1997. Clothes dryers and electric ranges are not part of the Energy Star program. 2008 numbers assumed to include average of all products, including the most efficient (Energy Star) products.

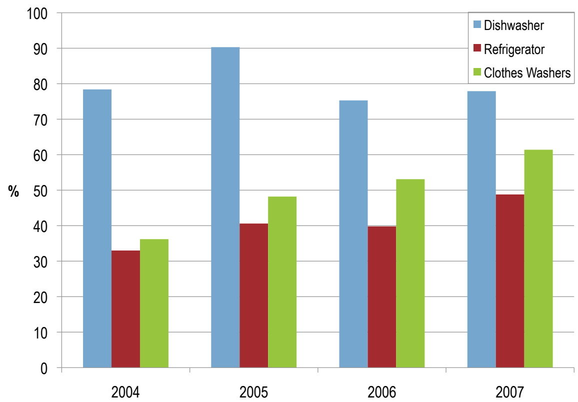

Figure iv: Energy Star qualified appliances as percentage of total shipments, Prairie region

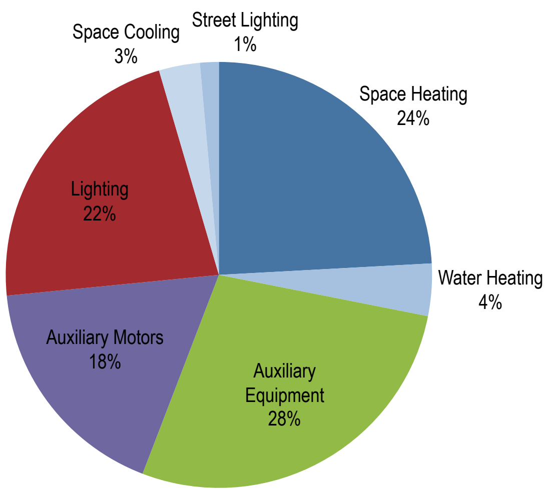

Figure v: GHG emissions by end use in commercial buildings in Alberta (2007)

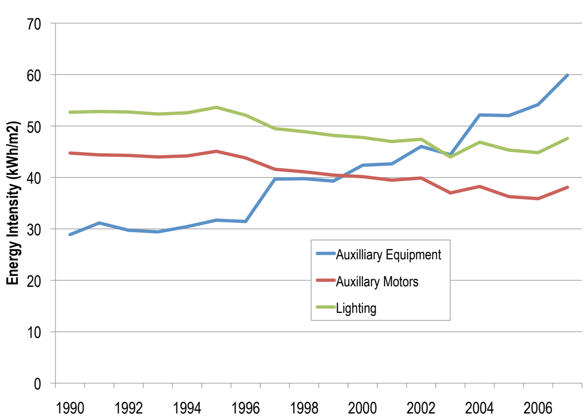

Figure vi: Electricity use in commercial buildings in Alberta by end use

top of incentives and education programs. Electricity used for appliances is estimated to be able to be reduced by 69% (economic potential), 49% (using regulations and price signals), or 14% (using just incentives and education).[60]

The same study estimated the economic potential for reducing energy use from natural gas hot water heating at 22%, and the achievable potential between 5 and 8%.

Cost implications

The energy efficiency potentials described in these studies are all considered to be currently economic although there are currently non-economic barriers to adoption.

Commercial sector

As shown in Figure v, in 2007 the electricity consumed by lighting, auxiliary equipment and auxiliary motors accounts for approximately 68% of total GHG emissions from commercial buildings in Alberta.

Trends in energy use in the commercial sector suggest that there have been large efficiency gains in commercial lighting, auxiliary motors and equipment (such as office equipment) in the last 20 years.[61] Between 1990 and 2005, energy efficiency in the commercial and institutional sectors in Canada is estimated to have improved by 9%. The gains in efficiency are attributed to improvements to the thermal envelope of buildings (insulation, windows etc. – see Appendix A.2) as well as improved efficiency of electricity consuming items such as lighting and auxiliary equipment. These efficiency improvements slowed the actual energy use increases in the commercial sector from 41 to 32% (again, comparing 1990 to 2005).[62]

Figure vi illustrates the energy intensity (GJ/m^2) by each electric end use. While the energy intensity of lighting and auxiliary motors has declined slightly between 1990 and 2007, the energy intensity of auxiliary equipment has more than doubled (again from 1990 to 2007).[63]

The increase in consumption of energy in the commercial building sector in Canada is attributable to an increase in the number of new buildings, growing auxiliary loads, higher occupant densities and sub-optimal building control.[64]

A conservation potential review completed for the B.C. commercial sector suggests potential cost-effective opportunities for lighting and equipment could reduce electric energy use and peak load by 15 to 20% of the expected electricity demand in 2026.[65]

Lighting

Lighting accounts for approximately 10% of energy consumed in the commercial sector in Alberta. The baseline for general lighting in commercial buildings in Canada is typically a combination of T12 magnetic and T8 electronic fluorescent lighting systems.[66] According to an assessment of the commercial building stock in the Pacific Northwest region of the United States, although installations of the less efficient T12 lights have decreased, they still account for 35% of fluorescent lighting. Higher-efficiency T8 installations have increased significantly since 2003. Lighting is predominantly controlled manually, although occupancy timers and energy management systems that control lighting levels based on preprogrammed building occupancy or use information have increased.[67]

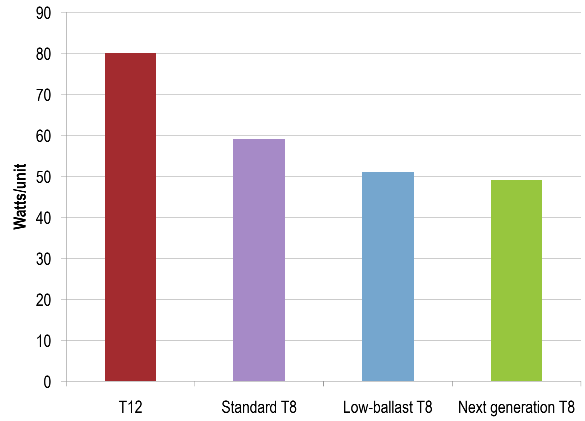

Figure vii: Per unit energy required for lighting technology

Potential reduction

Existing Buildings: Lighting retrofits in commercial buildings that replace general T12 lighting technology with standard or next generation T8 bulb technology offers lighting energy savings of 26 to 39%. Figure vii shows per unit energy consumption differences between T12 and T8 lighting technologies. A higher level of energy savings of 56 to 67% is achievable through space redesign that reduces the number of lighting fixtures. Incandescent, halogen, compact fluorescent and LED light sources typically provide the 'secondary' light used in common areas, washrooms and exit signs. Energy savings of between 69 and 75% are achievable when an incandescent lamp is replaced with a CFL or LED array.[68] (See Table iii.)

Table iii: Lighting retrofit savings and costs for existing buildings

Lighting retrofit action	% reduction in energy used for lighting	Per unit energy reduction (W/unit)	Full cost (2007 dollars)	
			per fixture	per square foot
T12 to standard T8	26	21	$41	
Plus redesign to lower lighting levels	56			$1.58
T12 to low-ballast T8	36	29	$41	
Plus redesign to lower lighting levels	53			
T12 to next generation T8	39	31	$50	
Plus redesign to lower lighting levels	63			$1.72
Redesign with fully integrated light and control systems	67			$2.50
Incandescent to CFL	69		$17/lamp (incremental cost)	
Incandescent to LED	75 to 90[69]		$38/lamp (incremental cost)	
Exit signs - Incandescent to LED	93	28	$61	

Commercial sector lighting product rebates

Fortis BC offered its commercial customers lighting product rebates of $5 or 50% of the cost of compact fluorescent lights, or a grant of 5 cents/kWh saved with a two-year minimum payback period. The program generated an annual savings of 3.3 GWh in 2005. The electricity savings from the program were approximately $234,000 based on an approximate rate of 7.1 cents/kWh. Program costs were approximately $282,000, while customer costs were approximately $170,000.[74]

New Construction: During new construction, the choice of lighting technology coupled with fewer fixtures and improved control systems (e.g., daylighting or occupancy sensors) offers the opportunity to achieve a 17 to 40% reduction in energy consumed by lighting[70] (see Table iv).

Table iv: Lighting retrofit savings and costs for new buildings

Lighting retrofit action	Reduction in energy used for lighting (%)	Per unit energy reduction (W/unit)
T8 to next generation T8	17	10
Plus redesign to lower lighting levels	33	
Plus improved control systems (i.e. daylighting, occupancy sensors)	40	

Cost implications

Commercial establishments can generate significant cost savings from upgrading to more efficient lighting systems. For example, upgrading from a T12 to standard T8 reduces energy consumption by 21 watts/unit. Based on continuous use for 10 hours per day, 260 days per year, the annual energy savings amounts to approximately 55 kWh and the annual cost savings are approximately $5.50. Since the average T8 lamp costs approximately $3,[71] the payback on the upgrade is less than a year.

Auxiliary equipment

Auxiliary equipment accounts for approximately 13% of energy consumed in the commercial sector in Alberta, and is defined as "stand-alone equipment powered directly from an electrical outlet such as computers, photocopiers, refrigerators and desktop lamps. It also includes equipment that can be powered by natural gas, propane or other fuels, such as clothes dryers and cooking appliances."[72]

The number of auxiliary equipment units in Canada was estimated at greater than 14 million in 2005.[73] Computers account for the greatest proportion of auxiliary equipment surveyed (at 55%) followed by printers, photocopiers and fax machines (20%) and refrigerators (10%). With respect to refrigeration units, multiplexed compressors have captured a significant market share, especially in new large supermarkets, but the less efficient single dedicated fixed demand compressors are still common.

Potential reduction

Research suggests that Energy Star labeled equipment can generate an electricity savings of 75% for computer and monitor equipment (24W per unit) and 40% for photocopier systems (61 W per unit). Refrigeration units that are upgraded to high-efficiency multiplexed compressors have the potential to generate energy savings of 25%. Doors and covers for

Xcel Energy Utility

In 2003, Xcel Energy Utility offered low cost energy assessments, low cost financing and both prescriptive and custom rebates for lighting equipment and installations in both existing commercial buildings and new construction. Close to 900 lighting projects were completed that achieved a net energy savings of over 61 million kWh.[75]

refrigerated display cases can provide refrigeration electricity savings of 20 to 30% over open display cases.[76]

Modelling completed by federal and provincial governments and industry associations estimates that electricity consumption from lighting, cooking and plug loads can economically be reduced by 20% over 20 years if all opportunities are captured, 18% if regulations and price signals are used, or 4% if just incentives and education are used.[77]

These models also estimated the economic potential for reducing energy use from natural gas hot water heating at 47%, and the achievable potential between 14 and 17%.

Cost implications

The energy efficiency potentials described in these studies are all considered to be currently economic although there are currently non-economic barriers to adoption.

Seattle City Light Utility

The Seattle City Light Utility began a program in 1998 that offered free facility assessments to commercial and industrial customers, coupled with financial incentives for upgrades to lighting, HVAC systems and auxiliary motor equipment. During the first two years of the program, an assessment of 96 projects found that the facility assessments identified 23 million kWh of potential electric savings, of which 9 million kWh of savings were realized through the implementation of recommended measures. Lighting, HVAC and controls were the measures most commonly recommended in the assessments.[80]

Auxiliary motors

Auxiliary motors account for approximately 8% of energy consumed in the commercial sector in Alberta, and are defined as "devices used to transform electric power into mechanical energy in order to provide a service, such as pumps, ventilators, compressors and conveyors."[78] Many of the auxiliary motors in commercial buildings are assumed to be used for heating, ventilation and air conditioning (HVAC), and are therefore considered as part of the building heating and cooling section (Appendix A.2).

Industrial processes

Industrial processes are estimated to be responsible for 22% of GHG emissions in Calgary with two-thirds of these emissions from electricity use and the remainder from natural gas use.

Industrial processes vary considerably from industry to industry. There are some studies, however, that have attempted to estimate the energy efficiency potential of the industrial sector in general.

Potential reduction

Marbek and Jaccard[79] modeled two different scenarios for energy efficiency in the industrial sector in Canada. The first scenario included mostly subsidies or incentives for energy efficiency equipment and estimated a 1.38% reduction in demand compared with a reference case over 20 years. The second scenario included an increase in energy prices, which then resulted in an estimated reduction in energy demand of 1.51% for the sector. If all economically viable efficiencies were achieved, the study estimated an energy savings of 12.89% over the same time frame.

A study by the International Energy Agency identified a generally available 10 to 15% efficiency improvement. About half of the efficiency savings are estimated to come from motor systems while the remainder are

Photo: The Pembina Institute

Power smart programs

BC Hydro and Manitoba Hydro both operate demand side management programs in their respective jurisdictions to help to reduce energy use for residential, commercial and industrial consumers. For example, BC Hydro offers a refrigerator buy-back program for its residential customers and provides a $30 rebate and free pick up of a second operating fridge. During the fiscal year of 2005–2006, the annual electricity savings attributed to the program was 27 GWh. A product incentive program implemented by BC Hydro that applied to commercial lighting, rooftop HVAC, controls, pumps and motors generated an annual savings of 15 GWh in the fiscal year 2005–2006.[88] The program savings amount to approximately 0.05% and 0.03%, respectively, of BC Hydro's total electricity demand in 2006.[89]

In 2008–2009, Manitoba Hydro offered over 40 incentive and customer service programs with target technologies including energy efficient lighting, commercial equipment such as clothes washers, and kitchen appliances. Since 1989, the combined effect of incentive-based programs, customer service initiatives and codes and standards saved 1,510 GWh of electricity. The cumulative customer savings to date total more than $399 million.[90]

Labelling

Both mandatory and voluntary product labelling programs are used around the world as educational tools to depict the energy use of home appliances, as a part of national demand side management and market transformation programs aimed at reducing overall energy consumption. The Energuide (in Canada) and EnergyGuide (in the United States) labels are mandatory on all major appliances and electrical equipment, while the Energy Star label is voluntary and initiated by product manufacturers.

a combination of combined heat and power, steam systems, process integration, increased recycling and energy recovery.[81]

Cost implications

The energy efficiency potentials described in these studies are all considered to be currently economic although there are currently non-economic barriers to adoption.

Common approaches to implementation

Market transformation: combined approach includes mandatory standards, labelling, incentives and education

Past improvements in the energy efficiency of residential appliances manufactured or sold in Canada shown in Figure iii (above) are attributed to a combined approach of mandatory appliance standards, voluntary and/or mandatory labelling, and other education and consumer awareness initiatives.[82]

The effects of mandatory standards, and voluntary and mandatory labels in the appliance, lighting and equipment market are complementary. Taken together, mandatory standards will "push" the market by causing manufacturers to eliminate the production of the least efficient models, while incentives and labels identifying the most efficient products "pull" the market by providing information to consumers that allows them to make better informed decisions, and purchase the most efficient and available models. This "pull" in turn stimulates manufacturers to design higher efficiency products.[83,84]

Mandatory minimum appliance, lighting or equipment standards

The implementation and updating of mandatory appliance standards can have an immediate impact on the efficiency of, and amount of energy consumed by, new appliances and equipment within a region. In a global review of best practices for reducing greenhouse gas emissions in buildings, appliance and equipment standards were identified as one of several programs that have the potential to reduce energy use at a relatively low cost compared to other measures.[85] Equipment and appliance standards have been implemented by both federal and provincial jurisdictions in Canada. However, there are continually new opportunities to improve equipment efficiency standards due to emerging technologies, new types of products and gaps within existing regulation.[86]

Potential roles: The federal government can set standards for products that cross provincial boundaries; whereas the provincial government can set standards for products sold in the province.

Key benefits: Broad adoption; net savings for consumers; positive return on the investment in new standards.[87]

Key challenges: Level of energy savings and reductions depends on the current market penetration of existing energy efficient or Energy Star products and appliance turnover. Current skills shortage for installation, operation and maintenance of energy efficient technologies and systems for commercial buildings.[91]

Other Considerations: Mandated standards limit consumer choice, which may or may not create challenges. For products with a well-developed set of high efficiency models, the impacts on consumer choice may be limited, while other products may be impacted more.

Incentives

Capital and fiscal incentives include grants, tax incentives, and subsidies. These approaches can generate significant reductions in energy use and CO_2 emissions, but can be expensive for government or utility providers.[92]

Tax incentives: Reduce or eliminate the total tax payable by individuals, businesses and corporations.

Subsidies and grants: Offered by government, utility or private corporations to encourage the replacement of older appliance, lighting and equipment models with energy efficient products. For example demand side management and resource acquisition programs are used by utilities to limit or delay the need for additional electric generation capacity. Typical programs offer financial incentives (consumer rebates) for the purchase of high efficiency products or equipment (commercial lighting and residential appliances are popular product types). A review in the United States of resource acquisition programs utilizing consumer rebate incentives revealed typical program energy savings of 1% of utility sales and demand reductions of 1% of peak load.[93]

Potential roles: Governments (federal, provincial and municipal) have all previously offered incentives for efficient products. Utility companies have also offered incentives as a method of avoiding costs to upgrade the electrical system.

Key benefits: Can contribute to market transformation; consumer choice; cost savings for consumers.

Key challenges: Cost to government or utilities.

Labelling

Mandatory labelling for equipment has been shown to be successful in achieving some changes to purchasing behaviour.[94] This is consistent with the results presented in Appendix A.2 regarding labelling of houses.

Potential roles: Governments most often set mandatory labelling requirements, although this could also be undertaken by product suppliers.

Key benefits: Emission reductions; contributes to and helps drive market transformation; consumer choice.

Key challenges: Limited market impact; can be difficult to measure; political will.

Supporting activities

Information and education campaigns, technical assistance, training programs and voluntary product labelling programs are examples of supporting activities utilized to drive market transformation towards greater energy efficiency and reduced energy use. The ability for these

U.S. federal appliance standards

U.S. federal appliance standards are applied to major residential appliances, commercial building equipment and lighting technology. The collective impact of all appliance and equipment performance standards implemented by 2005 is estimated to generate an electricity savings of 268 TWh/year in 2010 and 394 TWh/year in 2020. The reduction in electricity is 6.9% of the estimated U.S. electricity demand in 2010, and 9.1% of the estimated U.S. demand in 2020.

Cost benefit analysis of the standards indicates a cumulative consumer savings of $234 billion through to 2030, with a benefit-cost ratio of approximately 3 to 1. As well, consumer savings outweigh government expenditures about the program by more than 2000 times.[95]

Canadian energy efficiency regulations

The cumulative impact of the residential appliance standards implemented by the Canadian Energy Efficiency Regulations is estimated to generate an aggregate annual energy savings of 117.20 PJ in 2010 and 133.84 PJ in 2020. The cumulative impact of standards for residential and commercial lighting and auxiliary motors is estimated to generate an aggregate annual savings of 31.96 PJ in 2010 and 39.54 PJ in 2020.[96]

Energy Star

An assessment of the effectiveness of rebates offered by utility companies for Energy Star labeled appliances in the United States from 2001 to 2006 revealed that the programs increased the market share of Energy Star qualified clothes washers by 4.5%. Utility supplied rebates had no significant impact on the sales of dishwashers and refrigerators. Each megawatt hour of energy saved through the rebate program cost the utility approximately $35 US — significantly lower than the cost for a utility to purchase on-peak power, at an average price of $60/MWh.[100]

Australian appliance labelling program

An evaluation of the Australian labelling program estimated that due to the label, the sales-weighted energy consumption of products sold from 1986 to 1992 was reduced by 12% for refrigerators and freezers, 16% for dishwashers, 1% for clothes dryers and 6% for air conditioners.[101]

activities to reduce energy use in appliances and equipment in isolation is contested, though research suggests their use in conjunction with other implementation methods such as regulation or incentives can be effective.[97,98]

Potential roles: Government is typically a driver of providing information to consumers, but product suppliers and retailers are also often involved.

Key benefits: Contributes to and drives market transformation; provides support for successful program implementation of standards or incentives; can prepare the market for introduction of standards requiring higher efficiency.

Key challenges: Ability to shift the market using only information, awareness, education etc. is questionable without standards, and can be difficult to measure.[99]

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Photo: The Pembina Institute

Photo: The Pembina Institute

Appendix A.4

Wind power

Wind farms currently generate approximately 2% of the electricity used in Alberta[102] while producing no direct greenhouse gas emissions. When looking from a life cycle basis, electricity generated from the wind creates 99% less GHG emissions than Alberta's coal- and natural gas-dominated electricity grid.[103]

Potential reduction

Southern Alberta has an excellent wind resource, and until recently had the most installed wind power of any region in Canada. In fact, a very large number of applications have been submitted to the Alberta Electric System Operator for interconnecting new wind farms in the province. These applications account for twice as much electricity generating capacity than is currently installed by coal-fired power plants in the province.[104] It is unlikely that all of these applications would be approved; however, it has been estimated that approximately 20% of Alberta's electricity could come from wind power within the next 20 years. This is similar to penetration levels already experienced in other jurisdictions.[105]

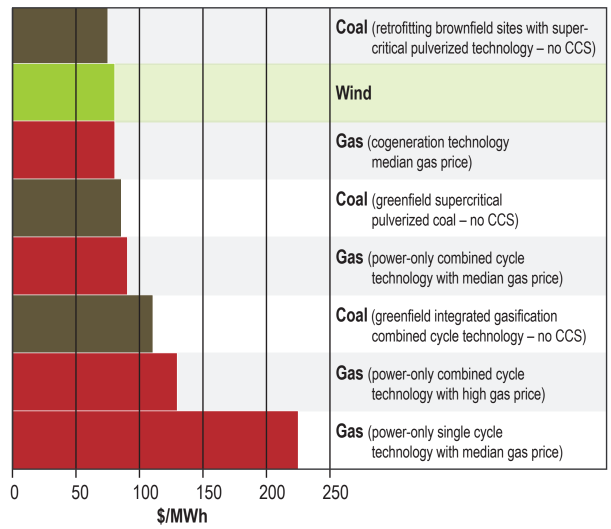

Figure viii: Cost per MWh of various power generation technologies in Alberta[106]

Cost implications

Figure viii shows that wind power is estimated to be cost competitive with other options for new power generation in the province.

Approaches to implementation

Regulations

One of the most common methods of regulating the source of power in a region is through a Renewable Portfolio Standard (RPS). An RPS can be placed on electricity retailers, or at other parts of the supply chain, requiring them to purchase a certain percentage of renewable power.

Low emission power can also be encouraged through a cap-and-trade system where power generators, or other parts of the supply chain, have a limited ability to emit GHGs and therefore must find ways to reduce the carbon intensity of their electricity sources.

Potential roles: Provincial or state governments have typically set renewable portfolio standards, whereas both the provincial and federal governments could establish cap-and-trade systems for GHG emissions.

Key benefits: Strong driver for emission reductions.

Key challenges: Political will.

Incentives or disincentives

Another common method of increasing the amount of renewable or low emission power in a region is to use financial incentives or disincentives. These are called various different names — production incentives, feed-in

Photo: City of Calgary

Green Power

Both Enmax and Bullfrog Power offer consumers an opportunity to pay a premium to support power producers who put green power on the grid on their behalf.

Incentives

The federal government previously had a Renewable Power Production Incentive that provided 1 cent / kWh for qualified renewable energy projects.

Ontario has a feed-in-tariff that provides a premium price for renewable energy projects.

British Columbia has a carbon tax that helps to make low emission energy sources more economically attractive.

Photo: The Pembina Institute

tariffs, carbon tax — but they are essentially designed to provide more revenue for low emission or renewable sources, or higher costs for high emission sources.

Potential roles: Governments are typically involved in providing incentives.

Key benefits: Creates price signals in the marketplace that increase considerations of environmental impact.

Key challenges: Level of impact on the market depends on the level of incentive or disincentive; incentives can be difficult for government to maintain without a dedicated funding source.

Engage consumers

Awareness could be raised or incentives provided for consumers to purchase or support green power.

Potential roles: Government, non-profit organizations, electricity marketers and green power producers are often involved in promoting lower impact electricity.

Key benefits: Additional revenue for green power producers; increased support for producers who are building low-carbon electricity infrastructure and other policies to support low impact electricity.

Key challenges: Paying a premium for green power likely to remain a niche market.

102 Jeff Bell and Tim Weis, *Greening the Grid: Powering Alberta's future with renewable energy* (The Pembina Institute, 2009), http://pubs.pembina.org/reports/greeningthegrid-report.pdf

103 Matthew McCulloch, Marlo Raynolds and Michelle Laurie, *Life-Cycle Value Assessment of a Wind Turbine* (The Pembina Institute, 2000), http://pubs.pembina.org/reports/windlcva.pdf

104 Transmission constraints have limited the ability of these interconnection applications from being approved.

105 Bell and Weis, *Greening the Grid.*

106 Alberta Electric System Operator, *Long-Term Transmission System Planning Stakeholder Meeting — Presentation* (November 16, 2007) http://www.aeso.ca/downloads/Nov_16_Long_Term_Transmission_Stakeholder_Presentation-_for_posting.pdf

Appendix A.5

Combined heat and power / district energy

Combined heat and power and district energy are two methods to reduce carbon emissions. In combined heat and power (CHP) or cogeneration, the fuel, often natural gas, is burned to generate electricity while the left-over heat is used in industrial processes or to heat buildings. Some systems can also provide air conditioning alongside electricity and heat. Those systems are considered tri-generation. Grid-connected cogeneration plants in Alberta have expanded rapidly in recent years, with capacity increasing from 500 MW in 1998 to 3,500 MW in 2006 mainly due to expanded use of cogeneration in the oilsands.[107]

District energy (DE) systems share energy between multiple buildings or properties to make the best use of the energy available. This is often done by pumping heat between multiple buildings, but can also be done for cooling and electricity as well. These systems work well with cogeneration and tri-generation plants and are often paired together.

Potential reduction

Significant emissions reductions are possible through CHP and district energy using natural gas as shown in Figure ix. CHP can achieve up to 80% efficiency while conventional electricity generation systems range from 40 to 60%. A tri-generation plant can be up to 90% efficient.[108]

Including current production, the potential for industrial-scale or community-scale cogeneration in Alberta has been estimated to be 8,000 MW generating capacity, or about two-thirds of Alberta's current electrical grid capacity. As with all cogeneration, this potential is highly dependent on matching it with heating or cooling demand.[109]

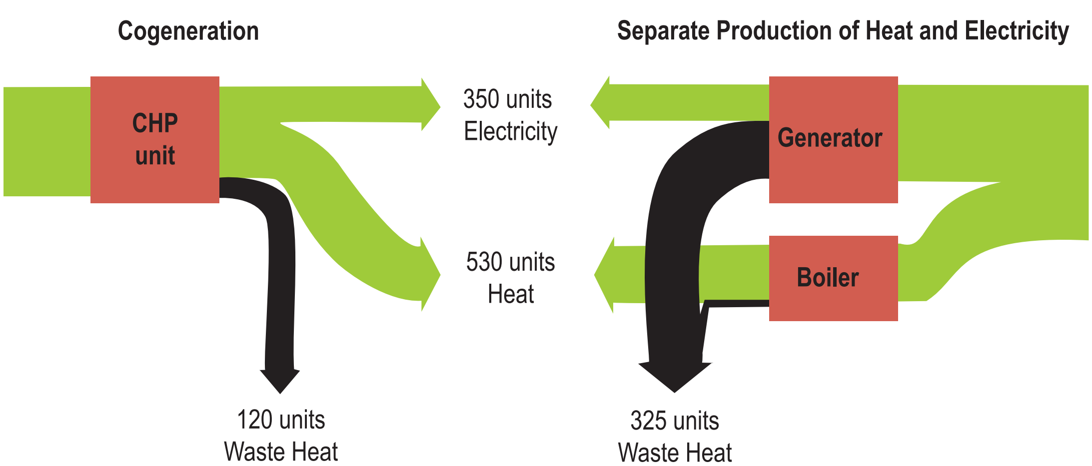

Figure ix: Comparing cogeneration to traditional heat and electricity production[110]

Appendix A.5 Combined heat and power / district energy

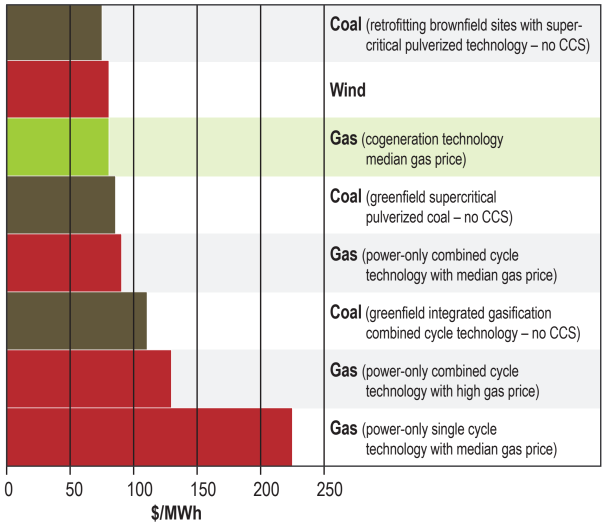

Figure x: Cost per MWh of various power generation technologies in Alberta[113]

Calgary

Enmax has recently built a $200 million district energy plant for an area of downtown Calgary. The project provides greater efficiencies and lower costs for energy, operations and maintenance than traditional power plants. Enmax hopes to build up to twelve district energy centres in Calgary.[114]

University of Calgary

The University of Calgary is expected to convert a central heating and cooling plant to a cogeneration facility in 2011. Instead of separately generating heat and purchasing electricity from the grid, the new 12 MW, $48 million plant will create $3.5 million in annual energy savings and reduce the university's GHG emissions by 80,000 tonnes per year.[115] This is a 50% reduction from 2009 levels.[116]

Micro-CHP is down-scaled cogeneration that can occur within a single residence. An estimated 75–110 MW of potential electricity generation from micro-CHP is thought to exist in Alberta over the next 20 years.[111]

Cost implications

For particular applications, both CHP and district energy can be cost competitive with conventional systems. Typically, a minimum heat demand is required.

For power generation, a cogeneration system is estimated to be among the lowest cost options for developing new power plants in the province (see Figure x). Internationally, the cost savings for retail customers has varied from 15 to 42%, while capital cost savings have also been shown to be up to 58%, depending on the jurisdiction.[112]

Approaches to implementation

Regardless of the implementation approach taken, some common considerations impact the success of all CHP/DE projects

- Managing multiple interests for DE: different businesses and residences need to work together instead of independently
- Matching heat loads for CHP: seasonal variation in demand exists for heating and cooling
- Siting of larger units in urban areas: CHP/DE performs best in higher-density districts
- Availability of micro-cogeneration units: these are not widely available in Alberta at this time

Some of the approaches to overcoming these barriers are listed below. Additional approaches include developing thermal storage and improving cooling integration to help manage heat loads, and investing into the further development of micro-generation technologies.

Incentives

A variety of subsidies or rebates can be offered to the power provider to offset capital costs, or to the ratepayer who occupies buildings that use CHP/DE systems.

Potential roles: Typically federal or provincial governments provide incentives for certain types of energy generation.

Key benefits: Levels the playing field with higher carbon power and heating systems; improved consumer choice; lower monthly power and heating costs for consumer.

Key challenges: Current limited uptake of CHP/DE systems; cost to government.

Organizational infrastructure

In some cases, CHP and district energy already make economic sense, but have other barriers associated with them — often related to matching the generators with the heat demand. Having an entity that works with various groups to identify and facilitate the development of CHP and/or DE could help overcome these barriers.

Potential roles: Municipalities are well-positioned to play a coordinating role as they are responsible for establishing community plans, and they also sometimes develop municipal energy plans. A private company could also play this role, but a revenue model would need to be identified.

Key benefits: Can help to overcome initial barriers of siting and managing the needs of multiple interests.

Key challenges: Requires funding or revenue source to facilitate development of projects; needs to be integrated into larger community development plans.

Supporting activities

Education and awareness-building for consumers, builders, developers and government can improve the speed and ease of implementation of other approaches.

Potential roles: Government, energy providers and technology suppliers are most often involved in education and awareness-building around opportunities for CHP and district energy systems.

Key benefits: Low costs and high visibility.

Key challenges: Low awareness of CHP/DE in Alberta; limited ability to effect change without additional measures.

Heathrow Marriot

Installed in 2001, the 230 kWe gas engine CHP unit for London's Heathrow Marriot Hotel runs an average of 17 hours per day at 97.5% availability. The hotel estimates it saves 75,700 euros and avoids 250 tonnes CO_2e per year.[117]

Hamilton

The City of Hamilton's CHP and district energy installations achieved 80% efficiency compared to 40–60% for conventional installations. During a prolonged blackout in 2003, the 3.5 MW power plant provided enough electricity to keep City Hall functioning through the crisis.[118]

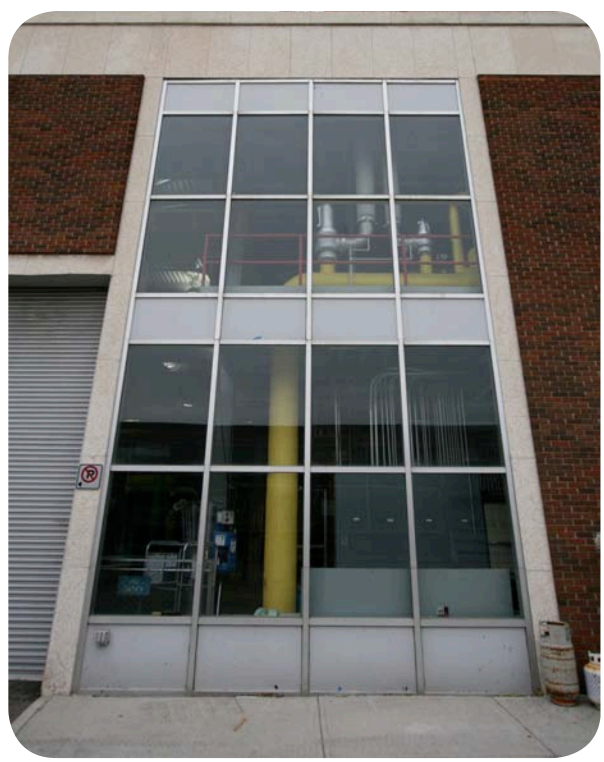

Photo: The Pembina Institute

107 Jeremy Moorehouse and Bruce Peachey, "Cogeneration and the Alberta Oil Sands," *Cogeneration and Onsite Power Production* 8, no. 4 (July- August 2007),. http://www.cospp.com/articles/print_screen.cfm?ARTICLE_ID=303182.

108 Trigeneration Technologies, "What is Trigeneration?" http://www.trigeneration.com/

109 Pembina estimate for the *Greening the Grid* report based on proprietary work by Mark Jaccard and Associates. Bell and Weis, Greening the Grid.

110 WADE Canada, "DE Technologies," http://wadecanada.ca/can_deb_technologies.html

111 Bell and Weis, *Greening the Grid*, 50.

112 WADE Canada, "Economic Benefits," http://wadecanada.ca/can_ben_economic.html

113 AESO, *Long-Term Transmission System Planning*.

114 Renato Gandia, "Enmax unveils new energy centre," *Calgary Sun,* June 18, 2010, http://www.calgarysun.com/news/alberta/2010/06/18/14443836.html

115 University of Calgary, "Economic stimulus boosts U of C building projects," May 15, 2009. http://www.ucalgary.ca/news/may2009/funding-cogen

116 Veronica Hoskins, "New U of C power plant will slash emissions," *University of Calgary ON Campus*, November 2008, http://www.ucalgary.ca/news/uofcpublications/oncampus/november2008/power/

117 COGENchallenge, Intelligent Energy Europe, *Cut your energy bills with cogeneration: A basic guide on the principles and profitability of small-scale cogeneration* (2009), 5, http://www.cogeneurope.eu/wp-content/uploads//2009/02/basic_guide.pdf.

118 Hamilton Community Energy, "Current Projects: Cogeneration and District Heating," http://www.hamiltonce.com/html/static/current_projects.shtml.

Photo: Enmax

Appendix A.6

Coal with carbon capture and storage

Coal-fired power plants supply 74% of the electricity in Alberta. These power plants typically have higher levels of emissions, both of greenhouse gases and other air pollutants, than other forms of power generation.

The GHG intensity of coal-fired electricity (the amount of GHGs created per unit of power produced, typically measured as tCO_2e/MWh) could be decreased by equipping new or existing coal facilities with carbon capture and storage (CCS).

In practice, CCS in the electricity sector (for coal here, but the technology could be used for other thermal generation facilities) refers to the process where carbon dioxide from power generation is captured before it is released to the atmosphere, compressed, transported and sequestered in geological formations.

Potential reduction

A variety of technologies and processes can be used to separate and capture CO_2 from electricity generation facilities; however, it is important to note two important caveats to the CCS process:

- First, CCS facilities at coal generating stations do not capture all emissions. Up to 70 to 90% of GHG emissions are predicted to be captured.
- Second, the capture process itself will require energy, meaning that there will be additional fuel use and additional fuel costs for a coal plant with capture. Some estimates suggest generation plants with capture will burn 30% more fuel (coal) to compensate for the parasitic energy consumption of the capture system.[119]

Caution is required when anticipating the impact that CCS can have for The City of Calgary; there are significant cost, technology, ecological and infrastructure barriers that must be overcome before a significant level of penetration or impact can be realized.

Cost implications

The cost of electricity will be impacted in two ways. First, the cost of retrofitting existing facilities or building new facilities will require capital investments greater than the current building costs. Second, increased operating costs are associated with increased fuel use at coal generating stations with capture, in addition to costs of other consumables at capture facilities.[120] The additional costs of power production range from 39 to 78% (depending on technology and process used) according to one study of CCS costs.[121]

Ontario

In Ontario, the provincial government has committed to phasing out coal-fired power plants. It is increasing the use renewable energy and improving energy efficiency to replace lost coal-power supply.

Canada

The Government of Canada recently announced its intention to reduce emissions from existing and new coal facilities, using the Canadian Environmental Protection Act (CEPA). Regulation would come into effect in 2015. The draft regulatory approach would see a performance-based standard for facilities; facilities would be expected to have greenhouse gas emission rates (tonnes per GWh) less than or equal to those of a natural gas combined cycle facility (approximately 360–420 t/GWh).

Several draft rules complicate the regulation. For instance, new facilities that have planned CCS would be exempt from the regulations until 2025, when CCS is anticipated to be cost effective. Existing facilities would not be required to meet the regulation until the end of their economic life.[122,123]

Appendix A.6 Coal with carbon capture and storage

B.C. carbon tax

British Columbia has a carbon tax that helps to make low-emission energy sources more economically attractive.

The Integrated CO_2 Network's (ICO_2N) review of CCS opportunities foresees the earliest capture facilities coming online at over $45/t$CO_2$e avoided — and this from the oilsands sector, not from power generation facilities. This review does not anticipate coal generation with capture coming online in significant quantities until a carbon price of $80/t is reached, and even then for a limited number of new coal facilities. Retrofitting of existing facilities for capture is only anticipated when prices reach $95/t.[124]

The Intergovernmental Panel on Climate Change estimates that the impact of CCS on electricity prices would be 1 to 5 cents US/kWh.

Approaches to implementation

Regulations

Regulations or provincial directives could lead to the phase-out of coal-fired power plants without carbon capture and storage.

Directives to governing bodies, including the Alberta Electricity System Operator, or changes to the Electric Utilities Act could stipulate requirements to phase out conventional coal, or to allow new coal power generation facilities only if they are equipped with CCS.

Potential roles: Governments are typically involved in establishing regulations or requirements for the electricity and transmissions system.

Key benefits: Creates legislative or regulatory framework to ensure that existing high-carbon sources are phased out and new, low-carbon sources of electricity are developed.

Key challenges: Level of impact on the market depends on rigour of the directive or legislation adopted.

Incentives and disincentives

Another common method of increasing the amount of renewable or low-emission power in a region is to use financial incentives or disincentives. Various types of incentives are commonly used in the electricity sector, each designed to increase the supply of low-carbon electricity sources and discourage the use of higher carbon, polluting sources such as conventional coal. Production incentives, feed-in tariffs and carbon taxes are examples of incentives.

In the case of CCS, the implementation of a price on carbon (either through direct carbon tax or cap-and-trade system) could spur development of CCS — if the price is set high enough. Earlier, it was noted that a price of carbon greater than $80/tonne would likely stimulate investment in CCS in the Alberta electricity sector.

Potential roles: Federal and provincial governments are typically involved in providing incentives or establishing a price on carbon.

Key benefits: Creates price signals in the marketplace that increase considerations of environmental impact.

Key challenges: Level of impact on the market depends on the level of incentive or disincentive.

Future projects

Several coal power plant CCS projects are in development worldwide, including four in Alberta and Saskatchewan.[125] These commercial-scale facilities will be larger than previous pilot projects such as the 30 MW Vattenfall CO_2-free power plant in Germany.[126]

The Bow City Power capture project in southern Alberta, a 1,000 MW facility adjacent to a coal mine, is in the planning and development stage.[127] At initial development, the plant will only capture 20% of total CO_2 emissions. There is a possibility that the percent of total emissions captured can be increased by phasing in additional capture capacity.[128] Project commissioning is not anticipated until 2014.

Other coal facilities planned to be built with some CCS capacity include: Boundary Dam (SaskPower, 100MW, target 2015), Project Pioneer (TransAlta, 450 MW, target 2015), and Belle Plaine (TransCanada, 500MW, date undecided).

119 Viebahn et al. "Comparison of Carbon Capture and Storage with Renewable Energy Technologies Regarding Structure, Economic and Ecological Aspects in Germany," *International Journal of Greenhouse Gas Control* 1 (2007).

120 Depending on technology option preferred.

121 Global CCS Institute, *Strategic Analysis of the Global Status of Carbon Capture and Storage* (2010), http://new.globalccsinstitute.com/resources/publications/strategic-analysis-global-status-carbon-capture-storage/

122 Environment Canada, "Government of Canada to Regulate Emissions from Electricity Sector," news release, June 23, 2010, http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=E5B59675-BE60-4759-8FC3-D3513EAA841C

123 Environment Canada, "Key Elements of Proposed Regulatory Approach," news release backgrounder, http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=55D09108-5209-43B0-A9D1-347E1769C2A5

124 ICO_2N, *CCS: A Canadian Environomental Superpower Opportunity* (2007), http://www.alston.com/files/docs/ICO2N Report_Carbon Capture and Storage_A Canadian Environmental Superpower Opportunity.pdf

125 Carbon Capture and Sequestration Technologies @ MIT, "Power Plant Carbon Dioxide Capture and Storage Projects," http://sequestration.mit.edu/tools/projects/index.html.

126 Vattenfall, "Pilot Plants," 2010, http://www.vattenfall.com/en/ccs/pilot-plant.htm

127 Bow City Power, "Bow City Power Project," http://www.bowcitypower.ca

128 B. Bietz, "The Bow City Power Experience," (presented at the CERI 2009 Electricity Conference, Keeping Our Act Together, October 19-20, 2009), http://www.bowcitypower.ca/pdf/CERI_Speaking_Notes_20Oct09.pdf.

Photo: Petroleum Technology Research Centre


Photo: The Pembina Institute

Appendix A.7

Nuclear power

There is currently no nuclear power generation in the western provinces, including Alberta. Saskatchewan is the largest uranium mining and processing centre in Canada. Ontario, and to a lesser extent Quebec and New Brunswick, use nuclear power to provide electricity in their jurisdictions.

Potential reduction

Alberta has never employed nuclear energy to generate electricity; it has recently commissioned an appointed panel to draft a report examining the potential for nuclear generators in Alberta. This report was completed in 2009.

This expert panel concluded that the life cycle emissions of CO_2 from nuclear power generation, including mining, refining and fuel transportation, are similar to those of renewable energy sources such as wind power.[129]

The creation of new nuclear energy facilities in Alberta is a long-term process. Nuclear power generating facilities are subject to very high capital costs and long construction times relative to other electricity supply options. In Ontario, a history of serious delays and cost overruns on nuclear facilities account for $15–20 billion in debt left by Ontario Hydro. The long timelines — an estimated total of nine years for power plant licensing[130] — and risks make it difficult for nuclear power to secure private investment or to contribute to short-term GHG reduction in the Alberta electricity sector.[131]

Cost implications

The expert panel review notes that the decision to build a plant is a private sector decision taken by a company based on its assessment of the project's economic viability; any new plant would require approval from both provincial and federal authorities.[132] The Expert Panel concluded that the cost of energy from nuclear plants typically ranges from 3.5 to 6.0 cents per kWh,[133] although other independent reports place the cost as high as 15 cents per kWh as shown in Table v.

Nuclear in Canada and worldwide

Ontario, Quebec and New Brunswick each have nuclear power generation as part of their supply mix. In 2005, the Ontario Power Authority announced its intention to acquire new nuclear power generation; it estimated in 2005 that the cost of this power would be over $3,000 per kW. In 2009, the OPA reportedly received a bid for new supply at a cost of over $10,000 per kW.[134]

The last new nuclear facility to be built in Canada is the reactor at Darlington, Ontario. It was completed in 1992. Three recent applications to the Canadian Nuclear Safety Commission were withdrawn in 2009 (Bruce Power/Triverton Site, Bruce Power Alberta, and Bruce Power Erie/Nanticoke site).[135] Ontario Power Generation (OPG) has completed early applications; application for license to operate is not expected until 2016.[136]

In the European Union and the United States, over 20 new facilities are planned.[137] Many planned new reactors will be constructed at existing nuclear facilities: of 22 applications to the U.S. Nuclear Regulatory Commission, all but three are at existing, operating plants.[138]

B.C. carbon tax

British Columbia has a carbon tax that helps to make low-emission energy sources more economically attractive.

Table v: Cost estimates for building new nuclear reactors and the power they produce[139]

Estimate source	Cost to build a new 2000 MW reactor	Estimated price of electricity generated (cents / kWh)
Ontario Power Authority (IPSP 2008)	$5.8 billion	8.6
Moody's Investment Services (2008)	$15 billion	15.1
Standard and Poor's (2008)	$10-$16 billion	N/A

Approaches to implementation

Regulations

Regulations or directives to governing bodies, including the Alberta Utilities Commission, could stipulate requirements that new electricity supply must be from zero-carbon sources.

Potential roles: Provincial governments are typically involved in establishing regulations or requirements for the electricity and transmissions system.

Key benefits: Creates a legislative or regulatory framework to ensure that only zero net greenhouse gas sources of electricity are developed.

Key challenges: Level of impact on the market depends on rigour of the directive or legislation adopted.

Incentives and disincentives

Another common method of increasing the amount of renewable or low-emission power in a region is to use financial incentives or disincentives. Various types of incentives are commonly used in the electricity sector, each designed to increase the supply of low-carbon electricity sources and discourage the use of higher carbon sources such as conventional coal. Production incentives, feed-in-tariffs and carbon taxes are examples of incentives.

Potential roles: Federal and provincial governments are typically involved in providing incentives or establishing a price on carbon.

Key benefits: Creates price signals in the marketplace that increase considerations of environmental impact.

Key challenges: Level of impact on the market depends on the level of incentive or disincentive.

Net Zero in B.C.

In B.C., the provincial government has stipulated that all new electricity supply must produce zero net greenhouse gas emissions. This type of provincial directive provides a mandate to guide utility regulators and operators in planning and managing the provincial grid.

129 Alberta Energy, *Nuclear Power Expert Panel: Report on Nuclear Power and Alberta* (2009), http://www.energy.alberta.ca/Electricity/pdfs/NuclearPowerReport.pdf.

130 Alberta Energy, *Nuclear Power Expert Panel: Report.*

131 Mark Winfield et al., *Nuclear Power in Canada: An Examination of Risks, Impacts and Sustainability* (The Pembina Institute, 2006), 110, http://pubs.pembina.org/reports/Nuclear_web.pdf

132 Alberta Energy, *Nuclear Power Expert Panel: Report.*

133 Alberta Energy, *Nuclear Power Expert Panel: Report.*

134 *Ontario's Green Energy Plan 2.0: Choosing 21st century energy options,* (The Renewable is Doable Coalition, 2010), http://pubs.pembina.org/reports/ontario-green-energy-report-august-web.pdf.

135 Canadian Nuclear Safety Commission, "New Nuclear Power Plants," 2010, http://www.cnsc-ccsn.gc.ca/eng/licenseesapplicants/powerplants/newapplicants/index.cfm

136 Canadian Nuclear Safety Commission, "Darlington Nuclear Power Plant," 2010, http://www.nuclearsafety.gc.ca/eng/readingroom/newbuilds/opg_darlington/

137 World Nuclear Association, "Plans for New Reactors Worldwide," 2010, http://www.world-nuclear.org/info/inf17.html

138 U.S. Nuclear Regulatory Commission, *Expected New Nuclear Power Plant Applications* (2010), http://www.nrc.gov/reactors/new-reactors/new-licensing-files/expected-new-rx-applications.pdf

139 Adapted from: T*he Perfect Storm in Favour of Green Power: Why there has never been a better time to not buy new nuclear reactors* (The Renewable is Doable Coalition, 2009) http://pubs.pembina.org/reports/risdbackgrounder-02-06-09.pdf

Photo: Canadian Nuclear Workers' Council

Photo: eastpole / Tai Viinikka via Flickr

Appendix A.8

Solar energy

Energy from the sun can be harnessed in many ways — to generate heat for living and working spaces, to heat water for personal, commercial or institutional uses, and to generate electricity.

Solar technologies are commercially available across the country, and have been proven in the Canadian climate.

The following applications are considered here:

- **Solar air heating (active)** – The use of solar energy to pre-heat air for indoor space heating before it is brought into a building. Residential use of this technology is less common than commercial/ institutional and industrial.
- **Solar water heating** – The use of solar energy to heat water for residential, commercial or industrial uses. This technology can displace natural gas use for residential water heating, for pool heating at public or private facilities, or for any number of applications that require hot water.
- **Solar photovoltaic (PV)** – The generation of electricity from the sun's energy. Common applications include roof-top mounted solar panels in both the residential and non-residential sectors.
- **Passive solar heating and lighting** – Buildings are naturally heated and illuminated by the sun. Building and neighbourhood design — including building orientation, window placement, thermal massing and shading — can be optimized to use more of the sun's energy to meet the building energy requirements.
- **Solar power plants** – Larger, centralized solar power plants can be built in undeveloped areas to provide electricity to the grid. This can include large arrays of ground-mounted solar PV panels, but other technologies — including the use of solar energy to generate steam for power generation — are in operation around the world and could find use in Alberta.

Solar applications are typically scalable — additional capacity can be added as financing or capital becomes available, provided there are no limitations of the physical space required (e.g., size of rooftop for solar PV) or the energy needs of the buildings (e.g., solar water heater should not be oversized for the building needs).

Potential reduction

The Calgary energy mapping study provides a reference point for energy produced by building integrated systems. The figures provided here reference the potential of each technology if applied within city limits using all available roof spaces. This is considered to be a very high estimate.

Green Power

Both Enmax and Bullfrog Power offer consumers an opportunity to pay a premium to support power producers who put green power on the grid on their behalf.

Spain

In Spain, the building code requires that 30 to 70% of water heating demand be met with renewable energy for new buildings and major renovations; in Barcelona the requirement is 60% for residential water use, 100% for uncovered swimming pools, and 20% for industrial hot water.[140]

Ontario

In Ontario, the MicroFIT (feed-in-tariff) program provides residents and businesses with a fixed-price contract for 20 years for the sale of power to the grid. The separate treatment of small-scale systems (appropriate for residential and businesses) encourages the participation of homeowners and commercial building operators within city limits by streamlining the application process and providing a higher rate for electricity sold, ensuring investors a reasonable rate of return on their investment.

Building mounted solar heating and electricity

For solar hot water heating, the Canadian Urban Institute estimated a maximum potential of 42 million GJ of heat production in 2036. This is about half of the total natural gas used in Calgary in 2008.

Solar air heating was estimated to have a potential of generation 8 million GJ of heat in 2036. Solar PV was estimated to have the potential to generate 1500 GWh of electricity in 2036, or about 16% of total electricity consumption in Calgary in 2008.

Passive solar

Passive solar refers to the use of solar energy to provide energy or services for buildings without the aid of mechanical systems; allowing the sun to warm living and working spaces by orienting windows to maximize solar access in heating seasons (while also providing shade during seasons where air conditioning is needed), or using the sun's light to reduce the need for electrical lighting systems.

Challenges and opportunities do exist for passive solar in urban environments. The Calgary Energy Mapping report discusses how new development that obstructs the solar access of a passive solar home can increase that building's energy needs by 22%.[141] For both residential and commercial buildings, careful consideration of the benefits and trade-offs of the use of solar energy is required — creating a city energy plan that provides clarity for builders in the design and planning process with respect to solar access ensures that designs can be optimized for solar energy use. The Energy Mapping report also indicates that while high-rise buildings will benefit from solar heating, overall energy consumption may actually increase compared with lower buildings of the same volume.

The energy savings realized from smart passive solar design varies significantly depending on the nature and objectives of the designer and builders. A modest passive solar design can result in energy savings of 5 to 25% of total energy use, where a more aggressive optimized design could reduce energy costs by 40 to 75%. Many passive solar actions cost nothing beyond good planning; the 'Building America' program has found that energy consumption of new homes can be reduced by as much as 50% with little or no impact on the cost of construction.[142] A reduction of 50% of heating costs corresponds to a 50% reduction in greenhouse gas emissions associated with building heating, as the dominant energy source for space heating in Alberta is natural gas.

Solar power plants

An additional consideration should be the production of electricity from large scale solar electricity facilities; this can include arrays of solar PV panels, as well as solar thermal facilities that use the sun's energy to generate steam that drives a turbine for electricity production. These facilities could be constructed outside city limits — and, similar to other forms of renewable power generation such as wind, they would decrease the greenhouse gas emission intensity of the provincial grid. In Calgary, the solar resource is very favourable compared to the rest of the country. Each kW of installed solar PV capacity would be expected to generate 1200kWh or power annually (see Figure xi).

The impact of centralized solar generation (including PV and solar thermal generation) on the provincial grid could be significant. In the United States, proposals for large-scale centralized solar thermal power generation could point the way for independent power producers in Alberta: a 1000 MW facility has recently been approved in California.[143]

Japan installed more than 400 MW of PV power in 2007 alone, more than the size of Alberta's average coal plant. The United States installed about 260 MW of solar in the same year whereas Germany installed almost 1,300 MW, more than Alberta's three biggest coal units combined.[144] In Ontario, 1131 MW of solar power is under development — 31% of the total new renewable power under development. 655 MW of the solar capacity under development is to be contracted under the new feed-in tariff.[145]The solar PV market is the fastest growing market in the world; it has been growing at an average rate of 42% per year for the last 15 years.[146]

Cost implications

Solar systems typically have higher up-front or capital costs and relatively low annual operating costs. The Calgary Energy Mapping Study provided estimates of the cost of both solar air and solar hot water heating at $15 per GJ of energy produced, although other sources put the cost of solar air heating as low as $7.50/GJ.[147] Solar PV was estimated in the Energy Mapping Study at a cost of $0.23/kWh produced; however, Ontario has put in place a feed-in tariff of $0.802/kWh for small PV installations.[148]

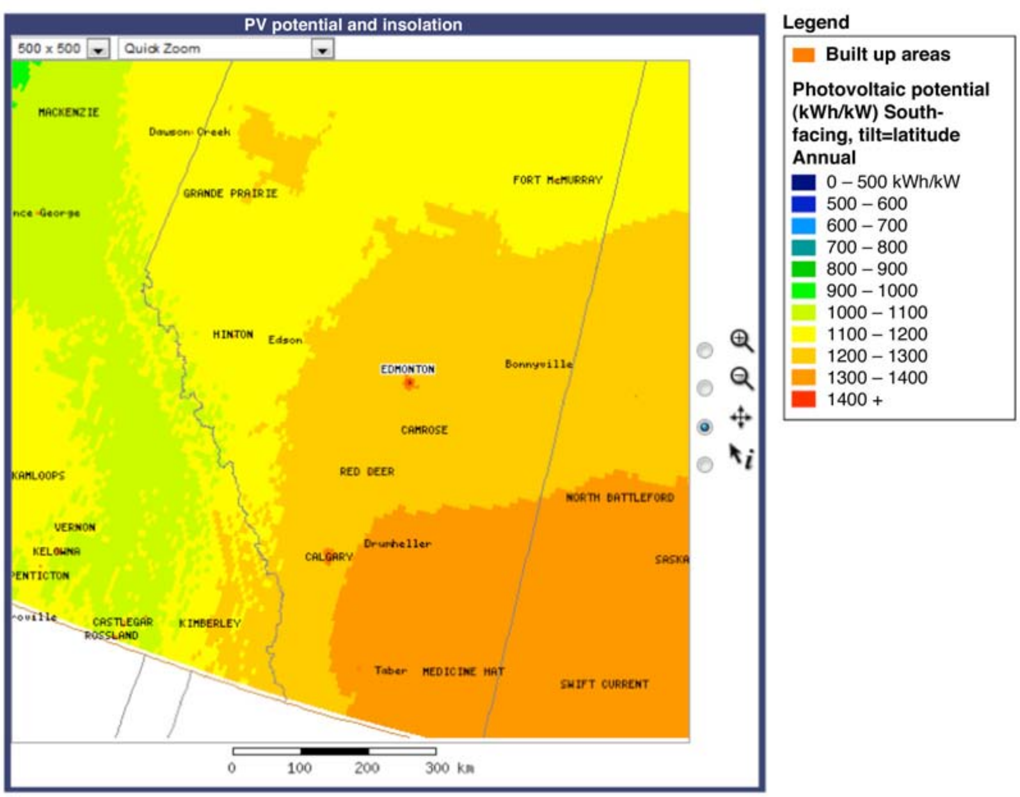

Figure xi. Photovoltaic potential in Alberta[149]

Photo: The Pembina Institute

Distributed solar and wind energy program

ENMAX, the Climate Change Emissions Management Corporation and Climate Change Central have launched a five-year initiative to install up to 9,000 distributed solar or wind energy installations.[152]

Federal incentive

The federal government previously had a Renewable Power Production Incentive that provided 1 cent / kWh for qualified renewable energy projects.

The price of these systems is expected to drop as more systems are installed. The International Energy Agency noted that the price for electricity from PV may become cost-competitive with current retail prices in some markets by 2015.[150]

According to the Calgary Energy Mapping Study, exploiting the full potential within the city limits was estimated to require an investment of $837 million (for solar air), $6.2 billion for solar hot water, and over $3.5 billion for solar PV. As mentioned earlier, as systems are scaleable, these investments would be made incrementally and over a number of years (if not decades) and would provide returns on investments in the form of energy savings (reduced natural gas and electricity use) and/or energy sales (sale of electricity to the provincial grid).

The installation cost of solar PV panels for a residential customer would be $3000-$5000 per kW (residential systems of 1 to 3 kW are common).[151] The cost of a residential-scale solar water heating system is approximately $5000.

The use of passive solar energy is considered to be very low cost as simple designs involve only building orientation, placement of windows and shading. More sophisticated systems are possible, but these would also displace more natural gas for space heating and electricity for lighting.

Approaches to implementation

Regulations for large-scale generation

One of the most common methods of regulating the source of power in a region is through a Renewable Portfolio Standard (RPS). An RPS can be placed on electricity retailers, or at other parts of the supply chain, requiring them to purchase a certain percentage of renewable power.

Low emission power can also be encouraged through a cap-and-trade system where power generators, or other parts of the supply chain, have a limited ability to emit GHGs and therefore must find ways to reduce the carbon intensity of their electricity sources.

Potential roles: Provincial or state level governments have typically set renewable portfolio standards, whereas both the provincial and federal governments could establish cap-and-trade systems for GHG emissions.

Key benefits: Strong driver for emission reductions.

Key challenges: Political will.

On-site renewable energy requirements for buildings

A performance-based requirement for integration of renewable energy sources in buildings could increase the uptake of all types of solar power. Performance-based approaches require that a certain percentage of a building's energy supply be provided by renewable energy, leaving the choice of renewable technology to the developer. The types of policies have been used since 2004 in the U.K., and are now widespread in many European countries.

Potential roles: Municipal, regional and national governments have implemented these types of policies in other jurisdictions.

Key benefits: Significant increase in integration of renewable energy in buildings, and a corresponding decrease in GHG emissions. In one jurisdiction, a 26% reduction in GHGs for new developments was realized following implementation of the policy

Key challenges: Implementation of the renewable energy requirement may require support from developers; however, the rule allows flexibility of choice of technology, allowing developers to select the most cost-effective technology.

Incentives or disincentives

Another common method of increasing the amount of renewable or low-emission power in a region is to use financial incentives or disincentives. These are called various different names — production incentives, feed-in tariffs, carbon taxes — but they are essentially designed to provide more revenue for low-emission or renewable sources, or higher costs for high-emission sources.

Potential roles: Governments are typically involved in providing incentives.

Key benefits: Creates price signals in the marketplace that increase considerations of environmental impact.

Key challenges: Level of impact on the market depends on the level of incentive or disincentive; incentives can be difficult for government to maintain without a dedicated funding source.

Engage consumers

Awareness could be raised or incentives provided for consumers to purchase or support green power.

Potential roles: Government, non-profit organizations, electricity marketers and green power producers are often involved in promoting lower impact electricity.

Key benefits: Additional revenue for green power producers, and increased support for producers who are building low-carbon electricity infrastructure and other policies to support low-impact electricity.

Key challenges: Paying a premium for green power likely to remain a niche market.

B.C. carbon tax

British Columbia has a carbon tax that helps to make low emission energy sources more economically attractive.

Photo: Gordon Howell

140 Matt Horne and Hayes Zirnhelt, *On-Site Renewable Energy Requirements for Buildings* (The Pembina Institute, 2010), www.greenbuildingleaders.ca.

141 City of Calgary, *Energy Mapping Study* (prepared by the Canadian Urban Institute, 2008), http://www.calgary.ca/docgallery/BU/planning/pdf/municipal_development_plan/plan_it/research/energy_mapping_study.pdf

142 Remi Charron, "A Review of Design Processes for Low Energy Solar Homes" *Open House International* 3, no.3 (2002), http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/Fr/2008-170/2008-170_TR-J_411-PVTZEH_OHI_charron_e.pdf

143 The California Energy Commission, "(Solar Millennium) Blythe Solar Power Project," November 23, 2010, http://www.energy.ca.gov/sitingcases/solar_millennium_blythe/index.html

144 Jeff Bell and Tim Weis, *Greening the Grid: Powering Alberta's future with renewable energy* (The Pembina Institute, 2009), http://pubs.pembina.org/reports/greeningthegrid-report.pdf

145 Ontario Power Authority, Progress Report On Electricity Supply Second Quarter 2010, http://www.powerauthority.on.ca/news/progress-report-electricity-supply-second-quarter-2010

146 Bell and Weis, *Greening the Grid.*

147 RetScreen International, "Solar Air Heating Project Analysis: Speakers Notes," 2009, http://www.retscreen.net/ang/speakers_notes_solar_air_heating_project_analysis.php

148 Ontario Sustainable Energy Association, *Generate Power… and Money* (2010), http://www.ontario-sea.org/Storage/45/3663_Generate_power_and_money_with_microFIT_pamphlet.pdf

149 Natural Resources Canada, Solar PV potential and insolation map, https://glfc.cfsnet.nfis.org/mapserver/pv/pvmapper.phtml?LAYERS=2700,2701,2057,4240&SETS=1707,1708,1709,1710,1122&ViewRegion=-2508487%2C5404897%2C3080843%2C10464288&title_e=PV+potential+and+insolation&title_f=Potentiel+photovolta%EFque+et+ensoleillement&NEK=e

150 International Energy Agency, "Current and Projected Costs," 2010, http://www.iea-pvps.org/pv/snapshot/costs.htm

151 California Energy Commission, *A Guide to Photovoltaic System Design and Installation* (prepared by Endecon Engineering, 2001), http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF.

152 Dina O'Meara, "Enmax Launches Solar, Wind Power Generation Project Aimed at 9,000 Alberta Homes," *Calgary Herald*, June 17, 2010, http://www.calgaryherald.com/technology/Enmax+launches+solar+wind+power+generation+project+aimed+Alberta+homes/3161837/story.html#ixzz12M8ov0L5

Photo: The Pembina Institute

Appendix A.9

Ground source heat pumps

Ground source heat pumps, or geoexchange technology, uses the relatively constant temperature beneath the surface of the earth to heat and cool buildings. Geoexchange systems are able to produce three to four units of free thermal energy from the ground for each unit of electricity input.[153] This thermal energy is typically used for space heating and cooling, but thermal energy can be harnessed for water heating and industrial processes as well.

Geoexchange technology can be scaled for residential buildings (both single-family homes and multi-unit buildings), commercial centres (including retail and office space, hotels, recreation centres and pools), institutional facilities (hospitals, schools) and industrial applications.[154]

Potential reduction

Geoxchange systems improve the overall efficiency of heating and cooling buildings and residences. Although less total energy is used to provide these heating and cooling services, there exists the potential that an increase in emissions would be associated with using geoexchange systems in place of natural gas systems. This is because the provincial electricity grid is powered in large part by coal power plants, and this would be replacing furnaces using natural gas.

Cost implications

Similar to other building-integrated sources of renewable energy, geoexchange systems typically have higher capital costs than conventional heating and cooling systems, but the increased efficiency and lower operating costs mean year-over-year savings in energy costs.

The typical costs and payback periods for geoexchange systems are listed in Table vi.

Table vi: Cost and payback for geoexchange systems[155]

System type		Average capital cost		Typical payback period
		$/sq.ft	Total cost	
Residential (2,500 sq.ft home)	Horizontal system	$9 – $11	$20,000 – $25,000	3 – 8 years
	Vertical system	$15 – $25	$30,000 – $40,000	5 – 10 years
Commercial	Horizontal system	$15 – $25	Varies depending on size of building	Immediate – 8 years
	Vertical system	$30 – $40		2 – 10 years

Planet Traveler Hotel

The Planet Traveler hotel in downtown Toronto underwent a significant renovation from abandoned building to updated, functioning hotel. A major part of the renovation was the inclusion of a vertical-loop geoxchange system that had an installation cost of $240,000. The 12,000 square foot building is now equipped with a system that delivers 6.8 MWh per year of energy, saving nearly $2,500 per month in energy costs. The building operators anticipate the investment will pay for itself in four years.[156]

Canada

Geoexchange systems are very common across Canada in both the residential and commercial sectors. Examples of installations that have improved building performance and reduced costs are numerous.

A family-owned bicycle store in southern Ontario installed a geoexchange system in its 7,200 sq.ft. facility and saved over $7,000 per year in energy costs. The system paid for itself in less than three years.[157]

Approaches to implementation

On-site renewable energy requirements for buildings

A performance-based requirement for integration of renewable energy sources in buildings could increase the uptake of all types of building integrated renewable energy, including geoexchange systems. Performance-based approaches require that a certain percentage of a building's energy supply be provided by renewable energy, leaving the choice of renewable technology to the developer. The types of policies have been used since 2004 in the U.K., and are now widespread in many European countries.

Potential roles: Municipal, regional and national governments have implemented these types of policies in other jurisdictions.

Key benefits: Significant increase in integration of renewable energy in buildings. In one jurisdiction, a 26% reduction in GHGs for new developments was realized following implementation of the policy.

Key challenges: Implementation of the renewable energy requirement may require support from developers; however, the rule allows flexibility of choice of technology, allowing developers to select the most cost-effective technology. Geoexchange does not currently reduce GHG emissions in Alberta due to the carbon intensity of the electricity grid.

Remove barriers to implementation

In some cases, barriers may exist to the implementation of geoexchange systems. The City of Toronto passed a municipal resolution facilitation the use of public land for geoexchange systems, recognizing the environmental and cost savings benefits for the building owners and the community at large. The use of public laneways to bury closed vertical loops facilitated the use of geoexchange for the refurbishment of the Planet Traveler hotel in Toronto, Ontario.

Potential roles: The City could facilitate and encourage the use of geoexchange systems through co-operation with developers and homeowners (permitting use of public lands where appropriate, facilitating permitting processes, or other).

Key benefits: Energy cost savings for building owners.

Key challenges: Availability of financing for up-front cost of geoexchange systems (including both retrofitting and new development). Geoexchange does not currently reduce GHG emissions in Alberta due to the carbon intensity of the electricity grid.

Engage consumers

Awareness could be raised or incentives provided for developers and/or homeowners to include geoexchange systems. Providing consumers information about scenarios under which geoexchange systems can be used to reduce greenhouse gas emissions would help builders and owners make the best possible 'green' choice.

Potential roles: Government, service providers and non-profit organizations, are often involved in promoting renewable energy systems.

Key benefits: Increased awareness among developers and owners about the potential cost saving and GHG benefits of geoexchange systems.

Key challenges: The greenhouse gas benefits may not be as great as other initiatives for the building sector due to the current dependence on coal power plants in the province.

153 The Pembina Institute, *Geoexchange: Energy under foot (2010)*, www.pembina.org/pub/2049.

154 Ibid.

155 Ibid.

156 The Pembina Institute, *Geoexchange: Energy under foot.*

157 Geothermal Heat Pump Consortium, *Braun's Bicycle Store Kitchener, Ontario* (2010), http://www.geoexchange.org/index.php?Itemid=25&option=com_docman

Photo: The Pembina Institute

Photo: The Pembina Institute

Appendix A.10

Personal mobility choices

(personal vehicles, transit, walking and cycling)

The mode of transportation that citizens in Calgary choose for everyday activities has the potential to significantly impact the fuel use and GHG emissions attributed to the transportation sector. This section identifies the opportunities for the City and its citizens to reduce the amount of vehicle travel that occurs by encouraging people to use less fuel-intensive means of transportation (e.g. walking, bicycling, riding a bus or train, carpooling or telecommuting).

In 2006, 75% of commuters in Calgary used a personal vehicle to get to and from work, 24% of commuters traveled by transit, and 7% walked or cycled as shown in Figure xii.

Transit trips in The City of Calgary increased by 18% from 2001 to 2006 (shown in Figure xiii). This is almost double the population growth of 10%, while the City improved transit service at approximately the same rate as population growth — transit service hours and vehicle kilometres increased by 11%.[158]

Transportation mode choices are impacted by a number of factors including speed, convenience, cost, access, the location of the destination and the purpose of the trip. A lot of these factors are themselves impacted by the design of the city and the type of transportation infrastructure that is developed (e.g., roads, transit, pathways and sidewalks).

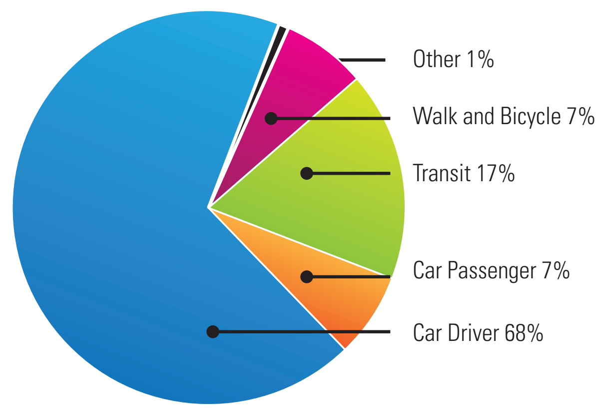

Figure xii: Commuting mode share in Calgary (2006)[159]

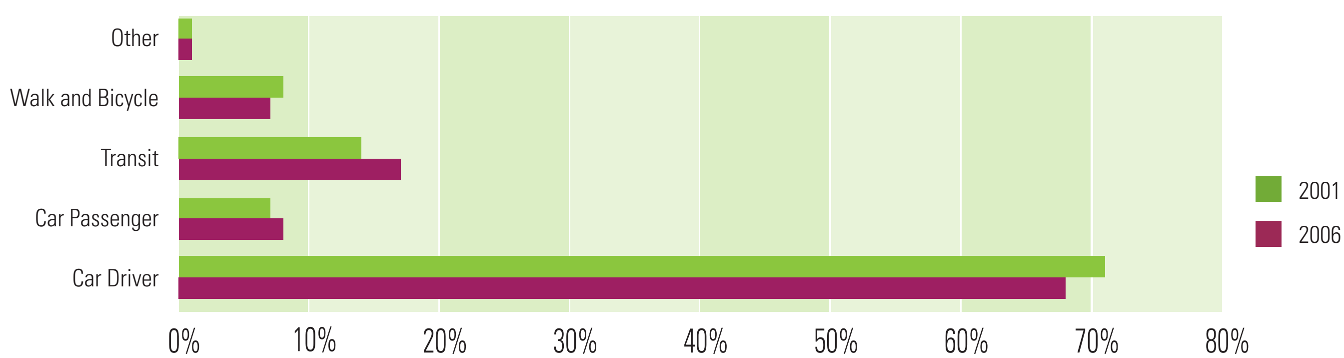

Figure xiii: Change in commuting mode share in Calgary from 2001 to 2006[160]

Densities in Calgary

Calgary suburbs in the 1960s to 1980s had densities of 4 to 6 units per acre, or about 25 to 37 people per hectare when assuming 2.5 people per unit. By the 1990s and 2000s, the densities rose to 6 to 8 units per acre or about 37 to 50 people per hectare (assuming 2.5 people per unit). This was mostly achieved by increasing the percentage of multi-family dwelling from 15 to 25%. Current plans include densities between 8 and 12 units per acre, or about 40 to 60 people per hectare when assuming 2 people per unit, with multi-family units making up 25 to 60% of the dwellings.[161]

Calgary's new Municipal Development Plan calls for 100 people or jobs per hectare within 400 metres of the primary transit network, and 200 people or jobs per hectare within Major Activity Centres or Urban Corridors. The MDP provides targets of 60 people and jobs per gross developable hectare for new communities in future greenfield areas. In addition to the intensity threshold, minimum residential density must be in conformity to the Calgary Metropolitan Plan, which requires that new communities achieve a minimum density of 8 to 10 units per gross residential acre. The city-wide target for 2070 is 45 people or jobs per hectare.

Kelowna

The City of Kelowna, B.C., is promoting smart growth and compact development through the use of varied development cost charges (DCC) that are levied against new development and paid by the developer. Two factors determine the charge: density and geographic location. In general, higher-density development that is close to the downtown core is charged a lower DCC compared to single-family development located at the periphery of the city. The program is allowing the City to optimize its infrastructure investments.[162]

Land use and urban design

This section considers how personal mobility choices can be impacted by land use and transportation design at a neighbourhood and city or regional scale.

Key variables that impact the use of personal automobiles and greenhouse gas emissions include:

- **Socio-economic** – In general, greater income and number of cars per household is associated with increases in vehicle kilometres travelled (VKTs) per capita or household.
- **Locational** – Increased distances from the Central Business District is associated with an increase in VKTs, while improved transit options and greater mixes of land uses and job opportunities in neighbourhoods are associated with a decrease in VKT.
- **Neighbourhood design** – Increased housing density, mixing land uses, the opportunity for local shopping opportunities adjacent to population centers, increasing the number of intersections per road km, and the availability of bike lanes and recreational paths are associated with decreases in VKTs. Neighbourhoods adjacent to wide arterial roads or with a curvilinear internal road layout are shown to increase VKTs.[163] The availability of parking also impacts vehicle ownership and VKTs.

Potential reduction

Neighbourhood development that is situated adjacent to a major transit system, is designed to support pedestrian and bike uses, and includes a mix of land uses has reduced vehicle kilometres traveled by 10 to 30%, per site. Reductions in VKTs of up to 50% have been shown when these neighbourhood design features are combined with infill and redevelopment of existing land, though the results depend on the density and location relative to key destinations and transit features.[164] Table vii shows the opportunities for reducing VKTs from the implementation of site-specific neighbourhood design features.

Table vii: VKT reductions through neighbourhood design

Neighbourhood design feature	Percent reduction in VKTs per site
Transit Oriented Development	10 – 30[165]
Pedestrian Oriented Design	1 – 10[166]
Pedestrian design combined with bike facilities	5 – 15[167]
Mixed-use development	5 – 20[168]
10 % increase in population density	1 – 3.5[169]

A regional or city-wide approach to land and transportation planning that locates new development around multiple transit corridors coupled with other improvements to transit frequency and options has the potential to reduce total regional VKTs by 2 to 5%,[170,171] while the addition of comprehensive smart growth planning has been shown reduce total VKTs by up to 20%.[172] For example, analysis completed for The City of Calgary's Plan It process during the development of its Municipal Development Plan revealed that over the course of the next 60 to 70 years, VKTs could be reduced by 33% if all new development was added to existing areas.[173]

Cost implications

Taking into account vehicle depreciation, the fixed costs of car ownership in Canada averages between $6,000 and $9,000 per year, depending on the type of car, insurance plan, and financing options utilized by the owner. Table viii shows average annual operating costs per kilometre of driving, a figure that varies from approximately 8 to 13 cents.[174]

Table viii: Average annual operating costs for personal vehicles

	Operating cost (cents per kilometre)		
	Cobalt LT	**Grand Caravan**	**Prius Premium**
Fuel	8.14	11.82	3.89
Maintenance	2.36	2.82	2.61
Tires	2.10	2.16	1.70
TOTAL	12.60	16.80	8.20

Note: Based on 18,000 km of driving per year using regular, unleaded gasoline at an average national gas price of $1.02 per litre.

Research indicates that households located in automobile dependent areas devote more than 20% of household expenditures to transport (totaling over $8,500 annually), while those in more compact, smart growth-type communities spend less than 17% (under $5,500 annually). Vehicle expenditures provide little long term economic value: $10,000 spent on motor vehicles provides $919 in equity, compared with $4,730 for the same investment in housing. [175]

Urban development patterns can significantly impact the capital and operating costs of road network infrastructure. More often than not, these municipal expenditures are downloaded to the taxpayer.

Analysis completed during the Plan It Calgary process revealed that the business-as-usual dispersed pattern of development would require an estimated 3,300 km of new high-capacity roads. In contrast, the compact scenario is estimated to require 1,900 km of new high-capacity roads, a difference in capital costs of $5.3 billion. The dispersed scenario requires more new roads associated with greenfield development whereas the more compact scenario puts more emphasis on redevelopment, which makes use of existing roads.[176]

With respect to road maintenance and operating cost, the more compact scenario is estimated to cost 10% less than the dispersed scenario over the next 60 years. The difference in cost is estimated to be approximately $40 million per year.[177]

Greater Toronto

An analysis of opportunities to expand the rapid transit service and transit oriented development in the area of Greater Toronto serviced by Metrolinx indicates that a 5% increase in population living within 500 metres of a rapid transit stop led to a 3% increase in ridership and a corresponding 3% decrease in VKTs. A similar population increase of 25% generated a 23% improvement in transit ridership, with a corresponding reduction in VKT.[178]

A separate study of transportation mode choice in 1,717 traffic zones in the Greater Toronto Area shows that the automobile is the transportation mode of choice on an average of 80% of trips. In neighbourhoods that feature a mix of land uses and close proximity between jobs, residences and amenities, the average mode share of the car drops to 63%. Those areas that have rapid transit and a mix of land uses have an automobile mode share of 44%.[179]

Photo: City of Calgary

Transit, cycling and walking — mode-specific opportunities

This section identifies the opportunity for reducing personal automobile trips from mode-specific actions.

Potential reduction

Transit

Investments in transit improve accessibility and ridership levels, and include increasing existing service levels, enhancing operational characteristics and providing incentives to encourage greater transit ridership. It is estimated that with each 1% growth in service levels (increased transit vehicle coverage and expanded operating hours), average ridership increases by 0.5%, while the implementation of one bus rapid transit corridor route can reduce the VKT in the area by 1 to 2%.[180]

Cycling

Bicycle programs can include a variety of initiatives to increase the safety and accessibility of cyclists, including designated and grade-separated bike lanes, improvements to signage and traffic signals, and the provision of bicycle parking and storage. Research suggests that each 1.6 km of bikeway installed per 100,000 residents increases bicycle commuting by 0.075%.[181]

Pedestrian environments

Pedestrian-oriented design improves the overall pedestrian environment by making walking easier, safer and more attractive. A key outcome is the replacement of automobile trips with walking, particularly for short trips. Research suggests that pedestrian design can reduce local, area-specific VKTs by 1 to 10%.[182]

The provision of safer pedestrian environments in school service areas coupled with education and awareness programs can encourage parents and children to walk and bike to school, reducing the VKTs attributed to school transportation by up to 5%.[183]

Cost implications

A cost-benefit analysis of walking and cycling track networks compared to the use of the automobile indicates that the benefits are at least 4 to 5 times greater than the costs. The study took into account health benefits, reduced air pollution and noise from road traffic, and reduced parking costs.[184]

Telecommuting

Potential reduction

Research conducted in 2005 attributed a national energy savings of 0.01 to 0.4% in the United States and 0.03 to 0.36% in Japan to telecommuting practices. In a future scenario where 50% of information workers

Minneapolis

The City of Minneapolis, Minnesota, has committed to providing abundant bicycle facilities. The city parking budget includes $40,000 each year for bicycle parking and a 50/50 cost share program helps local businesses who are interested in providing bike racks. Minneapolis ranks highest amongst U.S. cities in the provision of bike parking facilities, with 453 spaces per 10,000 people. Approximately 2.5% of trips to work are completed by bicycle.[186]

Vauban District

40% of households in a new development in Freiburg, Germany do not own a car as the development was built with limited parking, good access to transit and a car sharing system.

Calgary

Calgary Economic Development is promoting the 'WORKshift' initiative and piloted a program with municipal staff at the City in 2007. In four months where 100 employees engaged in part-time teleworking, 656 fewer commute trips were taken, which saved approximately 80,000 kilometres of driving.[187]

telecommute four days per week, the U.S. and Japan national energy savings are estimated be 1% in both cases.[185]

Cost implications

Telecommuting is generally associated with cost savings for both employees and employers except in cases of very high infrastructure costs coupled with relatively low usage.

Common approaches to implementation

Land use and transportation planning

Land use and transportation planning can be used to establish the type of development that occurs within the city and the type of transportation infrastructure that is developed.

Potential roles: The municipal government is primarily responsible for land use and transportation planning; however, land owners and community stakeholders also have an impact through how they develop their property and through their influence on city decision-making. The provincial government also has an ability to influence land use and transportation planning, which can be of particular importance when it comes to planning at a regional scale.

Key benefits: Cost savings; already incorporated as part of the city's new MDP and CTP.

Key challenges: Changes from current community design.

Pricing

The way transportation options are priced has a significant impact on mode choice. For example, the use of roads and most parking is paid for indirectly rather than directly so costs are hidden from users.

There are various different methods for changing the pricing of various transportation modes. These include pay-as-you-drive insurance, parking and road pricing, and fuel surcharges.

- **Pay-as-you-drive insurance** – Research suggests that the implementation of programs that base accident insurance on the number of kilometres travelled have the potential to reduce VKTs by 8 to 10%.[188,189] Implemented nationwide in the U.S., these programs could potentially reduce GHG emissions by 2% along plus decrease auto insurance costs for approximately two-thirds of consumers.[190]
- **Parking programs** – Increasing the rates to park downtown has been shown to decrease the numbers of drivers into a city's core area from between 15 and 30% per site.[191] Other studies indicate the potential for a 2.2% reduction in VKT from work commuting trips over 10 years,[192] or that a 1% increase in parking price corresponds to a 0.07% decrease in drivers.[193] Research suggests that financial incentives given to employees for not driving to work can decrease parking demands by an average of 24%. The average cost per employee was $47 per month.[194]

Toronto

Analysis completed for Metrolix assessed the impact of increasing the cost of driving a personal vehicle by 400%. Such an increase is double the projected increases in cost due to other factors such as carbon pricing and the increased cost of fuel. The results projected a 9% increase in transit ridership and an 8% decrease in automobile VKT by 2031 under this scenario.[197]

Kelowna

The City of Kelowna, B.C., is promoting smart growth and compact development through the use of varied development cost charges (DCC) that are levied against new developments and paid by the developer. Two factors determine the charge: density and geographic location. In general, higher-density development that is close to the downtown core is charged a lower DCC compared to single-family development located at the periphery of the city. The program is allowing the City to optimize its infrastructure investments.[198]

Whitehorse

In 2006, the City of Whitehorse implemented a 'Wheel 2 Work' campaign that uses social marketing to promote active transportation in the summer months. The program is designed to complement bicycle network and facility investments so that citizens use the new infrastructure to its full potential. During the program's first summer, 210 registered participants logged over 40,000 km of bike travel. In total, the program is estimated to have offset approximately 4.5 tonnes of CO_2e.[204]

- **Road pricing** – Though there are a number of different options for program design, road tolling is estimated to reduce VKT between 1 and 15%.[195,196]
  - Research suggests that a price of 5 to 12 cents per kilometre could reduce emissions by 4 to 8% in U.S. cities. In the U.K., a price of approximately 32 cents per kilometre is estimated to reduce trips by 10%.[199]
  - Cordon pricing is estimated to reduce VKT by 2.8% in 10 years, while congestion pricing is estimated to reduce VKT by 2.3% in 10 years.[200]
- **Fuel pricing** – The addition of a 10% tax in fuel prices can decrease VKT by 2.7% in the short term and by 7% in the long term.[201,202]

Potential roles: Prices of fuel, parking and insurance are set by private industry, but can be influenced or added to by the provincial or federal governments. Road pricing is typically done by the level of government that operates the road (i.e., municipal or provincial governments).

Key benefits: Potential for more direct market signals.

Key challenges: Increases direct cost of driving.

Citizen information and awareness campaigns to promote alternative transportation

Research suggests that information and awareness campaigns are important in supporting citizen and commuter choices to use alternative transportation. For example, the implementation of rideshare and transit promotion programs is estimated to decrease GHG emissions from transportation fuel by 2% in 2015 from year 2000 levels.[203]

Potential roles: Municipal, provincial or federal governments, or community and non-profit organizations could launch information campaigns to promote alternative transportation.

Key benefits: Politically attractive; promotes choice.

Key challenges: Programs can be costly; results limited without associated investments in alternative transportation infrastructure.

Calgary Region Transit Plan

The Calgary Regional Partnership has developed a Regional Transit Plan to encourage greater use of transit outside of Calgary.[205]

Sutton, U.K.

The Smarter Travel Sutton program uses social marketing, school and workplace travel planning, car co-op advertising and a host of other information and awareness events. The three-year program had a total budget of $5 million GBP. Notable behavioural changes as a result of the program include a 75% increase in recorded cycle traffic at counter locations and a 1.5% increase in cycling mode share from 2006 to 2009. The mode share of 'walk all the way' trips increased by 3% in the same period, and bus patronage rose by 16%.[206]

Photo: City of Calgary

158 Canadian Urban Transit Association, *Canadian Transit Fact Book: 2002 Operating Data*, 2002.

159 Statistics Canada, "2006 Community Profile, Calgary, Alberta," http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/details/page.cfm?Lang=E&Geo1=CSD&Code1=4806016&Geo2=PR&Code2=01&Data=Count&SearchText=Calgary&SearchType=Begins&SearchPR=01&B1=Place%20of%20work&Custom=

160 Alison Bailie and Claire Beckstead, *Canada's Coolest Cities: Calgary Case Study* (The Pembina Institute, 2010), http://www.pembina.org/pub/2022.

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Photo: City of Calgary

Appendix A.11

Vehicle efficiency, drivetrain technology and fuels

There is considerable opportunity to achieve reductions in GHG emissions through vehicle efficiency (e.g., lighter vehicles, more efficient engines), drivetrain technologies (e.g., hybrid electric, electric and natural gas vehicles) and alternative fuels (e.g., biofuels).

Vehicle efficiency

For the past thirty years Canada has had a voluntary policy for fuel efficiency improvements from cars and light trucks as shown in Figure xiv.

Potential reduction

Figure xv shows that several countries have been able to increase fuel efficiency standards considerably above Canadian levels. Experience in the European Union shows that efficiency standards can be achieved that are almost double the current Canadian standard.

Consideration is also being given to reducing fuel consumption in heavy-duty trucks by 20% through better engines and tires, and more aerodynamic truck cabs.[207]

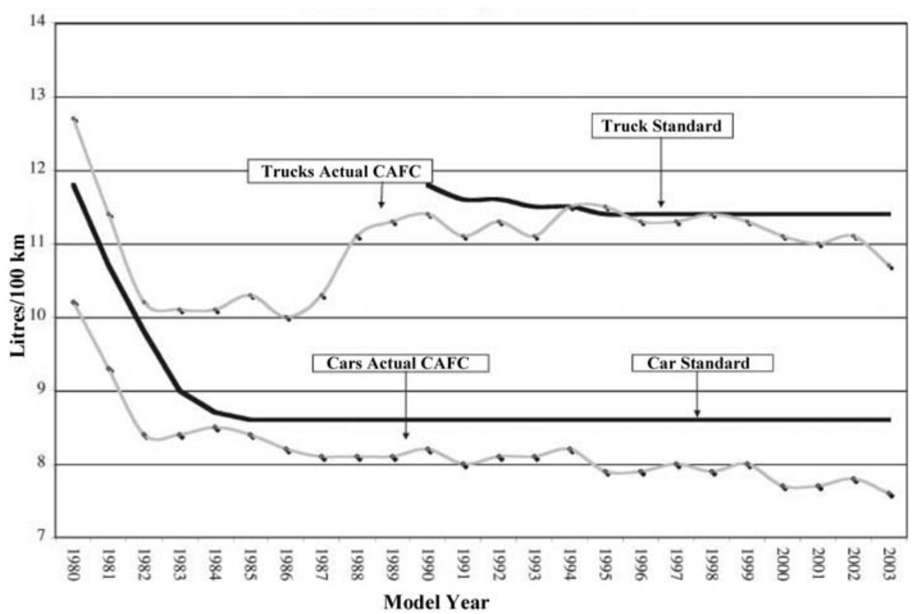

Figure xiv: Actual Corporate Average Fuel Consumption versus fuel consumption standards in Canada[208]

Note: The two solid lines represent CAFC standards for cars and light trucks respectively. The two gray lines represent fleet-average fuel consumption level achieved separately by cars and light trucks. When achieved fuel consumption levels are lower than the standards, it indicates that companies are able to meet the standards; otherwise, they would be subject to financial penalties.

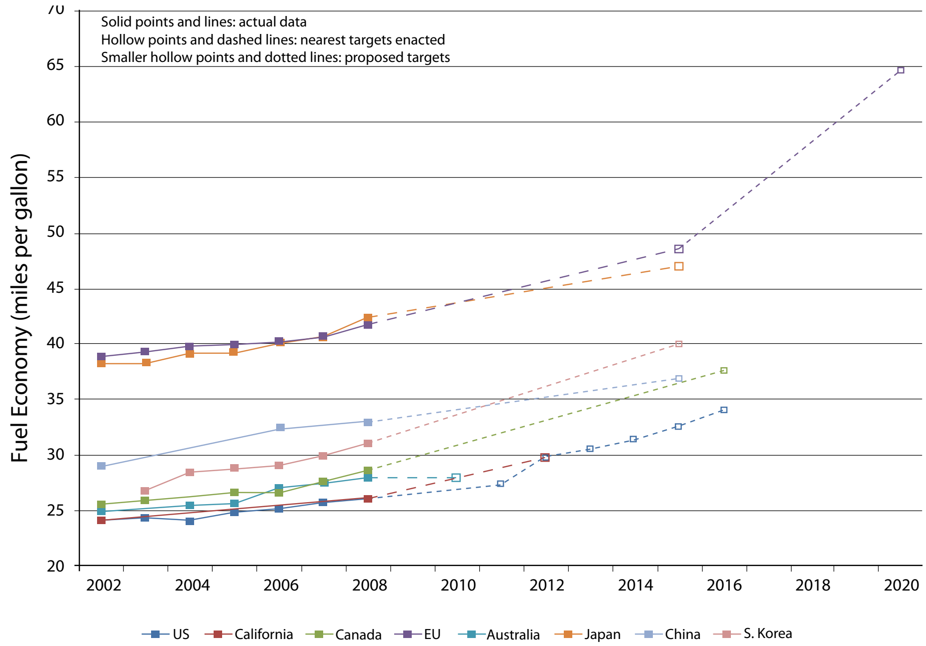

Figure xv: Comparison of prospective national fuel economy and GHG emission standards.[209]

Cost implications

In the United States, recent improvements to federal CAFE standards are projected to increase vehicle costs by $52 billion but save $240 billion from lower fuel bills, less traffic and reduced health care costs (from lower soot and particulate emissions).[210] The average cost of a vehicle will increase by $950 US but the payback period to offset these costs would be three years. Lifetime net savings are projected to be $3000 for a 2016 model year vehicle.[211] Similarly, the emerging B.C. fuel efficiency standards are expected to save consumers $5,000 over the life of the vehicle through reduced fuel consumption.

Drivetrain technologies

Hybrid electric vehicles

Potential reduction

Hybrid electric cars are 34 to 60% more efficient at converting energy to motion than conventional vehicles.[212] Hybrid electric delivery trucks can reduce GHG emissions by 25% compared to conventional diesel delivery trucks.[213]

Cost implications

Hybrid electric vehicles typically cost $5,000 more than conventional vehicles, with a payback period of eight years from gasoline savings.[214] Hybrid electric delivery trucks can save 35 to 42% in fuel costs compared to their diesel counterparts,[215,216] although they can cost 35 to 45% more than conventional delivery trucks.[217] Medium-duty work trucks can have a return on investment in three to five years while costing $30,000 more than their diesel counterparts.[218]

Rebates for fuel-efficient vehicles

The Ontario Ministry of Transportation has a four-year $15 million Green Commercial Vehicle Program to offset the purchasing costs of hybrid and alternative-fuel vehicles for commercial fleets. Up to one-third of the capital costs of a hybrid or alternative fuel vehicle could be reimbursed.[219]

Electric vehicles

Potential reduction

Fully electric cars are 80 to 90% more energy efficient than conventional cars from a vehicle perspective, but overall energy efficiency depends on where the electricity comes from.[220,221] In Alberta, where the majority of electricity comes from burning coal, generating electricity is approximately three times more carbon intensive than burning gasoline. As a result, EVs in Alberta are expected to generate about one-third fewer GHG emissions than gasoline cars given today's technology. If wind power was largely used to charge the vehicles, EVs would emit up to 90 % fewer emissions than conventional cars, depending on the vehicle.[222] Tailpipe emissions for electric vehicles are zero.

Cost implications

Electric passenger vehicles can range in price from $11,000 to $110,000.[223] The typical cost for an electric plug-in conversion from a conventional gasoline engine is $15,000.[224]

In Alberta, a plug-in hybrid electric vehicle could save $1,070 to $1,542 in fuel costs per year.[225,226] Electric short-haul freight trucks can save up to 75% in fuel costs compared to typical diesel freight trucks.[227]

Natural gas vehicles

Potential reduction

Compressed natural gas in light-duty vehicles reduces GHG emissions by around 25% relative to gasoline.[228]

Cost implications

Depending on the price spread of natural gas and gasoline, the cost of the natural gas vehicle and the annual mileage can vary considerably (Table ix). The expected payback could be 2 to 30 years depending on the cost of gasoline, vehicle incremental cost and the annual kilometres travelled. Using compressed natural gas in urban delivery vans has been shown to reduce fuel costs 32% relative to gasoline.[229]

***Table ix: Range of payback times for CNG light-duty vehicles (average and high-milage cases)*[230]**

		Payback time (years)			
		20,000 km / year		55,000 km / year	
	Incremental cost	**$3,000**	**$7,000**	**$3,000**	**$7,000**
Fuel price spread	0.15	13	30	5	11
	0.4	5	11	2	4

**Fuel price spreads between gasoline and CNG are on a litre of gasoline equivalent (Lge) basis. Table assumes 7.8 L/100 km.*

Rebates for fully-electric vehicles

The Government of Ontario has the goal of having one in twenty vehicles be electrically powered by 2020. To do this, they are providing rebates of $5,000 to $8,500 for individuals, business and organizations that purchase or lease a new plug-in hybrid electric or battery electric vehicle.[231]

Photo: Nissan

City of Ottawa hybrid transit buses

The City of Ottawa over the course of two years bought 175 hybrid electric buses. The city expects to reduce carbon emissions by 30% and pay off the cost of the buses within six years through anticipated fuel savings.[232]

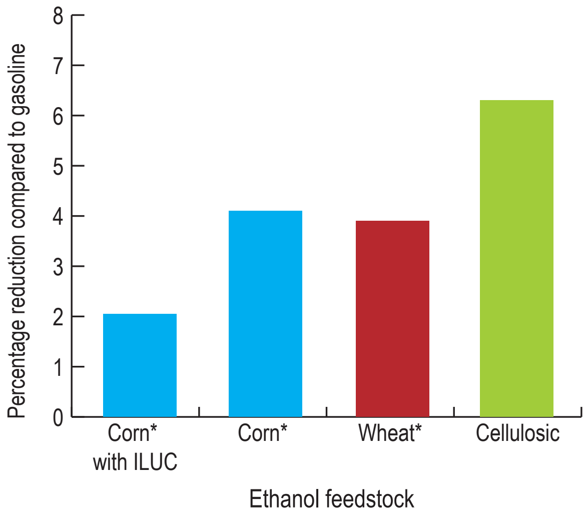

Figure xvi: Life cycle GHG emissions reduction for 10% ethanol in gasoline (e10) compared to gasoline only

Note: Life cycle emissions reductions from the production of ethanol and biodiesel have the potential to decrease when emissions from indirect land use change (ILUC) are considered. This is an emerging field of research and has only been presented here for corn-based ethanol as estimates for other feedstocks from dedicated cropland are not as readily available.

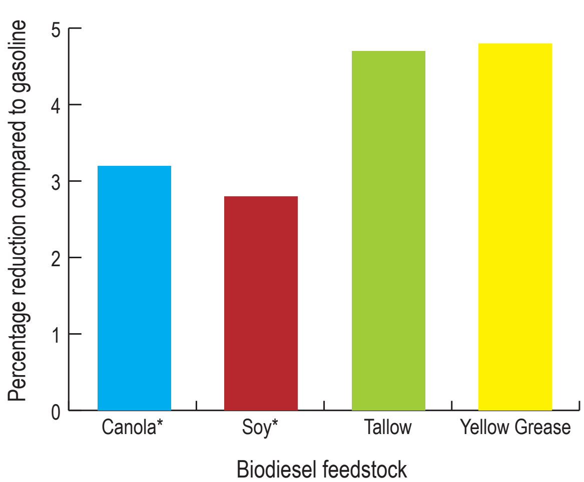

Figure xvii: Life cycle GHG emissions for 5% ethanol in gasoline (B5) compared to diesel only

**See note from Figure xvi.*

Alternative fuels

Biofuels

Potential reduction

Ethanol can be blended with gasoline up to 10% and used in current gasoline engines. There are also vehicles currently being sold that can run on any blend up to 85% ethanol. For biodiesel, up to a 100% blend can be used in most current diesel engines, although most manufacturers only warranty up to a 5% blend. Both the provincial and federal governments have indicated they will require an average of 5% ethanol in gasoline and 2% biodiesel in diesel.

Work commissioned by Natural Resources Canada[233] estimates that adding 10% ethanol to gasoline can reduce life cycle greenhouse gas emissions by between 3.9 and 6.3% depending on the ethanol feedstock as shown in Figure xvi.

New research reported by the California Air Resources Board[234] and the U.S. Department of Energy[235] indicates that these emission reductions could be overstated if the feedstocks are derived from dedicated cropland. Using dedicated cropland could result in land being converted to cropland in other parts of the world, a process that typically releases large amounts of greenhouse gas emissions from the existing vegetation and soil. An estimate of the impact of these emissions from indirect land use change (ILUC) are presented on Figure xvi for corn-based ethanol. ILUC emissions are relevant to all crops derived from dedicated cropland; however, estimates of the scale of impact for all of the crop-based feedstocks are not readily available and have not been included here. Cellulosic feedstocks such as wheat straw are not expected to contribute substantially to ILUC as they typically do not create the same incentive for developing new cropland.

Similarly, work commissioned by Natural Resources Canada estimates that adding 5% biodiesel to diesel fuel can reduce life cycle greenhouse gas emissions by between 2.8 and 4.8% depending on the biodiesel feedstock as shown in Figure xvii.

Again, the emissions reduction estimates for feedstocks from dedicated croplands are likely to decrease once ILUC considerations are added to the analysis.

Cost implications

The Government of Canada recently published an analysis of the cost impact of the proposed Renewable Fuel Standard requiring an average of 5% ethanol in gasoline. The most significant cost impact identified for consumers is that they would need to buy 2.2% more fuel to go the same distance as before, because a litre of ethanol has less energy than a litre of gasoline.

The total cost of reducing GHG emissions through the federal Renewable Fuel Standard is estimated to be at least $340 per tonne CO_2e,[236] not including other government incentives, while the total cost to reduce emissions using ethanol in the United States is estimated at more than \$700 per tonne CO_2e.[237]

Common approaches to implementation

Vehicle efficiency, vehicle technology and fuels share three major avenues for implementation — legislation, incentives and information.

Legislation

Vehicle fuel efficiency standards

For the past thirty years, Canada has had a voluntary policy for fuel efficiency improvements from cars and light trucks.[238] Modest increases in fuel efficiency have occurred over this time.[239]

Recently, the Government of Canada has announced plans to harmonize with the U.S. fuel efficiency standards.[240] This will result in a reduction of GHG emissions from light-duty vehicles of 25% from 2008 levels by 2016.[241] Heavy truck fuel efficiency standards are also expected, although not until 2014.[242] Quebec and B.C., on the other hand, both have fuel efficiency standards that match California's more stringent fuel economy standard, which are estimated to improve average efficiency for new cars by 30% compared to current vehicles.

As described above, fuel efficiency standards from Japan and the European Union are nearly double current Canadian standards.

Potential roles: Vehicle efficiency standards have been regulated at both federal and provincial levels.

Key benefits: Guaranteed minimum fleet efficiency; cost savings for consumers.

Key challenges: Political will; fleet turnover is approximately 15 years.

Renewable fuel standards

In Canada, federal regulations require 5% renewable content in the gasoline pool. A 2% requirement for renewable content in diesel has also been announced for 2012. Similar timelines and targets are expected from the Alberta government. The Unites States has had a federal renewable fuel standard since 2005 that requires 8.25% renewable content for both gasoline and diesel by 2010.[243]

Potential roles: Renewable fuel standards can be regulated at both federal and provincial levels.

Key benefits: Guaranteed biofuel uptake.

Key challenges: Currently a relatively high cost per tonne of GHG reduction; uncertainty of GHG reductions and impact on food markets.

Low carbon fuel standard

The low carbon fuel standard (LCFS) regulates the life cycle emission of transportation fuel. California has had an LCFS since 2009 that aims to

Biodiesel at container terminal

TSI Terminal Systems is a container terminal operator in Vancouver. In 2004, TSI began a biodiesel project that has seen overall GHG emissions decrease by 30%. Of the 8 million litres of diesel the company uses per year, over 1.5 millions litres are now biodiesel.[244]

Photo: The Pembina Institute

Biofuel feasibility studies

The Government of Canada's Biofuels Opportunities for Producers Initiative assisted agricultural producers in developing business proposals and feasibility studies on biofuels. The program ran from 2006–2008 and funded 121 projects for a total of \$18.2 million.[245]

Rebates for fuel-efficient vehicles

The Green Levy is currently applied in Canada to all passenger vehicles with a fuel consumption rating of 13 or more litres / 100 km and is imposed at rates between $1,000 and $4,000. Most current passenger vehicles have a fuel consumption of 5.6 to 15 litres / 100km. On the incentive side, the ecoAUTO Rebate Program provided a cash incentive of $1,000 to $2,000 towards the purchase or lease of a fuel-efficient vehicle (less than 8.1 litres / 100km). The program lasted from 2007 to 2008 and issued 169,800 rebates totaling $191.2 million, creating an estimated 0.01 to 0.03 Mt annual reduction in GHG emissions, which is a very high cost per tonne of GHG reduction.[249]

Preferential loan rates for fuel-efficient vehicles

Vancity offers a Clean Air Auto Loan that encourages customers to buy fuel-efficient cars by giving preferential loan rates. The bank offers loans for prime plus 1% for vehicles that emit at least 50% less CO_2 than average and prime plus 2% for vehicles that emit at least 33% less CO_2 than average. Choosing a fuel-efficient vehicle can eliminate 18 tons of CO_2 emissions and cut gasoline costs by $1,500 over five years.[250]

Transport Canada

Transport Canada's ecoTECHNOLOGY for Vehicles (eTV) program works to increase Canadians' awareness of these vehicle efficiency technologies through outreach events, technology articles, newsletters, interactive websites, a technical glossary, educational curricula and other demonstration and development activities.[251] eTV also connects industry and government, working to identify and address potential market barriers to the introduction of promising new passenger vehicle technologies in Canada. eTV is a four-year $15 million initiative that is expected to reduce annual GHG emissions by 0.09 to 0.56 Mt in 2012.[252]

reduce GHG emissions by 10% by 2020.[246] Ontario and British Columbia are both considering modified versions of California's policy.[247]

Potential roles: Low carbon standards can be regulated federally and provincially.

Key benefits: Creates a market for low carbon fuel.

Key challenges: Limited information on life cycle data for certain sectors and fuel sources; unproven policy that has not yet demonstrated success; difficulty in accounting for indirect land use change.

Incentives

Feebate programs

Feebate programs are revenue-neutral programs that use fees on less fuel-efficient vehicles to fund rebates on more efficient vehicles. This policy can theoretically create the same changes as fuel economy standards but without the regulation. Studies have shown that a feebate rate of $500 per 2.35 litres /100 km produces a 16% increase in fuel economy, while a $1000 per 2.35 litres /100 km results in a 29% increase.[248]

Potential roles: Any sector could provide incentives, but these are typically offered by governments, most commonly at the federal and provincial levels for vehicles.

Key benefits: Begins to shift purchasing habits; can support early market entry of new technologies.

Key challenges: Relatively high cost per tonne of GHG reduction if not funded significantly through fees on less-efficient vehicles.

Supporting activities

Business development

Government-sponsored programs can assist biofuel producers, distributers and retailers, and efficient vehicle technology producers in business development. As many of these companies face market entry barriers, business development grants can help to level the playing field with traditional fossil fuel-based players.

Education

Raising awareness of lower carbon vehicles and fuels is another method to reduce GHG emission. This can be achieved through websites, publications, technology demonstrations and carbon labelling.

Potential roles: Any sector can provide supporting activities such as business development and education, although typically these have been managed by provincial and federal governments.

Key benefits: Can assist the implementation of other approaches.

Key challenges: Sometimes difficult to connect direct GHG reductions from these activities.

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Photo: The Pembina Institute

Appendix A.12

Vehicle operation

Besides vehicle efficiency, vehicle technology and fuels, significant and low-cost GHG emission reductions can be achieved by changing the way the vehicle is operated. These changes include adjustments to driving behaviour and equipment to reduce idling.

Opportunities for on-road vehicles are presented first while opportunities for rail yards follows.

Driving behaviour

Modifying driving practices can demonstrably save fuel, which reduces costs and pollution. Examples include reducing idling while parked, avoiding aggressive driving, observing speed limits, removing excess weight, keeping the engine well-tuned, keeping tires properly inflated and using the recommended grade of motor oil. (See Table x for more detail.)

Potential reduction

Drivers can reduce their fuel use by up to 33% by using fuel efficient driving techniques and keeping their car well-maintained.[253] Larger-scale demonstration of this is most often seen in commercial fleets where driver engagement programs have shown 10 to 20% reduction in fuel use.[254] Programs aimed at the general public, on the other hand, are estimated to achieve 1 to 2% in GHG reductions.[255]

Table x: Driver practice modifications and potential fuel savings[256]

Driving practice	Fuel Savings (%)
Keeping engine well-tuned	4
Tires properly inflated	< 3
Using recommended grade of motor oil	1 – 2
Driving sensibly (not aggressively)	5 – 33
Observing speed limit	7 – 23
Removing excess weight	1 – 2 (per 100 lbs)

Cost implications

Reduced fuel consumption through driving efficiency has a direct reduction in fuel costs and in wear and tear on a vehicle. If drivers employed more sensible driving practices (respecting speed limits, slower acceleration and braking), they could potentially save $600 per year.[257]

Anti-idling

An anti-idling pilot project resulted in motorists reducing their idling by 32% and their idling duration by 73%. This was done using both signs and personal commitments to reduce idling.[258]

Dozens of municipalities in Canada have adopted anti-idling bylaws in an attempt to improve local air quality, save on fuel costs and reduce GHG emissions. For example, Toronto limits idling to no more than three minutes in a sixty-minute period.

Neptune Food Services

Neptune Food Services supplies restaurants and institutions throughout British Columbia with food products and equipment. They decided to install on-board computers in all 98 of their trucks and found they could reduce their idle time and save fuel costs. Neptune used a full suite of driver education programs including communications through voice-mail, personal follow-up on drivers' records from the program, and an incentive program that gives bonuses to drivers that reduce idling time. As a result, fuel usage dropped by 16%: 7% from anti-idling technology and 9% from driver education.[259]

Emission-reducing equipment for on-road vehicles

In addition to reducing idling through driver behaviour and vehicle maintenance, idling of delivery vehicles can be reduced through the use of specialized equipment such as electrical plug-ins in loading bays, auxiliary power units on trucks to allow refrigeration units to continue running without using the truck engine, and onboard computers that help drivers with speed management, optimum shifting, optimum route selection and idle reduction.

Potential reduction

Plug-in refrigeration units have demonstrated fuel savings of over 60%. Onboard computers have been shown to reduce carbon emission by 13%.[260]

Cost implications

Hybrid trailer refrigeration units and onboard computers have a payback of 15 and 18 months, respectively.[261]

Common approaches to implementation

There are several methods to achieve emission reductions through modifying driving behaviour and reducing idling time. There are also many additional benefits that are common to all of the approaches, including cost savings, reduced vehicle repair and maintenance costs from more efficient operation, and increased longevity of equipment due to reduced wear and tear.

Fleet programs

Fleet operators in Calgary could be engaged to establish driver training programs such as those offered by the federal government (ie. SmartDriver in the City) or other private fleets. This program could also include the engagement of fleet managers on the benefits of planning trips with closer-to-full loads.

Potential roles: The participation of fleet operators is essential to engaging commercial drivers. Governments, particularly at the federal level, have been important supporters of driver engagement.

Key benefits: Demonstrated success for commercial fleets; positive return on investment for fleet operators; can provide clear expectations to drivers.

Key challenges: Creating buy-in within companies; longevity of behavior change unknown.

Logistics management

Loading for maximized efficiency is another potential area for GHG emission reductions. Inefficient loading is more likely within urban regions, which the Centre for Sustainable Transportation recommends as a worthwhile short-term focus.[262] Filling trucks one-quarter full uses

Government of Canada fleet training

The Government of Canada's ecoEnergy for Fleets Program uses SmartDriver training workshops and Fuel Management 101 workshops to promote greater uptake of vehicle energy efficiency practices among vehicle operators and managers of Canada's commercial and institutional vehicle fleets.[263] The federal government has allocated $22 million over four years and expects to generate 0.16 Mt reductions in national GHG emissions as a result of this program, as well as about 60 million litres in fuel savings. ecoEnergy for Fleets had 7,500 participants in 2009–2010.[264]

Transport Canada operates a SmartDriver in the City program that focuses on fleets that operate within a 100 km radius of their head office.[265] SmartDriver also has specific curricula for transit and school bus fleets.

Heathrow Airport logistics management

Truck activity servicing retail operations at Heathrow airport was reduced by 90% by using a logistics company to increase the loading of all trucks entering the airport. As a result there was a major cost savings to suppliers and more frequent and better scheduled deliveries to terminal buildings, helping retailers to know more accurately when goods will arrive and reducing potential security risks.[266]

Consolidating urban delivery in Germany

City-Logistics in Germany experienced cost reductions of 3 to 5% when they consolidated trips in their urban delivery systems.

2.5 times more fuel per delivery than filling trucks three-quarters full.[267] Despite this fact, more than half of inter-city heavy trucks in Canada are less than half full.[268] In Europe and Japan there have been attempts to better use distribution centres to consolidate loads, rationalize pickups and optimize loading and routing of trucks.[269] Several studies have shown that urban consolidation centres can reduce vehicle trips and vehicle kilometres by 30 to 80%.[270]

Potential roles: Both fleets and their customers are important to improved logistics management.

Key benefits: Maximize loading and minimize hauling distances; reduce truck activity on city streets.

Key challenges: Can increase delivery times, level of effort and costs.

Incentives

Incentives have been used to encourage the adoption of new technologies such as auxiliary power units that help to reduce idling of delivery trucks while parked.

Potential roles: Governments, particularly at the federal level, have been previously involved in providing incentives for the adoption of technology to reduce idling from delivery vehicles.

Key benefits: Enables the adoption of technology that maintains or enhances the quality of service to the driver.

Key challenges: Upfront costs; uncertain uptake unless significant motivators used.

Legislation

Standards, regulations or bylaws could be used to require items such as plug-ins at loading docks and auxiliary power units, or to restrict unnecessary idling.

Potential roles: The federal and provincial governments have previously enacted legislation aimed at product and vehicle standards, while provincial or local governments are often involved in influencing or enacting building standards or idling restrictions.

Key benefits: Relatively high impact on emissions compared with other approaches to implementation.

Key challenges: Political will.

Supporting activities

Education and raising awareness among personal vehicle drivers, professional drivers and fleet managers can help increase the uptake of other approaches.

Potential roles: Government, motor associations and technology suppliers are most often involved in education and awareness building around modifying driver behaviour, vehicle maintenance, emission reduction technology and logistics management.

Key benefits: Low costs and high visibility.

Trucks of Tomorrow

The Province of Alberta and Climate Change Central are offering workshops, fleet analysis, case studies and rebates to improve the fuel efficiency of heavy-duty trucks base-plated in Alberta.

The rebates for cab heaters and coolers, auxiliary power units and hybrid engines would certainly help in the urban environment, while the rebates for aerodynamic improvements is more helpful for intercity travel.[271]

Transport Canada freight programs

Transport Canada's ecoFREIGHT Technology Incentives Program provides funding to purchase and install proven emission-reducing technologies. The ecoFREIGHT Technology demonstration fund assists in the testing of new and underused freight transportation technologies and disseminates that information to industry.[272]

Auto$mart driver training

The Government of Canada's Auto$mart fuel efficient driving curriculum reached 350,000 novice drivers in 2009/10 and was projected to reduce national GHG emissions by 90,000 tonnes.[273]

Switching technology

Hybrid switcher

A low-horsepower diesel generator charges a bank of long-life recyclable batteries. The batteries provide motive power; the diesel generator operates at optimum efficiency at all times.

Genset switcher

A series of low-emission diesel engines (typically two to three) replace the large single engine standard in locomotives. This improves the ability to match power output with work load, and increases start-stop flexibility.

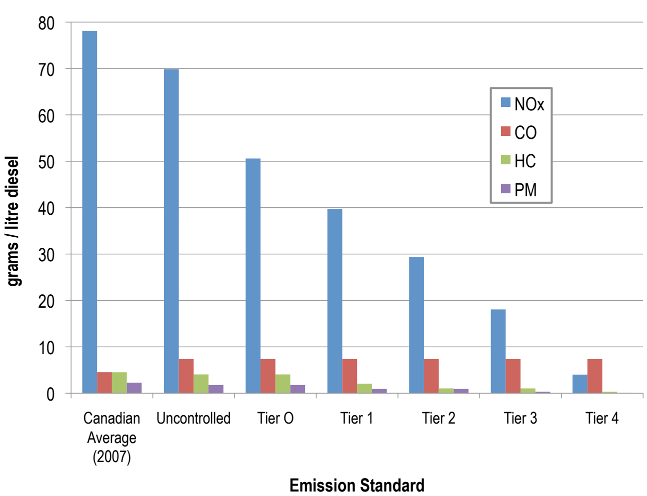

Figure xviii: Emissions rates for existing Canadian locomotives[279]

Key challenges: Large and diverse target population; uptake by some target audiences will be limited.

Rail-yard switching

In 2007, 2,237 million litres of fuel were consumed by rail operations; 62.2 million of which was in rail-yard switching. This corresponded to a total of 205 kt CO_2e for yard switching and work trains across Canada.

According to the Rail Association of Canada, there are approximately 3,046 locomotives in service in Canada; over 400 of these are dedicated to yard work and switching.[274]

Both Canadian Pacific Railway (CPR) and Canadian National Railway (CN) have major operations in Alberta, including recently opened intermodal facilities that provide increased access to North American markets. CPR's Calgary yard is their primary yard in western Canada which includes rail car repair and diesel locomotive servicing; CPR has estimated that they have approximately 50 yard switching locomotives in their Calgary yards.[275] CN also has existing facilities, and has planned new infrastructure for the eastern edge of the city.[276]

Potential reduction

At local switching yards, you can find both long-haul locomotives and dedicated yard switchers; switchers typically remain within the local yard and provide services such as assembly of trains. Switching locomotives are often older model locomotives that have been removed from long-haul line service. The emissions standards for these units are not comparable to newer Environmental Protection Agency (EPA) standards for diesel equipment, and as such the air pollution impacts of heavy diesel equipment and locomotives in the rail yards are disproportionately high.

As Figure xviii shows, emissions from existing Canadian locomotives, including switching locomotives, can be reduced significantly as new, efficient designs for dedicated switcher units can meet Tier 2 standards.

To estimate the savings that could be achieved through improvements to rail-yard practices and technologies, Table xi outlines a range of savings resulting from replacing standard dedicated yard switchers with new hybrid or genset switchers.[277]

Hybrid switchers and genset switchers are effective technologies to reduce emissions in rail yards. These estimates are for illustration only; actual reductions depend on knowledge of duty cycles for the locomotives in service.

As a rough estimate, several different scenarios have been used to demonstrate potential emission reductions. These include scenarios where 20%, 50% and 70% reduction in fuel use is accomplished. These potential reductions provide an indication of the potential impact of various approaches to implementing new railyard technologies and practices; this level of emission reduction is in line with results achieved through demonstration projects in Canada.[278]

Table xi: Potential fuel and GHG savings from changes to rail practices in the Calgary region

Per-unit fuel and GHG savings*	20%		50%		70%	
	Fuel (L)	GHGs (tCO_2e)	Fuel (L)	GHGs (tCO_2e)	Fuel (L)	GHGs (tCO_2e)
Total savings — 50 switching units	1,610,613	727	4,026,533	1,819	5,637,146	2,546
Total savings — 70 switching units	2,254,858	1,018	5,637,146	2,546	7,892,005	3,565

**Note: the per-unit savings are dependent on the current duty cycle of the locomotive*

Depending on existing duty cycles and the number of switching locomotives in the Calgary region, the city could expect to eliminate approximately 727 to 3,565 tonnes of GHGs annually.

Reduction in other air pollutants

Hybrid or genset locomotives can reduce NO_x and diesel particulate emissions by 70 to 90% compared to standard locomotives as a result of lower fuel use and ability to meet Tier II or higher emission standards.[280] As such, their use has a significant and immediate positive impact on local air quality. Locomotive emissions are currently not regulated through the Railway Safety Act and are generally uncontrolled; by comparison, new hybrid or genset locomotives meet EPA Tier 2 standards, reducing air pollutants that have been shown to significantly affect health.

Table xii: Air pollutant reductions from changes to rail practices in the Calgary region

Reduction of other pollutants	70% reduction		90% reduction	
	NO_x (tonnes)	PM (tonnes)	NO_x (tonnes)	PM (tonnes)
Air pollutants avoided — 50 switching units	440.32	12.85	566.12	16.52
Air pollutants avoided — 70 switching units	616.44	17.99	792.57	23.13

The table demonstrates that 440 to 790 fewer tonnes of NO_X and 12.8 to 23 fewer tonnes of diesel particulate matter would be emitted in Calgary if rail operators were to phase in cleaner application-specific rail yard switchers, including genset or hybrid switchers.

Cost implications

The Environmental Protection Agency estimated annual fuel savings of over $100,000 if hybrid locomotives are used. The unit costs are variable, as the hybrid locomotives can be constructed on retired locomotives

Locomotive Idling

In 2007, yard switching locomotives were idling for 84.9% of their engine operating time.

frames for a cost of approximately $200,000, where a new unit may cost up to $1.5 million.[281]

Additional idle reduction technologies for locomotives

A variety of idle reduction technologies and operations practices can be applied to reduce pollution and fuel use; these can significantly reduce fuel consumption and emissions of greenhouse gases and criteria air contaminants, and reduce engine wear.[282] The U.S. EPA offers general information about the control of emissions from idling locomotives while the Argonne National Laboratory's Center for Transportation Research offers an informative presentation on locomotive Idling.

Automated stop/start control

Automated stop/start units shut down the main engine when a locomotive is not working. Lubricant and cooling fluid temperatures are continually monitored and the main engine is restarted if temperatures fall below a set threshold. Automated stop/start control can reduce idling by up to 50% for a road locomotive and up to 70% for a switcher locomotive. The payback period for automated stop/start is generally 6 to 12 months.

Auxiliary power units and diesel-driven heating system

An auxiliary power unit (APU) is a small engine used to maintain main engine systems at working temperatures. When a locomotive is equipped with an APU, the nitrogen oxide emissions can be reduced by up to 91% and the fuel consumption by more than 80%. The payback period is generally 12 to 17 months. A diesel-driven heating system (DDHS) maintains main engine systems at working temperatures. The use of a DDHS can eliminate idling time by up to 11% and can reduce carbon dioxide emissions up to 1700 tons per year per locomotive. The payback period for DDHS is generally 6 to 12 months.

CN

"Automatic stop/start devices conserve fuel and reduce emissions by automatically shutting down locomotives when they are not in use. Over 50% of the switcher fleet in our Canadian operations has been retrofitted to employ this feature. We are also retrofitting our high horsepower fleet with Start/Stop devices and all new CN locomotives.

The Low Idle feature on locomotives saves approximately 10 litres of fuel an hour by allowing the diesel engine to idle at a reduced speed when locomotives are coasting down hill or awaiting assignment."

"Ongoing crew training and awareness programs focus on the importance of fuel conservation practices. CN reviews variances between how trains are operated and handled, which can have a significant impact on fuel consumption and emissions.

Locomotive shutdowns in yards, in accordance with our Shutdown Policy, bring important fuel savings.

Streamlined car handling results in switching only the number of cars needed in our yards — reducing emissions."[283]

Plug-in power

When locomotives are off-duty, the main engine systems are kept at working temperature by means of wayside electrical power. The payback period for plug-in power is generally 3 to 11 months, the shortest payback of all idle reduction technologies.

Potential reduction and cost implications

The Department of Energy (U.S.) summarized the potential of various anti-idling technologies and practices in 2004 (see Table xiii).

Table xiii: Comparison of fuel savings resulting from idling reduction technologies[284]

System	Fuel saving (L/d)	Annual savings	Cost	Payback (months)
Start/stop	136	$15,000	$7,500–$15,000	6–12
APU or DDHS	227	$25,000	$25,000–$35,000	12–17
Plug-in	189	$19,000	$4,000–$12,000	3–11
Hybrid/Genset Switcher	1,102	$122,000	-	-

Common approaches to implementation

Education

Engagement of railyard operators could increase the uptake of lower-emission technologies and practices.

Potential roles: The federal government, through Transport Canada, has already been engaging the freight industry on methods of reducing emissions. Other levels of government could play a role in this as well. Ultimately, it is the rail industry that would be required to act on the information provided. Other non-governmental organizations, such as the Calgary Region Airshed Zone, could also play a role in engaging railyard operators.

Key benefits: Existing activities already being undertaken.

Key challenges: Existing programs have achieved some success, but a significant increase in uptake may require other approaches to implementation.

Incentives

Incentives for railyard operators could increase the uptake of lower emission technologies and practices.

With a relatively short payback on many of the technologies, an innovative financing program could also be used to finance the purchase of new technology with the costs paid back using fuel savings.

Potential roles: Governments are typically involved in providing incentives, although innovative financing programs could be developed privately as well. Industry would need to participate in the incentive programs.

Key benefits: Industry free to decide level of participation.

Key challenges: Program funding and uncertain uptake.

IDC Distribution Services

The trial use of a hybrid locomotive that uses a small diesel engine to charge a bank of batteries reduced emissions and fuel consumption by 50% compared to a conventional switcher locomotive.

Secondary benefits: In addition to fuel savings and emission reduction, the Green Kid® hybrid locomotive was very quiet to operate. Even when the engine was charging the batteries, the small size of the engine made it much quieter than a standard locomotive. The neighbouring community had been concerned about noise from the yard but the hybrid locomotive reduced the overall sound level. The reduced fuel consumption also improved air quality for the yard employees and for the surrounding community.

IDC was very satisfied with the hybrid switcher locomotive's performance. It was reliable and well supported by Railpower Technologies Corp. From implementation, the hybrid locomotive was very effective and economical for IDC. The hybrid proved especially suitable for switcher applications because these locomotives are not operated at high speeds or for long distances. IDC concluded that the hybrid locomotive was ideally suited for its intermodal rail facilities.[285]

EcoFREIGHT

Transport Canada's ecoFREIGHT[286] program works with the freight transportation industry towards a greater uptake of technologies and practices that reduce fuel consumption, criteria air contaminants and greenhouse gas emissions.

The ecoFREIGHT program includes both a demonstration and incentive fund. The demonstration fund provides cost-shared demonstrations to test and measure new and underused freight transportation technologies in real-world conditions; the incentive programs cost-shares funding to companies and non-profit organizations to help them purchase and install proven emission-reducing technologies.

Mandate

The efficiency or emissions of locomotives could be regulated as a method of reducing emissions and introducing more efficient technologies.

Potential Role: The rail industry is typically seen as under federal government jurisdiction. Some regions are also interested in introducing bylaws that affect off-road emissions.

Key benefits: High level of implementation.

Key challenges: Political will.

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Photo: The Pembina Institute

Photo: City of Calgary

Appendix A.13

Landfills

Greenhouse gas emissions from the municipal solid waste stream are a measurable portion of the overall emissions in the community-based GHG inventory. Specifically, as solid waste streams slowly decompose in Calgary's landfills, methane (CH_4), a potent GHG, is formed. This methane gas is referred to as "landfill gas." Methane emissions resulting from the decomposition of landfill waste are estimated based on the composition and amount of waste sent to landfills, as well as how long it has been there and other environmental factors such as temperature.

The City of Calgary manages waste collection and landfills within the city boundaries. The City has been active in setting policy and developing programs that encourage citizens to dispose of their waste properly, including diversion programs such as recycling and organics composting.

It is important to note that the most effective method to manage waste-related emissions is proactively reducing the volume of waste generated. This is a key area of interest to The City of Calgary and industry across Canada. For example, proactive waste management programs such as packaging reduction can reduce emissions associated both with material production and with decomposition in the landfill.

Many materials entering Calgary's waste collection stream have a significant resource value. As such, recycling and organic programs are another method by which material production and landfill gas emissions can be avoided or reduced.

For the remaining residue landing in Calgary's landfills, technologies have been introduced in Calgary and in other jurisdictions to collect and burn the methane as a way to reduce GHG emissions and generate energy.

Three major streams contribute to municipal solid waste in The City of Calgary:

- Household waste: approximately 35%
  - Typical household waste includes: paper (25%), food waste (23%), yard waste (19%), plastic (9%), metal (3%), glass (2%), household hazardous waste (1%) and other (15%).[287]
- Industrial, commercial, and institutional (ICI) waste: approximately 45%
- Construction and demolition (C&D) waste: approximately 20%

The waste stream within the city is undergoing an updated compositional analysis at both the municipal and the household level; results are expected to be available in early 2011. Currently, Calgary operates three landfill facilities: Spyhill, Shepard, and East Calgary.

As the facility operator of landfills accepting waste from Calgary and surrounding areas, The City of Calgary is also subject to policies and programs which regulate the quantity of emissions generated at its landfills. For example, the Alberta Specified Gas Emitters Regulation mandates that facilities emitting more than 100,000 tonnes of GHG

Toronto

The City of Toronto's organics diversion program, "The Green Bin," is responsible for approximately 46% of all organic waste diverted from the landfill as of 2009. The remainder of the organics diverted from the landfill came from leaf/yard/Christmas tree collection programs, grasscycling and individual backyard composting for personal use. Of all waste generated in 2009, about 44% was diverted from the landfill.[288]

After waste reduction, diverting waste from the landfill is often the next strategy implemented. The City of Calgary has a goal to divert 80% of waste from landfills by 2020.[289] Since the current residential diversion rate is about 25%,[290] the successful implementation of this goal will have a profound impact on the amount of waste being disposed at The City's landfills.

Photo: Rhett Soveran via Flickr

Calgary

The City of Calgary has five guiding principles for their 80/20 by 2020 waste diversion goal:

- Resources NOT waste – To achieve the goal every citizen, business and industry must be involved in changing behavior and attitudes. The waste stream is rich in resources that have been relegated to the waste steam.
- Waste management hierarchy – The order of priority for waste management is 1) reduce, 2) reuse, 3) recycle and compost, and 4) residual management
- Financial management – Funding for programs needs to come from a long term sustainable source.
- Polluter pay principle – Waste generators should bear the full cost of consequences of their actions. This internalizes the costs of waste management.
- Environmental sustainability – Services are provided to support individuals in creating and maintaining a sustainable footprint.

Photo: D'Arcy Norman via Flickr

emissions per year must reduce their emissions by 12% annually. Although Calgary's landfills are not currently regulated under this program, the City is actively working on strategies by which to comply with these regulations, which are soon expected to include facilities emitting less than 100,000 tonnes annually. Many regulations under the Canadian Environmental Protection Act (CEPA) and the National Pollutant Release Inventory also apply to landfill facilities.

With a combination of programs including waste avoidance, diversion capture of landfill gas and planning for regulatory compliance, initiatives are already underway to reduce waste-related emissions in Calgary.

Potential reduction

Waste reduction and GHG emission reductions

According to the EPA,[291] waste prevention and recycling — jointly referred to as waste reduction — help to better manage the solid waste generated in municipalities. Waste reduction also contributes to reducing greenhouse gas emissions by, among other things, diverting organic wastes from landfills, thereby reducing the methane released when these materials decompose.

According to the United Nations Framework Convention on Climate Change (UNFCC) International[292] website, the most effective way to reduce GHG emissions from waste is through waste reduction.

Some of the policies and programs already in place within The City of Calgary that encourage reducing waste and in turn reducing emissions from waste are:

- Blue Cart residential recycling pickup
- a network of Community Recycling Depots
- commercial mixed paper and cardboard pickup
- increased landfill rates for designated materials for which alternative recycling opportunities are available, to encourage diversion
- a pilot project for diverting construction and demolition waste for recycling
- seasonal leaf and pumpkin collection depots for composting at landfill locations
- Christmas tree curbside collection for composting at landfill locations
- encouraging the use of design practices that reduce construction waste in both developing and developed areas
- utilizing best practices for building deconstruction with emphasis on recycling materials and material reuse through the development and building approvals process
- encouraging the use of landscaping practices that directly target the minimization of yard and garden waste
- through the development and building approvals process, encouraging the adaptation and reuse of older buildings for a variety of purposes.

Landfill gas capture[293]

Aside from reducing the amount of organic materials going to landfills, systems can also be used to capture the landfill gas (LFG) once it is generated. This is especially important for managing GHG emissions at landfills where waste is already in place (i.e. inactive landfill locations).

LFG contains approximately 50% methane and has a heat content of about half the value of natural gas. LFG is generated continuously at a landfill site as a by-product of anaerobic decomposition.

In landfill gas capture, wells are drilled into the landfill and gas is collected via pipes and transported to a central processing centre, where the gas is processed and treated.

At this point, the gas can be flared, used to generate electricity or heat, or upgraded to pipeline-quality gas. Figure xix depicts a landfill with a gas collection and control system. LFG capture is currently used at over 1200 landfills worldwide.

The City of Calgary's Waste & Recycling Services operates 13 kilometres of landfill gas collection systems at two of its three active landfills that produce 1.8 million cubic metres of landfill gas. Some of the gas is used to generate power through a micro turbine system (at East Calgary landfill) and a reciprocating engine (at Shepard landfill), with the remainder of the gas being thermally treated (flared) before it is released to the atmosphere. The treatment is done in order to reduce the global warming potential of the emitted product (methane has a global warming potential 21 times greater than that of CO_2). Specifically, both facilities have the capacity to export incremental electricity generated (the amount of power not consumed on-site) to the City electricity grid, which presents an opportunity to reduce community related GHG emissions, beyond the reductions achieved by flaring.

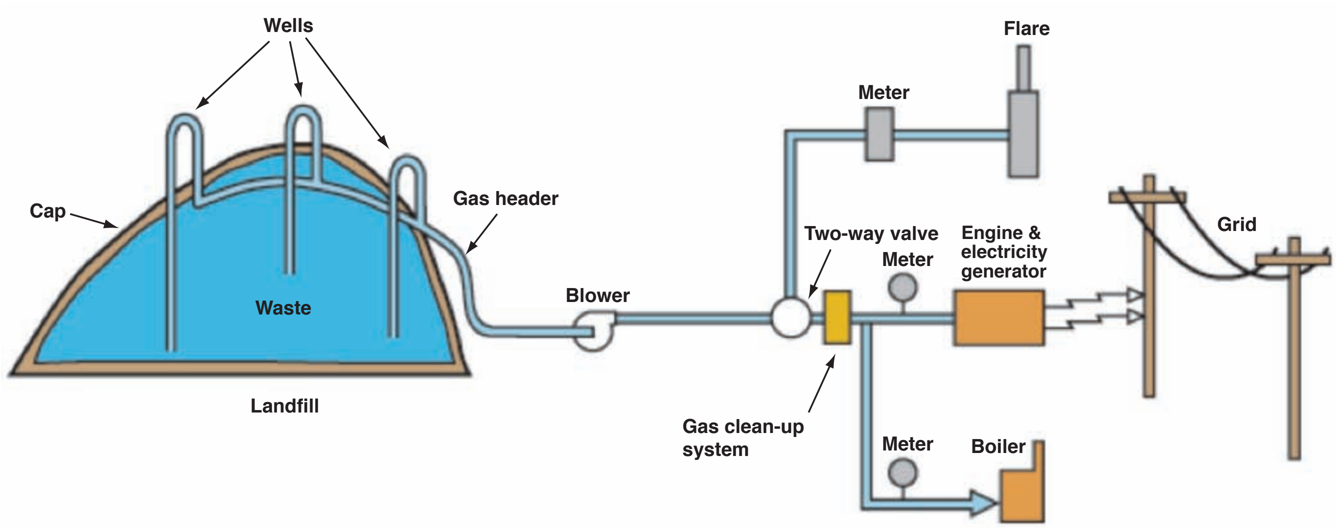

Figure xix: Schematic diagram of a landfill with a gas collection and control system[294]

Note: may not be an exact representation of the system at The City of Calgary

Vancouver

As mentioned previously, Metro Vancouver currently has a draft plan in place to manage its waste.[295] The overriding principle of the ISWRMP is the avoidance of waste through an aggressive waste reduction campaign and through the recovery of materials and energy from the waste that remains. The four goals in line with this principle are:

- Minimize waste generation
- Maximize reuse, recycling and material recovery
- Recover energy from the waste stream after material recycling
- Dispose of all remaining waste in landfill, after material recycling and energy recovery

According to the plan, Metro Vancouver anticipates a regional diversion rate of 55 to 70% by 2015, meaning that if the waste reduction and recycling initiatives in the plan are successfully implemented, only 30% of the generated waste stream will require treatment before disposal. Waste-to-energy capacity could recover energy from this stream.

Photo: The Pembina Institute

It is estimated that The City of Calgary landfills emit more than 125,000 tonnes CO_2e annually. Approximately 14% of the estimated methane gas produced was captured in 2008, and was either thermally treated, which reduces its global warming potential, or used to generate electricity and/or heat at the City's landfills. Currently, the process of capturing and using landfill gas for electricity generation has been limited as capture systems are in early stages of development and microturbine generators are needed to utilize the captured gas for electricity generation.

Over the next few years, LFG capture and utilization systems will continue to be developed at Calgary's landfills in order to address compliance with GHG emissions regulations in the province. This presents a dual reduction potential:

- **Avoided methane emissions:** As methane emissions are captured and the energy potential of landfill gas is diverted to powering electricity generation, these greenhouse gas emissions are avoided.
- **A reduction in GHG emissions associated with the community's electricity grid:** As power generating capacity is added at the City's landfills, electricity generated can be exported to the community electricity grid. For each kilowatt-hour of renewable electricity generated from landfill gas, the City estimates that 0.78 tonnes CO_2e are displaced.

It is important to note, however, that gas capture and utilization systems have capital and operational costs, and also face many regulatory procedures related to electricity generation and distribution. Landfill gas capture systems require a complicated assembly of capture pipelines and micro-generation systems for utilization of the gas. Although the City is currently developing the preliminary stages of capture systems at two landfills, reaching significant levels of capture and use is expensive. Generation technology can cost upwards of $1,100 per kW of capacity[296] in addition to the cost of the capture system. This would translate to approximately $1.2 million to effectively use the gas which is currently or potentially captured at Calgary's landfills.

Should the city's landfills become subject to GHG emission reduction regulations that include a price on carbon, these costs will become a factor in accounting for the cost of not taking action and continuing to emit. For the time being, LFG capture for generation presents an opportunity for the City to create carbon capital for reinvestment in infrastructure (i.e. capture systems and microturbines) to generate incremental reductions.

Waste to energy

An alternative method of managing municipal solid waste that is not already within landfills is through thermal treatment and power generation, also known as waste to energy (WTE).

WTE systems have both advantages and disadvantages. The primary benefits include reduced waste going to landfills, energy generation and reduced GHG emissions. However, WTE systems do include some noteworthy disadvantages. Systems that are less cost-intensive are often associated with significant air pollutants, such as particulate matter (PM), that have related health impacts. PM emissions are regulated provincially and federally. An effective WTE system would have to take into consideration the benefits of GHG emissions reductions versus the potential air quality impacts of the system in addition to the incremental costs of systems with lower air quality impacts.

Cost implications

In addition to avoiding future financial liabilities associated with carbon emissions, many waste reduction and waste-to-energy projects are being undertaken for reasons other than reducing GHG emissions. In some cases, the difficulty with siting new landfills is a strong motivator to introduce alternative waste management practices, while the municipal responsibility to address waste generation is another factor.

Sources show that landfill gas capture and conversion to electricity can have a positive return on investment.[297,298]

Approaches to implementation

There are a variety of approaches to implementation identified through the research:

Waste Diversion Programs

Composting or recycling programs can make it easier to for citizens and businesses to divert waste from landfills.

Potential roles: Local governments are the biggest implementers of waste diversion programs and services, although some private services are offered as well.

Key benefits: Avoids methane generation; reduces landfill space requirements; reuses resources.

Key challenges: Funding for programs.

Pricing

Increasing the direct cost of landfilling, combined with creating diversion opportunities, encourages waste diversion.

Placing a cost on methane emissions from landfills is another way to incent waste diversion, methane capture or waste-to-energy projects.

Potential roles: The municipal government sets the direct costs of landfilling within Calgary, while other landfill operators and governments can set or influence the costs outside of the city. The provincial or federal governments can put a cost on methane emissions, or they could implement a form of extended producer responsibility where product producers are encouraged to assist in waste minimization and take-back for their products.

Key benefits: Encourages behaviour change while still providing choices.

Key challenges: Alternatives to landfilling need to be available; political will; need to consider economic impacts to citizens and businesses as well as the impact on managing the waste stream; pricing needs to both encourage waste diversion and support local industry.

Hamilton

Since the recommendation of the Solid Waste Management Master Plan (2001),[299] the City of Hamilton has begun a strategic approach to municipal waste management. Hamilton currently has a waste diversion goal of 65% by 2011 (adjusted from the original goal of 2008). That original plan included a list of 19 recommendations with regards to re-thinking waste management in Hamilton. One of the recommendations included research into WTE as a possible way to optimize the disposal capacity at their aging landfill site. As of 2010, they do not currently incorporate any WTE or LFG technologies into their landfill management, but they do have a variety of diversion programs in place to reach their total diversion goal. A list of their programs includes: apartment recycling program, backyard composting promotion, bulk goods collection, one bag limit for regular garbage pick-up (started April 2010),[300] household hazardous waste program, leaf and yard waste programs, public space recycling programs, and appliances/scrap metal recycling.

Photo: City of Edmonton

Regulations

A policy around methane emissions management could be implemented. Note that this may occur if current large emitter regulations are expanded to medium-sized emitters.

Potential role: Provincial and federal governments can regulate methane emissions, while municipal or provincial governments can regulate what goes into landfills.The municipal government can develop policies around the effective use of all byproducts related to waste management (i.e., biogas).

Key benefits: High level of implementation.

Key challenges: Time to implement, doesn't deal with waste already in place (closed cells and inactive landfill sites); political will; availability of alternatives to landfilling.

Education

Outreach and engagement of citizens and businesses to encourage waste reduction and diversion from landfills.

Potential role: Municipal governments are typically involved; however, the provincial and federal governments may be involved in stewardship programs.

Key benefits: Creates a behavour change that can be re-created for a number of materials.

Key challenges: Diversion and reduction alternatives need to be attractive; uptake can be limited; costly to implement; lack of funding resources.

287 City of Calgary, "History of Garbage," 2010, http://www.calgary.ca/portal/server.pt/gateway/PTARGS_0_0_780_237_0_43/http%3B/content.calgary.ca/CCA/City+Hall/Business+Units/Waste+and+Recycling+Services/City+Initiatives/History+of+Garbage.htm#q1

288 City of Toronto, "Residential Waste Diversion Rates," http://www.toronto.ca/garbage/residential-diversion.htm. This rate includes single and multi-family residential collection. The single family diversion rate in 2009 was about 60% and the multi-family rate was about 16%.

289 This goal states that by the year 2020 Calgary will be recycling 80% of its waste, with the remaining 20% going to landfills.

290 Non-residential diversion rates are not currently reported.

291 United States Environmental Protection Agency, "General Information on the Link Between Solid Waste Management and Greenhouse Gas Emissions," 2010, http://www.epa.gov/climatechange/wycd/waste/generalinfo.html#q2

292 United Nations Framework Convention on Climate Change, "Reducing Greenhouse Gas Emissions," Feeling the Heat, http://unfccc.int/essential_background/feeling_the_heat/items/2908.php

293 Power-Gen Worldwide, "Garbage in, energy out – landfill gas opportunities for CHP projects," September 1, 2007, http://www.powergenworldwide.com/index/display/articledisplay/307885/articles/cogeneration-and-on-site-power-production/volume-8/issue-5/features/garbage-in-energy-out-landfill-gas-opportunities-for-chp-projects.html

294 Ibid.

295 Metro Vancouver, *Integrated Solid Waste and Resource Management: A Draft Solid Waste Management Plan for the Greater Vancouver Regional District and Member*

Municipalities (2010) http://www.metrovancouver.org/services/solidwaste/planning/SWMP%20Docs/DraftISWRMP.pdf

296 California Energy Commission, "California Distributed Energy Resources Guide on Microturbines," http://www.energy.ca.gov/distgen/equipment/microturbines/cost.html

297 Tom Kerr, United States Environmental Protection Agency, "Landfill Gas to Energy Economics," presented at the Fifth National Green Power Marketing Conference: Powering the New Millennium, August 7-8, 2000, Denver, Colorado, http://apps3.eere.energy.gov/greenpower/conference/5gpmc00/tkerr.pdf

298 Mark Messics, Waste Management, Inc., "Landfill Gas to Energy," presented at the U.S. DOE Natural Gas/Renewable Energy Hybrids Workshops, August 7-8, 2001, Morgantown, West Virginia, http://www.netl.doe.gov/publications/proceedings/01/hybrids/messics.pdf

299 City of Hamilton, *Solid Waste Management Master Plan Public Advisory Committee, Recommendations* (2001), http://www.hamilton.ca/NR/rdonlyres/C2FA1699-A452-4D31-8859-EDA8AD600F76/0/masterplan.pdf

300 City of Hamilton, "ONE Container Limit Program Details," 2010, http://www.hamilton.ca/CityDepartments/PublicWorks/WasteManagement/ONE+Container+Limit+Program+Details.htm

Photo: D'Arcy Norman via Flickr


Photo: City of Calgary

Appendix A.14

Wastewater treatment plants

Like solid waste, liquid waste (sewage) is also attributable to the city's household, industrial, commercial and institutional operations. Calgary currently maintains over 3,800 kilometres of sanitary drainage pipes, including three treatment facilities (Fish Creek, Bonnybrook, and Pine Creek), with a combined capacity of over 530,000 cubic metres of wastewater a day.

Methane is produced as organic solids in wastewater decompose, similar to solid waste decomposition in landfills. The City's wastewater treatment (WWT) process includes a stage at which the decomposition of waste is accelerated in an anaerobic digester, where bacteria quickly break down volatile waste. This process occurs in the absence of oxygen, therefore a significant amount of biogas, made up of approximately 50% methane, is produced. Biogas can be then be collected and either flared or used to generate electricity and heat.

The City's three wastewater treatment facilities are already doing their part in minimizing emissions associated with WWT, including the capture, use and/or thermal treatment of methane emissions. Currently, approximately 60% of the gas collected at the City's WWT facilities is used for generating heat and electricity, which is consumed on site. The City of Calgary's WWT processes have garnered attention and national awards.[301]

An opportunity does exist, however, for the implementation of additional microturbines at these facilities to fully take advantage of the gas produced in generating electricity to green Calgary's electricity grid.

Drain water heat recovery

Although not concerning emissions, commercial and residential technologies do exist to recover heat from wastewater. In buildings and industry, substantial energy savings can be achieved through reclaiming heat from drain water (or wastewater), a process commonly called drain water heat recovery (DWHR). The reclaimed heat is almost always used to preheat cold fresh water. The most cost-effective class of drain water heat exchangers are counter-flow. For example, water enters the home at a temperature of 5 to 12°C and is heated to 50°C in the hot water tank. Showerhead temperature is approximately 41°C and this water is sent down the drain at 37°C. Heat energy can be recovered from the drain water and used to pre-heat water entering the hot water tank to 8 to 23°C,[302] reducing the amount of energy needed to reach the final temperature.

Potential reduction

In multi-unit residential buildings, the overall savings on domestic water heating is typically 25 to 30%, but the potential savings can reach up to 46%. The lower end of this range is for centralized systems that reclaim

Photo: City of Calgary

Photo: City of Calgary

heat from a single building-wide drain water source. In restaurants and health clubs the range of savings is 40–75%.[303]

The costs of these units vary depending on the application and the size of the facility at which they are being installed. Generally speaking, heat recovery systems can run from $500 to $1,500 per installation.

Cost implications

GHG reductions associated with the use of anaerobic digesters in the wastewater treatment process are usually considered a secondary benefit; primary drivers include odor reduction and the need to reduce the volatility of sewage. However, the implementation of gas capture and utilization systems are associated with capital and operational costs similar to landfill gas capture and usage. The current capacity to convert biogas to electric energy at Calgary's wastewater treatment facilities is limited; the addition of generation systems is necessary to realize the full energy potential of the biogas produced. Generation technology can cost upwards of $1,100 per kW of capacity.[304] This would translate to $800,000 in capital costs for microturbine installations at the City's wastewater treatment facilities to effectively utilize gas that is currently captured. Similar to landfill gas capture and combustion, use of biogas for energy generation may present an opportunity for the City to create carbon capital for reinvestment into the infrastructure necessary to effectively use the biogas captured at the City's WWT facilities.

Approaches to implementation

Policy

Potential Role: The municipal government can develop policies around the use of biogas generated at wastewater treatment plants. Provincial or federal policies could also influence the implementation of this technology.

Key benefits: Would increase the amount of energy generated at facilities.

Key challenges: Cost of implementation.

301 The City of Calgary, "Wastewater Awards and Recognition," http://www.calgary.ca/portal/server.pt/gateway/PTARGS_0_0_780_227_0_43/http%3B/content.calgary.ca/CCA/City+Hall/Business+Units/Water+Services/Water+and+Wastewater+Systems/Wastewater+System/Wastewater+Awards+and+Recognition.htm

302 Spectra Energy, EnerSmart Energy Saving Programs, "Drain Water Heat Recovery," http://www.uniongas.com/residential/energyconservation/energysavings/drainrecovery/savings.asp#Savings

303 Natural Resources Canada, EE4 Version 1.7, Energy Use Assessment Software, http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/software_tools/ee4.html

304 California Energy Commission, "California Distributed Energy Resources Guide on Microturbines," http://www.energy.ca.gov/distgen/equipment/microturbines/cost.html