Edmonton's Energy Transition

Discussion Paper

June 20, 2012

Executive Summary

In July 2011, Edmonton City Council adopted *The Way We Green* — the City's environmental strategic plan.[1] This plan sets out a clear vision and approach for Edmonton to live in balance with nature. The plan states: "While this approach is crucial for the wellbeing of the environment, it is equally crucial for the wellbeing of our society, economy, and quality of life."

Where we get our energy from and how we use it will have a significant impact on *The Way We Green* implementation. Our energy system impacts our air, land, water, climate and biodiversity. It also impacts our ability to be sustainable and resilient — the two main focuses of *The Way We Green*:

> ***Sustainability:*** *our society's ability to endure over a prolonged period as an integral part of Earth's natural systems*
>
> ***Resilience:*** *the capacity of our city to withstand and bounce back intact from environmental disturbances.*

Risks

This project focussed on two main risks of our current energy system: climate change and energy supply.

Climate change

It is well accepted that burning fossil fuels is changing the Earth's climate. The predicted impacts of the current climate change trend include water shortages for over 1 billion people; food shortages for hundreds of millions of people; hundreds of millions of people permanently displaced; the extinction of up to 40% of species; more expensive and extreme weather events; and a permanent loss of quality of life of up to 20% of GDP worldwide.

Edmonton and Edmontonians will not be immune from these impacts as climate change is expected to have both direct and indirect impacts on all parts of the world. Direct impacts include more severe storms, floods, droughts, diseases and heat stress. Local ecosystems will change faster than ever before and there will be a significant loss of natural species. Indirectly, Edmonton is expected to be impacted by climate change as natural disasters, conflict and economic disruptions are expected to increase worldwide. This includes major changes to the global agricultural industry due to an increase in storms, droughts and unusual weather, and major changes to the global economy as a whole.

As part of *The Way We Green,* Edmonton City Council has set a goal of becoming carbon neutral as a way to reduce the city's contribution to human-caused climate change.

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[1] http://www.edmonton.ca/city_government/city_vision_and_strategic_plan/the-way-we-green.aspx

Energy supply

> It is generally agreed that the price of oil will continue to climb and become more volatile into the future. While an increase in oil prices may be welcomed by some, it will negatively impact Edmontonians and Edmonton businesses that don't directly benefit from higher oil prices. In addition, increasing price spikes are expected to bring tough economic times with them as they have in the past — in the last 40 years, any time oil prices have doubled, a recession has followed.[2]

Fortunately, there are a number of ways that these risks to Edmonton and Edmontonians can be managed and even reduced. The opportunities identified within this discussion paper have the potential to reduce fossil fuel use by 25% and GHG emissions by 80% by 2050 — in a cost effective manner. This would go a long way to transitioning Edmonton's energy system to become more sustainable and resilient to the risks that have been identified.

Opportunities

Provincial electricity grid

The most significant opportunity to reduce GHG emissions from energy use in Edmonton is through changes to the provincial electricity grid. The Alberta Electric System Operator estimates that building new wind or natural gas power plants (both producing lower emissions than Alberta's current electricity grid mix) are cost competitive with building new coal power plants (which have relatively high GHG emissions).

Urban form and transit

The way a city is designed has a significant impact on the amount of energy used in it. Neighbourhoods where people and services are close together, with safe and inviting walking and cycling areas and with convenient access to rapid transit, use less energy than neighbourhoods that are spread out, have bigger and more separated buildings, and require a lot more travel for a person to meet their daily needs.

More compact and walkable neighbourhoods also have documented health benefits for residents, are less expensive to build and maintain, and can provide a high-quality living environment at a lower cost.

Energy-efficient vehicles typically cost consumers less once fuel savings are accounted for, whereas new vehicle technologies can take some extra investment from industry, governments or consumers to get started.

Buildings and industrial facilities

Electricity and natural gas use in residential, commercial, institutional and industrial facilities can be reduced through conservation (e.g., turning off lights when they're not needed), energy efficiency upgrades, or on-site energy generation (e.g., using solar energy).

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[2] HSBC Global Research. 2011. The global economic impact of higher oil prices.

Energy efficiency and conservation typically reduce overall costs whereas the overall cost of on-site energy generation depends on the energy source and its application. For example, solar panels are currently more expensive over their lifetime than conventional energy, but their costs have been coming down rapidly over recent years and they are expected to eventually become cost competitive with fossil fuels. Combined heat and power generation from natural gas, which is much more efficient than separate generation, is an example of on-site energy generation that can currently reduce overall costs for facilities with high heating demands.

Both energy efficiency and solar energy can also create net increases in local economic development and employment.

Vehicles

There are a number of ways to change the amount and type of fuel vehicles use. Some reduce fuel use without any other noticeable changes (e.g., more fuel efficient vehicles), whereas others require a very significant change (e.g., refueling of electric vehicles).

Conclusions

The research completed shows that a significant shift in energy sources and GHG emissions is possible, and that most of the opportunities are currently either cost competitive with or less expensive than conventional energy systems. These opportunities include lower emission power plants; energy efficiency and conservation; and more compact, transit-oriented development.

Some opportunities, such as solar energy and other emerging technologies, are currently more expensive than conventional energy systems, but are expected to become more cost competitive as they reach greater economies of scale and as the cost of conventional energy increases.

The authors of this paper recommend the City of Edmonton take advantage of the most cost effective opportunities in the short term while preparing now for when more expensive opportunities become cost competitive.

Of course, even though some of the opportunities identified have attractive economics, there may be non-economic barriers to their adoption. Shifting from the current levels of 17% of new development going into existing neighbourhoods to an average of 40% over the next 30 years is one example. While *The Way We Grow* will begin this shift with a target of putting 25% of new development into existing neighbourhoods over this time, it is obvious that additional work will need to be done to shift the demand in Edmonton even further. Fortunately, the research identified a number of opportunities for building capacity within the marketplace over time that would encourage this shift in development patterns. These ideas are incorporated into the paper's recommendations.

Closing

The work completed for this discussion paper, and the work of many other municipalities around the world, shows there are definite benefits to undertaking an energy transition and that a significant energy transition is indeed possible. A reduced reliance on fossil fuels can make a community more resilient, sustainable, affordable, economically successful, healthy and vibrant.

The recommendations provided for the City of Edmonton's Energy Transition Plan have been pulled from global best practices and have been selected for their practicality and combined economic, social and environmental benefits.

The authors of this paper commend the City for examining and working to manage the risks associated with our current energy system. It is clear that these risks could have a significant negative impact on Edmontonians, but they can be reduced through a well-structured and executed management plan, which includes well-researched and achievable actions and goals.

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Appendix A: The Future of Energy and Climate Change for Edmonton

Appendix B: Energy Transition Options

Appendix C: Energy and Emission Modelling Cases

1 Introduction

As part of the implementation of *The Way We Green,* the City of Edmonton's environmental strategic plan,[3] the City is exploring what it would take to make its energy supply and use:

- more sustainable over the long term,
- more resilient to possible disturbances, and
- carbon neutral (no net greenhouse gas emissions).

1.1 Approach

The following steps were undertaken to explore this question:

1. Research was undertaken on the potential energy- and climate-related challenges that Edmonton may face in the future.
2. The energy/climate challenges research was used to develop a possible 'energy/climate future' for Edmonton. This energy/climate future is used to provide context for why energy transition planning is important.
3. Research was then undertaken to identify different ways to carry out an energy transition for Edmonton and avoid possible future energy challenges.
4. The energy transition research was used to model or estimate the potential impact of each energy transition option on energy use and GHG emissions in Edmonton.
5. The energy transition research and modelling was used to make recommendations for an energy transition plan for Edmonton.
6. Edmontonians from a variety of different business and public interest groups were brought together to review and provide feedback on this paper.[4]

This paper presents the results of this work.

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[3] http://www.edmonton.ca/city_government/city_vision_and_strategic_plan/the-way-we-green.aspx

[4] Various stakeholder groups contributed to the development of this discussion paper by providing feedback on the adequacy of methodologies, information and the draft discussion paper at it related to their particular areas of interest and expertise. Overall, stakeholders expressed no objections about the process used to develop the paper or to facts, information or assumptions contained in the final document. However, some stakeholders advised that their lack of objection should not necessarily be interpreted as support for the strategies, but rather acceptance of the facts and assumptions supporting the strategies.

2 Potential future energy and climate challenges for Edmonton

During the development of the City's environmental strategic plan (*The Way We Green*) – it was clear that relying almost entirely on fossil fuels to meet daily energy needs has risks. The two that were the main focus of discussions were the risk of over-relying on a potentially limited resource, and the risk of a rapidly changing climate.

To further explore these risks, research was undertaken to identify what these risks could look like into the future. The results were written as a possible future scenario giving readers a chance to 'live' with these challenges and helping them to better judge what should be done to try to avoid these risks.[5]

While other, more positive scenarios exist, this more extreme future scenario is explored because it is thought to be possible, and if it were to occur, the consequences would be severe. As such, it warrants consideration from a risk management perspective.

2.1 Edmonton in an energy constrained / climate changed world

In this potential future scenario (2040), the world population is approaching ten billion people (compared to seven billion in 2012), the city population is 1.2 million people (compared to 0.8 million in 2012) and the Edmonton region has a population of 1.6 million.

Outcomes that are anticipated in this scenario are ones that could occur in a business-as-usual world where governments and communities wait decades to take action, rather than taking preventive actions today. As with most scenarios, educated guesses are used to paint a picture of a possible future. We have tried to make these guesses as credible as possible by drawing on forecasts and assumptions used in scenarios developed by organizations such as:

- the International Energy Agency
- Royal Dutch Shell
- BP
- HSBC
- Canada's National Energy Board
- the U.S. Department of Energy
- the U.S. Joint Forces Command
- the Intergovernmental Panel on Climate Change

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[5] This is a common approach to strategic planning and is called scenario planning. Scenario planning is used by many prominent businesses, governments and non-government organizations to better understand possible future risks.

- Alberta Environment & Water
- Natural Resources Canada
- the U.K. government

Appendix A can be referenced for more details on the results of the research.

The scenarios are written in the voice of an Edmontonian speaking to us from the year 2040, in a way that evokes concern. By taking this approach, it is hoped that readers will be better able to assess and respond to what is being suggested.

Edmonton: Possible future scenario	
Effects of energy constraints in 2040	**Effects of climate change in 2040**
Economy	
Due mainly to a much larger world population and steady increases in the advancement of developing nations, global energy demand has soared. World energy production has increased 50% since 2012, with nearly 80% of our energy still coming from oil, gas and coal (i.e., much the same as 2012). While coal and gas production are at record high levels, conventional oil production has peaked and is in decline. Although renewable energy technologies have become more advanced and widespread in the past 30 years, they still provide less than 10% of the energy used in the world and in Edmonton. Significant energy technology breakthroughs have not occurred. While conventional oil production reached a peak sometime around 2015, world demand for oil continued to grow due to a much larger and relatively richer world population. This has led to higher oil prices, which now averages about $150 a barrel (2012 dollars). But perhaps the greatest problem in all of this has been the high price volatility. On a number of occasions oil prices spiked to $300 a barrel (2012 dollars). This typically led to economic recession, and at several times oil prices tumbled to short-term lows of $50 a barrel. While these lower prices acted as a catalyst for economic recovery, it wasn't long before demand outstripped supply and the cycle began again. After nearly two decades of economic starts and stops the world is in a general state of economic shock with a greater aversion to investment risk. This boom-bust cycle and increasing environmental concerns have also hampered investment into facilities that convert coal or natural gas into liquid fuels. Although Edmonton experienced several booms and busts in the 20th century, they are dwarfed by the ones experienced so far in the 21st century. Production from Alberta's oil sands has tripled since 2012, but development of this resource has not been smooth. High levels of market uncertainty caused numerous construction projects to be	Global efforts over the past 60 years to reduce greenhouse gas emissions have failed. CO_2 levels in the atmosphere are above 500 parts per million and Earth's average surface temperature is approaching 2 degrees Celsius higher than pre-industrial times and is expected to rise at least another 1 degree. Average temperatures have gone up twice that amount for Edmonton. Countries were unable to reduce emissions faster than they increased due to increasing population and development throughout the world. Nature's ecosystems are being destroyed on a scale rarely witnessed in Earth's history and the impact on people is severe. The majority of countries in the world are experiencing significant effects from climate change, both direct and indirect. Not only have governments around the world acknowledged that greenhouse gas emissions caused by human activities is a primary cause of climate change, in 2030 most signed an international accord committing to reduce GHG emissions by 80% by 2050. Since then, major efforts have been underway to drastically reduce the use of fossil fuels. Strategies have taken the form of high carbon taxes paid by industry and consumers; strict caps on the amount of greenhouse gases that countries, industries, corporations and individuals can emit; strict regulations controlling the burning of coal; and the rapid phase-out of coal. Governments and industries have invested significantly in carbon capture and storage technologies and it has been necessary for the wealthy nations of the world to support efforts in poorer countries. This has resulted in a dramatic increase in the cost of energy due to higher production costs (to prevent emissions), higher direct taxes, more expensive government programs, and the phasing out of coal (which has increased the demand and price for other energy sources). Moreover, it has resulted in the downsizing of many carbon-intensive industries such as airlines, coal-burning utilities, mining, steel manufacturing and construction. Farmers in northern Alberta have benefited from longer growing

Edmonton: Possible future scenario	
Effects of energy constraints in 2040	**Effects of climate change in 2040**
delayed when prices were low. When the construction climate was finally right, there was more work than workers. Although we were able to handle this through massive in-migration of permanent and temporary workers, the results were highly inflationary for our local economy. Canada adopted a National Energy Policy when it became apparent that some regions of Canada were being particularly disadvantaged by high oil prices and because there were strong calls to protect a larger portion of Canada's oil resources for future generations. In addition to pursuing aggressive energy efficiency improvements in Canada (primarily through regulations), the policy limited oil and gas exports and increased equalization payments to non-producing regions. The Government of Alberta has found it increasingly difficult to consistently balance the provincial budget. Challenged by highly volatile revenues, an aging population, inflation, significant unemployment (at times), growing social problems, aging infrastructure, and higher provincial equalization payments; provincial services are increased during boom times resulting in deficits when oil prices fall. Provincial debt climbs during low oil prices and there has been no choice but to increase taxes and cut spending. The effects have been hard-felt by all Albertans. City of Edmonton operations have been significantly impacted by higher energy costs for transit, LRT, City fleet, public facilities, and most infrastructure. The resulting higher property taxes needed to pay for these increased costs have contributed to the erosion of Edmontonian's disposable income. Municipal services have been scaled back in many areas. It is widely understood throughout the world that current rates of oil production are not adequate to meet society's needs. Most people expect economic stagnation to continue and tension between supply and demand to intensify until fossil fuel substitutes or other strategies are found. The good thing is that the world is talking openly about this urgent problem and trying to find solutions.	seasons, higher yields and much higher world prices resulting from food shortages around the world (brought on by climate change and a larger population). However, these higher revenues have been offset by higher costs for fuel, insurance, fertilizer, pest infestations, pesticide and transportation. Consumers have not seen prices go down either. In fact market prices have never been higher, as global food prices have gone up significantly due to increased crop failures and skyrocketing population. In southern Alberta, farmers have not fared so well due to the more severe droughts, extreme temperatures, high costs of irrigation and significant losses of top soil (i.e., wind erosion). These impacts are expected to hit northern farmers as well in the following decades. Summer rain storms have become more severe in Edmonton. This has resulted in more sewer backups and basement flooding (given that much of the City's sewer infrastructure constructed prior to 2020 was designed to withstand less severe rainfall events). Some areas of Edmonton are particularly susceptible to this flooding, and this is reflected in their much lower market value. No quick fixes are expected as infrastructure funding is extremely tight. In today's economy it will take many decades before this problem can be corrected.

<table>
<tr><th colspan="2">Edmonton: Possible future scenario</th></tr>
<tr><th>Effects of energy constraints in 2040</th><th>Effects of climate change in 2040</th></tr>
<tr><td>Energy conservation is now a priority in every area of society. Edmontonians have reacted to high energy prices with lifestyle changes and energy use (per person) has never been lower in Edmonton.</td><td></td></tr>
<tr><th colspan="2">Social</th></tr>
<tr><td>Three decades of increasing economic, social and environmental stress have resulted in greater geopolitical tensions, militarization, conflict, acts of terror, and worries about security for all countries. Serious conflicts have unfolded in the Middle East, Asia and Africa over the past few decades, at times threatening to spill over into Europe. The world has teetered on the brink of major regional and global conflicts. As a result of continued terrorist attacks on Western interests, security measures have been heightened around all major energy infrastructure.

The standard of living for Edmontonians not benefiting from high oil prices has dropped to pre-1960 levels, as it has throughout the developed world. High energy prices, driven primarily by ballooning demand in the developing world, have significantly increased household costs — not just through higher prices at the pump or for heat and power for our homes, but as a result of higher prices for food and nearly everything we buy. At the same time, two decades of global economic volatility and stagnation have weakened non-oil producing western economies.

In Edmonton, the gap between rich and poor has widened. Those benefiting from high oil prices have become richer and those that are not have become poorer due to higher costs for energy and other products. Edmonton's social challenges have never been greater, including increased levels of crime, illicit drug use, unemployment, homelessness, mental illness, family crises and need for immigration support services. Social service agencies are challenged to provide the level of service that is needed.</td><td>Several decades of global food shortages, regional water shortages, population displacement and economic disruption have resulted in greater geopolitical tensions, militarization, conflict, acts of terror, and worries about security for all countries. Serious conflicts have unfolded in the Middle East, Asia and Africa over the past few decades, at times threatening to spill over into Europe. The world has teetered on the brink of major regional and global conflicts. This situation has been exacerbated by continued terrorist attacks on Western interests.

The standard of living for some Edmontonians has dropped to pre-1960 levels, as it has throughout the developed world. High energy prices combined with high climate mitigation/adaptation costs have significantly increased household costs – not just through higher prices at the pump or for heat and power for our homes, but as a result of higher prices for food and nearly everything we buy. At the same time, two decades of global economic volatility and stagnation brought on by climate change have weakened the economy of most developed nations. A combination of these factors have reduced global quality of life equivalent to 20% of GDP per capita on a permanent basis.

As these impacts hit Edmonton's poor particularly hard, the gap between rich and poor has widened. Edmonton's social challenges have never been greater, including increased levels of crime, illicit drug use, unemployment, homelessness, mental illness, family crises and need for immigration support services. Social service agencies have been unable to provide the level of service that is needed.

The diversity and amount of food on Edmonton's store shelves is noticeably less than in the early part of the century. This is largely due</td></tr>
</table>

Edmonton: Possible future scenario	
Effects of energy constraints in 2040	**Effects of climate change in 2040**
The diversity and amount of food on Edmonton's store shelves is noticeably less than in the early part of the century and prices are generally much higher. This is largely due to high costs of inputs (related to the price of energy), high transportation costs, reduced agricultural capacity (due to issues of water supply and degraded agricultural lands) and the need for food to stay where it is produced to feed those extra 2 to 3 billion people. Edmontonians are opting for more energy efficient lifestyles to make their dollars go further. Significant shifts have included: • Reduced demand for old, energy-inefficient homes, built prior to 2000; • A much higher demand for much smaller, medium and high density homes that are net zero energy; • A much greater demand for homes that are situated close to LRT, major public transit centres and shopping centres; • A much greater trend toward living locally and having the option to walk, cycle or use public transit to get to school, work, shopping and recreation destinations; • A much greater demand for urban gardens to defray the high cost of food production; and, • A much more localized approach to energy generation at both the individual and neighbourhood level. Unfortunately, many of neighbourhoods that were developed before 2020 were not well designed for an energy-constrained world. As a result, property values in suburbs have tumbled and people who live there pay a disproportionate share of their income for transportation and home energy needs.	to regular crop failures due to droughts, heat waves and floods, high costs of inputs (related to the price of energy), high transportation costs, reduced agricultural capacity (due to issues of water supply and degraded agricultural lands) and the need for food to stay where it is produced to feed those extra 2-3 billion people. Increased agricultural yields in parts of Alberta were not enough to offset the majority of food that is imported from afar. Edmontonians are opting for more energy efficient lifestyles to make their dollars go further. Significant shifts have included: • Reduced demand for old, energy-inefficient homes, built prior to 2000; • A much higher demand for much smaller, medium and high density homes that are net zero; • A much greater demand for homes that are situated close to LRT, major public transit centres and shopping centres; • A much greater trend toward living locally and having the option to walk, cycle or use public transit to get to school, work, shopping and recreation destinations; • A much greater demand for urban gardens to defray the high cost of food production; and, • A much more localized approach to energy generation at both the individual and neighbourhood level. Unfortunately, many of neighbourhoods that were developed before 2020 were not well designed for today's energy-constrained world. As a result, property values in suburbs have tumbled and people who live there pay a disproportionate share of their income for transportation and home energy needs. Today, one in every six people on the planet (over 1.5 billion people) is threatened by water and food shortages. Hundreds of millions are expected to be forced from their homes and regions due to rising sea

Edmonton: Possible future scenario	
Effects of energy constraints in 2040	**Effects of climate change in 2040**
	levels, floods and intense droughts. The number of refugees and immigrants entering Canada has never been higher. Integration of these people into the Canadian society and workforce has been difficult due to the challenges already listed.
Environment	
The burning of oil, gas and coal is nearly 50% greater than it was at the turn of the century. While air emission standards and carbon sequestration technologies have been used quite extensively in the more wealthy parts of the world, generally this technology has not been used in poorer nations. Emissions of greenhouse gases and most other air pollutants have never been higher. The systematic physical degradation of natural ecosystems has continued, unabated, from the 20th century into this part of the 21st century. More people needing more resources to live have resulted in ongoing loss of forests, agricultural land, soil, fish and biodiversity. As we have struggled to maintain our economy and social conditions in Edmonton, we have given less priority to the environment.	Up to 70% of all species could be threatened with extinction by the end of the century as ecosystems become altered due to climate change. (Note: According to the IPCC, life on Earth has never been threatened to this degree. We assume that if biodiversity loss were to occur on this scale, the ripple effects would be far reaching and severe. We leave it to the reader to consider the possible outcomes.) Global ecosystems are in decline and unable to provide services to the levels they once provided. Main consequences to society so far have included less food, greater stress and uncertainty about food production, less clean water, more extreme weather, reduced air quality, and reduced opportunities to experience nature and biodiversity. Canada's Arctic has experienced melting permafrost, infrastructure failure, increased isolation due to shorter periods when ice roads are viable, and severe changes to animal and plant populations that are the source of food for some. Scientists have confirmed that global climate change has become self-reinforcing. Increasing temperatures over the past century is resulting in an uncontrolled release of greenhouse gases previously stored in the Arctic. Moreover, higher temperatures have weakened the ability of oceans to absorb carbon dioxide. It is speculated that this could cause rapid and abrupt changes to the Earth's climate that will continue to increase the impacts of climate change into the foreseeable future.

3 Potential energy transition strategies

The second half of this project focused on the different options for transitioning the energy system in Edmonton and reducing the possibility of facing the challenges outlined in the energy constrained / climate constrained future scenario in the previous section.

This section focuses on:

1. Current energy use and GHG emissions
2. Options for transitioning Edmonton's energy mix

3.1 Current energy use and GHG emissions[6]

Table 1, Figure 1 and Figure 2 show that most of the energy currently used in Edmonton is in the form of:

- natural gas and electricity[7] used in buildings and industry
- gasoline and diesel used in vehicles

Natural gas in buildings is mostly used for space heating, with a smaller proportion for water heating. Electricity in houses is mostly used for appliances, furnace fans, lighting and electronics / other 'plug loads'. Electricity in larger buildings is used almost the same way, but much more electricity is used for moving air and heat around (using fans and pumps) and for air conditioning than in houses. Industrial facilities use natural gas and electricity as a source of heat and power for the various processes and equipment that they run. Note that heavy industry (e.g., refineries and cement plants) is not included in Figure 1 and Figure 2 as this information was not available. Most of the electricity in Alberta is generated by burning coal.

Table 1: Energy use and emissions in Edmonton – 2009

Energy Use and Emissions In Base Year (2009)[8]		
Sector	**Energy Use (GJ)**	**Emissions (Tonnes CO_2e)**
Residential buildings	34,000,000	2,949,000

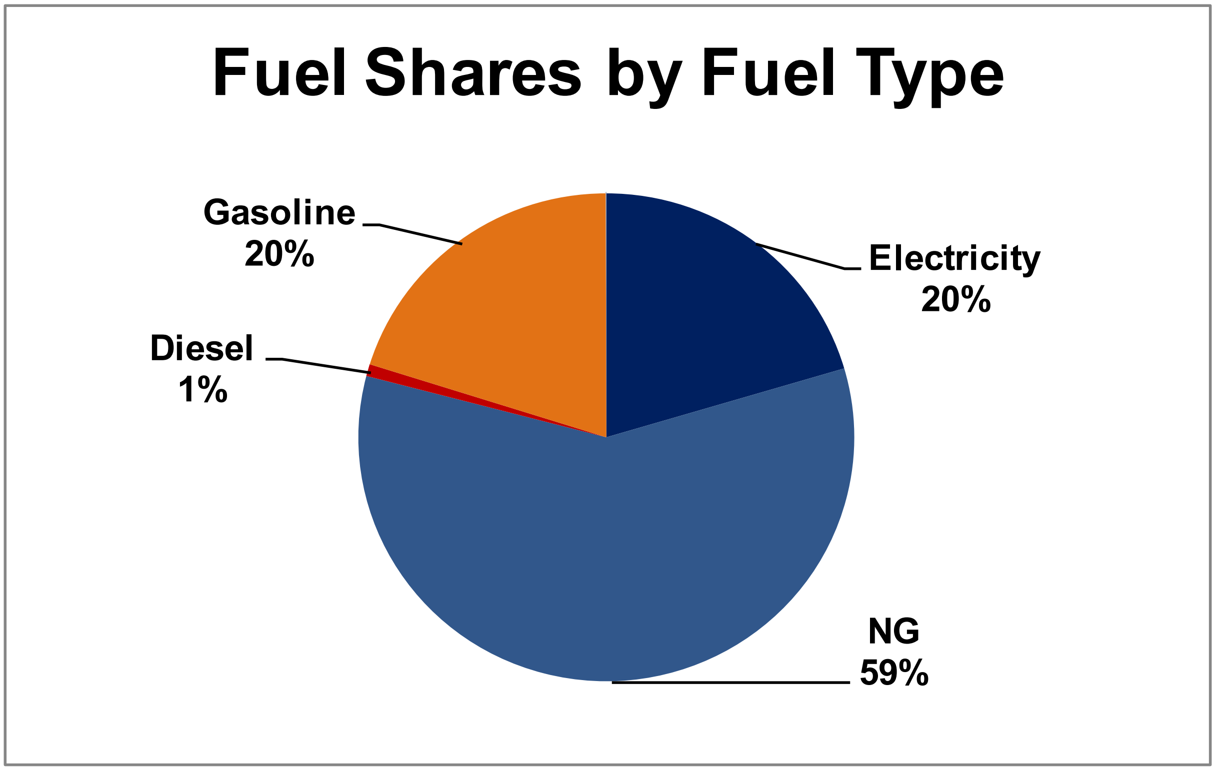
[6] Note that while this paper focuses on GHG emissions (and to some extent costs), energy use has many other economic, social and environmental impacts that are important to consider. Many of these impacts are discussed further within the Energy Transition Options section.

[7] Most of the electricity comes from coal-fired power plants.

[8] While Edmonton's Community GHG Inventory was used to calibrate the model used in this project where possible, the modelled numbers differ somewhat from the inventory due to differences in the scope and use of the inventory versus the model and due to the different methods used to compile each. These differences are most significant for the transportation sector. Also, solid waste/landfill emissions are included in the inventory, but not addressed in this study. Heavy industrial processing is equivalent to the "other/confidential" category in the Inventory.

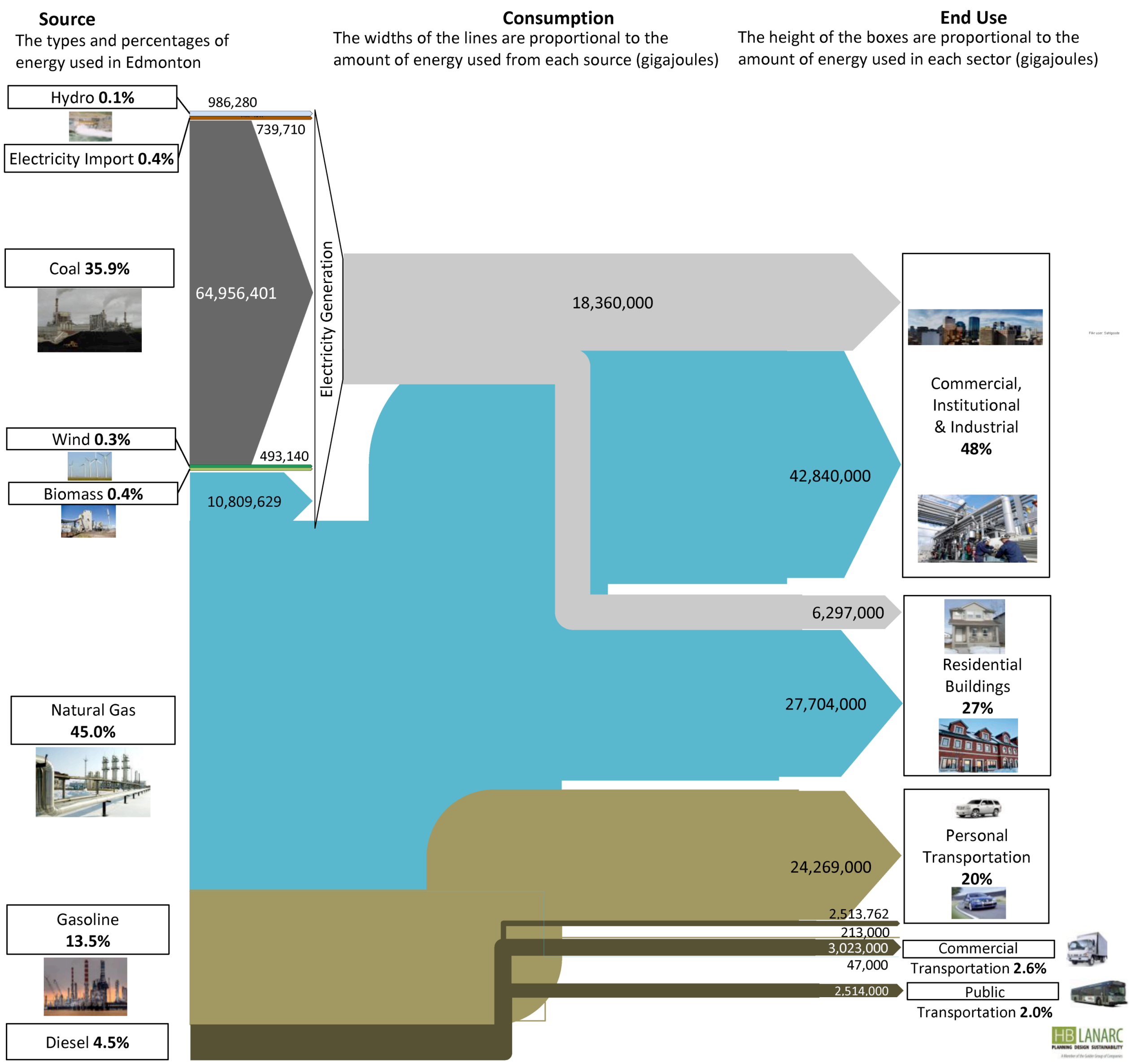
ICI buildings	61,200,000	6,665,000
Heavy industrial processing	Unknown[9]	1,947,000
Personal transportation	25,273,000	1,716,000
Commercial transportation	3,283,000	227,000
Public transportation	2,514,000	177,000
Total	**126,271,000**	**13,681,000**

Figure 1: Energy use in Edmonton (2009) – excluding heavy industry



[9] The energy use of very large industrial facilities is considered confidential and was not available for this research. Energy use data is not considered confidential for the other sectors, as each sector contains many customers and no one customer can be determined based on the aggregated data that is provided by utility companies. While very large facilities do report their GHG emissions through the National Pollutant Release Inventory, this data cannot be used to accurately estimate energy use since there are many different possible sources of those GHG emissions including combustion of natural gas and other hydrocarbons, fugitive methane emissions and emissions from chemical reactions within a plant's production processes.

Figure 2: Energy supply and use in Edmonton (2009) – excluding heavy industry[10]



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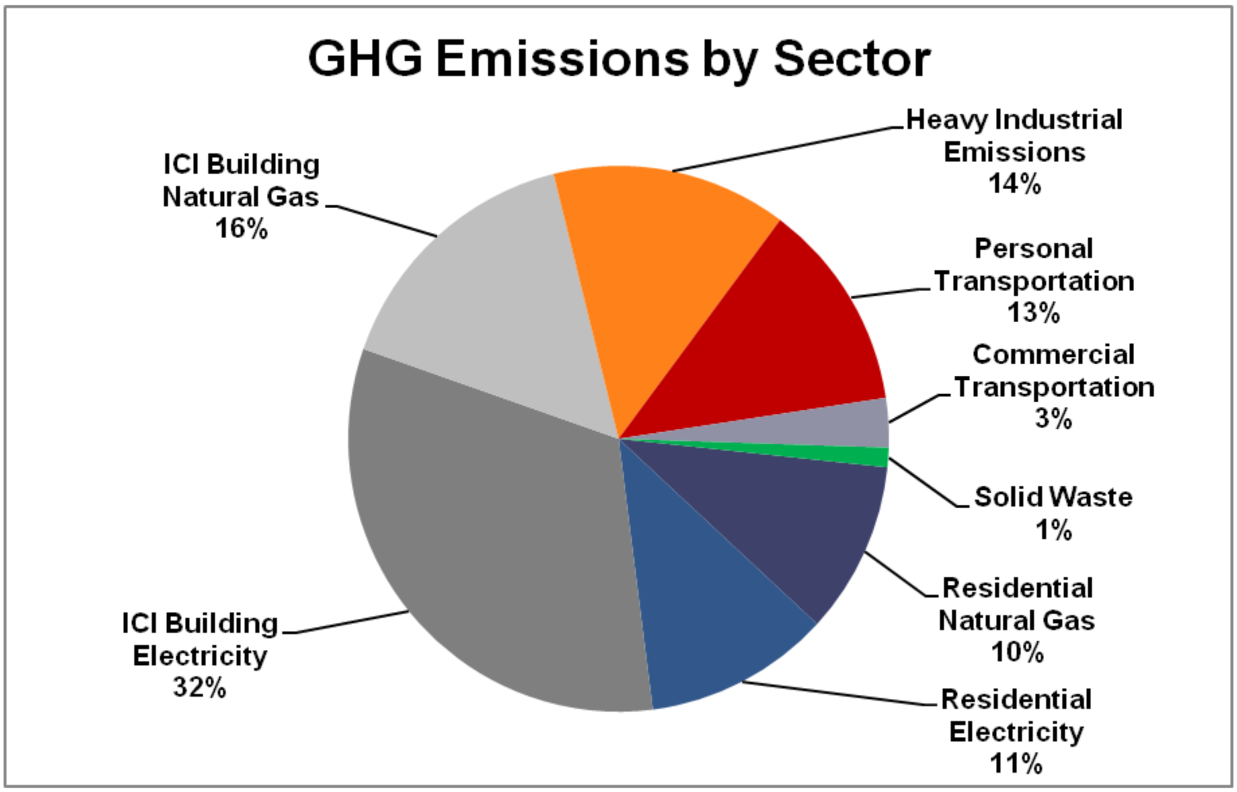
[10] Note that the amount of electricity generated from burning coal, natural gas and biomass is less than the amount of energy in the fuels. Not all of the energy in the fuels can be converted to electricity. For example, the most efficient coal-fired power plants in the province are about 40% efficient in converting coal energy to electricity. The rest of the energy from the fuels is generally released from power plants to the atmosphere, ponds or lakes as heat.

Table 1 and Figure 3 show the greenhouse gas (GHG) emissions for the city. Nearly half of the emissions come from energy used in commercial, institutional and small- to medium-sized industrial facilities. Very large heavy industrial facilities (e.g. refineries and cement plants) are reported separately. The residential, transportation and heavy industry sectors each contribute between 14% and 21% of total GHG emissions. Total GHG emissions in 2009 were about 13.68 million tonnes CO_2eq (carbon dioxide equivalent).

It is important to note that while electricity makes up only 20% of the energy used in Edmonton, it is responsible for more than 43% of the GHG emissions. This is due to the fact that the provincial electricity grid uses mostly coal-fired power plants, which have relatively high GHG emissions for every unit of energy produced compared to most other sources of energy.

Figure 3: GHG emissions in Edmonton (2009) – including GHG emissions from electricity used in the city[11]



3.2 Energy transition options

Based on the research completed (summarized in Appendix B), the following five areas present the greatest opportunities for transitioning Edmonton's energy mix and reducing GHG emissions:

[11] Note: ICI = Industrial, Commercial, Institutional

- Alberta's electricity grid
    - Increasing the percentage of electricity generated from wind farms and from natural gas combined heat and power plants
- Urban form and transit
    - Creating more compact, mixed use neighbourhoods with enhanced walking, cycling and transit infrastructure, and fewer people driving
- Heavy industry
    - Increasing energy efficiency of existing industry
    - Encouraging new economic development that is focused on less energy-intensive businesses
- Buildings
    - Increasing the energy efficiency of new and existing buildings (including the building envelope, the equipment within the building and the behaviours of the occupants)
    - Increasing renewable energy generation in buildings (mainly solar heating and electricity generation)
- Vehicles
    - Increasing the efficiency of gasoline and diesel vehicles and the uptake of electric vehicles

Each of these options were modelled for three different scenarios:

- Reference Case — the energy mix path that Edmonton is currently on
- Reduced Carbon Case — the energy mix path that is expected if current plans (e.g. the Municipal Development Plan, the transportation plan, expected energy efficiency regulations) are successfully implemented and increased over time
- Low Carbon Case — the energy mix path that is expected if all of the energy transition options are implemented to a high but achievable level

The following sections highlight some of the major assumptions modelled for each case. Appendix C can be referenced for additional detail.

3.2.1 Provincial electricity grid

The types of power plants on Alberta's electricity grid have a direct impact on the energy mix and GHG emissions from electricity used in Edmonton. GHG and other emissions could be significantly reduced, for example, by shifting from the current grid mix of mostly coal-fired power plants to increased use of natural gas or wind power.

The Reference Case assumptions for the provincial electricity grid are based on a projection from EDCA Associates.[12] In this projection, most of the growth in electricity supply for Alberta is expected to come from new natural gas power plants. The GHG intensity[13] of the grid in this case is estimated to be about 630 t CO_{2eq} per GWh of electricity consumed by 2025, and it is projected to be about 540 t CO_{2eq} per GWh of electricity consumed by 2044 if the same market trend continues.

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[12] EDCA Associates. 2011. Quarterly Forecast Update – First Quarter 2011.

[13] The amount of GHG emissions for each unit (kWh) of electricity produced.

The Reduced Carbon Case was set as a moderate improvement over the Reference Case. The 2044 emission factor of 429 t CO_{2eq} per GWh of electricity is similar to the GHG intensity of a typical natural gas power plant.

The Low Carbon Case is based on a scenario presented as a conservative projection of the energy efficiency, wind power, and combined heat and power plant potential for Alberta.[14] It should be noted that to achieve this potential, changes to government policy are required. Coal-fired power plants also need to be shut down after the end of their economic life (i.e., they are not refurbished or life-extended). The Low Carbon Case uses the GHG intensity provided by Bell, et. al. of approximately 440 t CO_{2eq} per GWh of electricity by 2024.

The Low Carbon Case also uses the more aggressive scenario from the Bell, et. al. study as the emission factor for 2044. The study estimated that a grid emission factor of about 140 t CO_{2eq} per GWh of electricity is possible by 2028 with a very aggressive approach to building new, low emission generation sources and an early phase out of coal-fired power plants. A 2044 emission factor of 100 t CO_{2eq} per GWh of electricity is therefore considered to be conservative compared to this aggressive approach, but still a significant shift from the Reference Case.

Table 2 highlights some of the major assumptions for each case.

Table 2: 2044 modelling assumption highlights – provincial electricity grid

Provincial electricity grid			
Indicator description	**Reference Case**	**Reduced Carbon Case**	**Low Carbon Case**
Avg. grid emission factor	538 t $CO2_{eq}$ / GWh	429 t $CO2_{eq}$ / GWh	100 t $CO2_{eq}$ / GWh

Government regulatory authority

The provincial electricity grid is managed by the provincial government, but the federal government is in the process of developing emission regulations for power plants.

Financial impact

Research indicates that building new natural gas power plants or large-scale wind farms is currently cost competitive with building new coal-fired power plants. Power plants with carbon capture and storage and nuclear power plants are considered to be more expensive than these other electricity sources.

Ease of implementation

Industry support for regulations depends on their current and planned mix of power plants. Companies that own, operate or have contracts with coal-fired power plants in the province

[14] Bell, J and Tim Weis. 2009. Greening the Grid: Powering Alberta's future with renewable energy. The Pembina Institute.

see significant financial risks for themselves and their customers with any policy that penalizes emissions from existing power plants. On the other hand, companies that do not have a large stake in coal-fired power plants and have an interest in developing new power plants within the province are more supportive of policies that favour lower emission power plants.

Other considerations

Changes to the type of power plants built in the province will impact regional air quality and the quality of the environment where the plants are built.

3.2.2 Urban form and transit

The research and modelling shows that the more spread out a city is, the more energy is needed for transportation.

Table 3 highlights some of the major assumptions for each case.

For the Reference Case, about 83% of population growth occurs in new neighbourhoods, and 17% occurs in existing neighbourhoods. This is the same as is currently happening in Edmonton. In this case by 2044, the rapid transit network doubles and the population density of mature neighbourhoods increases by about 15% compared to current levels.[15] (See Appendix C for an illustration of each land use and transportation scenario.)

For the Reduced Carbon Case, more population growth is allocated to new inner city developments (e.g. downtown and the airport redevelopment) than in the Reference Case. This shifts population growth to 25% in existing neighbourhoods, which is in-line with the recently approved Municipal Development Plan, *The Way We Grow*. In this case, by 2044 the rapid transit system is four times longer and the population density of mature neighbourhoods increases by 21% compared to current levels.

The Low Carbon Case assumes a shift in population growth well beyond current plans as the percentage of new population growth that takes place in existing areas rises to 40%. This was done to estimate the impact of a more aggressive approach to focusing new development in existing areas of the city. By 2044, the Low Carbon Case has a rapid transit network five times longer than current levels, and mature neighbourhoods have approximately 31% more population density than current levels.

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[15] There is little change in population densities between the cases for other neighbourhood types (e.g. both new and existing suburbs). New suburbs do take longer to build out for each case however.

Table 3: 2044 modelling assumption highlights – urban form and transit

Urban form and transit			
Indicator description	**Reference Case**	**Reduced Carbon Case**	**Low Carbon Case**
Ratio of growth in new vs. existing neighbourhoods	83%/17%	75%/25%	60%/40%
Population density of mature neighbourhoods	37 people / ha	39 people / ha	42 people / ha
Length of rapid transit service[16]	37 km	80 km	105 km
Population within walking distance (800m) of a rapid transit station	17.5%	34.8%	43.8%
Arterial road length	3,000 km	2,750 km	2,650 km

Government regulatory authority[17]

Municipal governments are primarily responsible for the planning and development of cities including the regulation of land development and redevelopment, and the design and construction of transportation infrastructure.

The provincial government has historically played a role in how different municipalities interact and has also been involved in deciding how regional planning will occur.

All orders of government (municipal, provincial and federal) have been and are currently involved in funding transportation infrastructure including transit and roads.

Financial impact

Compact development is generally lower cost for households and governments.

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.[18]

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).

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[16] Modelled as light rail transit (LRT), but could be implemented as bus rapid transit as well.

[17] It is important to note that while this work focuses on government authority, citizens and businesses also have important roles to play within any energy transition.

[18] Victoria Transport Policy Institute, “Online TDM Encyclopedia — Nonmotorized Transportation Planning.”

Research also indicates that more compact development has lower capital and operating costs for municipalities as it generally requires less overall infrastructure and services.[19,20]

Ease of implementation

Current development industry and purchasing decisions reinforce current development patterns. Approved plans (*The Way We Grow* and *The Way We Move*) are expected to move development patterns away from current practices towards those seen in the Reduced Carbon Case.

Decisions about urban form and transportation systems impact energy use in a community for a very long time. Placement of roads typically influence community design and transportation requirements for many decades. Changes to the way a city is designed also take a long time to implement since only a small portion of a city is built or changed every year. Over time, however, the shape and form of new developments or redevelopments can have very significant city-wide impacts as they influence both building and transportation energy use, and are not easily changed once they are in place.

Other considerations

How communities and transportation systems are developed has a direct impact on quality of life. It influences the types of homes people have, the form and quality of public space, how much time people spend travelling each day, and can even impact access to goods, services and employment. Air quality within cities and activity levels of people are also greatly affected by how much driving is done.

If done well, compact and complete development generally increases the amount of activity and the number of social interactions that people have in a day, both of which serve to increase personal well-being. Compact developments can also offer a greater range of housing and transportation options, which can greatly enhance the quality of life for low income households. Compact development also tends to reduce the amount of time people are required to travel each day.

3.2.3 Heavy industry

This model calculates GHG emissions for a set of heavy industry in Edmonton separately from GHG emissions from the rest of the commercial, institutional and light industrial sectors as they are reported separately. These heavy industrial facilities (e.g. refineries and cement plants) also generally have different emission reduction opportunities than smaller facilities. For example, there are not nearly as many building-related opportunities within large industrial facilities; instead, the opportunities are, for the most part, related to the efficiency of boilers,

[19] Halifax Regional Municipality, “Settlement Pattern and Form with Service Cost Analysis”, April 2005.

[20] IBI Group, “The Implications of Alternative Growth Patterns on Infrastructure Costs”, April 2009, produced for The City of Calgary.

pumps, motors, fans, cooling towers, chemical or other processes, and how the plants are operated.

For modelling purposes, the Reference Case assumes that GHG emissions from existing large industrial facilities do not change significantly from current levels[21], and that new large industrial facilities are created at the same rate as job growth within the city (i.e., the mix of businesses in Edmonton remains similar to its current makeup.)

For the Reduced Carbon Case, it is assumed that existing industrial facilities improve their efficiency by 10% by 2044 and very large heavy industry is created at half the rate of job growth within the city (i.e., industrial growth still occurs, but it is more focused on businesses that are not very large energy users).

For the Low Carbon Case, it is assumed that existing industrial facilities improve their energy efficiency to the highest levels currently considered economic (25%) and that the business growth in the city does not add to the GHG emissions from this category of heavy industry.

Table 4 highlights some of the major assumptions for each case.

Table 4: 2044 modelling assumption highlights – industrial facility energy efficiency

<table>
<tr><th colspan="4">Industrial facility energy efficiency</th></tr>
<tr><th>Indicator description</th><th>Reference Case</th><th>Reduced Carbon Case</th><th>Low Carbon Case</th></tr>
<tr><td>% improvement in efficiency</td><td>1%</td><td>10%</td><td>25%</td></tr>
<tr><td rowspan="2">Growth rate of very large heavy industry (e.g. refineries and cement plants)</td><td rowspan="2">Proportional to job growth</td><td>Proportional to half of job growth</td><td>No growth in refineries or cement plants</td></tr>
<tr><td colspan="2">Industrial growth in these cases are assumed to be focused away from very large energy users.</td></tr>
</table>

Government regulatory authority

Energy efficiency standards for equipment have been implemented by the federal government and some provinces, but energy efficiency of processes or whole facilities has not. Broader emission regulations do have an impact on facility efficiencies and are in place (e.g., Alberta's Specified Gas Emitters Regulation) or are under development (e.g., proposed and emerging federal regulations for several industrial sectors). Government approvals for large industrial facilities also often include minimum energy efficiency requirements.

[21] This assumes that efficiency improvements that are undertaken (as is currently the case) are offset by increases in production volumes at existing facilities.

Financial impact

Energy efficiency generally increases purchase costs, but decreases energy costs more over time than the increase in purchase cost.

Very large energy users (e.g., refineries and cement plants) have significant economic impacts for a city, including jobs and economic activity. It is possible, however, to create similar levels of economic benefits through the development of many industrial facilities that are not as energy intensive.

Ease of implementation

Businesses are generally resistant to added requirements, but they also recognize the need to reduce environmental impact and the financial benefits of saving energy.

An assessment has not been completed regarding the ease of focusing industrial development on facilities with lower levels of energy use, although it should be noted that the City is already in the process of developing an eco-industrial strategy.

Other considerations

Reduced energy use at very large industrial facilities because of energy efficiency improvements can have a positive impact on local air quality.

Changes to the types of businesses that are established and grow in Edmonton will have an impact on the types of jobs created and will help shape Edmonton's urban environment.

3.2.4 Buildings

This section includes all residential, commercial, institutional and light industrial buildings in the city.

Buildings can be made more efficient by upgrading the building envelope (walls and ceiling insulation and air leakage) and equipment within the building (e.g. appliances, lighting, electronics, fans, motors and pumps), and by changing the way they are operated. They can also change their energy mix and reduce GHG emissions by generating energy on-site (i.e. distributed energy).

Distributed Energy

Distributed energy generally means generating, converting and/or sharing energy close to where it is consumed. This includes heating water with the sun, generating electricity from solar PV panels, generating heat and electricity (at the same time) from burning natural gas, capturing waste heat from industrial processes or buildings, and piping heat between buildings using district energy systems.

Distributed energy has many advantages compared with centralized systems where energy is typically moved long distances (e.g. from other parts of the province). These advantages include: less energy used for energy transport; often fewer power lines and pipelines are needed; most distributed energy systems are more efficient than conventional systems as they make greater use of any 'waste' heat; buildings connected to district energy systems do not need on-site boilers or furnaces, and in some applications they save consumers money.

Distributed energy systems also have some disadvantages compared with centralized systems. Consumers are often unfamiliar with them as new technologies. Some systems, such as solar panels and combined heat and power plants, have high upfront costs that are then recovered either partially or fully over time.

Generally speaking, however, an increase in distributed energy within Edmonton helps to meet both goals of diversifying the energy mix and reducing GHG emissions.

The Reference Case includes the 25% improvement in energy efficiency that is the target for the current update to the National Building Code and another 25% improvement by 2030 for a total of 50% improvement in energy efficiency by 2044. The Reference Case also includes building retrofits and solar energy uptake that are comparable to current levels.

The Reduced Carbon Case improves moderately beyond the Reference Case. This is assumed to be possible through an introduction of incentive, financing and awareness raising programs.

The Low Carbon Case demonstrates the level of emission reductions possible through mandated energy efficiency and renewable energy levels. By 2044, it is expected that an 85% improvement in efficiency will be possible through cost-effective changes to the building code and/or local regulations. The level of retrofits undertaken are also considered to be cost effective — the only difference compared with the other cases is that cost-effective retrofits are required at time of sale[22] as opposed to being driven by the rate of voluntary retrofits. These improvements in energy efficiency are estimated to reduce city-wide GHG emissions by 5% compared to the Reference Case.

The solar energy uptake in the Low Carbon Case is meant to demonstrate the maximum solar energy generation (hot water, space heating and electricity) that is considered practically possible for Edmonton.

Table 5 highlights some of the major assumptions for each case.

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[22] City of Berkeley, *Title 19, Buildings and Construction,* http://www.codepublishing.com/CA/Berkeley/html/pdfs/Berkeley19.pdf

Table 5: 2044 modelling assumption highlights – buildings

Buildings			
Indicator description	**Reference Case**	**Reduced Carbon Case**	**Low Carbon Case**
Energy efficiency			
% improvement in new building energy efficiency from 2009	50%	52.5%	85%
% improvement in efficiency of existing stock through retrofits	8%	9%	22%
% reduction in residential electricity use through behaviour change programs	0%	3%	10%
Solar electricity (photovoltaics)			
% of building electricity consumption	0.3%	0.5%	5.3%
Solar heating (hot water and passive space heating[23])			
% of building heat consumption	1.2%	1.8%	22%

Government regulatory authority

The National Building Code is developed collaboratively between the federal government, provinces and stakeholders, and then generally adopted by the provincial government and amended with province-specific changes. The current update to the National Building Code now includes energy-efficiency-related code requirements for the first time.

The City of Edmonton is currently responsible for building code inspections and approvals within the city. Municipal governments also have the ability to enact bylaws in areas not already covered by provincial or federal regulations. This could be used to influence construction or renovations within the city, for example, but it is currently not used for energy efficiency or renewable energy. The provincial government also has the ability to use regulations to advance on-site solar energy generation.

Financial impact

Energy efficiency upgrades commonly undertaken for buildings generally increase purchase costs, but energy savings over time more than make up the increased purchase cost.

[23] Passive solar space heating involves increasing the amount of free heat a building gets from the sun by designing it to have most of its windows facing south.

Solar energy is currently more expensive than conventional energy sources; however, the cost of photovoltaics has dropped rapidly over the past few years and is expected to be cost competitive with conventional electricity sources in the future.

Ease of implementation

Building codes are currently updated at least every five years. With the addition of energy efficiency to the objectives of the National Building Code, it is expected that energy efficiency standards will continue to be increased over time. This increase, however, is often balanced with the desire of home builder associations to ensure changes to the building code (not just those for energy efficiency) do not adversely affect their industry.

Including a solar energy installation on a building requires additional investment from either government or consumers. Currently, this investment does not generally get fully paid back over the life of the panels, but this is expected to change over time. Some jurisdictions have provided incentives to encourage the uptake of solar panels on new and existing buildings, while new buildings are sometimes required to have on-site energy generation. Adding this requirement for existing buildings has not been widely attempted, so it may be challenging to implement.

Other considerations

Building occupants often find energy-efficient buildings to be more comfortable as they feature reduced temperature swings and increased natural light. Energy-efficient buildings are often water efficient as well.

Solar panels change the aesthetics of buildings where they are visible.

Both energy efficiency and solar energy can increase local economic development and employment.

3.2.5 Vehicles

More energy-efficient vehicles (including electric vehicles) use less energy and produce fewer GHG emissions than older, less efficient vehicles. Vehicle efficiency can be improved through more efficient gasoline and electric engines and drivetrains, by using hybrid electric vehicles, or by switching to electric vehicles, which are much more efficient energy users than conventional vehicles. (The level of emission reductions for fully electric vehicles depends on the source of electricity.)

For both the Reference Case and Reduced Carbon Case, a combination of increased tailpipe regulations and continuing demand for fuel-efficient vehicles (driven primarily by rising fuel prices) leads to an increased fuel efficiency and an increase in electric vehicles over time. The electric vehicle uptake in the Reference Case reflects expected national trends[24] whereas the Reduced Carbon Case assumes a higher rate of uptake.[25]

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[24] Electric Power Research Institute 2011. “Transportation Electrification: A Technology Overview”

[25] Assuming local actions are taken to encourage accelerated adoption of electric vehicles.

The Low Carbon Case assumes the uptake of low emission and electric vehicles North America-wide reaches the high end of current projections due to a combination of market conditions (including fuel prices) and government regulations. This case also assumes that the municipal government is an early adopter of new vehicle technologies and provides incentives for others that do the same.

Table 6 highlights some of the major assumptions for each case.

Table 6: 2044 modelling assumption highlights – vehicles

Vehicles			
Indicator description	**Reference Case**	**Reduced Carbon Case**	**Low Carbon Case**
Avg fuel efficiency (new and existing)	6.6 l/100km	6.6 l/100km	6.1 l/100km
% of fleet electric	20%	31%	67%

Government regulatory authority

Vehicle emission standards have historically been set by the federal government, but some provincial governments (B.C. and Quebec) have moved to introduce their own standards to varying degrees of success.

All levels of government have the ability to advance electric vehicles through capacity building and incentives. For example, governments can be early adopters; they can incent or require electric charging infrastructure to be built in new developments or added to existing developments; and the province can work to ensure the electricity grid infrastructure is suitable for large numbers of electric vehicles. It is unlikely that electric vehicles will be mandated at any point, but they could be incented through vehicle emission and/or efficiency regulations at the federal (or possibly provincial) levels.

Financial impact

Energy efficient vehicles typically cost consumers less once fuel savings are accounted for.

Electric vehicles are currently more expensive to purchase than comparable conventional vehicles, but their fuel is much less expensive. Electric vehicles are expected to become less expensive than conventional vehicles (when accounting for fuel cost savings) once they reach high levels of uptake.

Ease of implementation

Vehicle efficiency standards are regularly updated by the federal government based on U.S. federal fuel efficiency standards while the Province could legislate in this area as well. The next easiest and more stringent standards to benchmark against are California fuel efficiency standards. Increasing beyond California standards may be possible if market forces naturally move this direction, but may be difficult otherwise given the size of the Canadian and Alberta marketplaces.

Uptake of electric vehicles requires the development of considerable manufacturing and support infrastructure. A multi-national effort is required for high levels of penetration to be reached.

Other considerations

More energy-efficient vehicles are usually smaller and lighter than less efficient vehicles, but that is not the only way to improve the efficiency of vehicles. All types of vehicles have opportunities to become more efficient.

Fully electric vehicles (i.e. not hybrid electric vehicles) currently have less range than gasoline vehicles and take several hours to fully recharge — making them for now primarily an urban vehicle.

Natural gas vehicles are currently mostly used in fleets with dedicated fuelling infrastructure. Public fuelling stations for natural gas vehicles are currently very limited.

Biofuels are currently blended into most gasoline and diesel fuel sold. Higher concentration blends are not generally available to the public, but fleets may have opportunities to purchase such blends.

3.3 Energy and emission modelling results

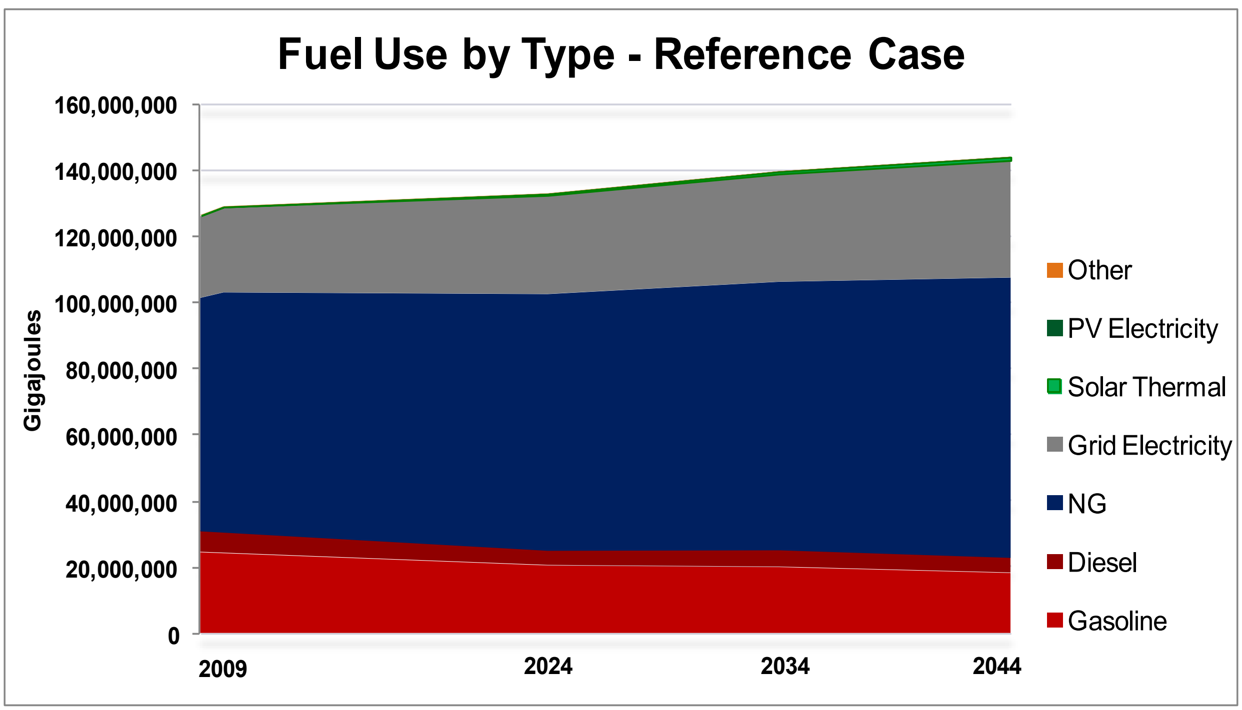
3.3.1 Reference Case

The reference case represents the energy mix path that Edmonton is currently considered to be on. This includes:[26]

- Continuation of current land development patterns (only 17% of new population growth occurs in developed areas of the city).
- Increased building code and vehicle efficiency standards in line with, but not beyond stated government policy.
- Electric vehicle uptake in line with projected national trends.
- GHG intensity of the provincial electricity grid decreases as currently expected (based on current market forces).
- GHG emissions from heavy industry (e.g. refineries and cement plants) increase at the same rate as city-wide job growth.

Figure 4 shows the fuel use expected in Edmonton for the Reference Case. Gasoline use is expected to decline in this scenario due to a combination of higher efficiency vehicles and a shift towards electric vehicles (electric vehicles are projected to make up 20% of the market by 2044). Natural gas and electricity use increases moderately, but not as fast as the city grows, since buildings and industrial facilities are expected to become more efficient over time.

Figure 4: Fuel use in the Reference Case – by fuel type (excludes heavy industry)



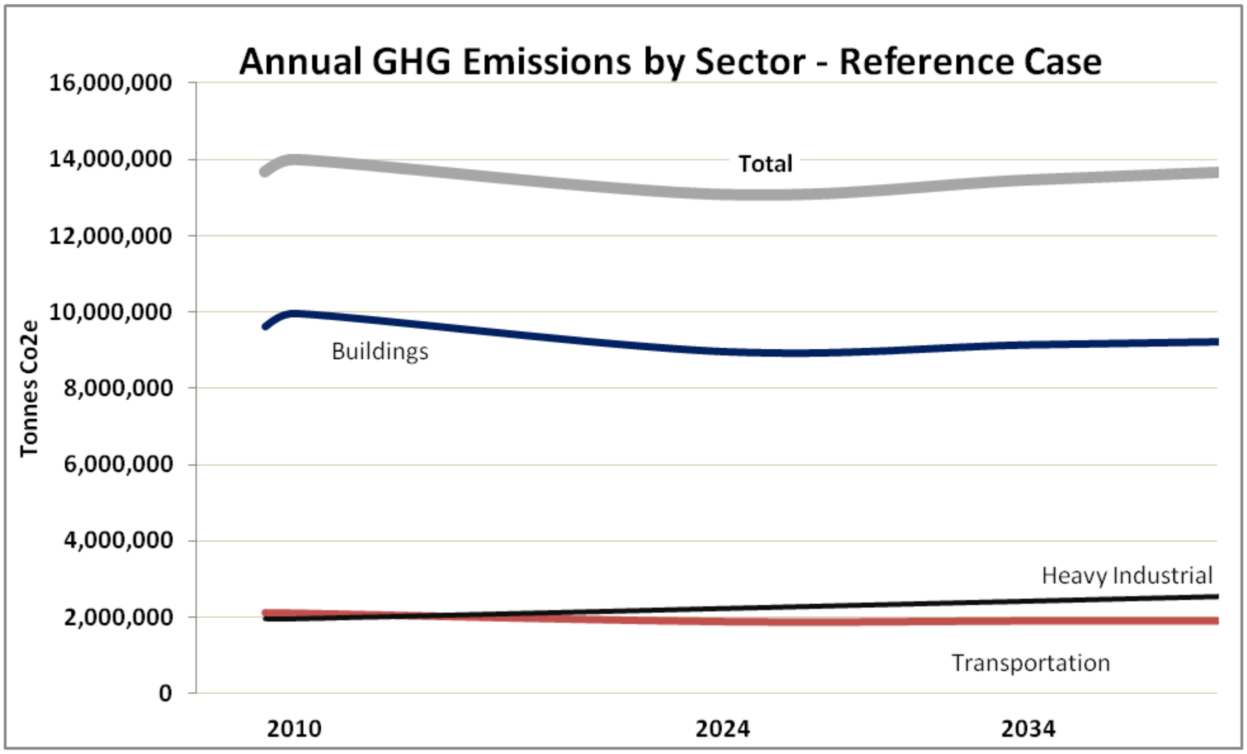
[26] More detail is available in the previous section.

Figure 5 shows the GHG emissions expected for the Reference Case. While energy use increases for buildings, overall GHG emissions are expected to decrease slightly as the provincial electricity grid makes a shift towards more natural gas power plants. (Coal-fired power plants are not expected to go offline in this Case, but their proportion of total electricity generation in the province is expected to go down as new natural gas power plants are built.)

GHG emissions from transportation remain relatively constant as the increase in the total amount of driving is offset by the use of more efficient vehicles and a shift towards electric vehicles. It should be noted that while most of the electricity still comes from coal-fired power plants in this case, electric vehicles are so efficient that they still reduce overall GHG emissions when compared with gasoline or diesel vehicles.

GHG emissions from heavy industry are expected to increase at the same rate as job growth.

Figure 5: GHG emissions in the Reference Case



3.3.2 Reduced Carbon Case

A Reduced Carbon Case (compared with the Reference Case) depicts current plans for changes to land use, transportation, energy efficiency and energy supply being successfully implemented and increased over time. These current plans include:

- Slower growth of suburbs than currently and faster build out of inner city developments (e.g. downtown and airport redevelopment) according to *The Way We Grow*. 25% of new population growth occurs in developed areas of the city.
- Transportation develops according to *The Way We Move* (Edmonton's recently approved transportation plan).

- Building code and vehicle efficiency standards increase moderately beyond stated government policy.
- GHG intensity of the provincial electricity grid decreases greater than currently expected to happen with existing market conditions (i.e., assumes the introduction of new government policy that encourages a greater shift towards lower emission power plants).
- GHG emissions from heavy industry do not increase dramatically from current levels as the amount of growth in the sector is offset by a combination of energy efficiency improvements and industrial development that is focused on less energy-intensive facilities.

Figure 6 shows the fuel use expected in Edmonton for the Reduced Carbon Case. In this scenario, the overall energy use is slightly lower than in the Reference Case as there are higher efficiencies for buildings, industry and vehicles. The changes to the overall energy mix are relatively small although there is a higher amount of natural gas and wind power supplying grid electricity, lower gasoline use and slightly more solar energy use.

Figure 6: Fuel use in the Reduced Carbon Case – by fuel type (excludes heavy industry)

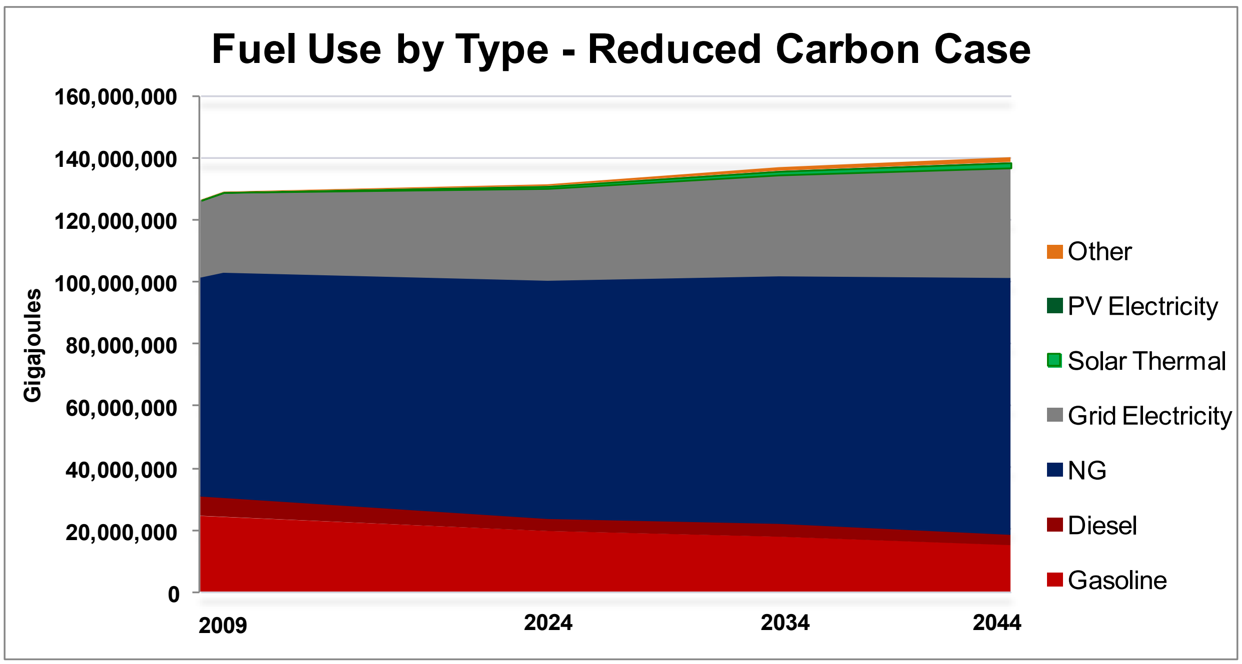
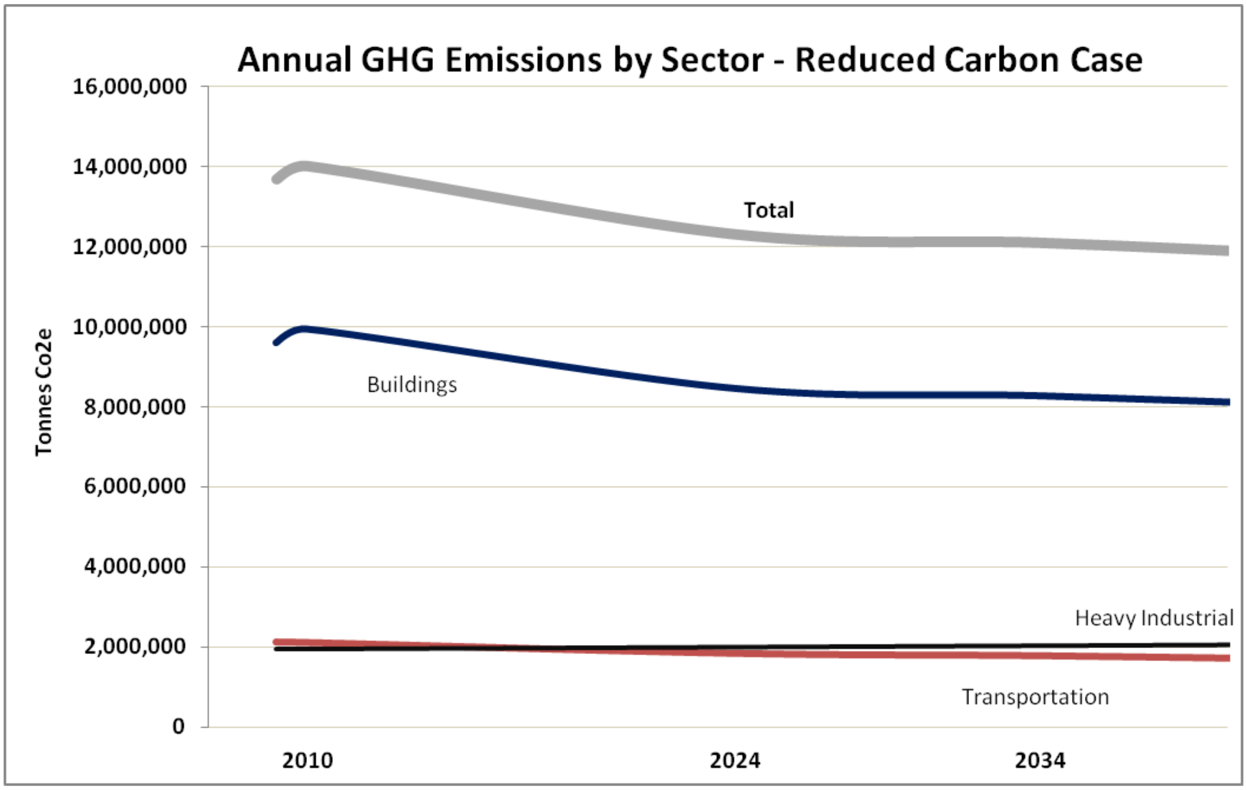


Figure 7 shows the GHG emissions expected for the Reduced Carbon Case.

The largest part of the reduction in GHG emissions results from a more active approach to developing wind power for the provincial electricity grid.

As well, more compact growth, increased transit use, more energy efficient buildings, vehicles and industry, and an increase in the amount of solar energy generated in Edmonton all contribute moderately to the overall GHG reduction.

Figure 7: GHG emissions in the Reduced Carbon Case



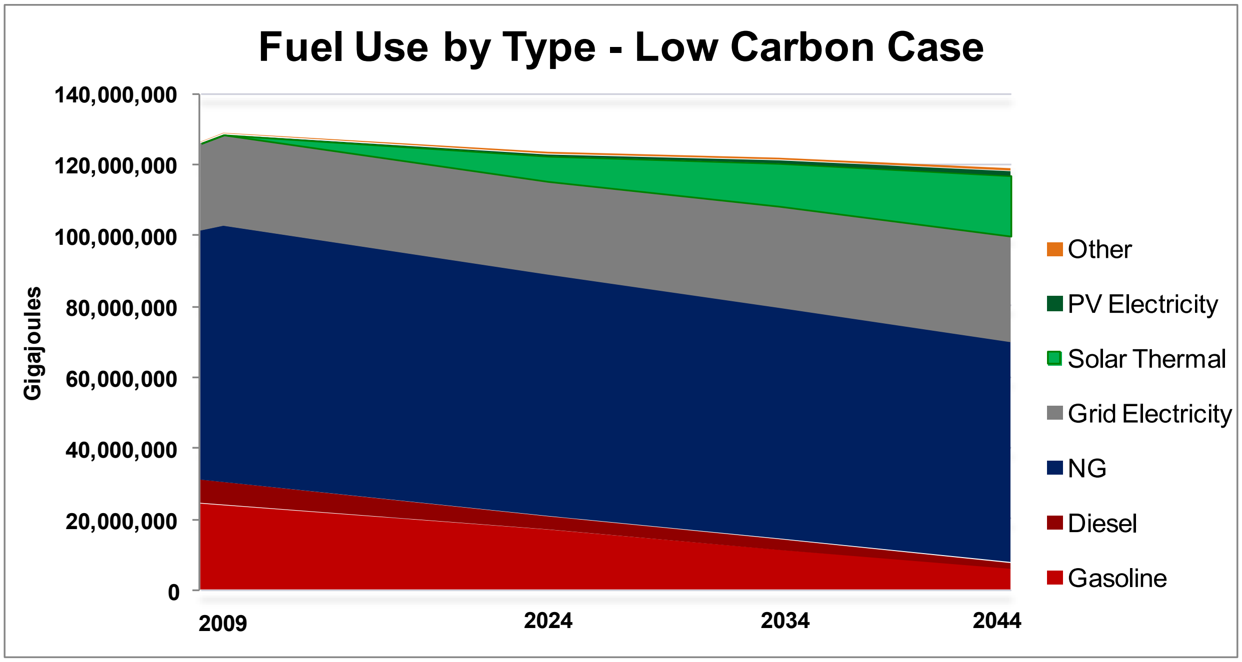
3.3.3 Low Carbon Case

The Low Carbon Case estimates the energy mix and GHG emissions possible if all of the major opportunities identified within the literature are implemented. This includes:

- 40% of new population growth happens in developed areas of the city, and transit networks are significantly expanded. These changes go beyond current City plans.
- Energy efficiency within building code standards (provincial and/or municipal) is maximized.
- All new electricity generation in the province is a combination of renewable energy and highly efficient natural gas combined heat and power plants.
- Uptake of electric vehicles meets the most optimistic projections.
- All buildings are required to undertake economic energy efficiency upgrades at time of sale.
- Solar energy is commonplace by 2030 and installed on virtually all suitable rooftops by 2044. New buildings are built to take advantage of low-cost passive solar heating as well.
- GHG emissions from heavy industry decrease by 25% from current levels by 2044 due to significant efficiency improvements. New industrial facilities are not as energy intensive as refineries or cement plants.

Figure 8 and Figure 9 show the fuel use expected in Edmonton for the Low Carbon Case. In this scenario, the overall energy use goes down over time as energy efficiency for buildings, industry and vehicles is maximized. There is also a significant shift away from gasoline and diesel as vehicle efficiency increases considerably and electric vehicles see very high penetration rates. Solar energy is also maximized in the city with virtually every suitable rooftop having solar panels for water heating and for electricity generation (separate systems for each), and new buildings are oriented to maximize passive solar heating. Most of the electricity in the province comes from natural gas power plants and wind turbines.[27]

Figure 8: Fuel use in the Low Carbon Case – by fuel type (excludes heavy industry)



[27] The values in figure 11 show the amount of fuel used for each generation sources. The percentage of electricity from each source in this case is approximately: natural gas 44%, wind 32%, coal 9%, biomass 8%, hydro 6%, imports 2%.

Figure 9: Energy supply and use in Edmonton (2044) – Low Carbon Case, excluding heavy industry

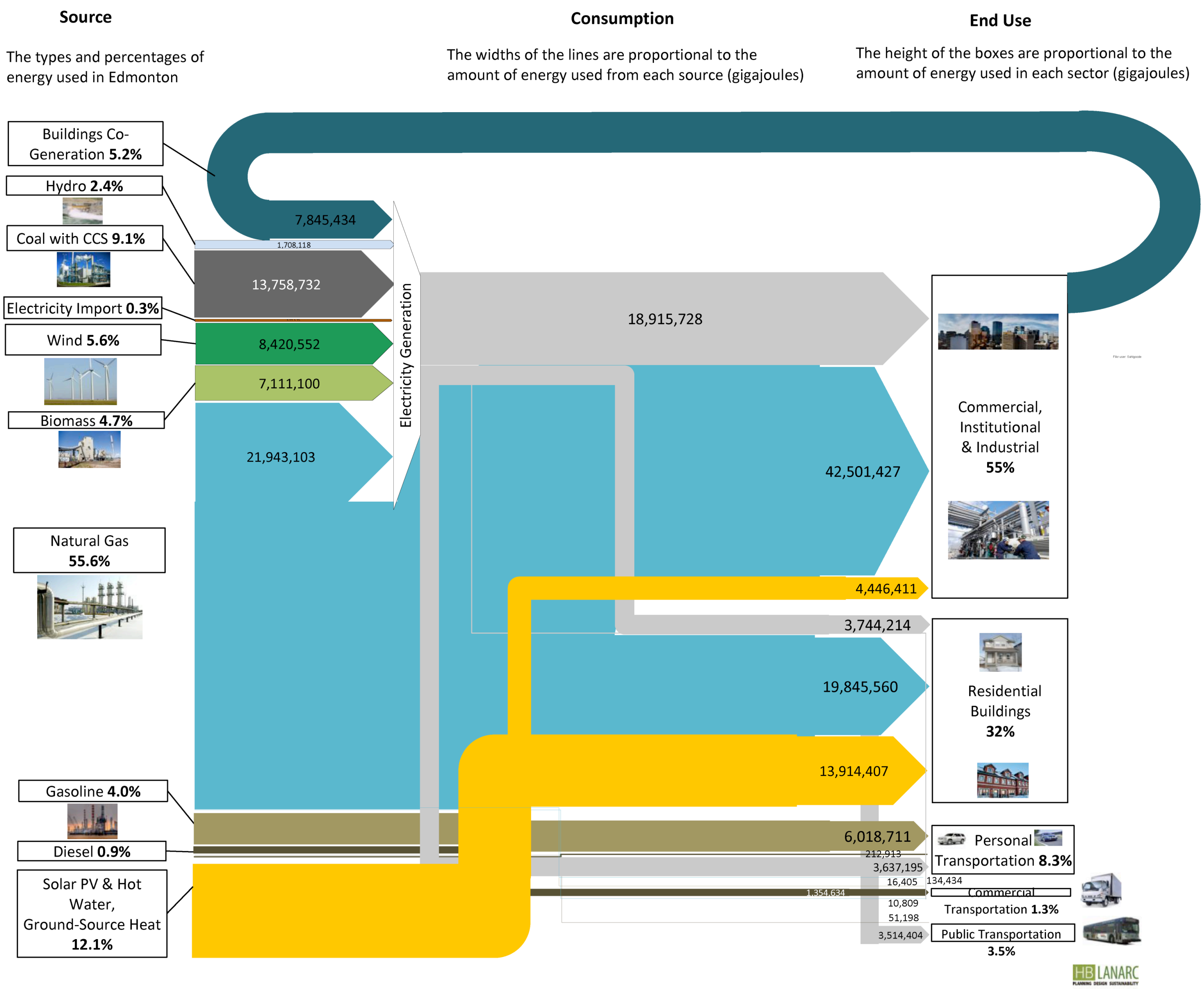
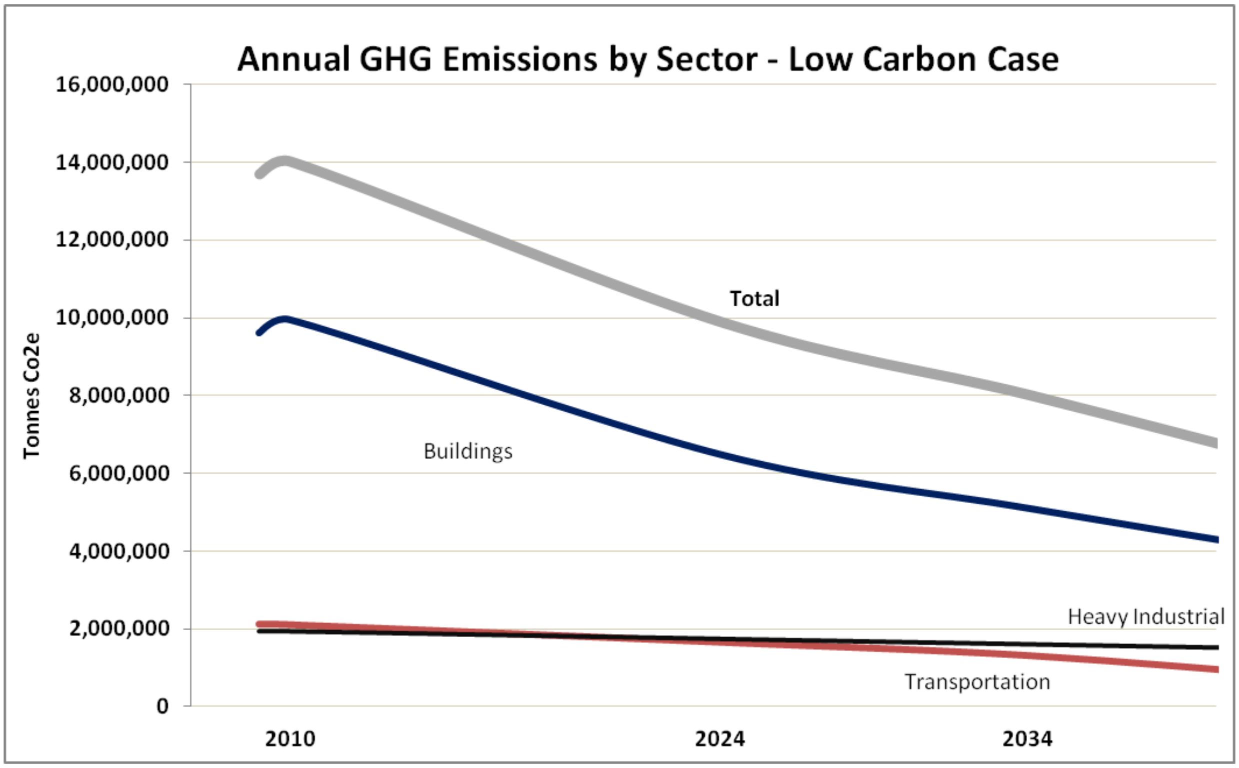


Figure 10 shows the GHG emissions expected for the Low Carbon Case while Figure 11 shows where the emission reductions come from.

Figure 10: GHG emissions in the Low Carbon Case



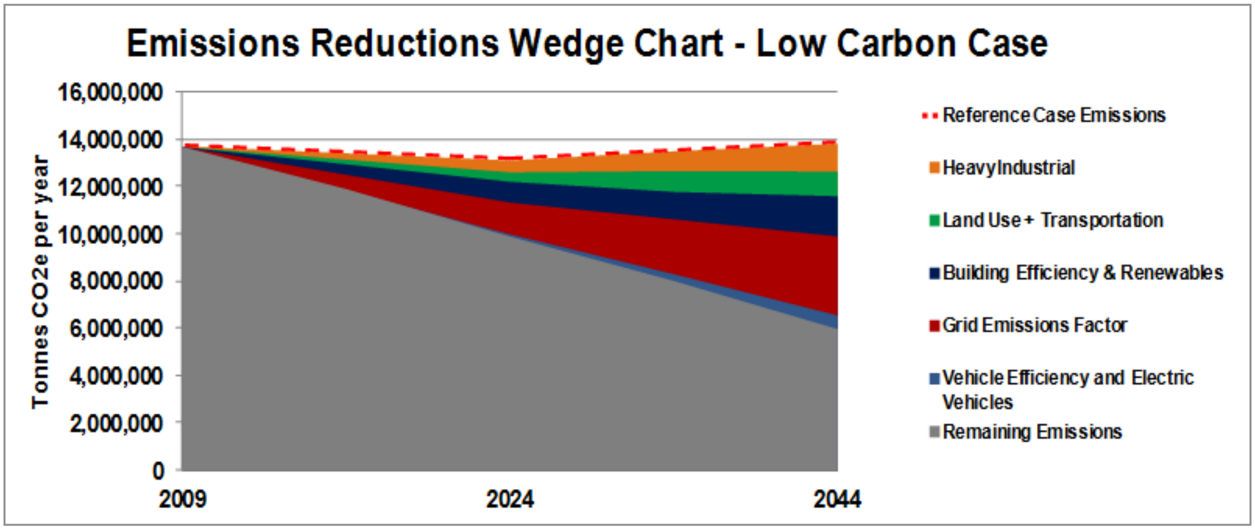
GHG emissions are mostly reduced as a result of a very active approach to developing wind farms and natural gas combined heat and power plants for the provincial electricity grid. (24% reduction in GHG emissions compared to the Reference Case.)

The second-largest emission reduction comes from more compact growth and increased transit use (8%). Reducing GHG emissions from heavy industry through a combination of energy efficiency and a shift to lower emission industries has similar emission reduction (8%).

Solar energy (for hot water, space heating and electricity) and building energy efficiency improvements reduce GHG emissions the next greatest amount (7% and 5% respectively).

Finally, improved vehicle efficiencies and a shift towards electric vehicles round out the major GHG emission reduction opportunities (4%).

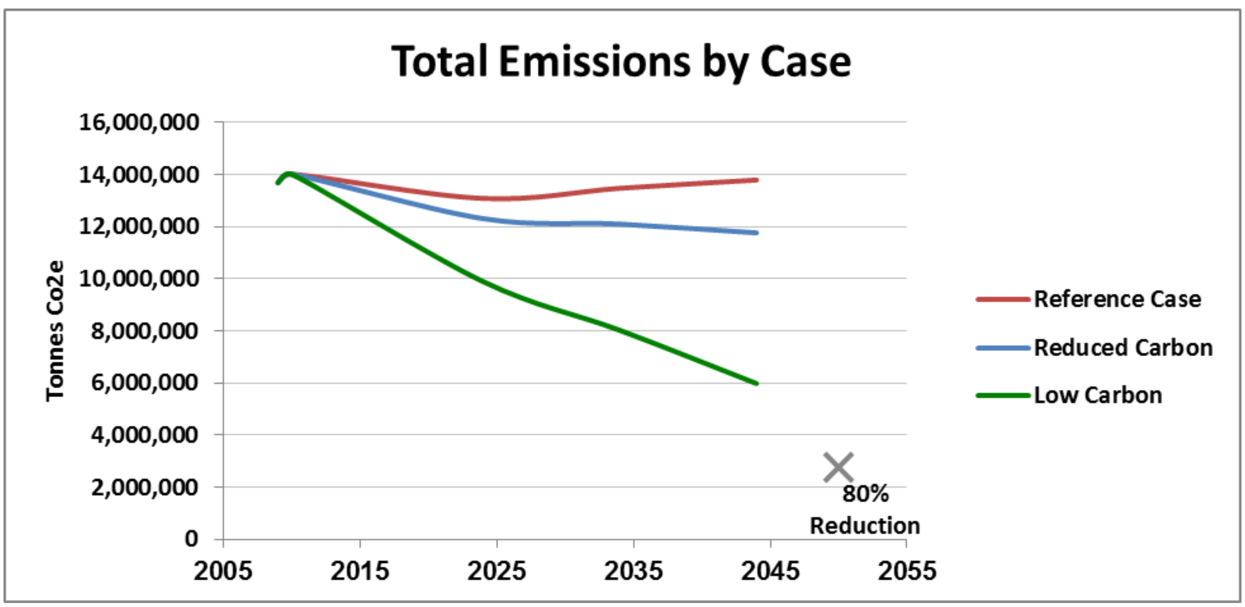
Figure 11: Low Carbon Case wedge diagram



3.3.4 Comparison

Figure 12 shows the GHG emissions estimated for each of the three modelling cases. As can be seen, the Low Carbon Case is the only one that puts Edmonton on track to becoming carbon neutral (one of the goals of *The Way We Green*) at a similar trajectory that the leaders of the G8 countries (including Canada) are recommending for developed nations — a target of 80% reduction in GHG emissions below 1990 to 2005 levels by 2050.[28]

Figure 12: Total GHG emissions for each modelling case



[28] The 80% reduction by 2050 target is considered to be within the margin of error for the Low Carbon Case.

Table 7 breaks out the GHG emission reduction for the Reduced and Low Carbon Cases compared with the Reference Case for reach opportunity area.

Table 7: Estimated reduction in GHG emissions from the Reference Case

	Reduced Carbon	Low Carbon
Provincial Electricity Grid	6%	24%
Land Use + Transportation	3%	8%
Heavy Industrial	3%	8%
Building - Renewables	1%	7%
Building - Efficiency	1%	5%
Vehicles	1%	4%
Total	**14%**	**57%**

The results of the Low Carbon Case are similar to results seen for other studies such as:

- *Advice on a Long-term Strategy on Energy and Climate Change* - National Round Table on the Environment and the Economy (NRTEE).
- *Options for Reducing GHG Emissions in Calgary* - The Pembina Institute.

3.4 Energy cost implications

An analysis of energy cost implications was also undertaken. This analysis provides a high-level assessment of energy spending and energy vulnerability for residents in the City of Edmonton, for the different modelling cases. It explores these issues through discussion of projected energy costs, energy demand, and household spending.

A key purpose of this analysis is to illustrate how energy spending and vulnerability for Edmonton residents might vary under different future scenarios.

3.4.1 Energy spending vs. net cost savings

While the energy spending analysis does consider all residential energy costs for homes and vehicles, it does not take into account some other costs that may vary between the three modelling cases, and thus does not represent the overall net cost difference to residents.

Table 8 summarizes and discusses some of these changes and the associated costs.

Table 8: Non-energy cost considerations

Non-Energy Cost	Discussion
Incremental cost of more efficient buildings (new or retrofitted) to homeowners and tenants.	A portion of building energy spending savings, particularly in the Low Carbon Case, are attributed to changes in building form associated with land use changes, which are not expected to increase average housing cost, but could potentially reduce it. Incremental efficiency and fuel shifting costs for new buildings would generally be borne by homeowners and amortized over time – thus reducing net savings. Modelling cases assume all building retrofits are "economic" – i.e., have a positive business case. After the typical payback period has been achieved (e.g., within 10 years or less), energy savings would fully accrue to the homeowner. Costs to tenants are more complex to assess as they do not pay building costs directly.
Transportation costs outside of vehicle fuels	Only the fuel components are considered within transportation costs. Both private vehicle operation and transit use have substantial cost components (e.g., maintenance, insurance) not related to fuel consumption; these are not taken into account.
Active transportation related costs	Increasing active transportation (walking, cycling) can potentially reduce costs related to health care, but data is not sufficient to confirm this.
Infrastructure costs	Decreasing urban sprawl and driving could potentially decrease City infrastructure costs that are passed along to residents; however, this has not been modelled.

Energy spending "elasticities", i.e., the potential effects of energy pricing on energy consumption, are also not specifically modelled here. For example, high electricity prices could induce residents to reduce consumption by turning off lights, which could decrease energy spending under any of the modelling cases. However, high energy costs would also tend to make the aggressive changes modelled in the Low Carbon Case more achievable, for example by improving the business case for energy efficiency and changing buying preferences.

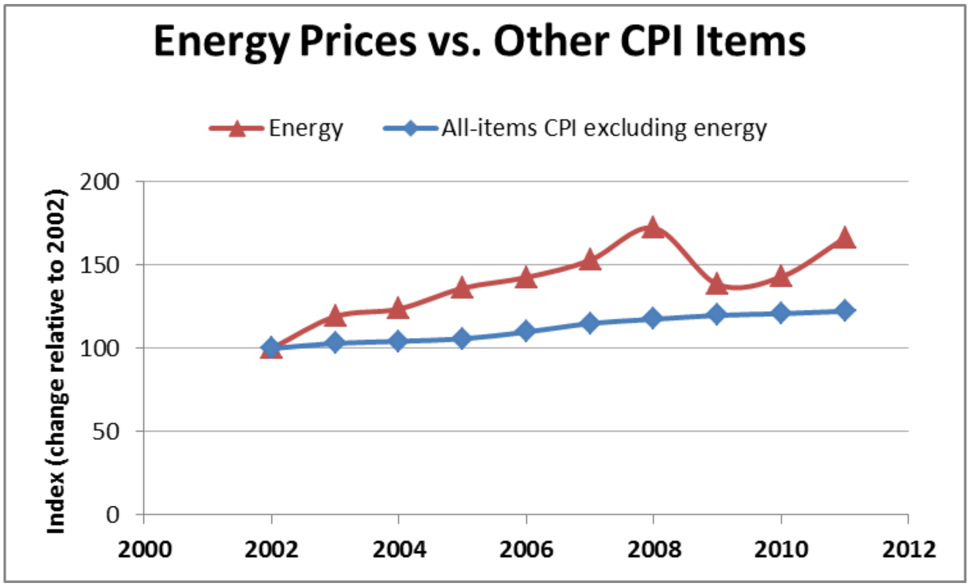
Energy costs also impact the cost of goods and services, such as food, that use energy for their production and/or transport. These cost impacts were not included in the analysis, but are nonetheless acknowledged.

3.4.2 Historic prices & relationship to other goods and services

As shown in Figure 13, energy prices paid by consumers are growing at a significantly faster rate than other goods and services. Median family income in Alberta has grown somewhat more slowly than the overall consumer price index (CPI), with energy prices contributing significantly to the gap.[29]

[29] Data Source: Statistics Canada, Family Characteristics.

Figure 13: Consumer Price Index for Alberta - 2002-2011[30]



In addition, energy prices are significantly more volatile than most other CPI items, as shown above in 2008-2010. This volatility provides particular challenges to individuals and businesses spending a significant share of disposable income on energy, particularly where incomes are low.

3.4.3 Energy prices

Two price projections were developed for this analysis, one Base Case and one High Case. The Base Case (see Figure 14) reflects projections of anticipated future energy prices that could be obtained or estimated with readily available data. The High Case is intended to reflect an alternate future scenario where energy prices rise much more quickly – double the price increases assumed in the Base Case.[31]

Note that these prices are in real dollars[32] (i.e. they have been adjusted to exclude the effects of inflation). Energy prices would appear to rise significantly more if measured in nominal dollars.[33]

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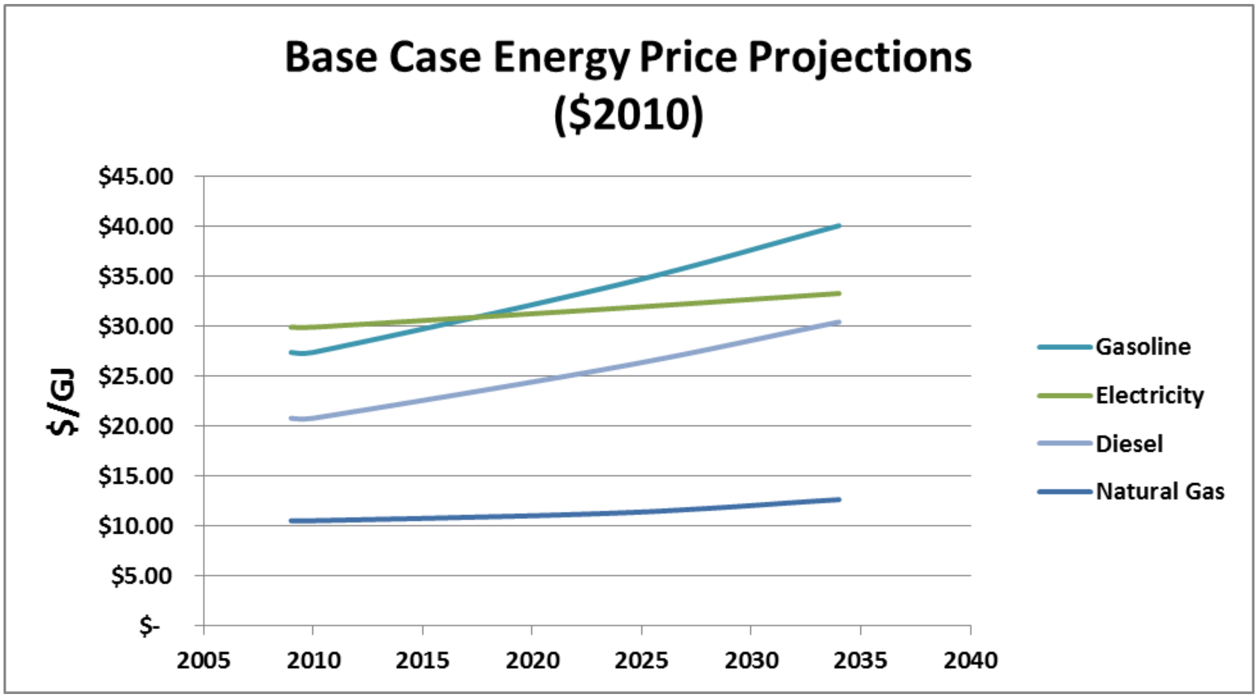
[30] Data Source: Statistics Canada, Consumer Price Index (CPI).

[31] It may also be the case that energy prices will be lower than the Base Case. This scenario is not analyzed here. However, it would presumably involve flat or near-flat prices in real terms.

[32] Figures that have been adjusted to remove effects of overall inflation. This is in contrast to nominal dollars, which take into account inflation.

[33] Gasoline prices, for example, triple from their 2010 prices by 2044 if measured in nominal dollars based on data from the US Energy Information Administration. However, much of this would be offset by the assumed rise in income.

Figure 14: Price projections for major fuel types - real dollars



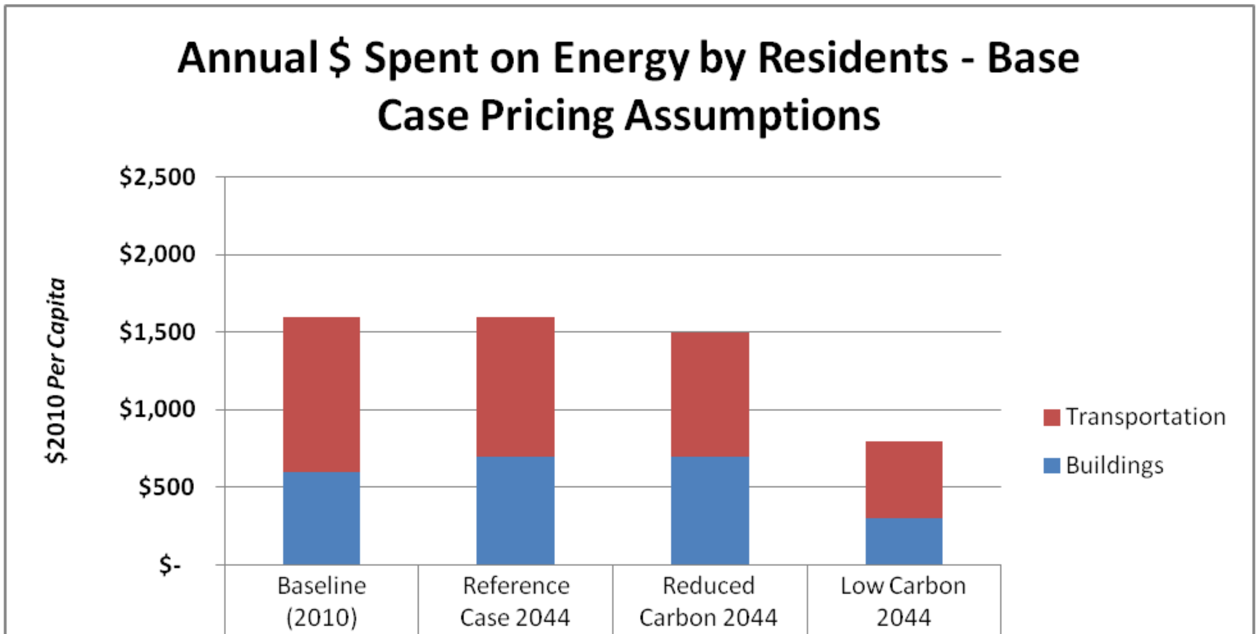
Additional references and assumptions for the energy pricing analysis are summarized at the end of Appendix B.

3.4.4 Energy spending under Reference Case, Reduced Carbon, and Low Carbon Cases

Under the Base Case energy pricing, residential spending *per person* is expected to remain relatively constant over time under both Reference Case and Reduced Carbon Case. This is because gains in efficiency largely match expected price increases.

The Low Carbon Case provides a reduction of around 50% from the Reference Case by 2044, a savings of around $800 per resident per year as shown in Figure 15.

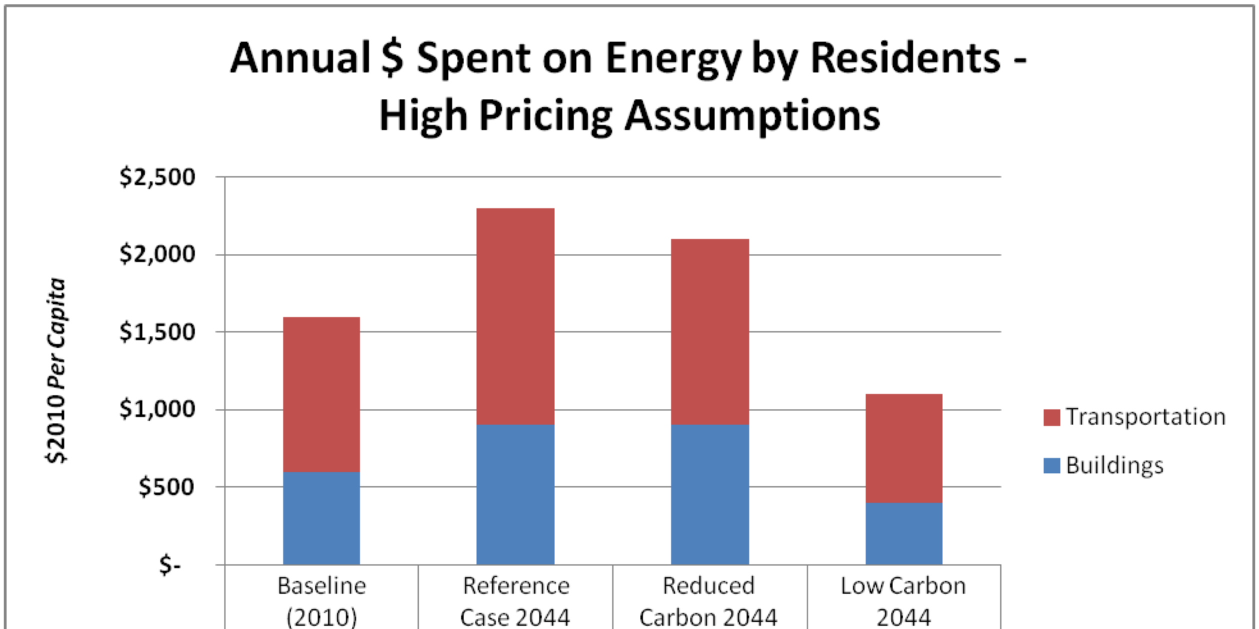
Figure 15: Annual energy costs for each case – base pricing assumptions



	Baseline (2010)	Reference Case 2044	Reduced Carbon 2044	Low Carbon 2044
Transportation	$1,000	$900	$800	$500
Buildings	$600	$700	$700	$300

By contrast, under the High Case energy cost assumptions (shown in Figure 16), energy spending increases rapidly under the Reference Case and Reduced Carbon Case, increasing approximately 50% by 2044. The Low Carbon Case again provides almost a 50% reduction in annual per capita spending on energy when compared with the Reference Case, saving around $1,200 per resident per year.

Figure 16: Annual energy costs for each case – high energy price assumptions



	Baseline (2010)	Reference Case 2044	Reduced Carbon 2044	Low Carbon 2044
Transportation	$1,000	$1,400	$1,200	$700
Buildings	$600	$900	$900	$400

3.4.5 Vulnerability assessment

Energy vulnerability indicates potential financial challenges or hardship that residents face as their energy spending increases versus their income.[34] How surmountable this issue is for a given resident is related to many factors.

Residents that are particularly vulnerable are typically lower-income residents who live in older dwellings that have not been upgraded, and who do not have practical alternatives to driving to work or other necessary destinations, such as using transit, walking or cycling.

The higher vulnerability not only results from higher ongoing energy spending, but also susceptibility to energy price volatility, or "price shocks". Improving the efficiency of vehicles and buildings, and providing for more housing and work opportunities via mixed-use developments will limit the impacts of both long-term price increases and shorter-term price volatility.

To conduct an analysis of energy spending vulnerability, the following factors are taken into account:

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[34] For this paper, a household in Edmonton is defined as "Energy Vulnerable" if it spends a share of income on energy that is twice that of a household with median income. Average energy spending in the base year (2010) was around $3,500 for a household, or around 5% of median household income. Energy vulnerability is therefore defined as those households that are spending 10% of their income on energy. Although this should be considered a working definition, it is a useful way to compare the relationship between energy use, energy price, and household income under different planning scenarios.

- Average household income
- Average annual cost of energy

As described earlier, median household income in Alberta has declined slightly relative to the overall basket of goods measured in CPI. As a simplifying assumption, future annual income is assumed to be held constant in real dollars. Any growth in energy prices beyond inflation will therefore increase the share of household income spent on energy.

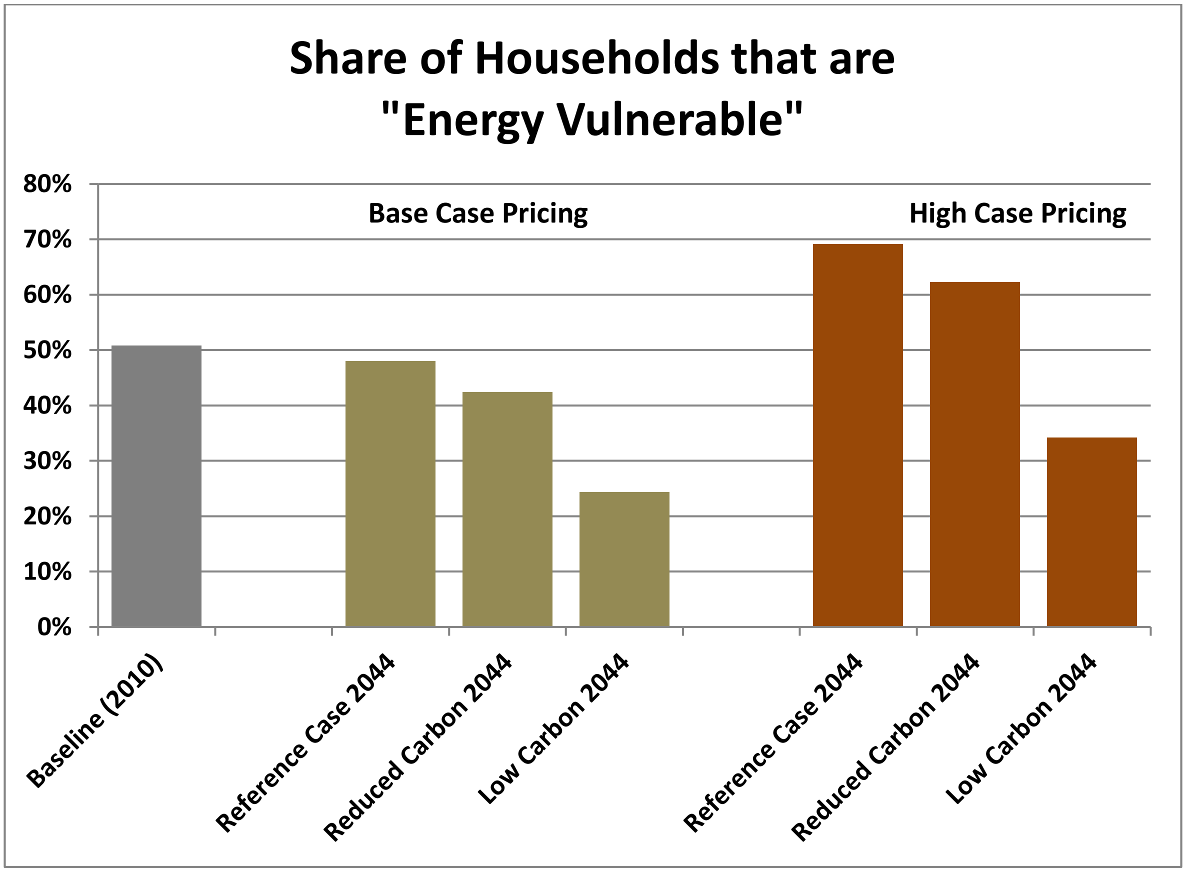
Table 9 and Figure 17 show the approximate differences in energy spending vulnerability across the modelling cases and energy cost cases.

Table 9: Energy vulnerability summary table

Pricing	Scenario	Average annual spending on energy		"Energy vulnerable" share of total households
		per capita	household	
Baseline	Baseline (2010)	$ 1,550	$ 3,565	51%
Base Case Pricing	Reference 2044	$ 1,580	$ 3,318	48%[35]
	Reduced Carbon 2044	$ 1,410	$ 2,961	42%
	Low Carbon 2044	$ 770	$ 1,617	24%
High Pricing	Reference 2044	$ 2,400	$ 5,040	69%
	Reduced Carbon 2044	$ 2,130	$ 4,473	62%
	Low Carbon 2044	$ 1,130	$ 2,373	34%

[35] Under base case pricing, the per household energy spending and vulnerability share decrease under the reference case in part because average household size (population per household) is assumed to decrease from 2.3 persons to 2.1 persons.

Figure 17: Share of population that is 'Energy Vulnerable'



3.4.6 Policy implications

Greater efficiency can significantly decrease operating costs and reduce vulnerability to price shocks. This is particularly significant for lower-income households.

A majority (approximately 60%) of energy costs are associated with vehicles, and fossil fuels used for transportation are likely to increase in cost more quickly than other fuel types. It will therefore be important to ensure low-income neighbourhoods have access to services and employment through alternative forms of transportation (biking, walking, public transit).

With regard to building efficiency, low-income households and rental properties face added financial barriers when compared to higher-income groups. One of these challenges is a lack of capital to make upgrades, and the other is referred to as the "split incentive" problem.[36] Currently, subsidies for furnace upgrades are offered to low-income households through

[36] When utility bills are paid by renters, they are the ones that benefit from energy efficiency upgrades while landlords would typically bear the cost of the upgrades.

CO2RE.[37] This program is admirable, but could be improved through more focus on rental housing and additional components, such as weatherization retrofits.[38]

3.4.7 Summary

- Assuming energy prices continue to rise as anticipated, Edmonton residents, especially low-income residents, will become more and more vulnerable to energy price changes and volatility over time in the Reference Case.
- This vulnerability will increase dramatically in the event that energy prices increase at higher rates than expected.
- Of the cases modelled, only the Low Carbon Case is expected to lead to a very significant decrease in energy spending and vulnerability over time.

[37] http://www.edmonton.ca/for_residents/LowIncomeFAQ-200-12-07.pdf

[38] Weatherization programs have grown rapidly over recent years, with dozens of jurisdictions at community and regional scales offering subsidies for low-income households.

4 Recommendations

4.1 Targets

As the City of Edmonton has already set a target of becoming carbon neutral, it makes sense to try to achieve this at the same rate as the leaders of the G8 countries have recommended for developed countries — an 80% reduction in GHG emissions (compared with 1990 to 2005 levels) by 2050.[39]

This analysis shows that this emission reduction target is possible through the opportunities identified in the Low Carbon Case, and largely depends on reducing the GHG intensity of the provincial grid; shifting towards more compact, transit-oriented communities; increasing energy efficiency in industry; increasing the uptake of distributed energy and energy efficiency in buildings; and reducing gasoline and diesel use in vehicles..

Interim targets on the road to an 80% reduction by 2050 — as shown in the Low Carbon Case — are a 20% reduction by 2020 and a 50% reduction by 2035 compared with current (2011) levels.

The Low Carbon Case modelled also demonstrates a noticeable decrease in the amount of fossil fuel based energy used in Edmonton. The recommended target for a more diverse energy mix — based on the Low Carbon Case — is to reduce gasoline, diesel fuel and coal-based energy by 75% from current levels by 2044. The modelling assumes a fuel mix that has natural gas-based energy close to current levels and increases the use of renewable energy to 23 times above current levels. The end result would be a shift in fossil fuel use (coal, oil and natural gas) from approximately 98.5% of Edmonton's energy to 75% by 2044.

[39] Leaders of the Group of Eight. 2009. Responsible Leadership for a Sustainable Future. http://www.g8italia2009.it/static/G8_Allegato/G8_Declaration_08_07_09_final,0.pdf

4.2 Action planning

Based on the research and analysis undertaken, it is clear that if Edmonton wants to reduce GHG emissions at the same rate as the G8 leaders' recommended goal for developed countries (80% by 2050), it will need to take action on all of the major emission reduction opportunities identified, and it will need to motivate other orders of government, organizations and individuals to do the same.

To reduce GHG emissions to this level and noticeably change the energy mix in Edmonton, the City of Edmonton would likely need to undertake the activities outlined below.

Note that the timing and sequencing of these recommendations has not been evaluated or proposed as part of this discussion paper. It is recommended that the City undertake further analysis on the resource requirements for these recommendations, opportunities for implementation, readiness of the marketplace, and timing considerations in order to prioritize these recommendations and create a more detailed implementation plan as part of the City's Energy Transition Plan.

<table>
<tr><th colspan="2">Goal #1: Reduce the GHG intensity of the provincial electricity grid</th></tr>
<tr><th colspan="2">Expected reduction: 24% below the Reference Case by 2044</th></tr>
<tr><th>Activity description</th><th>Level of change required</th></tr>
<tr><td>Influence (with others) the provincial and federal governments to reduce the carbon intensity of the provincial electricity grid
This would include increasing the percentage of power from natural gas power plants and wind farms.
Creating change within other governments in this way typically requires a long-term, coordinated effort to build support within different groups (including citizens and industry), and to engage with political decision makers on a regular basis.</td><td rowspan="2">All new power plants need to be either efficient natural gas plants (combined heat and power, or combined cycle) or cleaner (e.g. renewable energy).
Existing coal-fired power plants also need to be retired at the end of their current economic life (i.e. not refurbished or life-extended).
GHG intensities of 440 t CO_{2eq} per GWh of electricity by 2024 and 100 t CO_{2eq} per GWh of electricity by 2044 were assumed in the modelling in order to have the potential to reach the recommended GHG reduction target.</td></tr>
<tr><td>Purchase green electricity
By voluntarily purchasing green power, the City could lead by example and also directly increase the demand for green power production.</td></tr>
</table>

Additional information on this opportunity can be found in Appendix B – Section 2.2 and Appendix C – Section 2.5.

<table>
<tr><th colspan="2">Goal #2: Increase the proportion of development undertaken to create compact, mixed-use and transit-oriented neighbourhoods within already developed areas of the city</th></tr>
<tr><th colspan="2">Expected reduction: 8% below the Reference Case by 2044</th></tr>
<tr><th>Activity description</th><th>Level of change required</th></tr>
<tr><td>Land use and transportation planning beyond The Way We Grow and The Way We Move
These two plans include a shift from current development patterns (which are estimated to result in 37 people / ha in mature neighbourhoods) to more development in existing areas such as the downtown, the airport lands and inner city (which is estimated to result in 39 people / ha in mature neighbourhoods). The Low Carbon Case is estimated to increase the number of people in mature neighbourhoods to 42.
Increased integration of energy and emissions considerations into development of new plans is one mechanism to begin this transition.</td><td rowspan="3">This is a significant shift from current practices. However, it is expected that demand for more compact neighbourhoods will increase over time as consumer demands change and as more consumers are exposed to new, attractive and well-designed compact developments
In addition to changes in consumer preferences, the City will also likely need mechanisms to encourage new development within existing areas. These mechanisms could include policies for how new developments are approved, the way development levies are priced, and incentives for consumers to buy in particular neighbourhoods.
By 2044, the model assumed 40% of new development would occur in existing neighbourhoods in order to have the potential to meet the recommended energy and GHG targets.</td></tr>
<tr><td>Remove barriers to developing compact, mixed use, transit-oriented neighbourhoods
Infill development neighbourhoods are typically more challenging to get approved than traditional greenfield suburban development as existing residents often oppose changes to existing neighbourhoods. This leads to increased risk of not being approved and longer approval periods, which are barriers to undertaking more infill developments.
New development guidelines and approval processes to increase the speed and success of infill development applications and increase the quality and desirability of compact development are likely needed to make it easier for new infill developments to be approved. This would also help to increase the market demand for compact, mixed use, transit-oriented neighbourhoods.</td></tr>
<tr><td>Provide incentives to buying / building in compact, mixed-use, transit-oriented neighbourhoods
Research shows that incentives (such as lower mortgage rates) can encourage consumers to buy homes in particular neighbourhoods. It is recommended that the City first undertake research to determine and assess the different ways incentives could be provided before selected one or more to trial before full implementation. Incentives may also consider the cost differences in providing services in new vs. existing neighbourhoods, which would probably require further research.</td></tr>
</table>

Increase the frequency, capacity, convenience and quality of transit service in conjunction with increases in compact, walkable and transit-oriented development This can be accomplished through: • increased budget for transit development and operation at the municipal and/or provincial levels; and • combining areas of high population and employment densities (existing and planned) with rapid transit routes that have high levels of capacity (existing and planned).	As an example, the level of rapid transit service in 2044 was assumed to be approximately five times greater than current levels in order to have the potential to meet the recommended energy and GHG targets.
Increase the amount and quality of walking and cycling infrastructure and encourage its use This can be accomplished through policies, budgets and programs to identify and build new infrastructure, engagement programs (both public- and employee-based programs) and incentives. These activities can have significant social, health and economic co-benefits for residents.	These items were not explicitly modelled; however, they would support the targeted mode shift away from private vehicle transportation. Further analysis is required to determine the appropriate level of effort for these actions.
Work with insurance companies to develop pay-as-you-drive insurance and promote it to citizens The City will need to explore how it may be able to motivate the development of this new insurance product. A provincial or national effort may be required as insurance is regulated provincially, but most large insurance companies operate nationally or internationally.	
Consider parking supply restrictions, and toll roads or congestion pricing for vehicles These can be accomplished through parking and transportation policies adopted by the City. These items were not explicitly modelled within any of the Cases, but research shows that they can be effective in decreasing the amount of driving in a city as long as transportation alternatives are available. Further research is recommended to determine the feasibility, potential effectiveness and potential implementation approaches to these options including if and when they may be appropriate to use.	

Additional information on these opportunities can be found in Appendix B – Section 2.4, and Appendix C – Sections 2.1 and 2.2.

Goal #3: Reduce the energy use in industrial facilities through energy efficiency and a focus on industrial developments with lower energy use	
Expected reduction: 8% below the Reference Case by 2044	
Activity description	**Level of change required**
Consider supporting[40] industrial energy management systems[41] These systems have proven to be effective in saving energy, but they are not used in all facilities. Given the specialized expertise required for this action, it is recommended that the City consider partnering with other organizations to approach industrial facilities in the city to help build capacity in this area.	All currently economic energy efficiency opportunities would need to be implemented by 2044 in existing industrial facilities. This level of efficiency improvement (25%) was assumed to occur in order to have the potential to meet the recommended energy and GHG targets.
Consider encouraging, incenting and eventually requiring energy audits of industrial facilities Energy audits can provide valuable information on cost effective energy efficiency upgrades. By promoting and incenting energy audits to facilities in Edmonton (again, in partnership with other organizations), the City could build familiarity and capacity for energy audits and upgrades. It is also recommended the City consider pursuing the development of a bylaw to require energy audits for large energy users to ensure their universal uptake. There are ways to ensure the cost of the audits is not too onerous for facilities so that the bylaw will not be negatively received.	
Consider providing information to industrial facilities about how their energy use compares to similar facilities (i.e. benchmarking) and supporting the development of new financing tools Working with other organizations, the City could increase the generation and dissemination of information that encourages energy efficiency upgrades. A similar approach could be taken to developing new financing tools so facilities can easily undertake energy efficiency upgrades and reduce their annual energy costs in a way that provides them an immediate positive cash flow.	

[40] Support could include funding, in-kind resources, training, partnerships, unique financing opportunities, or enhanced visibility.

[41] Industrial energy management systems typically involved monitoring of energy use, identifying operational or retrofit opportunities to reduce energy use, and undertaking those opportunities that make sense. These actions occur on an ongoing basis and typically use structured management processes and staff to ensure they are done well.

Consider working with the provincial government to provide incentives for energy efficiency upgrades and eventually increase regulations that will further motivate energy efficiency upgrades Incentives and regulations related to energy efficiency of industrial facilities are often created at a provincial level. It is recommended the City consider working with the province to create incentives and eventually increased regulations for energy efficiency in the industrial sector. Possible regulatory mechanisms include the existing Specified Gas Emitters Regulation, which provides incentives for large facilities to reduce their GHG emissions, and the regulatory approval process for large facilities that often contain specified levels of environmental performance.	
Assess the feasibility, benefits and disadvantages of working to have future industrial development in Edmonton focus on facilities with low to moderate energy use Shifting towards low to moderate energy use industrial facilities is one way to reduce energy use and GHG emissions, but it has not been studied fully enough to determine its feasibility or implications. The City should undertake this work if it would like to use this strategy as a way to reach the recommended targets.	If this strategy is pursued, most new industrial facilities would need to be low to moderate energy users. New refineries, upgraders or cement plants would not likely fit this definition.

Additional information on these opportunities can be found in Appendix B – Section 2.1 and Appendix C – Sections 2.32.

<table>
<tr><th colspan="2">Goal #4: Increase the uptake of distributed energy[42] generation (e.g. solar heat and power, and natural gas combined heat and power plants) through barrier removal, capacity building, incentives and regulations.</th></tr>
<tr><th colspan="2">Expected reduction: 7% below the Reference Case by 2044</th></tr>
<tr><th>Activity description</th><th>Level of change required</th></tr>
<tr><td>Support companies providing distributed energy services
The companies that provide services such as feasibility studies, product installations, insurance, financing or maintenance are essential to increasing the uptake of distributed energy systems. The City would need to assess the variety of opportunities available to support these service providers (e.g., direct funding, in-kind resources, training, partnerships, unique financing opportunities, or enhanced visibility) so limited resources could be used effectively and strategically.</td><td rowspan="4">Initiatives such as these typically start with a small portion of the market, but will need to be increased to engage all buildings (e.g. through bylaws).
In order to have the potential to meet the recommended energy and GHG targets, the following changes (by 2044) were modelled:
• 5% of building electricity demand is generated by photovoltaics.
• 22% of building heat demand is met by solar hot water and passive solar heating.</td></tr>
<tr><td>Remove regulatory barriers to distributed generation
When regulatory barriers to distributed generation are identified (e.g. requiring a development permit to install a flat-mounted solar panel on a roof), work to remove these barriers.</td></tr>
<tr><td>Provide incentives for distributed generation
One method of increasing early market uptake of new technologies is to provide incentives. The City could provide the budget for these incentives while the incentives could be made available either through the City or a third party.</td></tr>
<tr><td>Design new neighbourhoods to take advantage of free heat from the sun
It is recommended that the City develop a policy for all new developments to maximize the southern exposure of buildings through optimizing street alignment for solar exposure, where reasonably possible.
Providing solar design guidelines and potentially requiring or incenting passive solar design is another step to maximizing this free heat.</td></tr>
</table>

[42] See page 25 for a more thorough definition.

Require all new buildings with solar access to be built 'solar-ready' It is much more cost effective to install a conduit from the roof to the mechanical and electrical room in a building when it is being built than to add it afterwards. Adopting this relatively low-cost measure will make it much easier and affordable in the future to install solar panels on buildings that have suitable exposure to the sun.	
Eventually require on-site energy generation on larger new buildings Similar bylaws have been adopted in other jurisdictions as a way to increase distributed energy generation and reduce GHG emissions. The amount of on-site energy generation required is often in the range of 10% and considered economically possible for larger new buildings (e.g. greater than 1,000 m^2 or approximately 11,000 ft^2)	
Require district energy in new developments where it is economic District energy is one of the ways to increase the efficiency of heating systems and make it easier to install combined heat and power plants, which are much more efficient than generating heat and electricity at separate sites. The City could begin this process by undertaking, encouraging or requiring district energy feasibility studies on proposed high density developments, and then, if economic, include district energy as a requirement for approval.	

Additional information on these opportunities can be found in Appendix B – Section 2.2 and Appendix C – Section 2.3.

<table>
<tr><th colspan="2">Goal #5: Increase the energy efficiency of buildings (new and existing) through capacity building, incentives and regulations.</th></tr>
<tr><th colspan="2">Expected reduction: 5% below the Reference Case by 2044</th></tr>
<tr><th>Activity description</th><th>Level of change required</th></tr>
<tr><td>Work with energy retailers to provide customers a way to compare the energy use of their building to that of similar buildings
This can be in the form of additional information on utility bills, online profiles or benchmarking studies that are customized for a particular customer. The feedback is provided regularly so behaviour changes can be maintained over a long period of time.</td><td rowspan="6">Initiatives such as these typically start with a small portion of the market, but will need to be increased to engage all buildings (e.g. through bylaws).
In order to have the potential to meet the recommended targets, the following changes (by 2044) were modelled:
• 22% improvement in the efficiency of existing buildings through retrofits.
• 10% reduction in residential electricity use through behaviour change programs.
New buildings built in 2044 were assumed to be 85% more efficient than new buildings currently constructed</td></tr>
<tr><td>Support the adoption of visible meters in homes
These types of programs often include fully or partially subsidizing the cost of a meter (either a physical device or an online profile) that provides ongoing information on a customer’s energy use and costs. The City could provide this subsidy or partner with others to make it available.</td></tr>
<tr><td>Support companies providing energy efficiency services for buildings
These services are essential to creating market transformation. The City would need to assess the variety of opportunities available to support these service providers so limited resources could be used effectively and strategically.</td></tr>
<tr><td>Support building energy management systems
These systems have proven to be effective in saving energy, but they are not used in all buildings. It is recommended the City partner with other organizations to increase the use of energy management systems within buildings in Edmonton.</td></tr>
<tr><td>Support and eventually require energy labelling of buildings at time of sale
Pilot projects have been used to develop the systems needed for broad energy labelling of buildings. Eventually, energy labelling will need to be required through a bylaw or other form of regulation. In order to accomplish this, it may be necessary to have a mechanism in place for people to easily upgrade the energy efficiency of their building and pass the costs on to the new buyer (as the benefits of the upgrade are passed on as well).</td></tr>
<tr><td>Support and eventually require building retrofits at time of sale
A similar process as energy labelling is likely required, i.e., piloting, developing systems, regulating and mechanisms for easy and cost effective upgrades to be undertaken so as to not make it onerous for owners and buyers.</td></tr>
</table>

Put in place a voluntary green building checklist and eventually require it The voluntary green building checklist helps to build awareness of green building practices. Once commonly understood, a bylaw to require the checklist to be undertaken will ensure the practices are considered for all new buildings. An independent design review panel could also be used for designers to get free advice on how to save energy and money with their building design and construction.	
Monitor the provincial and federal governments' efforts to continue to increase energy efficiency requirements in the building code Increases in the energy efficiency requirements in the building code are a base assumption within the Reference Case and are important to achieving the recommended targets for the Energy Transition Plan.	
Consider engaging facilities with large amounts of waste heat to see if this heat could be used elsewhere Using extra heat from one facility in another is one way to reduce energy use. The amount of extra heat, its location and opportunities for its use have not been studied as part of this discussion paper. An assessment of the potential to use waste heat and its ease of implementation is recommended to ensure City work in this area is a good investment compared to other opportunity areas.	

Additional information on these opportunities can be found in Appendix B – Section 2.1 and Appendix C – Section 2.3.

<table>
<tr><th colspan="2">Goal #6: Reduce the amount of gasoline and diesel used in the vehicle fleet through capacity building, incentives and regulations.</th></tr>
<tr><th colspan="2">Expected reduction: 4% below the Reference Case by 2044 (dependent on changes to the electricity grid)</th></tr>
<tr><th>Activity description</th><th>Level of change required</th></tr>
<tr><td>Encourage the adoption of fuel efficient vehicles
This could involve the engagement of taxi fleets, parking providers (preferred parking for hybrid and electric vehicles), the City’s transportation department (HOV lanes eligible for hybrid electric and electric vehicles) and fuel providers (making alternative fuels available). Incentives can also be used to encourage these measures.</td><td rowspan="4">City-wide reductions in gasoline and diesel fuel use (75% below current levels by 2044) and a relatively high penetration of electric vehicles (67% by 2044) will require local efforts to engage all fleets, consumers and buildings (for charging infrastructure). These levels of changes were assumed within the modelling in order to have the potential to meet the recommended energy and GHG targets.</td></tr>
<tr><td>Support fleet fuel management programs
These types of programs have proven to be successful. It is recommended the City work with the largest fleet operators in Edmonton to adopt or enhance fleet fuel management programs in a way that result in overall cost savings.</td></tr>
<tr><td>Support companies providing electric vehicles, natural gas vehicles, biofuels[43] and associated services
This could include purchasing vehicles and fuels, direct funding, in-kind resources, partnerships or enhanced visibility.</td></tr>
<tr><td>Encourage, incent and eventually require the electrification of loading spaces, truck stops and garages
This would help to ensure there is adequate infrastructure for electric vehicles and commercial vehicles that are able to plug in rather than idle to run onboard systems.</td></tr>
</table>

Additional information on these opportunities can be found in Appendix B – Section 2.3 and Appendix C – Section 2.2.

[43] Ethanol and biodiesel are currently required to be blended into gasoline and diesel fuel by law. Some biofuels create greater GHG reductions than others. It is recommended that any programs focus on the lower GHG biofuels as the more common biofuels are already being readily adopted in the marketplace.

Appendix A

The Future of Energy and Climate Change for Edmonton

Research Summary

Appendix A

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Executive Summary

This document has been compiled to present information on potential future energy and climate change scenarios that could affect Edmonton (i.e., scenarios that based on their probability and consequences would warrant a risk management response). This research summary was used as input for the City of Edmonton Energy Transition Plan discussion paper.

The research summary has been divided into two sections – energy and climate change – and organized according to the set of ‘burning questions’ that were previously circulated.

Energy

This section considers answers and discussion regarding the question:

What are the overall energy supply and energy demand outlooks for the planet over the next 40 years?

The following questions and answers summarize the findings of the research. Limited information was available on future energy supply and demand impacts for Edmonton, so those questions have not been included in this summary.

According to expert forecasts, how much will global energy demand change by 2050?

Most experts are projecting energy demand will continue to grow significantly in the future. Demand increases by 2030 range from 40% to 100%. Forecasts to 2050 show ranges of 47% to 100% (note that 2030 forecasts are from different sources than 2050 forecasts, which leads to apparent contradiction of having similar growth rates for 2030/35 and 2050).

According to expert forecasts, what factors will drive this change in demand?

The expert forecasts point to developing countries as the main driver for increases in energy demand. The energy demand in developed countries is projected to be stable or to decline. The end uses that are showing energy demand increases are transportation and electricity generation. For Canada, increases in energy production could increase overall energy demand.

According to expert forecasts, how much will global energy supply change by 2050?

Most energy forecasts indicate that fossil fuels will continue to provide the majority of energy supply by 2035/2050. However many forecasts indicate the share held by oil and coal will decline. One forecast reported by Alberta Energy projects a small increase in the share of energy that will be supplied by fossil fuels.

Renewable energy is expected to be the fastest-growing energy supply source, but remains below 20% of total supply in most scenarios. The share of natural gas is difficult to predict due to uncertainty on supply, especially from unconventional sources. Some sources expect the share of nuclear energy to increase slightly.

According to expert forecasters, what is today's reserve-to-production ratio for coal, natural gas, and oil?

The expert forecasters predict the reserve-to-production ratio to be the highest for coal and second-highest for natural gas. Oil is considered to have the lowest reserve-to-production ratio with, at lowest, approximately 50 years of known resources remaining.

Expert forecasters do not expect the world to run out of oil once these reserves are depleted, however; rather, their understanding of the economic and engineering connections led to the conclusions that concerns about oil depletion (including impacts of short-term, localized shortfalls) would lead to higher and/or more volatile oil prices. These prices would lead to additional resources being applied toward the development of unconventional resources and a shift towards alternatives to using oil.

According to expert forecasters, how critical is oil in the energy supply mix? What replacements/substitutes exist for this fossil fuel?

Oil is expected to remain the dominant form of transportation fuel despite a significant increase in price. A limited uptake of replacement fuels / substitutes is expected although some increase in vehicle efficiency and the use of alternative fuels, such as biofuels, is expected.

According to expert forecasters, how will global energy prices change up to 2050?

Globally, energy prices are predicted to increase and become more volatile.

According to expert forecasters, what are the implications to economic growth and political stability of a future reduction in conventional oil supply?

The experts provided a range of different scenarios that reflect potential alternative futures. The different scenarios reflect options that governments, businesses and individuals may take over the course of the next few decades. The implications on economic and political stability vary from localized short-term adjustments due to higher energy prices and stricter energy policies through to large price spikes, global economic slowdown and political turbulence.

According to expert forecasters, how will higher energy prices be reflected in other product and service costs, and how will this affect disposable incomes and quality of life globally?

The sources reviewed indicated that higher and more volatile energy prices would likely reduce GDP growth, lower household incomes, lower living standards, and — in cases of very high increases in oil prices — contribute to economic recession for most of the world.

Summary Statement

It is clear through the literature review that global energy demand is going to continue to increase as will the cost of energy — particularly oil, gasoline and diesel. For most of the world, this increase in oil prices and price volatility is expected to reduce GDP growth, lower household incomes, lower living standards, contribute to economic recession (in cases of very high increases in oil prices), and lead to a shift towards alternatives to oil.

Climate Change

This section answers the core burning questions about climate change:

> **According to experts, what are the probable outcomes of climate change (planet-wide) if left unchecked — socially, economically and environmentally? According to experts, how will these global changes affect Edmonton?**

The following questions and answers summarize the findings of the research.

According to generally accepted science, what are the factors contributing to climate change?

The burning of fossil fuels and changes in land-use patterns have been the dominant cause of climate changes observed since the mid-20th century. The global average net effect of human activities on climate has been one of warming.

According to generally accepted science, is the planet experiencing any statistically significant changes in climate today? If so, what are the size, extent and nature of this change?

Average temperature in Canada has increased by more than 1.3°C since 1948, with observed impacts including changes in precipitation patterns and melting permafrost. Globally, ocean temperatures have been warming, and sea levels have increased since the 19th and 20th centuries.

According to experts, how is Edmonton's climate expected to change if mitigation is unsuccessful? What effects will this have on Edmonton – socially, economically, environmentally?

Should mitigation be unsuccessful, the climate in the Edmonton and prairie region is expected to increase, with a corresponding increase in the number of days above 5°C. These climate changes will impact water scarcity and shift bio-climates, ultimately impacting terrestrial and aquatic habitats. The economic and social impacts for the Edmonton region include risks of expensive extreme weather events and disaster relief, drought, disease and heat stress. Opportunities may include longer growing seasons for agricultural products, and milder and shorter winters.

According to the generally accepted science, what reduction of GHG emissions on what timeline is needed to avoid severe climate change?

In order to avoid severe impacts of climate change, global warming should be restricted to 2°C. In order to do this, global emissions must peak between 2010 and 2020, and fall to a median level of 44 Gt of CO_2 equivalent in 2020. The emission reductions required by developed nations are 20 to 40% below 1990 levels by 2020, and further reductions of 80 to 95% by 2050.

Summary Statement

The generally accepted science indicates that the Earth is warming and the burning of fossil fuels is one of the main reasons for it. The predicted impacts of the current warming trend include water shortages for over 1 billion people; food shortages for hundreds of millions of people; hundreds of millions of people permanently displaced; the extinction of up to 40% of species; more expensive and extreme weather events; and a permanent loss of quality of life of up to 20% of GDP worldwide.

Introduction

This document has been compiled to present information on potential future energy and climate change scenarios that could affect Edmonton (i.e., scenarios that based on their probability and consequences would warrant a risk management response). This research summary was used as input for the City of Edmonton Energy Transition Plan discussion paper.

The research summary has been divided into two sections — energy and climate change — and organized according to the set of ‘burning questions’ that were previously circulated. Each section starts with a summary of the information gathered for each burning question and is then followed by a compilation of excerpts from various sources on the topic for those that would like more information.

Energy

This section considers answers and discussion regarding the question:

> **'What are the overall energy supply and energy demand outlooks for the planet over the next 40 years?'**

The answers and discussion represent a range of opinions from the sources listed in the *Sources* sub-section. Following that sub-section, we have included a short overview of *scenarios*, an important concept when considering mid to long-term energy forecasts.

Each of the remaining subsections considers particular research questions that contribute to the overall question. The answers and discussion are provided as direct quotes with the reference provided in each case.

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Glossary of terms

Conventional oil – petroleum extracted through traditional oil well and drilling methods.

Crude oil – petroleum that is usually extracted using the conventional method of drilling.

Proven reserves – quantities of petroleum which, by analysis of geological and engineering data, can be estimated with a high degree of confidence (usually at least 90%) to be commercially recoverable from a given date forward, from known reservoirs and under current economic conditions. Also referred to as proved reserves or economic reserves.

Unconventional oil – petroleum produced or extracted using techniques other than the conventional, oil well method. These include extra heavy oil and oil sands, oil shale and coal and gas conversion.

Undiscovered – those economic resources of oil and gas that are estimated to exist in favourable geologic settings but have not yet been discovered.

Scenarios and their role in energy forecasts

Most experts are careful to point out that projections past the short term (one to three years) are highly uncertain and subject to many factors, including actions by governments, businesses and individuals. Most long-term forecasts, 2030 and beyond, rely on "scenarios", which are linked sets of consistent assumptions. For example, assuming that most governments, businesses and individuals take action to reduce greenhouse gas emissions could be an underlying assumption of a scenario. The experts generally approach scenarios as "what if", rather than "this is highly likely." While a few experts may be willing to assess the probabilities to different scenarios, most experts attempt to provide a range of reasonable and consistent assumptions and learn from the resulting projections on energy demand, prices and other impacts.

The following quote provides an example of the use of scenarios, taken from the International Energy Agency's *Energy to 2050* report.

> *The three scenarios outlined in this chapter represent three rather extreme views of the future. This approach was taken on purpose, to cover a wide range of cases concerning the chosen variables and as a way to clarify logical chains of events and possible consequences. To some extent, all three scenarios have elements of plausibility. Thus, talking about the "likelihood" of any particular scenario is not appropriate. In fact, it seems likely that the future world will be some combination of the three cases – and perhaps other stronger drivers will emerge over time that will pull the future in entirely different directions.*

— International Energy Agency, *Energy to 2050*

One source reviewed took scenario development one step further and used a wargame approach to using assumptions on relationships to test future states.

> *Booz, Allen & Hamilton recently hosted an emissions "wargame," drawing on a technique the firm has long used with the Pentagon, to explore how competitive (or even partially cooperative) actors might respond to each others' moves when stressed by large, multidimensional, and uncertain changes. A wargame provides an efficient and intuitive way to begin the process of thinking through the strategic dynamics those actors will encounter. It challenges players to think systemically, and yields insights into the issues that can operate, often in unexpected ways, to validate or to undermine a given strategy.*
>
> *…*

The players in the emissions wargame were five fictional electric power generators / utilities and a regulatory team. The game covered the period 2009 to 2030.

…

The most important findings of the wargame approach were the interactions between actions and assumptions.

— Timothy Gardner and James Hendrickson, *Carbon Wargames*

Many forecasters note the importance of future actions to influence energy forecasts. For examples, see HSBC Global Research, Shell International BV and International Energy Outlook sources.

Questions and discussion

According to expert forecasts, how much will global energy demand change by 2050?

Most experts are projecting energy demand will continue to grow significantly in the future. Demand increases by 2030 range from 40% to 100%. Forecasts to 2050 show ranges of 47% to 100% (note that 2030 forecasts are from different sources than 2050 forecasts, which leads to apparent contradiction of having similar growth rates for 2030/35 and 2050).

In the New Policies Scenario, our central scenario, global energy demand increases by 40% between 2009 and 2035. Demand grows for all energy sources. Oil demand increases by 18% and is driven by transport. Coal demand, dictated largely by non-OECD countries, increases for around the next ten years but then stabilises, ending around 25% higher than 2009. Absolute growth in natural gas demand is nearly equal to that of oil and coal combined. Nuclear power generation grows by more than 70%, led by China, Korea and India. Modern renewables grow faster than any other energy form in relative terms, but in absolute terms total demand is still not close to the level of any single fossil fuel in 2035.

— International Energy Agency, *World Energy Outlook 2011*

In the IEO2011 Reference case, which does not incorporate prospective legislation or policies that might affect energy markets, world marketed energy consumption grows by 53 percent from 2008 to 2035.

— U.S. Department of Energy, EIA, *International Energy Outlook 2011*

World primary energy consumption grew by 45% over the past 20 years, and is likely to grow by 39% over the next 20 years. Global energy consumption growth averages 1.7% p.a. from 2010 to 2030, with growth decelerating gently beyond 2020.

— BP Statistical Review, *BP Energy Outlook 2030*

Energy demand grows 66% from 2010 to 2050 in Scramble scenario and 47% from 2010 to 2050 in Blueprints scenario

> *Scramble - reflects a focus on national energy security. Immediate pressures drive decision-makers, especially the need to secure energy supply in the near future for themselves and their allies.*
>
> *Blueprints - describes the dynamics behind new coalitions of interests. These do not necessarily reflect uniform objectives, but build on a combination of supply concerns, environmental interests, and associated entrepreneurial opportunities.*

It is a world where broader fears about life style and economic prospects forge new alliances that promote action in both developed and developing nations.

— Shell International BV, *Shell energy scenarios to 2050*

'If only' energy resources weren't a constraint and we could continue using energy the way we use it today, our World in 2050 would require:

- *A 110% increase in oil demand to more than 190 million barrels a day to fuel the extra billion cars that are likely to be on the road as emerging world incomes increase.*
- *A doubling in total energy demand as emerging market growth powers ahead.*
- *A doubling in the amount of carbon in the atmosphere, more than three and a half times the amount recommended to keep temperatures at a safe level."*
- *HSBC Global Research. 2011. Energy Constraints in 2050: Will fuel constraints thwart our growth projections.*

Total end-use energy demand growth slows from 1.4 per cent per year between 1990 and 2008 to 1.3 per cent per year over the projection period [2010 to 2035].

— National Energy Board, *Canada's Energy Futures*

A survey of expert consultants and energy forecasters show that North American natural gas demand is widely anticipated to increase by about 1% per year through to 2030.

Between 2009 and 2030, the reference forecast shows world oil demand growing by 1% per year, due entirely to demand from Non-OECD countries particularly from Asia. Demand for natural gas is expected to increase over the long term. This reflects a continuing trend that is decades old. Natural gas demand typically increases by about 1 percent per year.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

CERA projects that total world energy demand in 2035 could as much as double from where it is today. Alternative forms of energy, such as biofuels, wind, and solar power, will play a growing role in satisfying higher demand, but so will fossil fuels, including oil.

— IHS CERA Reports, *Growth in the Canadian Oil Sands*

World energy demand has grown at a steady pace in the last three decades and that growth is now accelerating as consumption rises in populous developing nations including China and India. At the same time, global energy supply has become more problematic.

Issues of technology, geology, politics, access and environment stand in the way of an assured, continuing flow of energy from traditional sources.

— Government of Alberta, *Provincial Energy Strategy*

The U.S. demand for electricity alone is expected to grow by 39 percent between 2005 and 2030 and global energy consumption is expected to grow by 60 percent by 2020.

— International Economic Development Council, *The Climate Prosperity Handbook*

A survey of expert consultants and energy forecasters show that North American natural gas demand is widely anticipated to increase by about 1% per year through to 2030.

Between 2009 and 2030, the reference forecast shows world oil demand growing by 1% per year, due entirely to demand from Non-OECD countries particularly from Asia.

Demand for natural gas is expected to increase over the long term. This reflects a continuing trend that is decades old. Natural gas demand typically increases by about 1 percent per year.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

CERA's estimates of global oil demand in 2035 range from 97 million barrels per day (mbd) to 113 mbd. In 2008 world oil demand was 85.2 mbd.

— IHS CERA Reports, *Growth in the Canadian Oil Sands*

Many countries plan to increase the share of natural gas in their national energy mixes as it has lower emissions than coal and oil and is more versatile (eg it can replace coal as a fuel for electricity generation and oil-based transport fuels in gas-to-liquid and compressed forms).

Uncertainty surrounds the supply and demand for gas in Asia and, in particular, China over the next decade. The Chinese government projects a tripling of current consumption to 300 billion cubic metres by 2020.

— Anthony Froggatt and Glada Lahn, *Sustainable energy security*

According to expert forecasts, what factors will drive this change in demand?

The expert forecasts point to developing countries as the main driver for increases in energy demand. The energy demand in developed countries is projected to be stable or decline. The end uses that are showing energy demand increases are transportation and electricity generation. For Canada, increases in energy production could increase overall energy demand.

Nearly 90% of global energy demand growth is in non-OECD countries. China consumes nearly70% more energy than the United States in 2035, is the largest oil consumer and oil *importer, and continues to consume nearly half of world coal production. Despite this, China's per-capita energy consumption is less than half the level of the United States in 2035.*

— International Energy Agency, *World Energy Outlook 2011*

As the SD Vision scenario suggests, it is possible to achieve, simultaneously, stringent goals for energy security, climate mitigation, and energy access, if our societies accept the inevitable, but not necessarily huge costs, and address the socio-economic implications. The policy tools are already available – although they must be applied at levels considerably more stringent than heretofore. The changes in the fuel mix, while significant, are within the range of shifts seen in the past – although earlier changes have been not as extensive or as cross-cutting. Current technologies are in many cases adequate to the task – and where new technologies are needed, they are in many cases already at the stage of pre-commercial development.

— International Energy Agency, *Energy to 2050*

In the Reference case, most of the growth in liquids use is in the transportation sector, where, in the absence of significant technological advances, liquids continue to provide much of the energy consumed.

— U.S. Department of Energy, Energy Information Administration, *International Energy Outlook 2011*

Prices, economic development (the rise and decline of the industrial sector) and energy policies (the promotion of energy efficiency) play important roles in changing technology and the energy required to support continued economic growth.

— BP Statistical Review, *BP Energy Outlook 2030*

The detailed results indicate a marked slowdown in many of the energy demand drivers (Figure ES.3). These drivers include slowing population growth, higher energy prices, lower than historical economic growth, and enhanced efficiency and conservation programs. Offsetting this slowdown is demand growth in the industrial sector, which made up nearly half of Canadian energy demand in 2010.

— National Energy Board, *Canada's Energy Futures*

Strong policy measures here (UK), and the uptake of new vehicle technology in major markets, such as the US and China, could set oil-fuel consumption on a downward trajectory.

— Anthony Froggatt and Glada Lahn, *Sustainable Energy Security*

According to expert forecasts, how much will Edmonton's energy demand change by 2050?

Information on changes to Edmonton's energy demand through 2050 was not available, but will be modeled in latter stages of this project. However AESO projects strong growth in electricity demand for the province and for Edmonton's peak electricity demand.

Only one forecast that was specific to Edmonton's energy demand was found in our literature review. Demand for electricity [Alberta-wide] is forecast to continue to grow, averaging three per cent annually over the long term.

> *City of Edmonton winter peak is projected to grow by 2.34% from 2009 to 2029 while the summer peak is projected to grow by 2.4% during same period.*
>
> — Alberta Electric System Operator, *Future Demand and Energy Outlook 2009-2029.*

According to expert forecasts, what factors will drive this change in demand in Edmonton?

As with the previous question, information on drivers for changes in Edmonton's energy demand were not found in this literature review, but will be investigated later in this project.

According to expert forecasts, how much will global energy supply change by 2050 (indicating the amounts and proportions of energy that are expected to be produced from coal, natural gas, oil, hydro, wind, solar, biomass, nuclear, other by 2050)?

Most energy forecasts indicate that fossil fuels will continue to provide the majority of energy supply by 2035/2050. However many forecasts indicate the share held by oil and coal will decline. Alberta Energy projects increased share of energy that will be supplied by fossil fuels and IHS CERA projects increased total consumption of oil (not necessarily increased share of total energy supply).

Renewable energy is expected to be the fastest-growing energy supply source, but remains below 20% of total supply in most scenarios. The share of natural gas is difficult to predict due to uncertainty on supply, especially from unconventional sources. Some sources expect the share of nuclear energy to increase slightly.

> *The share of fossil fuels decreases from 81% of world primary energy supply in 2009 to 80% in 2035 in the Current Policies Scenario, 75% in the New Policies Scenario and 62% in the 450 Scenario. In the Current Policies Scenario, coal represents nearly 30% of the energy mix and renewables 14% in 2035. In the 450 Scenario, the share of coal in total energy demand declines to less than 16% in 2035, while that of renewables increases to 27%.*
>
> — International Energy Agency, *World Energy Outlook 2011*

> *Fossil fuels are expected to continue supplying much of the energy used worldwide. Although liquid fuels—mostly petroleum based—remain the largest source of energy, the liquids share of world marketed energy consumption falls from 34 percent in 2008 to 29*

percent in 2035, as projected high world oil prices lead many energy users to switch away from liquid fuels when feasible. Renewable energy is the world's fastest growing form of energy, and the renewable share of total energy use increases from 10 percent in 2008 to 14 percent in 2035 in the Reference case.

— U.S. Department of Energy, *International Energy Outlook 2011*

The fraction of total global energy supplied by oil and other liquids is projected to decrease from 34% in 2008 to 29% in 2035, the fraction supplied by natural gas and coal remain stable in that time period (23% and 28%, respectively), nuclear increases slightly from 5% in 2008 to 7% in 2035, and renewable energy increases from 10% in 2008 to 14% in 2035.

— Based on values provided by the US Department of Energy, Energy Information Administration, *International Energy Outlook 2011*

In many parts of the world, concerns about security of energy supplies and the environmental consequences of greenhouse gas emissions have spurred government policies that support a projected increase in renewable energy sources. As a result, renewable energy sources are the fastest growing sources of electricity generation in the IEO2011 Reference case at 3.1 percent per year from 2008 to 2035 (Figure 6). Natural gas is the second fastest growing generation source, increasing by 2.6 percent per year. An increase in unconventional natural gas resources, particularly in North America but elsewhere as well, helps keep global markets well supplied and prices competitive. Future generation from renewables, natural gas, and to a lesser extent nuclear power largely displaces coal-fired generation, although coal remains the largest source of world electricity through 2035.

— U.S. Department of Energy, *International Energy Outlook*

The fuel mix changes relatively slowly, due to long asset lifetimes, but gas and non-fossil fuels gain share at the expense of coal and oil. The fastest growing fuels are renewables (including biofuels), which are expected to grow at 8.2% p.a. 2010-30; among fossil fuels, gas grows the fastest (2.1% p.a.).

— BP Statistical Review, *BP Energy Outlook 2030*

OPEC oil production reaches more than half of the world total in 2035. Non-OECD countries account for more than 70% of global gas production in 2035, focused in the largest existing gas producers, such as Russia, the Caspian and Qatar.

— International Energy Agency, *World Energy Outlook 2011*

The three fossil fuels are converging on market shares of 26-27%, and the major non-fossil fuel groups on market shares of around 7% each.

Oil continues to suffer a long run decline in market share, while gas steadily gains. Coal's recent gains in market share, on the back of rapid industrialisation in China and India, are reversed by 2030.

The diversifying fuel mix can be seen most clearly in terms of contributions to growth. Over the period 1990-2010, fossil fuels contributed 83% of the growth in energy; over the next twenty years, fossil fuels contribute 64% of the growth.

Taken together, the contribution of all non-fossil fuels to growth over the next twenty years (36%) is, for the first time, larger than that of any single fossil fuel.

Renewables (including biofuels) account for 18% of the growth in energy to 2030. The rate at which renewables penetrate the global energy market is similar to the emergence of nuclear power in the 1970s and 1980s.

…

Biofuels production (largely ethanol) is expected to exceed 6.5 Mb/d by 2030, up from 1.8 Mb/d in 2010 – contributing 30% of global supply growth over the next 20 years, and all of the net growth in non-OPEC. Continued policy support, high oil prices in recent years, and technological innovations all contribute to the rapid expansion.

…

We assume that policy supports the continued rapid growth of non- fossil power generation – especially renewables, which attain a global share of 10% by 2030.

— BP Statistical Review, *BP Energy Outlook 2030*

In both the Blueprints and Scramble scenarios, the portion of energy supply by *oil decreases by approximately 4% between 2010 and 2050 and is made up by increased portions supplied by coal and renewables (each increasing by approximately 2%)*

— Based on values provided by Shell International BV, *Shell energy scenarios to 2050*

One scenario from HSBC notes that "...our estimate of the energy mix required to meet the carbon constraint and limit temperature gains:

Fossil fuels represent less than half the total energy mix, and even here we have a significant use of carbon capture storage technology with only 10% of coal use unabated, and 20% of gas.

The share of energy mix met by renewables rises from 3% to 23%. The fastest growth is seen in wind and solar. Biomass and waste rises from 10% of the mix to 21%.

Reaching this target is clearly an enormous task and that assumes that nuclear can play an even greater role. If events at Fukushima hinder governments' desires to build nuclear plants this will place even greater weight on improving efficiency or expanding renewables. This will be difficult to achieve, but greater use of fossil fuels will make meeting the climate target impossible.

— HSBC Global Research, *Energy Constraints in 2050*

Global energy supply is 80 percent fossil-based, and due to growing energy demands in rapidly emerging countries like China it is forecast to be 82 percent by 2030. [Alberta Energy report did not provide a specific reference for the forecast used for the % of fossil fuel in 2030.]

— Alberta Energy, *Canada's Fossil Energy Future*

Oil today accounts for 35 percent of global energy supply—the largest share of any form of energy. In 2035 oil will still play a central role in world energy supply.

— IHS CERA Reports, *Growth in the Canadian Oil Sands*

Reference case:
Synthetic crude production -- 300% growth from 2005 to 2020)

— MK Jaccard and Associates, *Exploration of two Canadian Greenhouse Gas Emissions Targets*

Reference case:
Canadian crude oil production -- 48% growth from 2008 to 2020

— Environment Canada, *Canada's Emission Trends*

Overall, total Canadian oil production is expected to grow from 2.8 million b/d in 2010 to 4.7 million b/d in 2025. This is about 401,000 b/d higher than previously forecast, due primarily to the higher conventional production and the inclusion of some additional in situ projects that were previously put on hold.

— Canadian Association of Petroleum Producers, *Canadian Crude Oil Forecast and Market Outlook*

If natural gas prices recover to at least $5.50/ GJ then Canadian production is projected to rise to ~18.5 BCF by 2020. If prices do not exceed $4/GJ, Canadian production will decrease to ~13.5 bcf.

— Canadian Association of Petroleum Producers, *Canadian Natural Gas Production Forecast*

New Social Order imagines a world in which governments attempt to remake their economies on a platform of clean energy. The intersection of increasing costs and declining oil prices squeezes producers' margins and deters significant oil sands developments after 2020. Having reached 2.9 mbd by 2020—which represents more than a doubling from current levels—oil sands capacity essentially stagnates for the rest of the scenario period. In 2035 production is 3 mbd.

The Barreling Ahead scenario illustrates conditions that allow Canada to become one of the biggest producers of petroleum in the world by 2035. Ultimately oil sands production reaches 6.3 mbd in 2035. At this level of production Canada is by far the biggest source of oil for the US market, supplying 37 percent of US oil imports.

In the Deep Freeze scenario the great recession of 2008 and 2009 is just the prelude to a "great stagnation," in which low rates of economic growth persist for years in both North America and the overall global economy. Ultimately oil sands capacity reaches 2.3 mbd by 2035, the weakest of the three scenarios.

— IHS CERA, *Growth in the Canadian Oil Sands*

According to expert forecasters, what is today's reserve-to-production ratio for coal, natural gas, and oil (for both economic reserve and potential economic reserve)?

The expert forecasters from government and industry predict the reserve-to-production ratio to be the highest for coal and second-highest for natural gas. Oil is considered to have the lowest reserve-to-production ratio with, at lowest, approximately 50 years of proven reserves of supply remaining. Some experts expressed concerns of over-optimism in many of the published reserve-to-production ratios based on uncertainty of underlying factors for estimates and historic adjustments to such estimates.

Most sources noted that current supply and demand conditions for oil could not continue through 2050. The reports indicate that concerns about oil depletion (including impacts of short-term, localized shortfalls) would lead to higher and/or more volatile oil prices. These prices would lead to additional resources being applied toward the development of unconventional resources and a shift towards alternatives to using oil, including energy efficiency.

The literature referenced noted that the physical quantity of reserves is not the sole factor determining the use of different types of energy. A key question addressed by experts, through the use of scenarios, is "What are the implications on economic growth and political stability of a future reduction in conventional oil supply?" The experts responses to this question are reported in section 2.12.

*Reserve to production ratio (proved reserves):**

oil	46 years
natural gas	59 years
coal	118 years

— BP Statistical Review, *BP Energy Outlook 2030*

*Pembina note: BP includes 26.5 billon barrels of oilsands "under active development" in the ratio above. The ratio excludes a further 23.3 billion barrels from the oilsands which are considered not under active development. If these additional reserves were included the reserve to production ratio would be 51 years.

By 2030, the world will require production of 118 MBD, but energy producers may only be producing 100 MBD unless there are major changes in current investment and drilling capacity. By 2012, surplus oil production capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 MBD.

— U.S. Joint Force Command, *Joint Operating Environment*

To meet the increase in world demand in the Reference case, liquids production (including both conventional and unconventional liquids supplies) increases by a total of 26.6 million barrels per day from 2008 to 2035. The Reference case assumes that OPEC countries will invest in incremental production capacity in order to maintain a share of approximately 40 percent of total world liquids production through 2035, consistent with their share over the past 15 years. Increasing volumes of conventional liquids (crude oil and lease condensate, natural gas plant liquids, and refinery gain) from OPEC producers contribute 10.3 million barrels per day to the total increase in world liquids production, and conventional supplies from non-OPEC countries add another 7.1 million barrels per day.

Unconventional resources (including oil sands, extra-heavy oil, biofuels, coal-to-liquids, gas-to-liquids, and shale oil) from both OPEC and non-OPEC sources grow on average by 4.6 percent per year over the projection period. Sustained high oil prices allow unconventional resources to become economically competitive, particularly when geopolitical or other "above ground" constraints limit access to prospective conventional resources. World production of unconventional liquid fuels, which totaled only 3.9 million barrels per day in 2008, increases to 13.1 million barrels per day and accounts for 12 percent of total world liquids supply in 2035. The largest components of future unconventional production are 4.8 million barrels per day of Canadian oil sands, 2.2 and 1.7 million barrels per day of U.S. and Brazilian biofuels, respectively, and 1.4 million barrels per day of Venezuelan extra-heavy oil. Those four contributors to unconventional liquids supply account for almost three-quarters of the increase over the projection period."

— U.S. Department of Energy, Energy Information Administration, *International Energy Outlook*.

Oil

Rising supply to meet expected demand growth should come primarily from OPEC, where output is projected to rise by 13 Mb/d. The largest increments of new OPEC supply will come from NGLs, as well as conventional crude in Iraq and Saudi Arabia.

Non-OPEC supply will continue to rise, albeit modestly. A large increase in biofuels supply, along with smaller increments from Canadian oil sands, deepwater Brazil, and the FSU should offset continued declines in a number of mature provinces.

— BP Statistical Review. 2011. BP Energy Outlook 2030.

Even if demand doesn't increase, there could be as little as 49 years of oil left. Gas is less of a constraint, but transporting it and using it to meet transport demand is a major issue. Coal is the most abundant with 176 years left, but this is the worst carbon culprit.

— HSBC Global Research, *Energy Constraints in 2050*

Years left

	Proven	Resource	Potential
Oil			
conventional	43	44	108
unconventional	5	5	223
total	**48**	**49**	**331**
Natural gas			
conventional	53	53	98
Unconventional	11	56	320
Total	**64**	**109**	**418**
Coal	**176**		

— HSBC Global Research, *Energy Constraints in 2050*

Canada accounts for about 12% of the world's proved oil reserves, and 97% of Canadian reserves are in the form of oil sands. Based on the current rate of production, Canada has at least 175 years of crude oil reserves.

The province of Alberta estimates that proved oil sands reserves, currently estimated at 169.9 bbl, could grow to 315 bbl as technology improves.

Canada's conventional proved oil reserves are currently estimated at 4.3 bbl.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

As of year-end 2009, Canadian and US combined natural gas reserves totalled nearly 345 Tcf, with 61 Tcf in Canada and 284 Tcf in the US. Based on North American production of about 26 Tcf per year, the North American reserve-to production ratio (R/P ratio) is over 13 years.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

There is huge potential for tight and shale gas in Alberta, as well as natural gas from coal. New technology will be required to make the most of it.

Currently, only about 27% of light oil is recovered in Alberta, suggesting there is still plenty in the ground awaiting improved technology or improved prices.

The oil sands contain 173 billion barrels of economically recoverable crude bitumen (approximately 10% of the mineral deposit). Make no mistake; the oil sands are big, but Alberta's coal reserves contain more than twice the energy of all the province's other non-renewable energy resources.

— Government of Alberta, *Provincial Energy Strategy*

North American discovered natural gas resources have increased by more than 1,800 trillion cubic feet (Tcf) over the past three years, bringing the total natural gas resource *base to more than 3,000 Tcf, a level that could supply current consumption for well over 100 years.*

Development of this expanded resource may be able to meet significantly increased levels of demand without significant increases in prices.

Shale gas alone is expected to grow to more than 50 percent of the supply portfolio by 2030.

Indigenous natural gas supplies reduce the need for LNG imports into North America—which become a matter of choice rather than necessity.

— IHS CERA, *Fueling North America's Energy Future*

The North American natural gas resource base could support current levels of gas use for up to 100 years.

Unconventional gas production grows from one-third to over one-half of total gas supply by 2030.

— ICF International, *Integrated Energy Outlook*

The following table summarizes Alberta's energy reserves at the end of 2010.

Reserves and production summary, 2010

	Crude bitumen		Crude oil		Natural gas[a]		Raw coal	
	(million cubic metres)	(billion barrels)	(million cubic metres)	(billion barrels)	(billion cubic metres)	(trillion cubic feet)	(billion tonnes)	(billion tons)
Initial in place	286 627	1 804	11 245	70.8	9 513	338	94	103
Initial established	28 092	177	2 830	17.8	5 314	189	35	38
Cumulative production	1 194	7.5	2 593	16.3	4 221	150	1.46	1.61
Remaining established	**26 898**	**169**	**237**	**1.5**	**1 093[b]**	**38.8[b]**	**33**	**37**
Annual production	93.5	0.589	26.6	0.168	116	4.1	0.032[d]	0.035[d]
Ultimate potential (recoverable)	50 000	315	3 130	19.7	6 276[c]	223[c]	620	683

a. Expressed as "as is" gas, except for annual production, which is at 37.4 MJ/m^3. Includes unconventional natural gas.
b. Measured at field gate (or 35.3 trillion cubic feet downstream of straddle plant).
c. Does not include unconventional natural gas.
d. Annual production is marketable.

— Energy Resources Conservation Board, *Alberta Energy Reserves 2010 and Supply/Demand Outlook 2011-2020*

The new estimate of remaining ultimate potential for conventional natural gas in Alberta is 2,838,109 m^3 (101 Tcf).

Although increased from earlier estimates, Alberta's remaining ultimate potential of marketable conventional natural gas will require supplements from unconventional gas supplies in order to continue to meet Canadian domestic and export demands.

— Alberta Energy and Utilities Board, National Energy Board, *Alberta's Ultimate Potential for Conventional Natural Gas*

Conventional remaining established oil reserves are estimated to be approximately 1.5 billion barrels.

Alberta's oil sands reserve is considered to be one of the largest in the world, containing 1.8 trillion barrels of bitumen initially in-place. Of this total, 169 billion barrels are considered to be remaining established reserves, recoverable using current technology and under present anticipated economic conditions. To date, a little more than four per cent of the initial established resource has been produced.

— Government of Alberta, *Alberta's Energy Industry*

Alberta has a large natural gas resource base, with remaining estimated established reserves of 39 trillion cubic feet (Tcf). The province has remaining established reserves of 33.3 gigatonnes (Gt), with indications there is a resource of more than 2,000 Gt of coal in-place, underlying the Province.

— Government of Alberta, *Alberta's Energy Industry*

While estimates suggest coal reserves are plentiful, a gap in supply may arise as a result of sharp demand rises in Asia before new extraction projects are completed.

Recoverable reserves of natural gas are enough to meet world demand for heat, power and petrochemical uses to at least 2030, according to the IEA. But production equal to that of two Russias would need to come on-stream by then just to make up for the decline in existing fields.

Despite the global importance of oil (the most widely used fossil fuel) there is disagreement on how much will be available to meet future demands. There are basically three positions on this:

Using advanced technologies will allow us to carry on producing enough oil for generations, particularly from non-conventional sources, such as oil sands and shale.

Oil production will reach its peak level and go into irrevocable decline sooner than we are prepared for, with catastrophic effects on our societies and economies.

There may be plenty of oil in the ground but above-ground factors such as cost, willingness to invest and political barriers will constrain its production. Even before we reach peak oil, we could witness an oil supply crunch because of increased Asian demand.

— Anthony Froggatt and Glada Lahn, *Sustainable energy security*

A comparison of production forecasts by government and industry sources over time illustrates the uncertainty in the estimates:

As recently as 2007, Canada's National Energy Board (NEB) was highly optimistic about the tar sands, forecasting a near tripling of production from 1.4 million bpd at present to 4.15 million bpd by 2030. But in July 2009, owing to the suspension of several projects due to the 2008 economic downturn, NEB forecast a comparatively restrained doubling of tar-sands output by 2020. The Canadian Association of Petroleum Producers, noted for its bullish forecasts, is similarly now more restrained and forecasting an increase to 3.2 million bpd by 2025. Given some of the new environmental regulations being implemented for the tar sands, including tailings and carbon management (which will *increase cost and make this poor net-energy source of liquids even worse), these forecasts are still highly optimistic.*

…

the EIA provides basically another noworries forecast [of natural gas production] through 2035, with shale gas growing more than fivefold, a miraculous reversal in the geological fortunes of the Gulf of Mexico, and an overall growth in lower-forty-eight production of 22 percent by 2035.

This forecast is based on the following premises, which may prove to be unwarranted:

> *1. Drilling rates after a decline due to the current economic recession will be ramped up to equal and higher levels than those at their all-time peak (more than 36,000 successful gas wells per year in 2008), resulting in nearly one million new gas wells drilled by 2035.*
>
> *2. The observed "exploration treadmill" of declining average well productivity will cease to operate and in fact will reverse itself, as yet more wells are crowded into available prospects.*
>
> *3. Shale gas will live up to the hype, despite high decline rates, high costs, and significant associated environmental issues.*

Such forecasts do not reflect the underlying uncertainties controlling future gas supply and, in my view, are unhelpful in putting together a coherent plan for a sustainable energy future as they lull policy-makers into a false sense of security.

J. David Hughes, *Hydrocarbons in North America*

According to expert forecasters, how critical is oil in the energy supply mix? What replacements/substitutes exist for this fossil fuel?

Oil is expected to remain the dominant form of transportation fuel despite a significant increase in price. A limited uptake of replacement fuels / substitutes is expected although some increase in vehicle efficiency and the use of alternative fuels, such as biofuels, is expected.

Oil demand continues to grow and the global economy relies on oil more than on any other fuel. The global recession and high prices have had only a relatively small impact on demand for oil and it is likely to be temporary. Fossil fuels account for 59% of the increase in global energy demand from 2009 to 2035. This growth in demand comes in spite of increasing fuel prices and additional policy measures, such as energy efficiency measures in Brazil, China, India and Russia. Notwithstanding, this growth, its share in the primary energy mix actually decreases from 33% in 2009 to 27% in 2035. Significantly higher average oil prices and switching away from oil in the power generation and industrial sectors do not offset increasing demand in the transport sector, where demand is relatively price inelastic and substitution possibilities are limited. All of the net growth in global oil demand in the New Policies Scenario comes from the transport sector in the non-OECD countries

— International Energy Agency, *World Energy Outlook 2011*

During the next twenty-five years, coal, oil, and natural gas will remain indispensable to meet energy requirements. The discovery rate for new petroleum and gas fields over the past two decades (with the possible exception of Brazil) provides little reason for optimism that future efforts will find major new fields.

Efficient hybrid, electric, and flex-fuel vehicles will likely dominate light-duty vehicle sales by 2035 and much of the growth in gasoline demand may be met through increases in biofuels production. Renewed interest in nuclear power and green energy sources such as solar power, wind, or geothermal may blunt rising prices for fossil fuels should business interest become actual investment. However, capital costs in some power-generation and distribution sectors are also rising, reflecting global demand for alternative energy sources and hindering their ability to compete effectively with relatively cheap fossil fuels. Fossil fuels will very likely remain the predominant energy source going forward.

— U.S. Joint Force Command, *Joint Operating Environment*

World use of petroleum and other liquids grows from 85.7 million barrels per day in 2008 to 97.6 million barrels per day in 2020 and 112.2 million barrels per day in 2035.

— U.S. Department of Energy, Energy Information Administration, *International Energy Outlook 2011*

Oil is expected to be the slowest-growing fuel over the next 20 years. Global liquids demand (oil, biofuels, and other liquids) nonetheless is likely to rise by 16.5 Mb/d, exceeding 102 Mb/d by 2030.

Policy case - explores the implications of more aggressive policies to address climate change. The oil market path in the Policy Case will depend crucially on OPEC's ability to accommodate lower demand and to manage prices. As with other fuels, lower oil prices (because of lower demand) counteract the initial demand response to stricter policies. Netting out these effects, global liquids demand is expected to grow to 97.5 Mb/d (0.6% p.a.) to 2030 – 5 Mb/d below the base case.

— BP Statistical Review, *BP Energy Outlook 2030*

Based on input assumptions, oil sands production is expected to triple by 2035, increasing its share to 86 per cent of Canada's total oil supply, up from 54 per cent currently. Conventional oil production continues its historical decline over the projection period. East coast offshore oil production maintains near current levels until 2025, as new production facilities are built. By 2025, production begins a steady decline until the end of the projection period.

— National Energy Board, *Canada's Energy Futures*

According to expert forecasters, how will energy prices change up to 2050, both globally and in Edmonton?

Changes in energy prices through 2050 in Edmonton were not found in this literature review.

Globally, energy prices are predicted to increase and become more volatile.

The International Energy Agency is predicting average oil prices to increase to $120 / barrel (2010 dollars) by 2035 (over $210 / barrel when inflation is taken into account). Price volatility is also expected.

— International Energy Agency, *World Energy Outlook 2011*

In the New Policies Scenario, natural gas prices reach $12 per million British thermal units (MBtu) in Europe, $14/MBtu in the Pacific and $9/MBtu in North America by 2035 (in real 2010 dollars).

Coal prices averaged $99 per tonne in 2010. In the New Policies Scenario, they are assumed to rise gradually throughout the projection period, reaching $110/tonne (in year-2010 dollars) by 2035. The increase is much less in percentage terms than that for oil or gas partly because coal production costs are expected to remain low and because coal demand flattens out by 2020. Prices are higher in the Current Policies Scenario, reaching $118/tonne by 2035. By contrast, they are significantly lower in the 450 Scenario, dropping to $93/tonne in 2020 and $68/tonne in 2035, as a result of a widespread and large-scale shift away from coal to cleaner fuels.

— International Energy Agency, *World Energy Outlook 2011*

In 2011, the price of light sweet crude oil in the United States (in real 2009 dollars) is expected to average $100 per barrel, and with prices expected to continue increasing in the long term, the price reaches $108 per barrel in 2020 and $125 per barrel in 2035 in the IEO2011 Reference case.

— U.S. Department of Energy, Energy Information Administration,
International Energy Outlook 2011

NEB uses different prices in its scenarios - with price of oil in 2035 ranging from $85/barrel (low price scenario) to $155/barrel (high price scenario). The reference case uses $115/barrel in 2035.

Natural gas prices in 2035 range from $10.70/MMBTU to $6.40/MMBTU, with reference case at $8/MMBTU (2010$, Henry Hub)

— National Energy Board, *Canada's Energy Futures*

The crude oil price outlook to 2030 (from expert consultants and energy forecasters) shows a tendency towards rising prices. However, there is no consensus, which is not surprising given the variety of factors which can influence the price of oil.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

Natural gas prices are inherently hard to predict, even more so at a time when enormous supplies are on the verge of hitting the market. However, according to the forecasters surveyed, natural gas prices will gradually increase over the Outlook period to 2030.

— Natural Resources Canada, *Canadian Crude Oil, Natural Gas and Petroleum Products*

Reference case:
Crude oil price in 2020 $58 (WTI, $2006US / barrel)

— MK Jaccard and Associates, *Exploration of two Canadian Greenhouse Gas Emissions Targets*

Reference case:
Crude oil price in 2020 $96 (WTI, $2008US / barrel)

— Environment Canada, *Canada's Emission Trends*

Gas prices will rebound as the economy rebounds. Henry Hub gas prices likely to average $5.50 to $7.50 per MMBtu in real terms going forward.

— ICF International, *Integrated Energy Outlook*

Th[e] dynamic tension between volatile demand and inflexible supply means that oil prices are guaranteed to be highly unstable through the coming decades. However, if prices stabilize around $75 per barrel, perhaps falling to $50 and rising to $100, many new supply investments on the continental shelves, in deep water and in unconventional sources like oil sands will be economic.

— C. Bataille, *Peak Oil*

According to expert forecasters, what are the implications to economic growth and political stability of a future reduction in conventional oil supply?

The experts provided a range of different scenarios that reflect different paths through 2050. The different scenarios reflect different options that governments, businesses and individuals may take over the course of the next few decades. The implications on economic and political stability vary from localized short-term adjustments due to higher energy prices and stricter energy policies through to large price spikes, global economic slowdown and political turbulence.

Most experts provided more than one potential scenario for the evolution of energy demand and supply through 2050. The descriptions of a few scenarios are provided below as illustration of the possible paths through 2050. The pathway that ultimately occurs is unlikely to match any particular scenario, but experts use the scenarios to consider options and implications.

We emphasize four key points:

- *A solution is possible, but further efficiency gains and the deployment of low-carbon energy sources are unlikely to materialize without further upward pressure on fossil fuel prices.*

- *The lead times we highlight on the measures in 'the solution' are often long. Therefore the squeeze on fossil fuels in the interim could be both persistent and painful as oil prices are so sensitive to minor imbalances between energy demand and supply.*

- *Meeting growth targets [GDP] will be easier than meeting climate targets. It remains to be seen whether growth targets and climate targets can be disentangled.*

- *For the transition to [meeting GDP growth in] our World in 2050 to be smooth, governments will have to work together and be pre-emptive in driving change, before the commodity crunch really begins to bite.*

— HSBC Global Research, *Energy Constraints in 2050*

In ***Scramble****, a typical three-step pattern begins to emerge: first, nations deal with signs of tightening supply by a flight into coal and heavier hydrocarbons and biofuels; then, when the growth in coal, oil and gas can no longer be maintained, an overall supply crisis occurs; and finally, governments react with draconian measures — such as steep and sudden domestic price rises or severe restrictions on personal mobility with accompanying disruptions in value chains and significant economic dislocations. By 2020, the repetition of this volatile three-step pattern in many areas of the energy economy results in a temporary global economic slowdown.*

High domestic prices and exceptionally demanding standards imposed by governments provoke significant advances in energy efficiency. Eventually, locally developed alternative supplies -- biofuels, wind, and thermal solar -- also contribute on a much greater scale than before. By 2030, healthy economic growth is restored, with particular vibrancy in the new energy sector that has received a massive stimulus to innovation through this difficult period.

In ***Blueprints****, "while international bodies argue over what environmental policies should be and which policies are feasible, and many national governments worry about energy security, new coalitions emerge to take action.*

As more consumers and investors realise that change is not necessarily painful but can also be attractive, the fear of change is moderated and ever-more substantial actions become politically possible. These actions, including taxes and incentives in relation to energy and CO_2 emissions, are taken early on. The result is that although the world of Blueprints has its share of profound transitions and political turbulence, global economic activity remains vigorous and shifts significantly towards a less energy-intensive path.

By 2050, one of the key revolutionary transitions observable in ***Blueprints*** *is that economic growth no longer mainly relies on an increase in the use of fossil fuels. It is increasingly a world of electrons rather than molecules.*

— Shell International BV, *Shell Energy Scenarios to 2050*

Scenario 1 – ***Clean but not sparkling*** *- The initial emphasis [for developed countries] in this scenario would be on energy efficiency, conservation and measures on the energy demand side and then on shifts in the energy supply mix towards renewables and gas.*

The price of energy to the final consumer would keep increasing both due to increased fiscal pressure and to the increased costs of more efficient technologies for the system.

Oil demand will keep growing in developing countries, driven by income growth and by increased appetite for mobility in these societies. In fact, before the impact of conservation measures and of technology improvement on oil consumption is felt in those countries, some bottlenecks in oil supply may have emerged. One of them concerns the refining capacity installed to produce light distillates and particularly products that comply with higher environmental standards (low sulphur, etc.). But another bottleneck may be linked to political instability in some of the supplying regions…As a result of a combination of the use of the above technologies (on both the supply and the demand side) and a continuing shift in behavioural patterns towards less consumerist lifestyles, by 2040 the global GHG emission curve would be actually starting to bend down. Energy consumption patterns between developed and developing countries would be heading towards convergence, but this will also have been achieved at a cost of lower income growth and a substantial reduction of per capita energy consumption in developed countries, while a moderate increase would have taken place for developing ones.

Scenario 2 – ***Dynamic but careless*** *- This scenario is characterised by very dynamic technological change, low priority for climate change mitigation and a generalised belief that sustained growth and rapid progress in technologies will take care of all problems without need for much policy intervention.*

As a corollary, this scenario has more rapid economic growth than the first one, including more open but less regulated markets. Unhindered economic growth is the main priority, shared by developed and developing countries alike. However, not all countries are able to achieve fast growth rates and some lag behind. Global threats such as climate change take a back seat in the concerns of both citizens and politicians. Although energy represents a relatively small share of production inputs or household spending, low energy prices and security of supply are considered an important condition for economic growth.

At the beginning, progress is faster in fossil fuel based technologies, helping to maintain low prices. In both developed and developing countries local environmental problems are not ignored but are dealt with at the local level and consistently with the economic resources of the affected communities or individually through pollution impact averting behaviour. As a consequence of these initial conditions, fossil fuel demand grows rapidly, followed by an increase in GHG emissions. These two factors increase the likelihood of energy security of supply crises and worsening environmental conditions. To deal with security of supply, and in the continuous quest for low energy costs the system accelerates the development of new technologies. While the first phase of this scenario is therefore heavily oriented towards fossil fuel-based technologies, in the second part of the scenario horizon, non-fossil technologies emerge too.

As a result world oil demand would grow fast (over 2% per year). By 2015, tensions on the oil supply side would have become considerably exacerbated. Initially they would concern sporadic shortages in refinery capacity in developing countries. But with demand booming, investments in new capacity in many cases would catch up. Traditionally oil-exporting countries would, at last, massively enter the refining business but large refining *capacity will also be built in rapidly industrialising countries. In addition, some delocalisation of refining from developed countries due to increasing environmental regulations and pollution control costs could take place.*

At those rates of oil demand growth, the rate of resource extraction would also accelerate. This would not show up immediately in a price increase, because strong demand would sustain robust investment by the oil industry in new technologies to find and extract oil in increasingly difficult conditions without dramatically increasing costs. This and fierce competition among oil companies will prevent prices from increasing for some time. This process of adjustment in the oil market would take place rather smoothly until 2015. But eventually prices will start to creep up as a result of increasing resource exhaustion. Furthermore the high cost producing areas would yield to those supply areas with lower costs and larger reserves, determining an increasing import dependence on a few geographic regions, and increasing supply security issues.
In this scenario, this increasingly tense political and energy market situation would likely bring along a recrudescence of terrorism and an increasing preoccupation with security at many levels.

Scenario 3: ***Bright Skies –*** *This scenario is characterised by both rapid technological change and strong concern for the global environment by both the public and policymakers.*

Other features of this scenario include a (global) GDP growth rate somewhere in between the first two cases but closer to the second, robust trade and market liberalisation trends, a narrowing down of income differences across regions and countries. As a result, overall, energy prices will be somewhat higher than in the second scenario but lower than in the first.

As a result of large international research efforts, it is likely that significant breakthroughs in one or more of these technologies would be made before the end of the scenario horizon considered, thus providing a long-term answer to the problem of climate change mitigation without significantly restricting economic growth and the satisfaction of future demand for energy services.

Normative scenario – ***The SD Vision –****Estimates of both reserves and resources tend to differ across different data sources and are constantly revised as new knowledge becomes available: we must bear in mind that these estimates are not written in stone. However, today's knowledge of these stocks allows us to draw a few conclusions.*

For coal, at the level of resource use indicated by the SD Vision scenario no shortage can be anticipated.

On the other hand, at consumption rates like the one envisaged by the SD Vision scenario remaining discovered reserves of conventional oil, estimated at 130.5 Gtoe (IEA, 2001c) would largely be depleted by 2050. By then the world would be tapping into conventional oil resources that yet remain undiscovered, as well as drawing significantly from what are currently considered unconventional resources.

These considerations bear some important implications for hydrocarbon resources exploration, extraction and related technologies. For oil the issue is that easily accessible *resources are rapidly being depleted and new deposits being found are on average smaller and less accessible than those discovered 50 years ago. The problem is going to get worse and unless exploration and extraction technologies improve, finding oil and pumping it out of the ground will become more and more expensive. …Also, technologies would have to improve if unconventional oil resources are to be tapped.*

— International Energy Agency, *Energy to 2050*

According to expert forecasters, how will higher energy prices be reflected in other product and service costs, and how will this affect disposable incomes and quality of life both globally and in Edmonton?

The sources reviewed indicated that higher and more volatile energy prices would likely reduce GDP growth, lower household incomes, lower living standards, and — in cases of very high increases in oil prices — contribute to economic recession for most of the world.

Information specific to Edmonton was not found.

Equally important, oil prices have become more volatile, and the consequent unstable prices and supplies are reverberating across many sectors of the economy. Consumers and businesses are feeling the bite and an overall trend of increasing oil prices over the past decade are dampening U.S. GDP growth. According to the Congressional Budget Office (CBO), increased oil prices reduced GDP growth by about 1 percent in 2006, and lowered household savings rates as consumers spent more on energy. The CBO predicts that increases in energy prices over the next 10 years will reduce U.S. living standards as people spend more of their money on energy and less on other goods and services.

— International Economic Development Council, *The Climate Prosperity Handbook*

Oil price changes affect the price of other types of energy, particularly natural gas, and many aspects of the economy, for example: mobility; transported goods, including essential foods; importing government tax revenues or subsidy costs; and exporting country investment income. The global impact of higher oil prices on the economy was illustrated by the global recession of 2008-2009. Given the expense of extracting unconventional and difficult oils, the cost of oil is likely to rise.

— Anthony Froggatt and Glada Lahn, *Sustainable Energy Security*

Indeed, for those who believe the global economy is ultimately fuelled by oil and gas (as opposed to, for example, excessive credit), events in 2008 simply confirmed a pattern seemingly in place since the 1970s. Chart 1 shows the level of oil prices in real terms (adjusted using the US consumer price index) tracked against US recessions. Regular as clockwork, increases in oil prices of more than 100% lead to declining GDP.

— HSBC Global Research, *The Global Economic Impact of Higher Oil Prices*

As recent events have demonstrated, the impact of higher oil prices on international freight transport can be dramatic. Since the year 2000, the cost of transporting a single *forty-foot equivalent unit (FEU) container from Shanghai to Columbus, Ohio in the heart of the U.S. consumer market has increased by 265 percent, from $3,000 [at around $20 per barrel] to $8,000 (at around $130 per barrel). If oil prices increase to $150 and $200 per barrel, the impact will be even more severe and costs will increase to $10,000 and $15,000 respectively. High oil prices have led to increased production costs for manufacturers and lower purchasing power for consumers, which has slowed trade growth worldwide as well as for the United States.*

— Transportation Economics & Management Systems, *Impact of High Oil Prices on Freight Transportation.*

Climate Change

This section answers the core burning questions about climate change:

> **According to experts, what are the probable outcomes of climate change (planet-wide) if left unchecked – socially, economically and environmentally? According to experts, how will these global changes affect Edmonton?**

The answers and discussion represent a range of opinions from the sources listed in the following sub-section. Each of the remaining subsections considers particular research questions that contribute to the overall question.

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Questions and discussion

According to generally accepted science, what are the factors contributing to climate change?

The burning of fossil fuels and changes in land-use patterns have been the dominant cause of climate changes observed since the mid-20th century. The global average net effect of human activities on climate has been one of warming.

Natural factors and human activity influence global climate, but the burning of fossil fuels and changes in land-use patterns have been the dominant cause of climate changes observed since the mid-20th century.

…

2005 versus pre-industrial concentrations of main greenhouse gases		
	2005	**Pre-industrial**
Carbon dioxide	379 ppm	280 ppm
Methane	1774 ppb	715 ppb
Nitrous oxide	319 ppb	270 ppb

The predominant sources of $C0_2$ are fossil fuels, cement products and land use associated with forestry and agriculture.

— Donald Lemmen et al. *From Impacts to Adaptation*

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004…Global increases in $C0_2$ concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution.

…

There is very high confidence that the global average net effect of human activities since 1750 has been one of warming.

…

It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent.

—IPCC, *Climate Change 2007: Synthesis Report*

In the New Policies Scenario, global energy-related CO_2 emissions increase by 20%, following a trajectory consistent with a long-term rise in the average global temperature in excess of 3.5°C. Around 45% of the emissions in 2035 are already locked-in, coming from capital stock which either exists now or is under construction and will still be operating in 2035.

— International Energy Agency, World Energy Outlook 2011

Science clearly shows that anthropogenic greenhouse gas emissions - mainly produced by the use of fossil fuels - are provoking dangerous climate change, putting at risk not only the environment and ecosystem services but the very basis of our present and future prosperity. The costs of inaction far outweigh the costs of moving towards low-carbon societies.

…

Increase in global average temperature above pre-industrial levels ought not to exceed 2°C. Global emissions need to peak as soon as possible and decline thereafter in order to achieve at least a 50% reduction of global emissions by 2050.

— G8, *Responsible Leadership for a Sustainable Future*

The scientific evidence points to increasing risks of serious, irreversible impacts from climate change associated with business-as-usual (BAU paths for emissions.

The current level or stock of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) C02 compared with only 280ppm before the Industrial Revolution. These concentrations have already caused the world to warm by more than half a degree Celsuis and will lead to at least a further half degree warming over the next few decades, because of the inertia in the climate system.

Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 - that is 550ppm CO2e - and would continue growing thereafter.

But the annual flow of emissions is accelerating, as fast-growing economies invest in high- carbon infrastructure and as demand for energy and transport increases around the world. The level of 550ppm CO2e could be reached as early as 2035. At this level there is at least a 77% chance - and perhaps up to a 99% chance, depending on the climate model used - of a global average temperature rise exceeding 2°C.

— N. Stern et al. *Stern Review: the economics of climate change*

According to generally accepted science, is the planet experiencing any statistically significant changes in climate today? If so, what are the size, extent and nature of this change?

Average temperature in Canada has increased by more than 1.3°C since 1948, with observed impacts including changes in precipitation patterns and melting permafrost. Globally, ocean temperatures have been warming, and sea levels have increased since the 19th and 20th centuries.

The average temperature in Canada increased by more than 1.3°C since 1948. Observed impacts in Canada include the following:

- *Changes in precipitation patterns, more precipitation as rain instead of snow*
- *Permafrost has started to melt in the north*

— F.J. Warren, T. Kulkarni and D.S. Lemmen, *Canada in a Changing Climate*

During the past 50 years, average national temperature in Canada has increased by 1.3°C. Magnitude of future changes will vary across the country - south-central prairies are expected to warm the most.

— Donald Lemmen et al., *From Impacts to Adaptation*

Oceans are warming: from 1961 – 2003 global ocean temperature has risen by 0.10°C from the surface to a depth of 700m.

Global mean sea levels have been rising: from 1961 – 2003 the average rate of sea level rise was 1.8 +/- 0.5mm per year. There is high confidence that the rate of sea level rise has increased between the mid 19th and the mid 20th centuries.

There is evidence for increase in occurrence of extreme high water worldwide related to storm surges, variations in extremes and that are related to rise in mean sea level and variations in regional climate.

— N.L. Bindoffet al., "Observations: Oceanic Climate Change and Sea Level"

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

…

Observed decreases in snow and ice extent consistent with warming trends - annual average artic sea ice extent has shrunk by 2.7% per decade (since 1978). Mountain glaciers and snow cover on average have declined in both hemispheres. Extreme weather events have changed in frequency and intensity over last 50 years:

- *More frequent heat waves;*
- *Increased frequency of heavy precipitation events;*
- *Increased incidence of extreme high sea level is likely.*

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

— IPCC, *Climate Change 2007: Synthesis Report*

According to experts, how is Edmonton's climate expected to change if mitigation is unsuccessful? What effects will this have on Edmonton – socially, economically, environmentally?

Should mitigation be unsuccessful, the climate in the Edmonton and Prairie region is expected to increase, with a corresponding increase in the number of days above 5°C. These climate changes will impact water scarcity and shift bio-climates, ultimately impacting terrestrial and aquatic habitats. The economic and social impacts for the Edmonton region include risks of expensive extreme weather events and disaster relief, drought, disease and heat stress. Opportunities may include longer growing seasons for agricultural products, and milder and shorter winters.

Physical and environmental impacts of climate change in Canada and the prairie region:

Increase in water scarcity – lower summer streamflows; falling lake levels; retreating glaciers; increasing soil and surface water deficits

Shifts in bio-climate, insects, fire, stressed aquatic habitats and introduction of non-native plants and animals; risk of mountain pine beetle etc.

Potential economic and social impacts from climate change:

Climate change impacts will affect supply-demand dynamics and the competitive advantage of some industries in Canada - for example forest productivity. Even if productivity increases in Canada and elsewhere, this will result in lower product prices on the global market. Other impacts include those on tourism as a result of reduced attractiveness of natural areas in Canada.

Changes in climate offer opportunities for agricultural expansion of growing season, increased heat units and milder, shorter winters. Negative impacts include increased frequency and intensity of extremes - drought and intense storms, rapid rates of change

Climate variability is costly – the drought of 2001-2002 in prairies was a $3.6billion drop in agricultural production. The economic costs from extreme weather events since 1996 have been greater than for all previous years combined – hundreds of millions to billions associated with flooding, wind, hail ice storms, hurricanes, wildfires etc.

Increased need for disaster relief; increased political instability and displacement of populations

…

The primary climate impacts of concern for cities on the Prairies are extreme weather events, drought, disease, heat stress and the gradual ecological transformation of urban green space.

…

“Prairie specific impacts include: negative health burdens from air pollutions, food-borne pathogens, heat related illnesses, poor mental health, particulate matter, water-borne pathogens and vector born diseases.

— Donald Lemmen et al, *From Impacts to Adaptation*

Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C.

— IPCC, *Climate Change 2007: Synthesis Report*

Arctic Monitoring and Assessment Program: “The largest and most permanent bodies of ice in the Arctic, including multi-year sea ice, mountain glaciers, and the Greenland ice sheet, have melted faster since 2000 than in the previous decade. The Arctic Ocean will be nearly ice-free during the summer within this century, probably within the next 30-40 years.

— Earth Observatory, *Arctic Melt Raises Sea Levels and Reinforces Global Warming*

There are potential security implications of the adverse impact of climate change and the potential for increased conflicts over scarcer resources. "We are deeply concerned about *the consequences of climate change on development, ecosystem services, water and food security, agricultural output, forest, health and sanitation.*

— G8, *Responsible Leadership for a Sustainable Future*

There is clear scientific consensus that sea level is rising partly in response to past emissions of greenhouse gases from human activity. Melting glaciers and ice sheets are responsible for more than a third of the current rate of sea-level rise and the contribution of meltwater to the oceans can be expected to continue and accelerate s more land ice melts.

Sea level rise will be felt both through changes in mean sea level, and perhaps more importantly, through changes in extreme sea-level events. Natural system effects of sea level rise include: inundation, flood and storm damage; wetland loss; erosion; saltwater intrusion; rising water tables and impeded drainage.

A 40cm rise in sea level by the 2080s would result in over 100 million people being flooded annually

More than 1 million people living in the Ganges-Brahmaputra, Mekong and Nile deltas will be directly affected if current rates of sea-level rise continue to 2050. Also, most of the world's megacities are in vulnerable coastal regions.

— Church et al., *Ice and Sea-level Change*

Alberta: changes in annual mean temperature by 2050s is typically expected to be between 3-5°C

Annual mean temperature for Edmonton (°C):

- *1961 to 1990: 2.5°C*
- *2020s: 3.6°C*
- *2050s: 5.0°C*
- *2080s: 5.9°C*

An increase in the number of degree days above 5°C indicates longer growing seasons are expected for the Edmonton region.

Annual moisture index describes the indication of moisture available for plant growth. An increase in annual moisture index is expected for Edmonton, which indicates the potential for moisture stress on plant growth.

— Elaine Barrow and Ge Yu, *Climate Scenarios for Alberta*

Climate in the Prairie region is expected to become more variable; more extreme weather including heat waves, intense storms, torrential rains, hail and floods; droughts may become more frequent and pronounced. Flood control expected to be a significant issue, especially in urban areas.

Changes in terrestrial ecosystems most visible near sharp ecological gradients, such as mountains, island forest and along margins of northern and western coniferous forests; lower water levels and higher water temperatures will impact aquatic ecosystems, affecting fish and waterfowl.

— F.J. Warren, T. Kulkarni and D.S. Lemmen, *Canada in a Changing Climate*

The international rhetoric that surrounds the issue of climate change science offers indications that many countries recognize climate change as a significant problem. While these represent political statements, they are significant in that they identify commitments of leaders to address climate change.

Climate change as 21st century's biggest foreign policy challenge - effective responses to climate change underpins our security and prosperity. Food, water and energy security are connected to climate security, which threatened by dependence on coal, oil and gas. All countries need to ensure development is climate resilient otherwise changes in climate will block the path for hundreds of millions of people from poverty to prosperity. Countries that adapt quickly to a carbon constrained world will be better able to deliver lasting prosperity for their citizens.

— W. Hague, "An effective response to climate change 'underpins our security and prosperity.'"

The challenges of the economic crisis, poverty and climate change are interlinked and they require immediate action and a long term vision. G8 leaders call for the reduction of subsidies that artificially encourage carbon-intensive energy consumption. Further leaders are committed to significant change in investment patterns that will accelerate the transition towards low carbon, energy efficient growth models.

— G8, *Responsible Leadership for a Sustainable Future*

Climate change is one of the greatest challenges of our time. As leaders of the world's major economies, both developed and developing, we intend to respond vigorously to this challenge, being convinced that climate change poses a clear danger requiring an extraordinary global response, that the response should respect the priority of economic and social development of developing countries, that moving to a low--carbon economy is an opportunity to promote continued economic growth and sustainable development, that the need for and deployment of transformational clean energy technologies at lowest possible cost are urgent, and that the response must involve balanced attention to mitigation and adaptation.

— G8, *Responsible Leadership for a Sustainable Future*

Climate change threatens the basic elements of life for people around the world – access to water, food production, health and use of land and environment.

On current trends, average global temperatures will rise by 2 - 3°C within the next fifty years or so. The Earth will be committed to several degrees more warming if emissions continue to grow.

Warming will have many severe impacts:

- *Melting glaciers will initially increase flood risk and then strongly reduce water supplies, eventually threatening one-sixth of the world's population, predominantly on the Indian sub-continent, parts of China and the Andes in South America.*
- *Declining crop yields, especially in Africa, could leave hundreds of millions without the ability to produce or purchase sufficient food.*
- *In higher latitudes, cold related deaths will decrease. But climate change will increase worldwide deaths from malnutrition and heat stress. Vector borne diseases such as malaria and dengue fever could become more widespread if effective control measures are not in place.*
- *Rising sea levels will result in tens to hundreds of millions more people flooded each year with warming of 3 or 4 degrees C. According to one estimate, by the middle of the century, 200 million people may become permanently displaced due to rising sea levels, heavier floods, and more intense droughts.*
- *Ecosystems will be particularly vulnerable to climate change, with around 15-40% of species potentially facing extinction after only 2 degrees C of warming. And ocean acidification, a direct result of rising carbon dioxide levels, will have major effects on marine ecosystems, with possible adverse consequences on fish stocks.*
- *A 5 or 10% increase in hurricane wind speed, linked to rising sea temperatures, is predicted approximately to double annual damage costs, in the USA.*
- *In the UK, annual flood losses alone could increase from 0.1% of GDP today to 0.2 - 0.4% of GDP once the increase in global average temperatures reaches 3 or 4°C.*
- *Heat waves like that experienced in 2003 in Europe, when 35,000 people died and agricultural losses reached $15 billion, will be commonplace by the middle of the century."*

— N. Stern et al., *Stern Review: the economics of climate change*

In summary, analyses that take into account the full ranges of both impacts and possible outcomes - that is, that employ the basic economics of risk - suggest that BAU [business as usual] climate change will reduce welfare [the health, happiness, and fortunes of a person or group] by an amount equivalent to a reduction in consumption [or GDP] per head of between 5 and 20%.

— N. Stern et al., *Stern Review: the economics of climate change*

According to the generally accepted science, what reduction of GHG emissions on what timeline is needed to avoid severe climate change?

In order to avoid severe impacts of climate change, global warming should be restricted to 2°C. In order to do this, global emissions must peak between 2010 and 2020, and fall to a median level of 44 Gt of CO_2 equivalent in 2020. The emission reductions required by developed nations are 20 to 40% below 1990 levels by 2020, and further reductions of 80 to 95% by 2050.

> *The uncomfortable message from the scientific community is that although the difficulty of achieving [the 2°C goal] is increasing sharply with every passing year, so too are the predicted consequences of failing to do so.*
>
> — International Energy Agency, *World Energy Outlook 2011*

> *We find that in the set of scenarios with a 'likely' (greater than 66%) chance of staying below 2° C, emissions peak between 2010 and 2020 and fall to a median level of 44 Gt of CO_2 equivalent in 2020 (compared with estimated median emissions across the scenario set of 48 Gt of CO_2 equivalent in 2010). Our analysis confirms that if the mechanisms needed to enable an early peak in global emissions followed by steep reductions are not put in place, there is a significant risk that the 2°C target will not be achieved.*
>
> — Joeri Rogelj, "Emission pathways consistent with a 2℃ global temperature limit."

> *In order to limit the concentration of dangerous greenhouse gases to 450 ppm CO_2 equivalent, developed nations are required to reduce emissions by 20 to 40% below 1990 levels by 2020, and a further 80 to 95% by 2050.*
>
> — Gupta, et al. "Policies, Instruments and Co-operative Arrangements."

Appendix B
Energy Transition Options
Research Summary

Appendix B

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Executive summary

This appendix presents research on the potential options that could be implemented in Edmonton to alter future energy supply and demand activities toward the desired energy transition. The research was undertaken by the Pembina Institute, working with HB Lanarc – Golder and the City of Edmonton.

The research on each option includes potential energy and costs impacts, discussion of the potential to contribute to Edmonton's overall energy transition, implementation issues and examples from other jurisdictions. Research has been summarized in point form and presented in tables to facilitate scanning for key information. All sources are clearly documented if further information is desired.

Energy efficiency and conservation		
Definition	**Impact on energy transition**	**Implementation considerations**
Efficient building heating and cooling		
In general, there are two ways to reduce the demand for heating fuels: construction of efficient building envelopes (walls, roofs, windows and foundations) and the installation of efficient heating and cooling systems.	New houses: 25 – 35% energy reduction Existing houses: 10% energy reduction New large buildings: 25%, some up to 60% energy reduction Existing large buildings: 25% energy reduction	These measures will provide a positive return on investment for consumers. The adoption of a new building code would have an immediate impact on all new buildings constructed, as would efficiency standards for heating and cooling equipment. Incentive and labeling programs can assist with market uptake of energy efficient building envelopes and technology for both new and existing buildings.
Appliances, lighting, and other equipment		
Electricity that is used in appliances, lighting and other electrical equipment is the largest energy user in both residential and commercial buildings after space and water heating. The increase in overall 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.	A combined energy savings of 10 to 50% is achievable in residential homes by switching standard appliances and lighting to more efficient models (such as Energy Star). Energy savings from lighting range from 26 to 39% with simple bulb replacements, to as much as 75% with redesign and bulb replacements with CFL or LED technology. New construction can save between 17 and 40% in energy used for lighting. Energy Star labeled office equipment can generate an electricity savings of 75% for computer and monitor equipment	All of the residential products can be implemented economically, but there are non-economic barriers to implementation. Commercial establishments can generate significant cost savings from upgrading to more efficient lighting systems. For example, the payback on the upgrade to T8 lamps is less than a year.

	(24W per unit) and 40% for photocopier systems.	
Lifestyle choices in energy conservation (electricity and heating)		
Feedback systems provide consumers with detailed feedback about energy consumption and end use patterns. Research suggests that feedback systems can successfully reduce energy use.	Direct feedback systems that provide information about energy consumption in real time at the point of use can reduce electricity consumption by 5 to 18% per household. Indirect feedback that is provided after consumption occurs, typically by a utility provider, has been shown to reduce energy consumption by 0 to 10%, depending on the context and quality of the information provided.	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.

Electricity and heat sources		
Definition	**Impact on energy transition**	**Implementation considerations**
Combined heat and power and district energy		
Combined heat and power (CHP) – simultaneous production on both electricity and heat; scale can be building or power plant. District energy (DE) – share energy between buildings and/or sites.	These systems improve energy efficiency by reducing heat and/or distribution losses. Systems can use biomass or renewable energy. CHP potential in AB: • 75–110 MW for micro-CHP • 8,000 MW for industry/community scale	CHP and DE can be cost competitive at building scale. CHP is one of lowest cost options at power plant scale. For DE or building CHP, system must be appropriately sized to match heat/cooling demand.
Wind power		
Alberta has approximately 807 MW of installed wind capacity which generated 2% of Alberta's power in 2010. Systems ranges from building/farm scale to wind farms over 80 MW.	Approximately 20% of Alberta's electricity could come from wind power within the next 20 years. AESO has received applications for more than 11,000 MW wind projects (unlikely that all project will be developed).	Wind farms in Southern Alberta can be cost competitive with new natural gas or coal-fired generation. Intermittency is an issue that can be managed within the electric grid system.
Coal with carbon capture and sequestration		
Carbon capture and sequestration (CCS) is the process where carbon dioxide from fossil fuel combustion or other industrial processes is captured before it is released to the atmosphere, compressed, transported and sequestered in geological formations.	CCS facilities at coal generating stations are predicted to be able to capture up to 70% to 90% of GHG emissions. CCS is an emerging technology.	Experts estimate that the impact of CCS on electricity prices would be 1 to 5 cents US/kWh.
Nuclear		
Alberta has no existing nuclear	Experts estimate that the lifecycle emissions of CO_2 from nuclear	Experts estimates of costs for nuclear power range from 3

energy facilities.	power are similar to renewable energy.	cents/kWh to 15 cents/kWh.
Solar energy – Photovoltaic, solar thermal, solar water heating, passive solar		
Photovoltaic (PV)– convert solar energy to electricity directly.	Large potential - typical home in Edmonton can use solar PV to generate, on average, the same amount of electricity that home will consume in a year.	Cost of solar PV in Alberta is estimated to be 23 cents/kWh.
Thermal – use solar heat to generate steam and run generator for electricity production.	Significant potential in Alberta.	
Solar water heating – building scale, mature technology.	Solar hot water systems in Edmonton can reduce hot water heating costs by as much as 30 to 40 per cent.	Experts estimate the cost of solar hot water heating at $15 per GJ.
Passive solar – does not use mechanical system, range from building siting for heat/lighting to more complex systems like Canadian-made SolarWall.	‘Building America’ states that energy consumption of new homes can be reduced by as much as 50% with little or no impact on the cost of construction.	Costs range from $0/GJ for solar air heating to $15/GJ.
Ground source heat pumps		
Ground source heat pumps (GSHP) use the Earth’s energy to warm (or cool) a building leading to operating efficiency of over 300 per cent.	In Alberta GSHP tend to have similar GHG emission factors as a mid- to high-efficiency natural gas furnace, but the emissions factor will decline if the electricity grid becomes less GHG intensive, through more renewables and efficiency.	Payback periods range from less than one year to approximately 10 years.
Municipal biogas – Landfill gas systems and municipal wastewater		
Proactively reducing the volume of waste generated is most effective approach to GHG reduction. A second option is to capture landfill gas (LFG) which can then be flared, used to generate electricity or heat, or upgraded to pipeline-quality gas.	Clover Bar Landfill has been capturing LFG since 1992 and using this gas to create electricity since 2005. It delivers 4.8 MW of power to the grid each year. Opportunities for producing electricity from LFG will decrease if waste is successfully diverted from landfills in the future.	Experts indicate that landfill gas capture and conversion to electricity can have a positive return on investment.
Municipal wastewater - Biogas is produced as organic solids in wastewater decompose, similar to solid waste decomposition in landfills. Biogas can be collected and either flared or used to generate electricity and heat.	Edmonton’s Gold Bar Wastewater Treatment Plant collects biogas;70% is used for energy generation and 30% is flared.	

Vehicle technologies and fuels		
Definition	**Impact on energy transition**	**Implementation considerations**
Vehicle efficiency		
Building lighter vehicles and/or more efficient engines	Several countries have been able to increase fuel efficiency standards considerably above Canadian levels. Experience in the European Union shows that efficiency standards almost double those of the current Canadian standard can be achieved. 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.	Analysis of proposed fuel efficiency standards for B.C. indicated savings for consumers of $5,000 over the life of the vehicle.
Drivetrain technologies		
Hybrid, electric and natural gas vehicles	Hybrid vehicles – 34 to 60% more efficient than conventional vehicles. Hybrid electric delivery trucks can reduce GHG emissions by 25% compared to conventional diesel delivery trucks. Electric vehicles – 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. Tailpipe emissions for electric vehicles are zero. Natural gas vehicles – Compressed natural gas in light-duty vehicles reduces GHG emissions by around 25% relative to gasoline.	Hybrid vehicles - typically cost $5,000 more than conventional vehicles, with a payback period of eight years from gasoline savings. Electric vehicles – Electric passenger vehicles can range in price from $11,000 to $110,000. In Alberta, a plug-in hybrid electric vehicle could save $1,070 to $1,542 in fuel costs per year. Natural gas vehicles – The expected payback for natural gas vehicles could be 2 to 30 years depending on the cost of gasoline, vehicle incremental cost and annual kilometres travelled.
Alternative fuels		
Ethanol can be blended with gasoline up to 10% and used in current gasoline engines. Some vehicles currently being sold 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.	Adding 10% ethanol to gasoline can reduce life cycle greenhouse gas emissions by between 3.9 and 6.3% depending on the ethanol feedstock. 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.	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 1.1% more fuel to go the same distance as before, because a litre of ethanol has less energy than a litre of gasoline.
Vehicle operation		
Changes in vehicle operation include adjustment to driving behavior and equipment to reduce idling.	Drivers can reduce their fuel use by up to 1% to 20% by using fuel-efficient driving techniques and keeping their car well maintained.	Reduced fuel consumption through driving efficiency has a direct reduction in fuel costs and in wear and tear on a vehicle. If drivers

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.	Programs aimed at personal vehicles have achieved relatively low savings while those aimed at commercial fleets have been more successful. 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. Plug-in refrigeration units have demonstrated fuel savings of over 60%. Onboard computers have been shown to reduce carbon emission by 13%.	employed more sensible driving practices (respecting speed limits, slower acceleration and braking), they could potentially save $600 per year. Hybrid trailer refrigeration units and onboard computers have a payback of 15 and 18 months, respectively.

Urban form and transportation		
Definition	**Impact on energy transition**	**Implementation considerations**
Land use and urban design		
Personal mobility choices can be impacted by land use and transportation design at a neighbourhood and city or regional scale.	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.	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). Urban development patterns can significantly impact the capital and operating costs of road network infrastructure.
Transit, cycling, walking – mode specific opportunities		
Investments in transit improve accessibility and ridership levels. Investments could include increasing existing service levels, enhancing operational characteristics and providing incentives to encourage greater transit ridership. Bicycle programs can include a variety of initiatives to increase the	Transit – 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%. Cycling – Research suggests that	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.

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. Pedestrian-oriented design improves the overall pedestrian environment by making walking easier, safer and more attractive.	each 1.6 km of bikeway installed per 100,000 residents increases bicycle commuting by 0.075%. Pedestrian environment – Research suggests that pedestrian design can reduce local, area-specific VKTs by 1 to 10%.	
Telecommuting		
Providing support and opportunity for employees to work from home can reduce energy use and emissions from commuting.	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 telecommute four days per week, the U.S. and Japan national energy savings are estimated be 1% in both cases.	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.
Urban form and building energy		
Compact and multi-family development forms	Low-density development was estimated to be twice as energy and GHG intensive as high-density development per capita. More compact houses with the same occupancy would also reduce energy consumption per capita.	Compact building forms, including smaller houses and more multi-family buildings, can provide increased options for more affordable housing, and reduce energy costs to residents.

1 Introduction

This appendix presents research on the potential options that could be implemented in Edmonton to alter future energy supply and demand activities toward the desired energy transition. The research was undertaken by the Pembina Institute, working with HB Lanarc – Golder and the City of Edmonton.

The research on each option includes potential energy and costs impacts, discussion of the potential to contribute to Edmonton’s overall energy transition, implementation issues and examples from other jurisdictions. Research has been summarized in point form and presented in tables to facilitate scanning for key information. All sources are clearly documented if further information is desired.

2 Options for the future energy mix in Edmonton

This section summarizes the research completed on future energy options for Edmonton:

- Energy efficiency and conservation
- Electricity and heat sources
- Vehicle technology and fuels
- Urban form and transportation

This information will be used as the basis for the modelling and transition scenarios that will be presented in the upcoming discussion paper.

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2.1.2 Efficient building heating and cooling

Definition	Impact on energy transition	Implementation considerations
Efficient building heating and cooling		
In general, there are two ways to reduce the demand for heating fuels: construction of efficient building envelopes (walls, roofs, windows and foundations) and the installation of efficient heating and cooling systems.	New houses: 25 – 35% energy reduction Existing houses: 10% energy reduction New large buildings: 25%, some up to 60% energy reduction Existing large buildings: 25% energy reduction	These measures will provide a positive return on investment for consumers. The adoption of a new building code would have an immediate impact on all new buildings constructed, as would efficiency standards for heating and cooling equipment. Incentive and labeling programs can assist with market uptake of energy efficient building envelopes and technology for both new and existing buildings.

The demand for heating, primarily using 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.

Efficient buildings typically 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.

2.1.2.1 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 impact on energy transition for Edmonton

- Compared to houses built to minimum code, a 25 to 35% reduction in energy use is possible with efficient construction techniques,[1 2 3] although several examples of net-zero energy houses have also been constructed.[4 5] A home built to Passivhaus standards in Ottawa achieved 90% energy savings at a cost of 10% more per square foot.[6]

Key implementation considerations

- Increasing energy efficiency levels to EnerGuide 76 or 80 (compared with EnerGuide 70) 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. If the investment is mortgaged over a 25-year period, it can generate a positive cash flow in the first year of ownership and a 13% annual return on investment.[7 8]
- The adoption of a new building code would have an immediate impact on all new buildings constructed, as would efficiency standards for heating and cooling equipment.
- Incentive and labeling programs can assist with market uptake of energy efficient building types and technology.

2.1.2.2 Existing houses

Potential impact on energy transition for Edmonton

- An average of 10% improvement in energy efficiency has been achieved for market-wide home renovation programs in the past,[9] and some studies estimate that improvements of 25% are possible.[10 11]

Key implementation considerations

- 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 energy efficiency upgrades to renovations are expected to be recovered within an average of 6 years, while some individual measures pay back in 1 to 3 years.[12]
- Efficiency standards for heating and cooling equipment improve the performance of typical equipment that is periodically replaced in existing houses, such as furnaces, hot water heaters, and air conditioners.
- Incentive programs can encourage the uptake of higher efficiency equipment, while labeling can increase the likelihood and awareness of energy in home purchasing decisions.

2.1.2.3 New large buildings

Potential impact on energy transition for Edmonton

- Compared with conventional practice, new large buildings can be built with a 25% improvement in energy efficiency,[13 14] although some buildings are constructed to be 60% better.[15 16]

Key implementation considerations

- Net financial benefits of energy efficient buildings are estimated to be positive for energy savings as well as for operation and maintenance cost savings.[17]
- Several studies show that green buildings (which incorporate energy efficiency along with other elements) increase productivity, improve school test scores, and reduce illness.[18]
- Like new houses, a new building code would have an immediate impact, while incentive and labeling programs can assist with market uptake of energy efficient products.

2.1.2.4 Existing large buildings

Potential impact on energy transition for Edmonton

- Studies suggest that up to a 25% reduction in energy use in existing large buildings is possible through renovations.[19 20]

Key implementation considerations

- 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.[21]

2.1.3 Appliances, lighting, and other equipment

Definition	Impact on energy transition	Implementation considerations
Appliances, lighting, and other equipment		
Electricity that is used in appliances, lighting and other electrical equipment is the largest energy user in both residential and commercial buildings after space and water heating. The increase in overall 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.	A combined energy savings of 10 to 50% is achievable in residential homes by switching standard appliances and lighting to more efficient models (such as Energy Star). Energy savings from lighting range from 26 to 39% with simple bulb replacements, to as much as 75% with redesign and bulb replacements with CFL or LED technology. New construction can save between 17 and 40% in energy used for lighting.	All of the residential products can be implemented economically, but there are non-economic barriers to implementation. Commercial establishments can generate significant cost savings from upgrading to more efficient lighting systems. For example, the payback on the upgrade to T8 lamps is less than a year

	Energy Star labeled office equipment can generate an electricity savings of 75% for computer and monitor equipment (24W per unit) and 40% for photocopier systems.	

Aside from space and water heating, appliances, lighting and other electrical equipment is the biggest energy user in both residential and commercial buildings.

Efficiencies of these products have improved over the past few decades, but so have the number of products in buildings – particularly electronics.

2.1.3.1 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.
- During the last 20 to 30 years, the average energy efficiency of residential appliances has improved significantly. For example, current refrigerators use on average 70% less energy than models produced in 1984.[22]

Potential impact on energy transition for Edmonton

- Research suggests that a combined energy savings of 10 to 50% is achievable by switching standard appliances and lighting to Energy Star labeled products.[23] Similarly, NRCan estimates Energy Star labeled products can produce a 30% reduction in energy used by appliances compared to average household appliance energy consumption.[24]

Key implementation considerations

- The energy efficiency potentials described in these studies are all considered to be currently economic although there are currently non-economic barriers to adoption.
- 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 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).[25]
- Past improvements in the energy efficiency of residential appliances manufactured or sold in Canada are attributed to a combined approach of mandatory appliance standards, voluntary and/ or mandatory labelling, and other education and consumer awareness initiatives.[26]
- 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.[27]

2.1.3.2 Commercial sector

- In 2007 the electricity consumed by lighting, auxiliary equipment and auxiliary motors accounted for approximately 68% of total GHG emissions from commercial building in Alberta.
- 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.) as well as improved efficiency of electricity consuming items such as lighting and auxiliary equipment.[28]
- The energy intensity (kWh/m^2) of lighting and auxiliary motors has declined slightly between 1990 and 2007, while the energy intensity of auxiliary equipment more than doubled in that time period.[29]
- The increase in overall 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.[30]

Potential impact on energy transition for Edmonton

- Lighting – existing buildings[31]
    - Replace general T12 lighting technology with standard or next generation T8 bulb technology – lighting energy savings of 26 to 39%
    - Bulb replacement (as above) plus space redesign that reduces the number of lighting fixtures – energy savings of 56 to 67%
    - Replace incandescent lamp with a CFL or LED array – energy savings of 69 and 75%.
- Lighting – new construction
    - 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[32]
- Auxiliary equipment
    - 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%.[33]

Key implementation considerations

- Commercial establishments can generate significant cost savings from upgrading to more efficient lighting systems. For example, the payback on the upgrade to T8 lamps is less than a year.[34]
- 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.[35]

2.1.4 Lifestyle choices in energy conservation (electricity and heating)

Definition	Impact on energy transition	Implementation considerations
Lifestyle choices in energy conservation (electricity and heating)		
Feedback systems provide consumers with detailed feedback about energy consumption and end use patterns. Research suggests that feedback systems can successfully reduce energy use.	Direct feedback systems that provide information about energy consumption in real time at the point of use can reduce electricity consumption by 5 to 18% per household. Indirect feedback that is provided after consumption occurs, typically by a utility provider, has been shown to reduce energy consumption by 0 to 10%, depending on the context and quality of the information provided.	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.

Energy conservation means 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 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.[36]

2.1.4.1 Feedback systems

- Feedback systems provide consumers with detailed feedback about energy consumption and end use patterns.
- Feedback delivery mechanisms can be characterized according to the type of feedback provided:[37]
  - direct feedback is provided in real time at the point of use
  - indirect feedback is provided after consumption occurs.

Potential impact on energy transition for Edmonton

- Direct feedback systems
  - Electricity consumption can be reduced by 5 to 18% per unit (or household)
    - 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).[38 39 40]

- Indirect feedback[41]
    - Energy savings range 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.

Key implementation considerations

- 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.
    - Costs for an indirect feedback program, where additional information is supplied to the consumer at the time of billing, consists mainly of administrative costs.
- The implementation of direct feedback systems residential homes can be encouraged through a residential incentive program. Legislation that requires all new homes to be supplied with direct feedback systems could have an immediate uptake on electricity use in Edmonton. Greater uptake of feedback systems could be encouraged through a City program that supplies the product to all households over a number of years.

2.2 Electricity and heat sources

A number of potential electricity and heat sources for Edmonton have been researched. These include:

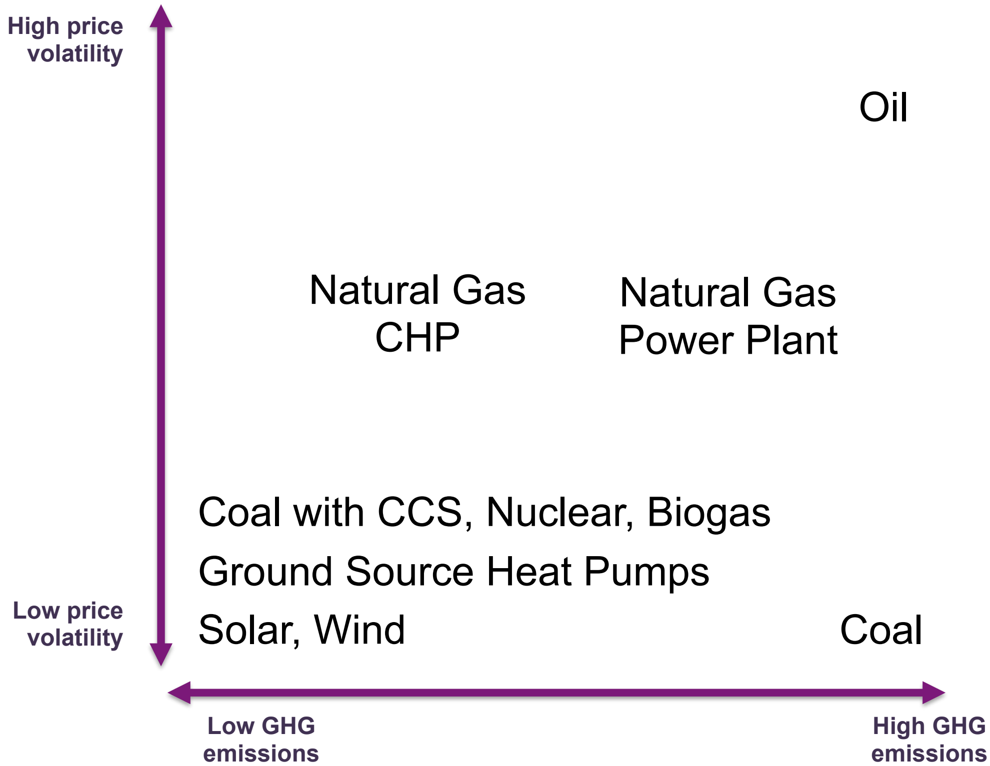
- Existing electricity and heat sources[42]
- Natural gas combined heat and power cogeneration plants (CHP or co-generation)
- Wind power
- Coal with carbon capture and storage
- Nuclear power
- Solar energy
- Ground source heat pumps
- Biogas

While there are always new emerging technologies, and many more energy sources have the potential to be used in Edmonton, the energy sources in this list have been selected based on their ability to have a significant impact on Edmonton's energy mix over the next 10 to 20 years (the timeframe that has been selected as the focus of this discussion paper). It should be noted, however, that other energy sources and technologies may be worth further consideration as they mature.

2.2.1.1 Centralized vs decentralized

It should be noted that some of the energy sources investigated are more amenable to being used in a large, centralized fashion (e.g., coal-fired power plants, nuclear power plants), whereas others (e.g., ground source heat pumps, solar energy, biogas) are more often used in smaller, decentralized or distributed applications. The other energy sources (natural gas and wind power) have applications that are sometimes considered centralized (i.e., require large electricity or natural gas transmission infrastructure) and sometimes considered decentralized (e.g., small generators connected to local distribution systems or used on-site).

The degree to which energy systems are centralized or decentralized has an impact on how well they perform in energy- or GHG-constrained environments. Centralized systems, by their nature, require more energy to transmit their product to customers than systems that can generate energy close to the end user. This does not mean, however, that decentralized systems will always perform better than centralized systems, as indicated in the figure below, but decentralized systems certainly do have some inherent benefits that should be considered in any municipal energy planning exercise.



Note that this figure does not include any consideration of cost or other environmental or social impacts of the technologies. A more detailed consideration of each energy type will be undertaken as the project progresses.

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2.2.3 Combined heat and power and district energy

Definition	Impact on energy transition	Implementation considerations
Combined heat and power and district energy		
Combined heat and power (CHP) – simultaneous production on both electricity and heat; scale can be building or power plant. District energy (DE) – share energy between buildings and/or sites.	These systems improve energy efficiency by reducing heat and/or distribution losses. Systems can use biomass or renewable energy. CHP potential in AB: • 75–110 MW for micro-CHP • 8,000 MW for industry/community scale	CHP and DE can be cost competitive at building scale. CHP is one of lowest cost options at power plant scale. For DE or building CHP, system must be appropriately sized to match heat/cooling demand.

Combined heat and power (CHP) — also known as cogeneration or simply "cogen" — refers to the simultaneous production of both electricity and heat by burning a single fuel. The heat from cogeneration plants can also be used by absorption chillers to provide industrial or space cooling (known as tri-generation).

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.

CHP systems range in size and application from centralized plants focused mainly on electricity generation to community, building or household scale units that tend to be optimized for heat/cooling demands.

- 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.[43]
- Nearly every apartment building and industrial complex that uses a boiler heating system could be retrofitted with a cogeneration system.[44]
- Micro-CHP is smaller scale cogeneration that can occur within a single residence.

Potential impact on energy transition for Edmonton

- Cogeneration is not necessarily renewable (unless the fuel is biomass) but it offers considerable potential for reducing GHG emissions for three reasons.
  - First, it is a highly efficient process as it uses much of the heat that would otherwise be wasted out a chimney.
  - Second, the power that is generated in the same location that it will be used, either in the building itself, or nearby within the city. Almost one-tenth of all of the power that is generated in Alberta is currently lost in large-scale power transmission.
  - Third, significant emission reductions occur when natural gas-based CHP is used to avoid electricity generation from coal power plants, since natural gas has much lower emission factor than coal.[45]
- Cogeneration using natural gas represents some of the largest and fastest GHG reductions that can be made in Edmonton in the near term. A recent study found that cogeneration was one of the most significant near-term emission reduction opportunities for the entire province's electricity system.[46]
- An estimated 75–110 MW of potential electricity generation from micro-CHP is thought to exist in Alberta over the next 20 years.[47]
- 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.[48]

Key implementation considerations

- For particular applications, both CHP and district energy can be cost competitive with conventional systems.
- For power generation, a cogeneration system is estimated to be among the lowest cost options for developing new power plants in the province.[49]
- For cogeneration systems to be efficient, they must be appropriately sized to match heating and/or cooling demand. Typically, a minimum heat demand is required.[50]

2.2.4 Wind power

Definition	Impact on energy transition	Implementation considerations
Wind Power		
Alberta has approximately 807 MW of installed wind capacity which generated 2% of Alberta's power in 2010. Systems ranges from building/farm scale to wind farms over 80 MW.	Approximately 20% of Alberta's electricity could come from wind power within the next 20 years. AESO has received applications for more than 11,000 MW wind projects (unlikely that all project will be developed).	Wind farms in Southern Alberta can be cost competitive with new natural gas or coal-fired generation. Intermittency is an issue that can be managed within the electric grid system.

The global wind power market continues to grow rapidly, with total installed capacity more than doubling between 2005 and 2008.[51] For the last decade, wind energy has been the fastest growing source of electricity worldwide. Technologies range from small turbines suitable for providing power to a single home or farm to "utility-scale" turbines of 3 megawatts (MW) or more, capable of producing enough electricity to power hundreds of average homes. Alberta. Wind farms, comprising multiple large turbines over an contiguous area, have been developed in Alberta, including Ghost Pine Wind Farm (81.6 MW) and Taber Wind Farm (81.4 MW).

Alberta has approximately 807 MW of installed wind capacity (as of October 2011)[52] Wind power generated approximately 2% of the total electricity generated in Alberta in 2010 while producing no direct greenhouse gas emissions.[53]

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.[54]

Potential impact on energy transition for Edmonton

- A large number of applications have been submitted to the Alberta Electric System Operator for interconnecting new wind farms in the province, more than 11,000 MW as of mid-2008. These applications account for twice as much electricity generating capacity than is currently installed by coal-fired power plants in the province.
- Transmission constraints have limited the ability of these interconnection applications from being approved. It is unlikely that all of these applications will be approved.
- 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.[55]

Key implementation considerations

- The price for wind power depends on the quality and quantity of wind at the site and the installed equipment. Southern Alberta has excellent wind sources and costs per MWh of wind farms can be competitive with new natural gas or coal generation.[56]
- One challenge with wind power is the variable nature of the resource. It is important to note, however, that the intermittency can be managed and that it has been successfully integrated into electricity systems around the world.[57]

2.2.5 Coal with carbon capture and sequestration

Definition	Impact on energy transition	Implementation considerations
Coal with carbon capture and sequestration		
Carbon capture and sequestration (CCS) is the process where carbon dioxide from fossil fuel combustion or other industrial processes is captured before it is released to the atmosphere, compressed, transported and sequestered in geological formations.	CCS facilities at coal generating stations are predicted to be able to capture up to 70% to 90% of GHG emissions. CCS is an emerging technology.	Experts estimate that the impact of CCS on electricity prices would be 1 to 5 cents US/kWh.

The GHG intensity of coal-fired electricity (the amount of GHGs created per unit of power produced, typically measured as tCO2e/MWh) could be decreased by equipping new or existing coal facilities with carbon capture and storage (CCS). CCS refers to the process where carbon dioxide from fossil fuel combustion or other industrial processes is captured before it is released to the atmosphere, compressed, transported and sequestered in geological formations.

This section includes discussion on CCS applications for coal power generation plants, but the technology could be used for other thermal generation facilities or other industries.

2.2.5.1 Potential impact on energy transition for Edmonton

- CCS facilities at coal generating stations are predicted to be able to capture up to 70% to 90% of GHG emissions. The carbon capture process itself requires energy, meaning that there will be additional fuel use and associated GHG emissions 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.[58]
- CCS is an emerging technology with a number of projects currently under development within Alberta.

Key implementation considerations

- The Intergovernmental Panel on Climate Change estimates that the impact of CCS on electricity prices would be 1 to 5 cents US/kWh.[59]
- 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. The additional costs of power production range from 39 to 78% (depending on technology and process used) according to one study of CCS costs.[60]

2.2.6 Nuclear

Definition	Impact on energy transition	Implementation considerations
Nuclear		
Alberta has no existing nuclear energy facilities.	Experts estimate that the lifecycle emissions of CO_2 from nuclear power are similar to renewable energy.	Experts estimates of costs for nuclear power range from 3 cents/kWh to 15 cents/kWh.

Alberta has no existing nuclear energy power plants and the creation of new nuclear energy facilities would be a long-term process.

Potential impact on energy transition for Edmonton

- Government of Alberta commissioned an appointed panel to draft a report examining the potential for nuclear generators in Alberta. 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.[61]

Key implementation considerations

- 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 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.[62]
- Any new nuclear plant would require approval from both provincial and federal authorities.
- Analysis completed for Alberta's expert panel report indicates that the cost of energy from nuclear plants typically ranges from 3.5 to 6.0 cents per kWh.[63] However, other independent reports place the cost as high as 15 cents per kWh.[64]

2.2.7 Solar energy

Definition	Impact on energy transition	Implementation considerations
Solar Energy – Photovoltaic (PV), solar thermal, solar water heating, passive solar		
Photovoltaic (PV)– convert solar energy to electricity directly	Large potential - typical home in Edmonton can use solar PV to generate, on average, the same amount of electricity that home will consume in a year.	Cost of solar PV in Alberta is estimated to be 23 cents/kWh.
Thermal – use solar heat to generate steam and run generator for electricity production.	Significant potential in Alberta.	
Solar water heating – building scale, mature technology	Solar hot water systems in Edmonton can reduce hot water heating costs by as much as 30 to 40 per cent.	Experts estimate the cost of solar hot water heating at $15 per GJ.
Passive solar – does not use mechanical system, range from building siting for heat/lighting to more complex systems like Canadian-made SolarWall.	'Building America' states that energy consumption of new homes can be reduced by as much as 50% with little or no impact on the cost of construction.	Costs range from $0/GJ for solar air heating to $15/GJ.

This section covers several distinct technologies that can be used to capture the solar radiation and convert it to power or heat.

- Solar photovoltaics or PV systems capture energy from the sun and convert it to electricity. Both small-scale distributed systems and large centralized plants are feasible in Alberta.
- Solar thermal facilities use the sun's energy to generate steam that drives a turbine for electricity production. These facilities are typically large and would likely be constructed outside city limits.

- Solar water heating is a mature technology and is commonly used in many other countries around the world (including those with cold winters). In Edmonton, a solar hot water system would not replace a hot water tank. Instead, it pre- heats the water before it goes into the hot water tank.
- 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.
- On larger buildings, such as apartments and warehouses that actively bring fresh air in to their heating systems, a Solarwall® can be added. The Canadian-invented Solarwall® is a dark (preferably black) wall that is added to a south-facing wall of a building. The many small perforations in the Solarwall® allow air that has naturally warmed to pass through to the building. Pre-heating the air this way can reduce heating needs by up to one quarter.[65]

Potential impact on energy transition for Edmonton

- The impact of centralized solar generation (including PV and solar thermal generation) on the provincial grid could be significant.
- Alberta and Saskatchewan DNI solar resource is the highest in Canada (1500+ kWh/m2/year)[66]
- Edmonton has an excellent solar energy resource, better solar potential than Berlin or Tokyo, two of the leading solar photovoltaic cities in the world.[67] Additionally, solar PV systems are already at work in Edmonton and they operate more efficiently in cold temperatures.
- PV systems have the advantage of having no moving parts, and are well suited to generate electricity in the same location where it will be used. A typical home in Edmonton can install enough solar PV panels on its roof to generate, on average, the same amount of electricity that home will consume in a year.[68]
- Based on an estimate of the residential dwellings and industrial, commercial and institutional buildings that are suitable for PV in Edmonton, there is currently the potential for 567 GWh of electricity per year from PV in the city itself, representing 8% of the city's overall electricity demand, and reducing almost 500,000 tonnes of GHG emissions annually. Based on estimates for new builds and a requirement that all new houses have proper solar orientation, there is potential for an additional 78 GWh of PV electricity per year by the end of this decade.[69]
- City of Medicine Hat is developing a feasibility project to demonstrate the integration of solar thermal steam generation into a combined cycle electrical generating plant. The pilot project will be 1 MWe, reduce 600 tonnes of GHG per year and go through testing and evaluation in 2012 and 2013.[70]
- Passive solar space heating can provide 40% to 60% of the energy required for space heating, or 32% of total energy used, in a typical single-family household. If all new homes in Edmonton are designed for passive solar heating over the next ten years, the heating potential would displace around 6% of the city's current annual natural gas consumption in residential buildings, avoiding around 91,000 tonnes of CO_2 emissions.[71]

- Solar hot water systems in Edmonton can reduce hot water heating costs by as much as 30 to 40 per cent. They are most advantageous on buildings such as apartments, hotels and pools with high daily water heating needs[72]. Based on estimates of currently suitable buildings, of all types, for solar hot water systems, there is the current potential for around 1586 TJ (terajoules) of annual heat production in the city itself, with an additional 263 TJ possible after the next ten years if all new residential buildings are built for solar hot water capacity. Under the current potential, this would represent over 92,000 tonnes of GHG emissions avoided, or over 107,000 tonnes at the end of the decade.[73]
- 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 through buildings siting that accounts for solar.[74]
- 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.[75]

Key implementation considerations

- While solar PV systems are coming down rapidly in price (costs fell almost 30 per cent in 2009), they are still relatively expensive compared to buying electricity from the 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).[76]
- The cost of solar PV in Alberta is estimated to be $0.23/kWh produced.[77]
- The cost of the pilot project in Medicine Hat (integrating solar thermal steam into a combined cycle generating plant) is $9 million for the 1 MWe system.[78]
- Many passive solar actions cost nothing beyond good planning.
- 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.[79]

2.2.8 Ground source heat pumps

Definition	Impact on energy transition	Implementation considerations
Ground source heat pumps		
Ground source heat pumps (GSHP) use the Earth's energy to warm (or cool) a building leading to operating efficiency of over 300 per cent.	In Alberta GSHP tend to have similar GHG emission factors as a mid- to high-efficiency natural gas furnace, but the emissions factor will decline if the electricity grid becomes less GHG intensive, through more renewables and efficiency.	Payback periods range from less than one year to approximately 10 years.

Ground source heat pumps, or geoexchange systems, use the Earth's energy to warm (or cool) a building. A ground source heat pump takes heat out of the ground and releases it inside your home (it works in reverse in the summer). Because heat pumps are actually just moving heat from one location to another, they can actually deliver significantly more heat than the energy required to run them. Most heat pumps have an operating efficiency over 300 per cent – that is for every unit of electricity needed to run the system's pumps and compressors, the system is able to deliver three units of heat to the building.

Heat pumps can be coupled with solar pre-heating systems, as well as into district heating systems. The thermal energy is typically used for space heating and cooling, but thermal energy can be harnessed for water heating and industrial processes as well.

2.2.8.1 Potential impact on energy transition for Edmonton

- GSHP systems are most cost effective for heating new buildings rather than retrofitting existing buildings.
- A typical single-family house can produce 43% of its total energy consumption with GSHP technology.[80]
- By retrofitting 10% of the current housing stock and 50% of existing industrial, commercial and institutional (ICI) buildings to include GSHP and installing GSHP in 25% of new housing starts and 100% of new ICI buildings over the next ten years, there is the potential for 9,980 TJ of energy production from GSHP in the city of Edmonton. If the emissions intensity of electricity also improves, this could represent substantial GHG emissions avoidance.[81]

Key implementation considerations

- GSHPs 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. Payback periods, relative to natural gas furnaces range from less than one year (from some commercial applications) to up to ten years (for smaller residential systems).[82]
- While GSHPs are very energy efficient, they run on electricity and in Alberta, most electricity still comes from coal and has resulting high GHG emissions. Fortunately, a heat pump is so efficient that even when it runs on coal-based electricity it tends to have similar, or lower, GHG emissions as a natural gas furnace. Comparisons of GHG emissions between GSHPs and natural gas furnaces need to carefully account for emissions factor of electricity (and how that will change over time), efficiency and lifespan of natural gas furnaces, and losses for both electricity and natural gas distribution.

2.2.9 Municipal biogas

Definition	Impact on energy transition	Implementation considerations
Municipal biogas – Landfill gas systems and municipal wastewater		
Proactively reducing the volume of waste generated is most effective approach to GHG reduction. A second option is to capture landfill gas (LFG) which can then be flared, used to generate electricity or heat,	Clover Bar Landfill has been capturing LFG since 1992 and using this gas to create electricity since 2005. It delivers 4.8 MW of power to the grid each year. Opportunities for producing	Experts indicate that landfill gas capture and conversion to electricity can have a positive return on investment.

or upgraded to pipeline-quality gas.	electricity from LFG will decrease if waste is successfully diverted from landfills in the future.	
Municipal wastewater - Biogas is produced as organic solids in wastewater decompose, similar to solid waste decomposition in landfills. Biogas can be collected and either flared or used to generate electricity and heat.	Edmonton's Gold Bar Wastewater Treatment Plant collects biogas; 70% is used for energy generation and 30% is flared.	

2.2.9.1 Landfill gas systems

- GHG emissions come from municipal solid waste in landfills as the solid waste slowly decomposes to form a mixture of gases including methane (CH_4) a potent GHG. These gaseous emissions are referred to as biogas or "landfill gas" (LFG).
- The most effective method to manage waste-related GHG emissions is by proactively reducing the volume of waste generated. The City of Edmonton currently diverts 60 per cent of residential waste from landfills through recycling and composting.[83]
- Aside from reducing the amount of organic materials going to landfills, systems can also be used to capture the LFG once it is generated. LFG contains approximately 50% methane and thus 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 LFG 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.[84]
- In Edmonton, the Clover Bar Landfill has been capturing LFG since 1992 and using this gas to create electricity since 2005.[85]
- Additionally, Edmonton is building a waste-to-biofuels facility with a goal of increasing the diversion rate of residential waste from landfills to 90 per cent.[86]

Potential impact on energy transition for Edmonton

- The Clover Bar LFG recovery is able to supply 4.8 MW of electricity into the electricity grid, enough to power over 4,600 homes annually.
- The overall potential for biogas energy production from manure, sewage sludge, municipal solid waste and biodegradable waste in the city itself is for 3.5 to 9 MW of electricity generation and, if combined with heat in a cogeneration system, another 260 to 685 GJ of heat production, annually.[87]
- By including crop residues from the surrounding agricultural community, these numbers can be increased by a factor of about ten. This would lead to overall city GHG emissions reductions of almost 7%, without accounting for the avoidance of methane emissions by the decomposing biomass.[88]
- Table 1 shows the total GHG emissions from City of Edmonton landfills, as estimated by City staff. Both Clover Bar and West Edmonton landfills have demonstrated significant GHG reductions in the past.

Table 1 GHG emissions from City of Edmonton landfills

Landfill site	GHG emissions (tonnes of CO_2e per year)			
	1990	2001	2005	2010
Beverly (Rundle)	7,276	5,357	4,937	4,391
South Side	20,469	14,786	13,703	12,288
Frontier Farms	18,811	14,370	13,029	11,733
West Edmonton	72,409	115,312	142,559	98,808
Clover Bar	149,048	31,083	30,530	31,320
Total	**268,013**	**180,909**	**204,758**	**158,541**

- The opportunities for producing electricity from LFG will decrease in the future if Alberta succeeds in decreasing the amount of waste going to landfills

Key implementation considerations

- LFG capture and utilization systems have capital and operational costs, and also face many regulatory procedures related to electricity generation and distribution.
- Generation technology can cost upwards of $1,100 per kW of capacity[89]
- Sources show that landfill gas capture and conversion to electricity can have a positive return on investment.[90, 91]

2.2.9.2 Municipal wastewater systems

- Methane is produced as organic solids in wastewater decompose, similar to solid waste decomposition in landfills. This process produces a significant amount of biogas, made up of approximately 50% methane. Biogas can be then be collected and either flared or used to generate electricity and heat.
- Edmonton's Gold Bar Wastewater Treatment Plant is operated by EPCOR and handles the wastewater requirements for over 820,000 people in the greater Edmonton area. This facility collects biogas of which 70% is used for energy generation and 30% is flared.[92]

Potential impact on energy transition for Edmonton

- The current capacity to convert biogas to electric energy at Edmonton's wastewater treatment facilities may be limited; the addition of generation systems is necessary to realize the full energy potential of the biogas produced.

Key implementation considerations

- Generation technology can cost upwards of $1,100 per kW of capacity.[93]

2.3 Vehicle technology and fuels

Considerable opportunities to achieve reductions in GHG emissions are available through:

- vehicle efficiency (e.g., lighter vehicles, more efficient engines),
- drivetrain technologies (e.g., hybrid electric, electric and natural gas vehicles)
- alternative fuels (e.g., biofuels)
- vehicle operation (changing the way a vehicle is operated – driving behavior and equipment to reduce idling)

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2.3.2 Vehicle efficiency

Definition	Impact on energy transition	Implementation considerations
Vehicle efficiency		
Building lighter vehicles and/or more efficient engines.	Several countries have been able to increase fuel efficiency standards considerably above Canadian levels. Experience in the European Union shows that efficiency standards almost double those of the current Canadian standard can be achieved. 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.	Analysis of proposed fuel efficiency standards for B.C. indicated savings for consumers of $5,000 over the life of the vehicle.

For the past thirty years Canada has had a voluntary policy for fuel efficiency improvements from cars and light trucks,[94] and in 2010 the country introduced mandatory standards for new automobiles and light trucks. It is expected that by 2016 the average fuel efficiency will improve by 25% compared to 2008 levels.[95]

Potential impact on energy transition for Edmonton

- Several countries have been able to increase fuel efficiency standards considerably above Canadian levels. Experience in the European Union shows that efficiency standards almost double those of the current Canadian standard can be achieved.[96]
- 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.[97]

Key implementation considerations

- B.C. fuel efficiency standards that were proposed in 2008 were expected to save consumers $5,000 over the life of the vehicle through reduced fuel consumption.
- In the United States, recent improvements to federal Corporate Average Fuel Economy (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).
    - 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.[98]

2.3.3 Drivetrain technology

Definition	Impact on energy transition	Implementation considerations
Drivetrain technologies		
Hybrid, electric and natural gas vehicles	Hybrid vehicles – 34 to 60% more efficient than conventional vehicles. Hybrid electric delivery trucks can reduce GHG emissions by 25% compared to conventional diesel delivery trucks. Electric vehicles – 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. Tailpipe emissions for electric vehicles are zero. Natural gas vehicles – Compressed natural gas in light-duty vehicles reduces GHG emissions by around 25% relative to gasoline.	Hybrid vehicles - typically cost \$5,000 more than conventional vehicles, with a payback period of eight years from gasoline savings. Electric vehicles – Electric passenger vehicles can range in price from \$11,000 to \$110,000. In Alberta, a plug-in hybrid electric vehicle could save \$1,070 to \$1,542 in fuel costs per year. Natural gas vehicles – The expected payback for natural gas vehicles could be 2 to 30 years depending on the cost of gasoline, vehicle incremental cost and annual kilometres travelled.

Potential impact on energy transition for Edmonton

- ***Hybrid vehicles*** – Hybrid electric cars are 34 to 60% more efficient at converting energy to motion than conventional vehicles.[99] Hybrid electric delivery trucks can reduce GHG emissions by 25% compared to conventional diesel delivery trucks.[100]
- ***Electric vehicles*** – 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.[101] [102] In Alberta, where the majority of electricity comes from burning coal, generating electricity is approximately three times as 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 vehicles could be charged using mainly wind power, EVs would emit up to 90% fewer emissions than conventional cars, depending on the vehicle.[103] Tailpipe emissions for electric vehicles are zero.
- ***Natural gas vehicles*** – Compressed natural gas in light-duty vehicles reduces GHG emissions by around 25% relative to gasoline.[104]

Key implementation considerations

- ***Hybrid vehicles*** - Hybrid electric vehicles typically cost \$5,000 more than conventional vehicles, with a payback period of eight years from gasoline savings.[105]
  - Hybrid electric delivery trucks can save 35 to 42% in fuel costs compared to their diesel counterparts,[106] [107] although they can cost 35 to 45% more than conventional delivery trucks.[108]

- ***Electric vehicles*** – Electric passenger vehicles can range in price from $11,000 to $110,000.[109] The typical cost for an electric plug-in conversion from a conventional gasoline engine is $15,000.[110]
  - In Alberta, a plug-in hybrid electric vehicle could save $1,070 to $1,542 in fuel costs per year.[111] [112]
  - Electric short-haul freight trucks can save up to 75% in fuel costs compared to typical diesel freight trucks.[113]
- ***Natural gas vehicles*** – Depending on the price spread of natural gas and gasoline, the cost of the natural gas vehicle and the annual mileage can vary considerably. The expected payback could be 2 to 30 years depending on the cost of gasoline, vehicle incremental cost and the annual kilometres travelled. This is described in Table 2 below. Using compressed natural gas in urban delivery vans has been shown to reduce fuel costs by 32% relative to gasoline.[114]

Table 2. Payback time for natural gas vehicles

		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

2.3.4 Alternative fuels

Definition	Impact on energy transition	Implementation considerations
Alternative fuels		
Ethanol can be blended with gasoline up to 10% and used in current gasoline engines. Some vehicles currently being sold 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.	Adding 10% ethanol to gasoline can reduce life cycle greenhouse gas emissions by between 3.9 and 6.3% depending on the ethanol feedstock. 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.	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 1.1% more fuel to go the same distance as before, because a litre of ethanol has less energy than a litre of gasoline.

Potential impact on energy transition for Edmonton

- Ethanol can be blended with gasoline up to 10% and used in current gasoline engines. Some vehicles currently being sold 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.

  - Adding 10% ethanol to gasoline can reduce life cycle greenhouse gas emissions by between 3.9 and 6.3% depending on the ethanol feedstock[115]
  - 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.[116]

- The emissions reduction estimates for feedstocks from dedicated croplands are likely to decrease once indirect land use change considerations are added to the analysis.

Key implementation considerations

- 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 1.1% more fuel to go the same distance as before, because a litre of ethanol has less energy than a litre of gasoline.

2.3.5 Vehicle operation

Definition	Impact on energy transition	Implementation considerations
Vehicle operation		
Changes in vehicle operation include adjustment to driving behavior and equipment to reduce idling. 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.	Drivers can reduce their fuel use by up to 1% to 20% by using fuel-efficient driving techniques and keeping their car well maintained. Programs aimed at personal vehicles have achieved relatively low savings while those aimed at commercial fleets have been more successful. 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. Plug-in refrigeration units have demonstrated fuel savings of over 60%. Onboard computers have been shown to reduce carbon emission by 13%.	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. Hybrid trailer refrigeration units and onboard computers have a payback of 15 and 18 months, respectively.

Changes in vehicle operation include adjustments to driving behavior and installation of equipment to reduce idling.

Potential impact on energy transition for Edmonton

- Drivers can reduce their fuel use by using fuel efficient driving techniques and keeping their car well maintained.[117]
  - 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.[118]
  - Programs aimed at the general public, on the other hand, are estimated to achieve only 1 to 2% in GHG reductions.[119]
- 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.
  - Plug-in refrigeration units have demonstrated fuel savings of over 60%. Onboard computers have been shown to reduce carbon emission by 13%.[120]

Key implementation considerations

- 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.[121]
- Hybrid trailer refrigeration units and onboard computers have a payback of 15 and 18 months, respectively.[122]

2.4 Urban form and transportation

The mode of transportation that citizens in Edmonton choose for everyday activities has the potential to significantly impact the fuel use and GHG emissions attributed to the transportation sector.

Transportation 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).

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2.4.2 Land use, urban design and transportation

Definition	Impact on energy transition	Implementation considerations
Land use and urban design		
Personal mobility choices can be impacted by land use and transportation design at a neighbourhood and city or regional scale.	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	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). Urban development patterns can

	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.	significantly impact the capital and operating costs of road network infrastructure.

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 numbers of cars per household is associated with increases in vehicle kilometres travelled (VKTs) per capita and per household.
- *Locational* – increased distances of residents from the central business district and employment centres are associated with an increase in VKTs, while proximity to transit and proximity to neighbourhood destinations and amenities such as grocery stores are associated with a decrease in VKT.
- *Neighbourhood design* – increasing housing density, mixing land uses, providing local shopping opportunities adjacent to population centres, increasing the number of intersections per kilometre of road, and providing 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 associated with increases in VKTs. Increased density supports higher levels of transit service, which in turn support decreased VKTs. Note also that any one design factor on its own, such as density, will not necessarily lead to significant VKT reductions; a combination of design factors including density, mixing of uses, transit service and appropriate street patterns is required.The availability and cost of parking also impacts vehicle ownership and VKTs.

Potential impact on energy transition for Edmonton

- 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.[123] Additional details about the opportunities for reducing VKTs from the implementation of site-specific neigbourhood design features are shown in the table below.

Table 3. VKT reductions by neighbourhood design

Neighbourhood design feature	Percent reduction in VKTs per site
Transit-oriented development	10 – 30[124]
Pedestrian-oriented design	1 – 10[125]
Pedestrian design combined with bike facilities	5 – 15[126]
Mixed-use development	5 – 20[127]
10% increase in population density	1 – 3.5[128]

Key implementation considerations

- 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.[129]
- Urban development patterns can significantly impact the capital and operating costs of road networks and other types of municipal infrastructure[130] and services. More often than not, these municipal expenditures are downloaded to the taxpayer.

2.4.3 Transit, cycling and walking – mode-specific opportunities

Definition	Impact on energy transition	Implementation considerations
Transit, cycling, walking – mode specific opportunities		
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. 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. Pedestrian-oriented design improves the overall pedestrian environment by making walking easier, safer and more attractive.	Transit – 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%. Cycling – Research suggests that each 1.6 km of bikeway installed per 100,000 residents increases bicycle commuting by 0.075%. Pedestrian environment – Research suggests that pedestrian design can reduce local, area-specific VKTs by 1 to 10%.	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.

Potential impact on energy transition for Edmonton

- ***Transit*** - Investments in transit improve accessibility and ridership levels. Investments could 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%.[131]
- ***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%.[132]
- ***Pedestrian environment*** – 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%.[133]
    - 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%.[134]

Key implementation considerations

- 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.[135]

2.4.4 Telecommuting

Definition	Impact on energy transition	Implementation considerations
Telecommuting		
Providing support and opportunity for employees to work from home can reduce energy use and emissions from commuting.	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 telecommute four days per week, the U.S. and Japan national energy savings are estimated be 1% in both cases.	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.

Potential impact on energy transition for Edmonton

- 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 telecommute four days per week, the U.S. and Japan national energy savings are estimated be 1% in both cases.[136]

Key implementation considerations

- 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.

2.4.5 Urban form and building energy

Definition	Impact on energy transition	Implementation considerations
Urban form and building energy		
Compact and multi-family development forms	Low-density development was estimated to be twice as energy and GHG intensive as high-density development per capita. More compact houses with the same occupancy would also reduce energy consumption per capita.	Compact building forms, including smaller houses and more multi-family buildings, can provide increased options for more affordable housing, and reduced energy costs to residents.

Potential impact on energy transition for Edmonton

- Empirical data indicates that per-person energy consumption of residential buildings is significantly lower for multi-family residences compared to single-family residences, especially apartments.
- Building operations (i.e. energy consumption) for low-density development was estimated to be twice as energy and GHG intensive as high-density development per capita[137]; this is corroborated by data from the US Energy Information Administration (EIA)[138] showing an average 48% reduction in energy intensity per person for apartments compared to single family homes.
- More compact houses with the same occupancy would also reduce energy consumption per capita, as energy consumption of a given house design is related to the size of the space that is heated, cooled and lighted.

Key implementation considerations

- Compact building forms, including smaller houses and more multi-family buildings, can provide increased options for more affordable housing, and reduced energy costs to residents.

3 Examples of options for energy transitions from other jurisdictions

3.1 Energy efficiency and conservation

3.1.1 Efficient building heating and cooling

Provincial building codes

- The provinces of Ontario, British Columbia, Nova Scotia and Manitoba have all added energy efficiency to their building code. A process is also underway 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.[139] Many of the code changes affect both small and large buildings.

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.[140]

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). Buildings must be oriented and massed buildings to maximize opportunities for passive solar heating and cooling, natural lighting and ventilation.[141]
- In the town of East Gwillimbury, Ontario, all new residential developments that require either site plan or subdivision approval must meet Energy Star standards. Energy Star qualified homes are approximately 30 to 40% more energy efficient than those built to minimum Ontario Building Code standards.[142]
- The City of Vancouver, using powers outlined in the Vancouver Charter, has a set of energy efficiency standards for both houses and larger buildings.[143]

EnerGuide rating system

- The EnerGuide rating system is available to homeowners as a way to measure home energy performance. A number of companies in Edmonton offer EnerGuide audits, which will provide an EnerGuide rating for the house and recommendations on how to improve the house's energy performance.
- Both the federal and provincial governments have ended their incentive programs for home renovations in March 2012. Several municipalities in Alberta currently offer incentives for their citizens.

- Other 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.[144]

BOMA BESt

- The Building Owners and Managers Association (BOMA) of Canada has developed BOMA BESt[145] — an environmental certification program for commercial buildings. 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. Buildings certified under BOMA BESt between 2005 and 2009 (450 buildings) consumed on average 11% less energy than the average commercial building in Canada. Buildings certified under BOMA BESt between June 1, 2009 and June 30, 2010 (300 buildings, 92.3 million square feet) consumed 13% less energy than the average commercial building in Canada.[146]

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.[147]

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 data fields to the Multiple Listing Service System that identify a home's energy efficiency based on the EnerGuide rating system.
- The program's goal is to have at least 2,500 homes rated using the EnerGuide rating system within 12 months.[148]

3.1.2 Appliances, lighting, and other equipment

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.[149]

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.[150]

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.[151]

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. The program savings amount to approximately 0.05% and 0.03%, respectively, of BC Hydro's total electricity demand in 2006.[152]
- 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.[153]

Canadian energy efficiency regulations

- The residential appliance standards implemented by the Canadian Energy Efficiency Regulations are estimated to generate an aggregate annual energy savings of 117.20 PJ in 2010 and 133.84 PJ in 2020. The standards for residential and commercial lighting and auxiliary motors are estimated to generate an aggregate annual savings of 31.96 PJ in 2010 and 39.54 PJ in 2020.[154]

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 at 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.[155]

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.[156]

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.

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.[157]

3.1.3 Lifestyle choices in energy conservation (electricity and heating)

Florida Direct Feedback Pilot

- 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.[158]

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.[159]

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.[160]
- 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. 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.

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.[161]

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 historic 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.[162]

3.2 Electricity and heat sources

3.2.1 Combined heat and power and district energy

- In Europe, cogeneration systems are already widely available at a household size, so individuals can generate their own power instead of just their own heat.
- There are three district energy systems in Edmonton: Alberta Public Works Supply and Services (start year 1955), Caritas Health Group (start year 1968), and University of Alberta (start year 1958).[163]
- ENMAX has recently constructed a district energy plant in downtown Calgary that has the capability of being connected to a combined heat and power plant in the future.
- Examples of cogeneration in commercial facilities in Alberta include: Medicine Hat Family Leisure Centre, the TransAlta Electrical Power Industry Centre at SAIT, and hospitals in Edmonton (Alberta Hospital), Calgary (Foothills) and Lethbridge (Chinook Regional).[164]

3.2.2 Wind power

- Spain, a world leader in wind energy development despite having an area smaller than Alberta, had installed 20,676 MW of wind capacity by end of 2010[165]

3.2.3 Coal with carbon capture and sequestration

- Several coal power plant CCS projects are in development worldwide, including four in Alberta and Saskatchewan.[166]
- 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. Project commissioning is not anticipated until 2014.[167]
- Other coal facilities planned to be built with some CCS capacity include: Boundary Dam (SaskPower, 100MW, target 2015) and Belle Plaine (TransCanada, 500MW, date undecided).

3.2.4 Nuclear

- The last new nuclear facility to be built in Canada was 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).[168]
- Ontario Power Generation (OPG) has completed early applications for up to four new nuclear reactors at the existing Darlington site to generate approximately 4,800 MW of electricity to the Ontario grid. An application for license to operate is not expected until 2016.[169]

3.2.5 Solar energy

- The Medicine Hat Concentrating Solar Thermal Energy Demonstration Project is a unique system, first in Canada, to link solar thermal generation with an existing natural gas-powered electricity generation plant. This project is expected to be completed in fall 2012.[170]
- The Edmonton International Airport expansion will have a 64-module solar hot water collector system that will generate enough energy to provide most of the hot water for washrooms in the new facility.[171]
- ENMAX, the Climate Change Emissions Management Corporation (CCEMC) and Climate Change Central have launched a five-year initiative to install up to 9,000 distributed solar or wind energy systems.[172]
- In 2001, City of Okotoks implemented a multi-year solar energy technologies initiative with the goal of lowering municipal building operating costs and reducing greenhouse gas emissions. Okotoks implemented five main solar projects:
    - Swindell's Pool – solar water heating system
    - Murray and Piper Arenas – solar ice resurfacing system
    - Recycling Centre – cardboard baling building solar heating system
    - Operations Building – solar wall heating system
    - Recreation Centre Expansion – south face solar wall
- The California Energy Commission has approved over 3000 MW of solar generation plants (mostly solar thermal) and these developments will provide lessons for development elsewhere.[173]

3.2.6 Ground source heat pumps (GSHP)

- Atco Gas' North Edmonton Operations Centre, which opened in 2010, uses geothermal heating, ventilation and cooling technology. According to the company's media release, "It uses approximately 40 percent less energy than a similar size building heated through conventional means. The energy savings equate to a reduction in carbon dioxide emission by an estimated 60 metric tonnes annually."[174]
- 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.[175]

3.2.7 Cross-cutting examples

Support and leadership from municipal governments

- City of Edmonton - Renewable energy task force
- City of Calgary's recently approved Greenhouse Gas Reduction plan states:

- The City will take a leadership role in establishing partnerships with other local governments, AUMA, provincial governments and the private sector to promote low-carbon electricity generation.
- The City will look into opportunities to increase electricity generation from its own facilities including landfills and waste water treatment plants.[176]

Feed-in tariffs

- **Feed-in tariffs** (FITs) guarantee a price for renewable energy generation that is "fed in" to the grid. They are proliferating around the world, including recent new policies in Ontario and Nova Scotia. Feed-in tariffs are very successful; they are responsible for 50 per cent of the wind energy and over 75 per cent of the solar energy constructed in the world. The policy has been found to be the most effective and proven mechanism for rapidly stimulating wide-scale renewable energy deployment at lowest cost.
- In **Germany**, the feed-in tariff is implemented through the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), which obliges operators of power grids to give priority to purchasing electricity from renewable energies and to pay fixed prices for this. The EEG is an important driving force in the expansion of renewable energies in the electricity sector. From 1995 to 2007, Germany's share of renewables in its electricity mix from increased from 1 percent to 14 percent.[177]
- **Gainesville, Florida** has launched the very first municipal feed-in tariff program to facilitate solar energy on homes and businesses. Gainesville's feed-in tariff guarantees a payment for 20 years for electricity fed back to the grid, set at a rate that will allow owners to recover their costs and obtain a four to five per cent rate of return. To control costs, the program is capped so that contracts are only available for four megawatts of new installed capacity each year. The first 4 MW has cost the average resident about 70¢ per month. As installation costs quickly decrease with a new, robust local solar market, future phases will cost even less.[178]

Building code

- 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.[179]
- Renewable energy requirements in buildings codes were first implemented in Merton Borough, London, U.K. in 2003.[180] The "**Merton Rule**" required that 10% of expected energy demand be met by renewables. Croydon implemented its renewable requirement in 2003 and Greater London followed in 2004. Similar policies have since been implemented by approximately 325 of 390 England councils as well as councils in Scotland and Wales.[181]

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. EPCOR no longer offers this option to its customers.

Regulation / senior government directives

- The **Government of Canada** recently announced its intention to reduce GHG 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 GHG 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.[182]
- **British Columbia's** energy objectives include:
  - to generate at least 93% of the electricity in British Columbia from clean or renewable resources and to build the infrastructure necessary to transmit that electricity.[183]

Municipal initiatives

- The city council of **Medicine Hat** set aside $1 million in 2005 for renewable energy development; part of the funds were invested directly in a 5 kW concentrating photovoltaic panel project. The city's Municipal Development Plan requires that solar orientation of buildings and properties be considered in new property development."[26]

3.3 Vehicle technology and fuels

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.[184]

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.[185]

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.[186]

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.[187]

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.[188]

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/100 km. 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.[189]

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.[190]

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. 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.[191]

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.[192]
- 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 voicemail, personal follow-up on drivers' records from the program, and an incentive program that gives bonuses to drivers who reduce idling time. As a result, fuel usage dropped by 16%: 7% from anti-idling technology and 9% from driver education.[193]

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. 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.[194]
- Transport Canada operates a SmartDriver in the City program that focuses on fleets that operate within a 100 km radius of their head office.[195] 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.[196]

Trucks of Tomorrow[197]

- 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.

3.4 Urban form and transportation

Kelowna

- The City of Kelowna, B.C., is promoting smart growth and compact development through the use of varied development cost charges 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 assessed a lower development cost charge compared to single-family development located at the periphery of the city. The program is allowing the City to optimize its infrastructure investments.[198]

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 at 23% improvement in transit ridership, with a corresponding reduction in VKT.[199]
    - 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%.[200]

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.[201]

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 kilometers of driving.[202]

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.[203]

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Appendix C

Energy and Emission Modelling Cases

Summary

Appendix C

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Introduction

HB Lanarc-Golder (HBLG) worked with Pembina and the City to create three future *modelling scenarios*, or cases for two future milestone years, 2024 and 2044. This background paper summarizes the assumptions for each scenario through descriptions, numeric indicators and maps (for residential density).

The scenarios were defined using a set of indicators and assumptions (or variables) that include land use mix, the distribution of population density, housing mix, building performance, energy supply and transportation networks and infrastructure. These variables have been shown through research to influence the energy used, and GHG emissions generated, in the built environment. Furthermore, they are variables over which the City has significant influence through land use planning, investment, policy and regulation. The options described in the complementary document, *Energy Transitions Options: Research Summary,* provide examples of how the City can influence Edmonton's future state of these built environment variables.

The three main modelling cases are defined as follows.

1. Reference Case

This case is intended to reflect a continuation of current development patterns and practices in Edmonton. This representation is based largely on adopted plans (ASPs, NSPs); however, it also incorporates estimates of development that is anticipated but may not have been approved at the time of reference case creation. This case also reflects current policies and programs already in place that would influence energy and emissions, such as existing green building plans and incentives.

2. Reduced-Energy and Carbon Case

This case represents adjustments to the Reference Case that (based on research) would lead to a reduction in energy and emissions. These adjustments are limited to those that could be reasonably achieved given the current planning directions and market context. This would include allocating more growth to existing built-up areas that are well served by frequent transit, creating more walkable, mixed use centres and improved building energy efficiency. Currently adopted plans such as the Way We Grow and the Way We Move already identify directions in development that are expected to contribute to reductions in energy and emissions compared to the growth assumptions included in the reference case.

3. Low-Energy and Carbon Case

In this case significant shifts have been made to the assumptions that are aimed at reducing community-wide energy consumption and emissions to levels that are consistent with Edmonton's long term goal of carbon neutrality — for example, an 80% reduction in emissions by 2050. Clearly, the assumptions in this case are subject to practical constraints, such as demand for specific housing types and locations. However, the intent is to provide a hypothetical representation of a future low-energy and carbon path for Edmonton, with the assumption that this path could be achievable if there were sufficient shifts in market demand and other constraining factors.

The above three cases will utilize HB Lanarc–Golder's CEEMAP model for analysis. Assumptions such as population and job growth applied consistently across the cases. In addition, there may be an opportunity to combine the above analysis cases with scenarios that will be developed as part of the food and agriculture strategy.

Modelling case framework

The following tables document modelling assumptions for each modelling case. In addition to these tables, more detailed "buildout model" spreadsheets were developed that allocate growth in the different planning areas of Edmonton. This growth allocation, along with rapid transit line assumptions, are shown in the maps at the end of the document.

In the following sections, the *Description* tables provide a qualitative description of the assumptions for each case; this includes strategies (e.g., City policies or actions) and descriptions of outcomes of those strategies.

The *Indicators* tables provide a quantitative representation of the assumptions for each case; many of these indicators are used in the model. **Numbers shown generally reflect the 2044 buildout, unless noted otherwise.**

Land use

Description

	Reference case	Reduced carbon case	Low carbon case
General description	As per adopted plans (ASPs, NSPs), with some buildout anticipated in areas without approved ASPs. Generally a continued focus on suburban and greenfield development, with future dwelling demand reflecting historical trends.	Increase infill and intensification in mature neighbourhoods, especially near mass transit. Increase TOD where practical. Alter the form of development in new neighbourhoods to create more walkable, transit-friendly, complete communities. Generally push the boundaries of status quo development while respecting what is practical and achievable given the current market context.	Maximize infill and intensification, and TOD. Aim to retrofit existing neighbourhoods over time, to create attractive, highly livable, compact and complete neighbourhoods. Dwelling demand would shift markedly towards medium and high density dwellings away from the historic trend of low density dwellings
1. Growth Distribution			
Central Core & Airport redevelopment	Current market conditions would limit demand for dwellings in Central Core and Airport Redevelopment	As per Downtown Plan and Airport Redevelopment Plan	Assumed growth in these areas would exceed targets set in the Downtown Plan and Airport Redevelopment Plan

Established and mature neighbourhoods	Very limited development Infill is distributed across the city	Increased infill and intensification, with some priority on central core, town centres, transportation nodes and corridors. Increase mix of uses (e.g. more commercial & amenities in residential neighbourhoods) Encourage active transportation and transit use through local infrastructure improvements where possible.	Maximize growth via infill and intensification in central core, town centres, transportation nodes and corridors. Increase/maximize mix of uses and encourage active transportation and transit use. Increase in multi-generational households with emphasis placed on new construction of secondary suites and coach housing. A general increase in occupancy in existing areas, lowering demand for suburban dwellings.
Developing and planned neighbourhoods	Extensive growth, especially in areas such as southeast, southwest and northeast Limited mix of land uses or housing densities	Greater mix of housing densities, increased mix of residential and commercial. Some clustering of development where practical.	Focus growth to areas served by frequent transit. Cluster development to preserve green space including agricultural land and provide transit-supportive densities. New development to fully incorporate low carbon strategies and maximizing livability – compact housing forms, mix of uses, amenities, TOD and street design.
Employment lands	Commercial growth is concentrated in larger standalone commercial centres in developing neighbourhoods, including large power centres Majority of office growth is in suburban office parks Industrial growth is in northwest, southeast, and northeast	Substantial commercial growth is located in mixed use centres and existing neighbourhoods. Some shift in office growth to mixed use areas/town centres. Industrial growth patterns will remain similar to the reference case	Commercial growth is virtually all in mixed use centres and existing neighbourhoods. Office growth to be focused on downtown and mixed use areas/town centres, with access to transit Industrial growth patterns will remain similar to the reference case
2. Housing typology	Largest share is suburban low-density forms.	Modest shift toward medium density where possible. Very modest decrease in house sizes for single family dwellings.	Substantial shift toward medium and higher densities plus increases in secondary suites and coach houses. Greater decrease in house sizes for single family dwellings, based on market trends and pricing.

Indicators

Note: This is an overview of land use indicators. More detailed neighbourhood projections are developed to run the model.

Indicator	Indicator Description	Base Yr	Reference Case	Reduced Carbon Case	Low Carbon Case	Notes
Growth distribution	Share of new growth allocated to newly developed areas vs. existing urbanized areas.	83%:17%	83%:17%	75%:25%	60%:40%	
Allocation of new population	Downtown	NA	5.8%	7.3%	10.5%	
	Mature	NA	12.0%	17.4%	25.7%	
	Established	NA	2.7%	4.0%	7.5%	
	Residential ASP	NA	64.1%	59.3%	50.9%	
	Urban Growth Area	NA	15.3%	12.1%	5.5%	
New residential building mix (% of total dwellings of each building type)	Single family	NA	64.4%	58.7%	39.7%	
	Townhouse	NA	10.8%	12.0%	19.8%	
	Low rise apartment	NA	17.8%	21.1%	29.2%	
	High rise apartment	NA	6.9%	8.2%	11.3%	
Total number of dwellings	Total number of dwellings	360,000	560,000	562,000	578,000	Increase in dwellings is due to changes in dwelling mix. Persons per multi-family dwelling are ~33% less than that of single family dwellings
Allocation of new employment	Downtown	NA	7.4%	7.4%	7.3%	
	Mature	NA	14.0%	14.0%	15.0%	
	Established	NA	4.7%	4.7%	5.8%	
	Residential ASP	NA	33.7%	33.7%	36.3%	
	Urban Growth Area	NA	9.5%	9.5%	9.0%	
Employment	Employment	NA	30.7%	30.7%	26.8%	
ICI new building mix (% of total ICI building floor area)	Commercial	NA	15.3%	15.3%	15.8%	
	Office	NA	31.5%	31.5%	30.4%	
	Institutional	NA	33.1%	33.1%	33.5%	

	Industrial	NA	20.0%	20.0%	20.3%	
ICI building	Total ICI square feet	260,000,000	350,000,000	350,000,000	360,000,000	
Proximity to rapid transit	% of population within 800m/10 minute walking distance (one way) to a rapid transit station	15.2%	17.5%	34.8%	43.8%	

Transportation

Description

	Reference case	Reduced carbon case	Low carbon case
Rapid transit	Extension of LRT to old airport and to Southeast	Includes extensions in reference case, plus new line to West and extensions to other lines. This reflects LRT expansion as per the Transportation Master Plan.	Full buildout of LRT as per TMP, with some additional extensions.
Bus services	Maintain current assumptions and density thresholds (i.e., population densities needed to support different levels of transit service). Local bus service only to new ASPs. Bus technology remains as per today.	Adjust local service levels using current density thresholds. Transition towards lower emissions bus technology including hybrid diesel and compressed natural gas powered buses.	Adjust local service levels with incorporation of additional metrics to allocate/increase transit service levels, including daytime population. Increased transition towards lower emissions bus technology including hybrid diesel and compressed natural gas powered buses.
Active transportation			
Pedestrian systems	Sidewalk network in Edmonton is relatively well developed.	Completion of sidewalk network. Ensure that all local roads are suitable for walking unless it is specifically prohibited and suitable alternatives are available.	Completion of sidewalk network. Improve pedestrian accessibility by creating location-efficient, clustered, mixed land use patterns, with good road and path connectivity, and pedestrian-oriented buildings. Ensure that all roadways are suitable for walking unless it is specifically prohibited and suitable alternatives are available. New above- or below-grade pedestrian connections are aggressively implemented if warranted by increases in residential and commercial density.

Cycling network	Substantial bike paths are in place, and will increase with population growth.	Modest increase in bike paths relative to reference case.	Substantial increase in bike paths relative to reference case.
Road network	Four lane and some six lane arterial roads are built for all new ASP areas. Widening of existing collectors to four lanes occurs where appropriate, though limited widening is anticipated. Continue traditional suburban road patterns for new development.	Four lane arterial roads are built for all new ASP areas. Limited widening of existing collectors to four lanes occurs where appropriate. Mix of suburban and new urbanist road patterns for new development.	Four lane arterial roads are minimized based on provision of transit/bike/walking infrastructure and limited new development in greenfields. No new widening of existing collectors to four lanes. Utilize new urbanist, highly connected street network for all new development.
Low emission vehicles[1]	***National*** Federal Corporate Average Fuel Economy regulations in effect through 2016. Market trend of steadily more fuel-efficient vehicles within each class of vehicle over the last five years carries forward through 2016. A combination of vehicle efficiency and drivetrain technologies leads to lower emissions for conventional vehicles. After 2016 new vehicles maintain efficiency levels. Electric vehicle sales increase gradually, but steadily over time reflecting projected national trends. ***Local*** Minimal action at community scale.	***National*** Corporate Average Fuel Economy fuel consumption regulations. ***Local*** A suite of local actions leads to electric vehicle sales in Edmonton to be higher and the fuel efficiency of conventional vehicles to improve at a rate faster than the national average. These actions include: • Encourage green fleet management for City vendors and large fleet operators. • Encourage LEV taxis. • Encourage electric charging infrastructure in new developments and parking facilities and adopt guidelines for infrastructure. • Encourage private parking facilities to provide LEV priority parking. • Encourage alternative fuels at service stations.	***National*** Corporate Average Fuel Economy fuel consumption regulations. Fuel prices and Market conditions across North America lead to electric vehicle demand and adoption rate to be near the high end of projections. ***Local*** A concerted effort is made to facilitate the transition to electric vehicles given the national market conditions and provincial action to dramatically increase the proportion of renewable electricity generation. Specific actions by Edmonton include: • Adopt green fleet management vendor preference in City purchasing policy, and incentivize green fleets where possible. • Incentivize LEV taxis. • Encourage/incentivize electric charging infrastructure in new developments and parking facilities and adopt guidelines for

[1] For the Reduced Carbon and Low Carbon cases, increased LEV rates relative to the reference case may be a combination of increased national regulations, changing market conditions and increased local actions.

			infrastructure. • Incentivize private parking to provide priority LEV priority parking. • Require alternative fuels at service stations.

Indicators

Indicator	Indicator Description	Base Yr	Reference Case	Reduced Carbon Case	Low Carbon Case	Notes
Tailpipe emission performance	Average grams of carbon dioxide emitted per kilometre driven for all passenger vehicles (g CO_2e / km)	284	2024: 188 2044: 146	2024: 187 2044: 132	2024: 177 2044: 65	
Vehicle fuel efficiency	Average fuel consumption of non-electric passenger vehicles (L/100 km)	11.4	2024: 8.0 2044: 6.6	2024: 8.0 2044: 6.6	2024: 7.8 2044: 6.1	
Electric vehicle fleet share	The percentage of total passenger and commercial vehicles on the road that are electric drive.	0.01%	2024: 3% 2044: 20%	2024: 5% 2044: 31%	2024: 9% 2044: 67%	
Transit tailpipe emission performance	Average grams of carbon dioxide emitted per passenger per kilometre driven for transit vehicles (g CO_2e / PKT)	247	2024: 220 2044: 193	2024: 186 2044: 105	2024: 164 2044: 41	
Rapid transit	km of LRT service	20	37	80	105	
	Coverage (% of city area within 800m)	5	8.6	17.6	23.3	
Transit supportive density	% of residential development that exceeds minimum density threshold for transit service	TBD	TBD	TBD	TBD	
Conventional service	Total hours of peak service	2.4	3.0	3.0	3.0	
	Coverage (% of city within 400m of basic service)	80%	90%	90%	95%	

Length of transit routes	Total one-way transit route km	3,928km	4,468km	4,468km	4,468km	Length of routes (ie geographic coverage) is one component of overall vehicle service hours
Average length weighted peak hour headway	Time between buses at peak hours (minutes)	32.3	30.5	29.5	27.5	Peak hour headway is a model input and along with length and service day impacts vehicle service hours
Bike routes	One way length of bike routes (on and off road) (km)	576	Approx. 1,500 km of paths by 2044	Approx. 1,750 km of paths by 2044	Approx. 2,000 km of paths by 2044	
Arterial roads	(km)	2,538	3,000	2,750	2,650	This excludes highways

Buildings

Description

	Reference case	Reduced carbon case	Low carbon case
Land use*	Largest share is suburban low-density forms Single family lot sizes remain constant	Modest shift toward medium density where possible Very modest decrease in lot sizes for single family dwellings	Substantial shift toward medium and higher densities plus increases in secondary suites and coach houses Decreasing lot sizes for single family dwellings
Energy efficiency and renewable energy in new buildings	Some local education through CO2RE program, and a few demonstration projects New building energy efficiency increases modestly over time Very limited adoption of renewable energy systems	Financing program Green building checklist is voluntary New building energy efficiency increases slightly over reference case Adoption of renewable energy systems (e.g., solar hot water) increases slightly	Green building checklist requires higher efficiency and sometimes renewable energy Green Lease program (commercial) Mandatory energy labeling New building energy efficiency increases dramatically Adoption of renewable energy systems (e.g., solar hot water) increases dramatically
Energy efficiency improvements and renewable energy in existing buildings	Some local education through CO2RE program, and a few demonstration projects. Low uptake. “Background” rates of efficiency retrofits based on existing programs and policies. Retrofit rates for renewables are near zero	Financing program and some incentives in key building types (mainly single family homes) Modest increases in efficiency retrofit rates, and substantial increases in renewable retrofit rates, based primarily on “soft” policies	Significant financing opportunities and some incentives for all building types Mandatory retrofit & re-commissioning program at time of sale or rental Dramatic increases in renewable retrofit rates, via regulatory policies

Notes: * Building energy consumption is related to floor space; per capita energy consumption is generally much lower for higher density buildings such as apartments compared to single family dwellings. Decreased size of single family dwellings and a shift to smaller dwelling types (multi-family and suites) therefore helps to decrease energy use and emissions.[2]

Indicators

Indicator	Indicator Description	Base Yr	Reference Case	Reduced Carbon Case	Low Carbon Case	Notes
Tailpipe emission performance	Average grams of carbon dioxide emitted per kilometre driven for all passenger vehicles (g CO_2e / km)	284	2024: 188 2044: 146	2024: 187 2044: 132	2024: 177 2044: 65	
New building energy efficiency improvement for residential buildings	Improvement in energy efficiency per square metre relative to base year.	n/a	2024: 25% 2044: 50%[3]	2024: 27.5% 2044: 52.5%[4]	2024: 50% 2044: 85%[5]	This is driven foremost by changes to building efficiency through building envelope improvements.
Renewable energy uptake for new construction (% annually)	The share of *new* buildings constructed in a given year that include renewable energy, assumed to be a mix of solar hot water and passive solar heat[6]	~0%	2024: 1% 2044: 1%	2024: 1.5% 2044: 2%	2024: 90% 2044: 90% (Virtually all new buildings include renewables by 2034)	Green Building Checklist Energy labeling Financing Mandatory for buildings with good solar exposure

[2] In fact, in most dwelling types, gains in efficiency over the past several decades on a per square meter basis have been offset by increases in the size of dwellings, increasing per dwelling and per capita energy use and emissions.

[3] 25% reduction assumed to be achieved at next building code update, in keeping with national code. 50% reduction assumed to be achieved by around 2030. Note that these are relatively pessimistic assumptions compared to current building code standards in other jurisdictions. For example, if Alberta adopts the Passivhaus standard, they would potentially see an 80-90% reduction in energy consumption for new dwellings.

[4] 2.5% improvement over Reference Case comes from a voluntary Green Building checklist for exceeding code by 25%, but uptake assumed to be low at around 10%

[5] 2044 figure based on Passivhaus standard.

[6] The share of energy met by renewables varies across building types, from 20% in single family to 10% in multi-family and commercial. Values for effectiveness of solar in meeting annual energy needs based on CO2Re are available at http://www.edmonton.ca/environmental/documents/Renewable_Energy_2010-03.pdf. Note also that solar PV adoption is included in the electricity emissions factor assumptions (see Energy Supply section).

Renewable Energy Uptake for existing buildings (% annually)	Share of existing buildings retrofit each year to include renewable energy, assumed to be two-panel solar hot water	~0%	0.25%	0.5% Assumes that financing is a major barrier and a program will double uptake	5% until 2034 (Virtually all existing buildings include solar hot water by 2034)	Energy labeling Renovation program Financing Mandatory at time of sale or retrofit
Share of buildings retrofit for energy efficiency (% annually)	Share of buildings that are retrofit each year, resulting in a 10%[7] improvement in energy performance for each building retrofit	2.5%	2.5%	3% by 2024	8% by 2024[8]	Energy labeling Financing Program Mandatory retrofit program (where economically viable)
Residential electricity DSM programs (% Improvement)	Assumed improvement in residential electricity efficiency through various Demand Side Management programs	n/a	0%	3%	10%	Education Real-time metering/billing Time-of-use billing
Industrial processing efficiency	Changes in the efficiency of heavy industrial processing (e.g. cement production, refineries, etc.)	1%	1%	10%[9]	25%[10,11]	Broadened Specified Gas Emitters Regulation Require audits Energy management program Government funding Streamlined offset system
Average size of new single family homes	Average size of new dwellings	Historically, average dwelling	180 square meters	170 square meters by 2024 (average size of	160 square meters by 2024 (average size of	This indicator is used to inform discussions of policies to encourage higher occupancy

[7] In the residential sector these improvements relate to heating energy consumption, while for the ICI buildings this includes improvements in process loads

[8] Rate is assumed to be half as high for buildings constructed from 2010-2034 as these buildings are less likely to have economically viable retrofit opportunities available. For buildings constructed after 2034, a retrofit rate of 0% was applied. Some existing buildings are assumed to be retrofit twice, in which case it is assumed that they improve their efficiency by 20% overall.

[9] In addition to this efficiency improvement, it is assumed that there is half as much growth in this sector relative to BAU. It is assumed instead that this growth is shifted to less emissions-intensive businesses in the ICI sector.

[10] In addition to this efficiency improvement, it is assumed that there is no growth in the number of size of heavy industrial facilities. It is assumed instead that this growth is shifted to less emissions-intensive businesses in the ICI sector.

[11] The following sources suggest that a 25% improvement is possible:

Stantec Consulting. 2010. Alberta Energy Efficiency Action Plan. prepared for the Alberta Energy Efficiency Alliance

McBride, M. 2011. EcoENERGY Efficiency for Industry Program. Natural Resources Canda. Presentation to PTAC workshop on October 13.

		size has been increasing, from around 100 square meters in 1950 to 180 square meters in 2010		new homes in 2005)	new homes in 2000)	per area and/or smaller area per person. Average dwelling size is the best way this can be currently measured. A small home can provide the same amenities as a larger one at lower cost through improved design (e.g. layout and multi-purpose rooms)

Demographics

Indicator	Indicator Description	Base Yr	Reference Case	Reduced Carbon Case	Low Carbon Case
Population growth	Growth of total population	1.1% per year	1.1% per year 1,180,000 by 2040	No change from reference case	No change from reference case
Job growth	Growth of total number of jobs	0.89% per year	0.89% per year	No change from reference case	No change from reference case
Persons per household	Average number of persons per household	2.19	declines to 2.05 Assumes current trends continue (household splitting and aging population)	stabilizes to 2.1 Assumes current demographic trends but with reduced levels of household splitting + construction of multifamily dwellings	increases slightly to 2.25 Assumes current demographic trends but with considerably reduced levels of household splitting + increased construction of multifamily dwellings

Energy Supply

Indicator	Indicator Description	Base Yr	Reference Case	Reduced Carbon Case	Low Carbon Case
Electricity Emissions Factor (tonnes CO_2e/GWh)	Emissions associated with the consumption of electricity[12]	880[13]	2024: 628[14] 2044: 538[15]	2024: 580 2044: 429[16]	2024: 442 2044: 100[17]

[12] The Reduced Carbon and Low Carbon cases include an emissions reduction component that includes some solar PV generation (i.e., distributed on buildings).

[13] Derived from Edmonton Energy and Emissions Inventory

[14] Based on EDCA Associates, 2011. Quarterly Forecast Update – First Quarter 2011. P.90.

[15] This assumes the grid will, on average, match the emissions factor of existing Natural Gas generation facilities. This is intended as a conservative assumption. Emissions factor for electricity from Natural Gas drawn from the National GHG Inventory Report, 2008.

[16] These figures are estimated based on the Reference Case, Low Carbon Case, and aligned with the relative difference in intensity of effort in the policies proposed in other sectors (e.g. transportation and land-use).

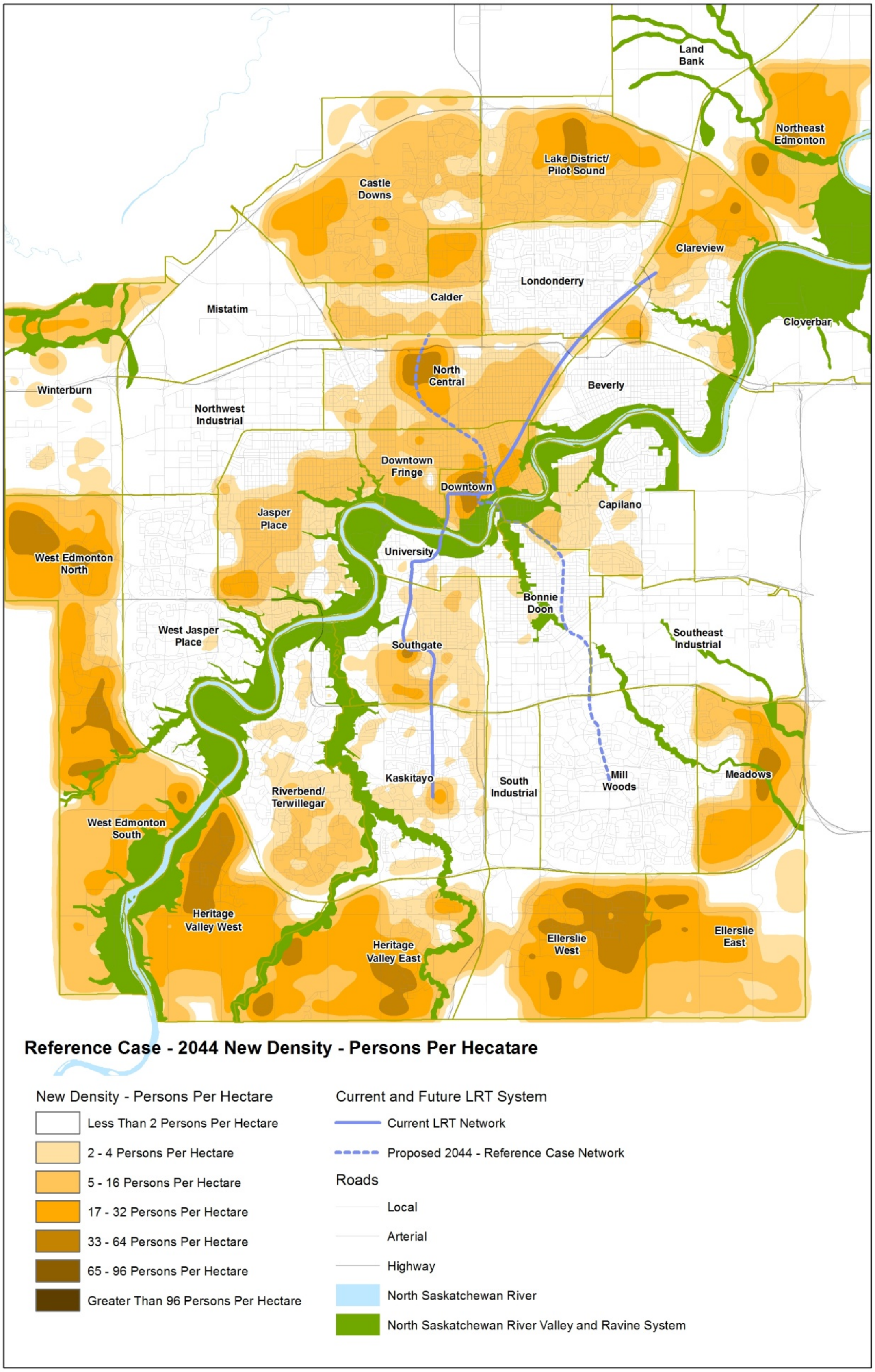
[17] Figures estimated Pale Green and Deep Green scenarios in Bell, J and Weis, T. 2009. Greening the Grid: Powering Alberta's future with renewable energy. The Pembina Institute.

Land use and transportation maps

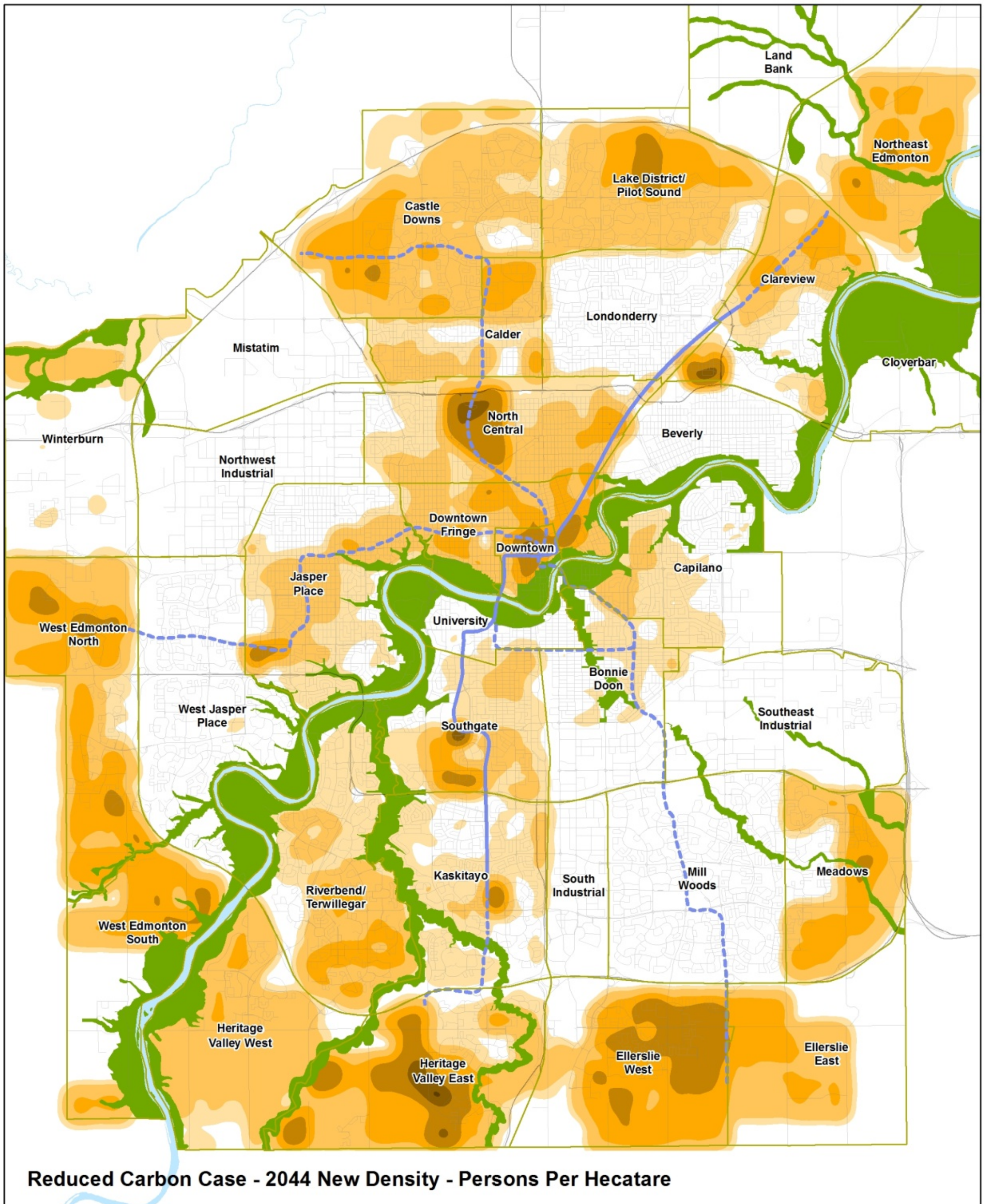
The following maps provide a spatial representation of the allocation of population growth, in terms of residential density, for each scenario. The graduated (yellow to brown areas) indicate the approximate density of all new growth that occurs between the baseline year and 2044. Blue lines indicate assumed extent of the LRT network.

Overall, the low carbon and reduced carbon cases assume that more population is clustered around rapid transit lines and within infill areas. Note however that while the goal was to attempt to create alternate patterns that minimize GHG emissions, significant restraints were put in place (i.e., capping the ratio of infill to greenfield development) so that the resulting patterns would be considered achievable based on a demand for multi-family urban housing that is assumed to increase over time.

What is not evident in the maps, however is noted in the summary data earlier, is that within some areas that appear similar between the Reduced Carbon and Low Carbon cases (e.g., Meadows), the characteristics of development differ (e.g., building type, street network type).



Reference Case - 2044 New Density - Persons Per Hecatare



Reduced Carbon Case - 2044 New Density - Persons Per Hecatare

New Density - Persons Per Hectare

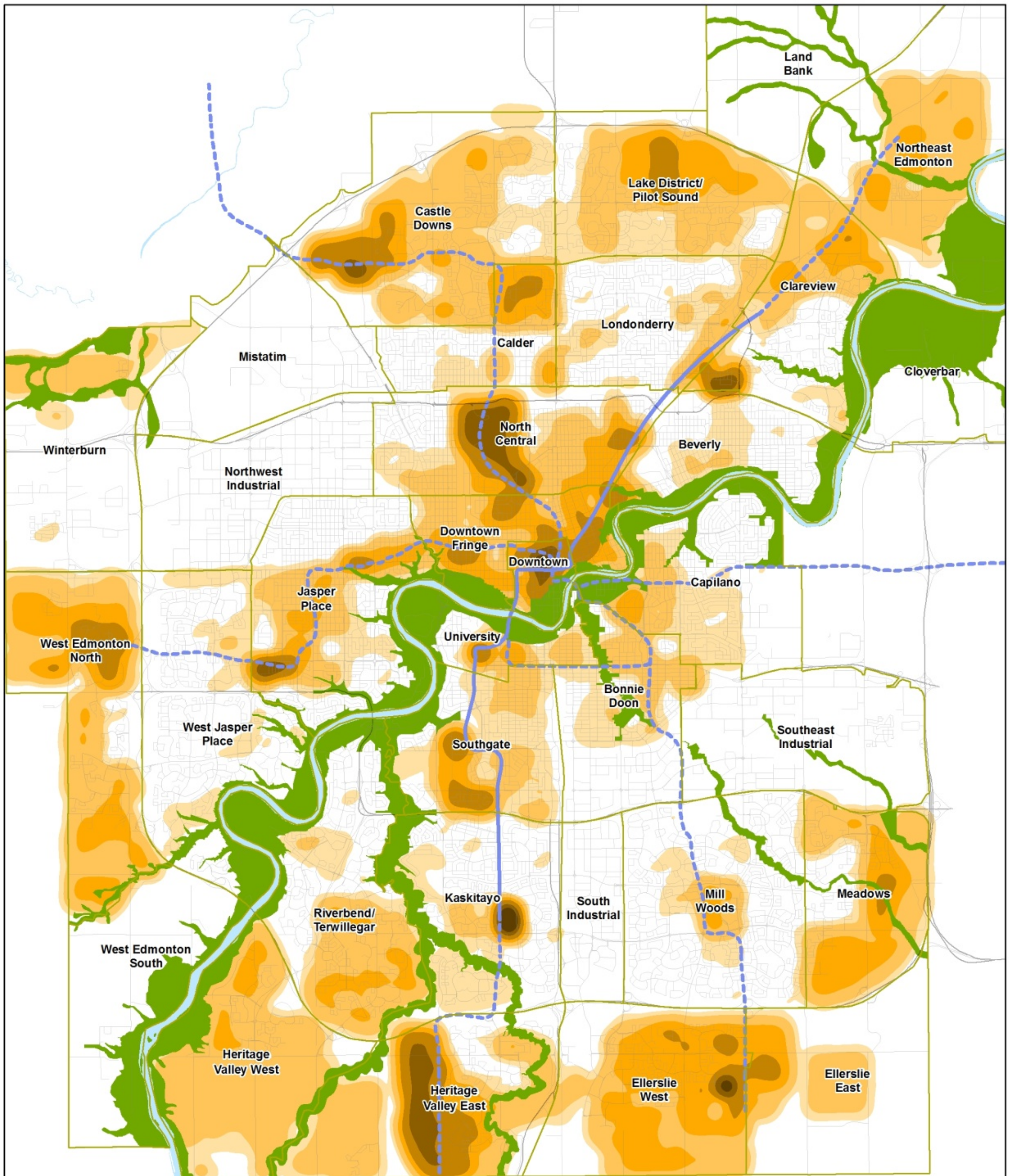
- Less Than 2 Persons Per Hectare
- 2 - 4 Persons Per Hectare
- 5 - 16 Persons Per Hectare
- 17 - 32 Persons Per Hectare
- 33 - 64 Persons Per Hectare
- 65 - 96 Persons Per Hectare
- Greater Than 96 Persons Per Hectare

Current and Future LRT System

- Current LRT Network
- Proposed 2044 - Reduced Carbon Case Network

Roads

- Local
- Arterial
- Highway
- North Saskatchewan River
- North Saskatchewan River Valley and Ravine System



Low Carbon Case - 2044 New Density - Persons Per Hecatare

New Density - Persons Per Hectare

- Less Than 2 Persons Per Hectare
- 2 - 4 Persons Per Hectare
- 5 - 16 Persons Per Hectare
- 17 - 32 Persons Per Hectare
- 33 - 64 Persons Per Hectare
- 65 - 96 Persons Per Hectare
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Current and Future LRT System

- Current LRT Network
- Proposed 2044 - Low Carbon Case Network

Roads

- Local
- Arterial
- Highway
- North Saskatchewan River
- North Saskatchewan River Valley and Ravine System

Energy pricing assumptions

The following assumptions and references were used to generate the energy pricing analysis for each of the modelling cases.

General comments on methodology and approach

- Electricity deregulation makes electricity prices and costs difficult to quantify. For base year, where 2009 rates were not readily available, 2010 rates were used. This is considered to be of little consequence as the analysis looks at the long term (33 years) so these variations are comparatively small.

Methodology for price projections

- Prices for base year were drawn from utilities operating in Edmonton.
- Prices in original units (i.e. kilowatt-hours and litres) have been converted to gigajoules so that all energy types can be compared.
- All prices include estimated taxes and delivery charges. Where relevant, rate riders and variable costs are included and embedded in the per unit energy prices.
- Price projections hold tax rates and fixed charges constant.
- To estimate future unit energy costs, a literature review was conducted. It was found that the best available third-party estimates available at a reasonable cost for this analysis were those from the U.S. Energy Information Administration (EIA). These were compared to price projections provided by Natural Resources Canada and found to be reasonably consistent. Although there are other third-party estimates specific to Alberta, these were considered too expensive to obtain for this analysis.
- EIA figures were only available out to the year 2035. Most price projections use shorter time horizons. To project prices for the period between 2035 and 2044, the annual rate of increase was projected forward at the same rate.
- The EIA projections for the U.S. (national) and Mountain region did not appear to correlate with electricity prices in Alberta, therefore it was assumed that under the Base Case that electricity prices would grow at one half the rate of growth for coal and natural gas.

Assumed energy unit cost growth rates for base case prices			
Fuel type	**Assumed annual avg. growth rate**	**Data source**	**Notes**
Natural Gas	1.00%	EIA 2012	Conservative growth rate for the 2035-2044 period as much of the growth occurs in the last 5 years of the EIA projection
Electricity	0.73%	Estimate	Estimated using the Average of Annual Growth Rate for natural gas and coal, divided by 2. The original EIA figure for the U.S. essentially has a growth rate of 0, likely unrealistic for Alberta.
Gasoline	1.60%	EIA 2012	EIA estimate is conservative relative to some older projections from Natural Resources Canada
Diesel	1.70%	EIA 2012	
Coal	1.40%	EIA 2012	Used only to help derive a realistic estimate for energy prices

The tables above and below show the core assumptions about price increases by fuel type for the Base Case and the High Case. These growth rates are only applied to energy unit costs (e.g. each kilowatt-hour of electricity or each litre of gasoline); tax rates and delivery charges are held constant to base year (2010) in this analysis. As a result, total delivered energy costs for natural gas and electricity do not rise as much as their respective growth rates, and the unit energy costs form only a portion of total costs.

Assumed energy unit cost growth rates for sensitivity analysis prices			
Fuel type	**Assumed annual avg. growth rate**	**Data source**	**Notes**
Natural Gas	2.00%	Estimate	Doubling of Base Case – also fairly consistent with EIA's estimate for 2030-2035
Electricity	1.70%	Estimate	Electricity prices reach the levelized cost of major renewables, calculated using data from U.S. National Renewable Energy Laboratory data[18]
Gasoline	3.20%	EIA 2012	Based on High Oil Price Projection from EIA 2012[19]
Diesel	3.20%	EIA 2012	Based on High Oil Price Projection from EIA 2012
Coal	1.40%	EIA 2012	Used only to help derive a realistic estimate for energy prices

[18] U.S. National Renewable Energy Laboratory, "Utility-Scale Energy Technology Capital Costs." http://www.nrel.gov/analysis/tech_costs.html

[19] U.S. Energy Information Administration, *Annual Energy Outlook 2012 Early Release Overview,* "Energy Prices." Available at http://www.eia.gov/forecasts/aeo/er/early_prices.cfm